
AASHTO-AGC-ARTBA Joint Committee

Subcommittee on New Highway Materials

Task Force 34 Report

Guide Specifications for Polymer Concrete Bridge Deck Overlays

October 1995



GUIDE SPECIFICATIONS FOR POLYMER CONCRETE BRIDGE DECK OVERLAYS



AASHTO-AGC-ARTBA

TASK FORCE 34

OCTOBER 1995



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TASK FORCE 34

Polymer Concrete Bridge Deck Overlays

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CHAPTER 1—INTRODUCTION

1.0—Definition of Terms

Monomer as used herein is a low-viscosity, liquid organic material from which a polymer is made.

Polymers are hard, glassy solids commonly called plastics.

Polymerization is a chemical process by which a monomer is converted into a polymer.

Inhibitors are materials that are added to monomers to prevent polymerization from occurring during shipping and storage.

Initiators are chemical materials that are required to start the polymerization process.

Promoters are chemicals used to accelerate the polymerization process.

1.1—Abbreviations

AASHTO. American Association of State Highway and Transportation Officials.

ACI. American Concrete Institute.

AGC. Association of General Contractors.

ARTBA. American Road and Transportation Builders Association.

ASTM. American Society for Testing and Materials.

MSDS. Material Safety Data Sheet.

VTM. Virginia Test Method.

1.2—Polymers in Concrete

Polymers have been used in concrete as construction materials since the 1950s. The use of polymer concrete materials for highway and bridge deck applications has been increasing in the United States since the 1970s.¹⁻⁴ As the traffic volume grows, the benefits of the quick repairs possible with polymer concrete materials will likely lead to continued growth of the polymer concrete industry.⁵⁻⁷

Polymer concrete is a composite material formed by polymerizing a monomer and aggregate mixture. It has properties that make it highly desirable as a bridge deck overlay, among other things. Although these guide specifications focus on the use of polymer concrete for bridge deck overlays, it has many other uses, including building panels and tiles, cultured marble, pipe and liners, flooring, pilings, railroad ties and crossings, machine bases, adhesives, anchors, and grouts.^{1,2,5} Polymer concrete materials can also be used for patching bridge decks.

1.3—Properties of Polymer Concretes

Polymers are long molecules composed of repeating or random chains of smaller molecules called monomers. Certain chemicals, or catalysts, cause a reaction known as polymerization, which combines monomer and polymer molecules into polymer chains and causes the polymer chains to link together into even longer chains and three-dimensional networks.^{8,9} This chemical process is used to transform a liquid resin into a solid mass. The polymer network binds aggregate particles together in a polymer concrete.

Depending on the formulation of polymer used, polymer concrete can exhibit different properties. Some of the features that are generally true of polymer concrete include the following^{2, 3, 7, 10-14}:

- rapid curing at ambient temperatures
- good bond strength to concrete bridge decks and other surfaces
- high flexural, tensile, and compressive strength
- very low or negligible permeability
- good long-term freeze-thaw durability
- low dead load, when compared to conventional or polymer-modified concrete overlays
- high friction resistance, depending on the aggregate used
- resistance to deicing salts, acids, petroleum products, etc.

It is also generally true that polymer concrete is relatively expensive in terms of initial material unit costs. These high costs can, however, be mitigated by the small volume of material required relative to hydraulic cement concrete and by the reduction in other construction costs, such as raising end dams, joints, and scuppers. Life cycle costs may be lower than for other rehabilitation techniques. Also, consideration of traffic control and user costs attributable to

construction delays can make polymer concrete overlays attractive because placement can be accomplished in hours with short lane closure times.^{12,15,16}

1.4—Polymer Concrete Overlays

The most commonly used polymers for bridge deck overlays include epoxy, unsaturated polyester styrene, and methacrylate. Different polymers are suited to various applications because of their viscosity, gel time, flexural strength, modulus, coefficient of expansion, etc. For example, low-viscosity binders tend to be well suited to crack filling, prime coats, and highly filled premixed and slurry mixtures. High-viscosity resins may be better suited to multiple-layer overlays.^{3,5,6} Different formulations of these basic polymers can be designed with particular properties for specific types of applications. For example, formulations can be prepared to have the desired tensile strength, elongation, and time to set.

