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Guide for Polymer Concrete Overlays

Reported by ACI Committee 548



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Guide for Polymer Concrete Overlays

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This guide provides an overview of thin (less than 1 in. [25 mm] thick) polymer concrete overlays for concrete and steel substrates. Emphasis is placed on their use in the transportation sector, specifically for bridge decks and parking garages. Surface preparation, application, quality control, and safety aspects are included.

Keywords: aggregate; bridge deck; epoxy; high friction surface; methyl methacrylate; mortar; overlay; parking garage decks; polyester; polymer concrete; premixed; resin; skid resistance; slurry.

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CHAPTER 1—INTRODUCTION**1.1—General**

Reinforced concrete, steel grid, and steel orthotropic decks are constantly exposed to deicing salts and other environmental factors such as acid rain and pollution chemicals. Escalating costs of preservation and replacement of bridges and parking garage decks have promoted construction and maintenance options such as high-density concrete overlays, latex-modified concrete overlays, membrane/asphalt overlays, cathodic-protection systems, epoxy-coated reinforcing bars, and thin polymer concrete (PC) overlays (Mo et al. 2012).

Each option has advantages and disadvantages that should be analyzed before a choice is made. Costs vary by region with the availability of materials and experienced contractors. In addition, the life expectancies of these options are different.

Bridges and parking garage decks contain structural elements that are susceptible to premature failures due to moisture, chlorides, freezing and thawing, and wear from high traffic volumes.

1.1.1 Advantages—Compared with other overlay systems, PC overlays are cost effective on a life cycle cost basis (Kim and Lee 2013). Rapid-cure characteristics of PC overlays minimize disruptions, reduce traffic-control costs, and ease the inconvenience of scheduling repairs. With dead load of only 2 to 6 lb/ft² (9.8 to 29.3 kg/m²), PC overlays result in greater live-load capacity than heavier conventional systems. This is a critical factor to be considered for aging structures. At application thicknesses of 3/8 to 1 in. (10 to 25 mm), PC overlays do not require modification of expansion joints or drainage structures. They are highly resistant to the penetration of water and exhibit better chloride-intrusion resistance than other types of concrete overlays. In addition, they offer a high skid resistance and wearing resistance for both concrete and steel deck protection (Lopez-Anido et al. 1998; Wang et al. 2013). PC overlays can be installed without specialized equipment; however, technical expertise is required. Maintaining quality control is important, and proper surface preparation requires close attention.

1.1.2 Disadvantages—A disadvantage associated with PC overlays is that they must be applied to dry surfaces. The workability and curing rate of PC overlays are dependent on the substrate, material, and ambient temperatures. Polymer overlays are not intended to provide resistance to reflective cracking.

1.2—History of polymer concrete overlays

Polymer concrete (PC) overlays date back to the 1950s, with original systems consisting of a single layer of coal-tar epoxy evenly spread over the substrate and broadcast with aggregate. These overlays were relatively porous and did not stand up well to heavy traffic. In the early 1960s, oil-extended epoxy came into use in an attempt to improve resistance to water penetration. By the mid-1970s, low- and medium-modulus 100 percent solids epoxy formulas were introduced, and many of these systems continue to be used successfully today.

By the mid-1960s, single- and double-layer polymer broadcast systems and polyester resins, and methyl methacrylate overlays were introduced. The first premixed and screeded polymer and aggregate systems also appeared at this time. Thicker PC overlays and brittle materials were used, frequently exhibiting cohesive failure in the concrete. Through trial and error, resin formulations were modified to provide better thermal compatibility and improved physical properties. Resistance to chemical and mechanical attack, corrosion resistance, and performance under adverse installation conditions have also been the subject of extensive development. For instance, Whiting (1991) showed, using field measurements, that corrosion current in reinforced concrete bridge deck substrates is decreased when a low-permeability overlay (for example, latex-modified concrete overlay) was installed. Virmani (1992) showed that electrically conductive PC overlays can be used as secondary anodes to distribute cathodic protection current across the concrete surface and provide a skid- and water-resistant surface. PC overlays have been shown to be successful, though some problems still exist. Many of these problems are the result of inadequate surface preparation, improper application techniques, or inappropriate selection of polymer materials.

There have been many improvements in PC materials and technology. PC overlays are now generally specified with flexible resins and high-friction wear-resistant aggregates. Workmanship and inspection techniques have also improved as designers, inspectors, and applicators have gained experience related to the causes and prevention of PC overlay defects continues to improve. Some of the best practices on PC overlays have been reported by Fowler and Whitney (2011).

1.3—Scope

This guide is intended to aid in the proper selection and application of PC overlays for structures in the transportation industry, focusing primarily on bridge and parking garage decks. Materials discussed are epoxies, polyesters, and methacrylates for application on either concrete or steel surfaces.

In general, these overlays are used for the protection of the substrate and are designed to be compatible without causing stress. The low permeability of PC overlays makes them resistant to the penetration of water and provides protection against chloride penetration. Overlays are designed to minimize deterioration from repeated thermal expansion and contraction (Fowler et al. 2001). In addition to describing the characteristics of PC overlays, this guide includes chap-

ters on surface preparation, application, quality control, and handling and safety. The information should allow the reader to select materials for a given application and may serve as the basis for the preparation of overlay specifications.

CHAPTER 2—DEFINITIONS

Please refer to the latest version of ACI Concrete Terminology (<https://www.concrete.org/store/productdetail.aspx?ItemID=CT13>) for a comprehensive list of definitions. Definitions provided herein complement that resource.

