ADVANCED CONCRETE TECHNOLOGY

(For 5th semester B.Tech Degree Students Under Kerala Technological University

MODULE :I

CEMENT & AGGREGATES

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CEMENT


PAKLAND
SULPHATE RESISTANT
PORTLAND CEMENT
BS-4027/1972
50KG
PS-612/1989 (R)
Made in Pakistan
A Unit of Dewan Mushtaq Group
BLOCK CEMENT
50 kg

CEMENT

- Cement act as a binding material and if forms a paste with water and hold CA & FN together to form a solid mass.
- Most of the concrete work done with ordinary Portland cement.
- Cement is prepared by mixing calcareous (chalk, lime stone)& argillaceous(clay) materials.

- **What are the properties of cement?**
  - It gives strength to the masonry
  - It gives an excellent binding material
  - It is easily workable
  - It is posses a good plasticity
  - It is stiffness or hardness early

Ingredients of cement

- *Cement is manufactured through a closely controlled chemical combination of **calcium**, **silicon**, **aluminium**, iron and other ingredients.*
- *Common materials used to manufacture cement include **limestone**, shells, and **chalk** or **marl** combined with **shale**, clay, slate, **blast furnace slag**, silica sand, and **iron ore**.*
- ***What are ingredients used in production of cement?***
  - *Silica*
  - *Lime*
  - *Alumina*
  - *Sulphur /sulfur*
  - *Iron oxide*
  - *Magnesium oxide*

Chemical composition

Oxide	Common name	Approximate amount (%)	Functions
CaO	Lime	60-67	Provide strength (sound) Excess unsound
SiO2	Silica	17-25	Provide strength Excess silica < setting time
Al2O3	Alumina	3-8	Quick setting property
cas04	Calcium sulphate	3-4	From gypsum .its increase initial setting time of concrete
Fe2O3	Iron oxide	0.5-6	Gives colour ,hardens & strength to cement
MgO	Magnesia	0.1-4	Gives colour ,hardens & strength to cement . Excess unsound .
Alkalies (Na2O ,K20)	Soda,potassa	0.4-1	Excess causes efflorescence and staining when used in concrete work.
SO3	Sulphuric Anhydride	1-3	Small amount need for making sound cement. But excess unsound

USES OF CEMENT

- Cement is used for the preparation of cement mortar, cement concrete and reinforced cement concrete.
- Cement mortar is used for masonry work, plastering and pointing.
- Cement concrete used in RCC for roof slabs, columns, water tanks, dams, foundations, railway sleepers etc.
- Cement is used in the manufacture of dust bins, posts, pipes, garden benches, flower pots etc.
- Cement mortar is used for all most all decorative and aesthetic works.

Properties of cement

- **Fineness:**
- **Setting time:**
- **Soundness:**
- **Heat of hydration:**
- **Setting & Hardening of Cement**
- **Compressive strength:**
- **Specific gravity**

Heat of hydration:

- The reaction of cement and water is known as hydration due to this hydration cement paste gives binding properties to the concrete.
- During the process, lots of gasses are evolved namely **C_3S, C_2S, C_3A, C_4AF** these chemical compounds which are known by the name ***Bogue's compounds.***

Name of Compound	Formula	Abbreviated Formula	Functions & Properties
Tricalcium silicate	$3\ CaO.SiO_2$	C_3S	Gives early strength to cement. Heat of hydration is 120 Cal/gm
Dicalcium silicate	$2\ CaO.SiO_2$	C_2S	Gives later strength i.e. after 7 days. Less heat of hydration
Tricalcium aluminate	$3\ CaO.Al_2O_3$	C_3A	Gives initial setting and strength High heat of hydration 320 Cal/g
Tetracalcium alumino ferrite	$4\ CaO.Al_2O_3.Fe_2O_3$	C_4AF	Very high heat of hydration. Contributes to the colour effects that makes cement grey.

HYDRATION OF CEMENT

- When cement is mixed with water this process is known as hydration of cement. During the process lots of gasses are evolved namely c3s,c2s,c3A,c4AF.
- 1. solution mechanisms (early strength)
- 2. solid mechanisms(later strength)
- **Tricalcium silicate (c3s):**
- C3s readily react with water produce more heat of hydration responsible for early strength .
- Cement with more c3s is better for cold weather conditions
- C3s produces lesser quantity of c-s-H gel and more calcium hydroxide (ca(oH)2)
- calcium hydroxide is soluble in water and gets reached out making concrete porous.
- So cement with more c3s is not preferable for hydraulic structure .
- **Dicalcium silicate (c2s):**
- C2s hydrates slowly ,generates less heat of hydration ,responsible for ultimate strength of concrete .
- calcium hydroxide its forms 20 -25 % volume of solids in hydrated cement paste.
- It react with sulphate in soil or water to form calcium sulphate which react with C3A, causing deterioration of concrete. This is known as sulphate attack

TESTING OF CEMENT

1. *FILED TEST*

colour ,physical property ,presence of lumps, strength.

2.LABORATORY TEST:

Fineness test

Standard consistency

Initial setting time

Final setting time

Compressive strength test

Soundness test

TYPES OF CEMENT:

Types of Cement	Description	Uses
Rapid Hardening Portland Cement	RHPC manufactured by combining lime stone (finely grounded) and shale at high temperature. This type of cement is used where high strength is needed to be achieved in initial stage quickly.	1. Road Pavement Works. 2. Precast concrete casting (Beams, Columns etc.).
Sulphate Resisting Cement	SRC is manufactured with less than 5% calcium aluminate to withstand Sulphate attacks. This type of cement is used where the concrete is direct contact with soil (which has high sulphate content)	1. Pile foundation. 2. In Coastal area Works. 3. Sewage and water treatment plants.
Low Heat Cement	This type cement is produced by lowering the amount of tri-calcium aluminate (C_3A) & di-calcium silicate (C_2S). This type of cement is used in mass constructions (like dams) and in high wear resistance required area	1. Mass Construction (Dams, Marine constructions). 2. Hydraulic Engineering. 3. Retaining wall construction.

Portland Pozzolana Cement	**PPC is manufactured by adding pozzolanic materials such as fly ash, shales, clays etc.** **It gains high compressive strength with age unlike rapid hardening cement.**	**1. It is cheap and affordable.** **2. Mainly used in building construction where strength required with age.** **3. Water tightness.**
High Alumina Cement	HAC is produced from lime stone/Chalk and Bauxite. This cement is used in construction of refineries, factory or other workshop type structure because HAC is counter to high temperature	1. Used in Sewage structures and in acidic structures.
Coloured Cement	Coloured cement is manufactured by mixing colour pigments (5-10 %) with OPC. As the name suggests, it is used where coloured cements required for	1. Artificial Marble. 2. Floor finishing.

Hydrophobic Cement	**This type of cement is manufactured by mixing admixtures like petrolatum, naphthalene soap which forms layer and act as water repellent.** **It is useful in wet climatic conditions**	**1. Useful when cement is stored for longer duration in wet climatic conditions.**
Ordinary Portland Cement	OPC is manufactured by mixing limestone/chalk with shale/clay to form clinker which is then finely crushed to form grey color cement. Commonly used for all type of construction works	1. Widely used in residential construction where special type of cement properties is not required.
Expansive Cement	Expansive Cement is formed from the reaction of tri calcium aluminate (C_3A) with Calcium Sulphate (C_2SO4).As the name suggests, it expands and increases in volume while settled. Used to avoid the shrinkage of concrete	1. Used in repair works (to create a bond with old concrete surface). 2. Used in Hydraulic Structures.

Quick Setting Cement

- **This type of cement is manufactured by reducing the amount of gypsum and adding small amount of aluminum sulphate to accelerate setting time of cement.**
- **As the name suggests, it is used where the works needs to be done quickly**

Applications

In Underwater Constructions.

In Cold and Rainy Weather Conditions.

Blended cement

- Blended cements is obtained by mixing OPC with mineral admixtures or additives like fly ash, slag or silica fumes.
- Blended cements are now being considered superior as compared to conventional opc category of cements.

Advantages of blended cement

- It reduces water demand and therefore water-cement ratio can be reduced.
- It improves workability for the same water content.
- The blended cements are finer as compared to OPC, therefore the permeability of concrete is less. This results into improved durability.

Environmental advantages

- **Energy saving**: Blended cements are obtained by adding mineral admixtures with OPC. The energy, which would have otherwise been utilized for production of OPC, is thus saved. This saving is to the tune of 0.8 to 1.2 MWH/ton of cement.
- **Conservation of natural resources**: The used mineral admixtures are the waste products of thermal and steel plants. By using these products, we are conserving the precious minerals like lime stone, clay and silica etc.
- **Pollution control**: By reducing the production of cement, pollution is also controlled as cement is an energy intensive product. It has been estimated that 7% of total pollution is only due to cement production which can proportionately be reduced if more blended cement is used.

Aggregates

Aggregate

- Aggregate is general term applied to those inert or chemically inactive materials which are bonded by cement and water to form concrete.
- Aggregate are the important constituents in concrete.
- They give body to the concrete, reduce shrinkage and effect in economy.
- Its constitutes 70 to 75% of volume of concrete
- mainly two types of aggregates : fine aggregate
- : coarse aggregate

Classification

1.Classification based on geological origin

2. Classification based on size

3. Classification based on shape

4. Classification based on surface texture.

1.Classification based on geological origin

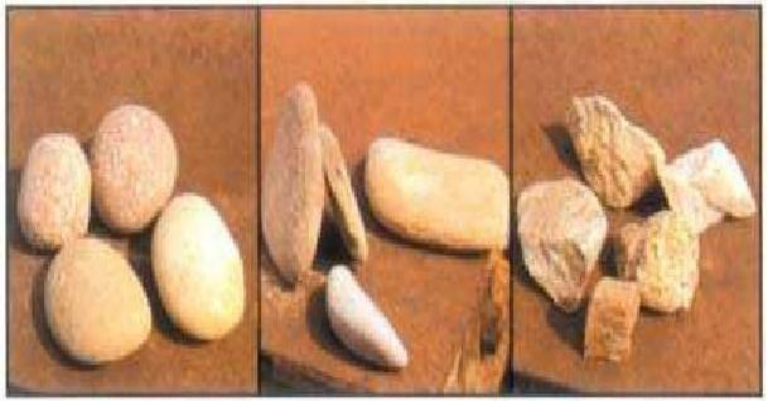
- It can be natural or artificial.
- Almost all natural aggregate materials originate from bed rocks.
- There are three kinds of rocks, namely, igneous, sedimentary and metamorphic.
- Natural eg: sand, crushed rocks.
- Artificial eg: air cooled slag, broken bricks.

Classification based on size

- Aggregates are divided into two categories from the consideration of size.
- I) Coarse aggregate
- (ii) Fine aggregate.
- The size of aggregate bigger than 4.75 mm is considered as coarse aggregate and aggregate whose size is 4.75 mm and less is considered as fine aggregate its determined from sieve analysis
- Course aggregate (crushed stone, gravel)
- Fine aggregate (sand)
- Course aggregate:
- It makes concrete strong and tough.

