Comparison between the PPC overlay system and the EPC overlay system for bridge deck protection

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Executive Summary

This white paper explores the evolution of polymer deck overlays within the California Department of Transportation (CalTrans), focusing on their role in protecting bridge decks from the corrosive effects of weather, traffic, and de-icing chemicals. It highlights the historical context, beginning in the 1970s when aging infrastructure necessitated innovative solutions for extending the lifespan of bridges. With over 26,000 bridges under its jurisdiction, California sought cost-effective methods to prevent deterioration, leading to the adoption of polymer concrete systems, specifically Polyester Polymer Concrete (PPC).

PPC overlays, developed using polyester-styrene resin, have served as the standard protective measure for decades. However, despite their effectiveness in waterproofing and enhancing durability, PPC systems present significant challenges. These include hazardous material handling, environmental concerns, and health risks due to the use of flammable and carcinogenic chemicals such as methyl methacrylate and styrene. These risks have prompted a reevaluation of PPC's suitability, particularly as stricter safety regulations and environmental standards emerge.

In response to these challenges, the Epoxy Polymer Concrete (EPC) overlay system has been developed as a safer, more environmentally friendly alternative. Introduced by Meridian Adhesives' E-Chem division, EPC utilizes a two-component epoxy resin system that eliminates the need for hazardous pre-treatments, offers superior adhesion without primers, and poses no flammability or carcinogen risks. Additionally, EPC is VOC-compliant, easier to apply, and more cost-effective, making it a preferred choice among contractors and state transportation departments.

This white paper provides a comprehensive comparison of PPC and EPC systems, examining their composition, adhesion properties, durability, application safety, environmental impact, and cost. It concludes by advocating for the adoption of EPC systems as a more sustainable and safer approach to bridge deck protection, offering improved performance and reduced health and environmental risks. With the development of EPC, transportation departments now have a viable alternative to traditional methods, aligning with modern safety and environmental standards while ensuring the longevity of critical infrastructure.

Introduction

We will understand the history of polymer deck overlays with the California Department of Transportation (DOT) and the purpose of polymer overlay systems to protect bridge decks from the corrosive effects of weather conditions, traffic, and de-icing chemicals that shorten the serviceable lifespan of bridges. We will also compare the benefits and risks of the currently available protective methods: PPC and EPC.

Problem to be Solved

As bridges and overpasses age, especially those in California's vast network, they are increasingly vulnerable to the corrosive effects of weather, traffic, and de-icing chemicals. These elements accelerate deterioration, leading to costly repairs and replacements that strain state and local budgets. Historically, the California Department of Transportation (CalTrans) has relied on Polymer Concrete (PPC) overlay systems to protect bridge decks from this deterioration. While PPC has provided effective protection, its use presents significant challenges, including hazardous material handling, environmental concerns, and health risks associated with flammable and carcinogenic components such as methyl methacrylate and styrene.

Given the escalating safety and environmental concerns, as well as stricter regulatory standards, there is an urgent need to identify a safer and more sustainable alternative to PPC systems. The newly developed Epoxy Polymer Concrete (EPC) overlay system by Meridian Adhesives' E-Chem division offers a promising solution. EPC eliminates the hazardous components of PPC, providing a non-flammable, VOC-free, and easy-to-apply system that meets modern safety and environmental standards while ensuring long-term protection for bridge decks.

This white paper aims to critically evaluate the risks associated with PPC overlays and demonstrate how EPC systems can provide a superior, safer alternative for protecting infrastructure, thus addressing the pressing need for a more sustainable approach to bridge deck preservation.