A/B component—individual parts of a polymer binder system; components typically consist of resin and curing agent (also known as a hardener).

broadcast—to scatter over a wide area by hand or mechanical method.

catalyst—substance that markedly speeds up the curing of a binder when added in minor quantity.

compressive strength—measured maximum resistance of a concrete or mortar specimen to axial loading; expressed as force per unit cross-sectional area.

crosslinking—joining of preformed linear polymer chains to each other to form three-dimensional networks.

cure time—interval after mixing in which a polymer concrete system develops the required strength

flexibilizer—additive that gives a rigid plastic flexibility.

gel time—time interval after mixing that a liquid material exhibits a significant viscosity increase.

high-molecular-weight methacrylate—low-viscosity substituted methacrylate monomer that is characterized by low volatility.

initiator—substance capable of causing the polymerization of a monomer by a chain reaction mechanism.

methyl methacrylate—low-viscosity methacrylate monomer that is characterized by high volatility.

monomer—organic liquid of relatively low molecular weight that creates a solid polymer by reacting with itself, other compounds of low molecular weight, or both.

organic peroxides—sources of free radicals used in polymerization and crosslinking.

polyester—group of resins, mainly produced by reaction of unsaturated dibasic acids with dihydroxy alcohols; commonly dissolved in a vinyl group monomer such as styrene.

promoters—reducing agent compounds added to the monomer system to cause the decomposition of the peroxide initiators in the system (often called accelerators).

reflective cracking—phenomenon where cracks form in the overlay directly over existing cracks in the substrate.

rutting—formation of a depression in the overlay.

scarification—process of scratching, cutting, or chipping the existing concrete surface for the purpose of cleaning and texturing it.

sensitization—act, process, or result of sensitizing or making sensitive.

skinning—in polymer concrete, the loss of patches of material from the top surface of the overlay, usually associated with overworking it.

surface failure—loss of top surface aggregates from the polymer binder in polymer concrete.

surface broadcasting—application of aggregate to the freshly applied polymer concrete resin or premix matrix overlay to provide intercoat adhesion or to act as the wearing course.

surface tining—scoring or grooving of the polymer concrete overlay to provide for drainage, additional skid resistance, or both.

wear—deterioration of a surface due to traffic, use, the environment, or a combination of these.

near white metal surface—metal substrate that has been abrasively blast-cleaned.

working life—time period between the mixing of polymer concrete and the point at which its viscosity has become too high to be workable or too high to bond properly to the substrate.

CHAPTER 3—POLYMER BINDERS

3.1—General

Polymer concrete (PC) is a class of composite materials that includes a broad group of organically bound mortar, each with its own distinctive properties. Familiarity with the properties of each group is essential to understanding PC.

The resins used as binders for the formulation of PC are monomers or polymer/monomer solutions that are mixed at the time of application with their respective curing agents. The cured polymer serves as the binder for aggregate and fillers in the same manner that portland cement acts to bind conventional concrete.

The polymer families most commonly used for the preparation of PC overlays are epoxies, polyesters, and methacrylates. The chemical compositions of each of these polymer binders are distinctly different, and the PC they form have varying properties.

3.2—Properties of polymer binders

Polymer binders are classified by both uncured and cured properties that are measured in the laboratory according to industry standards. The nature of these properties and their relationship to the performance of the PC are described in the following.

3.2.1 Uncured properties—The uncured properties of polymer binders are related to their handling characteristics. In addition to methods of application, environmental conditions may dictate the use of selected systems.

Polymer binders may be distinguished by the viscosities of the individual or mixed components. These values may range from 100 to 2500 centipoise (cps). For applications with deck surface slopes of greater than 3 percent, higher viscosities may be required for neat applications of the polymer with aggregate broadcast into the surface to maintain uniform thickness. Binder resins with a low initial viscosity are suitable for highly filled PCs prepared by the premix or slurry method, with or without broadcasting on the surface.

The working life of the binder is dependent on the amount mixed, material temperature, substrate temperature, and the ambient temperature. As more material is mixed in bulk or as

the ambient temperature and substrate temperature increase, the working life is reduced. Gel time of the mixed polymer can be determined by observing a 2.5 oz. (70 mL) sample in a container until it begins to solidify. The time recorded does not describe the exact working life of the PC; however, it gives an indication of the relative reactivity.

Resins and their curing agents may be toxic before cure. Toxicity potential varies widely from one system to another, even within the same polymer family. Contact may result in allergic reactions such as dermatitis. Unprotected exposure could lead to health hazards. It is for these reasons that toxicity information, handling precautions, and disposal procedures supplied by the manufacturer should be understood and observed. In general, protective clothing, adequate ventilation, and cleanliness are necessary. The safety data sheets should be reviewed before handling any polymer system.

Most resins will burn under certain conditions. Flammable components of a polymer system may ignite under high concentrations of vapor in air, especially when their flash points are within the range of temperatures found under ambient conditions. Handling and safety of PCs are covered in Chapter 8.

3.2.2 Cured properties—Impermeability of the cured binder will reduce or eliminate penetration of oxygen, moisture, and the infiltration of chlorides, which are the cause of corrosion of reinforcing steel. Chloride levels that result in current recordings of less than 100 coulombs per **ASTM C1202** are associated with negligible corrosion. Properties of cured polymer binders contribute to the behavior of the PCs and thus dictate their uses. Knowledge of cured properties of the binders, such as compressive strength, tensile strength, and elongation, are important in determining key characteristics that are not easily measured on installed PC overlays.

The bond strengths of polymer binders directly affect the bond of their corresponding PCs to various substrates. They are also important factors when these binder resins are used as primers before the application of a PC overlay.

Bond strength depends on the cleanliness, soundness, texture, and moisture content of the substrate—a fact to be kept in mind when considering the use of any polymer system. Methods of preparation, testing, and general precautions are described in **Chapter 4**.

3.3—Epoxies

3.3.1 Description—Epoxy systems used as binders for polymer concrete (PC) overlays are two-component system, with one component containing the epoxy resin and the second containing the curing or hardening agent (**Barbuta et al. 2010**). Because of their specific molecular structure, epoxy polymers develop strong bonds to portland-cement concrete, steel, and other surfaces. Neither the uncured nor the cured binders are affected by alkalinity; therefore, they are particularly useful when applied to concrete. A variety of curing agents, flexibilizers, and other additives affect the properties of the cured epoxy. Properties of concern include mechanical properties, thermal compatibility that is related to coefficient of thermal expansion, modulus of elasticity,

Table 3.3.2a—Typical uncured properties of epoxy binders for PC overlays

Property	Value	Test method
Viscosity mixed	700 to 2500 cps	ASTM D2556 No. 3 at 20 rpm. Brookfield RVT
Gel time	15 to 45 minutes	ASTM C881/C881M at 73°F (23°C) (modified 70 mL)
Flash point	200°F (93°C) minimum	ASTM D3278

Table 3.3.2b—Typical physical properties of cured epoxy binders for PC overlays

Property	Value	Test method
7-day tensile strength	2000 to 5000 psi (14 to 35 MPa)	ASTM D638 (Type 1)
Tensile elongation	30 to 70 percent	ASTM D638 (Type 1)
Modulus of elasticity, maximum	130,000 psi (895 MPa)	ASTM D695 compressive modulus
Permeability of chlorides – rapid chloride permeability test values at 28 days	100 coulombs maximum	AASHTO T 277

creep resistance, rate of strength development, and the ability to cure and perform within a wide range of environmental conditions. Epoxy systems can be formulated to resist attack from a variety of chemicals, such as acids, bases, solvents, and fuels. Epoxy systems containing solvents and unreactive diluents should not be used.