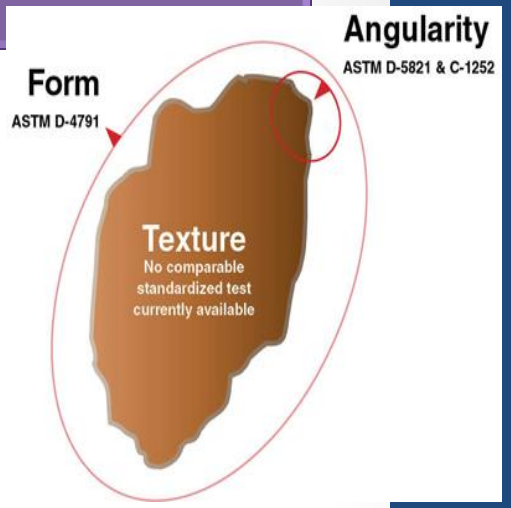
Classification based on shape

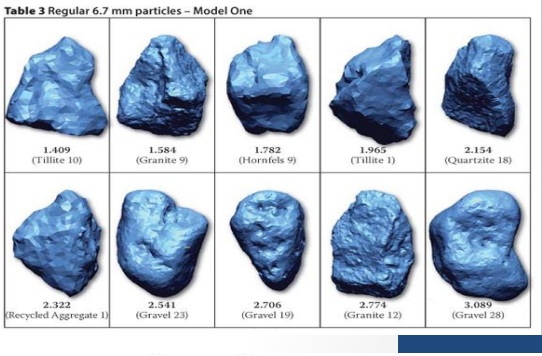
- The shape of aggregates is an important characteristic since it affects the workability of concrete.
- Round shape (eg: river or sea shore gravel)
- Irregular or partially rounded
- Angular (sharp edges : crushed rock of all types.
- Flaky: thick is very less compared to its length

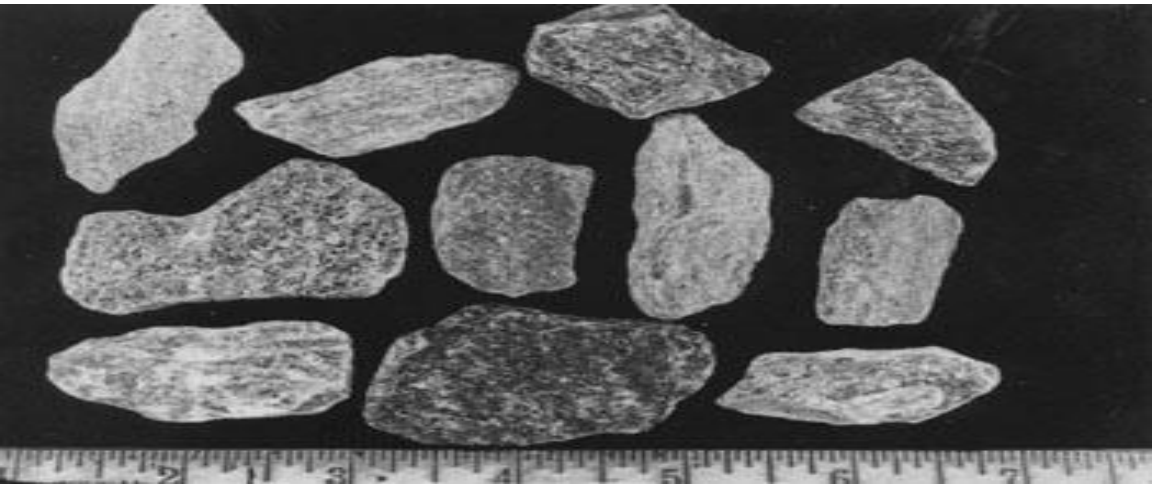


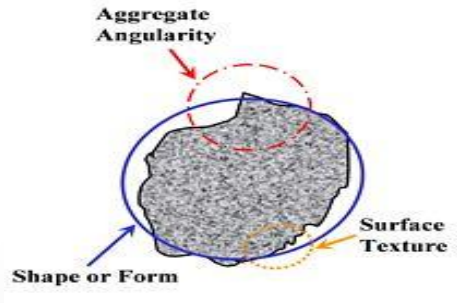
Classification based on surface texture.

- Glassy
- Smooth
- Rough
- Crystalline
- Honeycomb.









Characteristics of aggregates

- **Cleanliness :**
- **Surface texture**
- **Bond strength or strength of aggregate**
- **Hardness**
- **Specific gravity**
- **Bulk density**
- **Porosity and absorption of water by aggregate**
- **Bulking of fine aggregates**
- **Deteriorates substance presents in aggregates**
- **Soundness of aggregates**
- **Grading of aggregates**

Characteristics of aggregates

- **Cleanliness :**
- It should be clean from impurities, if organic impurities presents it will affects the strength of concrete.
- Organic impurities can be tested by colouring test .
- Presence of slit and clay causes shrinkage, increases the permeability also affects bond strength.
- The presences of slit and clay should be below 4% for fine aggregate and 1 % for coarse aggregates.
- Presences of salt will affects setting property.
- Aggregate which contain more than 3% should be washed away.
- Salt content causes efflorescence

MODULE :II

ADMIXTURES

- It is an optional ingredient of concrete which is added to modify the properties of fresh and hard concrete and grout materials as per some specific requirements.
- Addition of admixture may alter workability, pumping qualities, strength development, appearance etc in fresh concrete and permeability, strength, durability etc in hardened concrete.
- But use of chemical admixture is a must for producing high grade concrete.

Admixtures

- Admixtures is defined as a material other than cement, water and aggregates.
- it is used as an ingredient of concrete and is added to the concrete before mixing.
- Its is used to enhance the properties of cement .

Functions of admixtures

- a) To increase workability without increasing water content or to decrease the water content at the same workability.
- b) To retard or accelerate both initial and final setting times.
- c) To reduce or prevent settlement.
- d) To create slight expansion in concrete and mortar.
- e) To modify the rate or capacity for bleeding or both.
- f) To reduce segregation of concrete, mortars and grouts.
- g) To improve penetration and or pump ability of concrete, mortars and grouts.
- h) To reduce rate of slump loss.

Classification of admixtures

- **I Mineral Admixtures**
  - **Blast Furnace Slag**
  - **Fly ash**
  - **Silica Fume**
  - **Rice Husk etc.....**
- **I Chemical Admixtures**
  - **Plasticizers**
  - **Super Plasticizers**
  - **Accelerators**
  - **Retarders**
  - **Air entraining agents etc.....**

Mineral Admixtures

- **Mineral Admixtures** are insoluble siliceous materials, used at relatively large amounts (15-20% by weight of cement).
- ▪ Fine particle size, siliceous material that can slowly react with CH at normal temperatures, to form cementitious products

Ground granulated blast furnace slag (GGBFS)

- Ground granulated blast-furnace slag is the **granular material** formed when molten iron blast furnace slag (a by-product of iron and steel making) is rapidly chilled (quenched) by immersion in water.
- It is a granular product, **highly cementations** in nature and, ground to cement fineness, hydrates like Portland cement.
- Concrete made with GGBFS cement **sets more slowly** than concrete made with ordinary Portland cement, depending on the amount of GGBFS in the cementitious material.

Rice Husk Ash:

- This is a bio waste from the husk left from the grains of rice. It is used as a pozzolanic material in cement to increase durability and strength.
- **RICE HUSK ASH**
- It is obtained by burning the rice husk in a controlled manner without causing environmental pollution. This is generated in huge quantity in the rice shelters and each tone of paddy produce 40 kg rice husk ash. It consist of,
- 90% of silica
- 5% of carbon
- 2% of K_20

- The specific surface area of rice husk is 40 to 100 m^2/kg. Rice husk exhibits high pozzolanic characteristics and contribute to high strength and high impermeability of concrete because the size of cement particles is about 100 microns whereas the size of rice husk ash is 25 micron.

METAKAOLIN

- It is the unpurified thermally activated ordinary clay and kaolin clay.
- It shows high pozzolanic reactivity and reduction in $Ca(OH)_2$ even as early as one day.
- It is found that cement paste undergoes distinct densification and as a result helps to increases the strength and decreases the permeability.
-

SILICA FUME

- These are the byproduct of the reduction of high purity quartz with coal in electrical arc furnaces in the manufacture of Ferro silicon and Silicon metal.
- These are spherical in shape and size less than 0.1 micron.
- Surface area of silica fume is 20m2/g and it size is 100 times smaller than average cement particles.
- Chemical composition of silica fume is,
- 85% of silica
- 1% Al_2O_3
- 6% of Fe_2O_3
- 12% of carbon

FLY ASH

- It is the residual form obtained from combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitation.
- It has a surface area 300 to 700 m^2/kg. Its particles are finer than cement particles.
- It is light grey to dark grey in colour. Its chemical composition is,
- 30 to 60% of silicon
- 15 to 30% of Aluminum oxide (Al_2O_3)
- 30% of carbon
- 1to 7% of calcium oxide and
- Small amount of MgO & SO
- It is used in mass concreting in dams, retaining walls etc.

- **Chemical Admixtures**

Accelerators:

- An admixture which, when added to concrete, mortar, or grout, increases the rate of hydration of hydraulic cement, shortens the time of set in concrete, or increases the rate of hardening or strength development.
- These are used in concreting under flowing water and in road repair works so that work can be put to use as earliest as possible.

Retarders:

- The function of retarder is to delay or extend the setting time of cement paste in concrete. These are helpful for concrete that has to be transported to long distance, and helpful in placing the concrete at high temperatures.
- Initial setting time can be delayed by more than 3 hours

The commonly known retards are **Calcium Ligno-sulphonates** and **Carbohydrates derivatives** used in fraction of percent by weight of cement.

Air Entrained Admixtures:

- These are also surface active agents that form stable air bubbles of very small size ranging from 5 micron to 80 micron.
- The main function of air bubbles is to break capillary structure within the concrete and to act as roller ball bearings so that the particles in the mix move freely against each other, thus improving the workability of concrete without adding more water.

Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete. These include:

- Resistance to freeze – thaw action in the hardened concrete.
- Increased cohesion, reducing the tendency to bleed and segregation in the plastic concrete.
- Compaction of low workability mixes including semi - dry concrete.
- Cohesion and handling properties in bedding mortars.

WATER REDUCING ADMIXTURES

- These admixtures reduce the requirement of water for a given workability.
- For full hydration a water-cement ratio of 0.23 is sufficient but generally much higher water-cement ratio is adopted due to the requirement of workability.
- Workability is an equally important design parameter in addition to strength because inadequate workability leads to honeycombing and non uniform strength.
- Excess water is used to overcome the internal friction between solid particles of concrete and facilitate mixing, placing, transportation and compaction of concrete.
- There are two categories of water reducing admixtures.

- Plasticizers
- Super-plasticizers
- Super plasticizers are improvised version of conventional plasticizers. They reduce water requirement significantly. These are, therefore, also called '**High range water reducers**'. Plasticizers reduce water requirement up to 15% whereas super plasticizers can reduce this requirement even up to 30%.
- There are four types of super plasticizers which are generally used for concrete as given below.
- **Sulphonated melamine** – It is suitable in low temperature areas
- **Sulphonated naphthalene** – It is more suitable in high temperature areas
- **Ligno sulphates** – It is suitable for Indian conditions where temperature variation is high
- **Carboxylated admixture** – It is suitable where workability is required to be retained for large duration.

Concrete mix design

- **Concrete mix design** is defined as the appropriate selection and proportioning of constituents to produce a concrete with pre-defined characteristics in the fresh and hardened states.
- In general, concrete mixes are designed in order to achieve a defined workability, strength and durability

The selection and proportioning of materials depends on:

- The structural requirements of the concrete
- The environment to which the structure will be exposed
- The job site conditions, especially the methods of concrete production, transport, placement, compaction and finishing
- The characteristics of the available raw materials

The various factors affecting the choice of concrete mix design are:

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

2. **Workability of concrete:**

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

3. Durability of concrete:

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

4. Maximum nominal size of aggregate

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

5. Grading and type of aggregate

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

6. Quality Control at site:

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

MODULE :IV
properties of Hardened concrete.

