Subject : Maintenance and Rehabilitation of Structure

"UNIT-4 : Materials and Techniques For Repair"

UNIT –IV Materials and Techniques For Repair”

- Topic-Techniques for Repairing cracks in concrete &
  Methods of Corrosion Protection

INTRODUCTION

- Building cracks are most common problem found in any type of building. It is necessary to have a house which is structurally safe and beautiful, but it is not so easy; one has to overcome natural calamity, soil failure, construction faults, improper design, and inadequate joints causing to develop cracks on the building. Though the cracks in concrete cannot be prevented entirely but they can be controlled by using adequate material and technique of construction and specific design criteria.
- On timely identification of such cracks and adopting preventive measure are essential. Active cracks causes seriously problem, and they need special attention as they are structurally hazardous. So, it is important to understand the types of cracks, crack patterns and their causes and the preventive measures to be taken to control the cracks.

- Cracks in the building are a universal problem faced throughout the world. Building components develops cracks whenever stress in the components exceeds its strength. Stress in the building components could be caused by externally applied forces such as dead, live, wind, seismic loads or foundation settlement or could it be induced by internally due to temperature variations, moisture changes and chemical actions. Cracks affect the building's artistic look, and it destroys the wall integrity, affects the safety of structure and even reduces the durability of structure.

PRINCIPLES OF INVESTIGATION OF STRUCTURE

STEP 1:

Discussion With Client/Owner of the Building : One of the simplest and most important thing is to discuss with client or owner about the cracks on the building and gathering information from them. Ask them:

- when was the building constructed? Date and year of construction?
- Ask for building drawings? And the details of constructions if available.
- Ask them when the cracks first appeared? Or how long was the cracks seen?
- Check whether the client makes complaints about pieces of concrete falling, excessive deflections, large cracks, staining, and water leakages?
- Ask them whether any repair work was carried out if yes, what was the result?

STEP 2: Visit The Site

When you visit the site, always carry proposed building drawings.

- Check whether the building is constructed as per the plan.
- Check its present use of the structure or any change in the usage of building.
- Photograph the cracks and number them.
- Mark the width of crack
- Check for any tilting of walls or tilting of any structural members, deflections, staining, water leakage, spalling, and corrosion.
- Collect the samples from the site.

STEP 3: Finding The Suitable techniques To Repair Crack

- Epoxy injection
- Routing and sealing
- Stitching
- Drilling and plugging
- gravity filling
- Drying packing
- Polymer impregnation and underpinning

TYPES OF CRACKS IN CONCRET

- Plastic **shrinkage** concrete cracks. ...
- Expansion concrete cracks.
- Heaving concrete cracks.
- Settling concrete cracks. ...
- Concrete cracks caused by overloading the slab. ...
- Concrete cracks caused by premature drying.
- https://youtu.be/dgGl8GSSUPA
- https://youtu.be/4o1furHMVlg

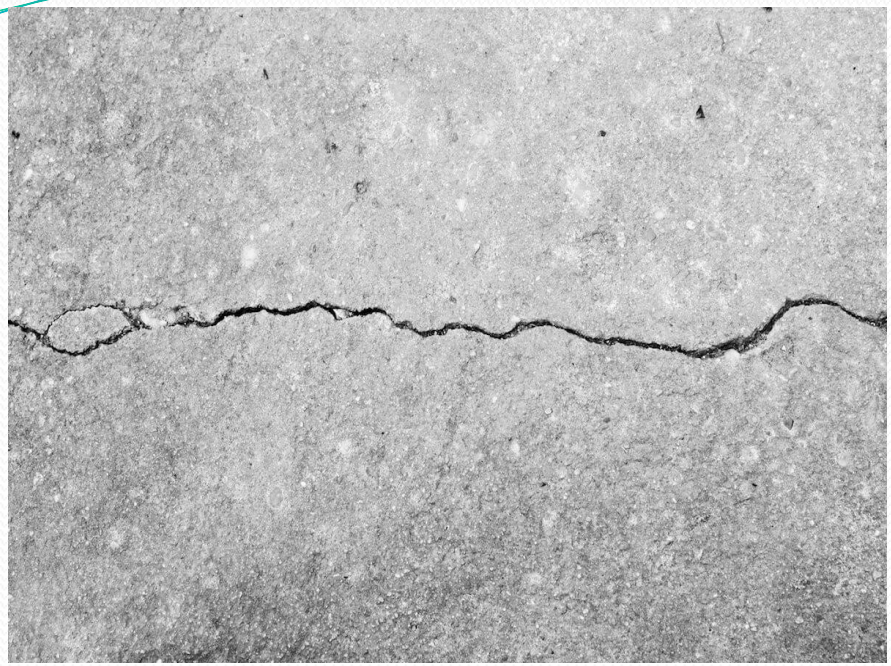
TYPES OF CRACKS

Structural Cracks

Structural cracks are those which result from incorrect design, faulty construction or overloading and these may endanger the safety of a building.

Non-Structural Cracks

Non Structural cracks occur mostly due to internally induced stresses in building materials. These cracks normally do not endanger the safety but may look unsightly, create an impression of faulty work or give a feeling of instability.



CRACK REPAIRING MATERIALS:

Basically, the concrete repair materials can be grouped into:

1. Cementitious System
2. Polymer Modified Cementitious System
3. Polymer Concrete System
4. Reactive Thermosetting Resin System

1. Shotcrete
2. Epoxy resin
3. Epoxy mortar
4. Gypsum cement mortar
5. Quick setting cement mortar
6. Mechanical anchors

Polymer

- Impregnation Monomer systems can be used for effective repair of some cracks. A monomer system is a liquid consisting of monomers which will polymerize into a solid. The most common monomer used for this purpose is Methyl methcrylate.

POLYMER


COMMERCIAL GRADE
QUIKRETE
Polymer Modified
STRUCTURAL REPAIR
Modificada con polímeros reparación estructural
Vertical & Horizontal Concrete Repair

Crack Repair Techniques:

1.Epoxy Injection
2.Routing and sealing
3.Stitching
4. Dry Packing
5.Drilling and Plugging
6.External stressing(additional steel)
7.Grouting
8. Jacketing (Blanketing)

