Patching Portland Cement Concrete on Bridge and Parking Decks; Ramps and Slab-on-Grade Pavements Using an Epoxy Polymer Concrete

This guide provides the engineer, architect, contractor or maintenance crew with a description of the various site conditions that could influence the installation methodology of placing the Epoxy Polymer Concrete (EPC) in shallow, partial or full depth patching.

This guide emphasizes the factors that should be considered for product conditioning, handling, mixing, placement, and curing of the Epoxy Polymer Concrete. Special emphasis is placed on surface preparation of the concrete, site preparation of the hole and cracks and joints crossing through the area to be patched. The advantages and limitations of the Epoxy Polymer Concrete and methodology are discussed throughout the guide.

The polymers discussed in this guide are Thermal-Chem Mortar Resin, Product No. 3 and Thermal-Chem Fibrous Mortar Resin, Product No. 306 and the aggregate combinations used to complete the Epoxy Polymer Concrete.

KEY WORDS: Epoxy; epoxy polymer concrete; surface preparation; handling; conditioning; mixing; placement; finishing; curing; cracks; and joints.

Typical Areas of Use on Elevated Decks or Slab-on-Grade Pavements

- Slab edges where spalling is on one or both sides of a joint.
- Spalling on crack edges.
- Expansion joint nosing.
- Corners of slabs that have broken off.
- Replacing other patching materials that are not providing a permanent repair.
- Deteriorating concrete areas.

Training

All personnel involved in the patching process, supervisory or workmen, should attend an orientation sponsored by the polymer manufacturer prior to starting the project on the proper concrete surface preparation, handling and placement of Thermal-Chem Epoxy Polymer Concretes.

Lighting

If the patching is to take place at night, or during low light conditions, **the contractor must supply sufficient lighting to allow clear, shadow-free viewing of the areas to be patched.** The lighting shall be of sufficient strength to reveal surface defects, surface contamination, cracks, joints and other unsound concrete conditions, as well as a properly prepared surface.

Surface Preparation

Defining Area to be Patched: The area that is broken or spalled does not always comprise the entire area of deterioration. The adjacent concrete surfaces should be sounded with a hammer or chain dragged to determine the actual perimeter of the area to be patched. When marking the areas to be patched, they are often irregular in shape; therefore, it is extremely important to the life of the surrounding concrete and the new patch to reshape the areas into straight lines, typically squares or rectangles. Allow a few inches of solid concrete on each side of the hole to be removed as part of the new patch area. This technique reduces labor time in getting to solid clean concrete as part of the surface preparation.

Saw Cutting: Make all saw cuts in straight lines because squares or rectangles will produce a longer life-cycle of the patch and adjacent concrete. The minimum depth of the saw cut shall be 1/4 in. (6 mm). However deeper cuts often improve the surface preparation process by making the chipping of the concrete easier and keeping the chipping tool further away from the top edge of the concrete. Chips along the edge of the concrete are often a cause for patch rejection. Good quality saw blades, such as diamond or carbide, improve sawing production and the appearance of the concrete edge sawn. All dowel or reinforcement steel slots should be saw cut before the removal of the concrete. See plan details for spacing, width, length and depth of saw cut.

Concrete Removal: Hand held chipping hammers having less than 30 lbs. impact are recommended to help prevent micro cracks from developing in the concrete and causing separation of the cement paste surrounding the reinforcement steel from the repeated blows of the hammer to the surface being prepared. Blow energy to the surface of the concrete may have to be limited to protect the structure and adjacent surfaces when the concrete is of questionable quality. Micro cracking may produce a weakened plane just below the bond line and when thermal change occurs, the micro cracks can grow into a full delamination causing patch failure. Hand held chipping hammers or breakers are the most common tool used for shallow and partial depth concrete removal and are available in different levels of energy and efficiency. Performance of chipping hammers is largely a function of the concrete soundness and aggregate toughness. Larger hammers are used only for complete removal.