3.3.2 Epoxy properties—All components used for physical testing should be conditioned at $73 \pm 2^\circ\text{F}$ ($23 \pm 1^\circ\text{C}$) for at least 24 hours before mixing, curing, or testing. Typical properties of uncured and cured epoxy binders are listed in Tables 3.3.2a and 3.3.2b, respectively.

3.3.2.2 Chemical resistance—Cured epoxy binders are resistant to water, deicing chemicals, dilute acids, gasoline, and other petroleum products.

3.3.2.3 Weathering—The surface broadcast aggregate protects the epoxy binder from weathering.

3.3.2.4 Wear—The wear performance of the PC overlay will be determined by several factors, including the polish and wear resistance of the aggregate, vehicle type, traffic volume, tire abrasion, and chain abrasion.

3.3.3 Primers—Many application methods do not require the use of a primer. Primers can be used where required to achieve improved bond and water tightness. Ultra-low-viscosity epoxy formulas are also used to seal hairline cracks before placing a PC overlay.

3.3.4 Working life—The period of time in which the epoxy may be applied is measured by the gel time (pot life). The working life is approximately doubled by decreasing the binder temperature for every 18°F (10°C); increasing the temperature has an equal and opposite effect. Each formula has a low temperature limitation of workability and curability and is measured by **ASTM C881/C881M**. Low-modulus formulas will cure and create adhesion to a substrate from 50 to 120°F (10 to 49°C). Formulas should only be used within the curable range specified by the epoxy manufacturer. Careful evaluation of each system is advisable.

Table 3.4.1a—Typical uncured properties of polyester binders for PC overlays

Property	Value	Test Method
Viscosity	100 to 400 cps	ASTM D2196 No. 3 at 20 rpm. Brookfield RVT
Gel time	15 to 45 minutes	ASTM C881/C881M (modified 70 mL)
Flash point	100°F (38°C) minimum	ASTM D3278

Table 3.4.1b—Typical physical properties of cured polyester binders for PC overlays

Property	Value	Test method
Tensile strength	1700 to 5000 psi (12 to 35 MPa)	ASTM D638 (Type 1)
Tensile elongation	30 to 70 percent	ASTM D638 (Type 1)
Modulus of elasticity	130,000 psi (895 MPa) maximum	ASTM D695 compressive modulus
RCPT values at 28 days	100 coulombs maximum	AASHTO T 277

3.4.3.5 Permeability—PC overlays will exhibit low permeability, reducing the penetration of chlorides into the substrate that are the primary cause of reinforcing steel corrosion and subsequent damage.

3.4—Polyesters

3.4.1 Description—Polyester binders used for the preparation of polymer concrete (PC) are two-component systems, with one containing the polyester resin and the second containing the initiator, which is usually an organic peroxide (Ribeiro et al. 2003). The properties of the polyester binder depend primarily on the chemical composition of the polyester resin component and are much less influenced by the selection of the promoter/initiator system, the primary contribution of which is to control the rate of cure.

The peroxides, used as initiators, gradually lose their reactivity at elevated temperatures (over 90°F [32°C]). Additionally, polyesters exhibit a strong odor during application, due to the presence of styrene in the resin, which are regulated by the National Institute for Occupational Safety and Health. Both polyester resin and initiator components should be stored in cool, protected areas. Systems containing solvents and unreactive diluents should not be used.

3.4.2 Polyester properties—All components used for physical testing should be conditioned at 73 ± 2°F (23 ± 1°C) for at least 24 hours before mixing, curing, or testing (Tables 3.4.1a and 3.4.1b).

3.4.2.2 Chemical resistance—Cured polyester binders are resistant to water, deicing chemicals, dilute acids, gasoline, and other petroleum products (Topliyska et al. 2006). Some polyester resins may not be resistant to alkaline substrates.

3.4.2.3 Weathering—The surface aggregate protects the polyester binder from weathering.

3.4.2.4 Permeability—PC overlays will exhibit low permeability, reducing the penetration of chlorides into the substrate that are the primary cause of reinforcing steel corrosion and the subsequent damage.

Table 3.5.2a—Typical uncured properties of MMA-based primer

Property	Value	Test method
Viscosity	40 to 150 cps	ASTM D2556 No. 3 at 20 rpm Brookfield RVT
Gel time*	20 to 40 minutes	ASTM C881/C881M (modified 70 mL)
Flash point	43°F (6°C) minimum	ASTM D1310

*Gel time can be maintained from application temperatures of 20 to 100°F (–7 to 38°C) by varying the initiator; however, the manufacturer should be consulted before any such adjustments are made.

Table 3.5.2b—Typical physical properties of cured MMA-based primer

Property	Value	Test method
Tensile strength	2500 to 6000 psi (17 to 40 MPa)	ASTM D638 (Type I)
Tensile elongation	2 to 10 percent	ASTM D638 (Type I)
Modulus of elasticity	75,000 psi (515 MPa) maximum	ASTM D695 compressive modulus
RCPT values at 28 days	100 coulombs maximum	AASHTO T 277

3.4.2.5 Primers—Priming is always necessary when premixed polyester systems are used. Primers improve the performance of polyester overlays. Polyester resins, epoxies, and methacrylates can be used, but the manufacturer of the polyester should be consulted before selection is made. Polyester primer, if recommended by the manufacturer to be the same resin used for PC binders, may be used with premixed systems. Epoxy primers are resistant to the styrene or other monomers present in the polyester resin. Epoxy primers can improve the bond of polyester PC overlays to damp or alkaline substrates, though the application of polyester PC overlays to damp surfaces is not recommended. Methacrylate primers are solutions of acrylic polymers in methyl methacrylate (MMA) or high-molecular-weight methacrylate (HMWM) monomers.

