UNIT-5
Repair Techniques

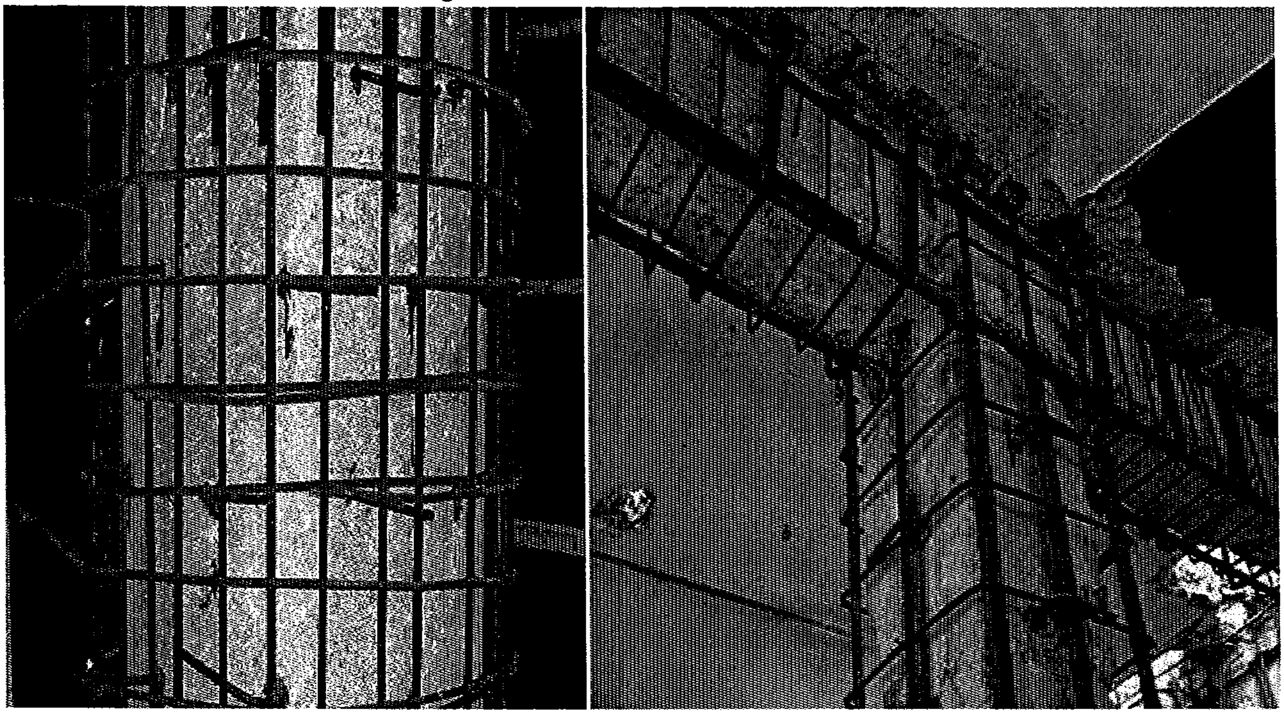
Grouting: The grouts described herein are categorized as either hydraulic cement or chemical.

a) Cement Grouts are mixtures of hydraulic cement, aggregate, and admixtures that when mixed with water produces a trowel able, flow able, or pump able consistency without segregation of the constituents. Admixtures are frequently included in the grout to accelerate, or retard time of setting, minimize shrinkage, improve pump ability or workability, or to improve the durability of the grout. Mineral fillers may be used for reasons of economy when substantial quantities of grout are required. Cement grouts are economical, readily available, easy to install, and compatible with concrete. Cement grouts may be used for repairs by injection only where the width of the opening is sufficient to accept the solid particles suspended in the grout. Normally, the minimum crack width at the point of introduction should be about 3 mm. Typical applications of hydraulic cement grout may vary from grout slurries for bonding old concrete to new concrete to filling of large dormant cracks or to filling of voids around or under a concrete structure. Non shrink cement grouts may be used to repair spalled or honeycombed concrete or to install anchor bolts in hardened concrete.

