CHAPTER 2 REPAIR OF CONCRETE STRUCTURES

2.1 CONCRETE FOR REPAIRS

Quality, lasting concrete for repair depends on the quality of the concrete mix, and careful attention to preparation and construction techniques. Both factors are important in making and placing conventional Portland cement concrete and the special types of repair concretes.

2.1.1 Portland Cement Concrete

(1) Important Properties

(a) Durability

Concrete of low permeability is important. The objective is to keep salt and water out of the concrete to protect the reinforcing steel from corroding, which result in the concrete spalling. The most important factors are a low water-to-cement ratio (0.40) in the mix, use of 25% Class F fly ash, and proper curing of the concrete when placed.

(b) Strength

35 MPa concrete is recommended for most repairs. Design of the mix and proper curing will determine the final strength.

(c) Workability

Concrete must be easily handled and placed. A dense concrete is important. This workability must be obtained without increasing the water content beyond the mix design. Enhanced workability is obtained by using 25% Class F fly ash. Admixtures conforming to ASTM C-494, *Standard Specification for Chemical Admixtures for Concrete*; Types A, D, E, F and G may be used, but not required.

(2) Preparation and Construction

To obtain quality concrete repairs, the following basics are mandatory for all jobs:

- Properly prepare the surface of the old concrete to be adjoined.
- Ensure a good bond between the old and new concrete.
- Do not add more water than specified for the concrete mix.
- Do not patch across active cracks or joints.
- Cure the concrete properly.

(a) Surface Preparation

All deteriorated concrete must be removed down to sound concrete. For some old concretes, exposed surfaces will soften after a few days of exposure; therefore, the surfaces should be checked closely before patching. Clean the old surface thoroughly just before placing new concrete.

Normally, when removing concrete hand tools or light duty hand-held power tools are used, particularly around the edges, to prevent damaging the remaining concrete. Do not use an impact hammer greater than 67 Newtons. Edges should be square, preferably cut by sawing to about a 25mm depth. Feathered edges must be absolutely avoided. Reinforcing bars should be exposed around their entire circumference by a 25mm clearance. Sandblasting surfaces removes loose concrete fragments and scaling rust from steel. Once the steel is clean, protect the coating with a slurry of portland cement grout or latex modified portland cement grout. This procedure improves the life of the repair.

(b) Bonding

Before patching, the existing base concrete should be kept damp (except for epoxy concrete repair) for several hours, preferably overnight. Remove free water or shiny wet areas by vacuuming or with oil-free compressed air. Then scrub a bonding agent into the surface with a stiff brush. The bonding agent can be portland cement mortar or a latex modified portland cement mortar. Do not use epoxy bonding agents. The mortars should be one-part cement and 1 part sand passing the No. 30 sieve, and have a consistency of thick cream. In all cases, it is important to place the repaired concrete immediately after placing the bonding agent.

(c) Curing

Concrete used in repairs must be protected and cured more carefully than usual. Curing should last for 7 days. The old concrete could absorb moisture too fast from the new concrete, or the temperature of the old concrete could be too low to permit early development of strength of a concrete patch. Shrinkage of the repair is the most common reason for delamination of the repair from the substrate.

Curing is important to allow strength development and minimize drying shrinkage. For portland cement mixes, water curing by ponding with water, fog misting, or covering with wet burlap are the best methods. If continuous moisture curing is not possible, then use two applications of a liquid curing compound. The repaired concrete should be kept wet or moist for a minimum of 7 days. When water evaporates from the concrete, drying shrinkage occurs. Shrinkage of a repair patch can cause the patch to crack or partially debond.

Curing for epoxy concrete is to provide the correct temperature for the epoxy resin to develop full strength. Epoxy resins that use 100% solids and no solvents do not shrink. Epoxy resins do, however, have a much greater coefficient of expansion than concrete. This often leads to failure in large patches and in environments that experience large temperature differentials between day and night. Epoxy can be mixed with sand (1 part epoxy: 7 parts sand) to minimize the difference in the thermal expansion characteristics.

(3) Guidelines

General guidelines for concrete used in repairs include:

(a) Use 35 MPa concrete.

(b) Use only Type I or II.

(c) Use a minimum of 360 kg to a maximum of 445 kg of cement per cubic meter in the concrete mix.

(d) Use a maximum water-cement ratio of 0.40 by weight.

(e) For most small volume repairs, use aggregate no larger than 20mm.

(f) Make sure the concrete cover over reinforcing steel is at least 100mm.

(g) Use epoxy-coated reinforcing steel, or epoxy coat exposed steel, in situations where steel is particularly susceptible to corrosion per ASTM A 934.

(h) Pay particular to the use of admixtures: DO NOT use an admixture containing chloride.

(i) Use a water-reducing admixture (ASTM C 494) when concrete is placed in area congested with reinforcing or in pours difficult to consolidate. This will decrease chance of voids and temptation to add water to the concrete.

Specific guidelines for underwater concrete include:

(a) Water-cement ratio must not exceed 0.40.

(b) Use a minimum of 445 kg to a maximum of 556 kg of cement per cubic meter.

(c) A water-reducing plasticizing admixture may be used to enhance placement and consolidation.

2.1.2 Special Types of Repair Concrete

(1) Fiber-Reinforced Concrete

Concrete and mortar containing fibers of steel, glass or polypropylene are sometimes used in repair work. Fiber reinforcement provides improved tensile strength, toughness and ductility to concrete. The fibers reinforce crack repair material by distributing tensile strains.

Fiber-reinforced shotcrete is good to use in marine repair work. In some applications, the fibers can replace steel mesh. Although steel fibers corrode near the surface, in the interior sections they are protected from corrosion by the high alkali of the cement paste. Steel fibers are usually 0.3mm to 5mm in diameter and 13 to 40mm long. The quantity of steel fibers used varies from 30 to 90 kg/m^2.

Glass fibers in concrete can lose strength over periods of time in a wet environment and are not recommended. Synthetic fibers reduce crack size due to plastic shrinkage, but should not be the primary reinforcement.

(2) Latex Modified Portland Cement Concrete

Latex modified portland cement concrete should not be confused with epoxy or polymer concrete. Latex modifiers improve the bond and tensile strength and reduce the permeability of portland cement concrete. Latex formulations of acrylics, styrene-butadiene, and polyvinyl acetates are available. The first two latexes are suitable for wet environments. Polyvinyl acetates should not be used in concrete for repairs exposed to water. Latex modified concrete is recommended for overhead and vertical repairs when placed in lifts less than 40mm.

Latex modified concrete, compared to epoxy concrete, is vapor permeable and lower in cost. Even though permeable to vapor, it is not very permeable to liquids. Repairs requiring thin sections, which will be exposed to the sun, should be breathable so that vapor pressure does not build up behind the patches or overlays. Vapor pressure can debond and cause a patch to spall off.

Recommended mix proportions for thin and medium thickness repairs are in **Table 3.2.1**.

Table 3.2.1
Recommended Mix Proportions

		Finished Thickness
	13mm to 32mm	32mm and up
Latex to cement ratio	0.10 to 0.20	0.10 to 0.20
Water to cement ratio	0.30 to 0.40	0.30 to 0.40
Fine aggregate to 1 part cement	3.0 to 3.5 parts	2.5 to 3.1 parts
Coarse aggregate to 1 part cement	2.5 to 3.1 parts	1.4 to 2.0 parts

Prepackaged latex modified mortars, or just the liquid latex modifiers, are commercially available. The mortar mixes can be converted to concrete by adding coarse aggregate. Latex modified concretes are sensitive to improper placement techniques, and noted failures have occurred. Carefully follow the manufacturers' recommendations.