- Fully cured, hardened concrete must be strong enough to withstand the structural and service loads which will be applied to it and must be durable enough to withstand the environmental exposure for which it is designed.
- If concrete is made with high-quality materials and is properly proportioned, mixed, handled, placed and finished, it will be the strongest and durable building material.
- :


Properties of
Hardened
Concrete

Properties

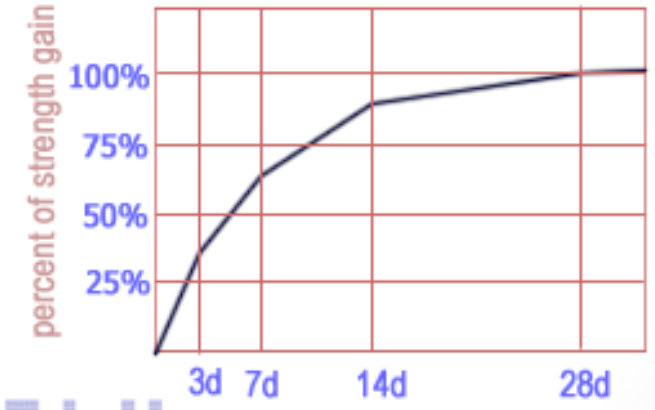
1. **Strength of concrete**
2. **Concrete Creep**
3. **Shrinkage**
4. **Modulus of Elasticity:**
5. **Water tightness (impermeability)**
6. **Durability**

Strength:

- The strength of concrete is basically referred to compressive strength and it depends upon three factors.
- 1- Paste Strength

  2- Interfacial Bonding

  3- Aggregate Strength



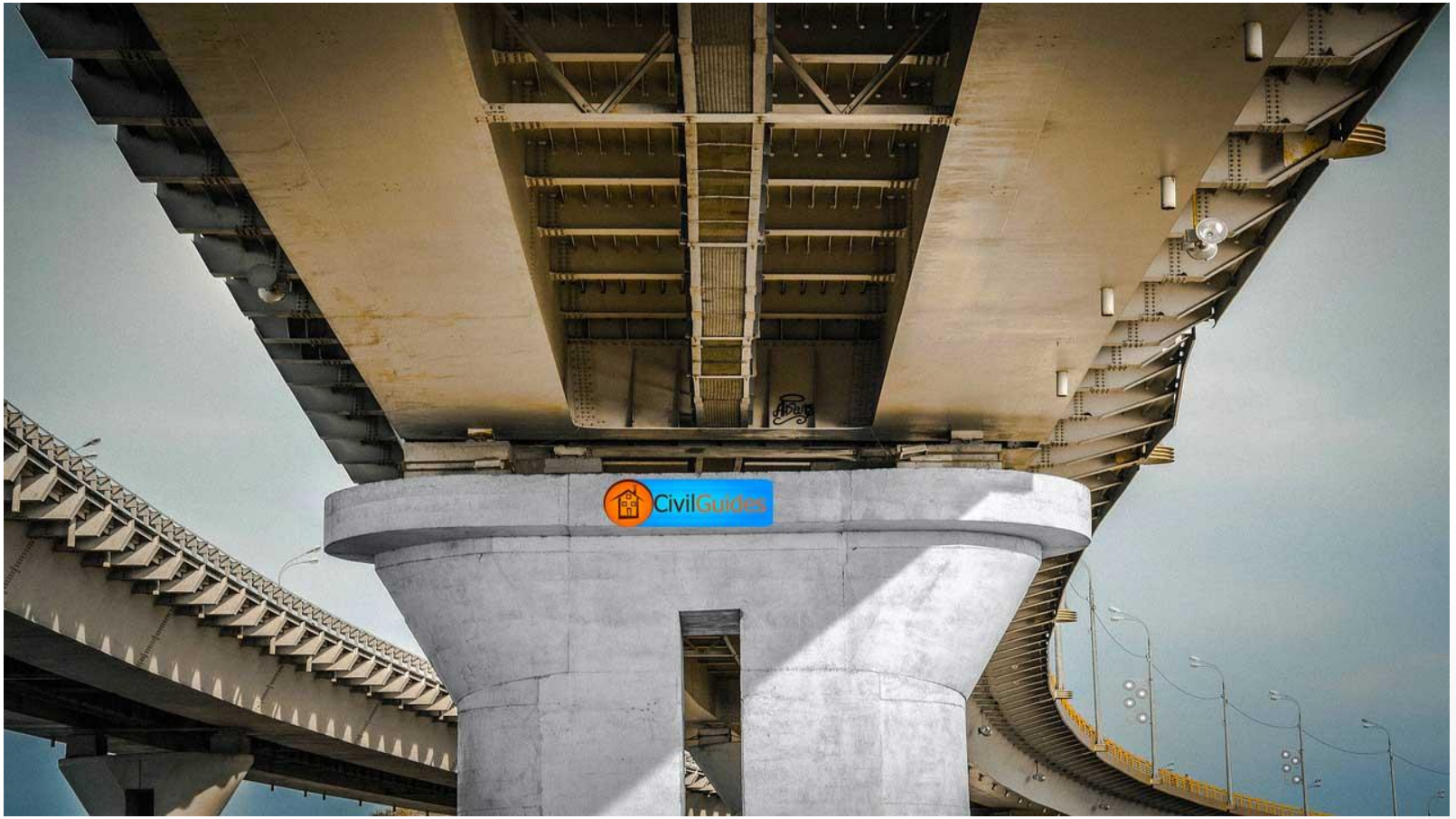
Strength gaining of concrete with age (day)

- **1. Paste strength:**
- It is mainly due to the binding properties of cement that the ingredients are compacted together. If the paste has higher binding strength, higher will be strength of concrete.
- **2. Interfacial bonding:**
- Interfacial bonding is very necessary regarding the strength. Clay hampers the bonding between paste and aggregate. The aggregate should be washed for a better bonding between paste and aggregate.
- **3. Aggregate strength:**
- It is mainly the aggregate that provide strength to concrete especially coarse aggregates which act just like bones in the body. Rough and angular aggregate provides better bonding and high strength.

Factors affecting Strength of concrete:

- Following are the factors that affect the strength of concrete:
- 1. Water-Cement ratio
  2. Type of cementing material
  3. Amount of cementing material
  4. Type of aggregate
  5. Air content
  6. Admixtures

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 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.

- **1. Water-Cement ratio:**
- It is water cement ratio that basically governs the property of strength. Lesser the water cement ratio, greater will be strength.
- **2. Type of cement:**
- Type of cement affect the hydration process and therefore strength of concrete.
- Amount of cementing material: it is the paste that holds or binds all the ingredients. Thus greater amount of cementing material greater will be strength.
- **3. Type of Aggregate:**
- Rough and angular aggregates is preferable as they provide greater bonding.
- **4. Admixtures:**
- Chemical admixtures like plasticizers reduce the water cement ratio and increase the strength of concrete at same water cement ratio. Mineral admixtures affect the strength at later stage and increase the strength by increasing the amount of cementing material.

2.Concrete creep

- Concrete creep is defined as: deformation of structure under sustained load. Basically, long term pressure or stress on concrete can make it change shape.
- This deformation usually occurs in the direction the force is being applied. Like a concrete column getting more compressed, or a beam bending.
- Creep does not necessarily cause concrete to fail or break apart. Creep is factored in when concrete structures are designed

Factors Affecting Creep

- Aggregate
- Mix Proportions
- Age of concrete

- **1. Influence of Aggregate**
- Aggregate undergoes very little creep. It is really the paste which is responsible for the creep.
- However, the aggregate influences the creep of concrete through a restraining effect on the magnitude of creep.
- The paste which is creeping under load is restrained by aggregate which do not creep.
- The stronger the aggregate the more is the restraining effect and hence the less is the magnitude of creep.
- The modulus of elasticity of aggregate is one of the important factors influencing creep.
- It can be easily imagined that the higher the modulus of elasticity the less is the creep.
- Light weight aggregate shows substantially higher creep than normal weight aggregate.

- **2. Influence of Mix Proportions:**
- The amount of paste content and its quality is one of the most important factors influencing creep.
- A poorer paste structure undergoes higher creep. Therefore, it can be said that creep increases with increase in water/cement ratio.
- In other words, it can also be said that creep is inversely proportional to the strength of concrete.

Influence of Age:

- Age at which a concrete member is loaded will have a predominant effect on the magnitude of creep.
- This can be easily understood from the fact that the quality of gel improves with time.
- Such gel creeps less, whereas a young gel under load being not so stronger and creeps more.
- moisture content of the concrete being different at different age also influences the magnitude of creep

Effects of Creep on Concrete and Reinforced Concrete

- In reinforced concrete beams, creep increases the deflection with time and may be a critical consideration in design.
- In eccentrically loaded columns, creep increases the deflection and can load to buckling.
- In case of statically indeterminate structures and column and beam junctions creep may relieve the stress concentration induced by shrinkage, temperatures changes or movement of support.
- In mass concrete structures such as dams, on account of differential temperature conditions at the interior and surface, creep is harmful and by itself may be a cause of cracking in the interior of dams.
- Therefore, all precautions and steps must be taken to see that increase in temperature does not take place in the interior of mass concrete structure.

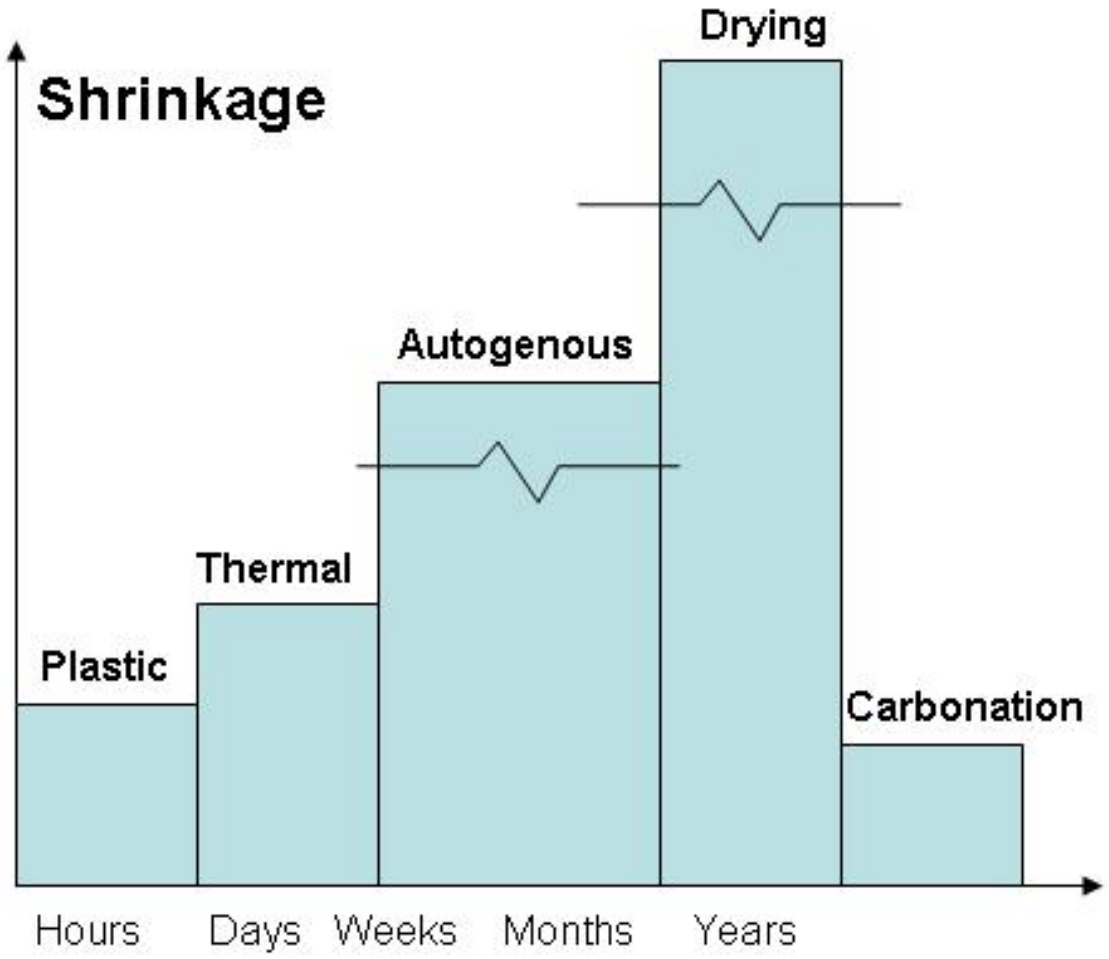
3.Shrinkage:

Shrinkage is the volume decrease of concrete caused by drying and chemical changes.

