Why coat concrete?

First of all, concrete is not the chemically inert material many people believe it to be. It is alkaline, and so any acidic materials can cause it to deteriorate. In addition, sulphate ions can attack the cement hydrates, soluble salts can be leached out, and steel reinforcement can corrode because of either the presence of chloride ions or a reduction in the local pH of the concrete.

Corrosion of the reinforcement can lead to rust staining of the concrete, delamination, and ultimately spalling as the reinforcement corrosion products increase in volume. Therefore, the first reason to coat concrete is to keep deleterious materials out and to increase its lifespan.

Since concrete is inherently porous, it is sometimes necessary to make it impermeable by coating it to provide ingress control against moisture and chloride, sulphate, etc.

To repair concrete, it is often necessary to remove the damaged concrete and replace it with a repair material. Matching the colour of the repair material to the colour of the original concrete is almost impossible, and so concrete can also be coated for aesthetic purposes (Fig. 1). New or intact concrete can be coated to provide it a decorative finish.

Finally, the surface properties of concrete may be insufficient. Coatings can then be used to enhance the mechanical or physical properties of concrete (e.g., to provide an improved skidding resistance or to reduce the level of dusting of the surface).

This article presents various considerations in the selection of surface preparation methods and coating materials for concrete surfaces. Epoxy, polyurethane, modified elastomeric bitumen, and modified cementitious coatings are discussed. It also deals with various factors that can lead to the degradation and failure of a coating film. Finally, testing criteria are presented.

Surface Preparation

For any coating system, one of the most important requirements is surface
preparation. As with steel, it is essential that a coating is applied to a clean and sound substrate free from oil and grease in order to achieve good adhesion.

The method of surface preparation will depend on a number of factors, including
• the condition and age of the concrete to be coated,
• whether the substrate has already been coated, and
• the type of coating to be used.

There are a number of surface preparation methods used for concrete: detergent scrubbing to remove surface contaminants; shot blasting for surface roughening and removal of old coatings; or heavy milling to remove high-build coatings and unsound concrete (although this may introduce micro-cracking into the surface of the concrete).

Since concrete can exhibit a number of surface imperfections, such as blow holes (Fig. 2), it may be necessary to apply a skim coat (or fairing coat) to the surface to fill defects prior to application of the coating. The skim coat should obviously be compatible with both the concrete and the coating to be used.

The International Concrete Repair Institute (ICRI) has produced detailed guidance on selecting and specifying surface preparation for concrete.¹ This information considers the coating to be applied and the methods that can be used to achieve the required profile. It describes available surface preparation techniques and discusses practi-

![Image](image-url)  
**Fig. 2:** Inadequate surface preparation can leave blow holes and cracks in the concrete.

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cal aspects of each one. In addition, the institute has de-
veloped a set of sample profiles to assess the surface
roughness of in-situ structures. Examples of the sample
profiles are shown in Fig. 3.
Likewise, the American Concrete Institute (ACI) has
published information that addresses such issues as sur-
face cleanliness, pH, moisture content of a concrete sur-
face, testing for excess laitance, and adhesion testing of
applied coatings.2

Coating Selection
A number of organic coatings are capable of protecting
concrete. The coating must be selected in accordance with
the specific requirements of the structure. Table 1 includes
various factors that should be considered. In addition, the
amount of volatile organic compounds (VOCs) that a coat-
ing contains also should be considered, since they affect
both environmental and health and safety concerns.
Considerations for the selection of coatings for new and
deteriorating structures vary. The approach to the selec-
tion can be summed up for each case in the form of a flow
chart, as shown in Figs. 4 and 5.3

Epoxy Coatings
These are chemically curing coatings consisting of a sepa-
rate base and curing agent that are mixed in specific pro-
portions. The base consists of molecules with a number of
reactive sites; the curing agent consists of short molecules
with reactive sites at either end. When mixed, the coating
cures by the molecules chemically bonding together to
form a three-dimensional array. The rate of curing is tem-
perature-dependent.
Epoxy coatings can be applied by brush, roller, or airless
spray.
They are generally strong, hard, and very chemically re-
sistant. They are often used to prevent the ingress of mois-
ture as well as chlorides and sulphates into concrete, such
as in tunnel walls, which tend to be damp. These coatings
also have good abrasion resistance, which can be further
improved by the introduction of glass flakes into the for-
mulation. Glass flakes dramatically reduce the rate of
chloride diffusion through the coating.
Epoxy coatings, being mostly hard and brittle, are not able
to cope with any significant movement in concrete, such as
the opening of cracks. Therefore, they generally are not suit-
able for coating existing structures that have “live” cracks.
Flexible epoxies have been developed, but this has usually
been achieved by a reduction in other properties. Most
epoxy coatings are not moisture tolerant during application