b) Chemical Grouts consist of solutions of chemicals that react to form either a gel or a solid precipitate as opposed to cement grouts that consist of suspensions of solid particles in a fluid. The reaction in the solution may involve only the constituents of the solution, or it may include the interaction of the solution with other substances, such as water, encountered in the use of the grout. The reaction causes a decrease in fluidity and a tendency to solidify and fill voids in the material into which the grout has been injected. The advantages of chemical grouts include their applicability in moist environments, their wide ranges of gel setting time, and their low viscosities. Cracks in concrete as narrow as 0.05 mm have been filled with chemical grout. Rigid chemical grouts, such as epoxies, exhibit excellent bond to clean, dry substrates, and some will bond to wet concrete. These grouts can restore the full strength of a cracked concrete member. Gel- type or foam chemical grouts, such as acryl amides and polyurethanes, are particularly suited for use in control of water flow through cracks and joints. Some gel grouts can be formulated at viscosities near that of water so they can be injected into almost any opening that water will flow through. Chemical grouts are more expensive than cement grout. Also, a high degree of skill is needed for satisfactory use of chemical grouts. Chemical bonding agents, such as epoxies, have relatively short *pot life* and working times at high ambient temperatures. Gel grouts should not be used to restore strength to a structural member.

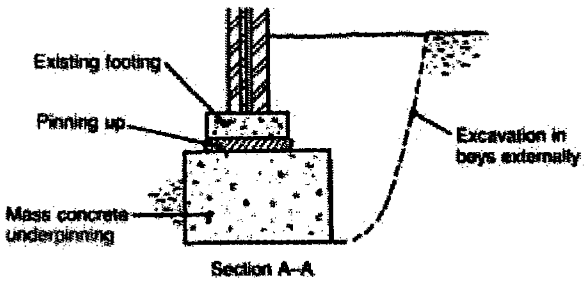
Shotcrete is a mixture of Portland cement, sand, and water " shot'' into place by compressed air. In addition to these materials, shotcrete can also contain coarse aggregate, fibers, and admixtures. Properly applied shotcrete is a structurally adequate and durable repair material which is capable of excellent bond with existing concrete or other construction materials. Dust and rebound require special attention in indoor application. The success of repair activity depends on the identification of the root cause of the deterioration of the concrete structures. Shotcrete technique is adopted for canal and spillway linings, faces of dams, tunnels, deteriorating natural rock walls and earthen slopes and to increase cover of existing concrete structures.

Jacketing: Primarily applicable to the repair of deteriorated columns, piers, piles and even employed for under water applications. Jacketing consists of restoring or increasing the section of an existing member, principally a compression member, by encasement in new concrete. The form for the jacket should be provided with spacers to assure clearance between it and the existing concrete surface. Filling up the forms can be done by pumping the grout, by using prepacked concrete, by using a *tremie*, or, for subaqueous works, by dewatering the form and placing the concrete in the dry. The use of a grout having a cement-sand ratio by volume, between 1:2 and 1:3, is recommended. The richer grout is preferred for thinner sections and the leaner mixture for heavier sections. The forms should be filled to overflowing, the grout allowed to settle for about 20 minutes, and the forms refilled to overflowing. The outside of the forms should be vibrated during placing of the grout.
Collars are jackets that surround only for a part of a column or pier. These are usually used to provide increased support to the slab or beam at the top of the column. The form for the jacket consists of timber, corrugated metal, precast concrete, rubber, fiberglass, or special fabric; and may be permanent in some cases. The form must be provided with spacers to ensure equal clearance between it and the existing member.



Permanent forms are preferred where protection against weathering, abrasion and chemical pollution takes place. The collar provides increased shear capacity for the slab, and it decreases the effective length of the column. Architecturally collars are considered better than jacketing but performing the same structural function. Before applying jackets or collars, all deteriorated concrete must be cleaned. For underwater conditions, a plastic shell may be applied at the splash zone to help minimize abrasion. Jacketing is to provide lateral confinement such as to bear longitudinal loads, needs special considerations. Expanding concretes can be made by adding aluminum powder to the matrix to overcome the setting shrinkage and some part of the drying shrinkage.