Aggregates for use in polymer concrete should be hard, high-quality aggregates, such as basalt, silica, quartz, or granite. Synthetic aggregates, such as aluminum oxide or emery, may also be used. To ensure a good bond with the polymer, aggregates should be clean and dry. The appropriate gradation to use depends on the application. Aggregates to be broadcast over the surface of a multiple-layer or slurry overlay should be angular and gap graded to give better stability and friction resistance. For slurries or premixed overlays, well-graded, rounded aggregates are generally recommended to reduce the binder demand and enhance workability, although gap-graded aggregates have been used successfully in slurry overlays.^{2,3,6,10,11}

Polymer concretes can be applied to bridge decks as overlays in three basic ways^{3,6,7,17,18}:

1. *Multiple-layer overlays*, also called broom-and-seed overlays, involve distributing a polymer binder or resin on the existing, prepared bridge deck followed by broadcasting gap-graded aggregate (see Figure 1). The polymer binder can be distributed by broom, squeegee, or spray bar. The aggregate can be broadcast over the top by hand, shovel, or automated spreading device. Two or three layers of resin and aggregate are typically used, resulting in an overlay approximately 6 to 9 mm (0.25 to 0.375 in) thick.
2. *Slurry overlays* are typically constructed by mixing the resin and uniformly or gap-graded aggregate (silica sand and flour) in a slurry form and placing it on the existing deck (see Figure 2). Gap-graded aggregate is broadcast over the top, as in multiple-layer overlays, for good friction properties. Some slurry seals may require the use of a prime coat on the existing, prepared deck and a seal coat to lock in the cover aggregate. The thickness of slurry seal overlays is usually about 8 mm (0.31 in), but it can vary from 6 to 19 mm (0.25 to 0.75 in).
3. *Premixed overlays* consist of mixtures of resin and uniformly graded aggregate struck off and compacted by a vibratory screed (see Figure 3). A prime coat is often used.

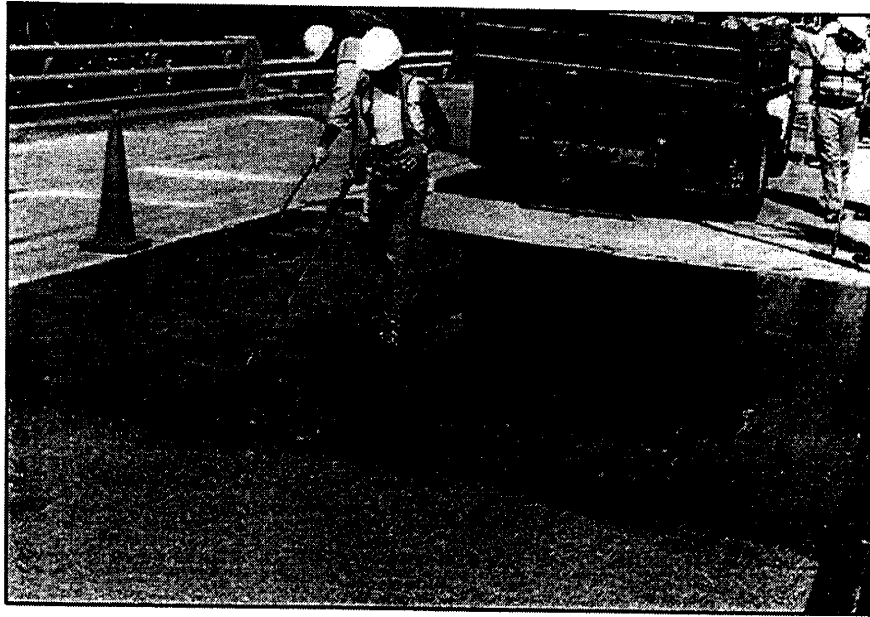


FIGURE 1. A multiple-layer epoxy overlay consists of two layers of epoxy and aggregate. An epoxy mixture is here spread over the deck with notched squeegees. Basalt aggregate is here broadcast to excess from the back of a dump truck.

