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Effective Use of Bonding Agents

by Noel P. Mailvaganam

The main types of bonding agents used in construction are latex emulsions and epoxies. This Update reviews the properties of each and guides the user and the specifier on their advantages and limitations.

Bonding agents are natural, compounded or synthetic materials used to enhance the joining of individual members of a structure without employing mechanical fasteners. These products are often used in repair applications such as the bonding of fresh concrete, sprayed concrete or sand/cement repair mortar to hardened concrete.

Two of the critical factors affecting the bonding between new and old concrete, provided sound concrete practices are followed, are (i) the strength and integrity of the old surface and (ii) the cleanliness of the old surface.

When a weak layer of concrete (laitance) exists on the old surface or when the old surface is dirty, a poor bond is obtained. The surface condition thus plays a critical role in bond development, although the strength of the bond depends on other factors such as proper compaction of the new concrete and proper surface preparation that takes into account the density of the base concrete. For a sound base concrete, for example, acid etching will suffice, while mechanical cleaning will be essential if the old concrete contains a weak or deteriorated surface.

The main types of bonding agents used in the construction industry are latex emulsions and epoxies. Although good adhesion may be obtained without a bonding agent, generally a bonding layer consisting of cement and sand slurry, cement/latex slurry or epoxy increases bond strength.

Latex Emulsions

There are a variety of applications for latex emulsions used as bonding agents (see Table 1). Some have a greater degree of water resistance than others. The latex emulsions generally used in cementitious compositions are of the oil-in-water type, and sometimes contain more than 50% water. They are generally stable in the cement/water system. However, not all emulsions are compatible with cement, and the selection of an appropriate product for a given application requires an understanding of its chemistry or, alternatively, consultation with the manufacturer.

Three methods can be used to modify a latex to make it a useful bonding agent:

(i) Prepare a neat cement slurry utilizing the latex as part of the mixing water;
(ii) Use a 1:1 water:latex diluted material;
(iii) Use a re-emulsifiable latex, which can be softened and re-tackified upon contact with water.

The use of method (ii) is now discouraged because of the lack of bonding encountered in field applications (corroborated by laboratory studies). The use of the latex without any cement in the mix produces a failure plane because of the lack of film formation at the bond interface.

The following description of the advantages and limitations of the various types of emulsions used as bonding agents is intended to serve as a preliminary guide for the user and specifier.

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Styrene Butadiene (SBR)
Styrene butadiene (SBR) latex, which is compatible with cementitious compounds, is a copolymer. This type of latex shows good stability in the presence of multivalent cations such as calcium (Ca^{2+}) and aluminum (Al^{3+}), and is unaffected by the addition of relatively large amounts of electrolytes (e.g., $CaCl_2$). SBR latex may coagulate if subjected to high temperatures, freezing temperatures, or severe mechanical action for prolonged periods of time.

Polyvinyl acetate latex (PVA)
Two main types of PVAs are used in repair: non-re-emulsifiable and emulsifiable. Non-re-emulsifiable PVA forms a film that offers good water resistance, ultraviolet stability, and aging characteristics. Because of its compatibility with cement, it is widely used as a bonding agent and as a binder for cementitious water-based paints and waterproofing coatings. Emulsifiable PVA produces a film that can be softened and re-tackified with water. This type of latex