In another word, the reduction of volume for the setting and hardening of concrete is defined as *shrinkage*.

Types of Shrinkage in Concrete

- To understand this aspect more closely, shrinkage can be classified in the following way:
- (a) Plastic Shrinkage
- (b) Drying Shrinkage
- (c) Autogeneous Shrinkage
- (d) Carbonation Shrinkage


Shrinkage
Drying
Autogenous
Thermal
Plastic
Carbonation
Hours
Days
Weeks
Months
Years

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.

b. 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).

c. Autogeneous Shrinkage

- Autogeneous shrinkage is an important phenomenon in young concrete.
- At low water/cement ratios, less than about 0.42, all the water is rapidly drawn into the hydration process and the demand for more water creates very fine capillaries.
- The surface tension within the capillaries causes Autogeneous shrinkage (sometimes called chemical shrinkage or self-desiccation)
- which can lead to cracking. This can be largely avoided by keeping the surface of the concrete continuously wet

Carbonation Shrinkage

- Carbonation shrinkage occurs when the concrete is exposed to air containing carbon dioxide.
- When the hardened concrete is exposed to this type of air, the weight increases, and the concrete undergoes irreversible carbonation shrinkage.
- The carbonation shrinkage may be as great as the shrinkage due to air drying at seventy degrees Fahrenheit, fifty- percent relative humidity, and a saturated condition.
- The carbonation process proceeds slowly and usually produces small shrinkage at relative humidity below twenty five percent, or near saturation.

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 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.

Water tightness:

- Another property of concrete is water tightness. Sometime, it's called impermeability of concrete. Water tightness of concrete is directly related to the durability of concrete.
- The lesser the permeability, the more the durability of concrete. Now the question is, what is the permeability of concrete?
  In simple word, the capability of penetrating outer media into concrete is the permeability of concrete. Outer media means water, chemicals, sulphates, etc.

Durability

- *Durability* might be defined as the ability to maintain satisfactory performance over and extended service life. The design service life of most buildings is often 30 years, although buildings often last 50 to 100 years.
- Most concrete buildings are demolished due to obsolescence rather than deterioration. Different concretes require different degrees of durability depending on the exposure environment and properties desired.
-

Appropriate concrete ingredients, mix proportions, finishes and curing practices can be adjusted on the basis of required durability of concrete.

Modulus of Elasticity:

- The *modulus of Elasticity* of concrete depends on the Modulus of Elasticity 0f the concrete ingredients and their mix proportions.
- As per ACI code, the modulus of Elasticity to be calculated using following equation:

$$E_c = 33\omega_c^{1.5}\sqrt{f'_c}$$

Where, ω_c = unit weight of concrete,

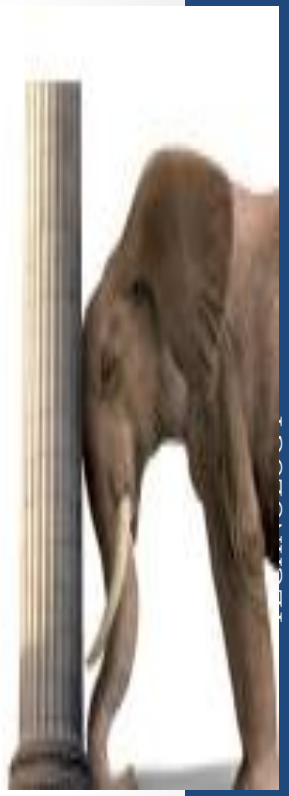
f'_c = 28 days compressive strength of concrete

MODULE :V

Concrete Durability

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.

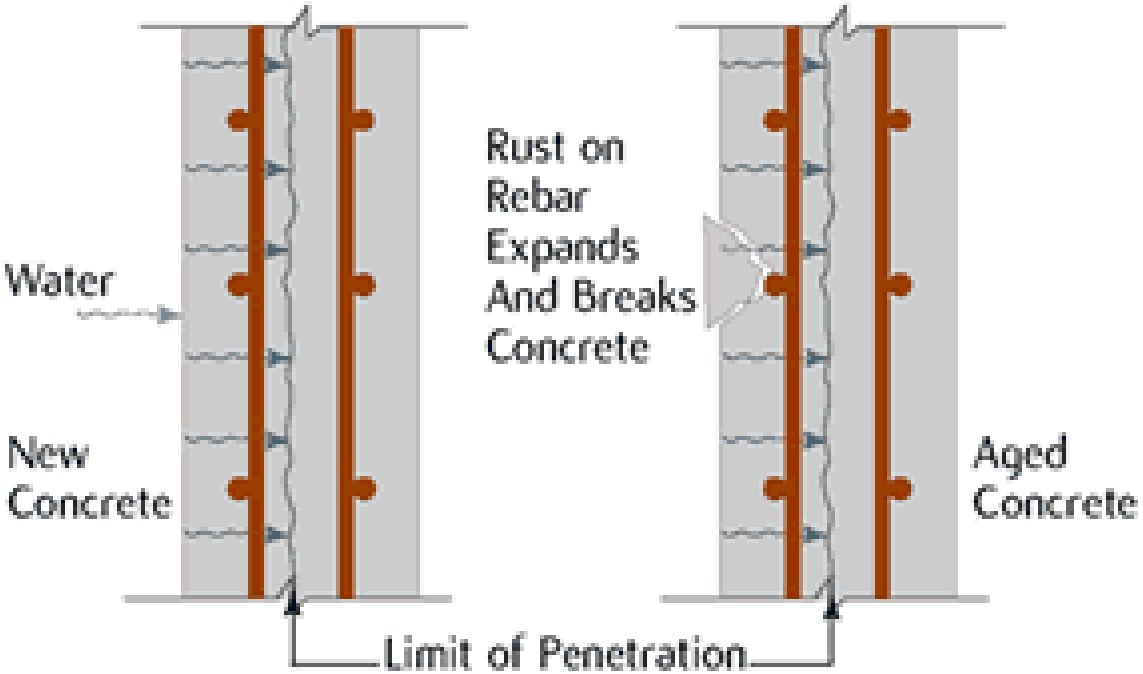


OR

- 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.

Deterioration of Bridge

CONCRETE WITH HIGH PERMEABILITY



CONSTRUCTION SITE

LACK OF COMPACTION ETC.

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 equipment 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
- **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

Honeycombed concrete

FACTORS INFLUENCING CORROSION OF REINFORCEMENT(ASSIGNMENT Q1)

DATE OF GIVEN : 8-11-17

SUBMISSION:15-11-17

- In reinforced cement concrete construction the corrosion of reinforcement takes place due to the presence of chlorides and sulphates beyond a critical limit and when sufficient alkalies is not obtained within the concrete to maintain steel in a positive condition.

Factors Influencing Corrosion of Steel Reinforcement

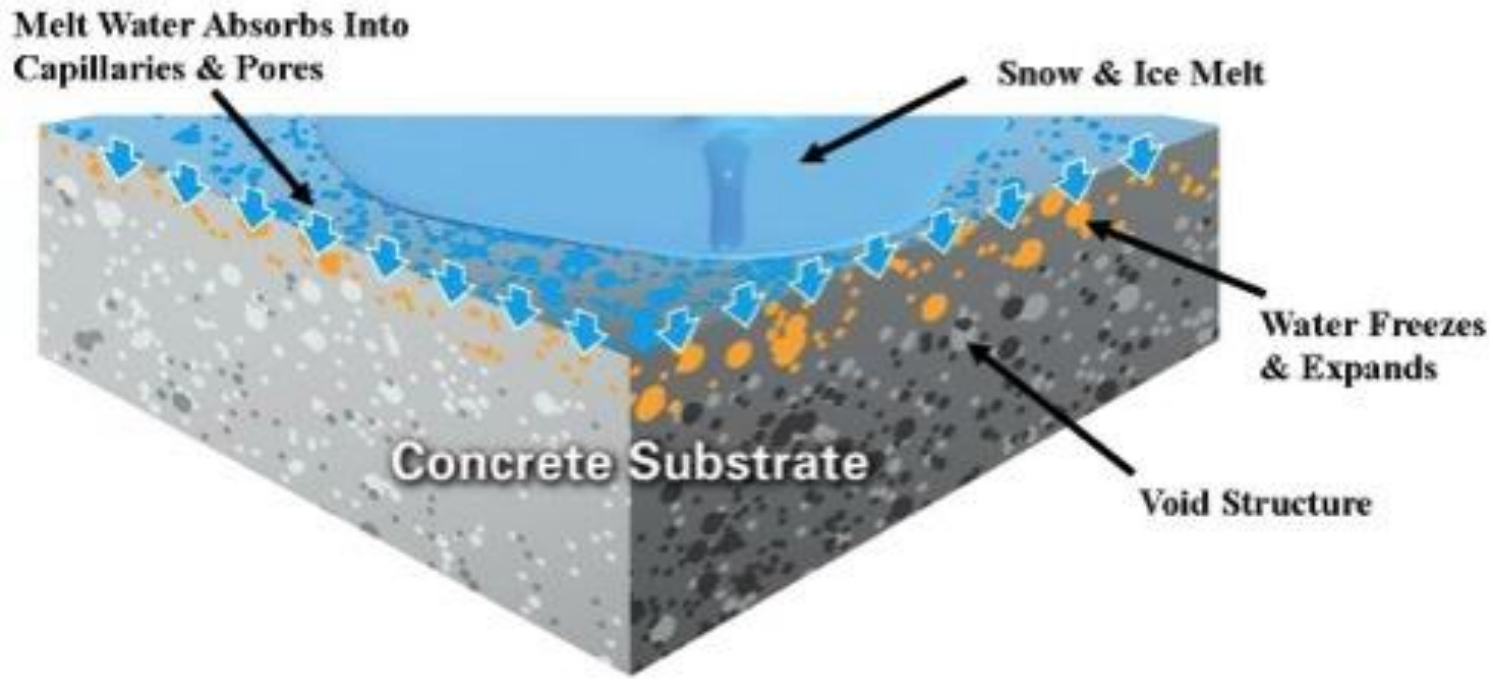
- pH value,
- Moisture,
- Oxygen,
- Carbonation,
- Chlorides,
- Ambient temperature and relative humidity,
- Severity of exposure,
- Quality of construction materials,
- Quality of concrete,
- Cover to the reinforcement,
- Initial curing conditions, and
- Formation of cracks.

Frost action in concrete

- Deterioration of concrete from freeze thaw actions may occur when the concrete is critically saturated, which is when approximately 91% of its pores are filled with water.
- When water freezes to ice it occupies 9% more volume than that of water. If there is no space for this volume expansion in a porous, water containing material like concrete, freezing may cause distress in the concrete.
- Distress to critically saturated concrete from freezing and thawing will commence with the first freeze-thaw cycle and will continue throughout successive winter seasons resulting in repeated loss of concrete surface.

AD

Frost contd…


Melt Water Absorbs Into
Capillaries & Pores
Snow & Ice Melt
Water Freezes
& Expands
Concrete Substrate
Void Structure

Steps damaged due to frost

Cracked Stairs due to Freeze Thaw Cycles

QUALIITY CONTROL OF CONCRETE

- The quality control is a corporate, dynamic program to assure that all the aspects of materials, equipment, and workmanship are well looked after. The quality control should have conformity to the specification. For the manufacturer of the concrete, the quality control process will involve material, personnel, equipment and workmanship in all stages of concreting.

