WATERPROOFING CONCRETE: A GUIDE TO USING WATER REPELLENT SEALERS AND THICK FILM BARRIER COATINGS

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Abstract: Concrete and other cementitious surfaces are porous materials that will allow water and soluble contaminants to penetrate the structure leading to degradation. The effects of degradation can include efflorescence, laitance and physical defects such as cracking and spalling. Waterproofing concrete can protect it from freeze/thaw cycles, increase chemical resistance, and provide protection to imbedded reinforcing steel. Waterproofing coatings for concrete may include silicon based water repellant sealers and a variety of organic coatings. Water repellent materials have minimal dry film thickness over the concrete surface, are generally not opaque and need replaced periodically. Thicker film coatings function by providing a physical barrier ranging from a few mils to 100 mils and greater depending on the coating type. Typical organic coating types include acrylic, vinyl, epoxy, polyurethane and specialized elastomeric coatings. Concrete surfaces must be properly prepared before the application of any waterproofing coatings. Methods may include mechanical abrasion, pressurized water cleaning and acid etching.

Characteristics of Concrete

Concrete is the most widely used construction material in the world and is seeing increased use today. The basic composition of concrete is Portland cement mixed with aggregates, such as sand or gravel, and water. Various additives or admixtures may be added to modify characteristics as desired. The result is that there are a wide variety of concrete compositions making concrete a complex material. How the concrete is poured or placed to form a slab or structure can also affect its properties. The exposed surface can be finished by a variety of methods that will affect the surface characteristics and impact future preparation and coating application.

The high compressive strength of concrete is what makes it such an important structural material, but its limited tensile strength creates potential problems. Steel reinforcement is often imbedded in concrete to increase its strength and add to its desired properties. However, the steel becomes an added concern in terms of future corrosion problems. Concrete is a naturally alkaline and porous material. The natural alkalinity actually serves to protect the steel from corrosion under normal conditions, although it can cause difficulties with coatings. The porosity allows water and soluble materials to absorb into concrete, potentially causing substantial degradation to the structure and corrosion of any steel reinforcement. Therefore, protection of concrete from environmental factors may be critical to preserving its function over time.

Degradation of concrete can take many forms. The limited tensile strength, as noted above, can result in cracking and spalling after freeze thaw cycling occurs. Another common problem is the formation of a white crystalline material on the surface of concrete called efflorescence. This occurs when moisture travels through the concrete, dissolving soluble salts from the composition, and then deposits this material on the surface. The moisture dissipates leaving the salt residue on the concrete surface. Efflorescence is primarily a surface contaminant that needs to be removed prior to the application of coatings. The residue can typically be removed by washing the surface.[2, 3]

A greater potential problem is the formation of laitance – a thin, weak, layer brought to the surface of the concrete during pouring or finishing. Laitance may be the result of too much water in the mixture or overworking. This layer is poorly adhered and must be removed prior to coating. Laitance may be difficult to detect which adds to the problem.[2, 3]

Other problems to consider are the inherent alkalinity (high pH) and moisture content of concrete. Both can cause problems with coating adhesion if not checked and dealt with. New concrete, which may have a pH of 13 or 14, will slowly decrease to a pH of between 9 and 10. General guidance prior to coating application states that concrete should cure for at least 30 days. Moisture is a problem when it is present in excess within the concrete or from an outside source. There are a variety of test methods than be used to assess the moisture level, such as the plastic sheet method and calcium chloride test. Moisture meters can also give qualitative assessments of the moisture content.

Surface Preparation

Proper surface preparation is always one of the most critical items in successful coatings application. This holds particularly true with concrete due to its variety and complexity. An assessment of existing conditions first needs to be completed to determine if repairs are necessary – whether the concrete is new or existing plays an obvious role here. To begin with, the surface must be intact and sound. Cracks, spalls, and voids should be filled with an appropriate concrete repair material. The repair materials must be intended for use with concrete and appropriate for the service environment. For example, if an acrylic based product is used for exterior concrete, the material should generally consist of 100% acrylic resin versus an acrylic vinyl or polyvinyl acetate resin. Materials containing polyvinyl acetate resins may degrade in moist, alkaline environments, which are likely to be present with exterior concrete.

