arious local and federal governmental regulations require secondary containment structures for chemical storage areas. Typically, secondary containment structures are made of concrete. They require protective linings to prevent chemicals from attacking the porous concrete or penetrating existing cracks and joints, thus breaching the structure. The linings are intended to serve two purposes: to protect the concrete substrate from chemical attack and physical abuse, and to help retain chemicals that leak from their primary containment or are spilled during transfer, preventing them from leaching through cracks or joints in the concrete and into the ground soil below. Typically, the linings are pre-fabricated liners, or they are fluid-applied polymeric coatings and linings, often with mat reinforcement, installed on site.

This article will describe the application of a mat-reinforced polymeric system at approximately 125 mils’ dry film thickness (dft). The discussion
will range from preparing the surface to applying the lining and mat reinforcement. Although a variety of polymeric coatings and linings can be used, the article is limited to polyamine and novolac epoxies and vinyl esters.

New vs. Existing Concrete

Both new and existing concrete structures have their challenges. While erosion from chemical attack and physical abuse are more of a concern for existing concrete, new concrete has its own issues. Although new concrete is typically given the proper time to cure as required per ACI 318-05, this does not mean that the residual water in the concrete has completely evaporated or that the concrete has finished settling into its permanent space. Continued settling and shrinkage of the concrete may cause further development of cracks even after the required 28-day cure time.

It is also impossible to gauge whether the concrete could have a continuous and high moisture vapor transmission (MVT) rate, because the concrete may still hold residual water that has yet to react or be released through evaporation, thus skewing the results of MVT testing. Assurance that a vapor barrier was properly installed before the pour can greatly alleviate this concern.

Even with new concrete, there could still be areas with imperfections in need of repair before coating application. Fins, splatters, and other protrusions should be ground smooth. Abrasive blasting will expose depressions such as bug holes and honey combs, and, depending upon the size of the area affected, either spot patching or resurfacing will be required.

In existing concrete, both cracking and MVT can be readily identified. Cracks may be visible once abrasive blasting is completed, and MVT can be detected through testing by either ASTM F 1869-04, “Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Sub-floor Using Anhydrous Calcium Chloride,” or ASTM F 2170, “Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes.”

Concrete eroded or destroyed from physical abuse and corroded from chemical exposure will also be detectable. These areas will require further investigation to determine the scope of damage and the necessary extent of the repair.

Small defects such as spalls, bug holes, and hairline cracks will be exposed during the surface preparation of the concrete substrate. These areas can then be filled through the use of engineered cements or polymer patching materials. The same patching materials can also be used to repair larger damaged areas; however, further preparation of these areas may be necessary before patching, such as removal of contaminated concrete or the repair of rusted or damaged rebar and the surrounding concrete. Repouring of curbs and shoulders as well as areas in the floor may be necessary in extreme circumstances.

Surface Preparation

Several viable options are available when it comes to the surface prepara-
tion of concrete. Water jetting, water blasting, wet abrasive blasting, dry abrasive blasting, shot blasting, and diamond grinding are the most common methods used. Abrasive blasting, shot blasting, and diamond grinding will be discussed here.

Per ICRI Guideline 03732 from the International Concrete Repair Institute (ICRI), a surface profile of CSP 4 or greater will achieve a roughness suitable for the application of the specific linings to be discussed in this paper. Although ICRI references several different preparation techniques, it does not require a specific method. The project engineer, coatings manufacturer, or the contractor performing the work chooses the method.

_**Abrasive Blasting**_

Abrasive blasting is commonly used to clean and profile the surface of both concrete and steel. Concrete can be profiled at pressures around 80 psi (5.5 bar). Proximity of the blasting nozzle to the substrate, the blasting media being used, the condition of the concrete, and how quickly the contractor moves or "sweeps" the blast nozzle across the surface can all affect how quickly the surface is blasted and how much profile is achieved. Based on ICRI Guideline 03732, the profile should be determined by an agreement among the project engineer, the material supplier, and the contractor.

Open abrasive blasting creates a significant amount of dust and debris; therefore, the applicator and any personnel in the immediate area should wear proper protection.