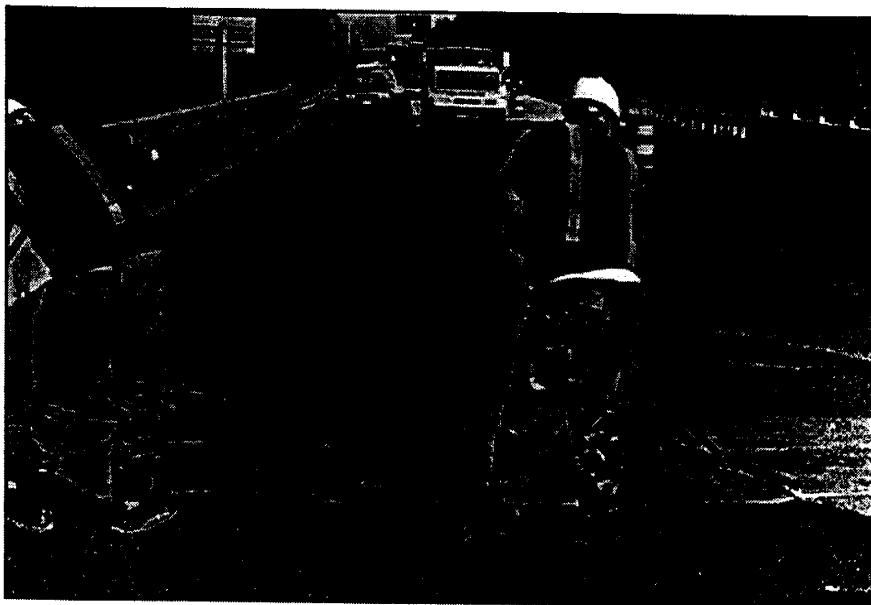


FIGURE 2. Methyl methacrylate aggregate slurry mixed with mortar mixers is here applied to a shotblasted surface that was primed at least 1 hr earlier with a methyl methacrylate primer. The primer must be cured prior to placement of the slurry. The overlay should be struck off with gage rakes set to provide a layer of slurry 5 mm (0.19 in) thick.

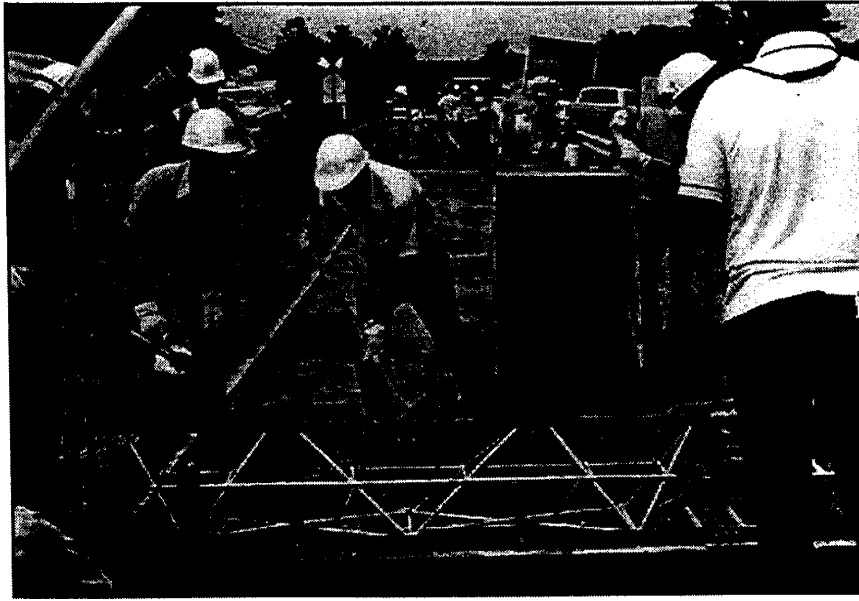


FIGURE 3. Premixed polyester styrene resin concrete may be consolidated and struck off with a transverse vibrating screed. The overlay is typically 6 to 25 mm (0.25 to 1.00 in) thick.

Friction properties can be improved by grooving the concrete or broadcasting aggregate onto the surface. Premixed overlays are typically at least 6 to 25 mm (0.25 to 1.00 in) thick.

Specifications for these overlays are provided in the following chapters.

1.5—When to Use Polymer Concrete Overlays

The use of polymer concrete overlays may be an appropriate rehabilitation technique for bridge decks with one or more of the following problems⁶:

- high permeability in the concrete cover over the reinforcing steel (in excess of 2,000 coulombs [AASHTO T-277])
- less than 50.8 mm (2 in) of clear cover over the reinforcing steel
- excessive cracking (non-moving)
- concrete cover lacking proper air entraining and air void system
- decks with patches (to extend the life of the patched areas)

- decks needing improved friction resistance
- decks needing improved ride quality.