- Corrosion Protection of Reinforcement

TECHNIQUES TO REPAIR OF CRACK IN CONCRETE

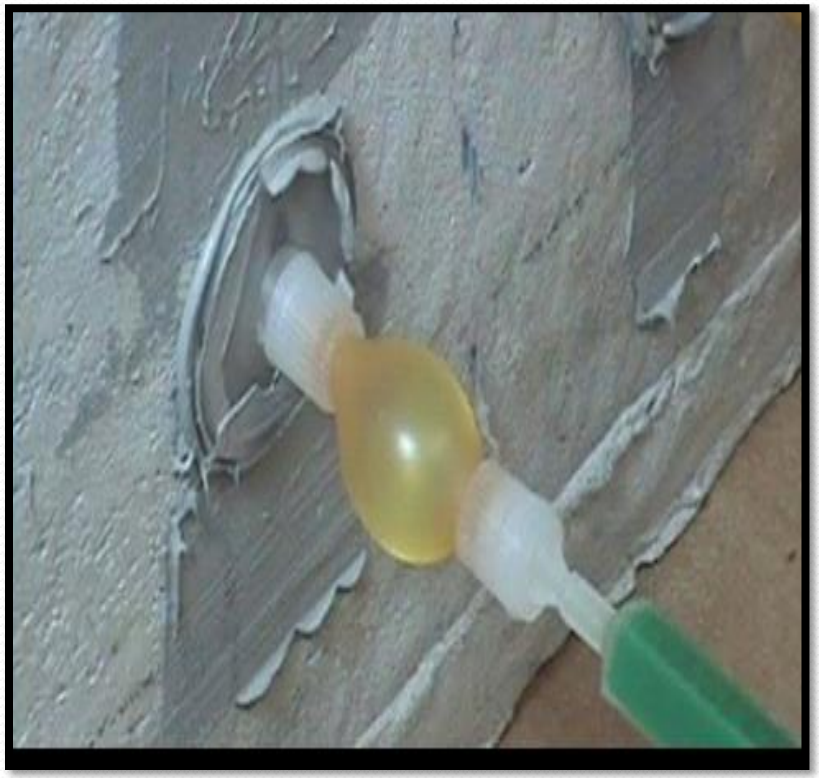
1. Epoxy Injection

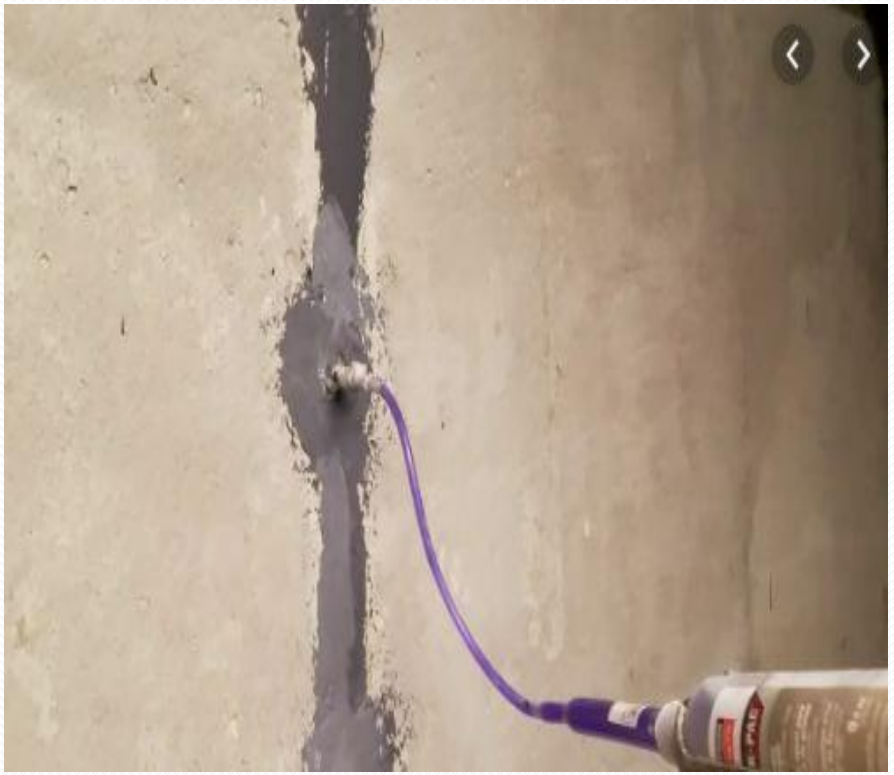
Epoxy injection is an economical method of repairing non-moving cracks in concrete walls, slabs, columns and piers as it is capable of restoring the concrete to its pre-cracked strength. The technique generally consists of establishing entry and venting ports at close intervals along the cracks, sealing the crack on exposed surfaces, and injecting the epoxy under pressure.

- Cracks as narrow as 0.002 in. (0.05 mm) can be bonded by the injection of epoxy.

- The Injection of polymer under pressure will ensure that the sealant penetrates to the full depth of the crack. The technique in general consists of drilling hole at close intervals along the length of cracks and injecting the epoxy under pressure in each hole in turn until it starts to flow out of the next one. The hole in use is then sealed off and injection is started at the next hole and so on until full length of the crack has been treated. Before injecting the sealant, it is necessary to seal the crack at surface between the holes with rapid curing resin.
- The technique generally consists of establishing entry and venting ports at close intervals along the cracks, sealing the crack on exposed surfaces, and injecting the epoxy under pressure. Epoxy injection has been successfully used in the repair of cracks in buildings, bridges, dams, and other types of concrete structures.

EPOXY INJECTION





Epoxy injection method of concrete crack repair may be used to bond the **cracks having greater than or equal to 0.05mm opening**. **This method is not suitable for crack is active and if the cracks are large in number, or when the water leakage cannot be controlled**.

For repairs of cracks in massive structures, a series of holes (Usually 20mm in dia and 20mm deep spaced at 150 to 300mm interval) intercepting the crack at a number of location are drilled.

- The general steps involved are as follows.
- i. Preparation of the surface
- ii. Installation of entry ports
- iii. Mixing of epoxy
- iv. Injection of epoxy
- v. Removal of surface seal
- Epoxy injection method of crack repairing requires a lot of discipline and skillful execution, so you need to be sure that the person executing the repairs knows his work.
- In this method of concrete crack repair, the cracks on exposed concrete surfaces are sealed by injecting epoxy under the concrete crack.

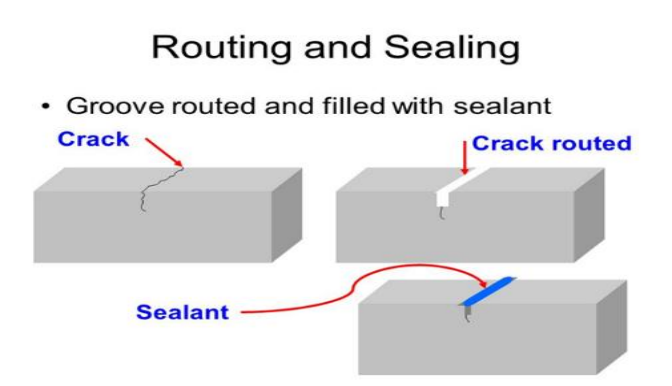
2.Routing and Sealing

- In this method, the crack is made wider at the surface with a saw or grinder, and then the groove is filled with a flexible sealant. This is a common technique for crack treatment and it is relatively simple in comparison to the procedures and the training required for epoxy injection.
- Procedure for Routing and Sealing Initially clean the surface, the surface should be free from paint, dirt, oil, efflorescence or any bond inhibiting agents. Then apply epoxy. To prevent epoxy flowing out insert foam breaker or rod of suitable diameter and sealant is applied to it.

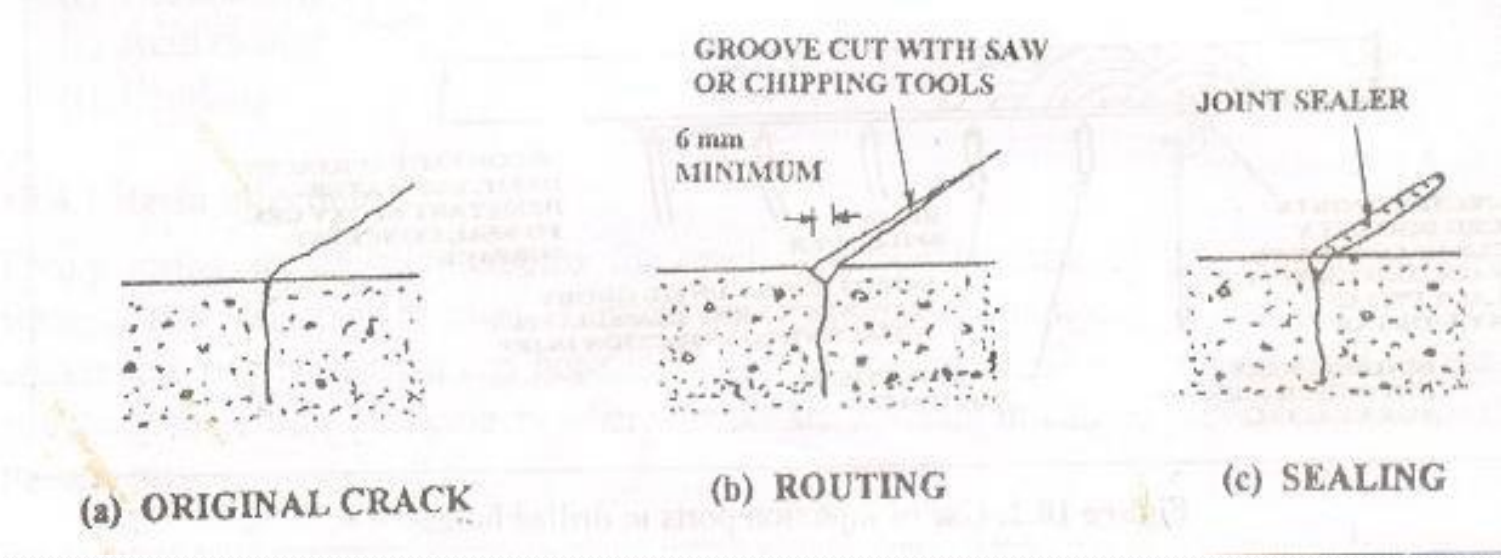
- Routing and sealing of cracks in concrete can be used for **inactive cracks** not involving the restoration of tensile strength.
- Under this method, the crack is enlarged along its exposed face and the V-shaped groove is formed up to a minimum width of 6 mm and a depth of 6 to 25 mm. This V-shaped groove is **filled and sealed with suitable material.** This is Popular concrete crack repair.