(3) Epoxy Concrete

Epoxy concrete does not contain portland cement. It is a mixture of an epoxy resin and aggregate. Epoxy concrete is the most popular polymer concrete used because of its many physical properties that can be obtained, good adhesion to existing concrete, and availability. Other commercially available polymers are acrylics, polyesters, polyurethanes, and polyvinyl acetate.

Epoxy resin, when mixed with a curing agent, forms a thermosetting plastic that rapidly develops adhesive strength. Epoxy mixes are used for several purposes:

(a) To repair cracks by injecting the resin.
(b) To make epoxy mortar or concrete by mixing the resin with fine and coarse aggregate.

Because the cost is high and the material is inflexible in thick layers, epoxy concrete is used mainly for thin section repairs. Proprietary, prepackaged systems should be used. Generally, the aggregate is a silica sand with little or no material passing the No. 100 sieve (dust). The aggregate must be clean and absolutely dry. Not all epoxy resins will bond to damp or wet concrete, so check the manufacturer's specifications.

Epoxy mortars consist of 1 part epoxy resin to 4 to 7 parts sand by weight. The resin is usually made up of two components that are batched by volume and thoroughly mixed before combined with the aggregate. Epoxy concrete contains 1 part epoxy resin to 6 to 10 parts aggregate by weight. Equal parts of the fine and coarse aggregate are used. Epoxy concrete should be placed in layers no more than 50mm thick, so that excessive heat buildup does not occur. Generally, one should avoid using epoxy mortars because of their high coefficient of thermal expansion that leads to early disbondment of the repair.

2.2 PLANNING THE REPAIRS

The first steps in planning a repair will be to:

(a) Conduct an inspection to determine the course and scope of damage or deterioration.
(b) Determine operational or functional constraints on the facility because of the needed repair.
(c) Establish a priority for the repair.

Based on these factors, planning will then proceed to determine the repair technique to be used, method of placing the concrete, special skills required, and unique equipment requirements. If underwater repairs are involved, give special attention to planning for the unique requirements, particularly involving safety.

2.2.1 Seismic Impact of Repairs

Any concrete repair that alters significantly the mass of a structure may increase seismic vulnerability. A structural analysis by a qualified structural engineer is required to ensure earthquake safety is not compromised by the repair.

2.2.2 Special Skill Requirements

Most concrete repair techniques and methods of placement require:

(a) Normal skills associated with concrete construction
(b) Building forms
(c) Setting reinforcing steel
(d) Mixing concrete
(e) Vibration
(f) Finishing
(g) Curing

Special skills and experience are required for placing shotcrete and for handling and placing concrete for underwater repairs. Shotcrete, in particular, requires a skilled nozzle operator to ensure quality results. Use experienced personnel when using epoxy components, epoxy injection, and sealing cracks and joints require experienced personnel.

Underwater repairs, depending on the complexity of the job, require special skills beyond placing the concrete, such as how to remove marine growth, underwater jetting and blasting, how to use underwater tools for cutting and drilling, and how to use certain materials for coating and caulking underwater.

2.2.3 Special Equipment Requirements

Unique equipment requirements exist on many jobs and often dictate the personnel skill requirements. Applying shotcrete requires a complete set of special equipment, as does pumped concrete. See the outlines in concrete placement methods **2.2.4.4 – Shotcrete (Gunite)** and **2.2.4.6 – Pumped Concrete**. Equipment for underwater repairs, however, may include:

(a) High-pressure water blaster
(b) Hydraulic grinders with barnacle buster attachment
(c) Hydraulic drill with bits
(d) Hydraulic power unit
(e) Hydraulic chain saw
(f) Concrete pump with hosting
(g) Jetting pump and hose
(h) Rigging equipment
(i) Float stage and scaffolding
(j) Clamping template for cutting piles
(k) Special clamping equipment
(l) Cane

Above water repairs require conventional equipment for surface abrasive blasting and air-jet cleaning, form construction, and mixing, placing, and finishing concrete.

2.2.4 Methods of Placing Concrete and Mortars

The seven most common methods for the placing concrete and mortars in repair are listed and described in **Table 3.2.2**.

Table 3.2.2
Placement of Concrete and Mortar

Section No.	Description
2.2.4.1	Hand Placement
2.2.4.2	Dry Pack
2.2.4.3	Cast-in-Place
2.2.4.4	Shotcrete
2.2.4.5	Tremie
2.2.4.6	Pumped
2.2.4.7	Prepacked

2.2.4.1 Hand Placement

Description: Troweling a mortar into shallow, relatively small areas requiring patching.

Uses: Patching surface areas small enough for hand work and shallow cavities not suitable for dry pack.

Materials and Curing: Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05% per ASTM C 157 modified and proper curing.

Preparation:

(a) Remove all loose and unsound old concrete.
(b) If reinforcing steel is exposed, ensure 25mm clearance all around and wire brush steel bar.
(c) Thoroughly clean repair area immediately before applying bonding coat.

Bonding: Vigorously brush coat repair area with sand-cement slurry: 1 part Type II cement; 1 part sand; and enough water or latex for a consistency of thick cream.

Mortar Mix: The proportions of the mix depend on the overall size and depth of the repair, accessibility, and whether the repair is large enough to require coarse aggregate. A typical cement-to-sand ratio is 1:2.5 to 1:3. The water-cement ratio should be no greater than 0.40.

Placement:
If repair is in direct sun or wind, build shade/wind break and leave in place during curing period.

Wet the surface of repair area for 24 hours. Do not leave any free water.

Brush coat repair area surface with cement slurry.

Immediately trowel on mortar mixture; completely fill voids and dense placement.

Curing: Use wet burlap for 7 days or use a curing compound.

2.2.4.2 Dry Pack

Description: Packing a stiff mortar into a confined hole or cavity.

Uses: Filling narrow slots cut during repair of dormant cracks, and filling cavities/small holes in cross-sectional area that are relatively deep.

Restrictions/Cautions:

Use for holes no larger than 225cm^2 in cross-sectional area.

The depth of the cavity should be equal to or greater than the smallest surface dimension.

DO NOT use for:

Shallow depressions where lateral restraint is not obtained.

Filling behind exposed reinforcing steel.

Holes that extend through the structure.

Maintain water content of mortar carefully.

Preparation:

(a) Thoroughly clean cavity.

(b) Remove all loose or cracked aggregate.

(c) Allow to dry at least 2 days before packing.

Bonding: Vigorously brush inside of cavity with a cement slurry: 1 part Type II portland cement; 1 part clean, dry fine sand; and enough water for a consistency of thick cream.

Dry Pack Mix: 1 part cement, 2.5 parts sand passing No. 16 sieve, only enough water so mortar sticks together when squeezed with slight pressure. Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05% and proper curing.

Placement:
Place and compact in layers 10mm thick.

Scratch surface of each layer for good bond of next layer.

Fully compact each layer over entire surface with hardwood stick and hammer.

If a layer becomes rubbery, delay about 30 minutes for mortar to stiffen and then compact.

Finish surface with flat side of stick. Steel tools and water are not recommended.

