Concrete Coatings:

Selection and Preparation Provide a Solid Foundation

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The types of coatings available for concrete surfaces vary extensively, as do the applications of the concrete material itself. Despite its strength, concrete must be protected, and coatings provide a first level of defense. In many cases, the decorative function of a coating is of equal or greater importance than its protective ability. Choice of coating type is determined by desired performance characteristics and environmental conditions. Regardless of the ultimate purpose, proper preparation of the concrete surface must be completed prior to application of the coating in order to achieve optimum results.

Concrete is used in industrial, commercial, and residential settings, and in many cases is exposed to harsh environments. It is used as a flooring material, for walls, for secondary containment systems, and in tank structures, to name just a few applications. Although it is considered by most people to be a very strong building material, concrete is actually porous and weak and requires protection from deterioration and contamination. Concrete does not flex, but tends to develop cracks that must be bridged with a flexible and elastic coating. Highly alkaline or acidic conditions can also damage concrete. Protective coatings provide abrasion-, corrosion-, and chemical-resistance. They may also need to protect the concrete surface from blushing and exposure to ultraviolet light.

Additional functional properties can be imparted by concrete coatings. Safety properties, including skid and slip resistance, are often important in flooring applications. Water resistance, static control, reduced wear (dust control), and increased ease of maintenance are additional benefits of some coatings used on concrete surfaces. Coatings can also be used to mark aisle ways and hazard areas. Coatings applied for decorative purposes can improve the aesthetics of both horizontal and vertical concrete surfaces through the addition of color and texture.

For all concrete surfaces, coating performance is directly linked to the care taken in preparing the substrate prior to coating application. Both new and old concrete surfaces require pretreatment before the paint or coating can be applied. "The porous nature of concrete leads to many difficulties in any coating or lining application," notes Christiane Hackl, polyurea industry manager for BASF's Intermediates group. "Many of the failures related to application of coatings over concrete have been due to the absence of, or incomplete, surface preparation," she adds. According to Dudley J. Primeaux II of Primeaux Associates LLC, one of BASF's collaboration partners for concrete coatings, guidelines set forth by the Society for Protective Coatings (SSPC), the International Concrete Repair Institute (ICRI), and the Polyurea Development Association (PDA) must be followed if the desired performance level and full lifetime of the coating are to be achieved.

"Proper surface preparation is of prime importance to the durability and adhesion of the coating applied," stresses Derek Kincaid, technical manager, Coatings Construction and Adhesives with Huntsman. "Poor surface preparation leads to coating failure through loss of bond rather than material deterioration," adds Robert Cain, president of Key Resin Company. "The surface must be structurally sound, clean (free of all surface contaminants including oil, grease, dirt, mildew, efflorescence, chalk and other foreign substances, flaking paint, etc.), and must not be contaminated with any foreign material that could interfere with the bond of a new coating system."

New concrete must be cured for at least 30 days with a pH of 10.0 or lower prior to painting, unless using an alkali-resistant primer, according to John Dorado, senior brand manager for ICI Paints' Devoe Coatings group. "The high alkalinity of new concrete can cause a breakdown of a coating binder (alkali burn), resulting in discoloration and/or deterioration of the coating system," he explains. Curing compounds, bond breakers, and form release agents remaining on the surface will prevent proper adhesion development of paints and coatings, according to Raj Sandhu, also a senior brand manager, Devoe Coatings with ICI Paints. "Failure to remove these materials can result in adhesion failure and blistering."

New concrete surfaces also typically have a thin layer of fine cement particles that are created from the vibration and toweling movement made when the concrete is finished, according to Mr. Kincaid. When this layer sets, it is called "laitance" and it gives the surface a uniform smooth appearance. "The preferred method of preparing new concrete is to remove this laitance through mechanical means such as grinding, sandblasting, and mechanical scarification, followed by vacuuming to remove all dust and loose material. Should mechanical cleaning prove impractical, then the surface may be cleaned by preparing with acid etching then flushing off with high pressure water and drying," he states. Regardless of the method, all remnants of the laitance layer must be removed prior to priming and painting.

For existing concrete surfaces, the required surface preparation will depend on the condition of the material. "Each substrate should be considered separately and its condition analyzed before making any decisions on placing a coating," Mr. Kincaid comments. "Old concrete is often deteriorated and presents a weak surface on which to bond. Removal of this weak upper layer is always preferable and often essential to ensure good bonding." Mr. Cain adds that patching, repairing, and leveling of existing concrete surfaces are as important as the coating system, and any material used to level, patch, or slope must be compatible with the total system.