Routing and Sealing

Routing and Sealing



Video link for method:
https://youtu.be/m_5bUpsad8U

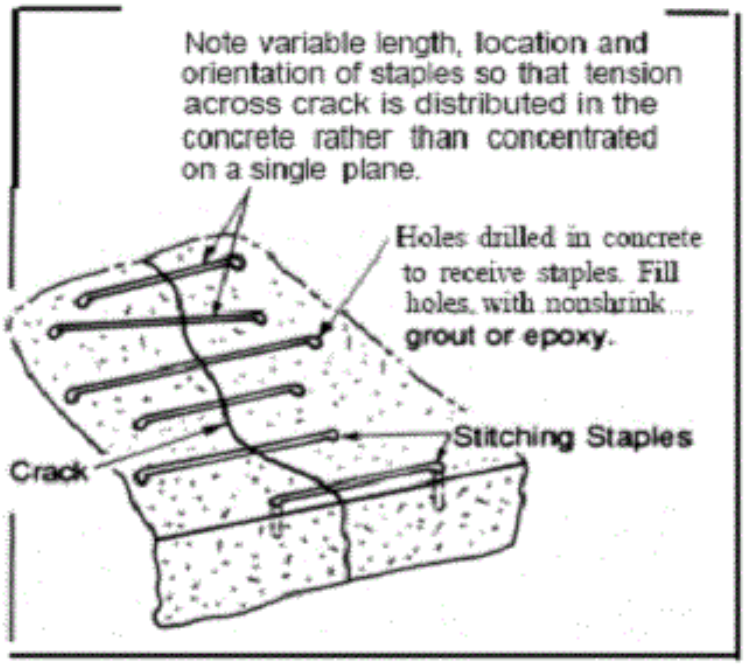


- This is the simplest and most common method of crack repair. It can be executed with relatively unskilled personnel and can be used to seal both fine pattern cracks and larger isolated cracks.
- The system can be used to repair dormant cracks that are of no structural significance and is used to seal the cracks against the ingress of moisture, chemicals and carbon dioxide. This involves enlarging the crack along its exposed face and sealing it with crack fillers as shown fig. Care should be taken to ensure that the entire crack is routed and sealed.
- This method involves enlarging the crack along its exposed face and filling and **sealing** it with a suitable joint **sealant** (Figure 1). This is a common **technique** for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection.

3. Stitching

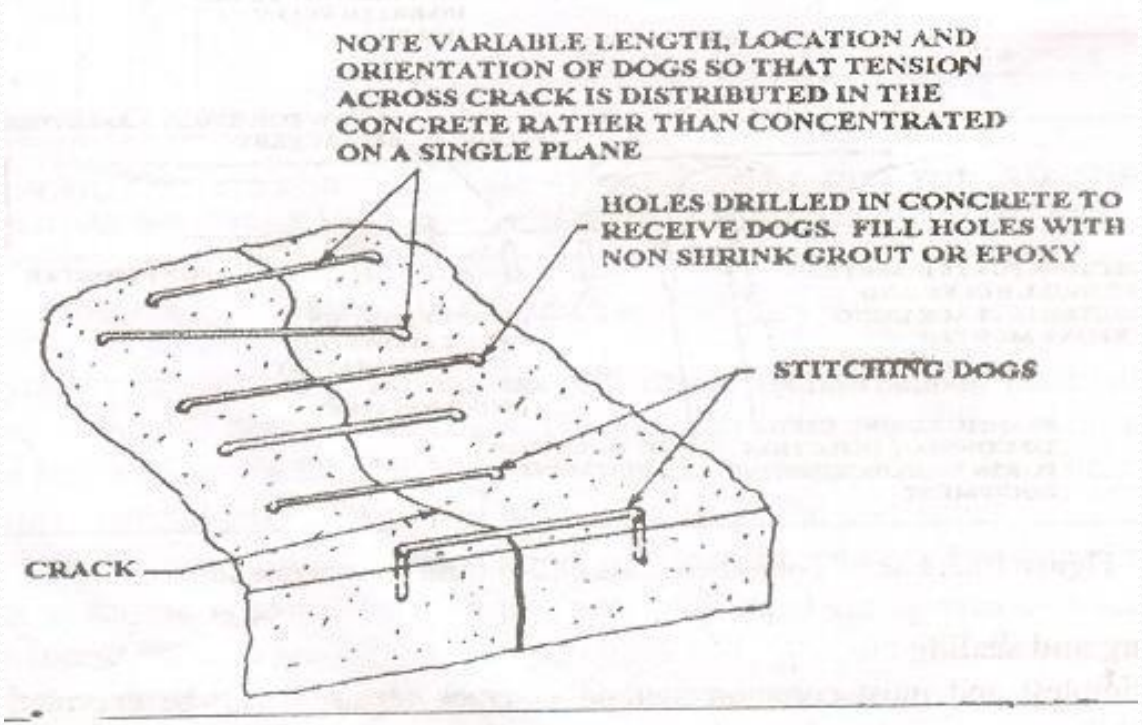
This method is done to provide a permanent structural repairs solution for masonry repairs and cracked wall reinforcement .

It is done by drilling holes on both sides of the crack, cleaning the holes and anchoring the legs of the staples.



Stitching the Cracks

In this technique, the crack is bridged with U-shaped metal units stitching dogs before being repaired with a rigid resin material. This can establish restoration of the strength and integrity of cracked section; due care is to be given to make analysis check to ensure that this will perform well under applied loads shown fig.



Repair of crack by stitching

Crack Repair by Stitching

4.Dry Packing

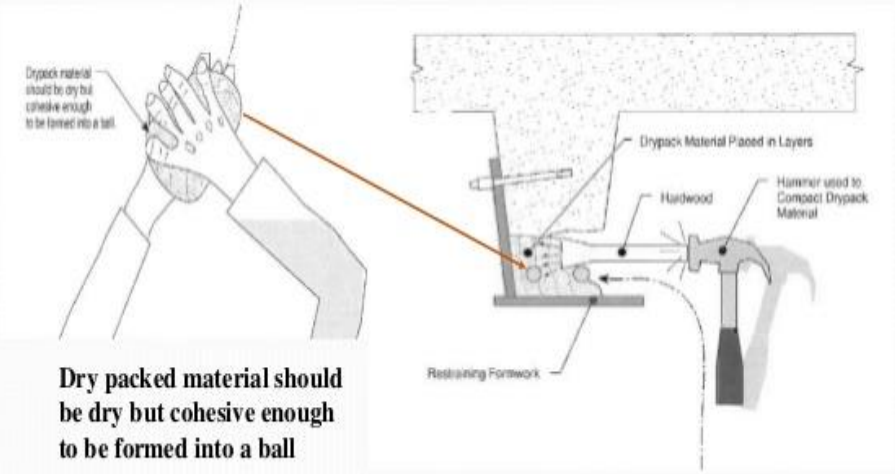
- It is the hand placement of a low water content mortar followed by tamping or ramming of the mortar into place and helps in producing intimate contact between the mortar and the existing concrete.
- Dry packing is the hand placement if a low W/C ratio mortar which is subsequently rammed into place to produce a dense mortar plug having tight contact to the existing concrete.
- Because of the low W/C ratio, there is e patch remains little shrinkage and the patch remains tight, with good durability, strength and water tightness.

- Dry pack should be used for filling holes having a depth equal to, or greater than, the least surface dimension of the repair area; for cone belt, she bolt, core holes and grout-insert holes; for holes left by the removal of form ties; and for narrow slots cut for repair of cracks.
- Dry pack should not be used for relatively shallow depressions where lateral restraint cannot be obtained, for filling behind reinforcement, or for filling holes that extend completely through a concrete section.
- In this technique of repair, dry Cement Sand mix(1: 2.5) is used.
- Sufficient quantity of water is to be added to form a ball by hand.
- The ball is immediately placed into place before the bond coat has dried or cured, with suitably shaped hardwood dowel and hammer in 8 to 10mm thick layers as shown in figure.

