CONCRETE PROTECTION SYSTEMS
COATINGS SEALERS AND MEMBRANES

Jay H. Paul
Klein and Hoffman, Inc.

April 19, 2005

Repairs of concrete parking structures and high-rise buildings are very costly, often exceeding several million dollars. When discussing protection systems, presumably during the planning process, the question engineers often must answer is why spend more for protection if the structure is sound upon completion of the concrete restoration and the structural integrity is re-established? It is imperative that the owners understand that protection of concrete is an important part of a complete repair program and if it is not included they must be made aware of the consequences.

SECTION 1
Why Protect Concrete Repairs?

The primary reason for protection is to extend the life of the concrete repairs. Although a protection system is an additional cost on a concrete repair project, one should be incorporated to extend the life of the repairs as long as possible. Otherwise, the Owner may be repairing the structure again long before it was ever anticipated.

SECTION 2
Concrete Repairs and Protection Go Hand in Hand

It is difficult, if not impossible, to change via repairs the conditions that triggered much of the deterioration of concrete we see. Most of the deteriorated concrete that we have repaired was caused by corrosion of embedded reinforcing.

On facades, the conditions that result in the deterioration of concrete are often due to cracking of exposed slab edges because of shrinkage, movement of the structure and thermal related volumetric stresses. Cracks provide paths for moisture to reach the reinforcing. Poor workmanship, especially misplaced rebar with insufficient coverage, usually results in corrosion problems. Because the corrosion products (rust) occupy about ten times the volume of the original metal, delamination and spalling of the concrete will occur. In addition, if the depth of carbonation of concrete extends to the reinforcing, the concrete will not protect the reinforcing against corrosion, thus further exacerbating the situation. Corrosion of reinforcing is likely to occur unless measures are taken to deal with the given parameters.

When developing a repair program to deal with these problems, it is usually not possible to attain the proper coverage without building out the concrete. This can be expensive and result in an unsightly appearance. Instead, a protection system can be employed to improve the performance of the repairs and to delay the onset of future spalling because of corrosion.

While it is not really possible to change the condition of the existing construction through a repair program, in some cases, it is possible to improve the conditions. In parking structures or bridge decks, for example, it is possible to remove much of the contaminated concrete.

Hydro milling techniques perform this task well by removing the top three inches or so of concrete from the substrate below. The repair program would then include a replacement bonded concrete overlay with new reinforcing steel to re-establish the integrity of the deck. In some cases, complete slab replacement might make better economic sense and thus achieve the benefits of an almost new structure. On most concrete repair projects, however, other means must be provided to extend the life of the repairs. This is achieved by incorporating an appropriate protection system, which is intended to improve the performance of repairs by moderating the underlying causes of concrete deterioration - i.e. reduce the likelihood of future corrosion. The benefits that can be achieved with a concrete protection program include the reduction of water or oxygen penetration into the concrete, the control or reduction of carbonation, reduction of erosion of the surface, reduction of chemical attacks, as well as other improvements in durability. An added benefit is that some protection systems mask repairs and improve the appearance of the repaired structure.

SECTION 3

Common Concrete Problems to be considered when selecting repair methods and protection systems

High chlorides, misplaced reinforcing, poor concrete and carbonation are some of the factors that contribute to corrosion. These factors as well as others must be addressed in the repair program if it is to be successful. A summary of parameters that must be considered when selecting a protection system follows:

a. **POOR CONCRETE**

The performance of any concrete structure is in part a function of the quality of concrete in the structure. Good, durable, properly consolidated concrete placed with the minimum of honeycombing and internal shrinkage cracks will provide an environment that should protect the embedded reinforcing for years before repairs, if ever, are required. Conversely, poor concrete with deficiencies such as excessive internal cracking, internal voids, the lack of consolidation or otherwise substandard conditions will contribute to the corrosion of the reinforcing as well as other deterioration of the structure. A protection system can improve the long-term durability of the concrete and thus the performance of the repairs.

b. **MISPLACED REINFORCING STEEL**

Misplaced reinforcing steel is a major contributing factor to corrosion. We have especially noted inadequate coverage with reveals on walls. Reinforcing in variable thickness decks (tapered for drainage), where the reinforcing is placed parallel with the bottom side commonly has insufficient coverage at the low end of the top bars. Edge bars along exposed slabs and hooked bars perpendicular to the slab edges, if too close to the surface, often corrode prematurely, usually at cracks crossing the plane of the bars.