Environmental conditions must be considered for both old and new concrete surfaces. Moisture can be a critical issue. Water ingress behind the paint or coating film, which can result from moisture content in new concrete, concrete walls, and parapets not properly capped and sealed; rain and weather exposure; improper coving and drainage; and other sources, can lead to blistering and adhesion failure, especially for elastomers. "Checking for the presence of excessive moisture and the elimination of sources of moisture intrusion is an important part of the preparation process," says Mr. Sandhu. The concrete must be dry prior to priming and painting. The surface and air tem-

Photo courtesy of Elphem.

perature should also remain above 50°F (10°C) when applying primers and paints unless using a primer and paint with cold temperature capability.

Coating thickness and uniformity is also an issue for concrete surfaces. "A protective coating should be penetrating and form a good film over the concrete surface," states Valerie Johnson, communications manager for Elliokem. Ms. Hackl adds, "For concrete, the coating/lining system must also be applied at a uniform, complete thickness. Voids in the coating system could lead to deterioration of the concrete underneath." Coating thickness can often be a problem area, according to Mr. Cain. "Getting the owner to realize the long-term benefits of applying thicker coatings can be challenging." Coatings for concrete are typically classified as thin film (1–10 mils), high build (10–30 mils), slurries (40–125 mils), and toppings and overlays (125 mils to one-half inch or more).

Overall, application of the coating according to the manufacturer's recommendations, including proper surface preparation, priming, application method, and film thickness, will lead to a high-performing and long-lasting concrete surface coating, as long as the coating best suited for the service and exposure environment has been selected. "Matching the coating with the proper environment, surface preparation, and the experience of the applicator are the three most important factors contributing to the successful application of coatings to concrete," says Randy Kerans, marketing manager with Sherwin-Williams Industrial Paints.

Several factors should be considered when determining the most appropriate coating type. Possible stresses to the coating including excessive moisture, chemical exposure (severity and types of chemicals), abrasion, impact, and thermal shock must be evaluated and prioritized, according to Mr. Cain. Aesthetics (color, texture, gloss, etc.), coating application issues (length of time, odors, etc.), life expectancy and maintenance requirements, and economics are other critical parameters.

The type of concrete structure, the environment in which it is located, and the desired performance of the coating will also determine the specific type of resin for a given coating application. There are five main types of resins used in coating formulations designed for concrete: acrylic, epoxy, urethane, ureas, and hybrids. Acrylics are used for decorative coatings as well as for primers. Epoxy, polyurethane, polyurea, and hybrid coatings are often referred to as high performance coatings, according to Mr. Sandhu. While these coatings primarily serve protective and functional purposes, they are often decorative as well. Epoxies are recognized for their chemical and abrasion resistance but have limited flexibility. Urethanes have more flexibility but less resistance. Ureas, which were introduced in the 1990s, offer flexibility and resistance with a very rapid cure, but require special application equipment. Hybrid resins attempt to achieve the combined properties of excellent resistance, good flexibility, and reduced cure time with ease of application.

Acrylic resins find wide application in coatings for concrete and allow coatings companies to formulate one-part coatings, according to Ms. Johnson. Tim Takas, technical business development representative, Epoxy Products and Specialty Resins with Reichhold, notes that acrylics can be used as thin film UV resistant topcoats, as floor coatings when used with heavy fillers, and as penetrating primers. "Concrete coatings that are mainly decorative in nature are based primarily on acrylic emulsion technology and, to a lesser extent, alkyd and epoxy resins," adds Mr. Kincaid. "These acrylic emulsions include pure acrylic, vinyl acrylic, and styrene acrylic technologies. The copolymers are formulated into water-based systems that offer a good balance of weathering resistance, moderate protective properties, and ease of application, lending themselves particularly to the DIY markets."

Coatings based on acrylic resins do present drying problems at lower temperatures and high humidities, but under good conditions dry quickly. The choice of co-monomers and the molecular weight of the resin can be tailored for the application as well. Vinyl

acrylics exhibit excellent water resistance and are used as primers, while styrene acrylics, which form harder coatings, offer high gloss retention and can be used for topcoats as well. According to Mr. Dorado, elastomeric coatings based on acrylic resins, in addition to being decorative, provide both crack-bridging capabilities and water resistance. "The texture properties of these types of products also help give a uniform appearance to rough and irregular surfaces," he notes.

Acrylic coatings also possess good corrosion and chemical resistant properties. "In addition, acrylic-based coatings can provide resistance to alkali, efflorescence, and abrasion. New generation acrylics are also available for coatings that require dirt pickup resistance, elongation, and tensile properties for vertical masonry such as stucco and E.I.F.S. (Exterior Insulating Finishing Systems)," Ms. Johnson says.