3.5—Methacrylates

3.5.1 Description—Methacrylate polymer concrete (PC) binders are normally two-component systems—a methyl methacrylate (MMA) resin and an organic peroxide initiator. The resins are generally based on an MMA monomer. As a slurry system, resins are combined with graded aggregates, producing self-leveling, low-modulus overlays 1/4 to 3/8 in. (6 to 10 mm) thick.

3.5.2 Methacrylate properties—The properties that appear in Tables 3.5.2a through 3.5.2f reflect those of the MMA primer, PC, and top-coat resins. Due to the high filler contents found in MMA PC, the properties of the PC are more significant than those of the binder.

All components used for physical testing are to be conditioned at 73 ± 2°F (23 ± 1°C) for a minimum of 24 hours before mixing, curing, or testing. Systems containing solvents and unreactive diluents should not be used.

Table 3.5.2c—Typical uncured properties of MMA-based binders for PC overlays

Property	Value	Test method
Viscosity	40 to 150 cps	ASTM D2556 No. 3 at 20 rpm Brookfield RTV
Gel time	10 to 30 minutes	ASTM C881/C881M (Modified 70 mL)
Flash point	46°F (8°C) minimum	ASTM D1310

Table 3.5.2d—Typical physical properties of cured MMA-based binders for PC overlays

Property	Value	Test method
Tensile strength	1000 to 2000 psi (7.0 to 14 MPa)	ASTM D638 (Type I)
Tensile elongation	30 to 70 percent	ASTM D638 (Type I)
Modulus of elasticity	75,000 psi (515 MPa) maximum	ASTM D695 compressive modulus
RCPT values at 28 days	100 coulombs maximum	AASHTO T 277

Table 3.5.2e—Typical uncured properties of MMA-based binders for PC top coat

Property	Value	Test method
Viscosity	40 to 150 cps	ASTM D2556 No. 3 at 20 rpm Brookfield RTV
Gel time	10 to 30 minutes	ASTM C881/C881M (modified 70 mL)
Flash point	43°F (6°C) minimum	ASTM D1310

Table 3.5.2f—Typical physical properties of cured MMA-based binders for PC top coat

Property	Value	Test method
Tensile strength	2500 to 6000 psi (17 to 40 MPa)	ASTM D638 (Type I)
Tensile elongation	30 to 70 percent	ASTM D638 (Type I)
Modulus of elasticity	75,000 psi (515 MPa) maximum	ASTM D695 compressive modulus
RCPT values at 28 days	100 coulombs maximum	AASHTO T 277

3.5.2.2 Chemical resistance—Methacrylate polymers are resistant to water, deicing chemicals, dilute acids, and alkalines.

3.5.2.3 Weathering—The surface broadcast aggregate and the low modulus of elasticity of the methacrylate resin will protect the PC overlay from the effects of weathering.

3.5.2.4 Wear—The durability of the PC overlay will be determined by the hardness and wear resistance of the aggregate.

3.5.2.5 Permeability—PC overlays will exhibit low permeability, reducing the penetration of chlorides into the substrate that are the primary cause of reinforcing steel corrosion and concrete spalling.

3.5.3 Primers—PC based on methacrylates require a methacrylate primer to achieve proper bond. Methacrylates are generally sensitive to damp and wet conditions, and their use should be restricted to dry surfaces.

3.5.4 Top coats—Methacrylate top coats are used to assure the broadcast aggregate on the PC overlay surface is sufficiently bonded.

CHAPTER 4—POLYMER CONCRETE

4.1—General

Polymer concrete (PC) is made by combining monomeric or polymeric binders with aggregates. The aggregates and binders can be mixed together and spread with screeds or gauge rakes, or the binders can be applied to the surface and the aggregate broadcast onto the liquid binder. PC used for overlays should have a low modulus of elasticity to reduce the shear stresses created by temperature changes. For a full description of PC binders, refer to [Chapter 3](#).

The addition of fillers, aggregates, and broadcast aggregates to the particular polymer system defines the resulting mixture as a PC or mortar. A brief description of common PC aggregates follows.

4.2—Aggregates

A variety of aggregates such as quartz, silica sand, basalt, trap rock, or aluminum oxide may be used in PC overlays. In general, broadcast aggregates should be hard, dense, durable, dry, clean, and resistant to polishing and crushing. PC filler aggregates are normally supplied by the resin manufacturer and are specially formulated to give the PC mortar the desirable physical properties and leveling characteristics.

In applications where aggregate particles are to be broadcast on the surface of a PC overlay to produce high-degree skid resistance, aggregates should meet the properties in [Table 4.2](#) and have hardness on the Mohs scale of 6 or more. Aggregates should contain less than 0.2 percent moisture when tested in accordance with [ASTM C566](#). Aggregates should meet the minimum weight loss in accordance with [AASHTO T 103](#).

4.2.1 Fillers—Some PC systems are supplied as two-component mortars, resin, and a component containing, but not limited to, well-graded silica aggregates and fine powder such as calcium carbonates ([Choi and Ohama 2004](#)). These fillers are formulated to achieve the desired flowability and low permeability of the different PC overlays and are usually supplied by or specified by the PC overlay manufacturer.