Table 1. Latex bonding agents comparative chart

Property/ test method	**Acrylic**	**Polyvinyl-acetate (non-re-emulsifiable)**	**Butadiene-styrene**	**Polyvinylacetate (re-emulsifiable)**
Appearance	Milky white	Milky white	Milky white	Milky white or clear
Solids Content	45%	55%	48%	50%
Primary Use	Bonding fresh concrete to old concrete	Bonding fresh concrete to old concrete, thin layer toppings	Bonding fresh concrete to old concrete, concrete admixture, thin layer toppings	Bonding to plaster
Application Methods	Brush, broom, spray, roller as adhesive, trowel as topping	Brush, broom, spray, roller as adhesive, trowel as topping	Brush, spray, roller as adhesive, trowel as topping.	Brush, spray, roller
Applications	<—Underlayments, stucco, grouting-mortar, terrazzo, crack fillers—>			
Cleaning, Surface Preparation	Remove oil, grease; wet surface	Remove oil, grease	Remove oil, grease	
Comp. Strength (MPa) 2 in. (50 mm) cubes ASTM C109	22.0 28.27	23.45 24.82	22.75 27.58	22.0 (air) 20.68 (wet)
Tensile Strength (MPa) 1 in. (25 mm) thick briquettes ASTM C190	4.0 4.24	2.41 3.10	3.10 4.0	2.06 (air) 2.83 (wet)
Flexural Strength Bar (MPa) ASTM C-348-61T	6.55 9.65	6.90 8.62	8.62 11.38	6.38 (air) 5.17 (wet)
Where to Use	Indoor and outdoor exposures; on concrete, steel, wood; guniting; thin section topping. May be used as a plaster bond within 45-60 min.	Indoor and outdoor exposures; on concrete, steel, wood; guniting; thin section topping. May be used as a plaster bond within 45-60 min.	Indoor and outdoor exposures; on concrete, steel, wood; guniting; thin section topping. May be used as a plaster bond within 45-60 min.	Indoor ceilings primarily, limited use as concrete bonding agent
Where Not to Use	Not for extreme chemical exposure, not for conditions of high hydrostatic pressure	Not for extreme chemical exposure, not for conditions of high hydrostatic pressure	Not for extreme accelerators, not for extreme chemical exposure, not for constant water	Do not use as an admixture. Do not use under wet or humid conditions. Do not use at temperatures below 10°C.

From P. Maslow, *Chemical Materials for Construction* (with permission).

permits the application of a film to a surface long before the subsequent application of a water-based overlay. Its use is limited to specific applications where the possible infiltration of moisture to the bond line is precluded. It is most widely used as a bonding agent for plaster, and to bond finish- or base-coat gypsum, or Portland cement plaster, to interior surfaces of cured cast-in-place concrete.

Acrylic latex

Acrylic ester resins are polymers and copolymers of the esters of acrylic and methacrylic acids. Their physical properties range from soft elastomers to hard plastics. This type of emulsion is used in cementitious compounds in much the same manner as SBR latex.

Epoxy latex

Epoxy emulsions are produced from liquid epoxy resin mixed with the curing agent. In addition to serving as an emulsifying agent, the curing agent also serves as a wetting agent. From the time of mixing until gellation occurs, the emulsions are stable and can be diluted with water. Pot life can be varied from 1 to 6 hours depending on the curing agent selected and on the amount of water added. Most epoxy emulsions are prepared on the job site just before use because phase separation occurs in prepackaged emulsions. Equal parts of epoxy and curing agent are mixed, then blended for 2 to 5 minutes and allowed to set for 15 minutes to enable polymerization to begin. While the mixture is being mechanically agitated, water is added slowly to form the emulsion.

As an alternative to these liquid-based systems, which require on-site measurement and pre-dilution, it is now possible to obtain factory-blended powders containing a mixture of cement, spray-dried latex powders, sand and other additives, which are simply mixed with water on site. The resultant “stipple” finish provides a good “key” for repair mortar or overlays. The stippled grout coat minimizes the loss of water from the overlay to the substrate, preventing desiccation of the cement and the resultant poor bond. Although the grout coat does provide points of anchorage for bonding, the application of the repair mortar or overlay while this key coat is still tacky is strongly recommended.

Epoxy Bonding Agents

Various epoxy products are available for the bonding of freshly placed concrete to cured concrete and of concrete to steel. Most products contain resins that are 100% solids. They may or may not contain fillers, such as calcium carbonate or silica flour, and other additives to enhance a particular property or reduce cost. Products are available in a variety of consistencies, ranging from a highly filled paste (for overhead work) to liquids with a viscosity of 100 cp (0.1 Pa•s), which is similar to that of water.