With their good adhesion and moisture and chemical resistant properties, epoxies are used for both protective and decorative coatings, according to Mr. Takas. Epoxy resins are often used for light duty industrial and commercial maintenance, heavy duty industrial applications such as secondary containment facilities, and in floor coatings, notes Mr. Dorado. "Epoxy resin systems have been used for over 50 years to protect concrete from severe environmental conditions. Their combination of excellent chemical resistance and mechanical properties makes them best suited for applications where the concrete will be exposed to severe conditions. Concrete used in both flooring and vertical surfaces which need protection include areas such as food processing plants, hospitals, and various industrial and chemical facilities," explains Mr. Kincaid.

There are some limitations to epoxy resins, of course. "The main drawbacks to the epoxy systems are slower cure/set and they are not very flexible," notes Mr. Primeaux. They also chalk on exposure to UV radiation in natural sunlight. Advances in epoxy technology have included development of 100% solids formulations, modification of the resin structure through incorporation of alcohols, phenols, fatty acids and other compounds, and introduction of curing agents exhibiting lower toxicities.

In general, urethanes are used for thin film to high build coatings, have excellent abrasion and wear resistance, excellent gloss retention, and good-to-excellent stain and chemical resistance, according to Mr. Cain. They also typically have improved flexibility as compared to epoxies. Some urethanes have excellent elastomeric properties and, together with their low permeability, are used extensively in waterproofing applications, Mr. Cain notes. There are several types of polyurethanes used for coating concrete. Aliphatic polyurethanes provide UV resistance in decorative coatings, while aromatic urethanes, which do not weather well, are used more as primers. Acrylic urethanes possess better weathering properties. On the negative side, most polyurethane coatings are usually solvent-based, they often have slow cure times, and two-part systems present handling issues due to the toxicity of the materials.

Polyureas were introduced to the marketplace in the 1990s. Like polyurethanes, polyureas are formed by the reaction of isocyanates, but with amine-functional oligomers rather than hydroxyl-functional polyols. Polyureas are typically solventless formulations that form flexible, extremely cold weather tolerant, fast curing coatings. Because the cure occurs within seconds, special multi-component sprayers that mix the isocyanate and amino-oligomers in the spray tip are necessary. Sometimes poor surface appearance and loss of adhesion can also occur as a result of the extremely short cure times.

"Despite these issues, polyureas do have an advantage over polyurethanes and hybrids because of their rapid set/fast return to service properties," says Ms. Hackl. "Coatings based on this technology are uniquely suited for applications where speed of cure is critical. Systems based on polyureas can be formulated to cure within seconds and can be returned to service in a matter of a few hours," adds Mr. Kincaid. Polyureas also possess good abrasion resistance and can tolerate higher temperatures than polyurethanes.

Photo courtesy of BASF.

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Hybrid technologies have also received interest from concrete coatings formulators. Silanised epoxies have much better weathering properties than typical epoxies while retaining the desirable properties of chemical resistance, durability, and gloss retention. Epoxy/urethane hybrids offer good-to excellent thermal and stress relieving properties as well as impact resistance.

Nanotechnology will likely play a part in future concrete coating developments. Epoxy coatings containing microcapsules of monomers that are released when the coating is damaged and then repair the damage are being investigated in a number of research laboratories. Other "self-healing coatings" contain anticorrosive additives that are released when corrosion is detected to halt further damage and possibly repair the coating. In a separate approach, nanoparticles are tested in sensor applications. Specific changes in the coating can trigger the release of colored or fluorescing particles that can indicate where damage has occurred. These approaches are most attractive for heavy duty coatings that can incorporate the nanoparticles without compromising the appearance and other performance aspects of the film.

Near term development efforts continue to be directed at reducing the cure times of traditional epoxy and urethane coatings and the development of low-VOC coatings. Peter Chetcuti, business director for the Coatings, Construction and Adhesives group of Huntsman Advanced Materials notes that, "There have been a number of advancements over the last 20 years in surfactant and dispersing technologies that have led to the replacement of solvent-based coatings with water-based systems. Epoxy-based coatings have benefited particularly from these advancements. This has enabled the reduction of VOCs and, in some cases, enabled complete elimination of VOCs."

Faster return-to-service will continue to be an issue as well. "There will always be a drive to create coatings that will cure faster, enabling the coatings to be returned to service quicker. The development of polyurea based systems has made the greatest progress in this area. Epoxy and acrylic-based systems will continue to move in this direction," asserts Mr. Chetcuti. Mr. Kerans adds that, "In addition, customers are also looking for improved ease-of-application and resin systems and coating formulations that are more forgiving with respect to surface preparation requirements." One example is the development of high performance flooring products/systems that are tolerant of moisture vapor emissions. These coatings continue to protect the concrete while allowing moisture to permeate through the system without disbondment.