Polymer concrete overlays can also be used as a protection system for new bridge decks.

The selection of the type of polymer concrete overlay to be used may depend upon the particular features and condition of the structure in question, appropriate thickness of overlay needed, availability, equipment, and other singular issues. Multiple-layer overlays are best suited for decks in good condition and with few surface imperfections. Premixed overlays are best suited for decks with surface irregularities that can be corrected with an overlay that is greater than or equal to 12.7 mm (0.5 in) thick. The use of premixed overlays also shortens the application time since there is no need to place two or three separate layers.

1.6—Surface Preparation and Application

Polymer concretes generally bond very well to bridge deck concrete. To ensure adequate performance of the entire overlay it is essential that the surface to which the overlay is bonded be sound and clean.³ This section serves as a general guide to surface preparation; specific information regarding the surface preparation requirements for a particular polymer concrete should be obtained from the materials supplier.

Any application of polymer concrete should be preceded by an evaluation of the deck surface. This evaluation, consisting of a visual inspection and the detection of delaminations, is necessary to determine what surface preparation steps are to be taken before the polymer concrete overlay is applied. Chain drags, hammer sounding, infrared thermography, radar, cores, ultrasound, electrical half-cell potentials, chloride contents, and other evaluation methods can be used to complete the condition survey. The evaluation should identify the extent of deteriorated, chloride-contaminated concrete that must be removed and replaced; the amount of cracking to be repaired; and the presence of laitance, curing compound, asphalt patching, and sealers, such as linseed oil, to be removed. The evaluation should also attempt to identify the cause of identified distresses and whether the distress is still active. If the cause of the distress is still active, steps other than a polymer overlay may be necessary to correct the problem.

Weak, delaminated areas should be removed or repaired. Shotblasting is frequently used to clean the deck and remove deteriorated, chloride-contaminated concrete at the surface in one operation (see Figure 4). The use of chipping hammers, scarifiers, scabblers, hydrodemolition, and other techniques may also be used, especially where more extensive concrete removal is necessary. A saw cut around the area to be removed is recommended to reduce edge spalling and provide a sound surface against which to place the patching material. The method used to remove the deteriorated, chloride-contaminated concrete should not weaken or crack the surrounding sound concrete. Final surface preparation should be by shotblasting. If delaminations are so extensive



FIGURE 4. The first step toward the successful placement of a polymer concrete overlay is to shotblast the concrete surface. Shotblasting equipment is available in a range of sizes. Units that blast a strip 230-mm (9-in) wide and a strip 1.8-m (6-ft) wide are shown here.

or the concrete is so badly deteriorated that a great deal of concrete must be removed, deck replacement may be a better, more cost-effective rehabilitation technique.

Cracks in the concrete surface should be examined to determine if they are working or stationary. Reflective cracking of the polymer overlay may occur if excessive movement of the cracks is not prevented, but the more flexible polymer concrete can accommodate some movement. Large, stationary cracks should be filled prior to overlaying the deck surface.

Materials used for patching and crack filling should be compatible with the polymer concrete overlay. All repair materials should be adequately cured before the overlay is placed. For best results, hydraulic cement concrete patching materials should be cured for 28 days. When they cannot be cured for 28 days, adhesion tests must be conducted to determine the age at which acceptable bond strengths can be obtained. Cracks can typically be filled with polymer materials that can be overlaid within hours.

Dirt, oil, grease, laitance, or other surface deposits can interfere with the bond of the polymer concrete overlay to the substrate. Deck cleaning, therefore, is necessary before the overlay is placed. Deck cleaning also removes any debris remaining after the removal of unsound concrete. Sandblasting or shotblasting, a scabber, grinding, or a high-pressure water jet can be used to clean surface contaminants from the deck. Oil-free compressed air can be used to remove any dust or debris immediately prior to application of the polymer.^{3,11}

The deck must be dry prior to placement of the polymer concrete overlay even though some formulations are more tolerant of moist conditions.¹⁵ Water vapor rising from the surface is a potential problem as well. A sheet of transparent plastic affixed to the concrete surface will reveal the presence of moisture after 6 to 24 hr, depending on the temperature, cloud cover, and other conditions (ASTM D4263).³ A tensile adhesion test (ACI 503R, Appendix A, or VTM 92) should be used to ensure that the polymer materials and surface preparation procedures will result in an adequate bond strength between the overlay and the substrate.