The repair program must provide in some manner for the lack of cover on the reinforcing. This can be accomplished with build-outs, which are generally undesirable and expensive. Appropriate penetrating sealers or barrier coatings, probably in combination with other techniques, will provide added protection against corrosion. Cathodic protection or corrosion inhibitors may also be useful to prevent or delay future corrosion.

c. **WATER PENETRATION**

Water may penetrate into concrete by hydrostatic pressure, water vapor gradient, capillary action, wind-driven rain, or any combination of these. Cracks, porous concrete, structural defects, or improperly designed or functioning joints will all contribute to this movement. Water penetration into concrete will contribute to corrosion of reinforcing, freeze-thaw damage, leakage into the interior of the structure or to occupied levels beneath decks and to possible structural damage. Any properly designed protection system must address this issue.

d. **CARBONATION**

Carbonation is the reduction of the protective alkalinity of concrete, caused by the absorption of carbon dioxide and moisture. In normal concrete the reinforcing is protected by the naturally high alkalinity of the concrete around the reinforcing, usually about a pH of 12. A passivating oxide layer is formed around the reinforcing which acts like a protective coating. The oxide coating helps prevent the reinforcing from rusting as long as the high alkalinity is maintained. When carbonation occurs, the alkalinity falls and once it goes below a pH of 10, the embedded reinforcing is subject to corrosion. Since carbonation occurs from the face of the concrete inwards, any bars close to the exterior surface will be subject to the effects of carbonation and thus not be protected against corrosion. There are products available that can provide protection against future carbonation where concrete coverage is insufficient.

e. **ANODIC RING OR "HALO EFFECT"**

On most concrete repair projects, situations arise where existing reinforcing extends from the parent concrete into a repair mortar or new concrete. Quite frequently, failures will occur due to accelerated corrosion of that reinforcing, just beyond the bond line. It is common to see delamination of concrete around the perimeter of new repair patches in spite of the fact that good quality materials, workmanship and methods were used. This is commonly referred to as an anodic ring or "halo effect".

It occurs because the same bar extends into two distinctly different environments setting up conditions that could result in an electrochemical process at the bond line between the new and the parent concrete. Corrosion will occur at the anode, usually in the parent concrete, as electrons are attracted to the cathodic portion of the reinforcing probably within the uncontaminated new patch. The build-up of rust will result in spalling of concrete due to the large internal forces developed at the surface of the reinforcing. The presence of chlorides will accelerate this process.

This is a very difficult problem to solve. Sealers or barrier coatings will help to some extent to slow down the process but not stop it. Corrosion inhibitors, although unproven in service, look promising toward reducing the occurrence of corrosion in the parent concrete adjacent to new repairs due to the "halo effect". Cathodic protection is another alternative that should be considered where economically feasible. (ACI 546R -Concrete Repair Guide-Chapter 4)

f. **CRACKS**

Any concrete repair program must address the repair of cracks. Only after determining the reason for the occurrence of a crack can a proper technique to repair it be developed. Structural cracks may have to be bonded back together in some manner. Moving cracks, especially those due to thermal changes on exterior exposures, would probably be repaired to allow for future movements. Techniques involving caulking, chemical grouts, elastomeric coatings and membranes have proven to be useful in bridging cracks.

The repair of moving cracks on exterior exposures can be very difficult. Most of the materials used for crack repair are temperature sensitive and cannot be installed much below 40 ^{o}F. It is most common to be repairing cracks at temperatures well above the recommendations of the manufacturers. Although this will facilitate the installation of the repair material, moving cracks due to temperature variations will tend to close in warm weather. Quite often, cracks that open in the winter, will be closed, difficult to detect or impossible to inject at the time the repairs are be done. Both the contractor and the engineer must be aware of this prior to commencing with the repair process. If feasible, an inspection of the structure should be conducted in the cold weather to document the location of the cracks.

g. **CHLORIDE/CHEMICAL ATTACK**

Penetration of chemical or salt solutions through concrete will contribute to the corrosion of the embedded steel. In addition, chemical attack may have a detrimental effect on the concrete itself.