Regardless of which surface preparation method is employed, any contaminants must first be removed from the concrete surface. Cleaning solutions using detergents recommended for cleaning concrete are the best choice due to the difficulties of cleaning a porous surface. Typical surface preparation methods include mechanical abrasion, pressurized water cleaning and acid etching.

Abrasive blast cleaning of concrete can be accomplished if proper care is exercised. The goal is to roughen the surface without causing damage or gouging that might require repairs. Lower blast pressures and a greater stand-off distance may be needed with blast cleaning. An alternative to traditional blast cleaning is wet abrasive blasting, which includes two variations: injection of water into the air stream propelling abrasive (similar to dry abrasive blasting) or injection of abrasive into a water stream propelling abrasive (similar to pressurized water cleaning).[3]

Blast cleaning may also be performed using self-contained centrifugal wheel blast units that use a vacuum system to contain the abrasive and debris. These units are well suited to large horizontal surface areas such as for concrete floors and parking decks. Power tools, with or without vacuum shrouding, are also an option for preparing smaller areas.

Pressurized water cleaning can also be a viable method for preparing concrete. Water cleaning is effective at removing water soluble contaminants, laitance and weak concrete, and deteriorated existing coatings.

Surface preparation can also be completed by acid etching. This is where the reaction of an acid with the alkaline concrete surface removes the outer layer of concrete, thereby etching the surface. The concrete must first be free of any coatings, sealers or waterproofing materials, grease, oil or other contaminants. Acids that can be effectively used are hydrochloric (muriatic), sulfuric, phosphoric or citric acid. If acid etching is used, a critical step is thorough cleaning and rinsing to remove the excess acid and reaction products that are formed. Scrubbing of the surface may be required for complete removal. Failure to adequately remove these materials will likely result in future coating failure.[3]

There are various standards that can be used for cleaning and preparing concrete prior to coating. A general standard that provides procedures for inspecting concrete prior to surface preparation and discusses the various preparation methods is SSPC-SP 13, "Surface Preparation of Concrete." SP 13 references other standards and test methods detailing specific aspects of preparation. The following table summarizes some of the key standards or test methods.

Table 1: Summary of Key Concrete Test Methods

Standard or Test Method	Title
ASTM D 4259	Standard Practice for Abrading Concrete
ASTM D 4260	Standard Practice for Acid Etching Concrete
ASTM D 4261	Standard Practice for Surface Cleaning Concrete Unit Masonry for Coating
ASTM D 4262	Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces
ASTM D 4263	Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method
ASTM F 1869	Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride

Waterproofing Coatings for Concrete

"Waterproofing" concrete can have different meanings depending on the particular requirements involved. This paper divides waterproofing coatings into two categories: very thin film water repellants/sealers that penetrate the concrete, and thicker film coatings that provide true barrier protection to the concrete.

Water Repellent Coatings

The purpose of applying repellents (or sealers) is to eliminate or reduce the penetration of water and soluble contaminants such as chlorides into the porous concrete layer. Repellents are generally intended for use in above grade applications where concrete is frequently exposed to moisture. A good example is a parking deck or exterior concrete where thicker film coatings are not desired. Water repellent coatings or sealers consist of a variety of types with silicon based materials used most frequently. Other common repellents are epoxy sealers and linseed oil solutions (diluted with solvents).

Water repellent coatings generally function by reacting with components of the inorganic concrete to fill pores and make it difficult for water to penetrate the surface. Although water repellents will not keep pressure driven water from penetrating the concrete, absorbed water can easily evaporate from the concrete since repellents are permeable to water vapor. Water repellents can be expected to last up to several years depending on the concrete surface, specific repellent properties, and service environment. Repellents are low viscosity materials that can be water or solvent based. The material is typically applied by low-pressure spray to concrete surfaces with a typical problem being light coverage. The proper application can be difficult to judge because of the thin viscosity. The repellent provides protection by penetrating the pores of the concrete leaving little measurable film on the surface.[4]

Silicon based compounds are among the most common repellents since they resist oxidation and offer good thermal stability and heat resistance as compared to typical organic compounds. They also have good resistance to ultraviolet radiation (sunlight) and water, making them ideal as water-repellent materials. The hydrophobic nature of the silicon-based material repels water from the surface causing droplets to bead.