- Quality of concrete construction on site can be accomplished in three distinct stages as follow
- **Quality control before concreting**
- **Quality control during concreting**
- **Quality control after construction**

TEST OF HARDEN CONCRETE

- Hardened concrete gains strength with time and testing these hardened concrete for quality check is important for structures.
- Different types of tests are available to check different properties of hardened concrete which are discussed.

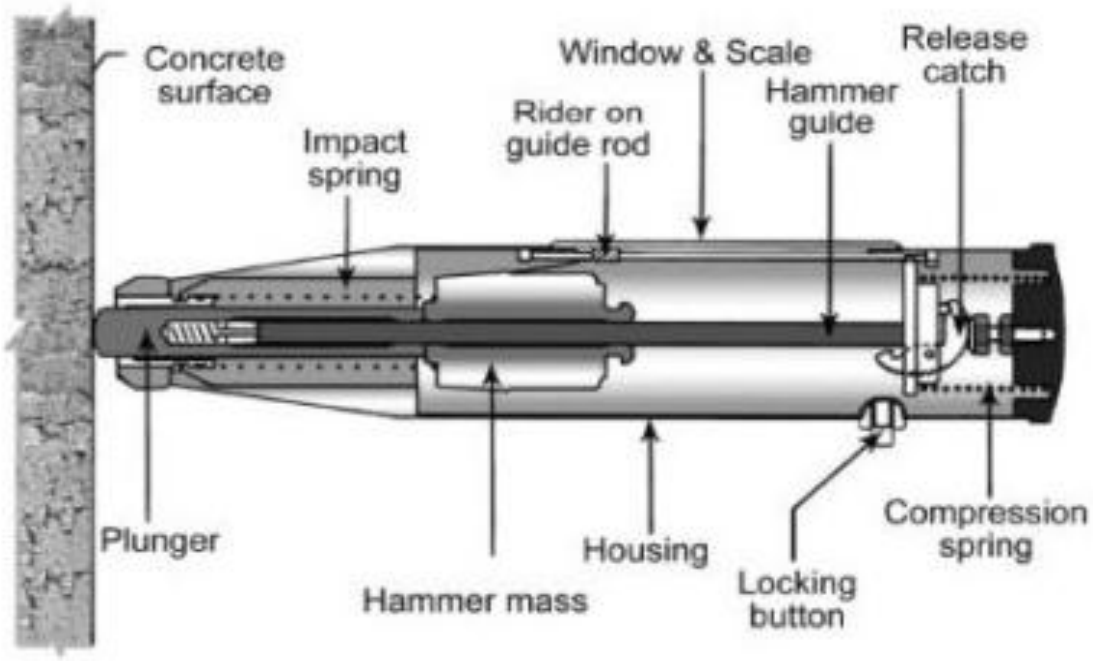
Method of Testing

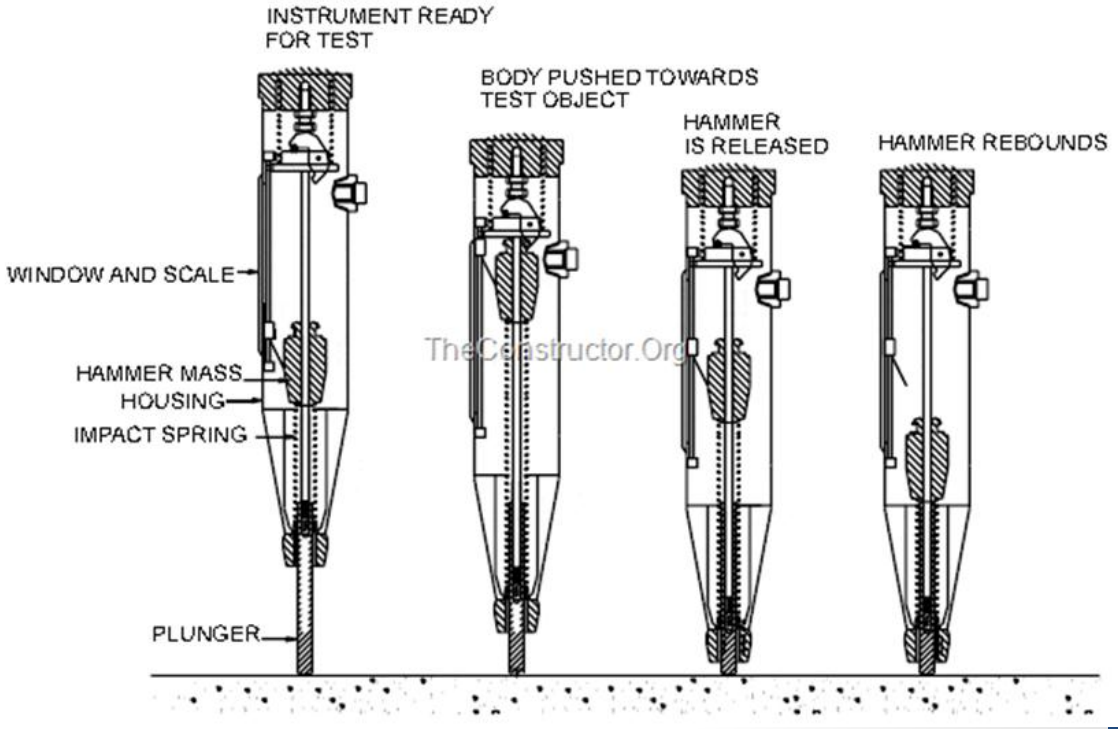
1. Surface hardness test (rebound hammer)
2. Ultrasonic pulse velocity
3. Penetration resistance test
4. Pull out test
5. Core cutting
6. Chemical test(chloride test & carbonation test)

SURFACE HARDNESS TEST (REBOUND HAMMER)

- It is a non-destructive test performed on hardened concrete.
- A spring-loaded mass hits the concrete's surface and scale measures how far the mass rebounds.
- The higher the rebound, the harder the concrete's surface, and the greater the concrete's strength. Use a calibration chart graphs supplied to related the rebound to strength.

- : Schmidt Hammer Test


Concrete surface
Impact spring
Rider on guide rod
Window & Scale
Hammer guide
Release catch
Plunger
Hammer mass
Housing
Locking button
Compression spring


INSTRUMENT READY FOR TEST
BODY PUSHED TOWARDS TEST OBJECT
HAMMER IS RELEASED
HAMMER REBOUNDS
WINDOW AND SCALE
HAMMER MASS
HOUSING
IMPACT SPRING
PLUNGER
TheConstructor.Org

INTERPRETATION OF THE TEST RESULTS

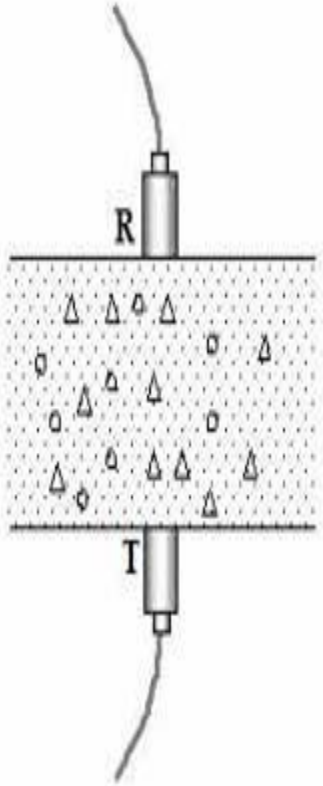
Average Rebound Number	Quality of Concrete
more than 40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
less than 20	Poor concrete
0	Delaminated

Ultrasonic Pulse Velocity Test

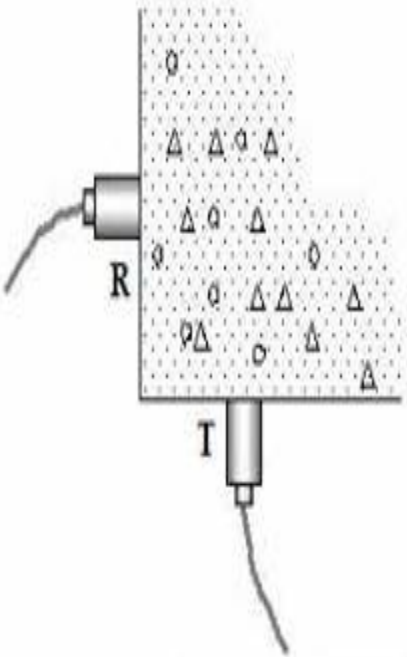
- This test measures the velocity of an ultrasonic wave passing through the concrete.
- The length between transducers/the travel time = average velocity of wave propagation.
- It is used to detect discontinuities, cracks and internal deterioration in the structure of concrete.

December 2017

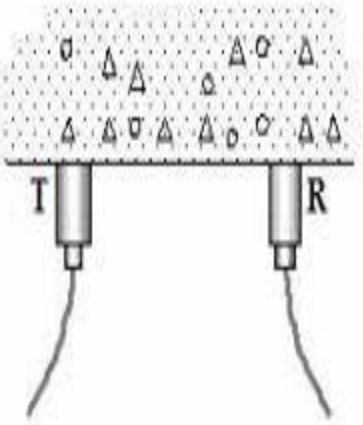
Three possible ways of measuring pulse velocity