Barrier protection systems are commonly used to minimize the intrusion of chemicals into concrete. In addition, concrete especially designed for the intended use of the structure should be incorporated (sulfate resistant concrete) when warranted.

h. **EMBEDDED DISSIMILAR METALS**

Dissimilar metals in contact with each other is a common occurrence that may result in corrosion. An example of this is when aluminum handrail posts come in contact with the embedded reinforcing. We have also seen misplaced reinforcing in contact with aluminum window components resulting in severe corrosion problems. Proper concrete repair details in conjunction with appropriate protection is required to eliminate or alleviate this problem.

SECTION 4
PROJECT SELECTION FACTORS

The requirements for each project must be determined and carefully evaluated prior to selecting a protection system. Although several different systems could be incorporated, the parameters unique to a particular structure might make one system more attractive than other alternative solutions. Concrete repairs and related protection systems should be carefully selected using techniques and materials that are appropriate for the situation. There are several selection factors that must be considered when evaluating a project prior to selecting a repair system. These include:

a. **TRACK RECORD**

There are a number of new systems for protecting concrete that have almost no service track record. Although the test results might be encouraging, most engineers and owners are reluctant to incorporate such systems on their projects. There are circumstances, however, where the problems are so acute, that new technology may be the only answer. For example, a structure with a serious carbonation problem might be suitable for incorporating anti-carbonation coatings. Although these coatings have been used in the United States for only about 8 years, they have been used in Europe for a much longer time. Presumably there should be available data on the performance of anti-carbonation coatings over at least a decade of service. It is incumbent for the engineer to consult with the manufacturers of these coatings for that information.

It is important that the owners are aware of the risk they are taking for any product without a long track record and the engineer must attain their full consent of whatever risk they will accept regarding the use of a system without a long track record. They also must be aware of the implications the system might have on their particular project including the potential for failure and future maintenance, prior to the engineer selecting a protection system.

b. **INITIAL AND LONG TERM COSTS (MAINTENANCE)**

Cost is an important factor that no owner can ignore. The given conditions that must be evaluated for a particular structure will have a major impact on the costs of a system. In addition, most protective systems have maintenance costs associated with them along with their initial cost. Sealers and paints need to be reapplied. Impressed cathodic protection systems need to be monitored and certain components replaced. Passive cathodic protection systems, which will extend the life of repairs, conversely, do not require maintenance, but they have a finite life and may need to be replaced during future repair programs.

The initial cost for a cathodic protection system might seem high. However, when considering its life cycle, its use on a repair project may be very competitive (in excess of an additional $4.00 per square foot). If down time for a structure is a major concern, the additional cost might be well worth it for that project.

Sometimes there are hidden costs associated with a protective system that was inexpensive initially. An example of this would be the removal of the coating during a future repair project. This might be necessary because of the buildup of coatings inhibits proper bond, reduces permeability, negatively impacts the appearance or other system characteristics necessary for it to perform properly. This can be difficult and expensive. The costs associated with the protective system other than the initial costs cannot be ignored. In some instances the initial costs may be attractive, but upon closer evaluation, the long-term expenses may be high.

When evaluating a protective system, it would make sense to consider all future expenses, including anticipated repairs. It is possible that by selecting a more expensive protective system as part of a repair program initially, a complete repair cycle might be eliminated or minimized in scope in the future. The savings in long-term expenditures might indicate that spending more money on protection initially would be the correct.

c. **APPEARANCE**

There might be several alternative protective systems that could extend the life of the repairs but not capable of providing the appearance characteristics required for a particular protect. On some garage restoration projects for example, the owner might not care that the repairs are obvious and not hidden whereas on other garages, appearance might be an important factor. Penetrating sealers or surface sealers might be appropriate for the former while a membrane would probably be the better solution for the latter,

Certain decorative coatings such as solvent acrylic coatings, might have a very positive impact on a building, because they could help to hide the repairs very effectively in addition to providing the necessary protection. Conversely, penetrating sealers do not affect the appearance and will not hide repairs. It is important that owners are informed as to what they are buying. Mock-ups serve this function well.