History

In the 1970s, as the Eisenhower-era Interstate Highway System reached its 20-year milestone, bridges and overpasses began showing their age. CalTrans had already set up its transportation laboratory in California to study the effects of deterioration and develop remedies. However, budget cuts in the 1970s shrank funding to California's laboratory and bridge maintenance funds. Steve Elkins, a retired CalTrans bridge engineer from California after 34 years, knows from experience that the bridge deck takes the most abuse from temperature extremes, vehicle wear, tire chains, de-icing chemicals, and freeze-thaw conditions that creates a vicious deterioration cycle of distress. Replacing or rehabilitating bridges that are in decline is extraordinarily expensive, especially in California, where there are approximately 13,000 bridges owned by the state and another 13,000 owned by local agencies, cities, or counties, according to Elkins. Preventing bridge deck distress with a waterproof, durable surface overlay system is far less expensive than full depth repairs or replacing. The main goal is to prevent moisture and de-icing chemicals that will, over time, corrode and weaken the rebar and other reinforcing components of the concrete structure. The believed solution, a polymer concrete system (polyester-styrene resin) that quickly became the standard for the DOT to protect bridge decks over the next 40 years.

History (continued)

Currently, there are two widely accepted polymer concrete systems for protecting bridge decks. The first method used since the mid-1980s is a polyester-styrene resin coating (PPC), similar in characteristics to a fiberglass resin. The second method is an epoxy polymer concrete system (EPC) introduced by E-Chem, a Meridian brand, to the Federal Interstate System in 2017.

The PPC Overlay System

The PPC overlay system for bridge decks is a protective layer from polyester-styrene resin, and a special blend of aggregate, applied on the concrete surface after a required pre-treatment of a high molecular weight methyl-methacrylate is applied. This overlay serves several purposes: Waterproofing, durability, chemical resistance, and skid resistance. Key components include the HMWMA primer, the polyester-styrene resin, the aggregate blend, and traction aggregate to improve skid resistance. Of the two overlay systems, PPC can use initiators and inhibitors to allow additional working time or the ability to apply at lower temperatures. But despite PPC's effectiveness for bridge deck protection, it has significant drawbacks and risks, especially the fact it can not bind to alkaline surfaces without the use of a primer.

Because of the chemical nature and handling of PPC, there are inherent challenges from a hazardous material for worker safety, flammability and environmental concerns. Many health and sustainability concerns about PPC among DOTs, contractors, architects, and engineers have arisen over the years of its use.

According to Kelsey Forde, CIH, CSP, CHMM of Parvati Consulting, "Application of existing PPC systems require use of methyl methacrylate as a pretreatment to the deck surface. Methyl methacrylate is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200). High Molecular Weight Methyl methacrylate is flammable with vapors forming explosive mixtures when mixed with air."

Explosive Flammability

PPC, by nature, is a flammable product, and there are numerous safety requirements when handling it. There are multiple instances where this system played a factor in auto igniting fires that caused total loss of installation equipment.

PPC also requires a high molecular weight methyl-methacrylate as a pre-treatment to the bridge deck surface. This three-component pre-treatment has become explosive when mixed in the wrong proportions.

Explosive Flammability (continued)

"I've seen mixing that HMWMA being done by inexperienced people, and I've said 'STOP,'" recalled Elkins. "You must put cobalt and cumyl hyper peroxide into the mix. But if those two touch, it blows up. It has killed people … as a state employee, I was required to wear a hazmat suit and an air-purifying respirator when around these materials."

Hazardous Storage

"When exposed to elevated heat, high molecular weight methyl methacrylate containers have the potential to overheat, generate flammable vapors, and explode. Elevated heat is commonly experienced on the jobsite or in material storage warehouses. Industry leaders have acknowledged the leading PPC overlay system and its components as a flammable and potentially explosive product," observed Forde.

Special handling for PPC is also noted by Ray Breer, Key Account Manager of Meridian/E-Chem: "Keep away from heat and sources of ignition. No smoking. Keep away from direct sunlight. Keep containers tightly closed in a cool, well-ventilated place. To ensure maximum stability and maintain optimum resin properties, resins should be stored in closed containers at temperatures below 77°F (25°C)."