Fig. 3: Samples of surface roughness profiles showing concrete prepared
by grinding (left), medium shot blasting (center), and scabbling (right).
ICRI has nine such surface profiles; the others illustrate preparation of
concrete by acid etching, light shot blasting, light scarification, medium
scarification, heavy abrasive blasting, and heavy scarification.
(Courtesy of the International Concrete Repair Institute)
or vapour permeable in service. Therefore, they should generally not be applied to concrete structures that are required to dry out.

Due to the nature of the curing process, epoxy coatings can be very difficult to repair or recoat. It is essential that the surface of any existing cured coating is abraded and thoroughly cleaned with an appropriate solvent before the application of any subsequent coating.

Polyurethane Coatings

Polyurethane coatings cure in a similar manner to epoxies. They also can be applied by brush, roller, or spray. Unlike epoxy coatings, they can be highly flexible. Therefore, they are capable of bridging “live” cracks in service.

Because of the combination of chemical resistance and flexibility that they offer, polyurethanes can be used as lining materials, such as for secondary containment structures.

As with all coatings, many different types of polyurethane coatings are available with widely differing properties. Some polyurethanes cure when in contact with moisture and, therefore, can be applied to damp surfaces. Other formulations have excellent abrasion resistance or exhibit enhanced crack-bridging properties.

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Fig. 5: Considerations for coating a deteriorating concrete structure

Fig. 6: Anti-carbonation coatings provide durability and improved appearance.
Polyurethane coatings are easily recoated or repaired, as the new coat tends to partially dissolve the surface layer of the old coat and thus allows an intimate bond to be formed. Some formulations require the application of a special bond coat prior to application of the new coat. It is essential to thoroughly clean any surfaces to be recoated in order to achieve a good bond.

**Modified Elastomeric Bitumen Coatings**
These coatings consist of long polymer chains dissolved in a strong solvent. The strong solvent is necessary to prevent the long polymer chains from “tangling” and causing the chains to stiffen.

They can be applied by airless spray or brush. After application, these coatings dry as the solvent evaporates. No chemical reactions take place, and the rate of drying depends on the rate of solvent loss. Therefore, it is faster at higher temperatures. Some bituminous coatings are moisture tolerant during application.

They can be removed by redissolving them in the same strong solvent used initially. Recoating is relatively simple as the surface of the original layer is dissolved and an intimate bond is created with the new coating layer.

Since these coatings are elastomeric, they have excellent crack-bridging properties. They also are very moisture tolerant, which enables them to be used on the exterior of buried pipe or on submerged surfaces such as pilings and jetties. However, they are relatively soft, and this can result in poor abrasion resistance.

**Modified Cementitious Coatings**
These are generally anti-carbonation coatings that can double as barriers against sulphate and chloride ingress. Cementitious coatings are relatively brittle even after polymer modification, and they generally are not capable of bridging active cracks.

Application can be by brush, roller, or airless spray. The concrete surface should be dampened with potable water before application. The presence of sea water in the structure to be coated may affect the quality of the bond; advice should be sought from the manufacturer should this situation arise.

An example of where such a coating material could be used is shown in Fig. 6.

Modified cementitious coatings traditionally are made with water-borne acrylic. Unlike the coating systems already mentioned, they do not contain solvents. Therefore, they do not usually require the same level of safety precautions required for use of solvent-borne materials. However, being cementitious, they are highly alkaline, and appropriate safety measures must be employed during their use to prevent chemical burns, dermatitis, and other skin irritations.

**Surface Impregnations**
As an alternative to coating, surface impregnations can be applied to impart a certain degree of resistance to moisture.