Patch is usually darker than surrounding concrete. For appearance, use white cement in mix for outside layers.

Curing: Use wet burlap for 7 days or use a curing compound.

2.2.4.3 Cast-in-Place Concrete

Description: Placing conventional concrete mix with a concrete mixer truck, chute, bucket, wheel barrows, concrete carts, or shovels.

Uses: Use in all repairs where the quantity of concrete required is too large for hand placement. Control of the concrete mix and strength of the completed repair is much better than with any other methods. Should be used when:

The hole/cavity extends through the concrete section.

The cavity in un-reinforced concrete is larger than 900cm^2 in area and over 100mm deep.

The cavity in reinforced concrete is over 450cm^2 in area and deeper than the reinforcing steel.

Major concerns are quality of the mix, good bonding to old surfaces, keeping a low water-cement ratio, and proper curing.

Restrictions/Cautions:
Concrete settles after placement, therefore, proper consolidation is essential to prevent cracking

Preparation:

Delay several days after demolition of old, deteriorated concrete to confirm the soundness of remaining concrete and excavated surfaces.

Check forms for tightness and stability.

Ensure that old surfaces are cleaned before repairs begin.

Ensure that reinforcing steel is cleaned of rust and scale and exposed at least 25mm all around.

Bonding: Usually, a sand-cement grout will suffice.

Concrete Mix: Give particular attention to:

Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05% and proper curing.

Consider moisture in aggregate when calculating quantity of water.

Use a water-reducing plasticizer admixture wherever placement and consolidation are restricted, or slumps greater than 100mm are required.

Placement: The equipment used depends on size of the pour, accessibility and working space, and availability of equipment. Concerns are placement speed and consolidation. In confined, hard to access locations, aid consolidation by using admixtures and mechanical vibrators and tampers. Elimination of voids and honeycombing is very important.

Curing: The most effective moist-curing method is using wet burlap for 7 days. Do not cut corners or try to economize. This is critical.

2.2.4.4 Shotcrete (Gunite)

Description: Sprayed concrete applied directly by an air jet gun. Equipment includes a mechanical feeder, mixer, and compressor. If using a dry-mix, water is added at the nozzle.

Uses: Shotcrete is relatively economical where deterioration is shallow and area is large and irregular in shape. Shotcrete requires no form work and thin patches can be made that have a high strength, is an efficient method for vertical and overhead surfaces, and is also used for encasing steel and timber piling.

Restrictions/Cautions:

(a) Must have enough repair work to justify the cost of equipment.
(b) Normally restricted to a depth of 100mm per lift.
(c) Can have a high porosity if improperly applied.
(d) Drying shrinkage rate and thermal expansion can be different than concrete being repaired.
(e) Can have wide variation in application/composition. Quality depends almost entirely on the operator's skill.

Preparation:
Thoroughly remove all defective and loose concrete.

Clean all rust off exposed reinforcing steel.

Roughen all smooth surfaces.

Wire brush or abrasive blast exposed concrete surfaces to be covered.

Bonding: A bonding agent is not required.

Shotcrete Mix:
Cement-to-aggregate maximum ratio 1 to 3.5. This will result in an in-place mix of about 1 to 2.5 after rebound.

Minimize the water-to-cement ratio.

May use a non-chloride type admixture for rapid setting.

Fiber reinforcing may help minimize shrinkage cracks.

Placement:
Install reinforcing wire fabric to ensure the laps project no more than 20mm from surface being covered.

Usually start work at bottom and move up; may follow the tide down.

Fix the profile.

Fill out the area to the original face.

Apply each coat at least 50mm thick. The final coat should be at least 13mm thick.

Ensure that rebound material is not trapped in corners or edges.

Ensure reinforcing bars are properly encased. Curing: Use wet burlap for 7 days or use a curing compound.

2.2.4.5 Tremie Concrete

Description: The primary method of placing concrete underwater when gravity flow is adequate. The tremie, a steel tube or rigid hose, runs from a hopper for filling its upper end into the form and is moved vertically as the concrete is placed.

Uses: All underwater pours at easily accessible locations that require a quantity of concrete to warrant the equipment set-up.

Restrictions/Cautions:
Do not use an aluminum alloy tremie to avoid reaction with the concrete mix.

Location, and space in the form, must be accessible for positioning and moving the tremie vertically and horizontally.

Slump of concrete mix must be carefully controlled within 150 to 200mm. Too wet a mix may segregate and too dry a mix will not flow properly in the form.

If practicable, place concrete when water temperature is above 10ºC.

Preparation: Prepare the repair location in the same manner as cast-in-place concrete. Also, ensure that the tremie pipe is heavy enough to be negatively buoyant, and that the joints in the tremie are well gasketed and sealed. The diameter of the tremie should be at least eight times the largest size aggregate used.

Bonding: Not usually required.

Concrete Mix:
A typical mix proportion for cement, sand, aggregate, is 1:1.7:2.4 by weight with a water-cement ratio of 0.45.

Use air-entraining and water-reducing plasticizer admixtures as required for the underwater repair. Admixtures conforming to ASTM C 494 are acceptable.

Use a mineral admixture of pozzolan in thick sections to control heat buildup. This will reduce amount of cement in the mix.

Placement:

Once the tremie pipe is filled, carefully lift the bottom end from the bottom of the form not more than 150mm to start the flow of concrete.

Placement should be as continuous as possible. The end of the tremie must remain embedded in the concrete by as much as 1 meter.

If the tremie is lifted out and the seal is lost, remove it, reseal, and start again.

Move the tremie horizontally while concrete is flowing

Curing: Not applicable.

2.2.4.6 Pumped Concrete

Description: Placing concrete through a pipe or hose using a concrete pump with attached hopper.

Uses: Often used for placement above water. May be used for underwater placement in locations with limited accessibility, where the tremie method is not efficient. The advantages for underwater repairs include:

(a) High quality concrete can be pumped. The mixture must be both workable and cohesive without blocking the pump.
(b) Workable mixtures containing relatively small coarse aggregate particles provide an easily placed and dense concrete.
(c) Concrete can be transferred from a barge directly into the forms.
(d) Pumped concrete fills forms from the bottom upwards, displacing the seawater as more concrete is added.

Restrictions/Cautions: (see **2.2.4.5 - Tremie Concrete**). Also:

(a) Carefully control slump of concrete to 150 to 200mm.
(b) Avoid inclines in the pipe whenever possible.
(c) If delays are encountered, move concrete about 1 meter every 5 minutes. If concrete becomes stiff due to a long delay, discard the mix. Do not retemper by adding water.
(d) Use rubber hose only for discharge end and short pumping distances.

Preparation: Prepare the repair location in the same manner as cast-in-place concrete. Also, carefully plan location of pump and routing of pipeline to minimize moves. The pipeline should be horizontal or vertical whenever possible.

Bonding: Not usually required underwater; for above water, (see **2.2.4.3 - Cast-in-Place Concrete**).

Concrete Mix:

A typical mix proportion is 1:3:1 by weight with a water-cement ratio of 0.45. Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05% and proper curing.

Use rounded coarse (10mm minimum) aggregate when possible.

Sand should have a higher proportion of finer sizes.

Avoid porous aggregates such as expanded clay, foamed slag, and pumice.

