Information and Instructions for Epoxy Use

Epoxy adhesives are very good construction materials. They are, however, somewhat complicated, so there are certain rules that must be followed when using them. Some of these rules are seemingly insignificant, but experience has shown that if they are not closely followed, failure is likely to occur. As a step toward reducing epoxy failures, the adhesive selection, mixing, and placing requirements for good performance will be reviewed herein. Ensure production work adheres to manufacturer's instructions, material safety data sheets, and requirements of the contract documents.

1 - Physical Properties of Epoxy

Epoxy adhesives in their pure form are very hard and extremely brittle, and have undesirable properties for structural use. These physical properties can be altered to fit a wide spectrum of hardness and flexibility by judicious selection of hardening and flexibilizing agents. It is only natural, then, that there is a correct epoxy adhesive formulation for each type of job requirement: high strength epoxy to resist high stresses, and flexible epoxy to resist high thermal changes.

All epoxies specified for use are of the two-component type. One component is the epoxy resin and the other is the hardening agent. To these components are added coloring, stiffening agents, and flexibilizers as required. Some epoxies are designed as 1:1 mix ratio of the components, others as a 2:1. They are also designed to have a specific pot life at a certain temperature. When the two components are combined, there are two very important rules which must be followed: (1) mixing proportions as shown on the container must not be changed, (2) the components must be thoroughly blended. One should never try to alter the pot life of an epoxy by changing the prescribed mixing ratio. Doing so would result in a very undesirable epoxy. The *Contract Specifications* include epoxies with designed pot lives from a few minutes to about 40 minutes. Hence, if the epoxy on hand is either too fast or too slow for a designated job, it should not be used; one which has a pot life that is more compatible with the job requirements should be obtained. The temptation to add solvents to reduce viscosity, extend working time, or improve application characteristics must be avoided. Such usage could cause poor adhesion, high shrinkage, and a "cheesy" effect.

2 - Surface Preparation

The surface receiving the epoxy adhesive must be clean, sound, and dry. Probably the most frequently ignored requirement for a receiving surface is cleanliness. This is especially true when saw-cutting has been done. It is often assumed that a freshly sawed surface is clean since it has been continuously washed by the saw blade cooling water, when actually a fine residue is left by the water. To ensure a clean saw cut surface, it should be sandblasted before application of the epoxy. Cracked or loose sections of concrete near the surface should be located by striking the concrete with a hammer or by dragging a chain over it. Hollow sounds are indicative of fractured concrete. Loose concrete must be removed.

With respect to strength and permeability, rules which have been developed for portland cement concrete (PCC) are also applicable to epoxy concrete. The primary difference between the two concretes is that cement, with water for hydration, is the binder in one whereas epoxy is the binder in the other. Similar conditions produce similar results in each. For instance, a uniform gradation of sand and aggregate produces a stronger product than does a single or gap gradation; the richer the mix the less permeable the final product, etc. It follows then that regular concrete sand and gravel, thoroughly dried, usually produces a good epoxy concrete mixture. The maximum size aggregate, as in regular PCC, is determined by specific job requirements and anticipated conditions: depth of section, reinforcing steel restrictions, etc.

3 - Mixing Epoxy

The ratio of epoxy to aggregate for a strong, dense mix depends to a great extent on the gradation and maximum size aggregate used. Rules of thumb for epoxy/aggregate-ratios (by volume) for good aggregate gradation of various maximum sizes are: 1/5 for 1 inch aggregate, 1/4 for pea gravel, and 1/3 for 20 mesh sand. The Contractor may make samples using different ratios of mixed epoxy and aggregates to determine the ratio that is most appropriate for the work. By comparing these sample mixes, it will be possible to select the epoxy/aggregate mix that is most appropriate to the work. Refer to the *Contract Specifications,* Section 95-1.02C, *Epoxy – Materials – Epoxy Binder,* for proportion requirements; for example, for high strength (HS) epoxy concrete or epoxy mortar, the mix proportion of 1 part epoxy to 4 parts aggregate by volume is specified, along with an upper limit for aggregate moisture content.

Since the viscosity of epoxies varies considerably with temperature, the mixing ratio of mixed epoxy to aggregate may have to be adjusted to maintain workability whenever there is a drop in temperature. When making the sample mixes, use the same compaction method that will be used when placing the production mix on the job. A good mix design is evident if the sample exhibits a mixed epoxy-rich surface when compacted in this manner. A mixed epoxy-rich surface results when the mix contains more mixed epoxy than is necessary to coat the aggregate and fill the voids.
If an epoxy patch is placed on an exposed deck, an epoxy-rich surface will be dangerously slippery. Required skid resistance can be obtained by broadcasting dry sand on the surface while the epoxy is still fluid enough to receive it.

Be aware that when sounding concrete with a chain after epoxy application, concrete may sound hollow due to the material properties of epoxy. Alternative methods should be used to verify the concrete is sound (e.g., impact with carpenter's hammer or rock hammer).