The temperature limitations specified for the particular polymer used should be adhered to strictly. The deck and air temperatures must be appropriate. In addition, the components of the polymer overlay (aggregate and binder) used must be at the appropriate temperature in accordance with the Manufacturer's recommendations. The viscosity of most polymers decreases with decreases in temperature and, thus, at lower temperatures a polymer may not adequately penetrate the surface and at elevated temperatures a polymer may be too thin. Mixing, workability, curing times, and other characteristics may also be affected.

Mechanical mixing is generally recommended. Hand mixing is often difficult and takes longer than mechanical mixing. The pot life of the materials used should be considered and accommodated by mixing only what can be placed in the time available for working the material. Pot life can vary depending on the temperature and quantity of material mixed.

Actual placement techniques used vary for different materials and overlay types. Many are manually applied, but the use of automated or semi-automated equipment (continuous blend mixers, slurry machines, etc.) is increasing. Premixed polymer concrete overlays can also be placed with modified concrete or asphalt pavers. Consolidation of the polymer concrete may be obtained by vibratory screeding.

1.7—Safety and Material Handling

When working with any resin, it is important to follow prescribed safety practices.^{3,17,19} This section discusses some of the common hazards and precautions associated with polymer concrete in general. The Manufacturer's recommendations for storing, mixing, and handling should be read, understood, and followed for the particular materials used in a given application.

Some commercially available resins, chemical catalysts, and reagents are toxic but have been shown to be safe for workers and the public when handled and placed properly. Eye, respiratory, and skin irritation are possible health effects of exposure. Skin sensitization, an allergic reaction, may occur with some materials, such as epoxies. Sensitization may occur immediately or may be delayed and develop only after continual exposure.

Many of the chemicals are flammable, so care should be exercised to avoid open flames from matches, heaters, and other sources. Smoking should be banned in storage, mixing, and work

areas. Certain chemicals used in polymer concrete are so flammable that all sparks should be avoided, even those from friction or electrical devices such as lights, power sources, storage refrigerators, etc.

Appropriate fire extinguishers should be available at the storage, mixing, and application sites. MSDSs, first aid kits, and emergency telephone numbers should also be readily available at the job site in case of an emergency. Appropriate materials for control of spills should be accessible as well. Absorbent clays are often suitable, but they may react exothermically with some monomers.

Care must be taken when combining components of the polymer concrete since the combinations may have different properties than the individual components. The order of addition recommended by the Manufacturer must be followed exactly. For example, promoters should never be mixed directly with peroxide initiators since an explosive mixture will be produced.

The chemicals can also change or decompose under storage conditions. Drums of certain materials should not be stored in the sun or in hot conditions since they can change upon exposure to heat or light. It is strongly recommended that all components of the polymer concrete be stored in cool areas. However, some components should not be allowed to freeze because they may segregate. Initiators should not be stored together with promoters and monomers. During storage and use, it is very important that the chemicals be clearly and properly labeled.

Safety equipment, as specified by the material supplier, should be provided to and used by workers for their protection. This includes safety goggles or full face shields, chemically resistant gloves, and protective clothing. Respirators may also be required with some materials. Face shields may also be required with some chemicals. Gloves and other protective gear should be impervious to the chemicals and solvent used. Disposable suits and gloves should, in general, not be reused. Contaminated clothing or gloves should not be reused.

If direct contact with skin occurs, the recommendations for cleanup for the particular material used should be followed promptly. Generally, washing the affected area with soap and water is adequate, but the Manufacturer's recommendations should always be followed. Eating, smoking, and touching the face or other skin should be avoided until protective gear has been removed and proper hand cleaning has been effected.

The best way to protect workers is to limit exposure to those employees who have been thoroughly trained in the specifics of the chemicals with which they are working. Non-essential personnel should avoid the job site.