_**Shot Blasting**_

While most contractors will abrasive blast walls and floors, some may choose another method for the horizontal surfaces, due to the excessive amount of spent media created by open abrasive blasting. Shot blasting is the most commonly used method for abrasive blasting horizontal concrete. The dust is self-contained through the use of a vacuum system, and the abrasive is a steel shot that is reclaimed and reused throughout the blasting process. A simple magnetic sweep of the floor removes any unclaimed shot, making the method much cleaner than open abrasive blasting.

_**Diamond Grinding**_

Small or hard to reach areas, such as the floor/wall transition, inside corners, or floors beneath existing equipment, can be abraded with a hand-held diamond grinding tool. Attaining a surface profile by this method equal to or greater than a CSP2 should be required per ICRI guideline 03732.

Once the concrete has been thoroughly abraded, the contractor will need to address various conditions in the concrete substrate. All cracks, spalls, and general defects must be addressed, as well as any control joints saw cut into the floor during its placement. Terminations will also need to be addressed in the exposed perimeters of the containment area.

_**Active and Non-Moving Cracks and Joints**_

Many times, it is nearly impossible to ascertain if a crack is static (non-moving) or active. Some cracks develop during the placement and curing of the concrete, and after time will no longer move, becoming static. Others develop due to thermal cycling, torsional or seismic movement, compressive forces from applied loads, or vibration from traffic or machinery. These cracks will continue to move throughout the life of the floor and must be addressed accordingly.
Active Joints and Cracks
Active joints, called expansion joints, account for any movement caused by the aforementioned physical dynamics, and they isolate two structural elements from one another. Active joints should not be overcoated. Instead, the contractor should terminate the lining on either side of the joint, or coat over the joint and then re-saw it, which will cut back through the lining and into the floor, thus reopening the joint. Either way, the joints should then be filled with the appropriate joint filler. In the case of secondary containment, the joints should be filled with an elastomeric, chemically-resistant joint compound such as a polysulfide caulking. Toolable or self-leveling grades of caulking may be used, depending on the contractor’s preferences.

Active cracks develop when the expansion joints are not adequate to handle the movement in the floor. Many times, these cracks will develop diagonally to a footing’s outside corner. These cracks may be addressed in two different ways, depending on how wide the crack is and how much it moves.

Minimum or hairline movement of the crack may be addressed by routing out the crack and then filling it with the appropriate flexible caulking. This repair should be performed after the lining has been applied. If the owner wishes to not see the crack, a slip sheet method may be employed. This method involves applying a non-adhering or bond breaking material over the crack. The crack should first be cleaned out and filled with a mixture of epoxy and fumed silica, forming a non-shrinking paste or mortar. The filler should be allowed to cure to ensure the bond breaking material does not adhere to the wet filler. Typical bond breakers include polyethylene tape or simple duct tape. Once the filler has cured hard, the tape may be applied over the entire crack, followed by the lining application. The theory behind this method is that the crack underneath the lining will be able to move independently of the lining because the crack and the lining are not directly bonded together in that particular area.

Non-Moving Joints and Cracks
Non-moving joints are referred to as contraction or control joints. The joints are created by saw cutting the concrete to a depth of at least \( \frac{3}{4} \) the thickness of the concrete slab and a \( \frac{1}{4} \) inch width. The joints create weak points in the concrete, allowing any cracking due to shrinkage or settling to be controlled within these joints. Once the concrete has fully cured, the control joints are no longer necessary.

Non-moving cracks are typically developed outside of the control joints during cure. This happens from time to time when there are not enough control joints cut into the floor or when the concrete has shrunk excessively from over-watering or rapid curing in hot weather.

Both of these non-moving openings may be routed out, patched in with non-elastomeric material such as 100% epoxy mixed with fumed silica, and reinforced with fiberglass tape. The paste should be similar in consistency to thick peanut butter. Once mixed, the material can be pushed into the opening with a putty knife and struck flush to remove protruding, excess material. Fiberglass tape may then be applied over the crack and into the wet filler, reinforcing the crack against movement. Excessive movement of the crack may tear the fiberglass and allow the crack to travel through the lining.