Underpinning is a method used to increase foundation depth or repairing faulty foundations. This might be the case if you plan to add stories to an existing structure or when the foundation has been damaged. One visible sign that your building needs underpinning is when cracks are visible. A building needs underpinning its foundation when cracks are wider than ¼ inch and there are some signs of a faulty foundation, especially diagonal cracks. Foundation failures could also be considered as heaved foundations, cracked or buckled walls and cracked concrete floors. The most used method of underpinning is mass pour method. This process requires excavating sections in sequence to a pre-established depth below the footing and place concrete on each pit. Repeat the method until the entire affected area has been underpinned.



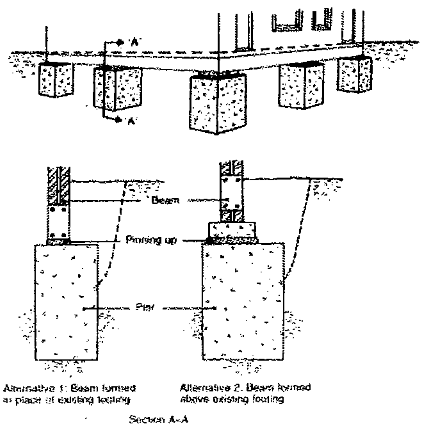
There are other methods and techniques to underpinning are as follows

Underpinning With Screw Piles and Brackets

Underpinning with screw piles and brackets is normally used in certain instances where traditional underpinning process is not possible. Some buildings might require excavating to great depths or maybe is unfeasible to use a piling rig making it ideal to use the screw piles and brackets method. The screw piles and brackets can be installed by only a two-man crew by hand or using small equipment such as a mini excavator. Screw piles can be installed in foundations having the capacity to work in tension and compression, withstand vertical and lateral wind forces, and vibration and shear forces. They are ideal when used with underpinning support brackets. The structure can then be lifted back to a level position and the weight of the foundation transferred to the pier and bracket system. Screw piles have many advantages over traditional pilings, such as the speed of installation, little noise and minimal vibration that may cause damage to the surrounding area.

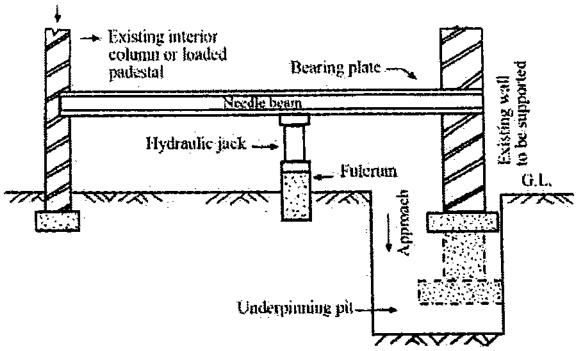
Pile and Beam Method

Underpinning with pile and beams is another great and preferred method to alleviate footing. Using this system



requires that a mini-pile must be installed on either side of the affected wall. After the piles have been installed, then brickwork is removed below the wall and reinforced concrete needle beam is used to connect the piles and support the wall.

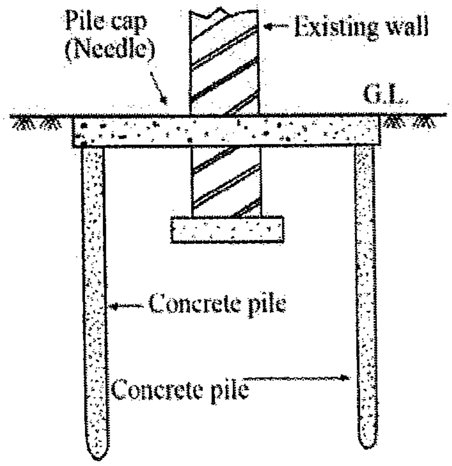
Reducing the distance between needle beams can accommodate very high loads. The bearing capacity of the underlying strata will determine the number, diameter, depth, and spacing of piles used. Augered piles or case driven piles can be used with this method of underpinning. The advantages of underpinning with pile and beams are:



- Suitable for restricted access
- Faster than traditional underpinning
- High load capability
- Less disruption, less spoil generated and completed quickly

Underpinning Using Piled Raft

Underpinning with a piled raft must be used when the whole structure needs to be underpinned. It is recommended when foundations are too deep for other underpinning methods or in areas where the soil is so hard that small equipment could not excavate up to require depth. Piles are placed at determined locations by loading conditions; then pockets below footings are broken and reinforced needle beams are placed to bear the wall's load. A ring beam is then built to link all needles and the structure is poured with concrete.



Advantages of this system are:

- Provides lateral and traverse ties throughout the structure.
- Economical at depths greater than 1.5m.
- No need for external access.
- Reduces disruption to drainage systems.

Underpinning Tips

Normally, this process needs to be designed or lead by a structural engineer for better results, but here are a few tips that will help you during the underpinning process.

- The underpinning process must be started from the corners and the working inwards.
- Underpinning must be made only on load-bearing walls.
- Do not underpin below non-load bearing walls.
- Start underpinning under a strip of footing. It is recommended to start with at least 3 feet long, two feet wide and two feet in depth.

- After the excavation has been completed, add concrete to the cavity. Concrete should be mixed using one part cement, three parts sand, and six parts aggregates.
- Remember to use formwork on the edges.

- Allowed concrete placed to set for at least two days.
- Use a rod bar ensuring that the cavity under the existing foundation is filled up.
- Ensure that the concrete is cured thoroughly before loading it.
- Once the concrete has gained sufficient strength, break off the projecting footing.
- Cut the concrete with the mass of concrete surface.
- Backfill and compact. If you are having problems achieving the required consolidation, use a hose to add water to the soil.

Pit Underpinning

1. To obtain additional foundation capacity
2. To modify the existing foundation system
3. To create new foundations through which the existing load may be wholly or partially transferred into deeper soil
4. To arrest the excessive settlement
5. To improve the future performance of the existing foundations

When Underpinning Is Required?

- Construction of a new project with deeper foundation adjacent to an existing building.
- Change in the use of structure
- The properties of the soil supporting the foundation may have changed or was mischaracterized during planning.
- To support a structure which is sinking or tilting due to ground subsidence or instability of the super structure

Several methods are used for repair of **underwater** concrete structure. These methods with procedure for repair of underwater concrete structures is discussed.

Repair of Underwater Concrete Structures – Methods and Procedure

Following are the different methods to repair underwater concrete structures:

Surface spalling repair

Large scale repair of underwater structural concrete

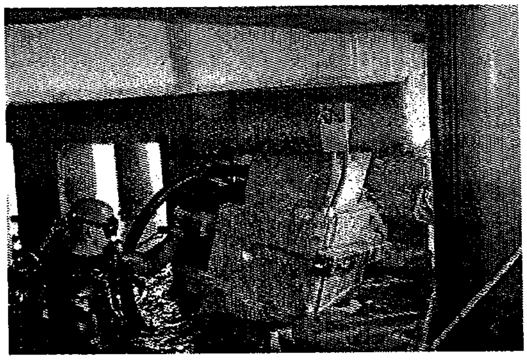
Preplaced aggregate concrete

Injection technique for restoring underwater concrete structure

Guniting or shotcrete method to repair underwater concrete structure

Steel sleeve repairing technique of underwater concrete

Surface Spalling Repair of Underwater Concrete Structures



Cover of underwater structural elements can spall off due to accidental damages. The damaged concrete cover must be replaced and repaired to prevent reinforcement corrosion in the future. Slightly deteriorated regions will turn to more severe and dangerous damages in short time, especially in splash zones. The deteriorated area of underwater structure should be cleared from both marine growth and loose concrete before repairing procedures are began. After that, based on the amount of damages, the boundary of spalled area should be saw-cut to a depth of 1.2-2 cm. In splash zones, cementitious mortar can be used for the damages region and water tolerant epoxy mortar may be employed in the case of small damage area. For large repaired area, formworks might be used to hold the repairing material at its position. This could postpone enhancement work and prevent epoxy coat utilization because if it hardens it would produce smooth surface and consequently the bond will be weak.