In an epoxy concrete mixture, it is of utmost importance that the epoxy resin components be blended first and then thoroughly mixed into the sand, or sand and aggregate. The sides and bottom of mixing containers should be scraped clean during the mixing operation. The mixing operation within the limitation imposed by the pot life must be completed and the mixed epoxy/aggregate placed and compacted before the pot life is exceeded. The results of improper mixing are: non-uniform curing, cheesy or sticky areas, brittle areas, poor adhesion, and poor performance. The sand and aggregate must be clean and dry to ensure proper bonding by an epoxy adhesive. Often it is incorrectly assumed that since epoxy will successfully bond wet concrete to dry concrete, good epoxy concrete can be obtained with damp aggregate. This is a false assumption. Note that the *Contract Specifications* cited above has an upper limit of 0.50 percent moisture content for the aggregate used for HS epoxy concrete or epoxy mortar.

In an epoxy-rich mixture, there appears to be enough free epoxy to provide a bond to the concrete surface against which it is to be placed. However, experience has shown that this is not true. Therefore, to ensure proper bond, the surface must be primed with pure epoxy adhesive just prior to placing the epoxy aggregate concrete.

Epoxy concrete differs in placing characteristics as compared to its counterpart, PCC. Epoxy concrete is too sticky and viscous to be effectively vibrated with a spud type vibrator. Surface vibration with a flat plate has not been tried, but may work. The most effective proven way to place epoxy concrete is to work it around reinforcing steel and into corners by hand. Rodding it with a small diameter rebar dowel helps, but generally the springing or bulking characteristic of the material makes rodding somewhat ineffective. Rodding is most effective after the material has been in place a few minutes and some bleeding of the pure epoxy has occurred.

4 - Epoxy Placement

When epoxy concrete is to be placed in a section greater than 2 inches thick, it should be placed and compacted in lifts of 2 inches or less.

The surface of an epoxy concrete can be finished with either a wood float or steel trowel as desired. The steel trowel is superior to a wood float in sealing the surface of an epoxy mixture.

Temperature is a critical parameter in the curing of epoxy; the higher the temperature the faster the cure (and generally the higher the strength.) This fact becomes important when epoxies are used for patches or seals on decks and the controlling factor for opening the deck to traffic is curing of the epoxy.

Curing of epoxy can be accelerated by externally applied heat. Best results for placement in cold weather is to heat the concrete receiving surface, preheat the epoxy components and aggregates before any mixing is done, and then heat the mixture after it is placed. Preheating the individual components will probably significantly decrease pot life. Experimentally determine the reduction of pot life at the temperature of application. The in-place heating should not be done by direct flame onto the epoxy, but rather by radiant heaters, or by heated air such as is provided by heating a steel plate elevated above the epoxy surface, or by heating the inside of a "tent" erected over the work. Heat lamps directed towards the epoxy is also another good source of heat. The heat of the PCC surface at the time of placement, heat of the components before mixing, or heat of the epoxy concrete after placing, should not be greater than about 110 degrees F. If using a heater to heat the PCC surface, one must be chosen which will not contaminate the surface .

When epoxy is used to bond fresh concrete to hardened concrete, the fresh concrete should be as dry as working conditions will allow and must be placed while the epoxy is still fluid and in a tacky state. If the epoxy reaches a firm state, a new coat of epoxy must be applied onto the hardened concrete before the concrete is placed. If, on the other hand, the epoxy cures beyond the tacky state, it should be sandblasted before the new epoxy coat is applied.

Epoxy concrete dams at expansion joints or epoxy repaired joint spalls should be protected during the epoxy curing period from harmful pressures caused by joint closure as the structure expands. Easily compressed plastic foam materials placed in the joint provide good protection. Forms against which the epoxy concrete is to be placed shall be coated with paraffin or silicone grease, or covered with polyethylene sheet to prevent bond. The epoxy concrete must not be allowed to flow under the forms and encroach into the space reserved for joint closure. If the material is allowed to flow into this space, failure of the repair is certain when the joint closes against it.

For epoxy crack injection or pressure sealing cracks with epoxy, review BCM 60-3.05C, *Existing Structures – Structure Rehabilitation – Repairing Structures – Epoxy Crack Injection.*

The coefficient of thermal expansion for epoxy adhesives is roughly 5 times that of concrete. This large thermal expansion difference can be tolerated for most epoxies down to approximately 15 degrees F, because they are still flexible enough at this temperature to "give" under the stress induced by volume change differences. However, since the flexibility of epoxies varies with temperature, the coefficient difference becomes critical at lower temperatures. Without proper flexibility in the epoxy system, the differential volume change will usually cause shear failure in the concrete, which is generally weaker than the epoxy. There is still sufficient residual flexibility at the lower temperatures in the epoxies designed to bond new concrete to old when their in-place thickness is 1/8 inch or less. These epoxies are not suitable for use in greater thickness, nor in epoxy concrete, or in epoxy mortar; more flexible epoxies are available for these uses.

The exact plastic flow characteristic of epoxy is still undetermined. Hence, until more knowledge is gained on this subject, epoxies should not be used in a manner that will subject them to sustained axial loads.

Rules, regardless of how complete they may be, are effective only to the extent to which they are followed. Each of the “epoxy use” rules discussed, is a vital link in the process which produces a successful job. Consequently, the degree of success, as measured by in-use performance of an epoxy application, is dependent on the attention given to the adhesive selection, mixing, and placing requirements.

For additional information concerning epoxies, contact the Chemistry Specialist at the Materials Engineering and Testing Services Transportation Laboratory.