Exposed Reinforcement Steel: When the excavated hole is as deep or deeper than the reinforcement steel the following procedures must be followed. If the exposed reinforcement steel has less than 50% of the bar uncovered, and there are no cracks separating the cement paste and steel, no further excavation of concrete is required. However, if the excavation is deeper than 50% of the steel bar thickness, or cracks are present at the attachment area of steel and cement paste, the concrete shall be excavated at least $^3/_4$ in. (9 mm) deeper than the bar.

Surface Preparation of the Hole: After the saw cutting and concrete removal processes, the exposed concrete still is not ready for patch placement. The concrete surface of the hole area will have partially loosened chips of concrete that are still attached to the substrate, with dust and possibly other contaminants that need to be removed. The reinforcement steel could also have dust or other materials on it that need to be removed during this phase of work. Removal is best accomplished by sand blasting or high pressure water blasting the surfaces to obtain a sound clean substrate. These blasting methods selectively remove defective concrete and other contaminants. Before the blasting process is started, remove all debris and dust from the hole and patch site area. Sound the hole surfaces by tapping with a hammer to determine that there are no delaminations or weak concrete. If delaminations or weak concrete are located, re-chip the area to sound concrete and then abrasive blast all surfaces in the hole. All steel surfaces shall be blasted to a minimum gray finish, to remove all scaling or other loose or unsound surface conditions. After the blasting process is completed, blow out all loose debris with clean air. The hole must be either dry or moist, with no standing water or ice crystals, before placement of the EPC. The abrasive blasting phase must be timed so that no more than two (2) hours have elapsed after the cleaning of the hole. This is to prevent the possibility of dust or other contaminants such as rain, snow or other weather related contamination from getting into the hole. The hole must be protected whenever there is a chance of contamination, by covering and sealing it with plastic or other methods to keep any contaminants from getting into the hole. Failure to properly protect the hole from contaminants will result in re-cleaning of the entire hole. Contaminants or loose chips can cause bond line failure.

Sub-Base Compaction of Full Depth Holes: Leaking cracks and joints often cause the sub-base materials under the concrete to wash-out, settle or become unstable. Large patch areas of concrete removal also disrupt the sub-base materials. Smaller patch areas typically do not disturb the sub-base. Before placement of the EPC all exposed sub-base areas should be inspected; filled and compacted to the appropriate grade, if required.

Bond Testing: After the hole(s) have been prepared as stated above, each hole, or a selected number of holes defined by the engineer, shall be tested for substrate cleanliness and soundness. The purpose of the test is to verify that the concrete is prepared sufficiently for placement of the Epoxy Polymer Concrete. The engineer shall select the appropriate test prior to the starting of the project. Two bond test methods are used. The difference in these two tests are the recordable data produced by each. Both tests will verify that the surface is sound and clean. Both test methods should have 100% concrete failure as the minimum measurement for passing the test.

1. The Simple Cup Shear Test, Thermal-Chem Bulletin No. 2-4-1 is the easiest to use in the field, however, it is only a pass or fail test. No statistical strength data is attainable.

2. American Concrete Institute Tensile Pull Test Method, ACI 503 R, Appendix A, will provide pound per square inch tensile strength measurements that are used to determine the quality of the concrete, cleanliness and soundness of the prepared surface. This test method should be used when the values of the concrete are unknown.

Crack and Joint Treatment

Cracks: All cracks that enter the patch area or are parallel to the edge of the patch should be welded together with Thermal-Chem Epoxy Injection Repair process to stop the flow of water and other chemicals through the open void. **When repair of the cracks is not going to be addressed as part of this project, it is of a paramount importance to the longevity of the patch to provide a channel in the patch so that the crack can continue to move when thermal changes occur.**

The following procedure will accomplish this task:

Place a suitable material such as jute, cane or foam board directly over the pathway of the crack. The board should connect on both sides of the hole where the crack is located on the vertical walls and it must follow the crack path in the bottom of the hole. Depth of the board must be the full depth of the hole and it should follow the profile of the hole bottom. If the crack varies in width, it is advisable to place backer rod in the crack opening to prevent EPC from filling or bridging the open crack. Thickness of the board can vary, (minimum form width shall be $^{1}/_{2}$ in. (12 mm), but it must be thick enough to accommodate the fully opened crack width during colder temperature exposures. This is the preferred forming method to address crack movement.