Placement: The principles of placing tremie concrete apply. Also:

(a) Before filling hopper, lubricate the pipe with water, then a cement-water slurry.
(b) Take all precautions to avoid separation of the mix.
(c) Always keep discharge buried in the fresh concrete.
(d) Control discharge to keep lateral flow of concrete within 0.7 to 1 meter.

Curing: Not applicable underwater. If above water, use wet burlap for 7 days or use a curing compound.

2.2.4.7 Prepacked Concrete

Description: Placing coarse aggregate in the form and filling the voids with grout. It is used on large repair jobs, and usually grout is pumped through grout pipes from the bottom up.

Uses: Prepacked concrete is used where placement of cast-in-place concrete is not practical. It is also used underwater where the tremie or pumped methods are not practical due to inaccessibility. It is suitable for vertical surface repairs that have a minimum thickness of 80 to 100mm.

Restrictions/Cautions:

(a) Prior to injecting grout, be sure fines have not collected in the coarse aggregate. Fines in the aggregate can impede the flow of grout and create voids.

(b) Protect the aggregate from contamination after it is placed.

Preparation: Prepare the repair location in the same manner as for cast-in-place concrete. Also, ensure grout pipes are well installed and fixed to forms or reinforcing. A vent must be provided at the highest point.

Bonding: Not required.

Concrete Mix: Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05% and proper curing. Coarse aggregate is sized to the size of repair. The sand-cement grout is usually richer than a 1:1 mix. Admixtures are used as required by the circumstances. Usually, a chemical admixture is used as an intrusion aid for the grout. This suspends solids and provides fluidity. An air-entraining admixture is used to obtain about 9% air in the grout.

Placement: Pump the grout soon after the aggregate is placed. Ensure that all voids are filled and that segregation in layers does not take place. When forms are filled, apply a closing pressure of about 0.1MPa to drive out air and water through the vent.

Curing: Use wet burlap for 7 days or a curing compound.

2.3 REPAIR PROCEDURES

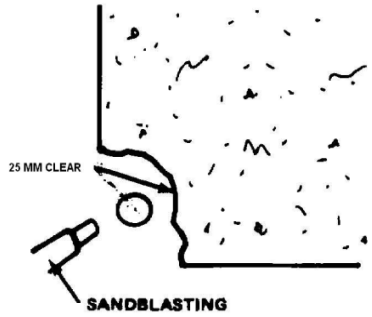
Figure 3.2.1 summarizes the general steps taken in concrete repairs. The more standard repair procedures and techniques are listed in **Table 3.2.3**. These repair techniques should be used in conjunction with the guidelines for concrete in **2.1.1(3) - Guidelines** and descriptions of methods of placement in **2.2.4 - Methods of Placing Concrete and Mortar** and the preservation measures outlined in **2.1.1(2) – Preparation and Construction**.

Table 3.2.3
Repair Techniques for Concrete Structures

Section No.	Description
2.3.1	Repair Small to Medium Cracks by Epoxy Grout Injection
2.3.2	Major Joint and Crack Repair
2.3.3	Repairs to Concrete Seawall
2.3.4	Miscellaneous Repairs to Concrete Piles
2.3.5	Concrete Jacketing of Concrete Piles
2.3.6	Combination Repair: Cast-in-Place Concrete and Epoxy Grout Injection
2.3.7	Repair Using Polymer Concrete
2.3.8	Typical Concrete Wall Repair

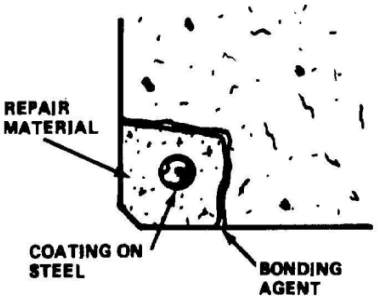
Figure 3.2.1
General Steps to Concrete Repair

REPAIR CONCRETE STRUCTURES



SURFACE PREPARATION

- Remove all deteriorated and loose concrete.
- Expose all uncovered reinforcing steel at least 25 mm clear all around.
- Sandblast/waterblast/wire brush concrete and steel as necessary to clean thoroughly.
- Keep concrete surface wet for several hours.
- Coat reinforcing steel with cement slurry.
- Just before placing repair material, apply cement slurry to old concrete.

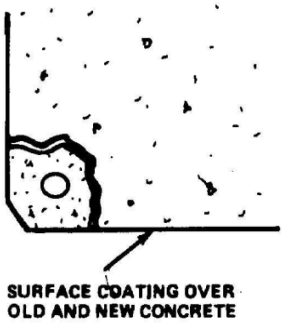


PLACE REPAIR MATERIAL

- Depending on size and type of repair, material may be a mortar or concrete, Portland cement concrete, or latex modified concrete.
- Above water placement: hand placement, dry pack, cast-in-place, or shotcrete.
- Underwater placement: tremie, pumped, or prepacked.

CURING

- Use most efficient moist curing for at least 7 days if practicable. Wet burlap is the best.
- Use two curing applications of compound. Wet burlap is not practical.



SURFACE COATING

- Determine if surface coating is required.
- Prepare surface by air/abrasive blasting.
- Apply coating applicable to location, exposure, and use of concrete.

2.3.1 Repair Small to Medium Cracks by Epoxy Grout Injection

Problem: Cracks caused by weathering, deterioration, or reinforcing steel corrosion allow water to penetrate the structure.

Description of Repairs: Filling and sealing small to medium cracks by injecting a low-viscosity urethane and sealing the outside with an epoxy paste. Routing and cleaning of cracks are performed with conventional hand and power tools. Injection for smaller jobs can be done with a hand-operated caulking gun. Large jobs are usually done with special equipment.

Materials:

Low-Viscosity Epoxy

Select a urethane suitable for wet surfaces and underwater application that is compatible with crack volume, crack movement, and equipment to be used for injection.

Sealing Epoxy

Use a quick-setting epoxy paste adhesive suitable for underwater application that has good bonding characteristics for concrete being repaired.

Preparation:

Rout out cracks to remove all deteriorated and loose concrete and aggregate. Clean area to receive sealing epoxy with wire brush, high-pressure water jet, or sandblasting.

Drill injection holes every 150mm along the length of the crack for larger jobs with deep cracks. Install a tube or one-way polyethylene valve in the holes as injection ports.

Repair small and shallow cracks with a hand gun, injection ports may be openings left in the sealing epoxy every 150mm.

Repair Procedures: (see **Figure 3.2.1**)

(a) Perform repairs when ambient/water temperature is at least 10ºC.