A plan for disposal of excess materials, disposable protective gear, and empty containers should be developed prior to working with the polymers and should be explained to the workers. The plan should be specific to the materials used since the polymers, catalysts, solvents, and other

chemicals used have differing requirements. Mixing only the amount of material required will reduce the amount of waste or excess material to be disposed of.

Some materials can be incinerated. Waste monomers that have not been polymerized can be polymerized in an open container in a process called bulk polymerization. The initiators and promoters are added to the monomer so that it polymerizes into a solid mass, which can be sent to a landfill. Excess epoxies can similarly be hardened by the addition of a curing agent and can then be disposed of in a landfill. Local, state, and federal regulations should be consulted and followed, especially for incineration or the placement of any chemical in a landfill.

1.8—Need for Performance Specifications

The basic resins can be formulated in different ways to provide a variety of properties such as set time, flexibility, etc. The most reasonable approach to specifying polymer concrete overlays is through the use of performance specifications, rather than material specifications. This allows material suppliers to compete with different materials that can provide the same level of performance.

Specifications, then, should detail the properties desired of the final product. Properties of interest would include the following^{2,10,12,15}:

- bond strength to ensure good adhesion to the substrate (>3.4 MPa [500 psi], California Test Method 551, or >1.7 MPa [250 psi], ACI 503R, Appendix A, or VTM 92)
- thermal compatibility of the polymer concrete with the underlying substrate to reduce differential thermal expansion and the resulting shear stresses
- compressive strength of the overlay to provide adequate mechanical strength (>34.5 MPa [5,000 psi], ASTM C579)
- tensile strength and elongation of the polymer binder to ensure that the overlay can bridge cracks and tolerate deflections and thermal movement (tensile strength of 13.8 to 34.5 MPa [2,000 to 5,000 psi], elongation of 30 to 80 percent, ASTM D638)
- low permeability to protect the reinforcing steel from moisture-carrying chloride ions that can cause corrosion (<200 coulombs in accordance with AASHTO T277 when tested in the thickness specified for the overlay)
- friction resistance to provide a safe wearing surface as prescribed by the Department.

Minimum or maximum levels of these and other properties should be specified. The values listed here are suggested values applicable to most systems that have been used successfully in

the past. They may, however, not hold for all polymer concrete overlay systems. (See the following chapters on individual systems for more specific information.) It is, after all, the final properties of the overlay that are a primary concern, not what materials are used to furnish those properties.

1.9—Performance of Polymer Overlays

Polymer overlays can be expected to last from 10 to 25 years; the life is a function of the type of overlay and the traffic conditions.¹⁸ Figures 5, 6, and 7 illustrate how typical polymer overlays perform with respect to bond strength, permeability to chloride ion, and skid number.¹⁸ Based on Figures 5, 6, and 7, multiple-layer epoxy, multiple-layer epoxy-urethane, and premixed polyester overlays are projected to last for 25 years when placed on decks with a volume of traffic less than 5,000 vehicles per day.¹⁸ Multiple-layer epoxy overlays are projected to last 10 years when the volume of traffic is more than 50,000 vehicles per day. A reduced service life can be expected when the predominant in-service conditions include saturated concrete, high relative humidity, and high temperatures.