It is important that the engineer consider the appearance of the system after it has been in place for a few years. What is the impact of Ultra Violet? How badly will it fade? When will it have to be ”refreshed” with a new topcoat? Some coatings have had a history of problems with dirt retention. The treatment of cracks prior to applying the finish coat is important to consider on the repair documents. If done improperly, the cracks may mirror through the coating or attract dirt. These considerations as well as others must be reviewed with the manufacturer and the owner must be informed of the results prior to the selection.

d. **VOC COMPLIANCE**

VOCs, **volatile organic compounds**, are materials that evaporate easily into the atmosphere under normal environmental conditions. For regulatory purposes, the Environmental Protection Agency (EPA) defines a VOC as ”any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium, which participates in atmospheric photochemical reactions.”

In particular, there are two concern regarding VOCs:

1 *Strong unpleasant odors that solvent based products emit*

This could result in health problems for applicators and others in the area of work especially in poorly ventilated indoor spaces.

2 *Smog related issues*

Smog is made up of various products of combustion including VOCs. Of particular concern is the photochemical reaction between nitrogen oxides and VOCs, which produces ozone. Ozone is a health hazard when it exists in significant amount in the air we breath.

Compliance with current VOC regulations is an important factor that must be considered when selecting a protection system. The conditions present for each project must be evaluated when reviewing compliance. The requirements will vary from state to state as well as by projects. (For example, the concerns for a poorly ventilated interior space would differ from an exterior exposure.) Because of the impact VOC regulations have on protection systems, it is important that the engineer have some background on the subject.

Paints and organic-based sealers have in the past been formulated with solvents and thinners that evaporated during mixing, application or curing. If these materials are VOCs, they react with nitrogen oxides to produce smog and ozone. In order to meet the regulations of several states that have such laws, low VOC products have been introduced into the marketplace. Water-based systems, incorporating emulsions of organic materials in water, have been introduced to meet the requirement.

Unfortunately, many of the products, engineers have relied on in the past are no longer available in their original formulations. The latest version of some of the long-standing products really don’t have the long track record that we would like for the product we specify. Because of the new and changing VOC regulations, the specifiers will have to be using some products without the benefit of years of in service performance. It is important that owner understand this dilemma.

e. **COMPATIBILITY**

One factor that requires special attention by the engineer is the existing condition of the concrete. Presumably most concrete defects will have already been repaired prior to installing the protection system and thus deteriorated concrete would not be a concern. Compatibility, however, could be a problem. Many of the proprietary products commonly used in repairs might have a chemistry that is not compatible with coatings or sealers that the specifier is considering applying over them. If embedded galvanic anodes (a passive cathodic protection system) are used on a project, the specifier must verify that resistivity of the repair materials is within limits of the manufacturer's requirements. All compatibility issues should be checked as part of the selection process.

The condition of the surface to be protected is very important to review when considering any protection system. Existing coatings or sealers on or near the surface of the concrete will have a significant impact on the selection. This could be a problem when placing coatings with widely different chemistries on top of each other. The potential for compatibility problems must be researched. In addition, the ability of penetrating sealers is greatly influenced by the presence of existing sealers or coatings. Because the removal of existing coatings is very expensive and typically approval of the substrate for a coating is required by most manufacturers to get any warranty, this is extremely important consideration as well as a cost item. Sometimes, only partial removal is required which could result in a significant cost savings on the project. In any case, prior to starting production work, the selected system should be tested on the jobsite.

f. **DURABILITY/PERFORMANCE**

The durability and performance requirements for an intended application must be carefully evaluated. On a parking deck, for example, the performance requirements in the drive aisles and ramps are much more severe than in the parking areas. In those areas, where the demand is much less, a lighter system could be used thus saving the client some money.