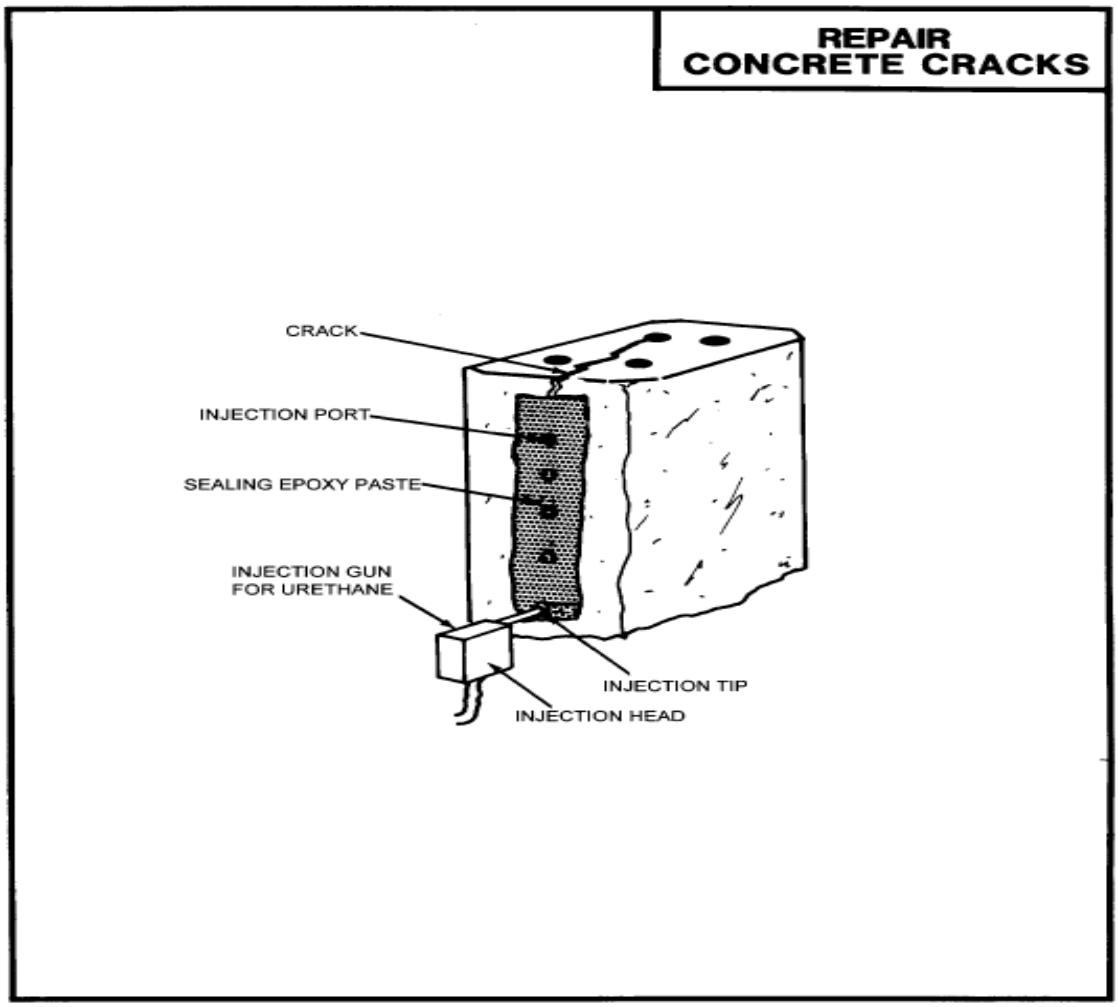
(b) Seal the outside surface of the crack with the epoxy paste, carefully sealing around the injection ports.

(c) After the surface seal has set, inject the urethane grout, starting at the bottom port for a vertical crack. Continue injection until grout shows in the next port then continue up the crack until the entire crack is filled.

(d) Plug the port holes with the sealing epoxy paste.

Application: Epoxy grout injection does not stop spalling due to rebar corrosion. This method is most useful in making structural repairs of cracked concrete that is static only. Cured epoxy is rigid, therefore, epoxy injection is not recommended where there is any additional cracking or movement of concrete anticipated.

Figure 3.2.2
Typical Crack Repair with Epoxy Grout Injection



2.3.2 Major Joint And Crack Repair

Problem: Large cracks or construction joints allow water to penetrate in or leak through the structure.

Description of Repairs: Sealing of cracks and construction joints to prevent leakage. This repair is performed after grouting of cracks is completed. Example given is for drainage and discharge tunnels, and should be modified for less demanding applications. Repair requires conventional hand and power tools and a heating bucket.

Materials:

Sealant No. 1 -Two-component epoxy coating system.

Sealant No. 2 - Non-meltable mastic of refined asphalts, resins, and plasticized compounds reinforced with non-asbestos fiber. Resistant to seawater, salts, acids, and dilute alkalis.

Primer for Sealant No. 2 - Asphaltic liquid primer compatible with sealant.

Sealant No. 3 -Two-component, moisture insensitive epoxy resin mortar; 1 part mixed epoxy to 7 parts aggregate by volume.

Copper Plate - 16 gauge conforming to ASTM B-370-92, Copper Sheet and Strip for Building Construction.

Preparation: Chip out and saw cut concrete as shown on **Figure 3.2.3** Clean all surfaces to receive sealants of all loose and deteriorated concrete and marine growth by chipping, scraping, and sandblasting. Provide clean, sound bond surfaces. Prepare surfaces to meet sealant manufacturer's requirements.

Repair Procedures:

Perform repairs when ambient or water temperature is at least 10ºC, depending on whether structure is exposed or submerged.

Apply Sealant No. 1 with a brush to cleaned surfaces.

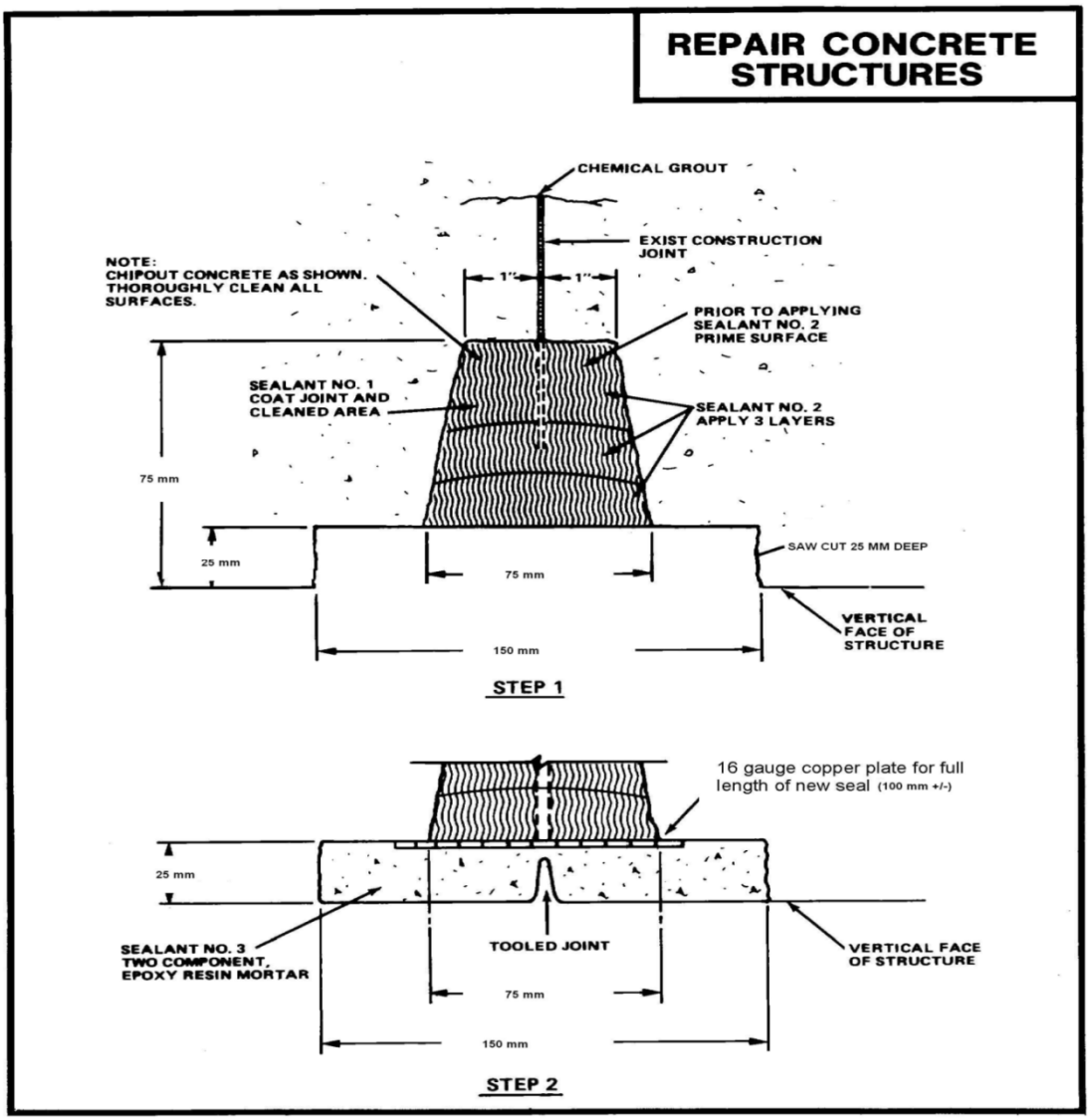
Prime all surfaces to receive sealant No. 2 with primer and let dry.