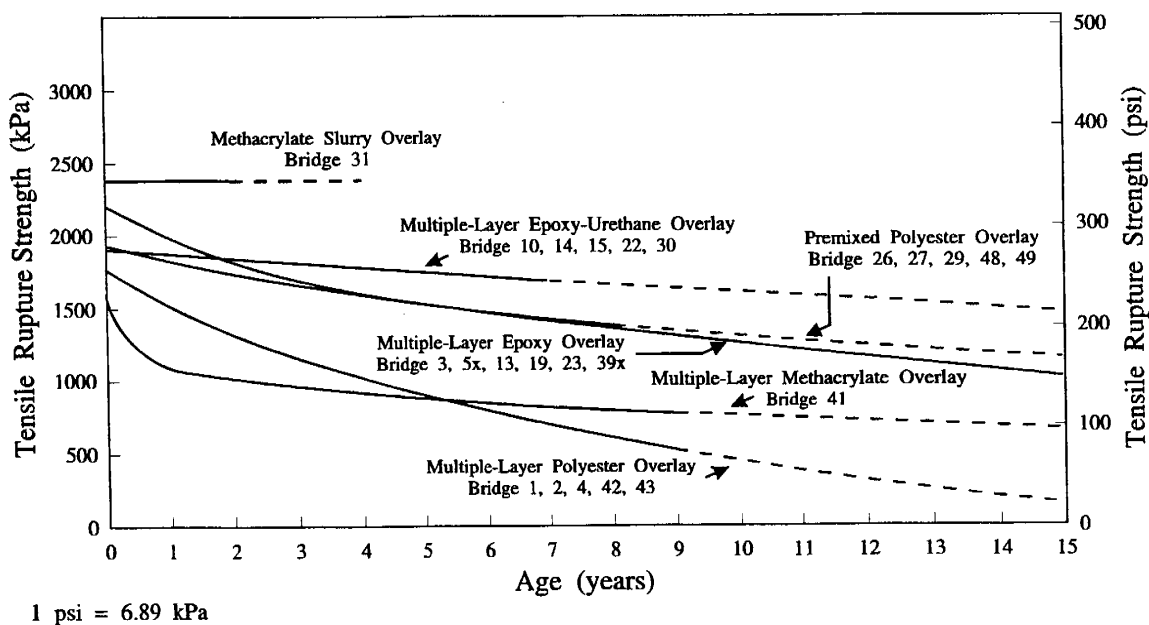


FIGURE 5. Tensile rupture strength (ACI 503R, VTM 92) versus age for polymer overlays.

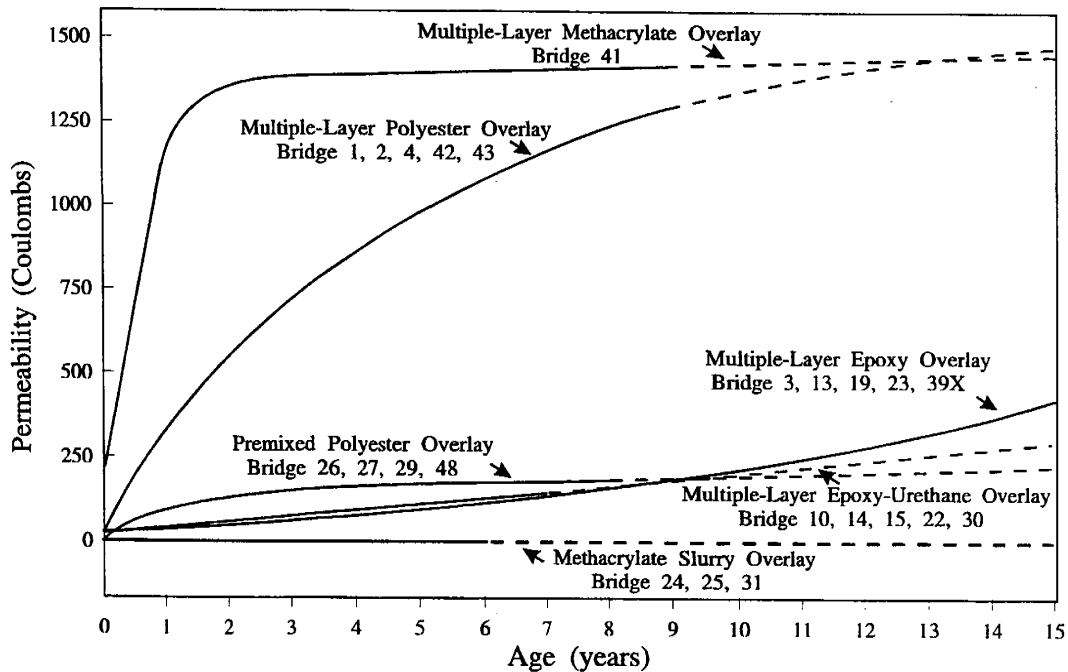


FIGURE 6. Permeability to chloride ion (AASHTO T277) versus age for cores taken from decks with polymer overlays.

