Is It Tough Enough?

How to protect concrete and steel with the proper coating

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By Mike Kramer

By definition, most heavy industries can be classified as part of the chemical process industry. Any industry whose products result from chemical, physiochemical, extraction or purification of a natural product or the preparation of specifically formulated mixtures of materials, either natural or synthetic, can be considered a chemical industry. Examples include the petroleum, paper, textile, perfume, plastics, rubber, leather, food, dye and pharmaceutical industries. Many of these involve one or more operations of chemical engineering as well as processes of polymerization, oxidation, reduction and hydrogeneration, usually with the aid of catalysts. This could be interpreted to include ore processing, separation and refinement as well as the manufacture of metal products, although these are usually considered metal and metallurgical industries. Although classifications may seem irrelevant, all these industries have something in common &#151 the need to protect structures and surrounding environments from corrosion and contamination. Today, we have more than 100 elements from which 7 million known natural or artificial compounds can be derived. Of this number, 96 percent or 6.5 million are organic or carbon bearing and one-half million are inorganic. A significant number of these elements and compounds are hazardous, i.e., poisonous, carcinogenic, corrosive or combustible. A good example is sulfuric acid, which is very corrosive to most metals and organic compounds. It is by far the most widely used industrial chemical, with U.S. production exceeding 80 billion pounds annually. Facilities that manufacture or store chemicals are constructed of concrete and steel, both of which are susceptible to acid attack. Concrete, which is the most widely used building material in use today, is a mixture of calcium, silica, iron and aluminum minerals. Limestone is the calcium-containing material most used to make cement. The pH of concrete normally runs 12-14, which is strongly basic and consequently readily reactive with acids. The result of the reaction is soluble salts and complete deterioration of the concrete.

In process areas, the structural steel, tanks, pump bases, deck slabs, trenches and drains all need protection.

Other characteristics of concrete are its porosity and susceptibility to cracking. For these reasons, even materials such as solvents that do not attack concrete or its reinforcement may be an environmental problem because they can soak through concrete. Consequently, concrete is not in itself an acceptable material for use in the containment of liquid chemicals or dry chemicals that are water soluble and exposed to exterior elements. Penetration of salt-laden moisture can also be detrimental to a concrete structure even though there is no reaction between the concrete and the particular salt involved. The salts can penetrate and corrode metal reinforcement in the concrete. The resulting expansion of metal oxide can cause immense internal forces that crack and split the concrete. Spalling of concrete is often caused by the simple result of wet and dry cycles combined with salts in the concrete or exposure to other sources of salt. The salt ions are absorbed into the concrete while in solution. As the liquid media evaporates, the salts recrystallize and exert tremendous internal pressure &#151 approximately 10,000 psi &#151 which far exceeds the strength of the concrete and in turn causes cracking and spalling.

Pinpointing Problems

IMPORTANT EPOXIES

Below is a list of the characteristics of four key epoxies. &#149 Bisphenol A Epoxies Chemical resistance: Good for mild acids and concentrated phosphoric and hydrochloric acids; excellent for salts and most bases including concentrated sodium hydroxide (caustic). Solvent resistance: Fair for straight chain hydrocarbons and some alcohols and acetates. Bond strength: Excellent chemical and mechanical adhesion. Moisture tolerance: Excellent; can be installed over damp surfaces. Resilience: Good; up to 9 percent elongation (resin only). &#149 Bisphenol F Novolac Epoxies Chemical resistance: Good for all inorganic acids including concentrated sulfuric; best for concentrated sulfuric acids; excellent for salts and most bases including concentrated sodium hydroxide (caustic). Solvent resistance: Good for all except chlorinated and ketone solvents. Bond strength: Excellent chemical and mechanical adhesion. Moisture tolerance: Very good; can be installed over damp surfaces. Resilience: Good; up to 14 percent elongation (resin only). &#149 Bisphenol F Modified Novolac Epoxies Chemical resistance: Good for all acids, organic and inorganic, including concentrated sulfuric acids; excellent for salts and most bases including concentrated sodium hydroxide (caustic). Solvent resistance: Best for all types including resistance to ketones and chlorinated solvents. Bond strength: Very good adhesion. Moisture tolerance: Good. Resilience: Good; up to 6 percent. &#149 Vinyl Ester Epoxies Chemical resistance: Best for organic acids; good for inorganic acids except concentrated sulfuric (unacceptable for concentrated sulfuric acids); excellent for salts and most bases including concentrated sodium hydroxide (caustic). Solvent resistance: Poor for ketones, chlorinated solvents and aromatics. Bond strength: Mechanical adhesion only. Moisture tolerance: Generally poor. Resilience: Poor.