Control, Isolation or Expansion Joints: All joints passing through or adjacent to a patch side shall be formed to the full depth of the hole prior to EPC placement. Special attention to joints that intersect within the patch area is very important. Place the joint material down into the joint void below the depth of the patch bottom and side walls by at least one (1) in. (25 mm). **The joint width should be equal in width to the existing joint in the adjacent concrete areas.** If two widths are present in the concrete use the wider width for the patch joint sizing. Acceptable materials which may be used to block out the joint area within the patch are jute, cane and foam boards. **Be careful that no EPC is forced into the joint void during placement. If EPC is placed in the joint it will act as a non-compressible material and cause cracking or delamination in the concrete, thus shortening the life of the concrete and EPC patch.**

In joints that are to be sealed, the joint forms may be recessed to 3/8 in. (9 mm) below the surface of the patch and saw cut to provide a clean, sharp edged sealant reservoir. The saw cut must be the same width as the forming material in the joint. Timing of the saw cutting is an important factor, Delay in the cutting process, or a thermal change occurring before the cutting, could cause random cracking on the surface of the EPC.

Conditioning of Materials

The epoxy and aggregate used must be protected from adverse weather conditions before and during use on the patching project. All materials must be kept dry and in their closed containers. During hot temperature exposures such as in summer months, the epoxy components must be covered or placed in a shaded area to prevent the sun from directly shinning onto the containers. If this happens the containers will absorb the heat and the temperatures will increase far above the ambient temperature. Hot polymer will shorten the working time during placement. This may or may not be an important factor to your project.

Cold temperature exposures create other problems that could be more difficult for the proper working of the project. Cold epoxy becomes thicker and it is harder to blend the components together. It will require more mixing time and this will shorten the working time (potlife) of the EPC. Colder EPC is also harder to place. More important, is the fact that the cold epoxy will not accept the full amount of aggregate of the designed mix, and this could change the physical strength properties that are designed into the patching material. Additionally, the cost per unit will be significantly increased by reducing the quantity of aggregate used.

All of the above problems can be avoided when the epoxy is simply kept warm. The desirable temperature range for the epoxy is based on the substrate temperature. When the substrate temperature is above 70°F (21°C) no warming of the epoxy is required. During colder temperature placements from 33°F to 70°F (1°C to 21°C), preheat each component to the 72°F (21°C). From 0°F to 32°F (-18°C to 0°C) preheat each components to 90°F (32°C). At any temperature range the epoxy can be preheated to 90°F (32°C) to shorten the tack-free and curing time. Normally the aggregate doesn't need to be heated, however if the temperatures are cold and tack-free time is crucial to the opening of the patched area to traffic heating of the aggregate is advisable. Another acceptable procedure is to thermo-set the 90°F (32°C) mixed EPC in the hauling container for 5 to 7 minutes. This will reduce the working time (potlife) by about 50%, but if you time your work properly, you will learn how to comfortably handle the reduced potlife and speed up the curing process many times. Also remember, the larger and thicker the mass of EPC the faster the cure.

Mixing Equipment

Selection of the mixing equipment is crucial to the placement process. Wrong selection of equipment could cause delays and unnecessary added labor costs to the project. Determine the amount of cubic footage (cubic meters) of EPC that must be placed in a given amount of time. Allow for curing of the EPC, and with this data you can make a selection of equipment size and method of mixing.