When evaluating a system for a particular project, the engineer must determine the anticipated years of use that the owner would like to get from a repair program before embarking on another repair program. This will have a major impact on the selection as well as the cost. Some systems are more durable than others and might be more appropriate for certain projects even though they cost more. Among other factors that must be evaluated when determining the required performance of a system are the environmental conditions (exposure to wind driven rains, temperature variations, acid rain, carbon dioxide exposure, etc.), the exposure to UV, the extent and nature of traffic for decks and the use of the structure (potable water reservoirs have certain regulatory requirements).

SECTION 5
Selection approach

Each protection system has its own characteristics. Although several of the available systems might provide adequate protection to the concrete and embedded reinforcing, there might be certain parameters for a project that make one more attractive than another. The following are many of the primary performance characteristics that must be reviewed when selecting a protection system.

PERFORMANCE CHARACTERISTICS

a. System history and in service performance
b. Initial and potential maintenance costs
c. Improvement in corrosion resistance
d. Crack bridging ability
e. Skid resistance (when required)
f. Appearance and ability to hide repairs
g. VOC characteristics
h. Compatibility characteristics
j. Durability and other performance characteristics including
    1) Water Permeability
    2) Vapor Permeability
    3) Carbonation resistance
    4) Penetration characteristics (when applicable)
    5) Abrasion resistance
    6) Elongation
    7) UV resistance
    8) Limitations
    9) Chemical/Chloride resistance
    10) Freeze-thaw resistance

SECTION 6
IMPLEMENTING THE WORK

On any repair project, it is important that the engineer has a clear understanding of the problems and their causes. If possible the repair program should include methods to eliminate the reasons or at least provide a means to reduce the magnitude of the problems in the future.

The concrete repairs should be carefully selected using techniques and materials appropriate for the conditions. Likewise, a protection system should address most if not all of the project parameters as discussed above. Of particular importance is the compatibility between all materials on the project. This concern, if not properly considered, failure of the protective system can occur resulting in significant extras on the project or even litigation.

The best procedure to check for compatibility as well as for other project conditions is to include mock-ups as part of the repair program. This can be done prior to preparation of the project documents or included as the initial work to be performed under the construction contract prior to implementing the production work. The latter approach is quite common and presents the added opportunity for the contractor working in conjunction with the engineer to fine-tune the repair techniques and possibly improve the quality of the project and/or reduce costs.

All of the basic repair techniques should be tested. Of particular importance is surface preparation, especially for coatings. If there are existing coatings on the building, the extent of removal must be determined at this time. In order to get the manufacturer's warrantees, it is important that they are involved at this time and in fact approve that the surface preparation is satisfactory for them to warrant their products. Testing should be done as part of this procedure to confirm that the bond and other significant criteria established in the specifications as well as by the manufacturer is generally being met. Those procedures that meet with the approval of the manufacturer, the engineer and the owner then become project standards. We have on occasion, left the mock-ups that illustrate an acceptable standard for surface preparation, in place throughout the duration of the project as a reference to judge the production surface preparation. Refer to ICRI Guideline No. 03732 "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings and Polymer Overlays" as a reference for surface preparation.

In addition to scrutinizing the technical aspects of the work, the mock-ups provide the opportunity for the owner to judge the appearance of each of the techniques and most important the final coating. It is our recommendation that the specifications require that the owner approves the appearance of the repairs including the final color and texture of the coatings before the production work commences. The approved mock-ups should be left intact until the project is completed in case there are any conflicts concerning the final appearance of the work.

SECTION 7
Installation Requirements

There are certain parameters that must be considered prior to selecting and installing a protection system, especially surface treatments. These include:

a. Concrete repairs should be completed and cured (usually 28 days)
   Note: The manufacturers of a few products claim they can be installed on moist surfaces and in considerably less time than 28 days

b. Surfaces should be dry and sound and surface preparation implemented in accordance with manufacturer's recommendations

c. Surfaces must be relatively smooth for applying liquid-applied membranes

d. Ventilation conditions and humidity must be considered when selecting products

e. Most products have temperature installation limitations that must be considered when scheduling the work.