Termination Details
Various termination details should be used, depending on the design of the con-
crete structure. Termination of the lining into trenches and exposed perimeters should be detailed using key ways. Key ways are created by saw cutting a line in the concrete where the lining will terminate and chipping the concrete back approximately one inch, or, in the case of a drain, chipping back from where the flange of the drain is set flush into the concrete. Both of these details produce a deep notch in the concrete and anchor the lining into it, thus preventing the lining from chipping or peeling at the exposed termination.

**Inside and Outside Corner Details**

When fiberglass mats will be used to reinforce a lining, detailing the inside and outside corners will be necessary if the intent is to wrap the glass around them. Both inside and outside corners are typically sharp 90-degree angles, making it difficult to wrap the fiberglass around or into these transitions.

Wrapping the fiberglass through a 90-degree angled inside corner will cause gapping behind the mat because the glass is somewhat rigid and will not lay completely into the corner. Such hollow spots should be cut out and repatched before the application of the next coat.

Wrapping the fiberglass over a 90-degree angled outside corner will often cause fiberglass hairs to pop up out of the mat, leaving strains of the fiberglass sticking out of the coating. The frayed glass will have to be addressed after the lining dries through, either by sanding or grinding before the next coat is applied.

Obviously, cutting the glass at these inside and outside corners is an option; however, many secondary containment designs require the mat to be overlapped at the seams to eliminate unreinforced areas in the lining.

To detail the inside corners, a one- to two-inch (2.5- to 5-centimeter) cant (or 45-degree angle) cove should be installed. A cant cove can be created by mixing a small amount of the mortar that will be used in the lining system. The material should be applied in a bead along the inside corner and tooled into the shape of a cant with a margin trowel. This technique will leave a 45-degree angle that the mat can then be wrapped over without leaving gaps behind the glass. The detailing can take place where the wall or vertical face of the concrete meets the floor, or at the inside corner of two walls.

Outside corners are more difficult because they must be ground down to eliminate the 90-degree angle. Addressing these edges in the design phase is recommended: require the outside corners of the concrete to be bull nosed while being poured and placed.

**The Lining Material and Its Application**

While the following discussion considers epoxies and vinyl esters, other polymeric linings may be suitable for a project, and it is the responsibility of the owner, engineer, and material supplier to determine what system is suitable for a project, based on the anticipated exposure conditions.

It is important to understand the chemistry of polymeric linings and how it affects their workability. Both epoxies and vinyl esters are highly cross linking materials and are supplied as two-part, chemically reactive liquids. Once mixed, the liquids immediately begin to react and crosslink. This chemical reaction causes the material to have a relatively short pot life. Combined with the inherent thickness of these resins, these materials can be much more difficult to apply than a solvent-borne epoxy or a single-part acrylic, both of which are normally sprayed or dipped from a bucket and then rolled.

Because the materials are chemically reacting with one another, energy is being produced. This energy creates heat, and heat speeds up the reaction of the two. This reaction becomes exponential in mass, making the pot life even shorter when the materials are worked out of the containers in which they’ve been mixed. To alleviate the problem of short pot life on horizontal applications, the mixed material is typically dumped immediately onto the area where it is to be installed and then quickly spread uniformly with a trowel or squeegee. These tools are either flat or notched, depending on the specified thickness of the coating.

When applying material vertically, it is impossible to pour the material onto the substrate. Instead, small amounts are mixed at a time or several applicators share a large mix, thereby shortening the amount of time the material is in the container.

Lastly, these types of materials develop their hardness rather quickly, thus shortening their recoat window to around 24 hours. If the recoat window is missed, a thorough abrading of the surface is required before applying another layer.

Close attention should also be paid to the temperature of the material, the surface to be coated, and the surrounding air. Material temperature is the most
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- Carbomastic 615 HS

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- Carboguard 893
- Carboguard 954 HB
- Carboguard 1207
- Carboguard 1289
- Carboguard 1340

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- Thermaline 450
- Thermaline 2954
- Thermaline 2977
- Thermaline 4700 & 4700 AL
- Thermaline 4900 R

Phenoline
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- Phenoline 309
- Phenoline 310
- Phenoline 373
- Phenoline 379
- Phenoline 380
- Phenoline 1205

Carbothane
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critical and should be between 65 and 80 F (18 and 27 C) at the time of installation. Colder material becomes thick and sticky, making it hard to apply, while warm material will drastically reduce pot life and can decrease working time.

