Chapter 7
Maintenance of Concrete

7-1. General

Preventing concrete deterioration is much easier and more economical than repairing deteriorated concrete. Preventing concrete deterioration should actually begin with the selection of proper materials, mixture proportions, and placement and curing procedures. If additional protection against deterioration is required, the need should be recognized and provided for during design of the structure. Of course, all potential hazards to concrete cannot always be predicted, and some well-engineered techniques and procedures may prove unsuccessful. Thus, there is generally a need for follow-up maintenance action. The primary types of maintenance for concrete include timely repair of cracks and spalls, cleaning of concrete to remove unsightly material, surface protection, and joint restoration. Materials and procedures for repair of concrete cracking and spalling have been described in previous chapters. Materials and procedures appropriate for cleaning and protecting concrete surfaces and joint maintenance are described in the following.

7-2. Cleaning

Stains seldom affect the service life of a structure, although they are often unsightly, especially on architectural concrete finishes. Some of the more common stains are iron rust, oil, grease, dirt, mildew, asphalt, efflorescence, soot, and graffiti. Stains often penetrate the exposed surface because concrete is porous and absorbent. Therefore, stains should be removed as soon as possible to prevent deeper migration into the concrete. Also, stains tend to bind more tightly to the concrete with time, and some undergo chemical changes that make removal more difficult. Almost all stains can be removed if the type of stain can be identified and the correct removal method is selected (REMR Technical Note CS-MR-4.4 (USAEWES 1985d)).

a. Identification. The first step in the removal process is to identify the stain and then select a cleaning agent and method accordingly. If the stain is impossible to identify, potential cleaning materials should be tested in an inconspicuous area in the following order: organic solvents, oxidizing bleaches, reducing bleaches, and acids.

b. Stain removal. Stains can be removed with several methods including brushing and washing, steam cleaning, water blasting, abrasive blasting, flame cleaning, mechanical cleaning, and chemical cleaning (*Concrete Repair Digest* 1993). Since there is usually more than one method that can be used to remove a given stain, the advantages and limitations of each potential method should be considered in making a final selection.

(1) Removal methods.

(a) Water washing. A fine mist spray is recommended, as excessive water pressure can drive the stain farther into the concrete. Washing should be done from the top of the structure down. If the water alone is not cleaning the concrete, it can be used in conjunction with the following in the order listed: a soft brush, a mild soap, a stronger soap, ammonia, or vinegar.

(b) Steam cleaning. Steam is generally good for removing dirt and chewing gum; however, in most applications it is relatively expensive.

(c) Water blasting. Water blasting removes less surface material than sandblasting because no abrasive is used; however, a test section to determine the effect of this method on surface texture is recommended.

(d) Abrasive blasting. Abrasive blasting tends to remove some of the concrete resulting in a nonuniform surface. The nozzle should be held farther from the surface than normal in any kind of blasting to minimize abrasion.

(e) Flame cleaning. Flame cleaning will remove organic materials that do not respond to solvents. However, this method can cause scaling of the concrete surface and may produce objectionable fumes.

(f) Mechanical cleaning. Power tools (grinders, buffers, chisels, brushes) may be required to remove the more stubborn stains from concrete. These tools can damage thin sections or remove more concrete than is desirable. Chiselling or grinding can be an effective cleaning method provided a roughened or uneven surface is acceptable.

(g) Chemical cleaning. Organic solvents can usually be used with little dilution. Inorganic solvents such as ammonium hydroxide, sodium hypochlorite, and hydrogen peroxide can be purchased in ready-mixed solutions; other organic solvents can be purchased as solids and then mixed with water according to manufacturer's directions. It may be desirable to mix the solvent to be used with an inert fine powder to form a poultice which is then troweled over the stain (REMR Technical Note CS-MR-4.4 (USAEWES 1985d)). Chemical cleaning is often the best way to remove stains because most chemicals do not alter the surface texture of the concrete nor do they require the equipment needed by mechanical methods. However, there are safety considerations: many chemicals are mild and safe if used with care, while others are toxic, flammable, or corrosive to concrete. Manufacturer's directions and recommendations for the protection of occupational health and safety should be carefully followed. Material Safety Data Sheets (MSDS) should be obtained from the manufacturers of such materials. In cases where the effects of a chemical substance on occupational health and safety are unknown, chemical substances should be treated as potentially hazardous or toxic materials.

(2) Removing specific stains. Detailed procedures for removing a variety of stains are described in REMR Technical Notes CS-MR-4.3 and 4.4 (USAEWES 1985c and d) and *Concrete Repair Digest* (1993). The procedures are summarized in the following paragraphs.