EPA’s regulation 40 CFR 264.193 states that secondary containment systems must be constructed of materials that are compatible and resistant to the chemicals to be contained.

Older technologies included the use of acid brick, which has given way to more modern technologies. Acid brick is extremely expensive, costing many times more than modern polymers. Structurally, it is weak at grout joints, where cracking often occurs. The bricks were also set in asphalt mastics, which are a chemically weak point of the system. Because of concrete’s susceptibility to corrosive acids and porosity, which allows penetration by liquids, a protective liner is required. The liner must be free of wrinkles that can cause puddling, and it must be able to resist the type of traffic to which the area will be subjected. Heavy wear areas, such as truck unloading bays or drum storage, usually require a one-fourth-inch topping. Often a fiberglass mat or cloth is incorporated in areas of frequent or potential movement, cracking or wetness, where cracks could go unnoticed. Tank farm areas that are subjected to mainly foot traffic and less physical abuse usually receive coatings ranging from 60-120 mils. For areas encountering no traffic, such as walls, the film thickness can be reduced to 30 mils. Because the film must be continuous, it’s necessary to surface the concrete to eliminate any porosity before applying a protective coating. Areas subject to more chemical exposure, such as pump bases, should have a thickness of 50 mils or more. Process areas are normally exposed to severe attack, potentially from all the chemicals used or produced. The structure and slabs in these areas can be constantly exposed to splash, spills and/or constant drips. In addition, they are often subjected to the most severe physical abuse in the plant. Storage areas in pharmaceutical, semiconductor and petrochemical plants are subject to cutting edges from steel containers, coupled with spills of aggressive chemicals. Metal refining plants are subject to severe spills of acids, constant fumes, heavy machine traffic and impact from metal anodes. In process areas, structural steel, tanks, pump bases, deck slabs, trenches and drains need protection. In these severe exposures, common paint and coatings are inadequate to protect exposed steel or concrete. Most acids and salts readily attack steel in the structure. While some chemicals such as sodium hydroxide or organic solvents do not corrode steel, inadequate protective coatings can be destroyed, which in turn leaves the steel exposed to other common corrosive conditions such as rain or airborne corrosives including salts and dew. This is a dichotomy since simple coatings would protect the steel from weathering rust, plus the steel may be impervious to the process corrosives; however, unless the coating used can resist the chemicals, the steel will be exposed to corrosion from simple weather exposure.

Suitable Protection

Heavy wear areas, such as truck bays and drum storage, usually require a ¼ in. topping.

The most suitable protection for structures, tanks and secondary containment is obviously a continuous coating system constructed in a manner that is appropriate for the traffic service. The selection of the correct coating is dependent upon the chemical resistance of the various generic types. Usually solvent-free 100 percent coatings will crosslink tighter and faster than solvent-containing coatings and consequently will develop greater chemical resistance quicker. Floor areas subjected to frequent spillage must be porosity-free. The best results will be achieved using a resin-rich system instead of a resin-starved topping. Aggressive chemicals can migrate through a porous resin-starved system much faster than the resin-rich toppings that are porosity-free.
The generic type of coating to be used is determined by the chemicals, concentration and period of exposure. Generally a period of 72 hours resistance is mandated to comply with EPA 40 CFR for secondary containment. The general housekeeping practices for the area being coated will also be a factor in the correct coating selection. Spills might not be cleaned up promptly or within 72 hours. An area subjected to constant exposure, such as wet trenches or sumps, will require a coating capable of indefinite contact, much the same as a tank lining. In such cases, 72-hour secondary containment exposure may be an inadequate gauge. Another variable to take into consideration is temperature. Generally, the higher the temperature of the chemical, the more aggressive it will behave. Also, if more than one chemical will be encountered, the synergistic effects of the mix must be considered and possibly tested if the combined effects are unknown. Tank linings, sumps and wet trenches offer the most severe exposures due to constant contact

