

UNIT 4-TECHNIQUES FOR REPAIR AND PROTECTION METHODS

2 Marks

1. What are the preliminary investigations before demolition of a structure? (April/May 2017)

The demolition contractor should have ample experience of the type of work to be offered;

- Fully comprehensive insurance against all risks must be maintained at all times;
- An experienced supervisor should be continuously in charge of the work;
- The contract price should include all safety precautions included in the relevant building regulations;
- The completion date should be realistic, avoiding and need to take risks to achieve the date.

2. Differentiate between: "shoring and underpinning"? (April/May2019)

Underpinning	Shoring
Underpinning in foundation should be addressed and supervised by and engineer. The underpinning process must be started from the corners and the working inwards. Underpinning must be made only on load bearing walls.	Shoring supports the forms, workers and fresh concrete at the top level. The shore posts may be wood, aluminium or steel. Shores distribute the load from the form to the slab below which is the top surface of the reshore system. Shoring and reshoring at the ground level is a special condition.

3. Give any four characteristics of coatings to concrete? (Nov/Dec 2018)

- Surface Coatings
- Anti Carbonation Coatings
- Surface Impregnation coatings
- Coatings to protect from Acidic environment.

4. Under what situation underpinning is warranted(Nov/Dec2018)(April/May 2017) (April/May 2018)

Underpinning is a process **used to** repair, strengthen, or increase the depth of an existing foundation by lowering the footing to allow it to rest on more supportive soil.

5.What is the advantages of Cathodic Protection (April/May 2017)

- Stops corrosion in contaminated concrete.
- Prevents corrosion from beginning.
- Effectiveness may be measured.
- Proven in tens of thousands of applications.
- Based on fundamental laws of nature.

6. Define the purpose of shoring(Nov/Dec 2017)

Shoring is employed to prevent a damaged structure due to foundation settlement or other reasons from collapse. It is also used to provide temporary supports to a structure which is being remodeled or where alterations of adjacent foundations are being carried out

7. Name any two NDT test for assessing quality of concrete (Nov/Dec 2017)

- Penetration method
- Rebound hammer method
- Pull out test method
- Ultrasonic pulse velocity method
- Radioactive methods

8. State the properties of corrosion inhibitors(April/May 2018)

A **corrosion inhibitor** is a chemical compound that, when added to a liquid or gas, decreases the **corrosion** rate of a material, typically a metal or an alloy. The effectiveness of a **corrosion inhibitor** depends on fluid composition, quantity of water, and flow regime.

9. Why reinforcement is coated in RCC structure(April/May 2019)

The purpose of providing reinforcement in R.C.C. is: To take up all the tensile stresses developed in the structure. To increase the strength of concrete sections. To prevent the propagation of cracks developed due to temperature and shrinkage stresses

10. What are protective surface coatings? (Nov/Dec 2018)

A wide range of surface penetrating sealers and coatings are available. They range from purely cosmetic treatments to thick membranes and can be applied to cracked concrete. If cracking has reached a stable condition, then a sealer can usually be applied successfully. Low viscosity, low solid resistance solutions such as epoxies have been used to seal the surface of concrete in areas that are not subjected to wear.

11. What is Vacuum concrete?

Only about half of the water added in concrete goes into chemical combination and the remaining water is used to make concrete workable. After laying concrete, water which was making concreting workable is extracted by a special method known as "vacuum method".

12. What are the equipments used in vacuum concrete?

The equipment essentially consists of:-

- i. vacuum pump
- ii. water separator and
- iii. filtering mat

13. What is Guniting?

Guniting can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity on to a surface.

14. What are the two types of process in Shotcrete?

- a. Wet mix process
- b. Dry mix process

15. What are the stages in dry mix process in shotcrete?

In this process, the concrete is mixed with water as for ordinary concrete before conveying through the delivery pipeline to the nozzle, at which point it is jetted by compressed air, onto the work in the same way as that of wet mix process.

16. What is shotcrete?

Shotcrete is a recent development on the similar principle of guniting for achieving greater thickness with small coarse aggregate.

17. Write about protective clothing given before demolition.

Buildings where chemicals have been stored or where asbestos, lead paint, dust or fumes may be present will require specialized protective clothing, e.g. gum boots, helmet, gloves etc.,

18. Give a brief note on shoring and underpinning in demolition.

The demolition contractor has a legal obligation to show technical competence when carrying out the work. When removing sections of the building which could have left other parts unsafe, adequate temporary supports and shoring etc. must be provided.

19. What are the major factors in selecting a demolition procedure?

Major's factors to be considered in selecting an appropriate technique include

- Safety of personnel and public
- Working methods
- Legislation applicable
- Insurance cover

20. Give the categories of demolition techniques.

Demolition techniques may be categorized as:-

- Piecemeal demolition, using hand-held tools or machines, to reduce the height of the building or structure gradually;
- Deliberate controlled collapse, demolition to be completed at ground level.

21. Write short notes on demolition by hand.

Demolition of buildings or structure by hand-held tools such as electric or pneumatic breakers, sometimes as a preliminary to using other methods, should be carried out, where practicable, in the reverse order to the original construction sequence. Lifting appliances may be necessary to hold larger structural members during cutting and for lowering severed structural members and other debris.

22. In what cases demolition by machine can be done?

Simple roof structures supported on wall plates should normally be demolished to the level of wall plates by hand, but if this may involve unsafe working, then demolition totally by machine may be appropriate.

23. Write short notes on balling machine.

Balling machines generally comprise a drag-line type crawler chassis fitted with a lattice crane jib. The demolition ball, with a steel anti-spin device, is suspended from the lifting rope and swung by the drag rope.

24. How are explosives used for demolition of a structure?

If explosives are to be used for demolition, the planning and execution,

include pre-weakening, should be under the control of a person competent in these techniques. For large demolition, the competent person is likely to be an experienced explosive engineer; for smaller work, a shot-firer may be sufficient.

25. What is a hydraulic pusher arm?

Articulated, hydraulically-powered pusher-arm machines are normally mounted on a tracked or wheeled chassis, and have a toothed plate or hook for applying a horizontal force to a wall. The machine should stand on a firm level base and apply force by a controlled movement of the pusher arm.

26. What is pre-weakening?

Buildings and structures normally have structural elements designed to carry safely the loading likely to be imposed during their life. As a preliminary to a deliberate controlled collapse, after loads such as furnishings, plant and machinery have been removed, the demolition contractor may be able to weaken some structural elements and remove those new redundant. This preweakening is essentially a planned exercise and must be preceded by an analysis of its possible effects on the structure until it collapses, to ensure that the structural integrity of the building is not jeopardized accidentally.

27. What is deliberate collapse?

The deliberate collapse of the whole or part of a building or structure requires particularly high standards of planning, supervisions and execution, and careful consideration of its effect on other parts of the structure or on adjacent buildings or structures. A surrounding clear area and exclusion zone are required to protect both personnel and property from the fall of the structure itself and debris which may be thrown up by the impact.

28. How can you develop a demolition strategy?

The strategy will need to take into account the method of construction used for the original building and its proximity to other buildings, structures and the general public. These factors, together with location, the cost and availability of tipping and disposal and the desirability and economics of reuse, must be taken into account in the development of an appropriate strategy for the demolition of a structure.

29. What are nibblers?

Nibblers use a rotating action to snap brittle materials such as concrete or masonry. In either case, material should be removed from the top of walls or columns in courses not greater than 600mm in depth, steel reinforcement should be cut separately as necessary.

30. What are the considerations before demolition?

Considerations should be given to

- Conducting a site and building survey, with a structural bias;
- The examination of drawings and details of existing construction where available;
- The preparation of details and drawings from site survey activities where no such information is available;
- Establishing previous use of premises, especially with regard to flammable substances or substances hazardous to health or safety;
- Programming the sequence of demolition work;
- The preparation of a Method Statement.

31. What is dry pack?

Dry packing is the hand placement of a low w/c ratio mortar which is subsequently rammed in place to produce a dense mortar plug having tight contact to the existing concrete, because of the low w/c ratio, there is little shrinkage and the patch remains tight, with good durability, strength, and water tightness.

32. How the jacketing is done?

Jacketing is the process of fastening durable materials over concrete and filling the gap with a grout that provides needed performance characteristics, the materials used for jacket are metals, rubber, plastics, ferrocement and concrete. A steel reinforcement cage is constructed around the damaged section onto which shotcrete or cast-in-place concrete is laid. Sometimes brackets are cast externally along with jackets to encase the damaged members.

33. Discuss about the process of guniting?

The guniting process applied to damaged concrete structures is as follows: The cement and sand are batched and are mixed in the usual way and conveyed through a hosepipe with the help of compressed air, a separate pipe line brings water under pressure and the water and cement aggregate mix are passed through and intimately mixed in a special manifold and then projected at high velocity to the surface being repaired.

34. Explain about vacuum concrete.

For concrete surfaces that contain a large number of cracks vacuum impregnation may be used. The part of structure to be repaired is enclosed within an air tight plastic cover and then the air from all cracks within cover is sucked by applying vacuum, after exhausting the air from all cracks. The monomer of resin grout is forced under one atmosphere pressure in cracks and pores of the concrete surfaces.

35. Define stitching?

The cracks are bridged with U shaped metal units called stitching dogs before being repaired with a rigid resin material. This can establish restoration of the strength and integrity of cracked section. Stitching may accentuate restraints causing cracking. Strengthening of adjacent areas of the structures to take the additional stress may be required.

36. Advantages of slab jacking technique.

- Cost effectiveness-grouts leveling is frequently the most economical method.
- Down time it's generally faster than other methods of repair.
- Surface maintenance - for concrete pavements, the repair maintains the surface of texture and appearance, provides a smooth riding surface, and extends the useful life of the concrete surfacing.

37. Define FRC; explain the effect of volume fraction on fresh concrete properties?

Define:

Fibre reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres.

Volume of fibres:

The strength of the composite largely depends on the quantity of fibres, the effect of volume on the toughness and strength. The fibre volume at which this situation is reached depends on the length and diameter of the fibre.