(a) Iron rust. If the stain is light or shallow, mop the surface with a solution of oxalic acid and water. Wait 2 or 3 hr, and then scrub the surface with stiff brushes while rinsing with clear water. If the stain is deep, prepare a poultice by mixing sodium citrate, glycerol, and diatomaceous earth or talc with water and trowel the poultice over the stain. If the stain remains when the poultice is removed after 2 or 3 days, repeat the process as necessary.

(b) Oil. If the oil is freshly spilled, soak it up with absorbent paper; do not wipe it up. Cover the stain with a dry powdered material such as portland cement, hydrated lime, cornmeal, or cat litter. Wait approximately 24 hr, then sweep it up. Scrub the remaining stain with scouring powder or a strong soap solution. If the stain is old, cover it with flannel soaked in a solution of equal parts acetone and amyl acetate. Cover the flannel with a pane of glass or a thin concrete slab for 10 to 15 min. Repeat if necessary. Rinse when the cleaning process is complete.

(c) Grease. Scrape the grease from the surface. Scrub with scouring powder, strong soap or detergent, or sodium orthophosphate. If the stain persists, make a stiff poultice with one of the chlorinated solvents. Repeat if necessary. Rinse.

(d) Dirt. Most dirt can be removed with plain water or with a soft brush and water containing a mild soap. If a stronger solution is necessary, use 19 parts water to 1 part hydrochloric acid. If the dirt contains a lot of oil, use the methods for removing lubricating oil. Also, steam cleaning is generally effective for removing dirt. If the dirt is clay, scrape off all that has hardened. Scrub the stain with hot water containing sodium orthophosphate.

(e) Mildew. Mix powdered detergent and sodium orthophosphate with commercial sodium hypochlorite solution and water. After applying the mixture, wait a few days and then scrub the area. Rinse with clear water. Caution: sodium hypochlorite solution bleaches colored clothing and may corrode metal.

(f) Asphalt. Chill molten asphalt with ice (in summer). Scrape or chip it off while it is brittle. Then scrub the area with abrasive powder and rinse thoroughly with water. Do not apply solvents to emulsified asphalt as they will carry the emulsions deeper into the concrete. Scrub with scouring powder and rinse with water. Use a poultice of diatomaceous earth or talc and a solvent to remove cutback asphalt. When the poultice has dried, brush it off. Repeat if necessary.

(g) Efflorescence. Most efflorescence can be removed soon after it forms by washing or by a scrub brush and water. After the efflorescence has begun to build up a deposit, it can be removed by light water blasting or light sandblasting and hosing with clean water. However, some salts become water insoluble shortly after reaching the atmosphere. Efflorescence from these salts can be removed with a dilute solution of hydrochloric or phosphoric acid. Since an acid solution may slightly change the appearance of concrete or masonry, entire walls should be treated to avoid blotching. Only a 1-to 2-percent solution should be used on integrally colored concrete; stronger solutions may etch the surface, revealing the aggregate and hence changing color and texture.

(h) Soot. Scrub the stain with water and scouring powder, powdered pumice, or grit. If this treatment does not remove the stain, swab the area with trichloroethylene and apply a bandage made of three or four layers of cotton material soaked in trichloroethylene. If the stain is on a horizontal surface, hold the bandage against the stain with concrete slabs or stones. If the surface is vertical, prop the bandage against the stain. Periodically, remove, wring out, resaturate, and replace the bandage. Several treatments may be needed. Note: trichloroethylene is highly toxic and can react with fresh concrete, or other strong alkalis, to form dangerous gases. An alternative to the bandage is a poultice. Mix sodium hypochlorite (commercial household bleach is about 5 percent hypochlorite) or diluted Javelle water with talc or other fine material to make a paste. Spread the paste on the stain and allow it to dry thoroughly. Brush off the residue. Repeat the treatment if necessary. Note: sodium hypochlorite and Javelle water will bleach colored clothing and are corrosive to metals.