Because of its porosity, concrete will contain air. This air will expand or "outgas" in rising temperatures and can cause pinholing or blisters in the lining system. When applying coatings in outside applications or when interior spaces are not climate controlled, air temperatures should be stable or descending during application. Also, if possible, the material should be applied in shaded areas and not in direct sunlight during outside applications.

Installation of the Lining
The installation of the lining system is a five-step process involving the primer, base coat, fiberglass mat, saturant coat, and finish coat. The first four steps should be performed as a wet-on-wet application, which means that all four steps should take place on the same day. Again, with a multi-component material, all parties involved in the installation must be ready to proceed once the material is mixed. That means all rollers are set up, spike shoes are already on, and areas to be protected are already masked. A mixing area should also be set up, and the material to be used should be stacked accordingly. Cutting the glass to the appropriate lengths and opening the aggregate container should also be done ahead of time. Most important, all workers should be aware of their roles in each of the first four steps of applying the system.

Since both walls and floors in secondary containment structures will be lined, the lining system should first be applied to the vertical portion of the containment area. Addressing the walls first allows for installation of the lining system while working on uncoated concrete. If the flooring were to be done first, the wall application could expose the flooring system to potential damage by the applicator. Floors could be protected by covering them with plastic or felt, but this is unnecessary if the walls are addressed first.

• Step One: The application process begins with mixing and applying primer. The material should be mixed per the manufacturer's instructions, either in small amounts at a time or split among a number of applicators. The material should be dipped and rolled onto the wall at approximately 160 to 200 sq ft per gallon. This rate can vary, depending upon the aggressiveness of the profile. At a typical temperature of 75 F (24 C), the material should be used within 15 to 20 minutes of mixing.

• Step Two: As the wet primer begins to tack up, the base coat can be mixed and applied at a dry film thickness of 60 mils (1.5 mm). Per the manufacturer's recommendation, the part A and B liquids should be mixed, and while they are under agitation, the part C filler should slowly be sifted into the mixed liquids and blended until thoroughly combined. The material should then be scooped out onto a mortar hawk (mortar tray) or directly onto the floor in front of the wall to be coated. With the use of a flat trowel, the material can be pulled up the wall and spread at a uniform thickness of approximately 60 mils.

• Step Three: Once the base coat is evenly applied, the glass should be laid into the wet base coat (Fig. 1). It is important to remember that there is a cant at the bottom of the wall and the glass mat may be applied over it as well. The glass mat should then be smoothed into place with a metal ribbed roller or a wide drywall knife, the purpose of which is to smooth out imperfections and ensure full contact of the glass with the base coat, making sure no voids are left between the two (Fig. 2).

• Step Four: The same resin used to build the basecoat can then be used to fully saturate the front surface of the fiberglass (Fig. 3). To do this, the appro-
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the applicator can then walk on the wet topcoat and backroll the material. Backrolling will prevent squeegee lines in the coating and will ensure that the topcoat is consistent in thickness and coverage.

Conclusion

Following these preparation, repair, detail, and application guidelines will ensure a properly placed, well-adhered lining that provides years of protection for the secondary containment concrete structure. To insure these guidelines are met, constant communication among all aforementioned parties is of the utmost importance. If the project is driven through the specification process, many of these details can be addressed early in the design phase of the project and included in the execution portion of the architect’s or engineer’s specification.

Chris Ard has over 17 years of experience in the installation, project management, technical service, and sales of fluid-applied protective flooring systems and reinforced epoxy wall coatings as well as secondary containment linings for chemical containment areas. He currently is a technical service representative for the Tnemec Co. in Kansas City. He is a member of the Construction Specifications Institute (CSI), the International Concrete Repair Institute (ICRI), and The Society for Protective Coatings (SSPC). He is C1 and C10 certified.
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