with chemicals. In these cases, the coating system must be pinhole-free and applied over the best possible surface preparation possible. The temperature of the liquids becomes even more critical. For steel tanks, the temperature of the liquids introduces another factor &#151 osmotic pressure. Osmotic pressure is commonly referred to as the cold wall effect in which liquids at elevated temperatures in non-insulated tanks have the tendency to pass through any membrane or coating to equalize concentrations on both sides of the coating. It is important to know the exact temperature of the liquid. When it exceeds 140&#176F, consideration must be given to the use of insulation for the exterior of the tank. At temperatures of 160&#176F and above, insulation is a necessity.

More Selection Guidelines

Concrete in chemical process areas are normally under severe attack, constantly exposed to the chemicals being used or produced.

The objective of selecting the correct coating system is more than just being sure of adequate chemical resistance. The cost of the materials increases along with chemical performance. Therefore, the material chosen should be adequate for the environment but not more than required.

For example, basic bisphenol F novolac materials are approximately 25 percent more expensive than an epoxy amine. Likewise, high functionality novolacs are 40 percent higher than an epoxy. Obviously, economics dictate selection of a generic type that is not in excess of the requirements. However, if there is a potential future change in the chemicals that may be encountered, they should also be included when the generic selection is made. It can be very expensive to recoat, and if future changes in the process are known, allowances should be made to compensate for them. Generally speaking, bisphenol A epoxies provide excellent resistance to salts, caustics, mild acids and straight chain hydrocarbon solvents. They do not do well in some strong oxidizing acids or solvents but do well in concentrated hydrochloric and phosphoric acid but only 50 percent or less sulfuric. The chemical resistance of various epoxies is shown in the companion article, “Important Epoxies.” For example, it indicates that the best resistance to concentrated sulfuric acid is achieved with bisphenol F novolac epoxies. These materials also offer better resistance to organic acids, aromatic solvents, bleaches and oxidizers. The article also indicates that high functionality bisphenol F novolac epoxies offer the best resistance to all organic solvents including chlorinated solvents such as trichloroethane and methylene chloride. Resistance to ketone solvents is also excellent as well as many organic acids.

Selection Notes

The selection of an appropriate coating is only one step in protecting concrete. Proper surface preparation and application are mandatory for satisfactory performance. Generally, concrete should be cured 28 days, and it should be dry. To determine if concrete is dry enough, use the sheet method in accordance with ASTM D 4263 in which a clear polyethylene sheet of four square feet is taped to seal the surface. When examined 24 hours later, there should be no evidence of water under

the plastic film. Interior slabs can be tested using the rubber manufacturers calcium chloride test. The theoretical limit is four pounds of moisture for every 1,000 square feet. Consult with the manufacturer if results are divergent from these standards.
In addition, the concrete must be clean and free of grease, oil or other contaminates. The best way to achieve this is by detergent or steam detergent cleaning. Because of the porosity of concrete, do not clean with solvent or the contamination will be absorbed deeper into the concrete. Before coating, the concrete should be blasted with sand or shot the same as when preparing steel. The purpose is to provide an anchor pattern and remove any loose laitance from the surface. Acid etching may be acceptable for thin film systems if done in accordance with the manufacturer's instructions. Application must also be done in accordance with the manufacturer's specifications. This includes paying particular attention to specific details such as isolation, expansion and control joints. Treat cracks, coating terminations and the junctures of walls and floors. Such small details can be the difference between success and failure.

Conclusion

To choose the correct coating for specific chemical resistance, it is necessary to know the exact chemical or chemicals and any combinations that will be encountered. Concentrations and temperatures are equally important as are the type of exposure, such as continuous, splash and spill, and the length of contact. This requires familiarity with the processes and the cleaning habits of the user. If these details are unknown, it is prudent to provide for the worst case. Physical conditions to which the substrate will be subjected is also a consideration in determining if a coating will suffice or if heavy service requires the use of wear- and impact-resistant toppings. Damage penetrating the system will allow chemicals to penetrate the substrate and undercutting damage will result. As with any coating system, the correct surface preparation and application are of equal importance to the coating selection. An error in any area will result in failure.