16 MARKS

1. Detail the procedure of Epoxy injection?(Nov/Dec 2018) (April/May 2017) (April/May 2018)

- Injection is typically used on horizontal, vertical, and overhead cracks where conventional repair methods cannot penetrate and deliver the specific repair product into the crack.
- Prior to proceeding with a crack repair by epoxy injection, the cause of the crack and the need for a structural repair must be determined. If the crack does not compromise the structural integrity of the structure, injection with polyurethane grouts or other nonstructural materials may be a more suitable choice to fill the crack.
- When a structural repair is required, conditions that cause the crack must be corrected prior to proceeding with the epoxy injection. If the crack is damp and cannot be dried out, an epoxy tolerant to moisture should be considered. Cracks caused by corroding reinforcing steel should not be repaired by epoxy injection because continuing corrosion will cause new cracks to appear.
- Clean the surface area about 1/2 in. (13 mm) wide on each side of the crack. This is done to ensure that materials used to seal the top of the crack (the cap seal) will bond properly to the concrete. Wire brushing is recommended because mechanical grinders may fill the cracks with unwanted dust.
- Contaminants can also be removed by high-pressure water,
- "oil-free" compressed air, or power vacuums. When using water to clean out the crack, blow out the crack with oil-free, compressed or heated air to accelerate drying. Otherwise, allow enough time for natural drying to occur before injecting moisture-sensitive epoxies.
- Where concrete surfaces adjacent to the crack are deteriorated, "V"-groove the crack until sound concrete is reached.

“V” grooves can also be used when high injection pressures require a stronger cap seal. For epoxy selection, the following product characteristics may also have to be considered:

1. Modulus of elasticity (rigidity);
2. Working life;
3. Moisture tolerance;
4. Color; and
5. Compressive, flexural, and tensile strengths.

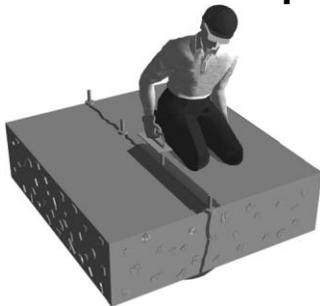
Repair procedure

1. Port installation

Install the entry ports only after proper surface preparation. Two types of entry ports are available for the injection process:

1. Surface-mounted
 2. Socket-mounted
- Entry ports (also called port adapters) can be any tube like device that provides for the successful transfer of the epoxy resin under pressure into the crack.
 - Proprietary injection guns with special gasketed nozzles are also available for use without port adaptors. Port spacing is typically 8 in. (40 mm) on center, with increased spacing at wider cracks.
 - Port spacing may also be a function of the thickness of the concrete element. Surface-mounted entry ports are normally adequate for most cracks, but socket-mounted ports are used when cracks are blocked, such as when calcified concrete is encountered.
 - Entry ports can also be connected by a manifold system when simultaneous injection of multiple port locations is advantageous.

2. Install the cap seal



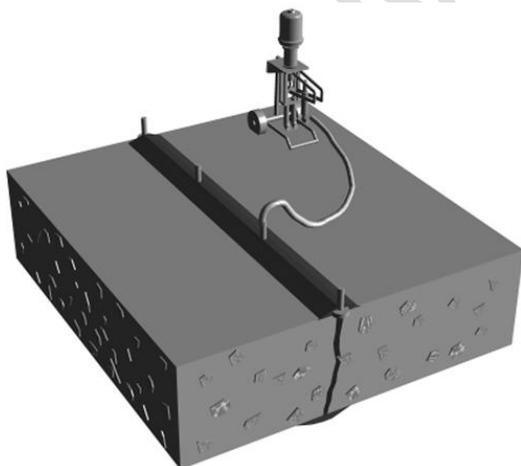
Installation of seal cap.

- Properly installed, the cap seal contains the epoxy as it is injected under pressure into the crack. When cracks penetrate completely through a section, cap seals perform best when installed on both sides of the cracked element, ensuring containment of the epoxy.

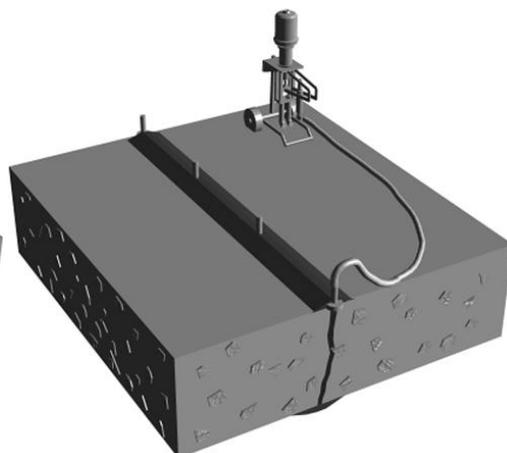
The selection of the cap seal material should consider the following criteria, subject to the type of crack to be repaired:

- Non-sag consistency (for vertical or overhead);
 - Moisture-tolerance;
 - Working life; and
 - Rigidity (modulus of elasticity).
- Concrete temperature changes after installation of the cap seal but prior to injection may cause the cap seal to crack. If this occurs, the cap seal must be repaired prior to resin injection.
 - Prior to proceeding with installation of the cap seal, mark the location of the widest portion of the crack and pay close attention to the following:
 - Use only materials that haven't exceeded their shelf life;
 - Accurate batching of components;
 - Small batches to keep material fresh, and dissipate heat;
 - Port spacing; and
 - Consistent application of the material (1 in. wide x 3/16 in. thick [25 x 5 mm]) over the length of the crack.

3. Inject the epoxy



Start injection at widest segment of the crack. until refusal.



Continue injection

- For a successful epoxy injection, start with the proper batching and mixing of the epoxy components in strict accordance with the manufacturer's requirements.
- Prior to starting the actual injection, be sure that the cap seal and port adapter adhesive have properly cured so they can sustain the injection pressures.
- Start the injection at the widest section of a horizontal crack. (Be sure to locate and mark these areas before installing the cap seal.) Vertical cracks are typically injected from the bottom up.
- Continue the injection until refusal. If an adjacent port starts bleeding, cap the port being injected and continue injection at the furthest bleeding port. Hairline cracks are sometimes not well suited to "pumping to refusal." In those cases, try injecting the epoxy at increased pressure (approximately 200 psi [1.3 MPa]) for 5 min.
- Closer port spacing can also be considered. When injection into a port is complete, cap it immediately. Higher pressure can be used for injecting very narrow cracks or increasing the rate of injection.
- However, the use of higher pressure should be managed with care to prevent a blowout of the cap seal or ports.

4. Remove ports and cap seal

Upon completion of the injection process, remove the ports and cap seal by heat, chipping, or grinding. If the appearance is not objectionable to the client, the cap seal can be left in place. If complete removal is required for a subsequent application of a cosmetic coating, prepare the concrete surface by grinding.

2. Explain different methods of prevention of corrosion in reinforcement: (April/May 2019)(Nov/Dec 2018)

Rebars can be protected from corrosion in three ways.

- Seal the surface of the concrete to prevent ingress of chlorides and moisture.
- Modify the concrete to reduce its permeability, thus retarding the flow of moisture and chlorides to reach the reinforcing steel.

- Protect the reinforcing bars to reduce the effects of chlorides when they do reach the steel.

Corrosion controlling steps in reinforcement are stated below:

(a) Good Concrete Practice:

1. Specify and introduce Chloride limit as part of the good concrete. The code shows limits for various type of constructions and exposure conditions.
2. Maintain a low water-cement ratio in concrete.
3. Provide adequate cover to the reinforcing steel. This helps in increasing the time it takes for the chlorides to reach the steel.
4. Provide adequate curing by not allowing fresh concrete to dry without curing for at least seven days of wet curing.
5. Use of water-reducing admixture to give the concrete enough workability so that workers are able to compact concrete properly with ease.
6. Consolidate the concrete thoroughly using suitable vibrators.
7. Include provision for immediate repair of cracks in the original Specifications assuming that the concrete will crack. Repair or seal the
8. Cracks before the new structure is put into service. good concrete practices are the most critical steps in controlling corrosion and other deterioration.
9. Typical cement contents are about 450 kg per cubic metre with water cement ratios at or below 0.35.
10. Performance of this concrete is fair to good depending on the degree of consolidation and curing. Low slump concrete has significantly low permeability than conventional concrete.

(b) Use of Latex Modified Concrete:

The latex modifies the pore structure of the concrete and reduces its permeability. Rapid chloride permeability test on latex modified concrete shows fall in permeability to a very low range.

(c) Use of Silica Fume Concrete:

Typical silica fume concrete mixtures contain 410 kg of cement per cum, 8% to 10% silica fume by weight of cement, a water powder (cement plus silica fume) ratio less than 0.40. Adequate plasticizer is provided to produce good workability with 50-200 mm slump. Silica fume concrete is approximately equivalent to latex modified concrete in its chloride permeability.

(d) Epoxy Coated Reinforcing Bars:

- Pre-cleaned reinforcing steel bars are protected with a coating of powdered epoxy. The epoxy is fusion bonded in an assembly line process.
- The coating physically blocks chloride ions and the performance of these bars ranges from poor to excellent depending on effectiveness of coating. Unless the bars are coated after bending there is a potential for cracking and chipping of the epoxy coating during bending.
- Damage to the epoxy coating may also occur during field handling of the bars. The relative cost of epoxy coated steel is moderate.

(e) Use of Membranes and Sealers:

- Membranes and sealer help prevent chloride entry when applied to concrete surface. Urethane, neoprene, or epoxies are usually used to built, up in multiple layer of membranes.
- These multi layered membranes have the ability to bridge cracks in the concrete. Sealers range from linseed oil to sophisticated silanes and siloxanes. The performances of these materials vary depending upon the base of the sealer.
- Most sealers are not suited for sites where abrasion occurs. The effectiveness of all these materials decreases over time and they are required to be reapplied at a regular interval. Cost of these materials range from low to high.
- There is continuous maintenance cost also and that should be included when comparing costs of different materials and techniques with reference to serviceable life.

(f) Cathodic Protection:(April/May 2019) (Nov/Dec 2018)

- Cathodic protection approach controls corrosion of steel embedded in concrete by applying direct current to the embedded steel by an external source. An electric current is applied to the concrete anode and the embedded steel.
- This action forces the steel in the concrete to become cathodic, which provides the protection. Cathodic protection is the only way to stop the ongoing corrosion in a concrete structure.
- Cathodic protection is a complicated process that requires extensive pro installation engineering and extensive post installation monitoring Its relative cost varies from high to moderate. Its performance can be termed as satisfactory.