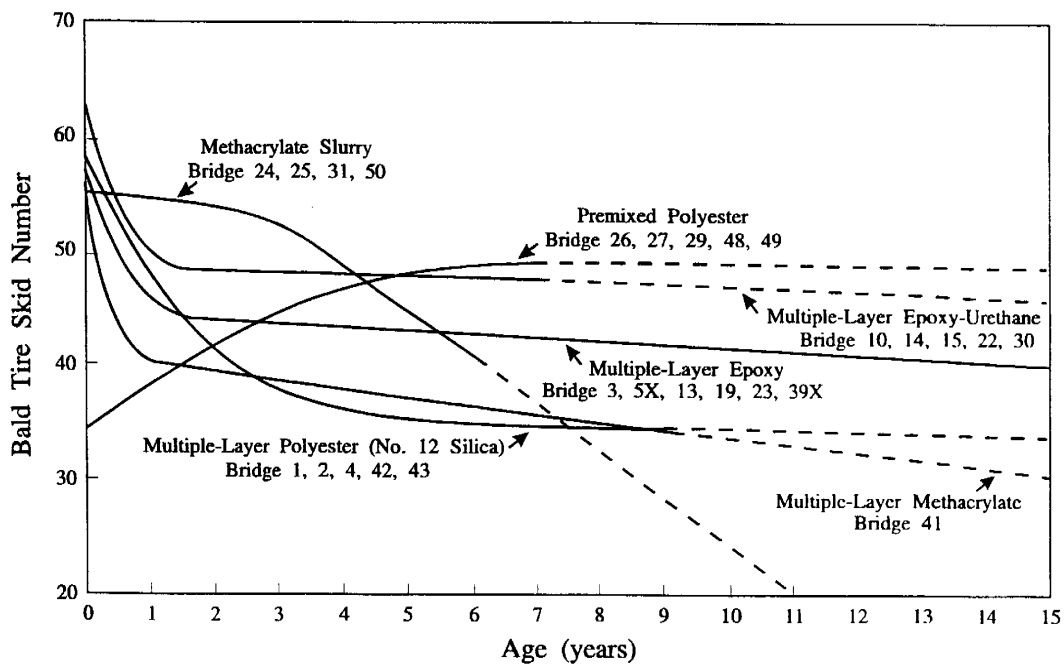


FIGURE 7. Bald tire skid number (ASTM E524) versus age for polymer overlays.

1.10—Research Needs

Research is needed to extend and improve these specifications and the uses of polymer concrete. Suggested topics include the following:

- determination of fundamental physical properties and tests that will identify systems that will perform under extreme conditions, such as very low or very high temperatures, heavy loads, or heavy traffic volumes
- development and validation of accelerated aging tests for polymer concrete
- development and validation of tests that will identify polymer concrete systems that will have sufficient flexibility at low temperatures and sufficient strength at high temperatures
- examination of the freeze-thaw performance of overlay composite specimens.

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CHAPTER 2—MULTIPLE-LAYER POLYMER CONCRETE OVERLAYS

2.0—Description

This work shall consist of preparing deck surfaces and furnishing and applying thin multiple-layer polymer concrete overlays on designated bridge structures in accordance with this specification and in conformity with the lines, grades, and details shown on the plans or established by the Engineer. The minimum overlay thickness shall be 6 mm (0.25 in).^{1*} Overlay systems include epoxy, epoxy urethane, and polyester with a methacrylate primer.

2.1—Materials

The polymer materials supplier shall provide technical literature to the Contractor to provide technical advice on storage, mixing, application, cleanup, and disposal of materials.

An MSDS shall be furnished for the resin (including promoter and initiator if applicable) to be used on the project. A certification showing conformance to these specifications shall be provided with each batch of resin. MSDSs for all materials shall be maintained with the materials at all times.

2.1.1—Aggregate

The aggregate shall be an angular-shaped silica with a Mohs scale hardness of 7 or greater or basalt with a hardness of 6 or greater. The aggregate shall be clean, dry (less than 0.2 percent moisture), and free from dirt, clay, asphalt, and other organic materials. Except as otherwise approved by the Engineer, the aggregate shall conform to the gradation specified in Table 2.1.1.²

TABLE 2.1.1—AGGREGATE GRADATION (PERCENT BY WEIGHT PASSING INDICATED SIEVE)

Sieve No.	4	8	16	30
Percent Passing	100	30-75	0-5	0-1

2.1.2—Epoxy

The epoxy resin base and hardener shall be composed of a two-component, 100 percent solids,³ thermosetting, moisture-insensitive, flexible, high-elongation compound with the properties specified in Table 2.1.2.

*Superscript numbers refer to the notes in Section 2.7, Commentary.