Providers of polyurea coatings are looking to develop resins that are easier to apply. "Some amine chain extenders have allowed for easier application of the aliphatic-based (color stable) polyurea systems, which results in improved adhesion as well as smoother, more aesthetic surfaces in the polyurea coating," Ms. Hackl explains. Easier-to-use primer systems based on single component materials are also helping to reduce the return-to-service time for polyurea systems even further.

These developments are occurring during a time of flux in the overall coatings market, which has impacted the concrete sector as well. Fluctuating raw material and energy prices have been an issue for resin producers and coatings formulators alike. At the same time, environmental regulations are becoming increasingly strict, particularly with respect to VOCs in coatings of all kinds. Consolidation and globalization are continuing trends as well. "The development of new technologies and innovation under such circumstances is a major challenge for the industry," Mr. Salvadore emphasizes.

VOC regulations are changing the concrete coatings industry dramatically. "As the VOC requirements are lowered, many producers are moving to water-based products in order to formulate within the VOC range and remain in this segment. The challenge is to create water-based products that have solvent-based performance," comments Ms. Johnson. "Solvent-based coatings continue to be in demand due to their penetrating and protection properties, however, and Eliokem will continue to develop new polymers to meet manufacturers' needs and to support this segment." The pressure being

imposed on the industry to lower VOCs while maintaining the same high performance levels and ease-of-use is significant, adds Mr. Chetcuti. "Products introduced to the market based on novel technologies will command an added value for both suppliers and formulators. The challenge to resin producers and formulators is to bring user friendly products into the market with the same level of performance as conventional solvent-based coatings."

Rising energy and raw material costs are expected to be a driver in the concrete coatings market for some time. "2005 was a very tumultuous year due to rapidly rising costs. Usually this situation will drive alternative products, and better systems and companies that are well established will survive," Mr. Cain states. He also expects that the global economy will keep the market and demand for material at a high level. According to Mr. Takas, low pricing from competitors to gain market share is another significant driver in the market, even in the face of rising raw material prices and energy costs. Resin manufacturers in particular are facing eroding margins. "Many customers are under strong pressures from their distribution outlets to maintain stable pricing. It has been a challenge to pass on price increases and in many cases resin producers have absorbed the increases," Ms. Johnson says.

Developing closer relationships with customers and developing products to meet their specific needs has been the approach of many resin and coatings producers. Eliokem is focused on developing low viscosity resins for VOC-compliant coatings for the concrete market. The company is launching a new resin for porch and floor paints to meet upcoming VOC regulations. Eliokem recently introduced Pliolite acrylic solvent-based thermoplastic resins that are compatible with several exempt solvents and can be used to formulate high-solids coatings while maintaining good working viscosity used for low VOC formulating. Pliolite PA90 is an all acrylic water-based resin used in clear concrete coatings that imparts excellent blush, alkali, and abrasion resistance. To support its acrylics business, Eliokem is expanding latex capacity at its Akron, OH, plant and is developing partnerships with other companies in order to expand its product and technology range and to increase its manufacturing capabilities.

Huntsman has developed rapid cure epoxy curing agents for the construction flooring market as well as low emission curing agents that will be introduced into the concrete coatings market in the near future. Key Resin is active in establishing a market for the decorative concrete and coatings area including decorative concrete designs, metallic finishes, and decorative coatings. Capital investments for the company include new manufacturing capacity at both its Phoenix, AZ, and Cincinnati, OH, facilities.

Reichhold recently patented waterborne epoxy systems that possess excellent adhesion to concrete and are extremely fast drying. These new products are now part of the company's line of resins designed for concrete coatings that includes styrene-acrylic emulsions, waterborne oil-modified and moisture-cured urethanes, traditional epoxy resins, epoxy curing agents, polyester and acrylic polyols, and hindered amines for polyurea systems.

Both ICI Paints and Sherwin-Williams offer broad lines of coating formulations for the concrete market. ICI Paints offers an assortment of acrylic, epoxy, polyurethane, polyurea, and advance resin technologies for applications ranging from decorative coatings for horizontal and vertical surfaces to highly protective and functional wall and floor coatings. Primers, sealers, and top coats in both waterborne and solvent-based formulations are available.

Sherwin-Williams also has a complete line of concrete coating products. Most recently, the company introduced two products for concrete floors that eliminate the potential failure due to moisture vapor emissions. Aquarmor is a waterborne epoxy that can be applied as a coating, slurry, or mortar, and Fastop mvt is a water-based cementitious system that controls moisture vapor emission. CT