Silicon-based materials include silanes, siloxanes and silicones as described below. The terminology of these compounds is not always well understood. Silicon, which refers to the uncombined element silicon, forms compounds with hydrogen, oxygen and possibly organic alkyl groups to form compounds known as silanes, siloxanes and silicones. Although the discussion in this section is related to water repellent coatings, these types of silicon compounds can also be the basis for thicker film coatings.

Silanes refer to inorganic compounds composed of silicon and hydrogen with the general formula Si_nH_{2n+2}, where the silicon atoms are single-bonded to each other in a chain, with the remaining bonds to hydrogen. Silanes are analogous to alkanes in organic chemistry. Siloxanes are compounds comprised from silicon, oxygen and an alkyl group. The name comes from a combination of <u>si</u>licon, <u>ox</u>ygen, and meth<u>ane</u>. The general formula for siloxanes is R_2SiO, where R is an alkyl group. An example is hexamethyldisiloxane Silicone compounds refers to polysiloxanes, which are simply polymeric versions of siloxanes as described above. An example is poly(dimethylsiloxane) with a repeating $(CH_3)_2SiO$ group, where the polymer backbone chain consists of alternating single-bonded silicon and oxygen atoms (e.g. Si – O – Si).

The surface preparation requirements for water repellants basically consist of clean and sound concrete. The surface does not need to be roughened appreciably since the repellant absorbs into the concrete rather than adheres to the outer surface. A clean surface is critical, however, for repellents to function as intended. For example, grease or oil on the surface will prevent the repellent from absorbing into the concrete.

<u>Thicker Film Barrier Coatings</u>

The requirements for waterproofing concrete might also dictate applying a conventional coating to protect the surface from exterior weathering, provide water resistance, or to otherwise protect the concrete. There are a wide variety of coating types that can be successfully used on concrete depending on the particular application. This section provides an overview of coatings for typical waterproofing applications, but does not address linings for immersion service or coatings for underground structures.

Thicker film coatings function by providing a physical barrier ranging from a few mils to 1/8 inch and greater depending on the coating. Typical organic coating types include acrylic, vinyl, epoxy, polyurethane, polyurea and specialized elastomeric linings.

Note that alkyd or oil-based coatings should never be specified for application to concrete since the alkyd resin may chemically react with alkaline concrete compounds and moisture leading to saponification. This reaction transforms the resin into a soft material that no longer resembles a coating and provides little protection to the concrete substrate. Saponification literally decomposes an alkyd coating into the chemical compounds that originally formed the resin, an alcohol and fatty acid.

Elastomeric coatings are generally thick (10 to 100 mils dry film thickness), flexible coatings with very low water permeability. They are typically used for exterior concrete applications such as building exteriors, roofing systems and parking decks, but can also be considered for interior applications such as showers and spas. There are multiple coating resin types that comprise elastomeric coatings, including acrylic and latex products, silicones, polyurethanes and polyurethane/polyurea hybrids.

Acrylic, latex and silicone elastomeric coatings are single component materials that are relatively easy to apply. Acrylic resins are commonly derived from ester monomers based on acrylic acid and methacrylic acid with the general formula $CH_2 = CR_1R_2$ (where R_1 is a hydrogen atom for acrylic acid and a methyl group for methacrylic acid). Many of the properties of the resulting polymer will be dictated by the R_2 group, leading to a wide variety of acrylic resins. Acrylic coatings are generally resistant to alkaline hydrolytic attack since the polymer backbone chain does not contain the ester group that is present in the resulting polymer. Acrylics may also include vinyl chloride and styrene in their formulation to increase acid, alkali, and water resistance.[4] Acrylic elastomeric coatings are typically applied up to 20 to 30 mils dry film thickness per coat, requiring multiple applications when thicknesses beyond this range are needed. Elastomeric coatings can also be based on silicone chemistry. Silicones, as described for water repellent coatings, are polymer resins containing silicon and oxygen (or polysiloxanes). Silicone elastomerics are typically applied to a minimum dry film thickness of 10 mils.