Procedure of Surface Spalling Repair of Underwater Concrete

The basic procedures of surface spalling repair technique might include:

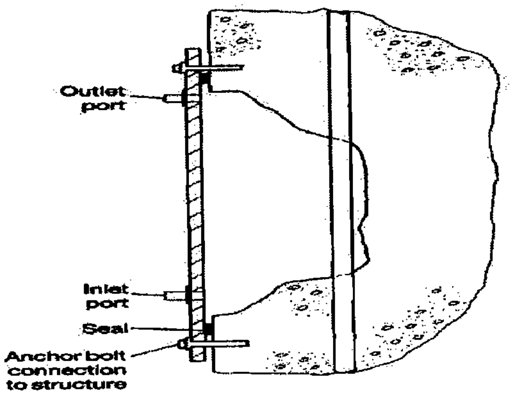
Flush damaged region with fresh water completely.

Apply a bonding coat.

Apply the repair mortar before the coat is set.

Apply a curing membrane to the applied repair mortar.

Protect the repaired area against wave action until it hardened adequately.



Large Scale Repair of Underwater Concrete Structures

This technique is suitable option when damages caused by structural overloading, fire, ship impact, or reinforcement corrosion especially in the splash zone. In the case where large areas are required to be restored, repair method and material selection is considerably important if shrinkage or bleeding lead to leakage path at the top of parent concrete and repair material interface. When repairing materials have great thickness, thermal cracking may develop due to rise of temperature even though surrounding water decline the temperature rise. Furthermore, repair of reinforcement is frequently needed because of distortion and considerable corrosion of reinforcement.

Procedure of Large Scale Repair of Underwater Concrete

The large-scale repair procedure is usually as follows:

Prepare the damaged region

Clean reinforcement adequately

Determine formwork typed based on the placement method of repairing material

Decrease concrete contamination with salts by flushing formwork with fresh concrete short period before pouring of repair concrete

Pumping is used most of the time for placing repair material and it should start at the bottom of the formwork to push water out of the formwork from the bottom.

Preplaced Aggregate Concrete

After the installing the formwork at the area intended to be repaired, a well graded aggregate is placed and compacted in the formwork. It is recommended that, fresh water is employed to clean the aggregate prior to grout placement. Then, appropriate grout is injected into the base of the well compacted aggregate in the formwork. In this process, water and voids are expelled out of the aggregate by the grout. It is essential that the formwork is grout proof in order to prevent leaking from the formwork in addition to provide proper venting at the top to permit escaping voids and air. It is substantially significant to sufficiently fill the formwork to the top of damage region with aggregate because when the grout is placed and aggregate is not present, the gout will shrink and cracks will develop. It is advised that, vibration is not applied during injection to avoid washing out of grout.

Injection Technique for Restoring Underwater Concrete Structures

Similar to the steps used for repairing dry structures, injection of cementitious grout or resin can be employed to repair cracks and or voids in the concrete structure underwater. Not only does the material selection is substantially based on void or crack size but also on possibility of anticipated movement of the member in the future. Epoxy resin is appropriate for crack width of 0.1 mm whereas cement grout is suitable for crack width of greater than few millimeters and when crack width is smaller than 0.1 mm, the injection is not required. Applied pressure and the time for which the pressure is kept prior to solidify repair material. There are two methods of injection that include pressure injection and gravity feed. It is necessary to break the concrete to reinforcement if corrosion evidence can be seen and complete repairing should be suggested instead of injection method.