For smaller projects with batch sizes 0.5 ft^3 (0.014 M^3) or smaller, use an electric or air power drill with an appropriate size stirring attachment to mix the EPC properly. It is very important to select the right size stirring attachment to match the mixing container size so that the Epoxy or EPC is not over heated or filled with air by the mixing process. The drill speed should be between 300-600 rpm and the size rating of the drill should be $^3/_4$ hp or larger. Five (5) gallon pails (20L) work well for up to 0.5 ft^3 (0.014 M^3) batches.

For projects requiring larger batch sizes, concrete drum or mortar mixers should be used. Select the capacity of the mixer size by figuring that approximately 75% of the drum rating capacity can be used for the EPC quantity to be mixed. Either electric or gasoline driven units are acceptable from a mixing standpoint, however, fuel driven mixers are often a problem, because of the exhaust, when used inside a structure without proper ventilation. Noise can also become a real issue when equipment is used indoors.

Other equipment and tools that are typically required for mixing include a scale, margin trowels, shovels, pails for measuring, non-absorbing gloves and safety glasses.

Mixing Preparation

Store the epoxy and aggregate components close to the mixer. Set up the mixing area like a production line. Provide surface protection for the area where the mixing is going to take place. Polyethylene plastic or other non-absorbing materials are best and typically less expensive to dispose of after use. When the patching project is spread over large areas, moveable equipment such as a low bed trailer, or truck bed are excellent ways of creating a moveable mixing unit. Moveable mixing units are cost effective, and it is more practical to have the mixing as close to the placement area as possible to reduce hauling expenses and reduced working time (potlife) of the EPC.

Poor measurement of the components and mixing of the epoxy components is the most common cause of bad applications. Determine the batch size and select measuring containers for each epoxy component. **It's best not to break aggregate bags into smaller portions**. When a bag is broken into partial units, the entire bag must be blended to properly distribute the finer and larger aggregates. This is time consuming and increases the labor requirement on the project. Design the batch size to use full bags of aggregate.

Place the epoxy resin, component "A" measuring container on the scale and adjust (tare) the scale to zero. Pour the correct amount of epoxy resin into the container. Use containers such as white plastic pails. Mark the fluid line and drill a small hole in the container at the fluid line. Place a screw in the hole for future measurements. After the first weight measurement, all measurements thereafter are by volume. Just pour the epoxy resin up to the screw. Follow the same procedure for the curing agent, component "B", as explained for component "A" above. Two or more measuring containers are appropriate for each component on larger projects to speed up the mixing process. Typically, the mixing process is the slowest part of the patch placement process.

Mixing Procedures

1. Select a container of sufficient size to blend the epoxy resin and curing agent. Pour the pre-measured epoxy resin into the container and then pour the pre-measured curing agent into the epoxy resin. Place the power drill with the paint stirrer into the epoxy and blend until a homogeneous mix has developed, about 1.5 to 3 minutes.

2. Batches less than $^1/_2$ ft^3 (0.014 M^3): Immediately after mixing the epoxy, pour about half of the aggregate into the container and blend thoroughly. Then add the remainder of the aggregate into the container and blend until a homogeneous mix is developed, about 1.5 to 3 minutes.

3. Batches larger than $^1/_2$ ft^3 (0.014 M^3): Immediately after mixing the epoxy, pour the epoxy into the concrete mixer. Start the agitation and slowly add the aggregate. Blend until the epoxy has coated all aggregate partials. Batch size and the type of mixer used will determine the mixing time.

Priming

To assure a proper bond between the concrete and epoxy polymer concrete, apply a thin coat of the same mixed epoxy product in a neat consistency, (no aggregate in the mix), evenly over the concrete just prior to the placement of the epoxy polymer concrete. The cleaned surface can be damp or dry with no free-standing water or ice crystals. Do not allow the primer to puddle or become thicker than 17 to 20 mils, (0.25 to 0.5 mm). Typical rate of application is 160 ft^2/gal. (3.85 m^2/L). If the prime coat can be spread further, do so. Just remember that the entire concrete surface must be evenly coated without any dry spots. Therefore, a good rule to remember is that the smoother the surface the better coverage of the prime coat. And the rougher the surface, the less coverage, because there is more surface area to a rough surface than a smooth surface.