Dry packing

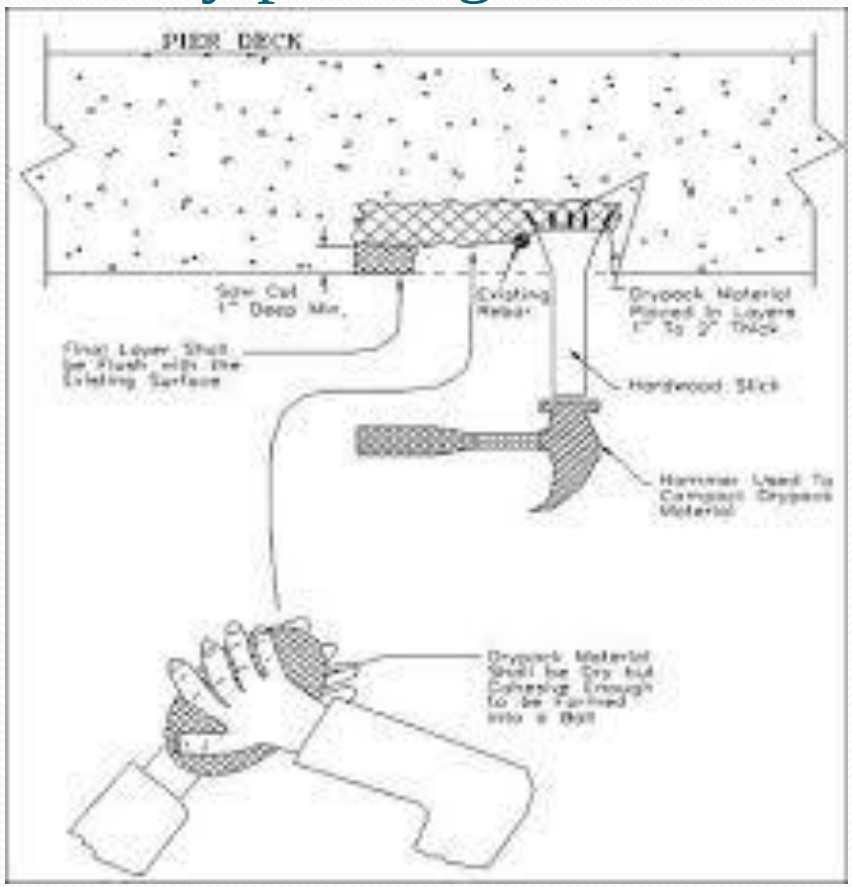
- For the dry pack method of concrete pair, holes should be sharp and square at the surface edges, but corners within the holes should be rounded, especially when water tightness is required. The interior surfaces of holes left by cone bolts and she bolts should be roughened to develop and effective bond; this can be done with a rough stub of 7/8 inch steel wire rope, a notched tapered reamer, or a star drill. Other holes should be undercut slightly in several places around the perimeter. Holes for dry pack should have a minimum depth of 1 inch

1. Dry Packing



Dry pack mortar is basically a combination of cement and fine sand which passes through sieve no 16 and thoroughly mixed with water to hydrate the cement. **Dry** Cement mortar is used for filling holes having a depth equal to or greater than the least surface dimension of the repair area.

Dry packing


PIER DECK
Saw Cut 1" Deep Min.
Existing Rebar
Drypack Material Placed In Layers 1" To 2" Thick
Final Layer Shall Be Flush With The Existing Surface
Hardwood Stick
Hammer Used To Compact Drypack Material
Drypack Material Shall Be Dry Mix Cohesive Enough To Be Formed Into a Ball

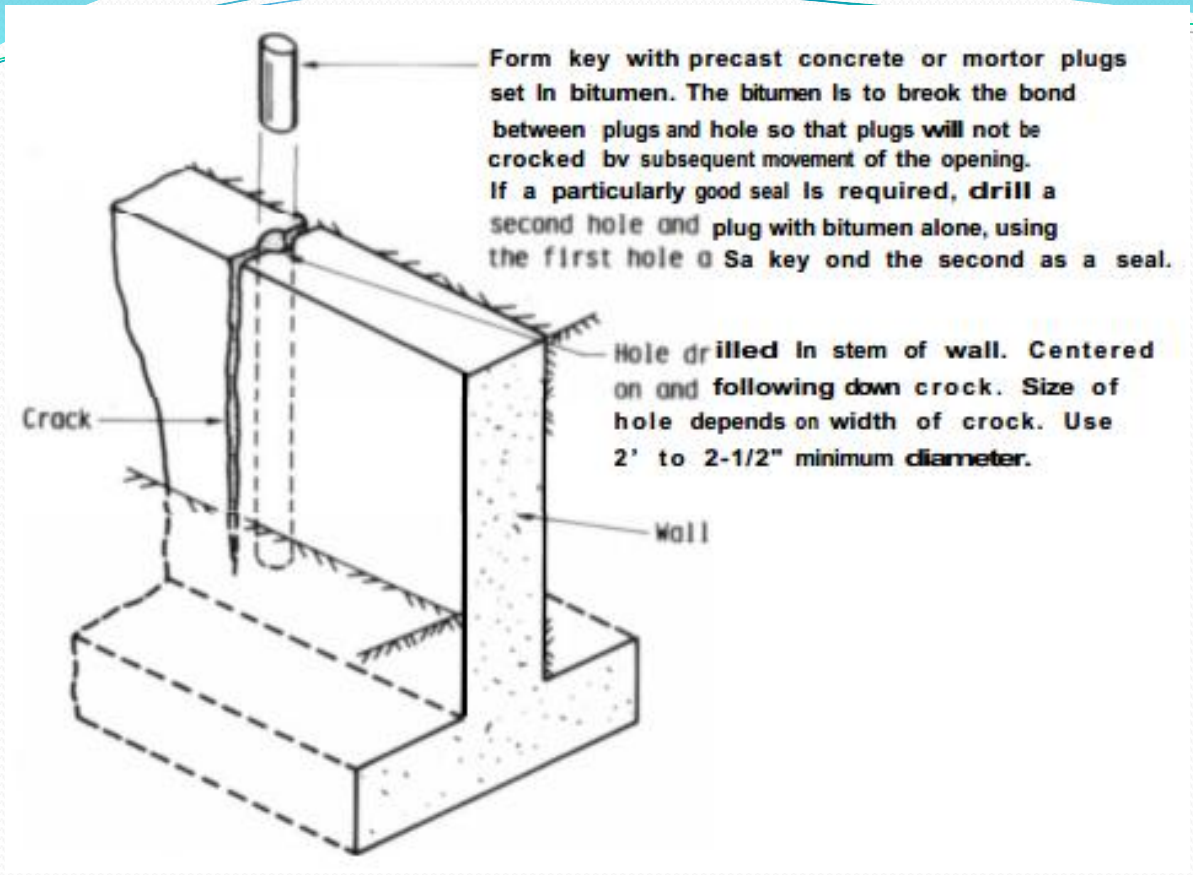
- Dry pack method can use for the small-sized crack of inactive nature. Dry pack method is not suitable for filling or repairing active cracks.
- Before applying grout by dry pack method, the slot of 25mm x 25mm must open to a concrete surface. The slot opening should be such that so that the base width is slightly greater than the surface width.
- The mortar should prepare before 30 min after mixing water to minimize chances of shrinkage and then should be remixed before use. This mortar should be placed in layers about 3/8 in. (10 mm) thick.
- Each layer should properly be compacted by blunt stick or hammer, and the old layer should be scratched to facilitate bonding with the next layer.
- The repaired surface should be cured by using either water or a curing compound.

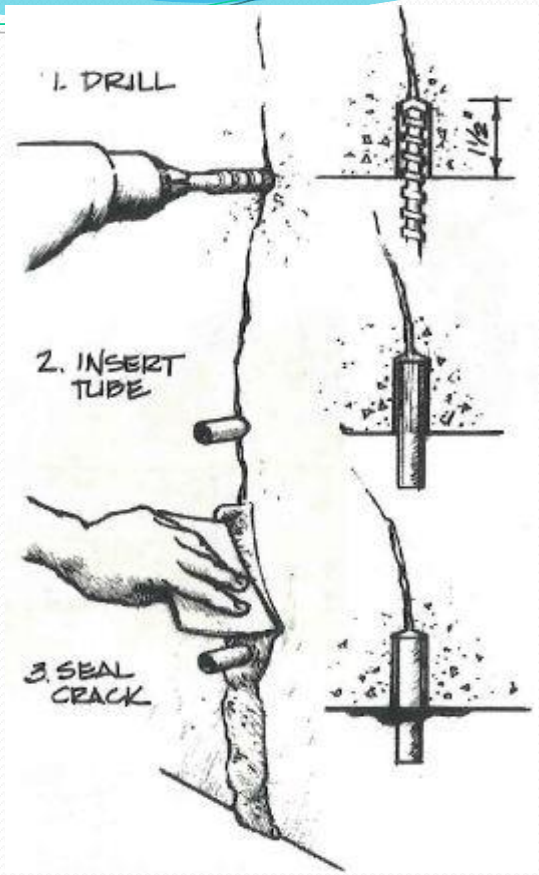
5. Drilling and plugging

- **Drilling and plugging** a **crack** consists of **drilling** down the length of the **crack** and grouting it to form a key (Fig.) This technique is only applicable when **cracks** run in reasonable straight lines and are accessible at one end. This method is most often used to repair vertical **cracks** in retaining walls.