DIRECT METHOD



SEMI DIRECT METHOD



INDIRECT METHOD

METODE PENGUJIAN UPVT

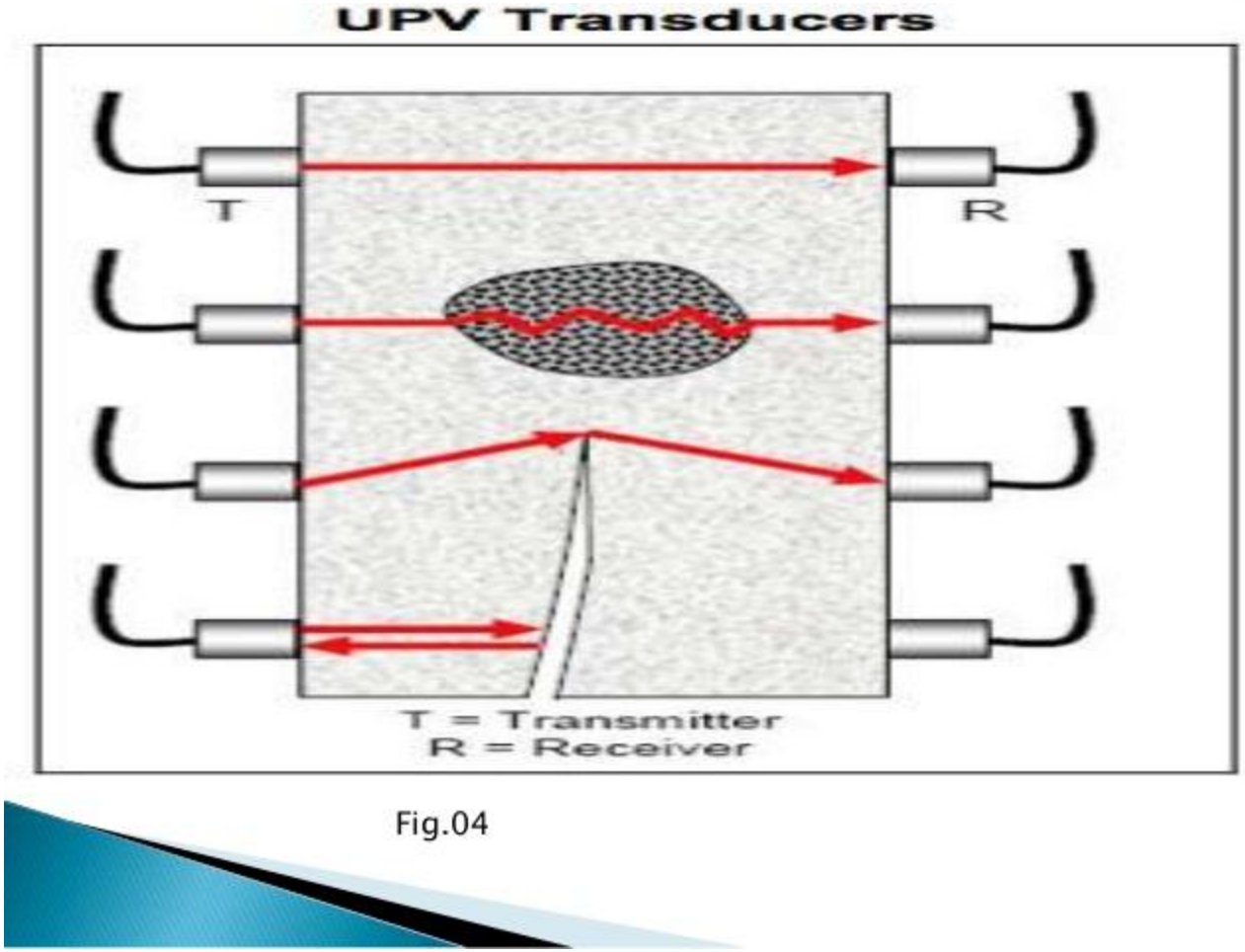


Fig.04

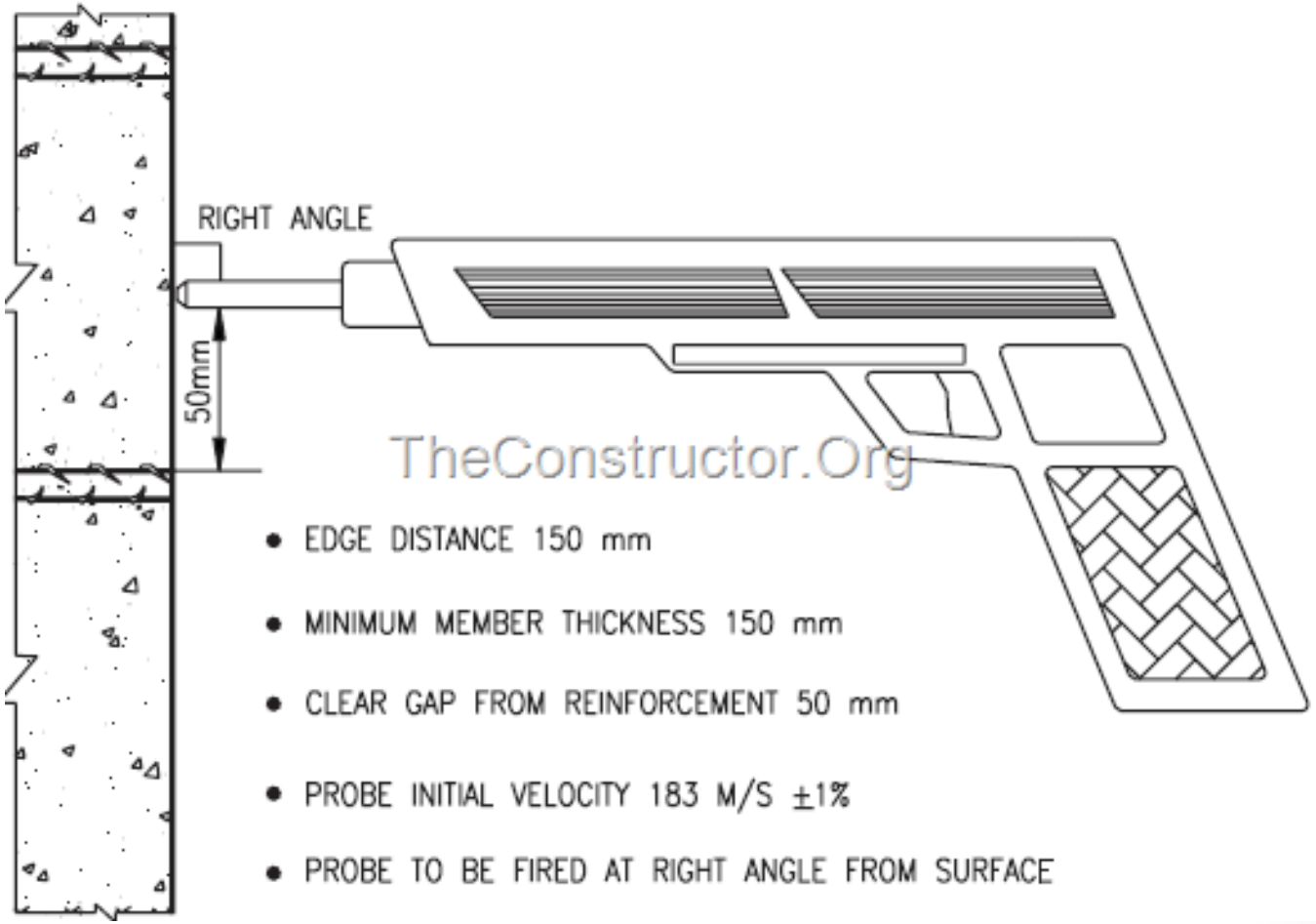
Pulse velocity=(Path length/Travel time)

TEST RESULT

Pulse Velocity (km/second)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

Penetration resistance test (Windsor Probe Test)

- It is a non-destructive test.
- Gun-like device shoots probes into the concrete's structure.
- It is performed on each of three holes in a special template.
- An average depth is then found.
- Depth is inversely related to the strength. It gives a better estimate than the rebound hammer.



- EDGE DISTANCE 150 mm
- MINIMUM MEMBER THICKNESS 150 mm
- CLEAR GAP FROM REINFORCEMENT 50 mm
- PROBE INITIAL VELOCITY 183 M/S ±1%
- PROBE TO BE FIRED AT RIGHT ANGLE FROM SURFACE

CONCRETE TEST

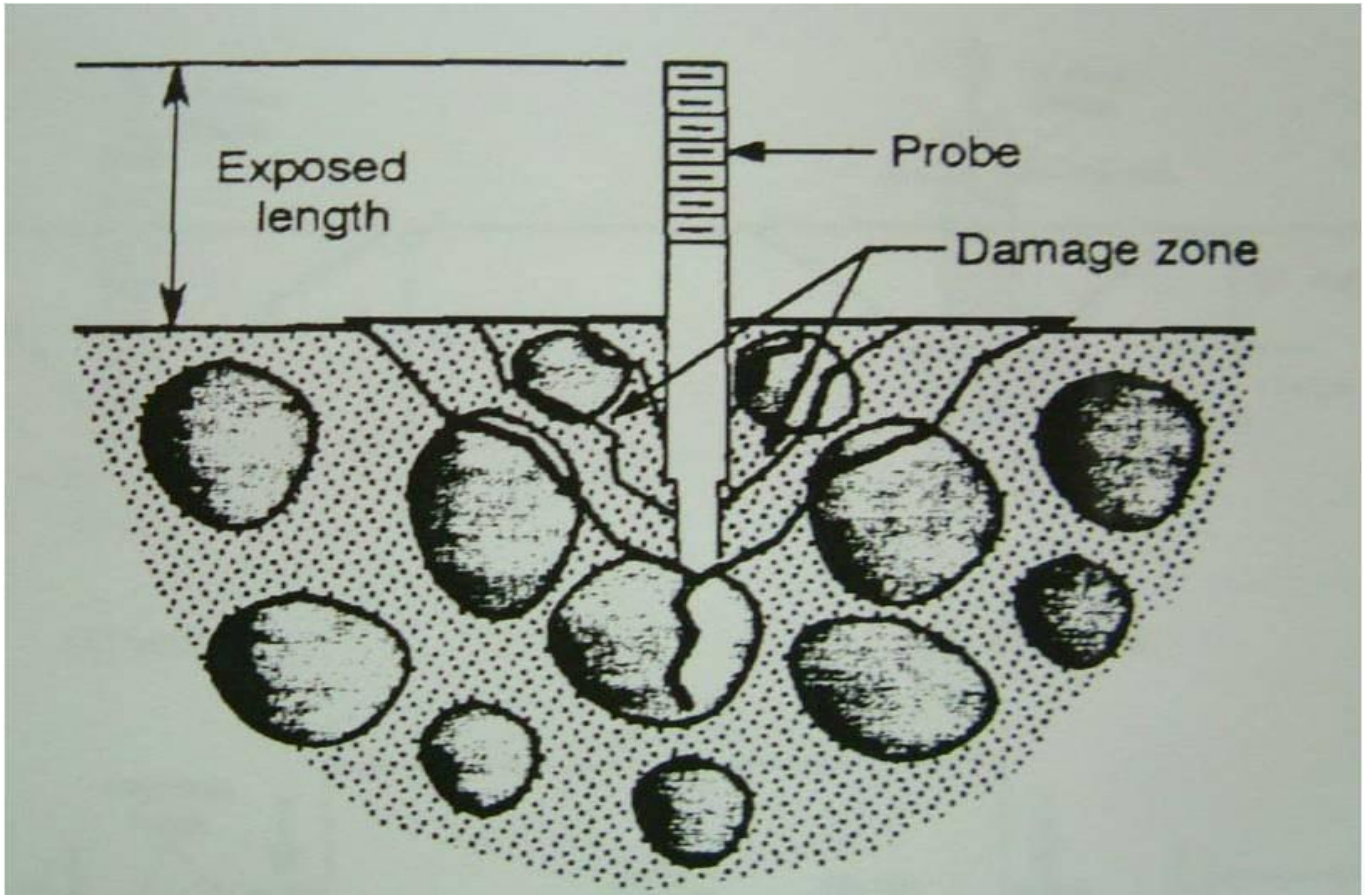


FIGURE 19.4 Schematic of conical failure zone during probe penetration test.

CHEMICAL TEST

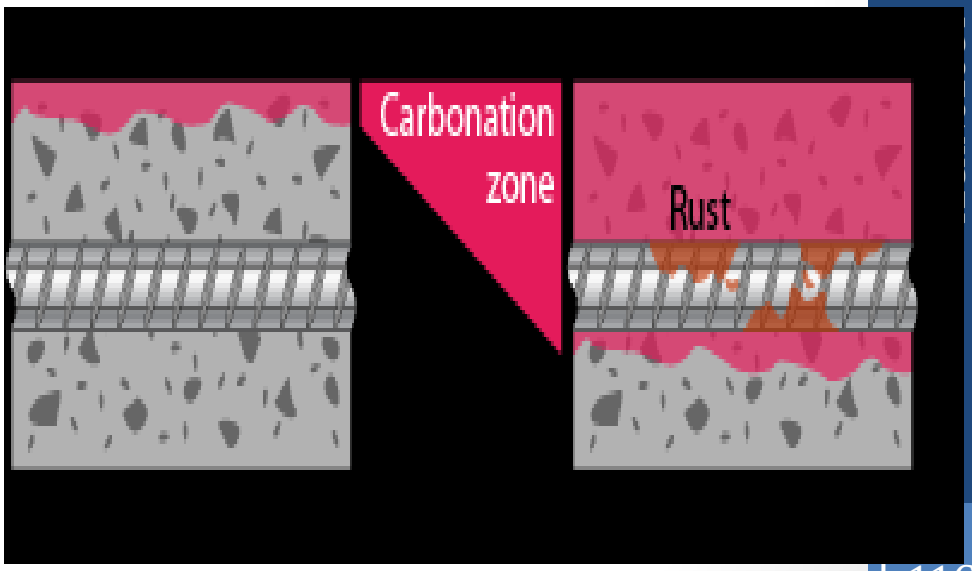
HARDEND CONCRETE

Carbonation Test on Concrete Structures

- This test is carried out to determine the depth of concrete affected due to combined attack of atmospheric carbon dioxide and moisture causing a reduction in level of alkalinity of concrete.
- A spray of 0.2% solution of phenolphthalein is used as pH indicator of concrete.
- The change of colour of concrete to pink indicates that the concrete is in the good health, where no changes in colour takes place, it is suggestive of carbonation-affected concrete.
- The test is conducted by drilling a hole on the concrete surface to different depths upto cover concrete thickness, removing dust by air blowing, spraying phenolphthalein with physician's injection syringe and needle on such freshly drilled broken concrete and observing change in colour.