The procedures for injection technique are

Prepare concrete surface along crack length

Along crack length, fix inspection nipples at specific intervals

Seal crack surface along the whole length of the crack

Remove contamination using fresh water and be sure that injection path is open

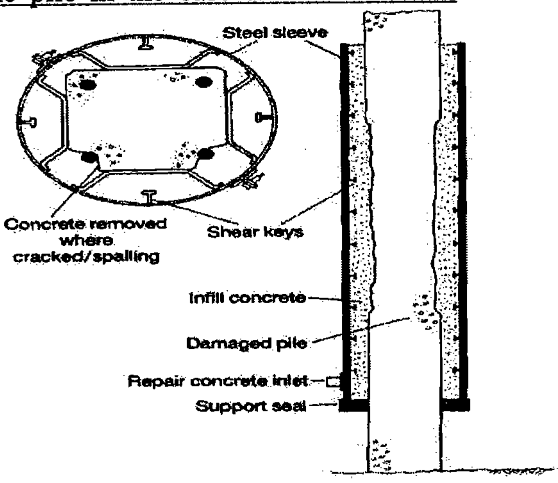
At one end of the crack, inject epoxy resin or cement grout into the crack through nipples

Guniting or Shotcrete Method to Repair Underwater Concrete Structures

This technique is the best option when large surface area or columns or beams are encased and usually dry process is used. In the dry method, dry mix is transferred by a hose and water is added to the dry mix at the nozzle. Despite the fact that, Guniting method is not suitable for underwater repairing but it can be employed in splash or tidal zones if seriously rapid setting additives is introduced. The success of this technique depends on nozzle-man skill and experience in adjusting water addition, pressure, and thickness uniformity. The maximum thickness of shotcrete should be restricted to fifty millimeter even though second layer can be employed if thicker layer is required.

Steel Sleeve Repairing Technique of Underwater Concrete

In this method, a steel sleeve is used around a pile or column after that the space between the sleeve and pile or column is filled with mortar or concrete. The sleeve could be designed to make rooms for further reinforcement corrosion. The sleeve need to exceed top and bottom of the damaged length of the pile and withstand the force of the pile in the case that the bars are ineffective due to corrosion.



A steel sleeve repair technique procedure is as follows

Prepare the damaged pile by loose concrete and marine growth

Clamp a temporary support or sealing ring around the pile below the damages area

Both the two semi circular sections of the sleeve

Pump grout or cement at the bottom of the sleeve

Remove the temporary support and employ corrosion protection to steel sleeve

Repair of reinforced concrete beam with **externally bonded steel plate** or fibre reinforced polymer (FRP) laminate is becoming both environmentally and economically preferable rather than replacement of deficient beam. The well known advantages of external reinforcement over other methods include; low cost, ease of maintenance and the ability to strengthen part of the structure while it is still in use. The disadvantage of this method, however, is the premature debonding of the externally bonded strips which is brittle and undesired mode of failure. It is also known that debonding of the externally bonded steel plates prevents the reinforced concrete (RC) beam from reaching its full strengthening capacity. The aim of this study was to increase the scientific understanding on the behaviour of damaged reinforced concrete beams strengthened and/or retrofitted for shear using vertical steel plate fixed with adhesive and steel connectors to eliminate or delay debonding failure. Four reinforced concrete beam specimens were prepared to investigate the effects of connectors in preventing or delaying premature debonding of shear strips to restore the capacities of fully damaged beams. Three damaged beams have been repaired and strengthened with steel plates and loaded monotonically up to the maximum load capacities in order to define load–deflection relationship. It is concluded that the repairing of severely shear-damaged RC beams with steel plates by using steel and adhesive connectors can fully restore the original shear capacities of the beams. The growing interest in FRP systems for strengthening and retrofitting can be attributed to many factors. Although the fibers and resins used in such systems are relatively expensive compared with traditional strengthening materials like concrete and steel, labor and equipment costs to install FRP systems are often lower. Fiber-reinforced polymer systems can also be used in areas with limited access, where traditional techniques would be very impractical-for example, a slab shielded by pipe and conduit. These systems can have lower life-cycle costs than conventional strengthening techniques because the FRP system is less prone to corrosion. Fiber-reinforced polymer (FRP) can serve as an alternative to the use of steel sheets. The use of FRP has a wide range of advantages and offers an alternative to the steel used in the strengthening process. s