Apply three layers of Sealant No. 2 (heat sealant) as shown in **Figure 3.2.3** Pound each layer during and after cooling.

Fasten copper strip in place for placement of sealant No. 3. Do not use fasteners of dissimilar metal.

Apply sealant No. 3 as shown and tool the joint as required. Curing: Cure sealants per manufacturer's specifications.

Figure 3.2.3
Major Joint and Crack Repair



2.3.3 Repairs to Concrete Seawall

Problem: Sulphate attack has caused limited disintegration of the seawall within the tidal zone.

Description of Repairs: Contact between the existing concrete and seawater is eliminated by adding a repair layer of sulphate-resisting concrete. Old concrete is replaced only to the extent necessary to repair damage and to isolate the old concrete from the seawater reaction. (see **Figure 3.2.4**).

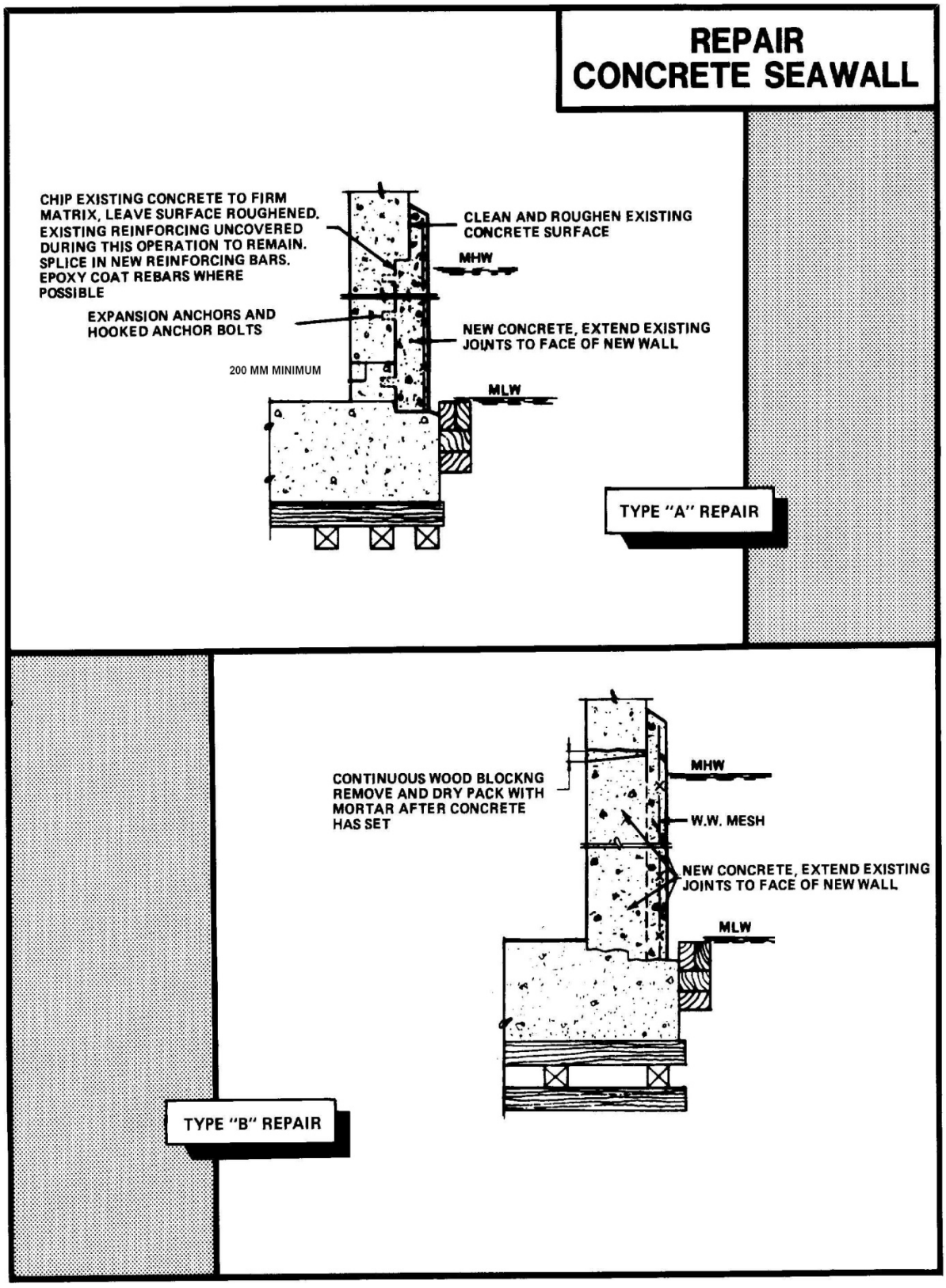
Repair procedures are as described in **2.2.4.3 – Cast-in-Place Concrete** or **2.2.4.5 – Tremie Concrete** if required.

(a) Type "A" Repair: In this case, a minimum of 200mm of the existing wall thickness must be sound concrete. A facia of new concrete is added, well anchored to the existing wall.

(b) Type "B" Repair: In this case, a section of the wall is replaced, through its entire width, which includes the facia on the water side. This type of repair uses the dry pack method (see **2.2.4.3 - Cast-in-Place Concrete**) to close the gap between the top of the new concrete and the existing concrete. (see **2.3.8 – Typical Concrete Wall Repair** and **Figure 3.2.7**).

Application: These types of repair are applicable where the extent of the deterioration is limited and is not threatening to the entire height of the seawall, and a partial repair from foundation to above high water will solve the problem. The wall foundation must be in good condition. Extensive deterioration along a length of the seawall would call for a complete demolition and replacement of a section of wall.

Figure 3.2.4
Repairs to Concrete Seawall



2.3.4 Miscellaneous Repairs To Concrete Piles

Problem: Concrete pile is worn from abrasion at waterline; has spalled areas above the tidal zone; or is badly cracked.