- Corrosion of steel in concrete is a electrochemical process. Cathodic protection is achieved by imposing a low voltage direct current from an anode system placed on the concrete surface through the concrete and on to the steel.
- The cathodic protection current opposes the current associated with the corrosion process. When sufficient current flow is achieved. the corrosion current will be suppressed. Areas of palled or delaminated concrete are required to be repaired prior to the installation of an imposed current cathodic protection system.
- There is need for periodic potential monitoring to ensure effectiveness of the system. Problems associated with corrosion at the boundaries of damaged areas are prevented by cathodic protection.
- This, cathodic protection has marked advantage over the procedures. The concept is simple but difficult to implement fully satisfactorily. If it is attended to when the damage is in initial stages, the cathodic protection is known to be cost effective. This is an emerging technique and has major potential to deal with chloride induced corrosion-problem.
- Cathodic protection is not recommended for carbonated concrete. This is because the carbonation increases the resistivity of the concrete making it more difficult to impose an electric current. The foregoing repair options are not mutually exclusive and could be used in combination.

Cathodic protection can be provided by conductive overlays, superficial anodes, conductive coating anode systems; wire and mesh anodes and combination. Cathodic protection needs following preparatory steps.

1. Deterioration diagnosis
2. Inspection mapping
3. Repair of damaged portion

Deterioration diagnosis is carried out to assess the root cause and the extent of corrosion damage. Details of damage are found by **inspection mapping** involving following steps:

1. Potential survey
2. Delamination survey
3. Loss of steel section determination
4. Cover survey
5. Reinforcement continuity survey

6. Concrete resistivity survey
7. Chloride content measurements
8. Carbonation depth measurements
9. Other aspect of concrete matrix

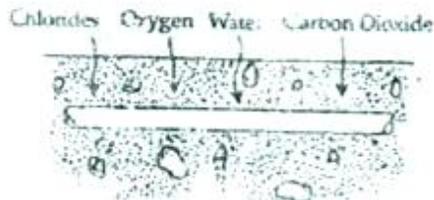
It is necessary to repair the damage in concrete structures before Cathodic Protection is installed. However, these techniques are more effective for steel structures such as pipe lines and oil platforms.

(g) Electro Osmosis

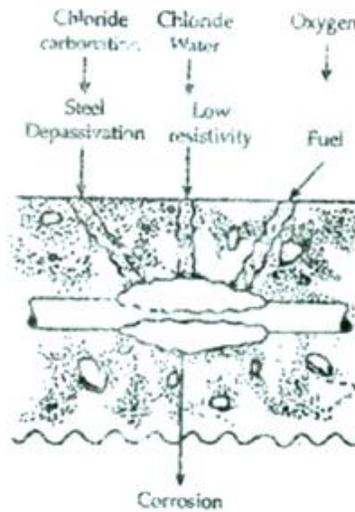
- The solutions to the carbonation problem depend upon the depth of the carbonation front. Electro osmosis makes it possible to restore the initial alkalinity of the concrete. These techniques have advantage and disadvantages on respective counts.
- The chosen method would depends on the structure and its state of deterioration 'Electro Osmosis' is yet another effective method. Electro osmosis is considered for the re-alkalisation and desalination.
- The introduction under pressure of an alkaline solution into the concrete pores gives a possible solution.
- An externally applied alkaline gel covering the external conductor is drawn inside during the electro osmosis process. The gel is used to increase the pH of the pore water.
- The alkalinity increase of a carbonated concrete restores the passivation layer of the steel reinforcement.
- At the same time, the rust when present in moderate quantity becomes magnetic. This transformation goes with a volume reduction so that the pressure on the concrete decreases.

The realkalisation take place simultaneously by two phenomenon

1. alkaline gel applied externally on the concrete is pumped inside during the process
2. cathodic reaction producing hydroxyl iron occurs around the reinforcement



(a) Corrosive Environmental Agents



(b) Three Pronged Attack

Fig. 4.1: Corrosion-Damage Mechanism

Without taking scattering into account, the principal motive force of the process is the potential difference between this reinforcement and the external conductor placed on the outside of the concrete surface.

- The reinforcement is connected to the negative pole (cathodic) while the external conductor on the concrete surface is connected to the positive pole (anode) the pore liquid of the concrete encasement acts as the conductor.
- An electrolyte in the form of an alkaline gel made of fibres impregnated with solution of Sodium Carbonate (Na_2CO_3) is applied on the concrete surface. At the more porous places when the carbonation is the deepest, the first "points" of the realkalisation front can reach the reinforcement after a few hours.
- The complete realkalisation of the places where the concrete density is higher, takes more time. The time required for the complete treatment varies according to the basic construction and depends on the quality and strength of cover concrete around the reinforcement.
- The other factors affecting the treatment are such as the concrete porosity, the localisation of the carbonation and the dimensions of the external conductor. This period of treatment varies from a few days to a few weeks. At the end of the process, the pores will contain the alkaline solution.
- The second phenomenon of the realkalisation process takes place around the reinforcement. A cathodic reaction occurs from the beginning of the process, the water and the oxygen around the reinforcement are transformed into (OH^-) hydroxyl ions.

- The presence of these ions increases the pH of the pore water near to the reinforcement and raises its value to over 1:3 the re-alkalisation develops readily from the reinforcement to the concrete.
- This process is necessary in order to form a buffer of alkaline materials in the pore water behind the reinforcements.

(h) A corrosion inhibitor is a chemical solvent which is applied in a particular environment that significantly decreases the corrosion rate of elements (especially metals) exposed to that surrounding environment i.e. air and water.

CIs are considered the vanguard defense against corrosion.

Types Of Corrosion Inhibitors (Nov/Dec 2018)

- Anodic Inhibitors
- Cathodic Inhibitors
- Mixed Inhibitors
- Volatile Corrosion Inhibitors (VCI)

Anodic Inhibitors

Anodic inhibitors (CIs) operate very uniquely by creating a preventive oxide film on the exterior of the metal.

The reaction results in a large anodic shift that makes the metallic surface into the passivation area, which helps in the reduction of the possible corrosion of the material.

This whole procedure is sometimes called passivation.

Examples of anodic inhibitors include:

- Chromate
- Nitrite
- Molybdate
- Orthophosphate

Anodic Inhibitors are considered dangerous because of their chemical characteristics

Cathodic Inhibitors

Cathodic inhibitors work in two different methods:

1. It may slow down the cathodic reaction itself Or,
2. It may selectively be precipitating on cathodic regions to restrict the diffusion of eroding elements to the metal surface.

The cathodic reaction rate can be decreased by the use of cathodic poisons. But, It can also enhance the sensitivity of a metal to hydrogen induced cracking because during aqueous corrosion or cathodic charging the hydrogen can also be absorbed by the metal.

The use of oxygen scavengers that react with dissolved oxygen can also decrease the corrosion rates.

Mixed Inhibitors

These are film-forming compounds that reduce both the cathodic and anodic reactions. The most commonly used mixed inhibitors are silicates and phosphates used in domestic water softeners to prevent the formation of rust water.

Mixed Inhibitors are film-forming compounds that reduce both the cathodic and anodic reactions. The film-forming solution causes the formation of precipitates on the metal exterior preventing both anodic and cathodic sides indirectly.

Volatile Corrosion Inhibitors

Volatile Corrosion Inhibitors (VCI), also called Vapor Phase Inhibitors (VPI), are products moved in a closed atmosphere to the section of corrosion by volatilization from a source. In boilers, volatile basic compounds, such as morpholine or hydrazine, are carried with vapor to stop corrosion in the condenser tubes by counterbalancing acidic carbon dioxide or by changing exterior pH towards less acidic and corrosive rates.

In closed confined spaces, such as shipping containers, VCI products such as VCI paper VCI bags or VCI rust removers are used. When these VC I come in contact with the metal surface, the vapor of these products is hydrolyzed by any moisture to release protective ions.

It is very important, for an efficient VCI, to produce inhibition quickly while lasting for a prolonged period.

Qualities of a VCI product depend on the volatility of its compounds; Quick action sequence high volatility while providing protection requires low volatility.

Example

In boilers, volatile mixtures such as morpholine or hydrazine, are carried with steam to stop corrosion in condenser pipes.

Only corrosion inhibitors professionals such as ZavenirDaubert can assess the efficiency of corrosion inhibitors that would be suitable for particular environments. Using these types of inhibitors should be part of corrosion prevention strategies of large-scale organizations.

3. Explain in detail about the different types of shoring (April/May 2019)(Nov/Dec 2017)

- Shoring is employed to prevent a damaged structure due to foundation settlement or other reasons from collapse. It is also used to provide temporary supports to a structure which is being remodeled or where alterations of adjacent foundations are being carried out.
- Shoring may be provided externally or internally or from both sides of the wall. For light loads or temporary shores generally limber is used whereas for supporting heavier loads steel beams or braced sections are employed. Sometimes concrete or masonry is also used for shoring.
- The shores are classified in the following types based on their supporting characteristics:
 1. Raking Shores,
 2. Horizontal or Flying Shores,
 3. Vertical or Dead Shores.