4.3—Properties of polymer concrete

Working life and cure times for some PC overlays are adjustable to suit needs at different application temperatures. Bond strength is normally an indication of the strength of the substrate or the quality of the surface preparation. With proper surface preparation, the bond strength of PC overlays should result in bond test failures in the concrete substrate. Wear resistance is a function of the broadcast aggregate quality and the ability of the PC to hold the aggregate under traffic conditions. An important factor when considering PC overlay materials is their thermal compatibility with the substrate ([O'Connor and Saiidi 1993](#)). Thermal compatibility is a function of the tensile elongation of the resin, aggregate loading, and bond strength. When a PC overlay

Table 4.2—Broadcast aggregate properties

Broadcast bridge deck aggregate	
Mesh size	Percent passing
No. 4 (4.76 mm)	100
No. 8 (2.38 mm)	30 to 75
No. 16 (1.19 mm)	0 to 5
No. 30 (0.595 mm)	0 to 1
Broadcast parking deck aggregate	
Mesh size	Percent passing
No. 8 (2.38 mm)	100
No. 16 (1.19 mm)	51 to 75
No. 20 (0.841 mm)	14 to 50
No. 30 (0.595 mm)	0 to 25
No. 40 (0.400 mm)	0 to 2

Table 4.3—Typical specified properties PC overlays

Property	Value	Test method
Bond strength	250 psi (1.7 MPa) minimum	ASTM C1583/C1583M
Compressive strength	1000 psi (7.0 MPa) (3 hours) 5000 psi (35 MPa) (24 hours) minimum	ASTM C579, Method B
Thermal compatibility	Pass	ASTM C884/C884M, Method B
RCPT values at 28 days	100 coulombs maximum	AASHTO T 277

is subjected to temperature changes, it undergoes greater volumetric changes than the substrate, creating stresses at the bond line. The cumulative effect of curing shrinkage and temperature changes may cause interface cohesive failure, shear failure in the substrate, or loss of broadcast aggregate in the polymer (Yeon et al. 2003; Rebeiz et al. 2004). The failure mode is dependent on compatibility of the substrate and the overlay.

Based on in field performance history, Table 4.3 shows the typical specified properties of PC overlays. PC overlay manufacturers should be consulted for specific information regarding individual products.

CHAPTER 5—SURFACE PREPARATION

5.1—General

The purpose of surface preparation is to improve bonding between the polymer concrete (PC) overlay and the substrate. Because these materials have very different coefficients of thermal expansion and permeability, surface preparation is the most important factor in achieving proper bond between the PC overlay and the substrate.

Polymer overlays should be applied only to clean, dry, physically sound substrates. Proper surface preparation removes contaminations and increases surface roughness, and the subsequent mechanical bond between the overlay and the concrete substrate. In addition to mechanical bond,

there may also be a chemical bond, depending on the type of polymer (Wells et al. 1999).

The manufacturers of PC overlay materials provide literature on recommended procedures for proper application of their product. For surface preparation, these instructions typically state that all bond surfaces are to be free of loose and unsound materials as well as contaminants and bond breakers, such as oils, grease, paints, sealers, curing compounds, water, waxes, dust, solvents, and laitance. No overlay site will be free of all of these contaminants without proper surface preparation.

Overlay surfaces of parking structures and bridges may be exposed to abrasion, freezing and thawing, UV radiation, chlorides, moisture, compressive and shear loads, reflective cracking, and vapor pressure from the substrate. The ability to survive these conditions is highly dependent on the sound bond of the overlay to the substrate.

5.2—Concrete surfaces

5.2.1 Preliminary surface evaluation—The deck should be strong enough to withstand the shear stresses at or below the bond line of the PC overlay that are caused by changes in temperature. Cores may be extracted and tested for compressive strength, and the results can be correlated with impact hammer readings. The calibrated impact hammer can then be used to locate isolated weak areas in the deck.

The deck should also be checked for delaminations at the top reinforcing steel mat level. Delaminations are most easily identified by chain dragging or hammer sounding to locate hollow-sounding areas. Particular attention should be paid to deck areas with cracks that allow chlorides and water to penetrate to the reinforcing steel and deck areas with cracks that have been created by the expansion of corroding reinforcing steel. Copper sulfate electrode tests (ASTM C876) may be conducted to locate areas of active reinforcing steel corrosion that will eventually result in delaminated concrete. Concrete around corroding reinforcing steel should be removed and the exposed steel should be cleaned by sand-blasting or a cathodic protection system should be installed. Concrete that is delaminated, that has sufficient chlorides to cause the reinforcing bar to corrode, or has a compressive strength less than 2000 psi (14 MPa) should be removed and replaced with high-quality concrete. PC overlays are a wearing surface and protective layer for decks and cannot perform well if placed on concrete that should be replaced or if reinforcing bar corrosion is present. If reinforcing bar corrosion is present, the engineer should consider installing a corrosion protection system. The age of the concrete surface should also be considered. Newly cast decks should be cured at least 28 days to allow the moisture content of the concrete to drop to a level that will prevent excessive moisture vapor pressure. Existing decks should be dry before application of the PC overlay. Proper surface evaluation requires trained personnel familiar with concrete, contaminants, methods of preparation, and PC materials to determine how best to prepare the concrete substrate.

5.2.2 Substrate repairs—Surface preparation for overlays frequently includes the repair of defects such as delamina-

tions, spalls, cracks, and improper drainage. Sounding is important to determine whether there is deterioration invisible to the naked eye. Damaged sections should be removed with tools that will not further damage adjacent areas, including reinforcing steel. Methods of concrete removal may include chipping, needle gunning, bush hammering, or lightweight (30 lb [14 kg] maximum) jack hammers.

5.2.2.1 Crack and joint repair—ACI 224.1R contains information on the causes of cracks and provides a summary of many repair methods. Expansion and contraction movements in bridge and parking garage decks should be retained by maintaining control and expansion joints in good working condition.

5.2.2.2 Patching—Deteriorated concrete should be removed to sound concrete and the areas patched before surface preparation. Patching materials can be cementitious or polymer-based and should be compatible with the PC overlay. The PC overlay should not be placed on hydraulic-cement concrete that is less than 28 days of age, unless overlay patch pulloff tensile tests in accordance with ASTM C1583/C1583M are performed at an earlier age and provide passing results. Magnesium phosphate cement concrete or any other material that causes out-gassing should not be used for patching, as out-gassing will have a deleterious influence on the long-term performance of an overlay.

5.2.2.3 Surface profile—PC overlays should not be placed on overly uneven surfaces. Thin PC overlays will not correct existing uneven surfaces; therefore, existing surface irregularities should be corrected before placement of PC. If not corrected, irregularities can cause premature wear and failure on the high spots due to impact stresses.

5.2.3 Surface preparation methods—Steel shot-blasting is the preferred method of surface preparation; however, sand/abrasive blasting is also acceptable if local environmental regulations allow it. Hydroblast is only recommended if followed by shot-blasting, as water-blasting will leave a cement paste slurry on the surface, resulting in an irregular surface texture. Milling is also not recommended as it could lead to introduction of microcracking and substrate damage.