Description of Repairs: In all cases, the repair area must be cleaned thoroughly of marine growth. All loose and deteriorated concrete must be removed. If reinforcing steel is exposed, it must be cleaned of all rust and scale and exposed at least 25mm clear all around.

Figure 3.2.6 illustrates:

Concrete Jacketing:

Wrap pile with spiral reinforcing length of jacket.

Place form around pile (metal, fiberglass, fiber, or other material).

Fill form with 35 MPa concrete, either pumped or placed with a tremie (see **2.2.4.5 – Tremie Concrete** and **2.2.4.6 – Pumped Concrete**).

Form may be removed or left in place.

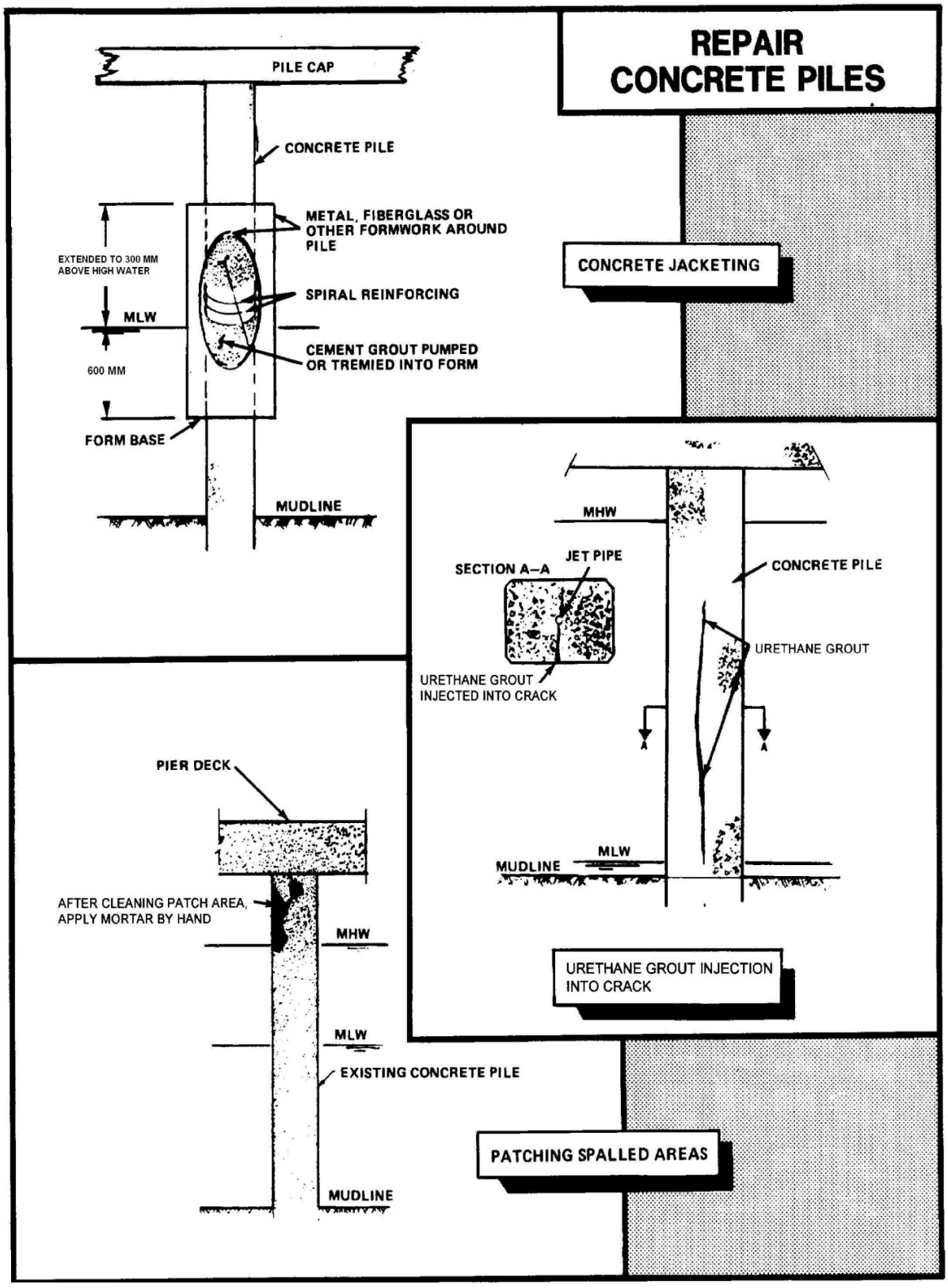
Patch Spalled Areas: Repair the spalled areas by hand (see **2.2.4.1 - Hand Placement**) or form and pour.

Fill Crack with Urethane Grout:

Applications: The concrete jacketing repair is a partial restoration when the pile is worn / deteriorated only in the tidal zone and sound below and above water (see **2.3.5 – Concrete Jacketing of Concrete Piles)** for more complete concrete pile restoration.

The spall patching and crack filling repairs are relatively minor, inexpensive techniques to protect the reinforcing steel from seawater. The effectiveness of the spall patches depend on the bond that is obtained with the old concrete and the corrosion activity on-going in the rebar in the substrate.

Figure 3.2.5
Miscellaneous Repairs to Concrete Piles



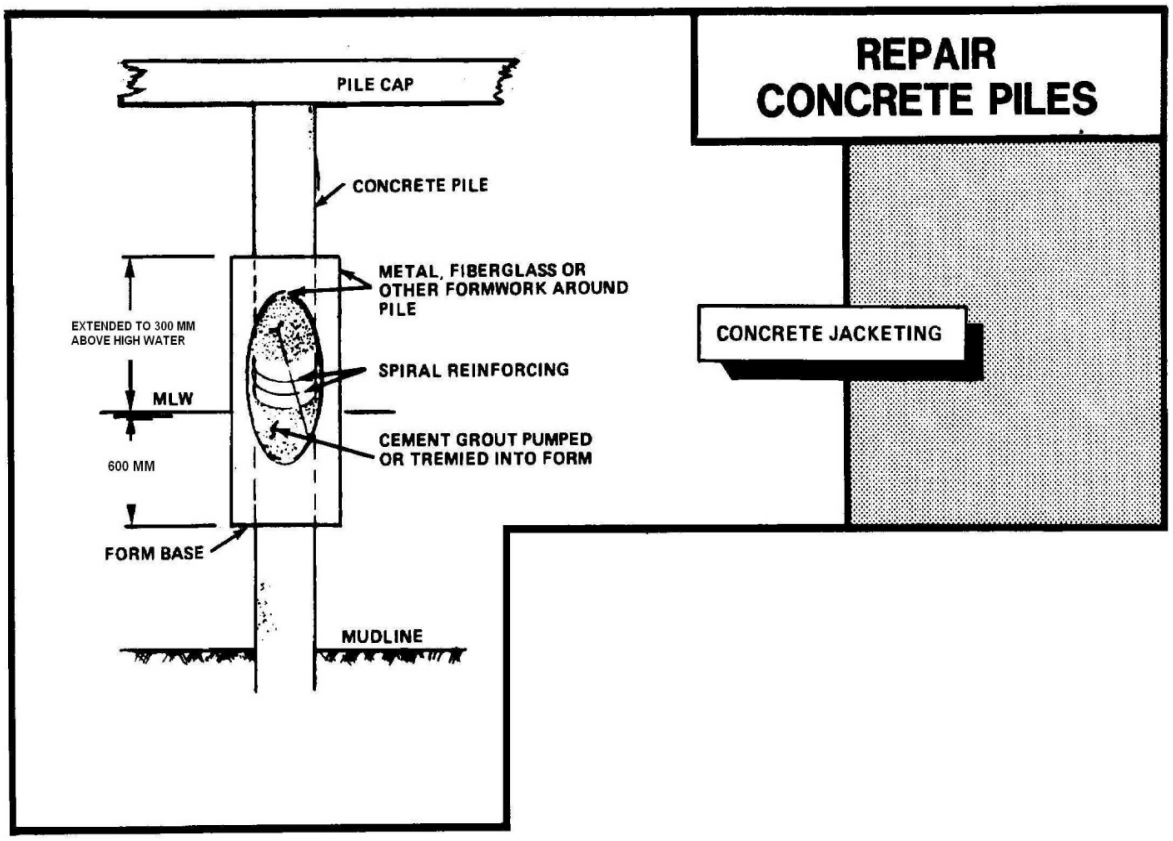
2.3.5 Concrete Jacketing of Concrete Piles