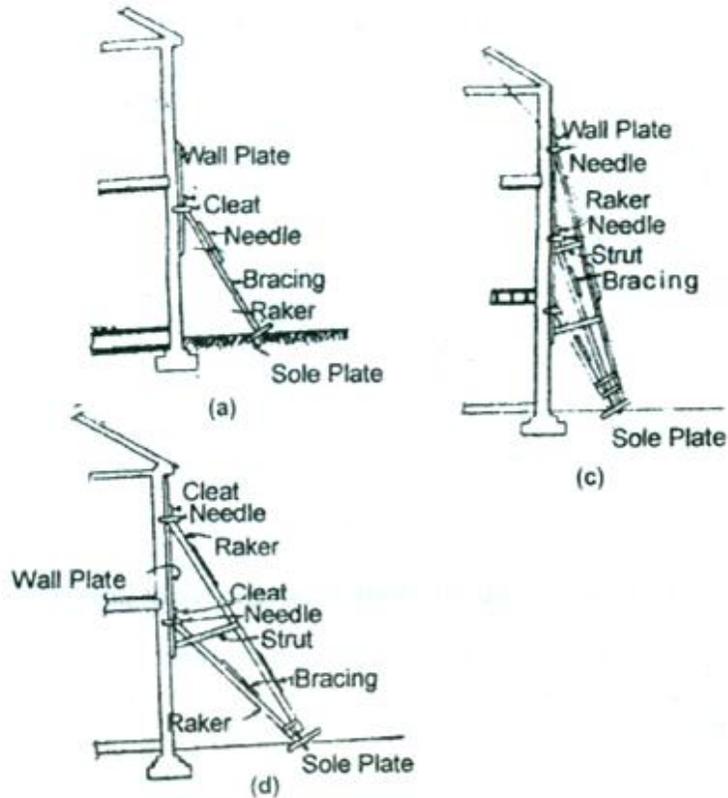


Fig. 4.10: Different Types of Raking Shores

Raking Shores:

There are various types of raking shores which are used according to the thrusts to be taken, the height of the wall or building to be shored, and the space available for the spread of the shores

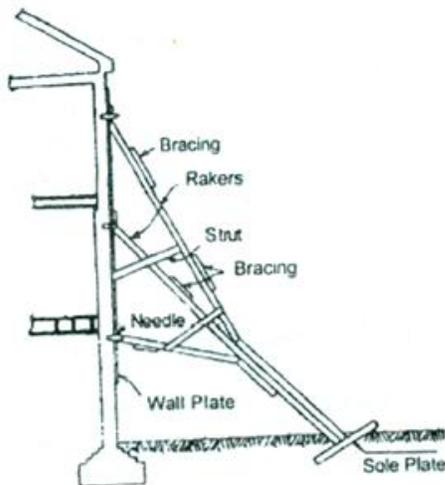


Fig. 4.11: Spreading Treble raking Shore

Fig. 4.10(a) illustrates a single raking shore. In this method of shoring, notches are cut in the walls of the building and inclined posts are inserted to

carry the weight of that part of the wall above the supports. The lower ends of the posts must be established on foundation pads, this method is adequate only for relatively unimportant structures.

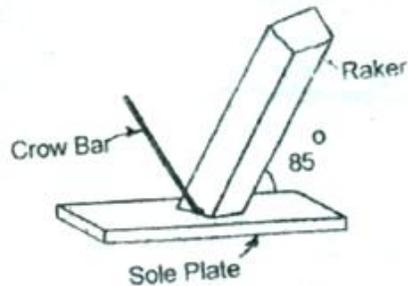


Fig. 4.12: Junction of Raking shore with Sole Plate

Fig. 4.10(b) and (c) illustrate double and triple raking shores respectively. The number of rakers may exceed three. Fig. 4.13 shows a method of arranging the shores where there is ample space for spreading. The advantage of this system is that shorter and a less number of members may be used.

The internal angle between the outer or top rakes and the horizontal or ground should be 60° to 75° . Raking shores should be placed about 3 metres apart, centre to centre, but the spacing is often guided by practical considerations.

Great care should be taken in arranging the top ends of the rakers. They should be placed at those points where there is an internal resistance to the external pressure of the rakers. The best position to comply with this condition is at floor or roof leaves.

Fig. 4.12 is a typical 2-7 detail of the base for rakers and consists of a sole piece beaded in an inclined position or perfectly firm ground, and set slightly acute (i.e., 85°), with the outer or top raker. The rakers are levered up with a crowbar orated in a notch and securely "dogged" and cleated to the, sole piece.

Wedges are, generally not used as knowing them into position is liable to shake the work. If the ground is not perfectly firm, the area of the sole piece must be increased by a platform of timber, so that the pressure may be distributed over a larger area.

Flying or Horizontal Shores:

Such shores are used to give horizontal support to two adjacent, parallel parity walls, which have become unsafe due to removal or collapse of the intermediate building. All types of arrangements of supporting the unsafe structure in which the shores do not reach the ground fall under this category.

If the walls are quite near to each other (distance upto 9m), single flying shore can be constructed. It consists of wall plates, needles, cleats, struts, horizontal shore, straining pieces and folding wedges.

When the distance between the walls is more a compound or double flying shore may be provided. Flying shores have the advantages that building operations of the ground are not obstructed.

The following points should be kept in mind while erecting the flying shores:

1. The central lines of flying shores and struts and those of the walls should meet at floor levels of the two buildings. If the floor levels are different, the horizontal shore should be placed either mid way between the levels of the two floors of equal strength or it should be placed at the level of weaker floor.
2. The struts should preferably be inclined at 45° . In no case should this inclination exceed 60° .
3. Single shores should be used only upto 9 m distance between walls. For greater distance, double shores should be provided. In that case, both the horizontal shores should be symmetrically placed with respect to the floor levels.

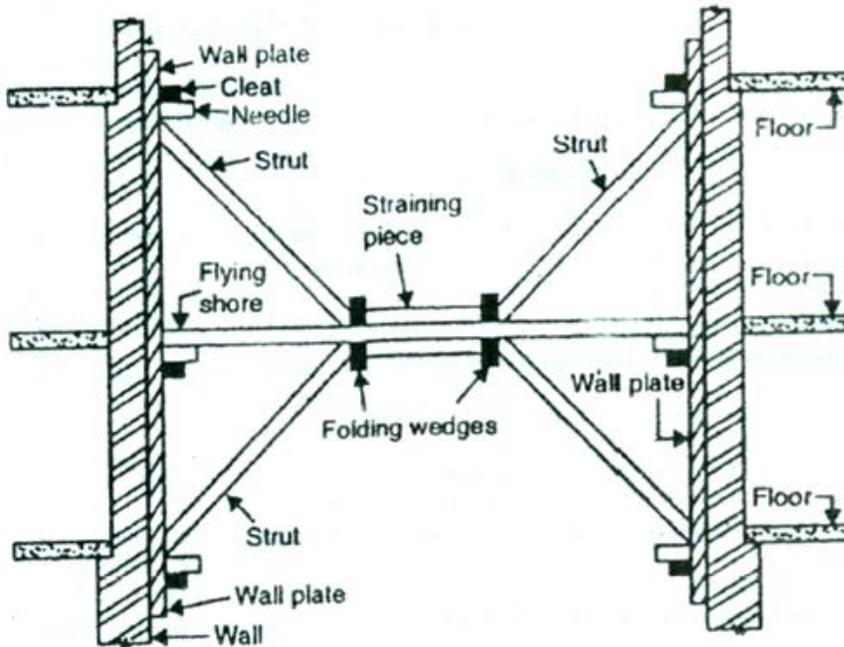


Fig. 4.13: Single Flying Shore

4. The flying shores should be spaced at 3 to 4.5 m centres, along the two walls, and horizontal braces should be introduced between adjacent shores.
5. Large factor of safety should be used for determining sections of various members of the shoring, since it is very difficult to assess the actual loads.

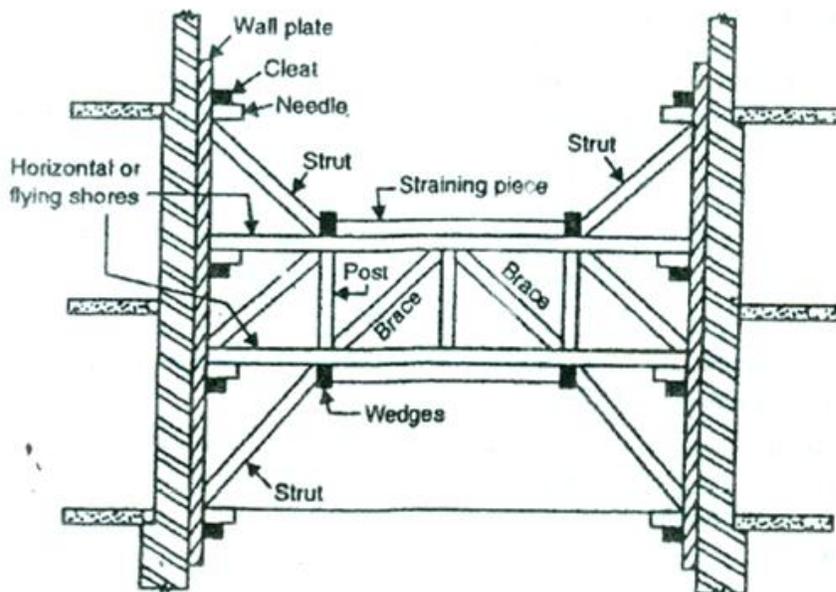


Fig. 4.14: Double or compound Flying Shore

6. Flying shores are inserted when the old building is being removed, and should be kept in position till the new unit is constructed.

Dead or Vertical Shores:

Such type of shoring consists of vertical members known as dead shores supporting horizontal members known as needles. The needles transfer the load of the wall etc. to the dead shores.

Such shoring is provided to serve the following purposes:

1. To rebuild the defective lower part of the wall
2. To rebuild or deepen the existing foundation.
3. To make large opening in the existing wall at lower level.

Holes are made in the wall at suitable height. Needles, which are made of thick wooden sections or of steel, are inserted in the holes. Each needle is supported at its two ends by vertical posts or dead shores.

The dead shores stand away from the walls so that repair work is not obstructed. The shores are supported on sole plates and folding wedges.

The following points are noteworthy:

1. The section of needles and dead shores should be adequate to transfer the load, which can be estimated with fair degree of accuracy.
2. The needles are spaced at 1 to 2 metre. A minimum of three needles should be used for an opening.
3. The needles should be suitably braced.
4. If the opening is made in an external wall the length of outer dead shores will be greater than the inner ones.
5. The dead shores are supported on sole plates. Folding wedges should be inserted between the two. It is preferable to use one single sole plate between dead shores in a row.
6. The floors should be suitably supported from inside.
7. If the external wall is weak raking shores may be provided, in addition to the dead shores.
8. Shores should be removed only when the new work has gained sufficient strength.

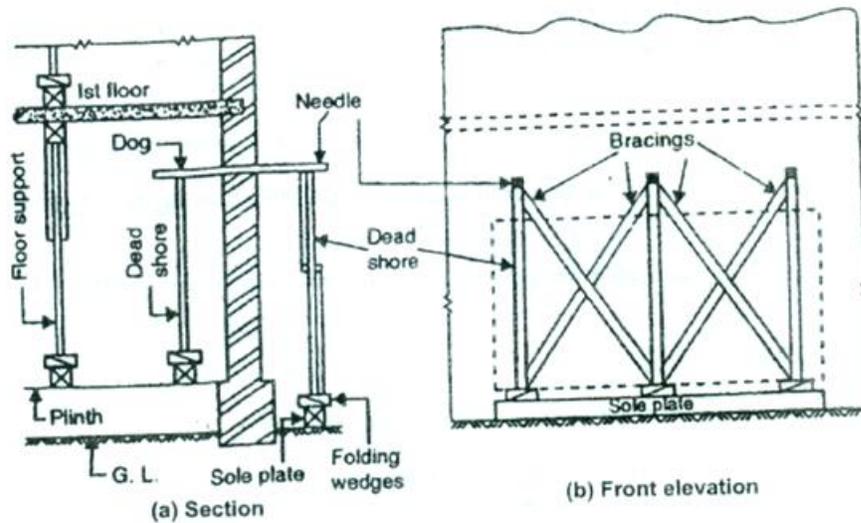


Fig. 4.15: Dead Shores (Vertical Shores)

4. Define underpinning and discuss the procedure of underpinning done for structures. (April/May 2017) (Nov/Dec 2017) (April/May 2018)

UNDERPINNING:

At times it is essential to replace or strengthen the foundation of an existing structure. The operation of providing this is known as underpinning. The art of underpinning structures is as old as that of building itself.