Drilling and Plugging

- This method consists of drilling down the length of the crack and grouting it to form a key. A hole, typically 50 to 75 mm in diameter should be drilled, centered on and the following the crack. The drilled hole is then cleaned, made tight and filled with grout. The grout key prevents transverse movements of the sections of concrete adjacent to the crack. The key will also reduce heavy leakage through the crack and loss of soil from behind a leaking wall.
- When structural strength is not the criteria but water-tightness is essential, the drilled hole, should be filled with a resilient material of low modulus in lieu of grout. If the keying effect is essential, the resilient material can be placed in a second hole, the first being grouted.

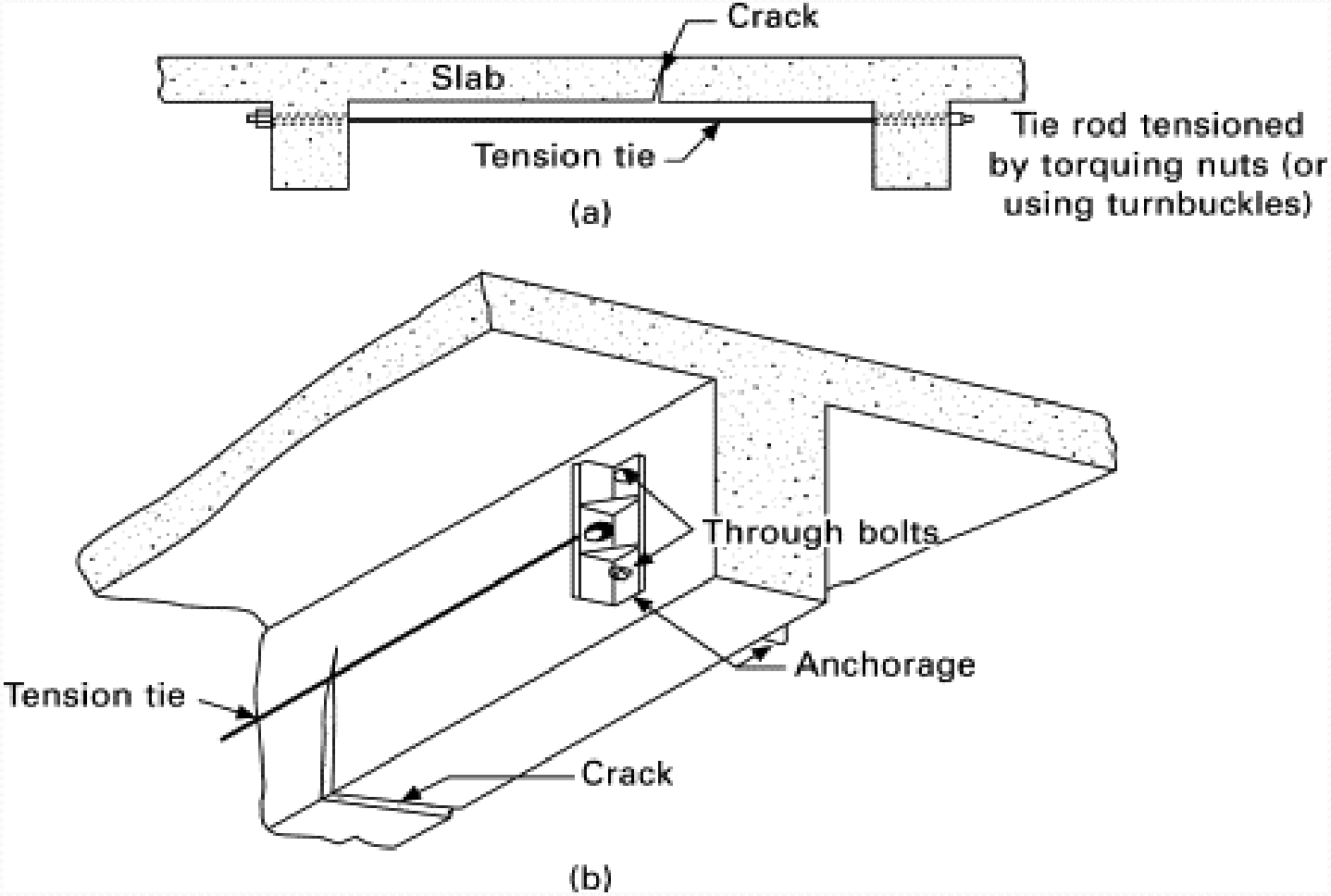




When it is required to repair a vertical crack in the concrete that runs in straight lines, this is a good method for its cost-effective and less time-consuming. In this method, holes are drilled vertically in the cracks and a key is formed by passing down a grout. The grout key drilled in concrete helps in preventing leakages.

Various techniques for repair of crack

6. Additional reinforcement techniques for repair of crack



- **External Stress**
- The development of cracking is due to the tensile stress, thus can be arrested by suppressing this stress
- Cracks can be closed by inducing a compression force to over come the tensile stresses
- The compressive force is applied by
  - Pre- stressing wires or rods
  - Wedging- by opening the cracks and filling with expanding mortar, by jacking and grouting or by actual driving wedges.

7. Grouting Method of Crack Repair

i) Portland cements grouting:

- In case of gravity dam and concrete wall large-sized crack formed. They can be repaired by filling with Portland cement grout. This grouting method is effective in stopping water leaks, but it will not structurally bond cracked sections.

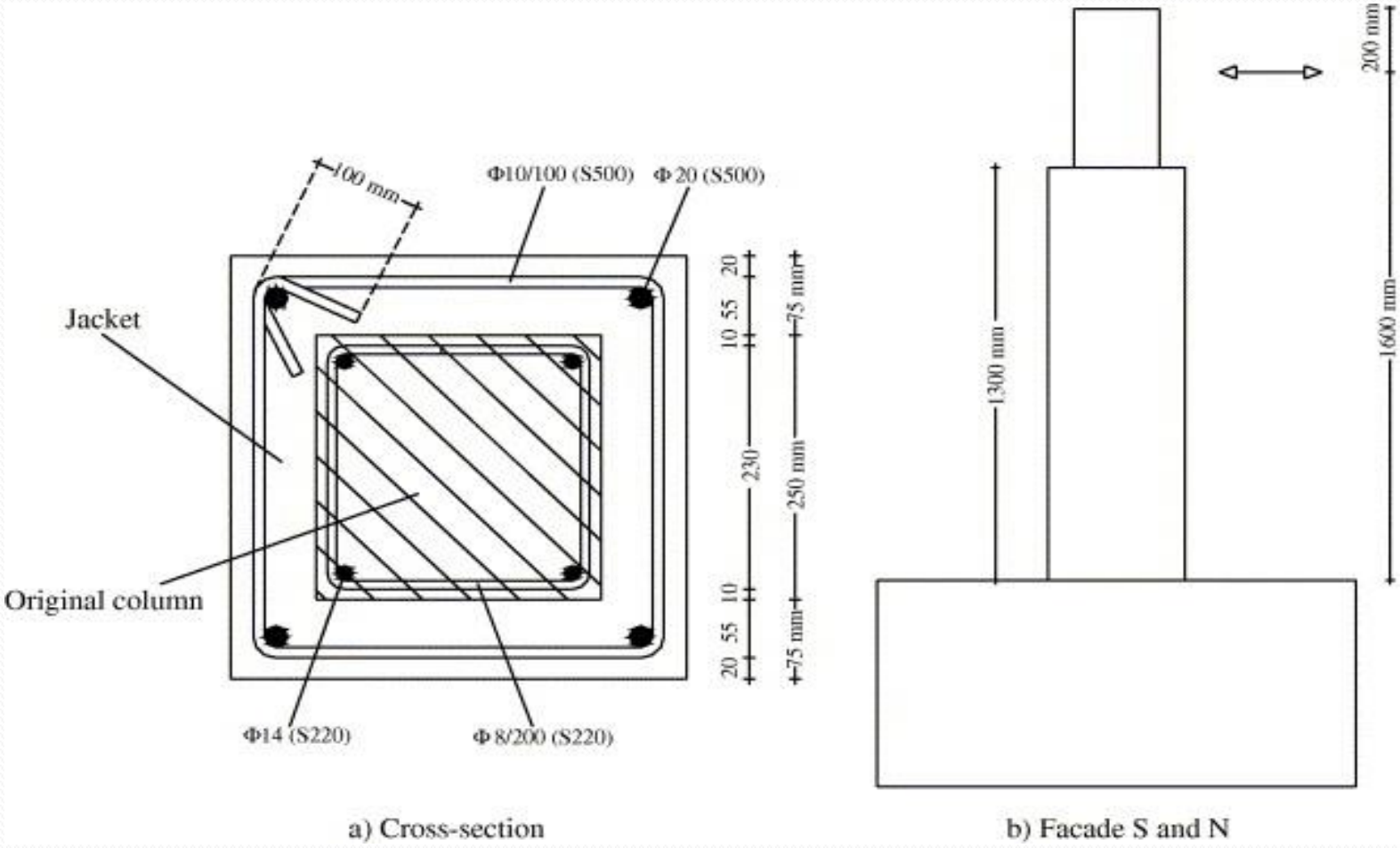
The procedure consists of,

- Cleaning the concrete along the crack.
- Installing built-up seats (grout mesh) at suitable intervals (to provide a pressure-tight connection with the injection apparatus).
- Sealing the crack between the seats with cement paint, sealant, or grout;
- Flushing the crack to clean it and test the seal; and then grouting the whole area.
- In this method, mixtures of grout may contain cement and water or cement plus sand and water, depending on the width of the crack.
- However, the water to cement ratio should be kept as low as practical to minimize shrinkage and to maximize the strength. Other admixtures or water reducer may be used to improve the properties of the grout.