Because the formulations can combine different resins, hardeners and modifiers to produce a great variety of end products, the user and specifier need guidance on the options available to them. The ASTM standard ASTM C881-78 “Epoxy-resin-based Bonding Systems for Concrete” is quite informative in this respect. It is a performance specification based on end use and there are no specific limits on chemical composition. Instead, the material selected must meet requirements related to physical properties such as viscosity, bond strength, shrinkage and thermal compatibility.

The specification classifies the epoxy-resin bonding system by type, grade and class. The type is determined by end use (see ASTM C881, Table 1, “Physical Requirements of Bonding Systems”). Systems can be summarized as follows:

- Type I, for bonding hardened concrete and other materials to hardened concrete;
- Type II, for bonding freshly mixed concrete to hardened concrete;
- Type III, for bonding skid-resistant materials to hardened concrete (or for use as a binder in epoxy mortars or concretes).

The grade of a system is defined by its flow characteristics. For example, materials of low viscosity suitable for injection into cracks, and where flow is required, are grouped in Grade 1. Grade 2 comprises medium-viscosity materials for general-purpose use, and Grade 3 materials are of a non-sagging consistency for overhead work or for bonding non-mating surfaces. The materials are further divided into classes by the test temperature at which the gel times are determined (gel time is the interval between the beginning of mixing an epoxy system and the first formation of a gelatinous

Table 2. Application factors for epoxy bonding agents

Mixing ratios	Vary from 100:1 to 1:1
Pot life	Instantaneous to several months; also influenced by amount of material mixed and ambient temperature.
Exotherm	Can vary from 0°C to over 100°C, in which case the cured system is literally charred.
Viscosity	Can vary from liquid of 100 cp (0.1 Pa•s), the consistency of water, to very heavy paste.
Penetrability	A function of viscosity and lubricity — varies widely.
Cure time	Varies from a few minutes to several days and is directly dependent upon the application temperature. (Some systems will not cure unless exposed to very high temperatures.)

From J. Warner, *Magazine of ASCE*, February 1978 (with permission).

mass within the system). The materials are not, however, restricted to use at the temperature designated for each class.

Class A – systems for use below 5°C
Class B – systems for use between 5 and 15°C
Class C – systems for use above 15°C.

Three properties stipulated in the ASTM specification are of great importance, namely: bond strength, shrinkage and thermal compatibility. ASTM tests C882, C883 and C884 determine the respective values for these properties required by the specification. The tests are an effective means of screening products that are unsuitable for the intended use. For example, the bond strength test (ASTM C882) will eliminate systems that are adversely affected by bleed water from plastic concrete if the intended use is the bonding of fresh concrete to hardened concrete. The shrinkage test (ASTM C883) will eliminate systems containing solvents, excessive quantities of dilutents or other chemicals that will induce shrinkage. If a bonding system has a high modulus of elasticity, a patch or overlay may delaminate as a result of changes in temperature. The ASTM C884 test measures this tendency.

Although the ASTM C881 specification provides a means of screening out materials that are likely to perform poorly, other properties not addressed in the specification should be taken into account when making a final choice among similar epoxy resin systems.

Most epoxy bonding products have a pot life or setting time of 15–30 minutes at 25°C, making it necessary to mix only the amount that can be properly used in that period of time. At temperatures below 0°C, the setting time is considerably longer (4–5 hours). Some of the application factors that should be considered are shown in Table 2.

Where extensive repair work is necessary — such as slab replacement or resurfacing of vertical walls or columns — epoxy bonding agents, in combination with new concrete, often provide the most economical solution. The use of the bonding agent ensures that the repair will have the strength of monolithically cast concrete.

Conclusion

One of the critical factors governing the achievement of an effective repair is good adhesion at the interface of the repair material and the concrete substrate. Good adhesion is imperative for structural repairs where monolithic character is required for the transfer of load. A proper bond between the repair material and the substrate can be obtained by diligent workmanship — involving surface preparation, consolidation and curing — without the use of bonding agents. However, bonding agents play a significant role where it is critical to ensure bond at the interface. For example, a weak and pliable substrate may need strengthening to match the modulus of the repair material. A bonding agent may be required because of the prevailing poor ambient conditions. Notwithstanding the advantages provided by bonding agents, they should not be used to compensate for poor workmanship.

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