Earlier underpinning was carried out mainly because of settlement of structure as a result of inadequate foundations. Remedial underpinning is done to provide additional foundation strength to an inadequately supported structure which may be settling or in danger of collapse.

Precautionary underpinning cannot be always avoided, as it becomes essential the construction of new foundations deeper than those of the existing building.

Method of Underpinning:

1. Pit Method:

- In this method, the entire length of the foundation to be underpinned is divided into sections of 1.2 to 1.5 m length. One section is taken up at a time.
- For each section a hole is made in the wall, above the plinth level, and needle inserted in the hole. Needles may be either of stout timber or steel section.
- Bearing plates are placed above the needle to support the masonry above it. Needle is supported on either side of the wall on crib supports (wooden blocks) and screw jacks. The foundation pit is then excavated upto the desired level and new foundation is laid.
- When the work of one section is over, work on next to next is taken up i.e., alternate sections are underpinned in the first round and then the remaining sections are taken up (Fig. 4.16). If the wall to be underpinned is weak, raking shore may be provided. Similarly, the floor may also be supported, if required.

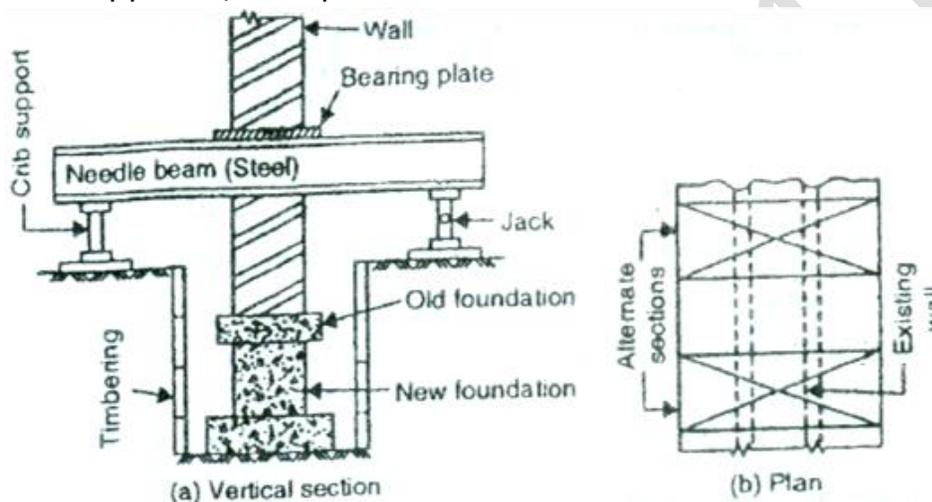


Fig. 4.16: Pit Method

- If an interior strong column resists, or if the foundation is to be extended only to one side, cantilever needle beam may be used in the place of central needle beam, as shown in Fig. 4.17. Jack is placed between the column and the wall.

The following points are note worthy in the pit method:

1. Alternate sections are taken up in the first round. The remaining intermediate sections are then taken up. Only one section should be taken at a time.

2. If the wall is long, the work is started from the middle, and is extended in both the directions.
3. If the new foundation is deeper, proper timbering of the foundation trench may be done.
4. The needle beams etc. should be removed only when the new foundation has gained strength.
5. It is desirable to do the new foundation work in concrete.
6. The needle holes etc. should be closed in masonry using cement mortar.

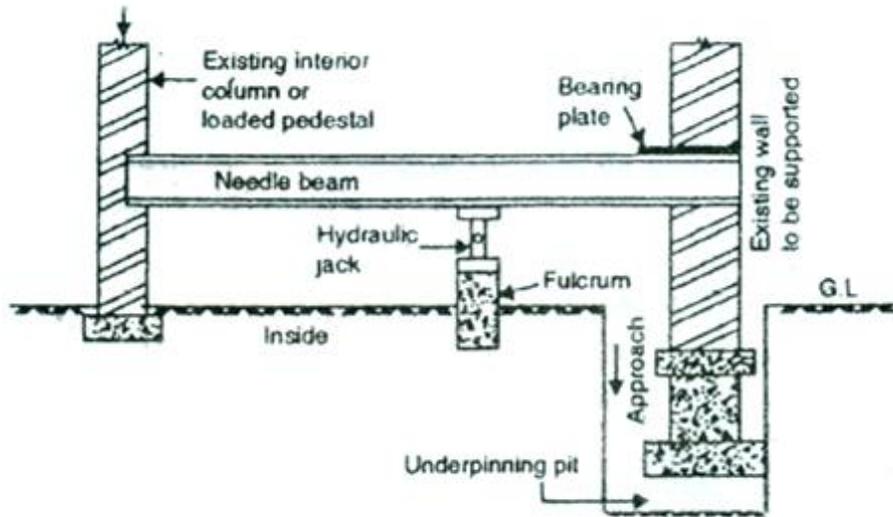


Fig. 4.17: Pit method with Cantilever needle

Pile Method:

- In this method, piles are driven at regular interval along both the sides of the wall. Generally, bore shore piles or under reamed piles may be used.
- The piles are connected by concrete or steel needles, penetrating through the wall. These beams incidentally act as pile caps also.
- This method is very much useful in clayey soils, and also in water logged areas. The existing foundation is very much relieved of the load.

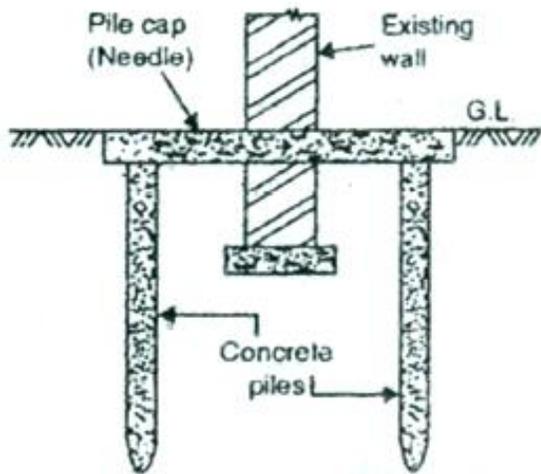


Fig. 4.18: Pile Method

5. Explain the Methods of Non-Destructive Testing of Concrete (April/May 2019) (April/May 2017) (April/May 2018)

- Non-destructive tests of concrete is a method to obtain the compressive strength and other properties of concrete from the existing structures. This test provides immediate results and actual strength and properties of concrete structure.
- **Methods of Non-Destructive Testing of Concrete**
 - Penetration method
 - Rebound hammer method
 - Pull out test method
 - Ultrasonic pulse velocity method
 - Radioactive methods

1. Penetration Tests on Concrete

- The Windsor probe is generally considered to be the best means of testing penetration. Equipment consists of a powder-actuated gun or driver, hardened alloy probes, loaded cartridges, a depth gauge for measuring penetration of probes and other related equipment.
- A probe, diameter 0.25 in. (6.5 mm) and length 3.125 in. (8.0 cm), is driven into the concrete by means of a precision powder charge. Depth of penetration provides an indication of the compressive strength of the concrete.
- Although calibration charts are provided by the manufacturer, the instrument should be calibrated for type of concrete and type and size of aggregate used.
- Benefits and Limitations
- The probe test produces quite variable results and should not be expected to give accurate values of concrete strength. It has, however, the potential for providing a quick means of checking quality and maturity of in situ concrete.
- It also provides a means of assessing strength development with curing. The test is essentially non-destructive, since concrete and structural members can be tested in situ, with only minor patching of holes on exposed faces.

2. Rebound Hammer Method

- The rebound hammer is a surface hardness tester for which an empirical correlation has been established between strength and rebound number.
- The only known instrument to make use of the rebound principle for concrete testing is the Schmidt hammer, which weighs about 4 lb (1.8 kg) and is suitable for both laboratory and field work. It consists of a spring-controlled hammer mass that slides on a plunger within a tubular housing.
- The hammer is forced against the surface of the concrete by the spring and the distance of rebound is measured on a scale. The test surface can be horizontal, vertical or at any angle but the instrument must be calibrated in this position.

- Calibration can be done with cylinders (6 by 12 in., 15 by 30 cm) of the same cement and aggregate as will be used on the job. The cylinders are capped and firmly held in a compression machine.
- Several readings are taken, well distributed and reproducible, the average representing the rebound number for the cylinder. This procedure is repeated with several cylinders, after which compressive strengths are obtained.
- To be planned in advance and pull-out assemblies set into the formwork before the concrete is placed. The pull-out, of course, creates some minor damage.
- The test can be non-destructive, however, if a minimum pullout force is applied that stops short of failure but makes certain that a minimum strength has been reached. This is information of distinct value in determining when forms can be removed safely.

Dynamic Non Destructive Test

- At present the **ultrasonic pulse velocity method** is the only one of this type that shows potential for testing concrete strength in situ. It measures the time of travel of an ultrasonic pulse passing through the concrete.
- The fundamental design features of all commercially available units are very similar, consisting of a pulse generator and a pulse receiver.
- Pulses are generated by shock-exciting piezoelectric crystals, with similar crystals used in the receiver. The time taken for the pulse to pass through the concrete is measured by electronic measuring circuits.
- Pulse velocity tests can be carried out on both laboratory-sized specimens and completed concrete structures, but some factors affect measurement:
 - There must be smooth contact with the surface under test; a coupling medium such as a thin film of oil is mandatory.
 - It is desirable for path-lengths to be at least 12 in. (30 cm) in order to avoid any errors introduced by heterogeneity.
 - It must be recognized that there is an increase in pulse velocity at below-freezing temperature owing to freezing of water; from 5 to 30°C (41 – 86°F) pulse velocities are not temperature dependent.
 - The presence of reinforcing steel in concrete has an appreciable effect on pulse velocity. It is therefore desirable and often mandatory to choose

pulse paths that avoid the influence of reinforcing steel or to make corrections if steel is in the pulse path.