8. Jacketing Method

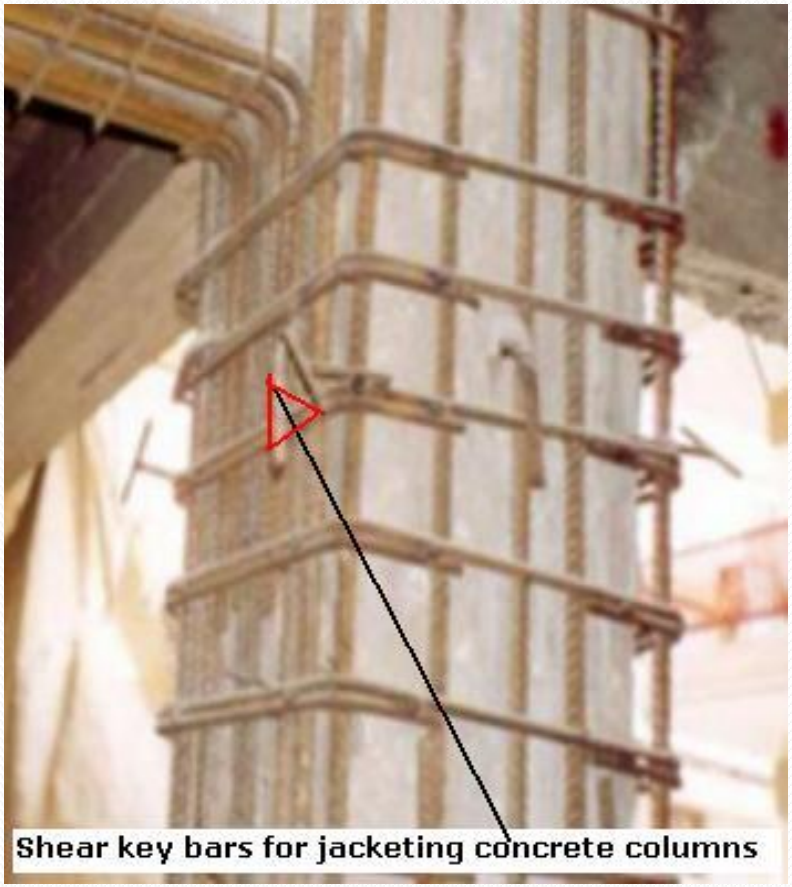
- Jacketing of RCC members increases its size significantly.
- This has advantage of increasing the member stiffness & is useful where deformations are to be controlled.
- Jacketing of slender RCC columns in a building provides a better solution for avoiding buckling problems.
- Design for strengthening is based on composite action between the old & new work.
- Strain compatibility calculations may have to be carried out carefully giving due accounts to factors such as creep.

Reinforcement details for Column Jacketing



a) Cross-section

b) Facade S and N

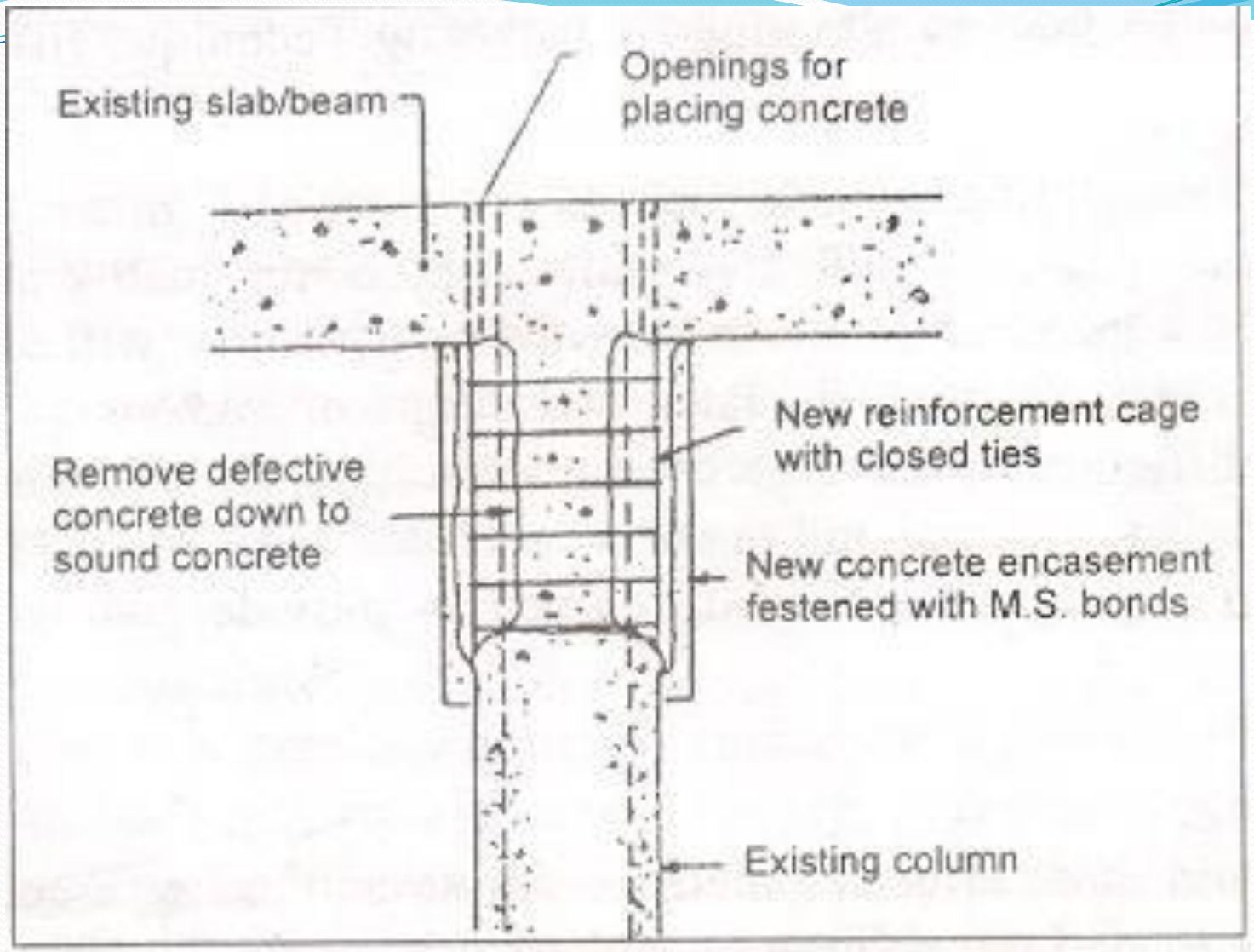


Excavation up to Footing and concrete work for pedestal- Reinforcement details for Column Jacketing

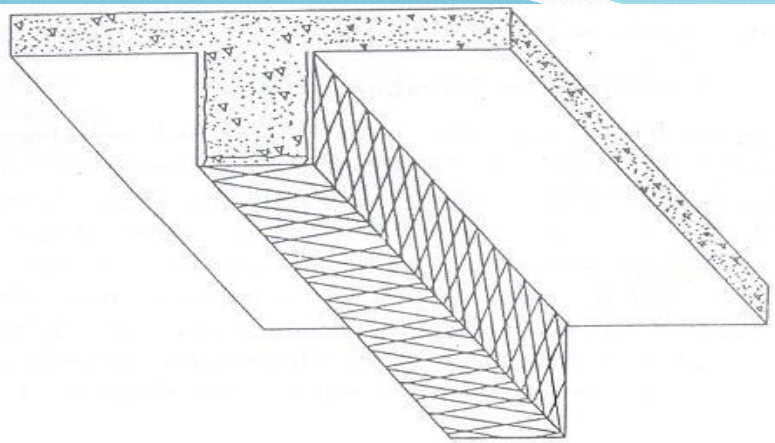

B-5
B-2

- Column jacketing is done to improve the load carrying capacity of the column.
- The minimum width of the jacket should be 10 cm for concrete cast in placed and 4 cm for shotcrete.
- Procedure:

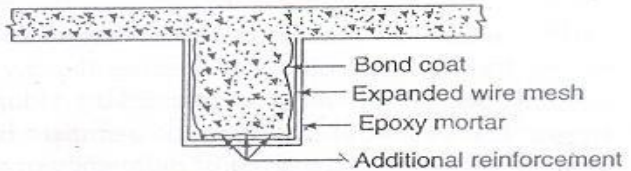
1. Open the footing of the column by excavating soil around it.
2. Remove the plaster from the surface of the column.
3. Make the surface of the column concrete rough.
4. Remove the corroded bars by cutting them .add new bars from footing to the slab as per instruction of engineer.
5. Add bonding agent on the old concrete for proper bonding between old and new concrete.
6. Erect necessary shuttering around the column.
7. Pour minimum M25 grade of concrete , vibrate and cure it.



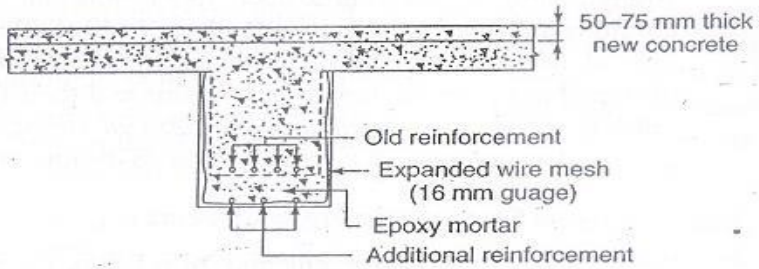
. Process of jacketing technique



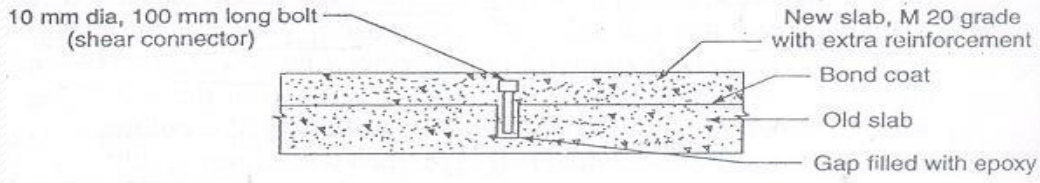
(a) Expanded wire mesh in position



(b) Repair scheme of the beam



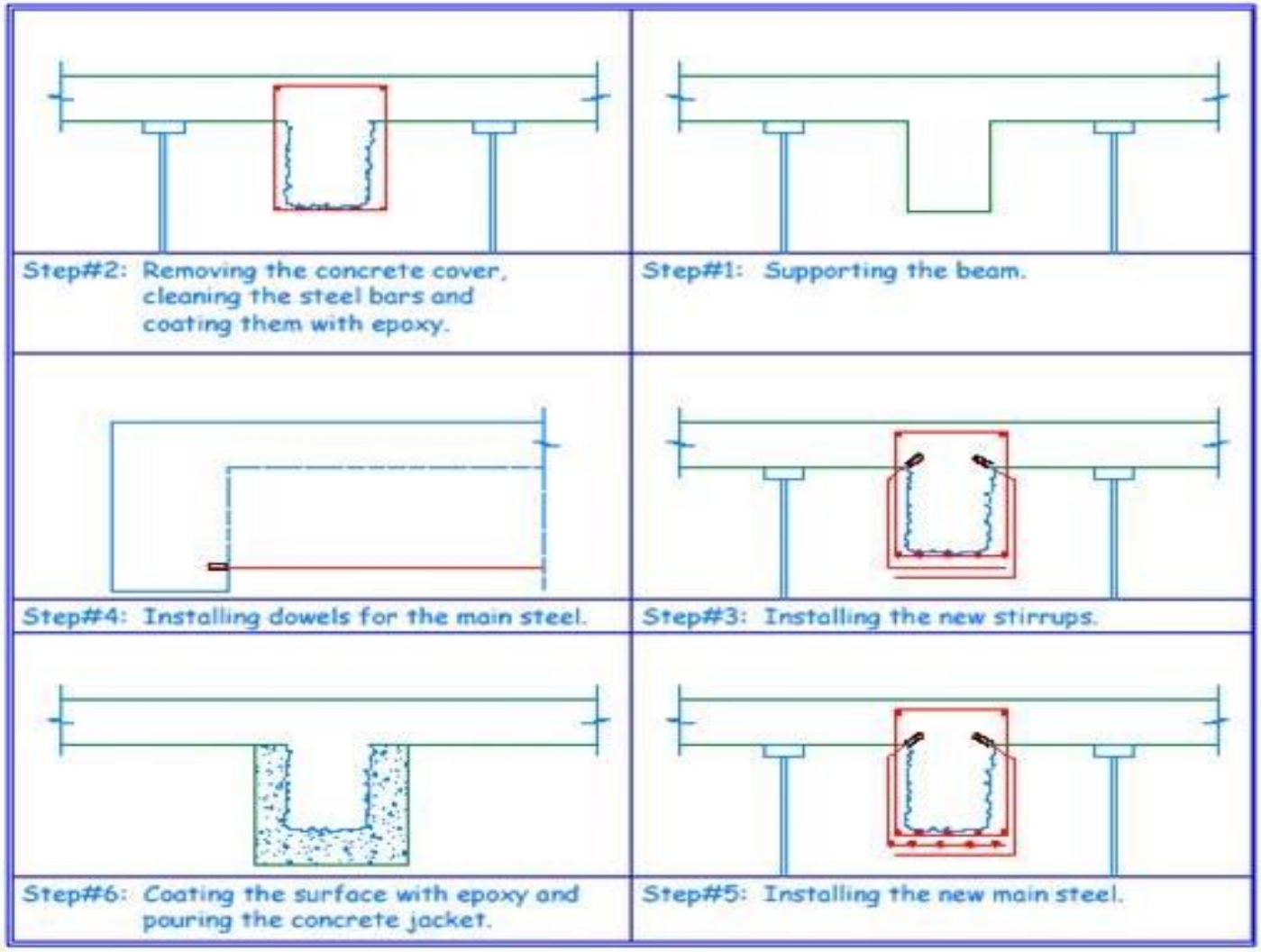
(c) Strengthened section of the beam



(d) Strengthening scheme of slab

Strengthening of a slab–beam system

Procedure for Beam Jacketing



Methods of Corrosion Protection

The following are some of the methods for protecting steel from corrosion

- Protective coatings for reinforcement
- Cathodic protection
- Corrosion Resistant steel
- Corrosion inhibitors

- **Protective coatings for reinforcement**
- This is an effective means to combat corrosion in such environment where ordinary concrete with surface coating is not able to protect reinforcement against corrosion. The surface coating for the reinforcement will increase the protection against corrosion.