To prevent flash rusting of the steel surfaces, it may be necessary to prime the steel before priming the concrete when a delay of the patching placement process could occur. If the earlier epoxy primed steel surface has developed into the tack-free stage of cure, the steel will need to be re-primed before placement of the EPC.

Application tools for rough surfaces include paintbrushes and paint rollers with medium height nap covers; and squeegees and paint rollers with short nap covers for smooth surfaces. Apply the prime coat to the bottom, all sides and over the upper saw cut edge of the hole. Coat all exposed reinforcement steel at the same time. Do not allow the prime coat to drip from the reinforcement steel and puddle on the concrete. Airless spray equipment can be used on larger projects when the Epoxy Polymer Concrete placement can keep ahead of the prime coat becoming tack-free. The EPC must be applied to a wet prime coat. If the primer becomes tack-free, re-prime the area as thinly as possible. Working Tip: If puddles occur before the placement of the EPC, sprinkle dry silica sand into the puddle to eliminate all free epoxy before placement of the EPC.

Placement and Finishing

Immediately after mixing the Epoxy Polymer Concrete, and before the primer goes tack-free, start the placement process. Place the EPC into the hole and consolidate thoroughly. Compaction is crucial for the success of the patch. When the hole is deeper than 6 in. (150mm), place the first lift approximately 6 in. (150mm) deep and compact. During the placement of each lift, place the EPC up against the hole walls and compact the EPC into a 45 degree angle. Then fill the center area of the hole and compact the entire area. Immediately place the next lift and compact, and continue the same process until the hole is filled. Do not wait between lift placements for the last lift of EPC to become tack-free. Leave each lower EPC lift with a rough finished profile, as caused by the compaction method. The only reason for placing in lifts is to obtain proper compaction, thus reducing the air voids in the EPC. Complete the filling of the entire depth of the hole as one work process.

On the final lift, overfill the hole, compact and screed off the excess EPC. During the screeding process maintain the EPC height in front of the screed bar by at least 1½ in. (38mm) to prevent starving. If any area under the screed bar, over the hole being patched is starved, the result will be a low spot that will hold water. As the screed process is taking place, be careful not to allow EPC to build up on the adjacent concrete surfaces because it will lift the height of the screed bar and make the patch higher than the adjacent concrete surfaces. The screeding process should obtain a similar surface profile and height as to the adjacent concrete surfaces. The finished textured profile of the patch should be as similar as possible to the pattern of the adjacent concrete surface. The finished patch surface shall have a straight-line surface from one side of the patch to the other side. Low spots or bumps will not be permitted. Either defect will shorten the expected life cycle of the patch, or cause early deterioration of the adjacent concrete.

Selection of the Epoxy Polymer Concrete Formula

1. Shallow Depth Patches are typically $^{1}/_{4}$ to 1 in. (6 to 25mm) in depth. They are filled with a shallow patch EPC formula in one lift. This formula contains only epoxy and a graded silica sand.

2. Dowel and steel reinforcement grouting uses the shallow patch formula.

3. Partial Depth Patches from 1 to 2 $^{1}/_{4}$ in. (25 to 56mm) in depth contain epoxy, a graded silica sand and a graded aggregate from $^{1}/_{8}$ to $^{1}/_{4}$ in. (3 to 6mm] in size.

4. Partial Depth Patches deeper than 2 $^{1}/_{4}$ in. (56mm) contain epoxy, a graded silica sand, and a graded aggregate blend from $^{1}/_{8}$ to $^{3}/_{4}$ in. (3 to 20 mm) in size.