- Applications and Limitations
- The **pulse velocity method** is an ideal tool for establishing whether concrete is uniform. It can be used on both existing structures and those under construction.
- Usually, if large differences in pulse velocity are found within a structure for no apparent reason, there is strong reason to presume that defective or deteriorated concrete is present.
- High pulse velocity readings are generally indicative of good quality concrete. A general relation between concrete quality and pulse velocity is given in Table.
- Table: Quality of Concrete and Pulse Velocity

➤ General Conditions	➤ Pulse Velocity ft/sec
➤ Excellent	➤ Above 15,000
➤ Good	➤ 12,000-15,000
➤ Questionable	➤ 10,000-12,000
➤ Poor	➤ 7,000-10,000
➤ Very Poor	➤ below 7,000

- Fairly good correlation can be obtained between cube compressive strength and pulse velocity. These relations enable the strength of structural concrete to be predicted within ± 20 per cent, provided the types of aggregate and mix proportions are constant.
- The pulse velocity method has been used to study the effects on concrete of freeze-thaw action, sulphate attack, and acidic waters. Generally, the degree of damage is related to a reduction in pulse velocity. Cracks can also be detected.
- Great care should be exercised, however, in using pulse velocity measurements for these purposes since it is often difficult to interpret results. Sometimes the pulse does not travel through the damaged portion of the concrete.
- The pulse velocity method can also be used to estimate the rate of hardening and strength development of concrete in the early stages to determine when to remove formwork. Holes have to be cut in the formwork so that transducers can be in direct contact with the concrete surface.

- As concrete ages, the rate of increase of pulse velocity slows down much more rapidly than the rate of development of strength, so that beyond a strength of 2,000 to 3,000 psi (13.6 to 20.4 MPa) accuracy in determining strength is less than $\pm 20\%$.
- Accuracy depends on careful calibration and use of the same concrete mix proportions and aggregate in the test samples used for calibration as in the structure.
- In summary, ultrasonic pulse velocity tests have a great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects. Its use for predicting strength is much more limited, owing to the large number of variables affecting the relation between strength and pulse velocity.

5. Radioactive Methods of NDT

- Radioactive methods of testing concrete can be used to detect the location of reinforcement, measure density and perhaps establish whether honeycombing has occurred in structural concrete units. Gamma radiography is increasingly accepted in England and Europe.
- The equipment is quite simple and running costs are small, although the initial price can be high. Concrete up to 18 in. (45 cm) thick can be examined without difficulty.
- Purpose of Non-Destructive Tests on Concrete
- A variety of Non Destructive Testing (NDT) methods have been developed or are under development for investigating and evaluating concrete structures.
- These methods are aimed at estimation of strength and other properties; monitoring and assessing corrosion; measuring crack size and cover; assessing grout quality; detecting defects and identifying relatively more vulnerable areas in concrete structures.
- Many of NDT methods used for concrete testing have their origin to the testing of more homogeneous, metallic system. These methods have a sound scientific basis, but heterogeneity of concrete makes interpretation of results somewhat difficult.
- There could be many parameters such as materials, mix, workmanship and environment, which influence the results of measurements.

- Moreover, these tests measure some other property of concrete (e.g. hardness) and the results are interpreted to assess a different property of concrete e.g. strength, which is of primary interest.
- Thus, interpretation of results is very important and difficult job where generalization is not possible. As such, operators can carry out tests but interpretation of results must be left to experts having experience and knowledge of application of such non-destructive tests.

Purposes of Non-destructive Tests

- Estimating the in-situ compressive strength
- Estimating the uniformity and homogeneity
- Estimating the quality in relation to standard requirement
- Identifying areas of lower integrity in comparison to other parts
- Detection of presence of cracks, voids and other imperfections
- Monitoring changes in the structure of the concrete which may occur with time
- Identification of reinforcement profile and measurement of cover, bar diameter, etc.
- Condition of prestressing/reinforcement steel with respect to corrosion
- Chloride, sulphate, alkali contents or degree of carbonation
- Measurement of Elastic Modulus
- Condition of grouting in prestressing cable ducts

6.Explain the significance of performance and integrity test on concrete (April/May 2017)

Integrity and reliability are the two most important factors in ensuring the safety of structural components. Equipped with non-destructive testing tools and backed by years of extensive experience, Setsco is able to provide comprehensive structural evaluation and diagnosis by applying techniques such as:

- Surface hardness (rebound hammer) test
- Ultrasonic pulse velocity test
- Electromagnetic cover meter survey
- Penetration resistance (Windsor Probe) test
- Half cell potential measurement
- Concrete resistivity test
- Impulse response test
- Impact echo test
- Infrared thermography inspection
- In-situ surface absorption test
- In-situ carboration test
- In-situ tensile pull-out and shear tests on structural fixtures and architectural finishes
- Crack monitoring
- Mechanical and strain gauging
- Temperature and strain monitoring of mass concrete casting
- Structural instrumentation and monitoring
- Full scale load test
- Surface penetration radar survey
- Fibrescope inspection
- Visual inspection of buildings in collaboration with profession engineers and accredited checkers
- Sprayed fire-proofing material compatability test
- Water tightness test on windows, curtain walls, precast panels, etc

- Investigation on structural healthiness after fire incident

7. Explain in detail foamed concrete and vacuum concrete?

1. Definition

Foamed concrete has been defined as a cementitious material, with a minimum of 20% (per volume) foam entrained into the plastic mortar. (As no coarse aggregate is used in foamed concrete, the term concrete is, strictly speaking, inappropriate.)

2. Production

Foamed concrete is produced by entrapping numerous small bubbles of air in cement paste or mortar. Mechanical foaming can take place in two principal ways:

- By pre-foaming a suitable foaming agent with water and then combining the foam with the paste or mortar.
- By adding a quantity of foaming agent to the slurry and whisking the mixture into a stable mass with the required density.
- The most commonly used foam concentrates are based on protein hydrolyzates or synthetic surfactants. They are formulated to produce air bubbles that are stable and able to resist the physical and chemical forces imposed during mixing, placing and hardening.

3. Properties

- Foamed concrete is the most popular of all low-density concretes in developing countries. The reasons for this are the low capital expenditure on equipment and the ready availability of the principal materials.
- Foamed concrete can be produced on a small scale, even at site level, and it is relatively easy to place and finish without heavy or expensive equipment.
- Foamed concrete is self-compacting, free flowing and pumpable and, foamed concrete therefore, easy to place in inaccessible places. It has good thermal and acoustic properties and is also frost resistant.
- It is however too weak for direct exposure to traffic and hail and should be protected by a wearing layer (asphalt can be used for roads).
- It is standard practice to classify foamed concrete according to the dry density thereof. This density is determined from oven-dried specimens

and the actual density of foamed concrete would usually be higher than this density as there would generally be evaporable water present in foamed concrete.

- The presence of water in foamed concrete elements also results in an increase in thermal conductivity.

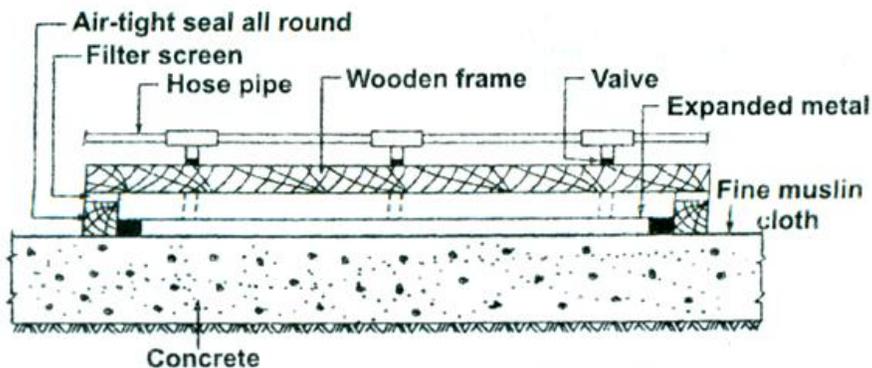
4. Applications

- Since the introduction of cellular concrete systems to the construction industry over 50 years ago, the use of foamed concrete has been almost exclusively limited to non-structural void filling, thermal insulation, acoustic damping, trench filling for reinstatement of roads and for building blocks.
- In the Netherlands foamed concrete has been used not only for level corrections in housing developments, but also as a fill material where ground subsidence has taken place and as a founding layer for road works on very weak soils.
- Historically, foamed concrete has been perceived to be weak and non-durable with high shrinkage characteristics.
- Unstable foams have in the past resulted in foamed concrete having properties unsuitable for reinforced, structural applications. Unprotected reinforcement in aerated concrete in which the voids are interconnected would be vulnerable to corrosion even when the external attack is not very severe.
- It is therefore important to ensure that the air entrained into the foamed concrete is contained in stable bubbles that remain intact and isolated, and do not thus increase the permeability of the cement paste between the voids.
- The development of protein-hydrolysis-based foaming agents and specialized foam generating equipment has improved the stability of the foam, making it possible to manufacture foamed concrete for structural applications.
- In recent years foamed concrete has been used as a structural material in schools, apartments and housing developments in countries such as Brazil, Singapore, Kuwait, Nigeria, Botswana, Mexico, Indonesia, Libya, Saudi Arabia, Algeria, Iraq and Egypt.

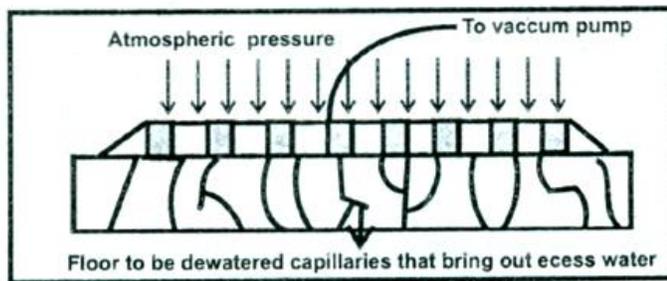
- For information on suppliers of foamed concrete, or materials for foamed concrete, contact The Concrete Institute Information Centre.