(i) Graffiti. Apply a proprietary cleaner that contains an alkali, a solvent, and detergent. After scrubbing the graffiti with a brush, leave the cleaner in place for the time indicated by the manufacturer. Rinse thoroughly. Avoid contact with skin. A less expensive, nonproprietary cleaner is dichloromethane, which can be washed off with water. The procedure is the same as with a proprietary cleaner.

c. Environmental considerations. In addition to the potentially adverse worker health and safety effects, improper handling and disposal of cleaning materials and their associated solvents may have adverse environmental effects. Reasonable caution should guide the use of cleaning activities involving the use of potentially hazardous and toxic chemical substances (REMR Technical Note EI-M-1.2 (USAEWES 1985h)). Manufacturer's directions and recommendations for the protection of environmental quality should be carefully followed. The MSDS should be consulted for detailed handling and disposal instructions. The MSDS also provides guidance on appropriate responses in the event of spills. In cases where the effects of a chemical substance on environmental quality are unknown, chemical substances should be treated as potentially hazardous or toxic materials. Residual cleaning solutions may be classified as a hazardous waste, requiring special disposal considerations. The MSDS will generally recommend that Federal, state, and local regulations be consulted prior to determining disposal requirements. Improper handling and disposal of waste materials may result in civil and criminal liability.

7-3. Surface Coatings and Sealing Compounds

Surface coatings and sealing compounds are applied to concrete for protection against chemical attack of surfaces by acids, alkalies, salt solutions, or a wide variety of organic chemicals. Coatings and sealers may also be used to reduce the amount of water penetration into concrete and as a decorative system for concrete. Thick filled coatings are occasionally used to protect concrete from physical damage. Before a protective coating or sealer is used on concrete, it should be determined that the concrete actually needs protection. The cause and extent of the deterioration, the rate of attack, the condition of the concrete, and the environmental factors must all be considered in the selection of a coating or sealer. For example, application of an impermeable coating or overlay may, under certain conditions, trap moisture within the concrete, thereby doing more harm than good (Section 6-16). Information on the susceptibility of concrete to chemical attack and selection, installation, and inspection of surface barrier systems is provided by ACI 515.1R, Pinney (1991), Bean (1988), and Husbands and Causey (1990).

a. Surface preparation. Proper concrete surface preparation is the single most important step for successful application of a coating. The concrete surface must be sound, clean, and dry before the coating is applied. Surface contaminants such as oils, dirt, curing compounds, and efflorescence must be removed. After the contaminants are removed, any unsound surface concrete must be removed before the concrete is coated.

(1) The most common method for determining the soundness of a concrete surface is the pipe-cap pulloff test (ACI 503R). Other commercial pulloff equipment such as the DYNA tester is satisfactory. Oils and other deep surface contaminants may have to be removed by chemical or steam cleaning. Abrasive blasting, shotblasting, high-pressure water, mechanical scarifiers, and acid cleaning are the methods must often used to remove the unsound surface concrete as well as most contaminants. Acid etching should be used only when other methods of surface preparation are impractical.

(2) Materials used to repair substrate surface defects should be compatible with the coating to be used. A latex-modified mortar should not be used if the coating to be used is solvent based. If epoxy resins are used, they should be highly filled and the surfaces should be slightly abraded before the coating is applied. Most coatings require a dry surface. Poor adhesion of a coating can result if water vapor diffuses out to the concrete surfaces.

(3) Some ASTM Standard Practices and Test Methods which may be helpful in preparing and inspecting concrete surfaces for coatings are listed below:

- Standard Practice for Surface Cleaning Concrete for Coating, ASTM D 4258.
- Standard Practice for Abrading Concrete, ASTM D 4259.

- Standard Practice for Acid Etching Concrete, ASTM D 4260.

- Standard Practice for Surface Cleaning Concrete Unit Masonry for Coating, ASTM D 4261.

- Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces, ASTM D 4262.

- Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method, ASTM D 4263.

b. Coatings. Factors to be considered in selection of a coating include intended function of the coating, properties of the coating, application conditions, anticipated service conditions, and life cycle costs. Coating properties that may be important, depending on the specific application, include abrasion resistance, water or chemical resistance, flexibility, curing time, temperature range, and aesthetics. ACI 515.1R and NACE International Standard RP0591-91 (NACE 1991) provide information on generic types of coatings that are appropriate for various exposure conditions. Candidate coating systems should be thoroughly evaluated to ensure that they are appropriate for the intended function and meet other desired characteristics such as ease of application and aesthetics. A test patch applied to the intended substrate in an area where the coating will be subjected to anticipated service conditions is recommended.

(1) General considerations.

(a) Typically, coating thicknesses range from a few mils to 3 mm (125 mils) or more, depending on the purpose of the coating. Thin coatings (<1 mm (40 mils)) are normally used for dampproofing, mild chemical attack, and for decorative coatings. Thick coatings (>1mm (40 mils)) are used for waterproofing, as protection against severe chemical attack, and as protection from physical damage.