Because ideal conditions do not always exist, the difficulty and cost to achieve appropriate installation conditions may influence the choice of the protection system. For example, products with low VOC emissions would need to be selected for use in indoor poorly ventilated spaces in order to comply with the current regulations even though they might be more expensive and lack the track record of traditional products that the engineer has probably used successfully in the past. Another example influencing the choice of a coating on an exterior exposure might be the low temperature limitations. If the work schedule indicates that it will be necessary to apply the final coating in fall, a product that can be installed at lower temperatures would probably be a significant factor in selecting that product assuming that the other protection and related project parameters are satisfied.

SECTION 8
PROTECTION METHODS

There are many methods and certainly a multitude of products available to protect concrete. The objective is to reduce the corrosion of metals in concrete and the related problems as well as the improvement of other characteristics of the concrete matrix that result in various types of deterioration that must addressed. This is generally accomplished by limiting the intrusion of moisture, chloride, carbon dioxide and other contaminants into the concrete substrate by surface treatments or by electrical-chemical principals. Protective systems also include materials and methods that increase the durability of the concrete surface to abrasion, impact resistance, or to other deleterious influences. (ACI 546R Concrete Repair Guide-Chapter 4)

The following is an overview of some of the various systems available for protecting concrete along with a brief description of the characteristics of each system:

a. **SURFACE TREATMENT**

Surface treatments have been for years the most common method of protection for concrete. The selection of a surface treatment is generally dictated by cost as well as the conditions that must be addressed for the particular project being repaired. The objective of a surface treatment is to limit corrosion by establishing conditions that reduce free water in concrete while preventing further moisture (and chlorine intrusion for parking or bridge decks), which is necessary for the corrosion reaction.

Surface treatments have been effective in substantially slowing reinforcement corrosion in lab tests, and some have performed well in field applications.

The general classifications used in ACI 546 Concrete Repair Guide for surface treatments is as follows:

Surface Treatments /General Classifications

- Penetrating Sealers (generally beneath surface)
- Surface Sealers (up to 10 mils)
- High-build coatings (10 to 30 mils)
- Membranes (30 to 250 mils)
- Overlays (over 250 mils)

1) Penetrating Sealers

Penetrating sealers which after application are generally within the substrate of the concrete. Depth of penetration will vary by the product, the properties of the concrete, the existence of contaminants, and to some extent, the surface preparation. Penetrating sealers are not subject to abrasion, generally not subject to ultraviolet (UV) degradation, will not bridge cracks and do not appreciably alter appearance. They will not hide concrete repairs. Included in this group would be boiled linseed oil, silanes, siloxanes, magnesium and zinc fluorosilicates, certain epoxies and high molecular weight methacrylates.

Because these products are beneath the surface of the concrete, they are excellent for use on parking decks. They are not suitable by themselves to stop water penetration through cracks. If appearance is a factor on the project, penetrating sealers will not by themselves be appropriate to hide the concrete repairs. Sometimes these products are used in conjunction with coatings to improve durability. Some manufacturers claim that their products will improve the bond of coatings to the concrete substrate. Because most of these products are intended to reduce moisture and thus chloride intrusion, they may reduce or delay the onset of future corrosion and freeze-thaw degradation. The specifier must check the VOC emissions with the manufacturer because that could be an issue in some applications.

2) Surface Sealers and High-Build Coatings

Because there are many products that depending on the application could be classified as a surface sealer (10 mils or less dry film thickness) or as a high-build coating (10 to 30 mils dry film thickness), the two classifications will be combined for the purposes of this overview. Many of these products are affected by UV and will wear under surface abrasion. Although most will not bridge moving cracks, they may be effective in bridging non-moving cracks. There are some elastomeric coatings, however, if properly detailed that will bridge small moving cracks. Although they may be pigmented, they will not appreciably alter the texture of the surface and most surface blemishes will reflect through. High-build coatings in some instance may be effective in masking repairs. Products that would be classified as surface sealers would include epoxies, polyurethanes, high molecular-weight methacrylates, siloxanes, silanes, moisture-cured urethanes, and acrylic resins. Certain paints, whether oil-based or latex-based would be included in this classification if less than 0.25 mm (10 mils) thick.

High-build coatings would include acrylics, alkyds, styrene butadiene, copolymers, vinyl esters, chlorinated rubbers, urethanes, silicones, polyesters, polyurea and epoxies.