Polyurethane and polyurea based elastomeric coatings are typically multi-component materials requiring application by plural-component spray equipment. While these types of coatings may function well as waterproofing coatings, they are also used where some chemical or solvent resistance is required. These coatings are typically 100% or very high solids materials that are applied in a single coat that cures very rapidly. The rapid curing can present problems with the coating adequately wetting the surface leading to poor adhesion. Polyurethanes are formed by the reaction between an isocyanate and a polyol, such as polyester, polyacrylate, or polyether. Polyurethanes formulated from polyether polyols generally have better water resistance and are often used in applications where water may accumulate on the coating surface (e.g. a roof).[4] Polyurea coatings are formed by the reaction between an isocyanate and an amine. One advantage with polyureas is that the rapid curing reaction is not affected by moisture or temperature, which can negatively affect the cure of polyurethanes. The cure is so rapid for polyureas however, that the problem with achieving adequate surface wetting can be more pronounced, sometimes preventing the successful use of these coatings. Hybrid polyurethane/polyurea coatings, formed using a combination of the two resin types, potentially offer a solution in combining the best features of each coating type.

Single-component elastomeric polyurethane coatings can also be formulated using moisture-curing polyurethane resins. These resins contain functional groups that react with moisture in the environment to form the cured coating film. Moisture-curing polyurethanes offer nearly the same performance properties as multi- component polyurethanes with the obvious advantage of a single pack product that does not need plural-component equipment for application.

Typical elastomeric coatings are generally a good match for concrete since they can tolerate some substrate movement and may be able to fill or bridge minor cracking. An alternative to spray applied elastomeric coatings are sheet materials or membranes that are set in place using adhesives. A critical step in sheet installation is properly sealing the seams between sheets of material. The seams are the obvious place where the system will fail if any defects are present. An advantage of using sheet materials is potentially faster installation.

Thinner film (as compared to elastomeric) acrylic and polyurethane coatings can also be used to protect concrete. These coating systems will be several mils thick and are typically applied at 2 to 3 mils per coat. Acrylic products will usually comprise a two or three coat system that includes a primer and one or two finish coats. With acrylics, it is again important that the coating consists of only 100% acrylic resins to prevent attack of the coating from the alkalinity and moisture of concrete. Polyurethane coatings will consist of one or two coats and may require a primer coat.

There are a variety of epoxy coatings that can be used for the purposes of waterproofing. Typical epoxies are multi-component materials based on bisphenol A resins with a polyamide or amine curing agent. Polyamide epoxies are known for having better flexibility and water resistance, while amine cured epoxies typically have better chemical resistance. These properties make polyamide epoxies a more logical choice for protection of concrete for the purposes of waterproofing and providing water resistance. Polyamide epoxies are typically applied in one to three coats at an application thickness of several mils per coat. Thicker film epoxy coatings, such as those based on epoxy phenol novolac resins, are also commonly used on concrete. Novolac epoxies, however, are more often used for the purpose of providing chemical resistance. For exterior exposure, epoxy coatings should generally be topcoated since they chalk in sunlight. Topcoats for epoxies include acrylics and polyurethanes.[1, 4]

The surface preparation for thick film coatings typically requires mechanical abrasion or acid etching to roughen the surface and ensure that coatings can properly adhere to the concrete. If the surface is too rough, damaged, or irregular, surfacing or block filler materials may be required. As cautioned previously, any surface repair materials must be appropriate for the intended service environment. Most thick film coatings have low water permeability and will not easily allow moisture in the concrete to escape. If the concrete contains too much moisture, blistering and delamination of the coatings results. Tests for moisture should always be completed before applying thick film coatings.

Conclusion

Waterproofing concrete using water repellent sealers and thicker film barrier coatings can significantly extend its useful service in many applications. Waterproofing can prevent water, soluble salts and other contaminants from absorbing into the naturally porous concrete structure. Waterproofing coatings will provide some protection from freeze/thaw cycles, increase chemical resistance, and provide protection to imbedded reinforcing steel. Successful application of waterproofing coatings includes performing the appropriate method of surface preparation, and selecting the right type of coating based on performance requirements and service environment.

References

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