5. Full Depth Patches use the same EPC formula as for Partial Depth Patches greater in depth than 2 $^{1}/_{4}$ in. (56 mm).

6. Partial and Full Depth Patches are composite designs. The entire hole is primed, filled with the approximate EPC formula and topped with a $^{1}/_{4}$ or $^{3}/_{8}$ in. (25 or 38mm) Shallow Depth Patch formula.

7. Patches that have a crack or joint running through them need to have both sides of the slot finished with a beveled edge. Do not allow the beveling process to change the straight-line surface of the patch.

8. Thermal-Chem formulates all epoxy polymer concrete mixtures using local aggregate when suitable aggregates are available. Contact your local Thermal-Chem representative or Thermal-Chem Corporation for exact formula data.

9. For smaller projects, convenient Ready-Pak Epoxy Polymer Concrete units are available. These easy to use units contain all necessary epoxy and aggregate in one container.

Placement and Finishing Tools

Place all dowels or reinforcement steel into saw cut slots and fill and compact the EPC into place, as shown on the drawings. Allow EPC to become tack-free before placement of the EPC patch.

Hand tool requirements are generally the same as for placing concrete. Margin and finishing trowels are typically used during all placement steps and even when the surface profile of the EPC will be only screeded. The tools need to be clean and undamaged. Tamping tools for small patching projects include 2 x 4 in. (50 x 100mm) studs or steel tamping tools that do not have a surface diameter greater than 4 in. (100mm). For larger projects, vibrating equipment is required to achieve proper consolidation in a reasonable period of working time. Flat plate vibrators such as used for soil compaction are ideal. Screed bars for finishing the surface can be made of wood, steel or aluminum. This tool will be used to assure a smooth, even straight-line transition from one side of the patch to the other side. The bar thickness will vary depending on the length requirement. The bar must be rigid and not bend during use. Typically the length will exceed the widest portion of the patch by approximately 12 in. (300mm). Ideal height of the bar is approximately 3 in. (75mm). Handles should be attached to the screed bar to assist in applying an even downward pressure for compaction and the push/pull sawing action required for the surface finishing of the EPC.

Curing

The curing process of Thermal-Chem EPC's are automatic. In general, the hotter the temperature of the substrate and EPC mixture the faster the cure; and the colder the substrate temperature the slower the cure. The term "cure" means full development of the EPC physical properties. In actual use the term "tack-free" is what we are concerned with, to allow traffic over the EPC patch. The tack-free stage of development is when the shallowest portion of the patch is hard so that the weight of a person or vehicle traveling over the patch will not cause any indentation to the EPC patch surface. At this stage of cure development, approximately 70 to 80 percent of the mechanical strength properties have been achieved.

No curing compounds or cover is needed for the curing process, unless adverse weather conditions such as rain, hail or snow occur prior to the tack-free stage of development. If such conditions prevail, provide protection by covering the uncured EPC with a polyethylene cover until the tack-free stage develops, then remove the cover and use the patch. If the cover is allowed to lie directly on the uncured surface of the EPC, the weight of water or snow could change the surface profile. Protect the uncured patch from water running over the area, it could affect the cure and change the surface profile.

Clean-Up

Protect the surface of the mixing area and areas adjacent to the patch from spillages. If the EPC has cured, use mechanical grinders or abrasive methods to remove the material. Follow the Material Safety Data Sheet for disposal methods.

Limitations

Do not place EPC when the temperature drops below Thermal-Chem's recommendation for proper placement and cure. Do not alter the product by adding solvents or other materials to the epoxy.

Personal Protection

Read all literature and Material Safety Data Sheets supplied by Thermal-Chem Corporation before using the product. Call Thermal-Chem Toll Free for any clarification of instructions or data in the Material Safety Data Sheets at 1-800/635-3773.

Manufacturer

Any questions or comments regarding the contents of this *Installation Guide*, for technical questions or assistance, and/or questions with regard to specific installation procedures, contact the manufacturer:

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