Surface sealers are used for protecting decks and vertical surfaces. Skid resistance may be reduced unless fortified with an appropriate aggregate. Because concrete repairs and blemishes may mirror through, high-build coating may be more appropriate where appearance is an important criteria such as on facades of buildings. Many of these products will effectively waterproof the surface and reduce water penetration into the concrete. Some of the manufacturers of elastomerics have data that indicates their products have good anti-carbonation resistance, which could be important where concrete coverage over reinforcing is insufficient. In many instances, water and vapor permeability are important parameters for product selection.

The products in these categories have varying properties and the selection of an individual product may be dependent on its ability to breath (or in some cases to act as a vapor barrier) as well as to provide sufficient resistance to water penetration. It is up to the specifier to select a product that meets these system characteristics as well as the other required for each specific project.

3) Membranes

Membranes are surface treatments with a thickness of greater than 30 mils (dry film) and less than 250 mils applied to the surface of the concrete primarily for horizontal applications. The products significantly alter the appearance of the concrete, can bridge small moving cracks, will mask most repairs, and with the introduction of appropriate aggregates provide adequate skip resistance and durability when required. Because they do reduce the intrusion of moisture and chlorides into the concrete, the onset of future corrosion may be delayed significantly. When exposed directly to the weather, UV degradation is a potential problem. Because of VOC regulations, most manufacturers have developed products with no or low emissions but in almost every instance do not have a long track record of in service use. Included in this category are urethanes, acrylics, epoxies, neoprenes, cement, polymer concrete, certain and asphaltic products.

Frequent maintenance of exposed membranes, especially in parking structures is required although it is usually inexpensive. There are membranes that are available that are self healing which would be beneficial under buried overlays.

Avoid situations where the concrete is encapsulated with none breathing membranes on each side. Generally membranes offer good elongation properties, excellent water permeability but only marginal vapor permeability. Membranes when applied over slabs on grade or in situations where there is a vapor drive from below must be done so with the greatest of caution.

There have been instances where some membranes are not compatible with certain proprietary concrete repair products. A careful evaluation of all the products to be used in the repair program must be conducted prior to selecting a membrane along with adequate testing to confirm the system will not have installation problems. Most membrane manufacturers offer five-year warrantees but usually only if installed by approved contractors.

4) Overlays

Overlays are installations of products of 250 mils or greater in thickness, that are generally bonded to the concrete. Overlays will add weight proportional to its thickness which must be considered in the analysis of existing structures. They can be installed to act compositely with the existing structure affording the opportunity to increase the strength. Additional reinforcement can be added. Because of the additional thickness, the overlay may in some instances be sloped to improve drainage. Although overlays will initially bridge cracks, moving cracks may mirror through. Very often, overlays are used to enhance appearance and are very effective in masking repairs below. Included in this category are portland-concrete, polymer concrete, epoxies, polysters, and polymer-modified concrete.

Overlays can be formulated to reduce moisture intrusion, to improve durability, corrosion resistance and the intrusion of chlorides. Many of the available products are fiber reinforced to reduce plastic shrinkage. For bonded overlays, it is best to select a product that has properties similar to the parent concrete to minimize compatibility problems. Because many of they products are cementitious, vapor permeability problems can be easily avoided. Products containing epoxies and polymers should be evaluated for UV degradation.

b. **CATHODIC PROTECTION**

An effective method to control corrosion of embedded steel in contaminated concrete is cathodic protection. The concept for this technique is to make the embedded reinforcing cathodic, as opposed to anodic where corrosion occurs, thereby preventing further corrosion of the steel. Cathodic protection is accomplished by electrically connecting the reinforcing to another sacrificial metal that becomes the anode. This can be done with power (impressed current system) or without power (passive system).