Problem: Precast concrete piles have major deterioration due to sulphate attack. Deterioration extends to the mud line.

Description of Repairs: (see **Figure 3.2.6**) in this example, the original pile section was 400mm square. The concrete jacket, as shown, is 760mm in diameter. A timber encasement, with galvanized steel bands, is used in the tidal zone. A corrugated sheet metal form is used down below the mud line. (see **2.2.4.6 – Pumped Concrete**) for the pumped concrete method of injecting the new concrete. The top portion of the pile encased with hand-placed grout (**Section 2.2.4.1 - Hand Placement**).

Applications: This method is applicable when the remaining section of pile is structurally sound and judged to be worth saving. Jacketing versus complete replacement is an economic decision.

Figure 3.2.6
Jacketing Concrete Piles



2.3.6 Combination Repair Cast-in-Place Concrete and Epoxy Grout Injection

Problem: Concrete footings with many cracks with some spalling, scaling, and delaminated areas.

Description of Repairs: Repair footings using a combination of restoration with portland cement concrete, and filling cracks and delaminated concrete by injecting urethane resin. Tools required: air hammer, conventional hand and power tools, and injection gun or pump for urethane.

Materials:
Portland cement concrete.

Urethane resin for injection.

Preparation:

Remove all unsound concrete.

Wire brush or sandblast all surfaces to receive bonding agent and clean thoroughly.

Thoroughly clean and coat any exposed reinforcing steel with cement slurry.

Sound concrete with metal rod to determine extent of delamination and outline the areas.

After restoration of concrete is completed, rout and clean racks to be filled with injected urethane.

Repair Procedures:
Place, cure, and finish concrete repairs to restore structure to its original shape.

Select epoxy injection points and drill holes if required. Insert injection tubes or valves if required.

Fill cracks 0.08mm wide and larger, and delaminated areas, by injecting the low-viscosity urethane. For jobs with large areas of delamination and deep cracks, pressures up to 6.9 MPa may be required.

Plug the injection holes with epoxy paste.

2.3.7 Repair Using Polymer Concrete

Problem: Concrete roof deck spalling due to corrosion of reinforcing steel and cracks around support columns.

Description of Repairs: Patch spalled areas with PCC mortar. Coat roof deck. Reseal joints with polyurethane joint sealer. Requires conventional hand and power tools. May not be suitable for vehicle traffic areas.

Materials: Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05% and proper curing.

Latex modified portland cement.

Polyurethane joint sealant that meets ASTM C 920, Standard Specification for Elastomeric Joint Sealant.

Preparation:
Remove all unsound concrete in the spalled areas. Expose reinforcing steel all around.

Clean the exposed reinforcing steel and entire deck area by sandblasting.

Thoroughly clean areas to receive new material immediately prior to placement.

Repair Procedures:
Patch spalled areas with Latex Modified Concrete.

Seal entire deck area with neat polyester resin.

Remove all joint sealant and reseal joints.

Limitations: The corrosion processes will continue to cause cracks and delaminations.

2.3.8 Typical Concrete Wall Repair

Problem: Holes or severely deteriorated areas require replacing the wall section with cast-in-place concrete.

Description of Repairs: Defective section of wall is removed, surfaces and reinforcing steel are prepared, form work built, and wall is restored with cast-in-place concrete. Repair may be an internal section, as shown in **Figure 3.2.7**, or may be the top of a wall or pier deck curb requiring an open-top form. Equipment used includes: sandblasting and air-water jet cleaning equipment, concrete saw, air chipping hammer, air-suction gun for mortar if available, power vibrator and tamper, and conventional concrete placement tools.

Materials: Portland cement concrete with maximum shrinkage of 0.05%.

Preparation:
Use air hammer or hand tools to remove all unsound concrete to the limits of the repair area.

Cut the top edge of the hole at the face of the structure to a fairly horizontal line (see **Figure 3.2.7**). Where a hole passes through a structural element, it may be necessary to fill the hole from both sides. In this case the slope of the top of the cut should be modified accordingly.

Cut the bottom and sides of the hole sharp and square with the face of the wall. When the hole goes entirely through the concrete section, spalling and feather edges can be avoided by having chippers work from both faces. All interior corners should be rounded to a minimum radius of 25mm.

Do not leave reinforcing steel partially embedded. Ensure there is a minimum of a 25mm clearance around each exposed bar. Remove unnecessary tie wires.

Clean all surfaces to bond to new concrete with wet sandblasting and air-water jet. Clean exposed steel with abrasive blasting or wire brushing.

Repair Procedures:

Construct front forms for patches more than 450mm high in horizontal sections so the concrete can be placed in lifts not more than 300mm high. The back form can be built in one piece. Sections to be set as concreting progresses should be fitted before concrete placement is started. (see **Figure 3.2.7**.)

For irregularly shaped holes, chimneys (accesses) may be required at more than one level. In some cases, such as when beam connections are involved, a chimney may be needed on both sides of the wall or beam. In all cases, the chimney should extend the full width of the hole.

Ensure forms are constructed so that pressure can be applied to the chimney cap at the proper time.

Ensure forms are mortar tight at all joints between adjacent sections, between the forms and concrete, and at the tie-bolt holes to prevent the loss of mortar when pressure is applied to the concrete during the final states of placement. Place twisted or stranded caulking cotton, folded canvas strips, or similar material between the joints as the forms are built.

Keep concrete surfaces wet for several hours, preferably overnight, before placement.

Before placing the front section of form for each lift, coat the surface of the old concrete with a 3mm thick layer of mortar. This mortar should have the same sand and cement content and the same water-cement ratio as the new concrete. The surface should be damp, but not wet. The mortar can be applied with an air-suction gun, brush, or rubbed into the surface by hand. (Be sure worker is wearing rubber gloves if doing by hand.)

Place concrete immediately. Ensure thorough compaction by vibration or pressure grouting to 0.1 MPa.

Remove forms the day after placement. If chimneys were used, remove the remaining projections the second day working up from the bottom.

Thoroughly moist-cure the new concrete. Finish with a wood float. Tool or chamfer edges and corners as required. Avoid using water in finishing.

Figure 3.2.7
Typical Concrete Wall Repair