(b) Coatings with very low permeabilities may do more harm than good by increasing the level of moisture in concrete if water enters the concrete from the side not coated (Section 6-16). Some coatings do transmit water vapor (breath) and these should be selected if it is expected that water will enter from the uncoated side of the concrete.

(c) Most coatings will not bridge cracks in concrete, but there are some elastomer coatings (polyurethanes and acrylics) that will bridge narrow cracks (<0.8 mm (<1/32-in)). Some thin polymer coatings (high-molecular-weight methacrylates and a few epoxy resins) are formulated to seal cracks in horizontal concrete structures by gravity.

(2) Characteristics of coatings. Characteristics of selected coatings for concrete that prevent attack from corrosive chemicals in the atmosphere and reduce moisture penetration are discussed in the following and summarized in Table 7-1 (NACE 1991).

(a) Silicones, siloxanes, and silanes are best used as water repellents. These materials are not designed to resist chemical attack or physical abuse.

(b) Cementitious coatings may be decorative products and are usually modified with latex for use in mild chemical exposure conditions. Certain inorganic silicate cements may be used to waterproof concrete from the positive or negative side.

(c) Thin film urethanes (up to 0.13 mm (5 mils) per coat) are used to seal concrete for nondusting, cleanability, graffiti resistance, and resistance to mild chemicals. They are used for dry interior exposures on walls and floors that have moderate physical abuse and for exterior weathering. Urethanes are available in two forms: aliphatic urethanes for color and gloss retention in exterior sunlight exposure and aromatic urethanes for exposures other than sunlight and UV light, or where ambering and chalking are acceptable.

(d) Epoxy polyesters are thin film coatings (up to 0.08 mm (3 mils) per coat) designed for color, nondusting, cleanability, and resistance to water for a brief period. They are used primarily for interior and exterior exposures on walls that experience little physical abuse.

(e) Latexes are coatings used for color, appearance, and cleanability. For exterior use, acrylic latexes provide improved color and gloss retention (vinyl latexes are not normally recommended because they tend to hydrolyze under high pH situations). Elastomeric formulations (e.g., acrylic, silicone), which provide waterproofing and crack bridging properties, are also available.

(f) Chlorinated rubbers are thin film coatings designed for color, nondusting, cleanability, and resistance to water and mild chemicals; chlorinated rubbers may chalk on exterior weathering exposures, unless modified.

Table 7-1
Guidance on Selection of Concrete Coatings to Prevent Chemical Attack and Reduce Moisture Penetration (NACE 1991)

Coating	Water Repellancy	Cleanability	Aesthetic	Concrete Dusting	Mild Chemical	Severe Chemical	Moderate Physical	Severe Physical
Silicones/Silanes/ Siloxane	R	NR	NR	NR	NR	NR	NR	NR
Cementitious	R	NR	R	NR	NR	NR	NR	NR
Thin-Film Polyurethane	R	R	R	R	R	NR	R	NR
Epoxy Polyester	R	R	R	R	R	NR	NR	NR
Latex[1]	R	R	R	R	NR[2]	NR	NR[2]	NR
Chlorinated Rubber	R	R	R	R	R	NR	R	NR
Epoxy	R	R	R	R	R	R	R	NR
Epoxy Phenolic	R	R	R	R	R	R	R	R
Aggregate Filled Epoxy	R	R	R	R	R	R	R	R
Urethane Elastomers	R	R	R	R	R	R	R	R
Epoxy or Urethane Coal Tar	R	R	NR	R	R	R	R	R
Vinyl Ester/Polyester	R	R	NR	R	R	R	R	R

Note: Reprinted with permission from NACE International. The complete edition of NACE Standard RP0591-91 is available from NACE International, P. O. Box 218340, Houston, Texas 77218-8340, phone: 713/492-0535, fax: 713/492-8254.

R = Recommended
NR = Not Recommended

[1] Excluding vinyl latices
[2] Certain latices may be suitable for service

NOTE: The recommendations provided are general. Candidate coating systems must be thoroughly evaluated to ensure that they are appropriate for the intended service conditions and meet other desired characteristics. The above list is not necessarily all-inclusive.

(g) Epoxies are two component products that are available in thin film (less than 0.25 mm (10 mils)) and thick film (0.25 to 1.27 mm (10 to 50 mils)) coatings. Epoxies have excellent adhesion to dry concrete, and epoxies have the ability to seal porous concrete and bug holes. Epoxies also exhibit good chemical resistance, hardness, and abrasion resistance. Epoxies are typically used for interior chemical and physical abuse conditions, because they tend to chalk and fade in atmospheric and sunlight exposure. Epoxy formulations that develop good adhesion to wet surfaces are also available.