1) Impressed current systems:

There are several types of impressed cathodic protection systems available. The primary difference between the systems is the anode system and its use. These systems include:

1) surface mounted anode systems without overlays
2) conductive mastic systems
3) plate type systems
4) surface mounted anode system with overlay
5) mesh type noble metal anodes
6) conductive polymer concrete strips
7) embedded anode systems
8) saw slot anode systems
9) embedded anodes in new construction

2) Passive systems
  a) zinc hydrogel anode
  b) sprayed zinc or zinc alloys
  c) embedded galvanic anodes

Cathodic protection will not replace the corroded reinforcing. Any required structural repairs would have to be performed consistent with any repair program. At the current state of development, impressed cathodic protection is not recommended for use on prestressed concrete because of hydrogen embrittlement of the high strength steels might occur. If there is epoxy coated reinforcing in the structure, a determination of electrical continuity must be conducted to establish whether cathodic protection would be effective.

Unlike some of the other techniques and products now entering the market for concrete protection, cathodic protection has been in use in one form or another for years. The primary use for concrete structures has been on bridge piers, however, as opposed to buildings but nevertheless, most manufacturers can provide at least a partial track record of similar applications that are now commonly in use. (Refer to ACI 222R-96 Corrosion of Metals in Concrete for further information on this topic.)

c. **CORROSION INHIBITORS**

Corrosion inhibitors can be added to concrete as an admixture to delay the onset of corrosion of reinforcing. Most admixture formulations are meant to supplement the concrete's natural ability to protect the embedded reinforcing by forming assivating oxide layer on the steel. This will normally occur when concrete maintains its alkalinity at a pH of about 12. When chlorides reach the reinforcing steel, however, the protective passivating layer is damaged and the steel is no longer adequately protected. A commonly used product to accomplish this is a product that contains calcium nitrite that is produced by a well-known manufacturer of construction products. The amount of this product that is added to the concrete is based on the anticipated chlorides that the concrete will be exposed to over a given period of time. This product has been in used successfully to protect reinforcing in concrete for about 25 years and thus has a reasonable performance track record for the engineer to review. This admixture is appropriate for use in full slab replacements and concrete overlays for bridge decks and parking structure decks to protect any embedded reinforcement within that concrete.

More recently, however, a new generation of products have entered the concrete repair market that are surface applied to existing concrete and designed to migrate to the embedded reinforcing to protect it against future corrosion. The effectiveness of these materials is somewhat controversial and is currently be studied by various entities. ACI 546 Committee for Concrete Repair recommends that manufacturers should include in their literature the corrosion inhibitor type, recommended uses, application rates, constraints, anticipated effectiveness, and monitoring method.

SECTION 9
SUMMARY

Concrete protection systems are constantly changing because of improved technology as well as other factors such as changing governmental regulations. The specifier must keep up to date with the newest developments and carefully evaluate the products that they specify on a given project. This is not an easy task to accomplish but it is certainly important if the repair program is to be successful.

SECTION 10
REFERENCES FOR SELECTING AND INSTALLING PROTECTION SYSTEMS

a. Document ACI 515.1R, AA Guide to the Use of Waterproofing, Damp proofing, Protective, and Decorative Barrier Systems for Concrete is a good reference to start with for coatings. Unfortunately it has not been updated since 1985 and is no longer include in the Manual of Concrete Practice. It also is limited to only coating techniques. Nevertheless, it can be useful to refer if a barrier coating is an appropriate solution.

b. National Cooperative Research Program Report 244
"Concrete sealers for protection of bridge structures"
By: Wiss, Janney, Elstner and Associates Dec. 1981

This report is a comparison of 21 selected materials (initially) for various parameters including:
1) Ability to reduce chlorine intrusion
2) Study effect of concrete moisture content at time of application
3) Study effect of different coverage rates
4) Accelerated testing to determine long-term weathering exposure conditions, such as exposure to acids, salts and fresh water, UV light radiation, heat, freezing-thawing and wetting-drying

c. ACI 546R-04, Chapter 4--Protection Systems should be quite useful as a reference. Surface treatments, joint sealants and cathodic protection systems are discussed in detail.

d. ICRI Guideline No. 03732 Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings and Polymer Overlays.

e. ACI 222R-96 Corrosion of Metals in Concrete.

f. Concrete Society Technical Report 50 Guide to Surface Treatments for Protection and Enhancement of Concrete. This document is in the Second Edition of the Concrete Repair Manual published by ACI, ICRI, The Concrete and BRE.