8. Explain Vacuum concrete in detail?

- In concreting thin sections like slabs and walls, a fluid mix with water-cement ratio of 0.50 to 0.65 is required to facilitate the placing and compaction. Such a mix will lead to relatively low strength and poor abrasion resistance.
- In such situations, the vacuum treatment of concrete, involving the removal of excess water and air by using suction can be helpful. An arrangement for vacuum dewatering of concrete using suction through a surface mat connected to a vacuum pump is shown in Fig.



(a) Schematic diagram showing vacuum dewatering process



(b) Vacuum process

Fig. 4.8: Typical arrangement for vacuum dewatering of concrete

- The duration of treatment depends upon the water-cement ratio and the quantity of water to be removed. It generally range from 1 to 15 minutes for slabs varying in thickness from 25 mm to 125 mm.
- The effect of treatment is more pronounced in the beginning and falls off rapidly. Hence, it is of no advantage to prolong the periods of treatment

beyond these values. The sequences of operations for vacuum dewatering the concrete are illustrated.

- The vacuum treatment is not very effective for water cement ratios below 0.4. The suction pressure on the concrete is about one-third the atmospheric pressure.
- The vibration of concrete before vacuum treatment can assist the process.
- The application of vibration simultaneously with vacuum treatment after initial vibration is very effective. Continued vibration beyond 90s may damage the structure of concrete, and hence the vibrations should be stopped beyond this period and only vacuum needs to be applied for the remaining duration of the treatment.
 - ✓ The vacuum treatment has been found to considerably reduce the time of final finishing of floor and stripping of wall forms.
 - ✓ The strength of concrete and its *resistance to wear* and *abrasion* increases and total shrinkage is reduced. Vacuum-treated concrete provides a good bond with the underlying concrete.
 - ✓ Vacuum concrete attains its 28 day compressive strength in 10 days and has a 25 per cent higher crushing strength.

The details of structural properties enhancement are:

1. Compressive strength of floor increases by up to 60 percent.
2. Tensile strength increases approximately by 70 percent.
3. Cement consumption is reduced to the extent of 10 percent; no cement is required separately for finishing the surface.
4. Abrasion resistance of the floor increases nearly by 60 percent.
5. Shrinkage of concrete and warping of floor are reduced.
6. The vacuum-processed concrete is extensively used for factory production of precast plain and reinforced concrete units. The other important application is in the construction of horizontal and sloping concrete slabs, such as floor slabs and road.

9. Write short notes on. I) Epoxy injection, ii) corrosion inhibitors, iii) cathodic protection iv) vacuum concrete

Epoxy injection

- Epoxy injection is a resin based sealer that is forced into cracks within concrete to protect the rebar from becoming damaged, and to stop water from pooling into the foundation.
- Cracks and weak rebar will cause the concrete foundation to weaken, which will make the building affected unsafe for occupancy.
- The epoxy that is injected into the cracks effectively seals them while allowing the concrete foundations to retain their original strength and integrity. Epoxy injection repairs are the only way to fix a cracked foundation without having to tear the building down and re-pour the concrete.
- The process involved in the epoxy resin process is precise and has to be done with an epoxy that is rated at least Grade A Type A for most applications.
- In order to effectively repair the crack, and to shield the rebar from premature deterioration, only the best products are used.
- The majority of epoxy injection repairs are done with injection machines or guns that are set at a air level suitable for the given application. There are maximum and minimum settings that are recommended, so all tools have to be adjusted before beginning each specific job.

Corrosion inhibitors

- A **corrosion inhibitor** is a chemical compound that, when added to a liquid or gas, decreases the corrosion rate of a material, typically a metal or an alloy.
- The effectiveness of a corrosion inhibitor depends on fluid composition, quantity of water, and flow regime.
- A common mechanism for inhibiting corrosion involves formation of a coating, often a passivation layer, which prevents access of the corrosive substance to the metal.
- Permanent treatments such as chrome plating are not generally considered inhibitors, however. Instead corrosion inhibitors are *additives* to the fluids that surround the metal or related object.

Cathodic Protection

- Cathodic protection approach controls corrosion of steel embedded in concrete by applying direct current to the embedded steel by an external source. An electric current is applied to the concrete anode and the embedded steel.
- This action forces the steel in the concrete to become cathodic, which provides the protection. Cathodic protection is the only way to stop the ongoing corrosion in a concrete structure.

- Cathodic protection is a complicated process that requires extensive preinstallation engineering and extensive post installation monitoring. Its relative cost varies from high to moderate. Its performance can be termed as satisfactory.
- Corrosion of steel in concrete is an electrochemical process. Cathodic protection is achieved by imposing a low voltage direct current from an anode system placed on the concrete surface through the concrete and on to the steel.
- The cathodic protection current opposes the current associated with the corrosion process.
- When sufficient current flow is achieved the corrosion current will be suppressed. Areas of pitted or delaminated concrete are required to be repaired prior to the installation of an imposed current cathodic protection system.
- There is a need for periodic potential monitoring to ensure effectiveness of the system. Problems associated with corrosion at the boundaries of damaged areas are prevented by cathodic protection.
- This, cathodic protection has marked advantage over other procedures. The concept is simple but difficult to implement fully satisfactorily. If it is attended to when the damage is in initial stages, the cathodic protection is known to be cost effective.
- This is an emerging technique and has major potential to deal with chloride induced corrosion problem.
- Cathodic protection is not recommended for carbonated concrete. This is because the carbonation increases the resistivity of the concrete making it more difficult to impose an electric current. The foregoing repair options are not mutually exclusive and could be used in combination.

Cathodic protection can be provided by conductive overlays, superficial anodes, conductive coating anode systems; wire and mesh anodes and combination. Cathodic protection needs following preparatory steps.

- Deterioration diagnosis
- Inspection mapping
- Repair of damaged portion

Deterioration diagnosis is carried out to assess the root cause and the extent of corrosion damage. Details of damage are found by **inspection mapping** involving following steps:

- 1) Potential survey
 - 2) Delamination survey
 - 3) Loss of steel section determination
 - 4) Cover survey
 - 5) Reinforcement continuity survey
 - 6) Concrete resistivity survey
 - 7) Chloride content measurements
 - 8) Carbonation depth measurements
 - 9) Other aspect of concrete matrix
- It is necessary to repair the damage in concrete structures before Cathodic Protection is installed. However, these techniques are more effective for steel structures such as pipe lines and oil platforms.
 - The Fusion Bonded Epoxy Coating is a process where epoxy powder is applied by electrostatic spray on hot steel at pre-set temperature level.
 - The powder, when in contact with the hot bar, melts, flows, gels, cures cools and produces a well-adhered continuous corrosion resistant protective coating.
 - This thermosetting is an irreversible process and provides the best protection to rebar against corrosion. It prevents attack of chloride ion on the metallic surface and occurrence of electro-chemical reaction initiating corrosion of steel.

The process involves following steps to be performed in a plant controlled by automatic quality control system.

- ❖ **Degreasing:** Bars are first cleaned from surface contaminations such as oil, grease etc. by chemical process before shot blasting.
- ❖ **Cleaning:** The reinforcement bars are cleaned by shot blasting or grit blasting to white or near white stage.
- ❖ **Heating:** The blast cleaned bars are then heated through induction heaters at preset temperature level around 2300C.
- ❖ **Coating:** Hot bars are then fed to the coating booth, where the epoxy powder is sprayed electrostatically.

- ❖ **Curing and cooling:** Coated bars are then cured and forced cooled by water spraying to enable handling and testing.

Inspection and testing:

- Fusion Bonded Epoxy Coated Rebars are tested at the coating plant to the codal requirements as specified in IS: 13620-1993. On line and off line holiday checks, thickness checks are carried out.
- The adhesions of the coated bars are also tested frequently by bending of the bar. Beside this, various other tests are performed in laboratory like chemical resistance, short spray, resistance in continuance boiling water, abrasion resistance and impact resistance etc. These are conducted on every batch of production.

Handling transportation and working:

- ❖ FBECR bars are required to be handled with extreme care so that coating is not damaged during transportation handling/concreting. Thus, Fusion Bonded Epoxy Coated Bars require padded contacts during transportation, stacking, handling and till the concreting is done.
- ❖ The cut ends, welded spots and handling damages are required to be repaired with special liquid epoxy compatible with the coating material as per specification of the coating agency.
- ❖ Rebar coating provide the most effective corrosion protection to the rebar.
- ❖ Epoxy coated rebar has been generally rated in excellent condition, despite high chloride contents in surrounding concrete.
- ❖ Based on the deterioration rate and life expectancy, epoxy coated rebar decks have performed better than calculated rates.

MERITS & DEMERITS:

Merits:

1. As the technique is factory based, better quality control is achieved. It gives uniform thickness of coating.
2. The bonding of coating with steel rebars is high as it has excellent adhesives property.
3. It is flexible to allow straight bars to be bend during fabrication on a special mandrill to protect the coating from damage.

4. The Fusion Bonded Epoxy Coating acts as insulator for electrochemical cells and offer barrier protection to steel which prevents entry of chloride ions through it.
5. There are well established criteria for acceptance for this coating (IS :13620-1993 and ASTM 775/A 775M-1992)

Demerits:

1. There is a reduction in bond strength between coated rebars & concrete (Clause A.5 of IS: 13620).
2. As the technique is plant based, double transportation/handling is involved.
3. It requires careful handling as coating may get damaged. Performance of the system depends upon least defect in the coating.
4. Patching may not always be effective.
5. Even the smallest damage in coating can initiate corrosion in severe environment.

10. Explain Cement-polymer composite coating system (CPCC):

- This is a new method developed by CECRI. This system has been developed to overcome demerits of inhibited cement slurry coating system.
- This system consists application of one coat of rapid setting primer followed by a coat of cement polymer sealing product. The primer and sealing products have thermoplastic acrylic resin as basic raw material.
- Sealing product is formulated with resin mixed with cement as a pigment. Rapid setting primer and sealing coats both are patented item. This system has been developed mainly as a factory / shop process.
- The approach behind development of this system is that the base metal of rebars, contains electrons which get readily released in corrosive environment leading to oxidation of iron and thereby formation of Fe₂O₃ (rust) as principal deterrent.
- In order to prevent this oxidation a surface coating capable of interacting/nullifying the released electrons is provided.
- Further prestressing and reinforcing steel, in concrete during service life, are exposed to an alkaline environment and this necessitates introductions of a top coat which should be compatible to primer and alkaline environment.