These materials generally work by impregnating the pores in the outer layer of the concrete with a water-repellent material. This prevents the ingress of water into the concrete. Thus, the movement of soluble aggressive species is dramatically reduced.

Examples of the ingredients in impregnating materials are silanes and stearates. Aluminium stearate dissolved in white spirit, a solvent, is frequently used, although its water-repellent properties are variable on siliceous substrates. Also, at temperatures below 10°C, the mixture tends to become viscous and separate.

Most silanes are clear and colourless, and some require in-situ dilution with solvent before application. In some cases, it is helpful to know what type of impregnating material has been used, but detecting the presence of silanes after application is difficult. Therefore, careful monitoring is required during the site stage.

Thin barrier coatings also can be used as surface impregnations to seal the surface. These are typically low-viscosity epoxies that can penetrate the concrete surface prior to curing and then seal the surface when they cure.

**Degradation Processes**
There are a number of factors that can lead to the degradation and failure of a coating film. Examples of degradation include chalking, swelling and softening, peeling, and pinholing.

**Chalking**
When exposed to ultraviolet (UV) light, many polymer coatings will chalk. This is caused by fragmentation of the polymer surface. Chalking results in loss of decorative and/or protective properties. In situations where exposure to UV light is likely, the coating should be selected to be UV-resistant.

**Swelling and Softening**
If solvent-borne physical and oxidative drying coatings (and in some cases chemically curing coatings) are exposed to solvents, they will often swell and soften. This at best causes a deterioration in the properties of the coating; at worst it causes total failure. Tests that expose the coating to its working environment can be used to determine whether it will swell and soften.
Peeling
Pull-off or cross-cut adhesion tests can provide data on the adhesive quality of the coating. Similar adhesion tests can be carried out after immersion tests in a specific environment to determine the effect of the environment on the coating adhesion. Any areas of disbonding or blistering on a coated surface should be removed, and the surface should be recoated after the reason for the disbonding has been discovered and corrected.

Pinholing
Pinholing describes tiny holes in the coating that could allow moisture or aggressive contaminants to penetrate the coating and come into contact with the substrate. Once a coating has been applied, it should be visually checked for pinholes, and if any are found, they should be repaired.

On concrete substrates, spark testing can be used to detect pinholes in non-conductive coatings. This is done by passing a high-voltage probe (commonly 5–10 kV) over the coating. If a pinhole is present, a spark will pass from the probe to the substrate, indicating its presence.

This method of pinhole detection is commonly used on sheet polymer linings. Care should be taken to avoid using excessively high voltages, because there is some evidence that they can produce sparks that can induce pinholes in the coating.

Testing and Monitoring Criteria
Before applying a coating system to a structure, it is generally advisable to perform a trial application on which tests can be performed to determine the suitability of the coating for the task.

Pull-off or cross-cut tests should be performed to determine the quality and nature of adhesion of the coating to the substrate. Three types of failure can be encountered:

- adhesive failure at the coating/substrate interface,
- cohesive failure within the coating, and
- cohesive failure within the concrete substrate.

Of these, adhesive failure is the worst case. It indicates that the coating is either unsuitable for its intended service or has been applied incorrectly. Provided the trial application has been applied on a sound substrate, cohesive failure of the substrate shows the coating is bonded strongly to the concrete; therefore, it is the most desirable of the three test results.

The test area should be checked for excessive pinholing and any other defects that may compromise the performance of the coating.

During the actual coating application, environmental factors, such as temperature and relative humidity, should be monitored to ensure they fall within acceptable limits for the coating system being applied. Dry or wet film thicknesses should be monitored to ensure the correct amount of coating is being applied, and adhesion tests should be carried out at intervals to ensure a consistent quality of bond.

Once the coating is in service, it should be regularly inspected for any signs of deterioration. It is difficult to directly monitor the rate of degradation of the coating other than by visual inspection. Cores can be taken to observe any changes in the condition of the coating and the concrete below it, although this results in damage to the coating and concrete that require repair.

Summary
As with any coating application process, the successful coating of concrete requires quality control at each stage, from initial selection, through surface preparation, to application of the coating to trial areas. If careful consideration is given to each stage of the process and regular inspections are undertaken, then numerous benefits can be achieved by applying coating systems to concrete.

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References

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