- There are several methods of providing protective coating to the reinforcement. The important ones are:

i. Cement Slurry Coating

- Cement Slurry Coating provides short-term protection until placement in concrete.
- Several methods have been developed for an effective corrosion protection using cement slurry.
- One such coating is a mixture of cement, condensed silica and polymer dispersion.
- This mixer found to be impermeable to water, chlorides and carbon-di-oxide.

ii. Epoxy Coating

- Epoxy coating is formed by application of an epoxy resin with appropriate curing agent catalysts, pigments and flow control agents.
- Fusion bonding using the electrostatic process is the recent development.
- Fusion bonded epoxy coating provides long-term protection against corrosion.
- Though the cost is relatively high, it is the one which is the most effective in high alkaline and chloride contaminated environment.

iii. Plastic Coating

- Similar to epoxy coating, the plastic coatings are very effective in preventing corrosion of reinforcement even in high alkaline or chloride contaminated environment.
- However, the reduction in bond between plastic coated bar and the concrete is quite substantial and hence plastic coating cannot be considered as a solution for prevention of corrosion which cannot be solved by conventional methods.

iv. Galvanizing

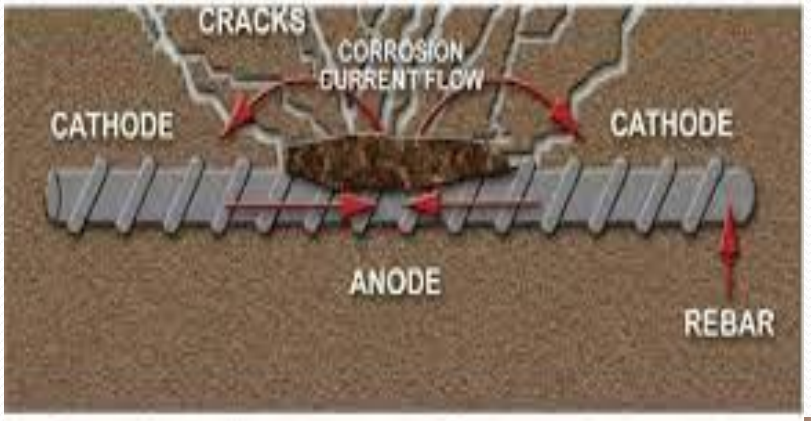
- Galvanizing gives protection to the reinforcement against corrosion, by means of metallic coating such as zinc.
- However, in case of corrosion due to excessive chlorides, the effect of galvanizing protection is reduce and hence is not advisable in highly chloride contaminated environments.

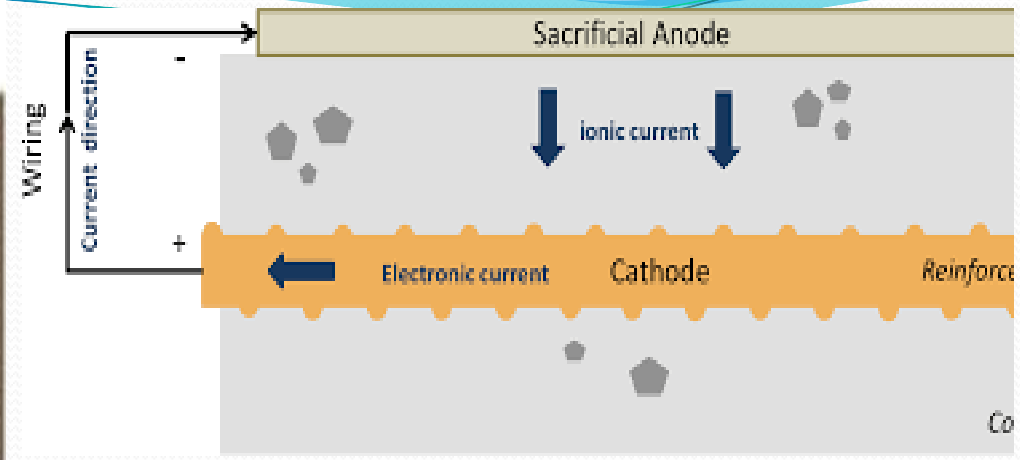
Corrosion Protection methods: Cathodic protection

- Cathodic protection interferes with the natural action of the electrochemical cells that are responsible for corrosion.
- Cathodic protection can be effectively applied to control corrosion of surfaces that are immersed in water or exposed to soil.
- Cathodic protection in its classical form cannot be used to protect surfaces exposed to the atmosphere.
- The use of anodic metallic coatings such as zinc on steel(galvanizing) is, however, a form of cathodic protection, which is effective in the atmosphere.

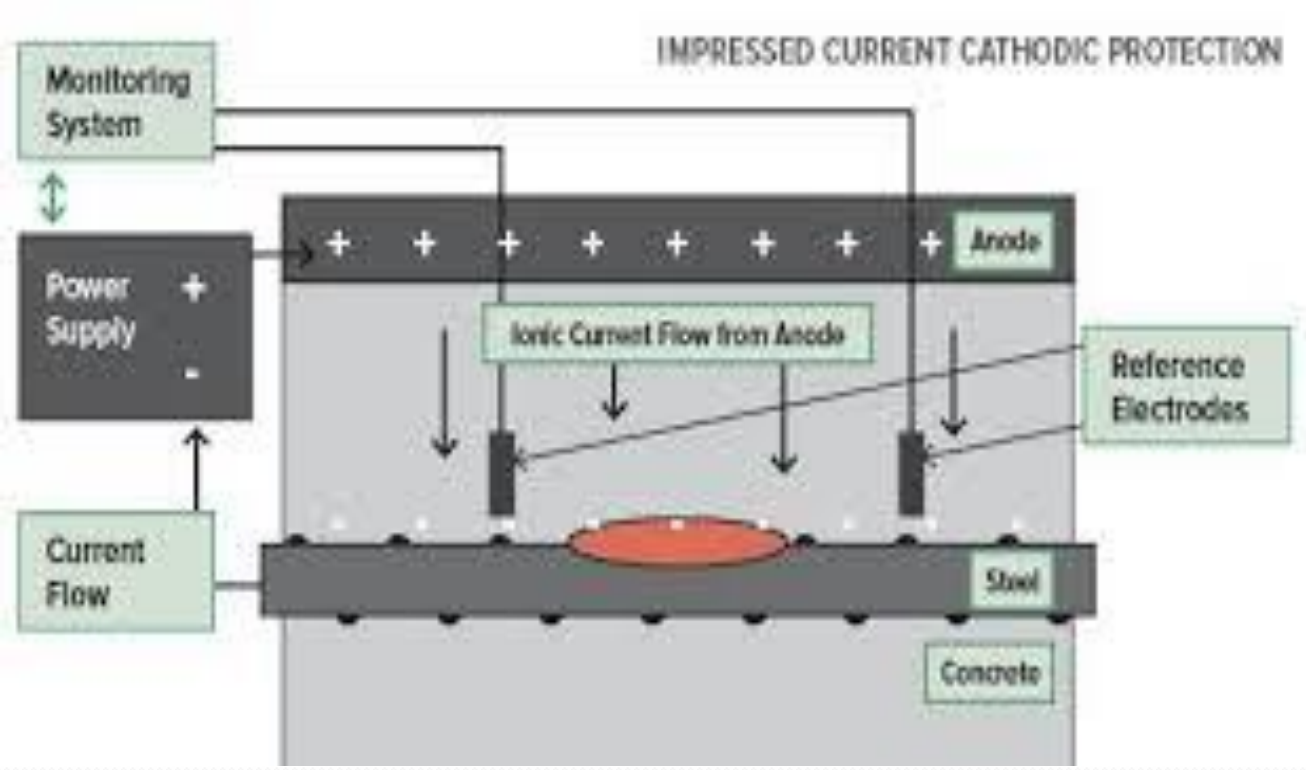
Cathodic protection with galvanic anodes

- **Cathodic protection (CP)** is a technique to control the corrosion of a metal surface by making it work as a cathode of an electrochemical cell. This is achieved by placing in contact with the metal to be protected another more easily corroded metal to act as the anode of the electrochemical cell.
- This method is also called sacrificial anode cathodic protection system, where the active metal is consumed in the process of protecting the surfaces, so that corrosion is controlled.
- In sacrificial anode systems the high energy electrons required for cathodic protection are supplied by the corrosion of an active metal.
- Sacrificial anode systems depend on the differences in corrosion potential that are established by the corrosion reactions that occur on different metals or alloys.


CRACKS
CORROSION
CURRENT FLOW
CATHODE
CATHODE
ANODE
REBAR


Sacrificial Anode
Wiring
Current direction
-
+
ionic current
Electronic current
Cathode

- **Impressed current Cathodic protection**
- In impressed current cathodic protection, an alternative source of direct electrical current, usually a rectifier that converts alternating current to direct current is used to provide the required electrical current. In this system, the electrical circuit is completed through an inert anode material that is not consumed in the process.


IMPRESSED CURRENT CATHODIC PROTECTION
Monitoring System
Power Supply
+
-
Current Flow
Anode
Ionic Current Flow from Anode
Reference Electrodes
Steel
Concrete

Corrosion-Inhibiting

- Corrosion-inhibiting admixtures fall into the specialty admixture category and are used to slow corrosion of reinforcing steel in concrete. Corrosion inhibitors can significantly reduce maintenance costs of reinforced concrete structures throughout a typical service life of 30 – 40 years. Other specialty admixtures include shrinkage-reducing admixtures and alkali-silica reactivity inhibitors.
- Corrosion-inhibiting admixtures have little effect on strength at later ages but may accelerate early strength development. Calcium nitrite-based corrosion inhibitors do accelerate the setting times of concretes over a range of curing temperatures unless they are formulated with a set retarder to offset the accelerating effect.

THANK YOU