(h) Epoxy phenolics are two component products similar to epoxies. They are phenolic modified to improve their chemical resistance. They are normally used for severe chemical environments and as floor coatings.

(i) Aggregate-filled epoxies are thick film coatings (3.18 mm (125 mils) or more thickness) that are usually applied by spray, trowel, or aggregate broadcast methods. Normally used in areas of severe physical abuse, these epoxies are still resistant to mild and severe chemicals. They are excellent floor coatings for areas of severe physical abuse. Floor toppings can be made aesthetically pleasing through selection of the appropriate color and type of aggregate.

(j) Thick film elastomers (up to 3.18 mm (125 mils)), such as urethane (ASTM D 16 Type V) and polysulfide, are normally applied by spray, trowel, or self-leveling methods. Normally used in areas of severe physical abuse that require a flexible coating, the rubber-like film displays excellent resistance to impact damage and the ability to bridge hairline cracks in concrete.

(k) Epoxy- or urethane-coal tars are moderately thick coatings (0.38 to 0.76 mm (15 to 30 mils)) with excellent water and good chemical resistance that are normally applied with a sprayer. The black color may restrict their usage for aesthetic reasons.

(l) Vinylesters and polyesters are moderately thick coatings (0.76 to 1.27 mm (30 to 50 mils)) with excellent resistance to acids and strong oxidizers that are applied by spray or trowel. Thicker films may be obtained with silica floor fillers and reinforcing fabric or mat.

(m) Coatings, such as inorganic silicate cementitious products, sulphur concrete, polysulfide elastomers, epoxy polysulfides, and others, also offer protection to concrete exposed to atmospheric and aggressive environments such as secondary containment structures.

(3) Application.

(a) The manufacturer's recommended application rate and method of application should be followed when a coating is applied to concrete. The surface profile and porosity will have an effect on the application rate. A test patch is useful in determining the surface preparation, application rate, and appearance of a particular concrete coating.

(b) The temperature of the concrete should be constant or dropping when some coatings are applied to avoid blisters or pin holes caused by the expansion of gases inside of the concrete. The temperature of the concrete should be above the dewpoint while the coating is curing to prevent water condensation on the coating.

c. Sealers. Sealers are thin, nonfilled liquids that penetrate or form a thin film (less than 0.13 mm (5 mils)) on concrete. Sealers are used for water repellency when there is no hydrostatic pressure, for dust control, and for reducing the amount of water soluble salts that enter into concrete. Penetrating sealers, such as the silanes and siloxanes, are recommended for areas subjected to traffic. Some sealers do not change the appearance of the concrete, but others may darken the surface. Some sealers are slightly volatile, and high winds and temperatures during application may affect their performance. Concrete sealers that have not been approved for the type of concrete masonry units (CMU) in service should not be used on CMU. Liquid surface treatments known as hardeners should be used only as emergency measures for treatment of deficiencies in hardened concrete floor slabs. They are not intended to provide additional wear resistance in new, well designed, well constructed, and cured floors (ACI 302.1R).

Pfeifer and Scali (1981) have provided what is probably the most comprehensive report on the sealer properties that are relevant for bridge concrete. The basic findings of this study were confirmed in subsequent work by Kottke (1987) and Husbands and Causey (1990). A performance-based specification for concrete sealers on bridges was developed by Carter (1993).

7-4. Joint Maintenance

Little maintenance is required for buried sealants such as waterstops because they are not exposed to weathering and other deteriorating influences. Most field-molded sealants will, however, require periodic maintenance if an effective seal is to be maintained and deterioration of the structure is to be avoided. The necessity for joint maintenance is determined by service conditions and by the type of material used.

Minor touchups of small gaps and soft or hard spots in field-molded sealants can usually be made with the same sealant. However, where the failure is extensive, it is usually necessary to remove the sealant and replace it. A sealant that has generally failed but has not come out of the sealing groove should be removed by hand tools or, on large projects, by routing or plowing with suitable tools. To improve the shape factor, the sealant reservoir may be enlarged by sawing. After proper preparation has been made to ensure clean joint faces and additional measures designed to improve sealant performance, such as improvement of shape factor, provision of backup material, and possible selection of a better type of sealant, have been accomplished, the joint may be resealed. For additional information on joint sealant materials, joint design, and installation of sealants, see EM 1110-2-2102, and ACI 504R.