Phenolphthalein & CUBE


10
20TOLED030
40


Carbonation
zone
Rust

CARBONATION DEPTH MEASUREMENT TEST

17

- Carbonation of concrete occurs when the carbon dioxide, in the atmosphere in the presence of moisture, reacts with hydrated cement minerals to produce carbonates
- Due alkaline nature of concrete, reinforcement is protected from corrosion. This is neutralized by carbonation, thus reinforcement becomes prone to in presence moisture and oxygen.

CARBONATION TEST

PREPARATION OF TEST SURFACE:

- By breaking a piece of concrete from the main area and spraying the underlying surface immediately

METHODOLOGY OF CARBONATION TEST (Phenolphthalein Test)

Generally Phenolphthalein indicator is used which indicate the carbonated concrete. The uncolored layer is considered to be carbonated.

Test Cylinder After Phenolphthalein Indicator Applied.

100ml of 1% Phenolthalein solution

Self compacting concrete

- Self-compacting concrete (SCC) 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.

Fresh SCC Properties:

- Filling ability (excellent deformability)
- Passing ability (ability to pass reinforcement without blocking)
- High resistance to segregation.

Advantages of scc

- Improved constructability.
- **Labor reduction.**
- Bond to reinforcing steel.
- **Improved structural Integrity.**
- Accelerates project schedules.
- Reduces skilled labor.
- Flows into complex forms.
- Reduces equipment wear.
- **Minimizes voids on highly reinforced areas**.

Roller compacted concrete

- Roller-compacted concrete, or RCC, takes its name from the construction method used to build it. It's placed with conventional or high-density asphalt paving equipment,then compacted with rollers.

  Roller-compacted concrete has the same basic ingredient as conventional concrete: cement, water, and aggregates, such as gravel or crushed stone.

  But unlike conventional concrete, it's a drier mix—stiff enough to be compacted by vibratory rollers. Typically, RCC is constructed without joints. It needs neither forms nor finishing, nor does it contain dowels or steel

rcc

- **No Rutting, No Pot Holes**
- The high strength of RCC pavements eliminates common and costly problems traditionally associated with asphalt pavements.
  RCC pavements:

- Resist rutting

- Will not deform under heavy, concentrated loads

- Do not deteriorate from spills of fuels and hydraulic fluids

- Will not soften under high temperatures


HAMM

ADVANTAGES OF SCC

- Elimination of problems associated with vibration.
- Faster construction
- Improves working conditions and productivity in construction industry.
- Greater freedom in design.
- Less noise from vibrators and reduced danger from hand-arm vibration syndrome (HAVS).
- Ease of placement results in cost savings through reduced equipment and labour requirement.
- Improves the quality, durability, and reliability of concrete structures due to better compaction and homogeneity of concrete.
- Reduced wear and tear on forms from vibration.
- Reduced permeability.

RMC

- Ready mixed concrete (RMC) is a concrete, delivered at site or into the purchaser's vehicle, in plastic condition and requires no further treatment before being placed in a position in which it is to set and harden.
- It is a high quality concrete of required grade produced under strictly controlled conditions in a centralized automatic batching plant and supplied to the customer in a transit mixer truck for its placement at site.
- The concrete can be mixed either dry at the batching plant, loaded into agitator truck mixers and water added during transportation; or itcan be mixed wet at the batching plant, discharged into the agitator truck mixers and transported

MERITS

- 1. Enhanced quality and durability resulting in lower maintenance costs and increased speed of construction.
-
- 2. Ready mix concrete is consistently of the same quality and provides a high quality of construction material; construction time is also reduced.
-
- 3. It reduces congestion at the site and prevents traffic jams.
-
- 4. It is an environmentally safer alternative.

RMC PLANT

FRC

- Fibre reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibres.
- The role of randomly distributes discontinuous fibres is to bridge across the cracks that develop provides some post-cracking “ductility”.
- The real contribution of the fibres is to increase the toughness of the concrete under any type of loading.
- added advantages of the fibre to shear resistance and crack control can be further utilised.

Application of FRC:

- The most common applications are
- pavements
- tunnel linings
- pavements and slabs
- shotcrete

Polymer concrete

- Polymer concrete is part of group of concretes that use polymers to supplement or replace cement as a binder.
- The types include polymer-impregnated concrete, polymer concrete, and polymer-Portland- cement concrete.
- In polymer concrete, 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.
- Polymer concrete may be used for new construction or repairing of old concrete .
- The low permeability and corrosive resistance 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.

Advantages

- Rapid curing at ambient temperatures
- High tensile, flexural, and compressive strengths
- Good adhesion to most surfaces
- Good long-term durability with respect to freeze and thaw cycles
- Low permeability to water and aggressive solutions
- Good chemical resistance
- Good resistance against corrosion

SPRAYED CONCRETE

- **Sprayed concrete** is a method of applying **concrete**that is generally self supporting without the need for form work.
- **Sprayed concrete** is often referred to as Gunite (dry mix) or Shotcrete (wet mix) The Gunite process was developed in 1895 and was commercially available in the early 1900´s.

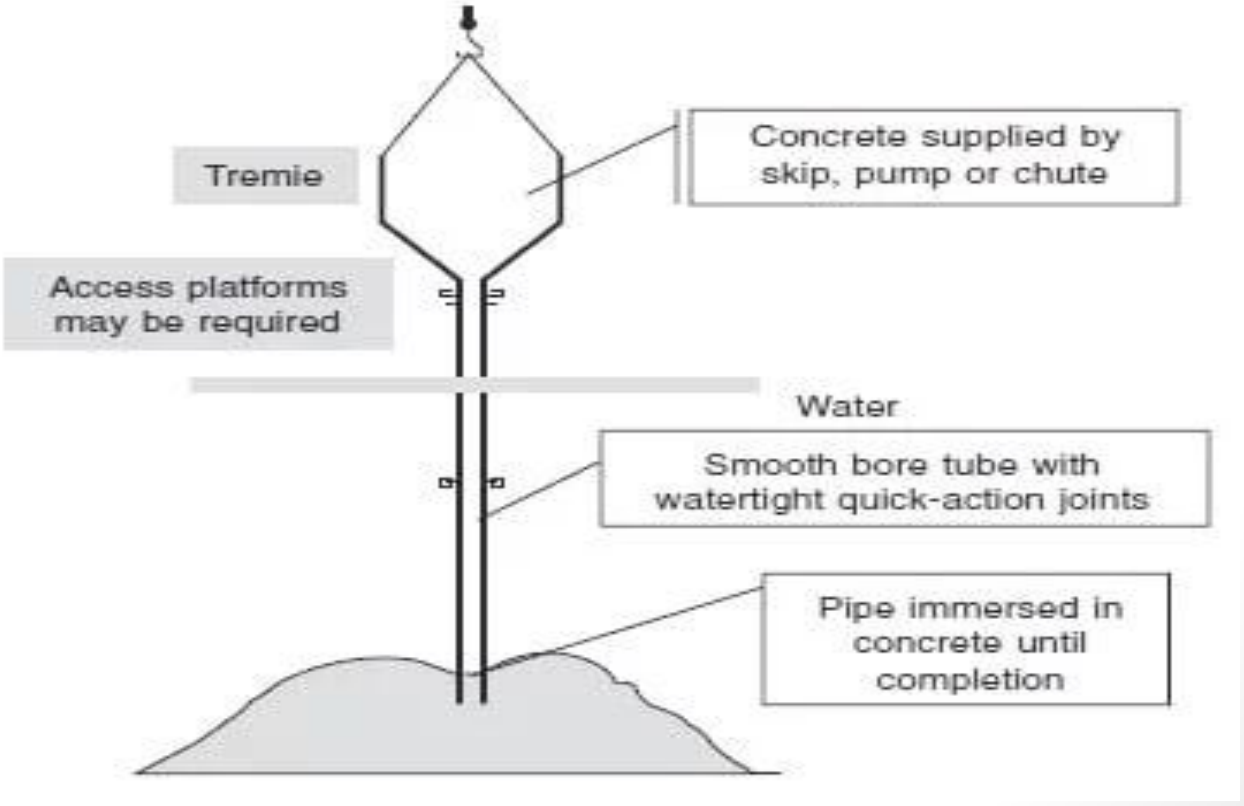

CONTECH UK

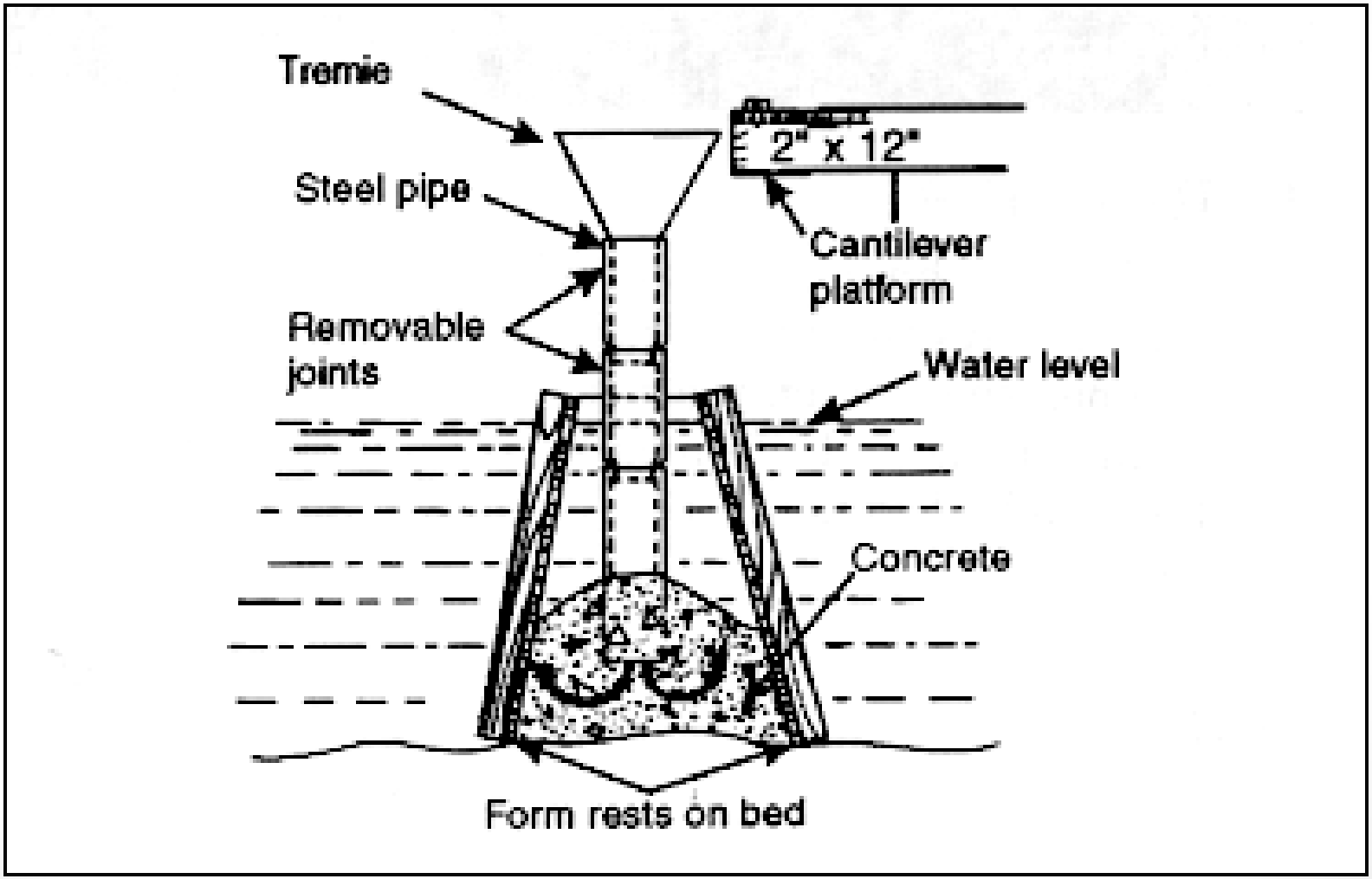
applications

- There are many applications and uses for sprayed concrete. These include curved structures (including shell roofs and domes and tunnel linings) and free-formed structures (such as swimming pools and climbing walls). Applications also include underground construction, retailing walls and piled wall facings. Sprayed concrete is also commonly used to provide fire protection to steelwork and for strengthening and repair works to existing structures.