5.2.3.1 Shot-blasting—The size and flow of abrasive media, forward speed, and number of passes should be established to provide the desired surface condition of the area to receive the PC overlay. Shot-blasted concrete surfaces should be rough and may expose the large aggregate in the concrete (Fig. 5.2.3.1a and 5.2.3.1b). Production rates of up to 1500 ft²/h (140 m²/h) are obtainable and should produce a minimum surface profile CSP 5 as defined by ICRI 310.2R.

5.2.3.2 Abrasive blasting—Sand or grit abrasive blasting are acceptable methods of surface preparation and will remove contaminants and laitance from concrete surfaces, but they are difficult and time-consuming processes for removing flexible concrete coatings. Wet abrasive blasting is not recommended because residual moisture and a cementitious slurry residue on the substrate will prevent proper adhesion of a PC overlay.

5.2.3.3 Scabbling impact tools—One mechanical method includes the use of scabblers to chip away the surface by pulverizing it with vertical hammer blows. A critical factor



Fig. 5.2.3.1a—Large ride-on shot-blast machine.



Fig. 5.2.3.1b—Small portable walk-behind shot-blast machine.

that cannot be controlled is the vertical fracturing of the concrete, which leads to crack development. This method is only used to remove deep contamination; however, invisible damage to the substrate may result from its use. Shot-blasting the surface after scabbling may correct the microfracturing created by the scabblers.

5.3—Steel surfaces

Mill scale, oil, and chlorides on steel orthotropic bridge decks have been found to be detrimental to the adhesion of polymer concrete (PC) overlays and therefore must be removed with surface preparation (Fig. 5.3).

5.3.1 Surface preparation—The surface preparation level of cleaning and surface anchor profile have been well defined by specifications such as SSPC SP10/NACE No. 2, which shows the abrasive blast standards for new mill scale-bearing steel, rusted steel, and visibly pitted corroded steel. The surface preparation standards are similar to those for concrete and use the same methods of abrasive blasting. The steel should be blasted to a near-white-metal condition and should exhibit a 4 mil or greater anchor surface profile.

After cleaning the steel substrate, areas with pitting, section loss, or cracking should be evaluated by the project



Fig. 5.3—Steel orthotropic bridge deck after shot-blasting.



Fig. 5.4a—Tensile bond test apparatus for 2 in. (50 mm) diameter bond tests.

engineer before installing the PC overlay. The placement of the PC overlay should start as soon as possible after shot blasting before flash rusting develops on the prepared steel surfaces.

5.4—Evaluation of surface preparation

For concrete surfaces, a visual comparison of the prepared surface can be made to the profiles in **ICRI 310.2R**. For steel surfaces, a visual comparison can be made to **SSPC SP10/NACE No. 2** and a test of the surface anchor profile to determine that the 4 mil minimum has been achieved. For concrete substrates, field tests measuring tensile bond strength (**ASTM C1583/C1583M**) may be used to determine if the surface preparation is sufficient (Fig. 5.4a and 5.4b). The same test method (**ASTM C1583/C1583M**) can be used for steel surfaces with the exception of coring into the substrate. An alternate test to determine adequacy of surface preparation is to perform bond tests at intervals on the prepared surface. For each test, apply a small patty of overlay binder/aggregate 3/8 to 3/4 in. (10 to 20 mm) thick to the surface. After the material has cured, remove the patty with a hammer and chisel and examine the mode of failure to determine if additional surface preparation is required.

Acceptable tensile bond strength tests should result in one of the following:



Fig. 5.4b—Tensile bond test apparatus for 1 and 2 in. (25 and 50 mm) diameter bond tests.

- a) Minimum tensile rupture strength of 250 psi (1.7 MPa) from an average of three tests regardless of the depth of failure
 - b) Failure in the base concrete at a depth of at least 1/4 in. (6 mm) over more than 50 percent of the test area for three of four tests
- Failure in the steel substrate should not occur.

CHAPTER 6—APPLICATION OF POLYMER CONCRETE OVERLAYS

6.1—General

Polymer concrete (PC) overlay placements generally consist of three steps that include preparing the substrate surface, placing the polymer concrete, and curing. The polymer is typically an epoxy, polyester, or methacrylate.

Surface preparation is necessary to achieve good bonding and best performance for any overlay. Any preparations should ensure that the substrate is clean, sound, and as dry as possible (refer to **Chapter 5**). Once surface preparation is completed, the use of the proper application technique is important to obtain the maximum PC overlay performance. Two methods of placing the PC are commonly employed. One application method is the multiple layer method, commonly known as broadcast or broom and seed method, in which alternate layers of resin and aggregate are built up to form a flexible, skid-resistant, high-friction surface, protective PC overlay. The resin and hardener will be properly proportioned and uniformly mixed using a mechanical mixer or an automatic mixing/dispensing unit with minimal air entrapment. The uniform resin mixture is evenly distributed on the deck with notched squeegees or rollers immediately followed by the broadcasting or mechanical distribution of aggregate into the mixture. Aggregate should be applied until a dry aggregate layer develops on the surface. This procedure should be repeated until the required overlay thickness is achieved. The most prevalent polymer type for this application method is an epoxy (**ACI 548.8**).



Fig. 6.2.1a—Mixing of two-component epoxy resin with drill and jiffy mixer.

An alternate method of placing PC is the premixed or slurry placement method, in which a single application of the polymer resin and aggregate filler mixture is placed onto a cleaned surface. These methods may require the application of a primer before placement. The premixed or slurry placement method is divided into two different types of polymer/aggregate mixing, placement, and finishing methods. The premixed method has all of the polymer resin and aggregate blended into a mixture, and is placed with screeds, trowels, or both. The slurry method contains mixed polymer resin and fine filler aggregates to form a self-leveling mortar. It is applied with hand gauge rakes that maintain the thickness and grade of the slurry mixture. The most common polymer types used in premix and slurry applications are epoxy, methyl methacrylates (ACI 548.9; ACI 548.10), and polyester.

6.2—Multiple-layer overlay

The multiple-layer method requires more than one application to achieve the specified overlay thickness.