- To meet these two contingencies, suitable polymers are carefully tailored through the formation of a single phase in the polyblend which provides the necessary mechanical and physical properties.

11. Briefly the following steps are involved in the process:

Surface preparation:

The surface of the steel reinforcing bars to be coated is cleaned by abrasive (dry sand) blast cleaning to the near white metal in accordance with SSPC-SP10/NAC No.2-1994. It includes the following procedures.

1. Prior to blast cleaning visible deposits of oil or grease are removed by suitable cleaning method.
2. Clean dry compressed air is used for nozzle blasting.
3. Dry uniformly graded silica sand is used for blast cleaning which should be free from contaminants.
4. Dust and residues are removed from prepared surface by brushing, blowing off with clean, dry air, vacuum cleaning.
5. The prepared surface shall meet the visual standards of comparisons as in SSPC-VIS 1 of SSPC-VIS 2.

Application of the coating:

1. The coating is applied to the cleaned surface as soon as after cleaning and before oxidation of the surface discernible to the unaided eye occurs. However, the application of the coating should not be delayed more than 4 hr. after cleaning.
2. A rapid setting primer shall be applied over the prepared surface of the reinforcing steel either by brushing or dipping.
3. After 30 minutes of application of the primer a cement polymer sealing coat shall be applied either by brushing or dipping.
4. The coated rods shall be handled after 6 hours.

Inspection and testing:

Coated rebars shall be checked for minimum average dry film thickness, uniformity of thickness, defects such as cracks, peeling, bulging and uncoated areas etc. Coating shall be tested for adhesion,

Merits & Demerits of the System:

Merits:

1. The composition has corrosion resistance, making it suitable for corrosion protection of steel in concrete structures in marine and industrial environments.
2. Being cement based composition, it is more compatible in concrete medium.
3. It is a passivating-cum-barrier type of coating and hence any localized defect in the coating may not lead to severe undercutting.
4. It can be brush applied or sprayed and hence defects in the coating can be easily patch repaired.
5. It has good bond strength and hence bond between coated rod and concrete is not affected.
6. This system is suitable for the protection of prestressing steel strands also.
7. The system can be adopted as in situ process also. The shelf life of treated bars is 6 months.
8. Considerable reduction in process time as compared to inhibited cement slurry system.

Demerits:

1. This system is newly developed system and the long term results are not known.

Performance:

- This system is now being used on three fly overbridges in Mumbai at Goregaon, Andheri and Mankhurd. As the system is a newly developed system, hence field performance is not known. However laboratory performance of the system, as reported by CECRI, is very good.
- The system has passed bond ability test, chemical resistance test, salt spray test, impressed voltage test and abrasion resistance test as per test procedure described in ASTM A77/775M-94. From structural point

of view, the coated bars have shown greater bond strength as compared to uncoated bars.

- This coating is superior to old CECRI coating and can be used effectively in marine structures in future. The cost of the coating is about 3200-8000/MT.

12. Explain the process of Guniting?

- Guniting can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity on to a surface.
- Recently the method has been further developed by the introduction of small sized coarse aggregate to the mix deposited to obtain considerably greater thickness in one operation and also to make the process economical by reducing the cement content.
- Normally fresh material with zero slumps can support itself without sagging or peeling-off. The force of the jet impacting on the surface compacts the material.
- Sometime use of set accelerators to assist overhead placing is practiced. The newly developed "Redi-set cement" can also be used for shotcreting process.
- There is not much difference between guniting and shotcreting. Guniting was first used in the early 1900 and this process is mostly used for pneumatic application of mortar of less thickness, whereas shotcrete is a recent development on the similar principle of guniting for achieving greater thickness with small coarse aggregates.
- There are two different processes in use, namely the "Wet-mix" process and the "dry-mix" process. The dry mix process is more successful and generally used.

Dry-mix Process:

The dry mix process consists of a number of stages and calls for some specialized plant. A typical small plant set-up is shown in Fig.

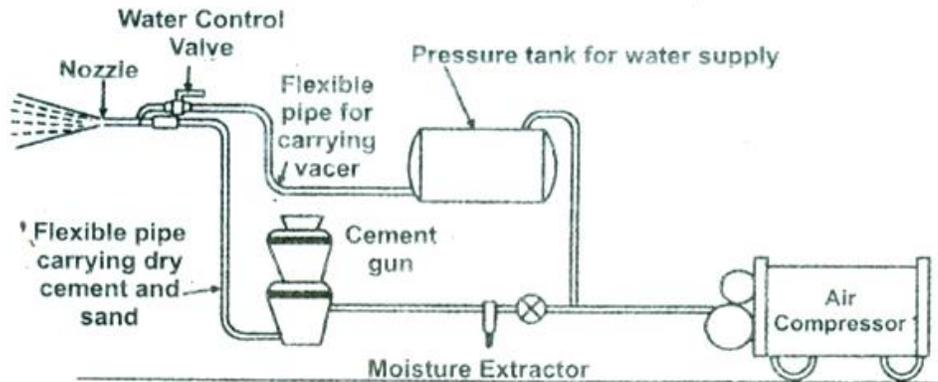


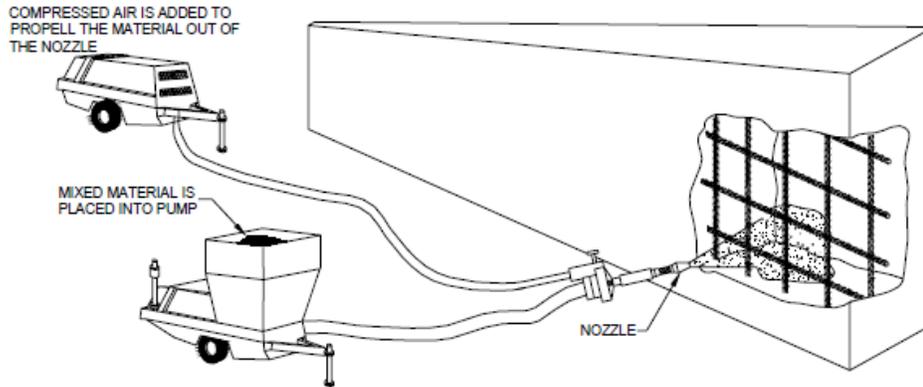
Fig. 4.9: General arrangement of apparatus in gunite system

The stage involved in the dry mix process is given below:

1. Cement and sand are thoroughly mixed.
2. The cement/sand mixture IS fed into a special air-pressurized mechanical feeder termed as 'gun'.
3. The mixture is metered into the delivery hose by a feed wheel or distributor within the gun.
4. This material is carried by compressed air through the delivery hose to a special nozzle. The nozzle is fitted inside with a perforated manifold through which water is sprayed under pressure and intimately mixed with the sand/cement jet.
5. The wet mortar is jetted from the nozzle at high velocity onto the surface to be gunited.

The Wet-mix Process:

- In the wet-mix process the concrete is mixed with water as for ordinary concrete before conveying through the delivery pipe line to the nozzle, at which point it is jetted by compressed air, onto the work in the same way, as that of dry mix process.
- The wet-mix process has been generally discarded 111 favour of the dry-mix process, owing to the greater success of the latter.
- The dry-mix methods makes use of high velocity OR low velocity system. The high velocity gunite is produced by using a small nozzle and a high air pressure to produce a high nozzle velocity of about 90 to 120 m/s. This results in exceptional good compaction.
- The lower velocity gunite is produced using large diameter hose for large output. The compaction win not be very high.



Advantages and Disadvantages of Dry and Wet Process:

1. In wet process, it is possible to maintain accurate water cement ratio. It is not possible to maintain accurate water cement ratio in the dry process due to so many natural objections.
2. There is difficulty in pumping of light weight aggregate in wet process and hence it makes dry process more suitable when this type of aggregate is used.
3. The dry process is very sensitive to the water content in the sand, due to too wet sand causes difficulties through blockage of delivery pipe line, this difficulty does not arise in case of wet process.
4. The lower water cement ratio obtained in dry process, probable accounts for the lesser creep grater durability of concrete is produced in this way compared to wet process.
5. Admixtures generally can be used more easily with the wet process. Admixtures can be used with little difficulty in case of dry process.

13. Explain Short Crete in Detail?

- Shotcrete is the concrete conveyed through a hose and pneumatically projected at a high velocity on a surface. It is similar to gunite (mortar) but with coarse aggregates.
- The normal specifications with respect to cement, aggregate and water also apply to shotcrete, but the coarse aggregate used should be harder to account for attrition and of small size.
- The w/c ratio is kept quite low. The admixtures such as accelerators are used to permit quick setting of shotcrete.
- Shotcrete can be made by dry-mix or wet-mix process, the former being more successful and generally used. In the dry-mix method the cement

and aggregates are mixed dry, conveyed through a hose into a special nozzle by compressed air.

- Water is sprayed, inside the nozzle, under pressure and intimately mixed. Shotcrete is projected at high velocity on the surface to be gunited.
- In the wet process the mixing is done as for normal concrete. The maximum rate of deposition of shotcrete is 15 m³/hr. for the dry process but it can be more with the wet process.

Properties:

- The strength and other properties of shotcrete are same as that for high quality concrete. Normal shotcrete mixes are capable of strengths above 35 N/mm².
- Shotcrete is highly durable. Shrinkage and creep for wet shotcrete is likely to be high, but for dry-mix shotcrete shrinkage is low and creep similar to high quality concrete.

Applications:

- Shotcrete finds its applications in tunneling, repairing of old concrete and thin sections. Though costly, shotcrete requires shuttering and for work only on one side resulting in economy and making it particularly suitable for thin sections.
- The fact that it can be conveyed over a considerable distance in a small diameter pipe makes shotcrete suitable for sites where access is difficult.
- However, it cannot be used in confined spaces as the expansion of compressed air causes turbulence. Which make accurate placing difficult. Also the variable quality of the finished product, highly skilled personals and its cost are some of the main disadvantages limiting its application.

General uses of Shotcrete:

1. Shuttering and form work need be erected only on side of the work and it does not have to be so strong as the shuttering for poured concrete.
2. It is highly durable compared to poured concrete.
3. The shrinkage is very low and creep similar compared to high quality concrete.
4. Shot create gives excellent bond with old concrete.
5. Mostly shot create concrete is frequently adopted in tunneling operations.

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