Underwater concreting

- Underwater concreting using tremie method is convenient for pouring large amount of high flowble concrete. The concrete is moved to the hopper by either pumping, belt conveyer or skips.




Tremie
Steel pipe
2" x 12"
Cantilever platform
Removable joints
Water level
Concrete
Form rests on bed

@ site execution

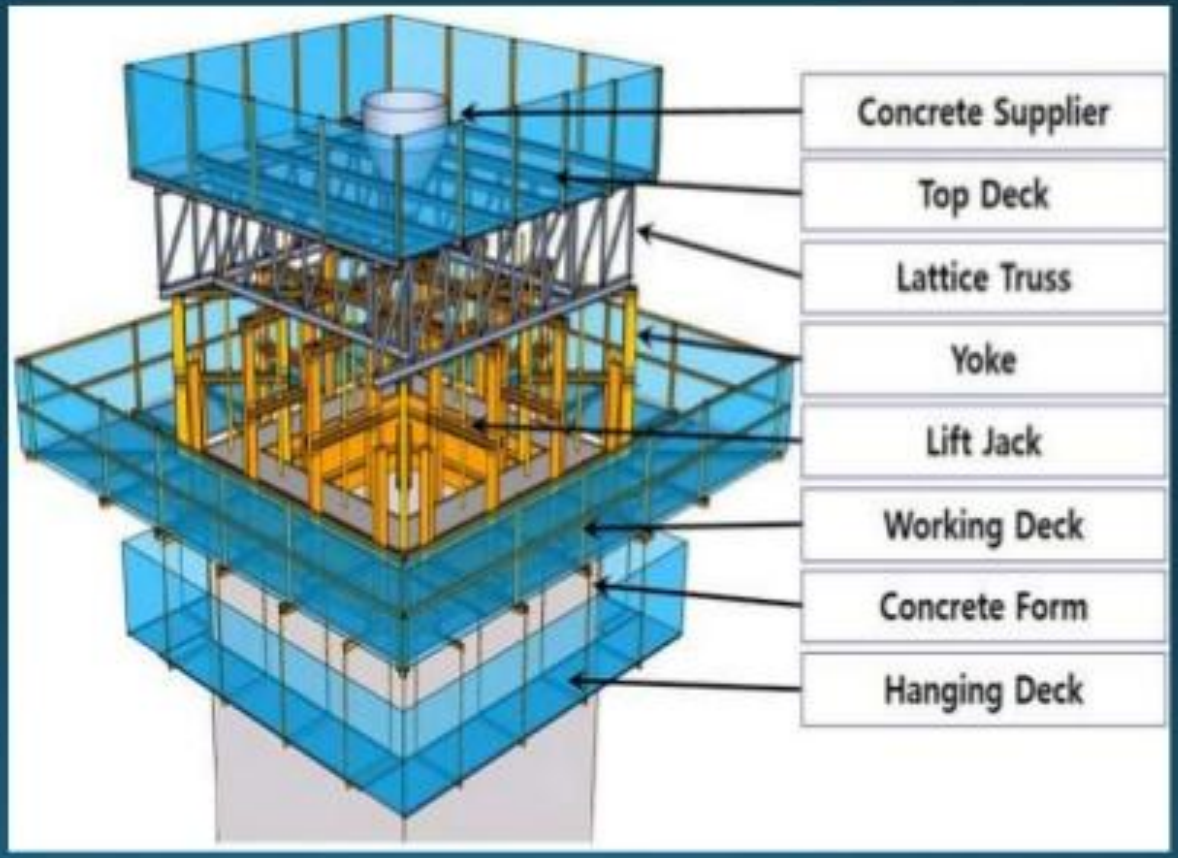

Marine Resources Inc.

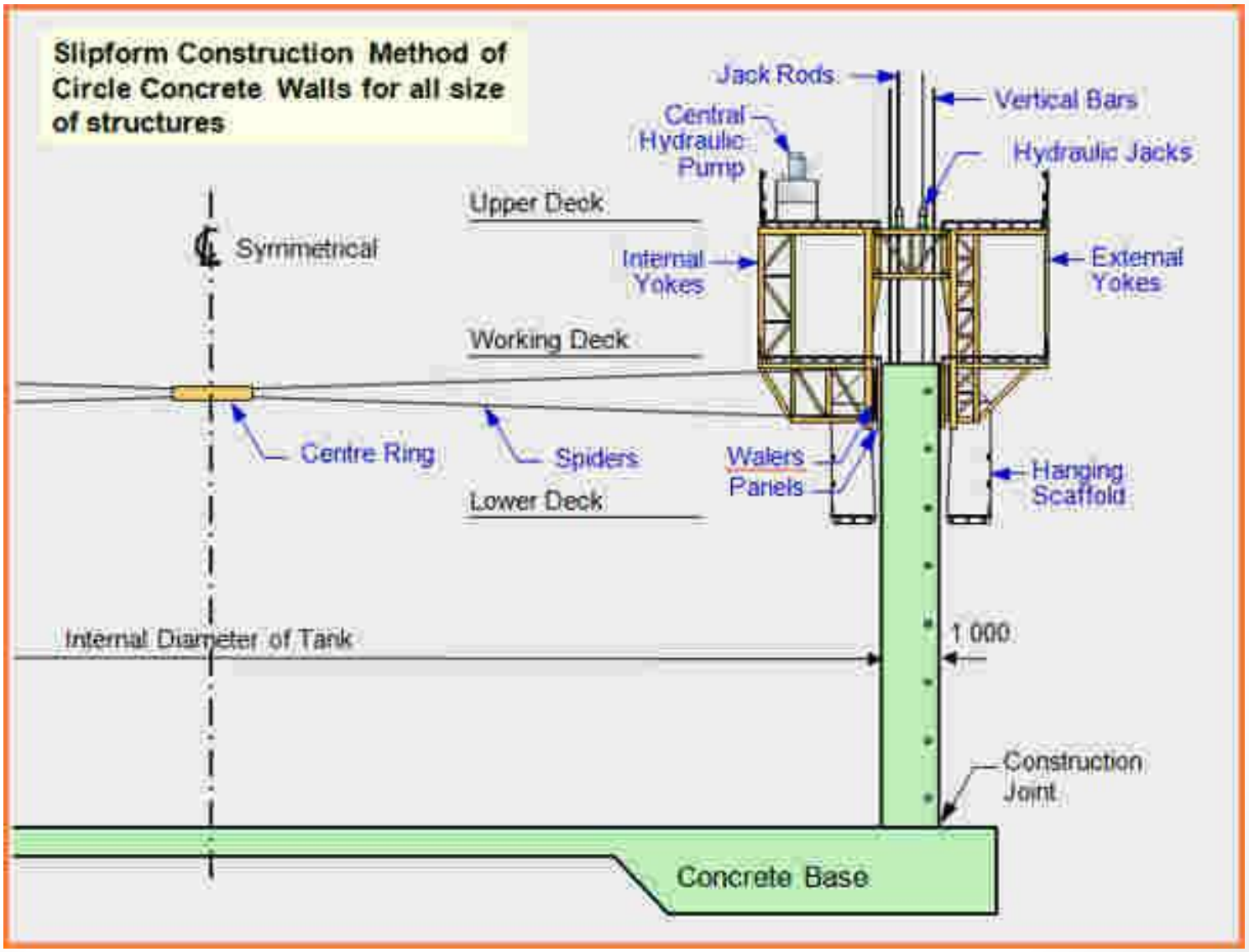
SLIPFORM

- Slipform construction is a method for building large towers or bridges from concrete.
- The name refers to the moving form the concrete is poured into, which moves along the project as the previously poured concrete hardens behind it. The technique has also been applied to road construction.

INTRODUCTION

- Slip form construction, or continuously formed construction, is a construction method in which concrete is poured into a continuously moving form.
- Basically, this method involves the continuous placing of concrete in a shallow mould having the same plan as the building to be constructed. This rigid mould, or "slip-form" as it is called, forms the working deck which is jacked slowly upwards at a controlled rate until the required elevation is reached.




Slipform Construction Method of Circle Concrete Walls for all size of structures
Jack Rods
Vertical Bars
Central Hydraulic Pump
Hydraulic Jacks
Upper Deck
Symmetrical
Internal Yokes
External Yokes
Working Deck
Centre Ring
Spiders
Walers
Panels
Hanging Scaffold
Lower Deck
Internal Diameter of Tank
1 000
Construction Joint
Concrete Base

Prefabrication technology

- Prefabricated construction is the practice of assembling a variety of components of a structure at a manufacturing site and transporting those sub-assemblies to the location of the construction jobsite.
- Prefabricated construction is sometimes thought of as a low-end and mass produced mode of construction.

Advatages

- **Eco-Friendly**
- Modular construction is often commended for energy efficiency and sustainable construction. Traditional construction methods require extra materials that lead to increased waste. However, since prefabricated sub-assemblies are constructed in a factory, extra materials can be recycled in-house

Financial Savings

- One of the greatest advantages of prefabricated construction would be financial savings. Although the perception of custom-made pieces may seem expensive, with prefabricated or modular construction, this is not the case. Modular construction targets all budgets and price points, creating an affordable option. Prefabrication manufacturers often receive bulk discounts from material suppliers which then trickles down to the cost of a construction project.

- **Flexibility**
- Modular construction can be easily be disassembled and relocated to different sites. This significantly reduces the demand for raw materials, minimizes expended energy and decreases time overall.
- **Shorter Construction Time**
- Portable construction takes significantly less time to build than on-site construction. In many instances, prefabrication takes less than half the time when compared to traditional construction. This is due to better upfront planning, elimination of on-site weather factors, subcontractor scheduling delays and quicker fabrication as multiple pieces can be constructed simultaneously. Shorter construction times allows construction companies to take on multiple projects at once, allowing businesses to grow rather than putting all their focus and resources on one or a few projects at a time.

- **Safety**
- Since sub-assemblies are created in a factory-controlled environment utilizing dry materials, there is less risk for problems associated with moisture, environmental hazards and dirt. This ensures that those on the construction site, as well as a project's eventual tenants are less likely to be exposed to weather-related health risks. Also, an indoor construction environment presents considerably fewer risks for accidents and other liabilities

Final Thoughts

- With the continued popularity of prefabricated construction, it is likely that it will only continue to grow in popularity. Customers who choose this option are able to enjoy a high quality, quicker, cost-effective, and eco-friendly construction method. Furthermore, construction companies may soon increase their investment in modular construction processes, benefiting both their business and customer relationships. Prefabricated construction is proving to be an extremely viable option, and as manufacturing technology continues to improve, expect to see its benefits and advantages rise in the future.

ASSIGNMENT FINAL

Q.1 Factors influencing corrosion of reinforcement.

Q.2 fire resisting of concrete.

Q.3 sulfate attack and alkali silica reaction in concrete.

Q.4 concrete in sea water.

DATE OF GIVEN : 8-11-17

SUBMISSION:15-11-17