6.2.1 Applying polymer—The polymer resin should be properly proportioned and mixed well with its curing component and then applied to the prepared substrate surface (Fig. 6.2.1a). Both the ambient temperature and the temperature of the substrate surface to which the material is applied are typically specified, although some epoxy systems can be readily adapted for wider application temperature ranges.

The multi-layer polymer systems are normally applied by one of two methods. Most often, the mechanically mixed polymer is poured onto the concrete surface directly and spread with squeegees or paint-type rollers (Fig. 6.2.1b). To control the quantity of polymer resin applied per unit area, the deck is marked into grid sections that are to be covered with a unit quantity of polymer. This provides the workers with a visual guide as they spread the polymer across the surface to assure that the appropriate amount of resin is applied to the surface.

The polymer system can also be applied using automatic mixing and dispensing equipment (Fig. 6.2.1c). A proportioning device is built into the dispensing



Fig. 6.2.1b—Spreading of mixed epoxy resin with notched squeegees.



Fig. 6.2.1c—Automatic metering/mixing equipment.

system so that the accurate quantity of polymer resin and curing agent are properly mixed through a static mixer or dispensing nozzle (Fig. 6.2.1d). Other automatic dispensing systems require premixing of the polymer before entering the spray system. With this method, it is critical that the proper mixing proportions are maintained. Improper proportioning can result in incomplete curing.

The material application rates are dependent on the type of polymer, aggregate size, and the structure that the overlay is being applied to. Bridge decks more typically will use a larger aggregate size compared to that used on a parking deck or pedestrian structure. Table 6.2.1 gives the typical application rates; however, these are to be considered as general guides.

6.2.2 Applying aggregate—Immediately after the polymer has been applied to the surface, the specified aggregate is broadcast evenly over the fluid polymer to saturation or until no wet spots appear. This ensures embedment of sufficient aggregate into the polymer and provides a uniform textured surface profile. One method of application is a mechanical spreader that will uniformly broadcast the aggregate in a manner that will not mark or rut the overlay (Fig. 6.2.2a). The spreader should broadcast the aggregate from as close to

Table 6.2.1—Typical application rates of resin and aggregates for multiple-layer PC overlays

Structure	Layer	Resin application, ft ² /gal.	Aggregate application, lb/ft ²
Bridge deck	1	30 to 40 (0.84 to 1.1 m ² /L)	1.0 to 1.5 (4.9 to 7.3 kg/m ²)
	Subsequent layers	15 to 20 (0.42 to 0.56 m ² /L)	1.0 to 1.5 (4.9 to 7.3 kg/m ²)
Parking garage (outdoor)	1	40 to 50 (1.1 to 1.4 m ² /L)	0.5 to 1.0 (2.4 to 4.9 kg/m ²)
	Subsequent layers	20 to 25 (0.56 to 0.70 m ² /L)	1.0 to 1.5 (4.9 to 7.3 kg/m ²)
Parking* garage (indoor)	1	25 to 30 (0.70 to 0.84 m ² /L)	0.5 to 1.0 (2.4 to 4.9 kg/m ²)
Pedestrian structure (outdoor)	1	40 to 50 (1.1 to 1.4 m ² /L)	0.5 to 1.0 (2.4 to 4.9 kg/m ²)
	Subsequent layers	20 to 25 (0.56 to 0.70 m ² /L)	1.0 to 1.5 (4.9 to 7.3 kg/m ²)
Pedestrian* structure (indoor)	1	25 to 30 (0.70 to 0.84 m ² /L)	0.5 to 1.0 (2.4 to 4.9 kg/m ²)

*Parking garages and pedestrian structures that are not exposed to weather can use a single layer application that will not have the same resistance to water as a multi-layer application.



Fig. 6.2.1d—Two-component resin mixed through a static mixing nozzle before application.



Fig. 6.2.2a—Broadcast aggregate applied with truck-mounted chip spreader.

the surface as possible to avoid displacement of the polymer. Another method is to blow the aggregate into the air and allow it to drop vertically into the polymer (Fig. 6.2.2.b). With this method, caution should be taken not to allow fine aggregate dust to settle onto the resin surface before it is covered with the aggregate, as it may lead to improper aggregate bond. In addition, the aggregate should not be blown directly at the polymer, as it could cause the resin to move and result in an uneven finished surface. Hand-broadcast application is also an acceptable application method (Fig. 6.2.2c).

6.2.3 Curing—Depending on the substrate temperature, ambient temperatures, material temperature, and type of polymer binder, the cure time for each layer may vary from 1 hour to more than 8 hours. Excess aggregate that is not embedded in the cured polymer is then removed with brooms or dry high-pressure air, and the overlay application is repeated until the proper number of layers have been applied and the specified thickness is achieved. Depending on the type of polymer and aggregate size, a multiple-layer overlay might consist of two or three layers to meet specified thickness. The PC overlay should not be opened to traffic until it is sufficiently cured that it will not permanently deform under traffic.

6.3—Premixed or slurry overlays

Premixed or slurry polymer concrete (PC) overlays achieve the required thickness with a single application.



Fig. 6.2.2b—Broadcast aggregate applied with pressurized aggregate tank.

They can be applied using methacrylate, epoxy, or polyester binders. Placement of an overlay using the premixed method will require the use of hand or mechanical mixers and may require the use of placement equipment. The use of vibrating or nonvibrating screed to place premixed PC overlays will develop the necessary material compaction. Placement of an overlay using the slurry method will require the



Fig. 6.2.2c—Broadcast aggregate hand applied.



Fig. 6.3.1.1—Mixing of slurry components with drill and jiffy mixer.

use of mechanical mixers, and the overlay is applied using hand gauge rakes that determine the total thickness of the application.

6.3.1 Mixing—Several mixing procedures can be used for premixed or slurry PC overlay installations. Generally, the type of polymer used for the PC binder and the filler aggregate dictate the preferred mixing procedure.

6.3.1.1 Hand-mixing—Hand-mixed systems normally come prepackaged and preproportioned; therefore, field batching operations are generally eliminated (Fig. 6.3.1.1).

6.3.1.2 Batch machine mixing—Machine mixing of the polymer and aggregate systems in small concrete or mortar mixers, also known as mechanical mixers, is acceptable. The proper ratio of resin-to-curing agents and polymer-to-aggregate for each batch should be maintained (Fig. 6.3.1.2).

6.3.1.3 Continuous machine mixing—Specially modified volumetric mixers and modified mobile concrete batching plants have been used for the continuous mixing of premix and slurry PC overlay materials (Fig. 6.3.1.3). Another type of machinery for the continuous preparation of PC overlay



Fig. 6.3.1.2—Batch machine mixer.



Fig. 6.3.1.3—Mobile continuous mixing truck.

materials can be described as a continuous metering, mixing, and dispensing machine.

6.3.2 Placing and finishing equipment—The type of placement and finishing equipment used is generally dependent on the type of resin/aggregate filler system. This section describes several methods of application and equipment that are used to install premix and slurry PC overlays.

6.3.2.1 Gauge rakes—Gauge rakes using adjustable pins to determine application thickness have been used for slurry applications (Fig. 6.3.2.1).

6.3.2.2 Vibrating screeds (manually advanced)—There are several vibrating screeds that can be used with premix PC overlay installations. These screeds can span across a full lane width. Some screeds can be adjusted to give a uniformly thick overlay (Fig. 6.3.2.2).

6.3.2.3 Self-propelled finishing machines and screeds—Self-propelled finishing machines can be adjusted to place overlays evenly across an entire lane. Some of the machines have an auger strikeoff to provide a uniform thickness of PC overlay.

6.3.2.4 Surface texture—Aggregate broadcasting is an acceptable method of obtaining the desired surface texture. The overlays are put down as a slurry or premix, and once the surface is finished to the desired thickness and excess

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Fig. 6.3.2.1—Application of PC slurry with gauge rakes.



Fig. 6.3.2.2—Application of premix PC overlay with vibratory screed.

resin appears on the surface, aggregate (approximately 1/8 in. [3 mm], No. 6 to 16 [1.00 to 3.35 mm]) is broadcast onto the surface. When the PC cures, the top layer of aggregate provides a high-friction, skid- and wear-resistant surface. Some premix PC overlays will not have excess resin formation on the surface to bond broadcast aggregate. They therefore require surface tinning to provide a skid-resistant surface.

6.3.3 Curing—Cure times are dependent on the resin type, substrate temperature, binder temperature, and aggregate temperature. Overlays are normally placed when the average of these temperatures is between 50 and 95°F (10 to 35°C). At these temperatures, cure times can range from 1 to 8 hours. Some systems can be installed at temperatures below freezing and still cure in less than 2 hours; however, any ice in the pores of the substrate may act as a bond breaker. The PC overlay should not be opened to traffic until it is sufficiently cured that it will not permanently deform under traffic.

CHAPTER 7—QUALITY CONTROL

7.1—Quality control needs

After the material selection and application procedures have been established for the project, a program of surface preparation, polymer concrete (PC) materials mixing, and PC overlay application testing and monitoring should be developed to ensure quality control and quality assurance.

7.1.1 Surface preparation—Surface preparation methods and procedures are described in Chapter 5. Evaluation and testing of prepared substrate surface should be continuously monitored to assure that the prepared substrate surface meets the project requirements. Refer to 5.4 for recommended test procedures and acceptable test results for the evaluation of surface preparation of the substrate.

7.1.2 Polymer concrete overlay materials—All components of the PC overlay should be certified by the material manufacturer or aggregate supplier to meet the typical physical properties as listed in Chapter 3. During the PC overlay application, mixed binder samples should be taken as quality control/quality assurance checks to determine that the materials are properly mixed, as recommended in Chapter 6. In addition to checking for proper mixing, record the volume of PC overlay materials applied and the substrate surface area covered by the PC overlay to determine that the required thickness of overlay materials have been applied.

CHAPTER 8—STORAGE, HANDLING, AND SAFETY

8.1—General

The information contained in this chapter is for the safe storage, handling, and use of various polymer concrete (PC) overlay materials. This is not a replacement for the material manufacturer's recommendations.

8.2—Storage

Store polymer overlay materials in an area that prevents them from getting wet. Store polymer resins away from open flames and other sources of ignition. Materials should be stored at temperatures between 50 and 90°F (10 to 32°C) unless otherwise recommended by the manufacturer. Fillers and aggregates should be stored in an area that will prevent them from getting wet.

8.3—Handling and safety

Some of the polymer resins are toxic but have been shown to be safe for workers and the public when handled and placed properly. Skin sensitization may occur immediately or may be delayed and develop only after prolonged exposure. Personal protective equipment specified by the manufacturer should be available to all personnel that may come in contact with the polymer resins. Review the manufacturers' safety data sheets prior to the start of work and have a plan for disposal of polymer materials and empty resin containers that meet all state and local environmental requirements.

CHAPTER 9—REFERENCES

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AASHTO T 277-15—Standard Method of Test for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

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As ACI begins its second century of advancing concrete knowledge, its original chartered purpose remains “to provide a comradeship in finding the best ways to do concrete work of all kinds and in spreading knowledge.” In keeping with this purpose, ACI supports the following activities:

- Technical committees that produce consensus reports, guides, specifications, and codes.
- Spring and fall conventions to facilitate the work of its committees.
- Educational seminars that disseminate reliable information on concrete.
- Certification programs for personnel employed within the concrete industry.
- Student programs such as scholarships, internships, and competitions.
- Sponsoring and co-sponsoring international conferences and symposia.
- Formal coordination with several international concrete related societies.
- Periodicals: the ACI Structural Journal, Materials Journal, and Concrete International.

Benefits of membership include a subscription to Concrete International and to an ACI Journal. ACI members receive discounts of up to 40% on all ACI products and services, including documents, seminars and convention registration fees.

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The American Concrete Institute (ACI) is a leading authority and resource worldwide for the development and distribution of consensus-based standards and technical resources, educational programs, and certifications for individuals and organizations involved in concrete design, construction, and materials, who share a commitment to pursuing the best use of concrete.

Individuals interested in the activities of ACI are encouraged to explore the ACI website for membership opportunities, committee activities, and a wide variety of concrete resources. As a volunteer member-driven organization, ACI invites partnerships and welcomes all concrete professionals who wish to be part of a respected, connected, social group that provides an opportunity for professional growth, networking and enjoyment.

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