Carcinogen Hazard

PPC (Styrene), as well as other carcinogens used in the PPC system, are considered a HAP by the EPA. This means that it is either a carcinogen or a highly suspected carcinogen. OSHA has an 8hr PEL of 100PPM, but in 2023, the ACGIH recommended an STEL of 20PPM and an eight hr. TWA of 10PPM. This level is 10x lower than current regulations. If OSHA adopts this standard, it will cause challenges for PPC users.

In California, Styrene is listed as a Proposition 65 Highly Suspected Human Carcinogen. Note >50% of this product is Styrene. This is also known as the Safe Drinking Water and Toxic Enforcement Act of 1986. It is a California law that requires businesses to provide warnings to individuals about significant exposures to chemicals that cause cancer, birth defects, or other reproductive harm. Some studies suggest a possible association between exposure to styrene and certain types of cancer, particularly leukemia and lymphoma.

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VOC Respiratory Irritation

Styrene resin in PPC emits high levels of Volatile Organic Compounds (VOCs). This means that workers must continually adjust their respiratory protection, affecting their job performance. VOCs can cause a severe reaction in people, even outdoors, irritating the eyes, nose, and throat or triggering asthma attacks or allergic reactions.

While on a PPC job site, Elkins recalled, "We had fire department out here several times. The local people called them because residents said they smelled hazardous waste and thought something serious was happening."
In fact, PPC requires an industrial hygienist to monitor PPC emissions on every project due to the chemical nature of its components and the inherent liability using these types of chemicals.

Performance and Chemistry Issues

PPC also has a high shrinkage and related failure rate. The chemistry of the PPC can be equally challenging. There are three chemical components in the resin binder. Two of these are micro-dosed and have become an issue when the ratios are off or inconsistent. As the micro-dosed components are adjusted, this has a direct correlation to the finished performance characteristics of the PPC. Laboratory testing does not relate to field chemistry or field-cured conditions. Over the years, PPC manufactures have been challenged to meet he lower emission requirements (as they have been instituted). The addition of the required VOC inhibitors adversely affects the resin binder performance.

As we have examined here, the traditional PPC method of protecting bridge decks, while effective over the years, has severe drawbacks and concerns regarding worker safety and environmental impact. Scientists at E-Chem/Meridian, while being very familiar with adhesive technology and epoxies, knew from experience that there had to be a much better, easier to use, and far less hazardous way of achieving the desired result. The epoxy polymer concrete (EPC) was created to address these concerns.

The EPC Overlay System

The Epoxy Overlay System (EPC) has been recently developed by Meridian Adhesives' E-Chem company as an alternative to the toxic and dangerous PPC system. Instead of a polyester-styrene resin, EPC uses a two-component epoxy polymer resin in a simple 2:1 binder formulation that can run through multiple pumping systems without needing a primer or pre-treatment to bond to the substrate. It is impervious to water and de-icing chemicals while also providing a skid-resistant surface for bridges, elevated slabs, and PCCP. Being proven as a safer alternative to PPC by numerous DOT's, it is now under review by CalTrans and showing excellent results in side-by-side applications with PPC.
In addition, the EPC overlay system is being used by numerous DOT as a polymer repair mortar for patching concrete.

The EPC Overlay System (continued)

Unlike PPC, which uses radical chemistry to achieve its results, EPC does not. According to Artem Bobylev, Sr. R&D Chemist, Meridian Adhesives/ATC, "A lot of times, the radical chemistry uses harsher chemicals or possibly some other volatiles that are more difficult to deal with and require additional PPE. You also get into flammability and health concerns. Our system relies on crosslink density to achieve the desired properties for the material. The two to one mix ratio system also makes it easier to achieve the published performance values."

The EPC system is not only safer and easier to use, but also easier to clean-up. "The clean-up of the newer EPC system application is with simple water-based products or pressure washer. The clean-up of the older PPC system application may require more hazardous products," according to Forde.

Explosive/Flammability:
EPC is non-flammable. While PPC has a flashpoint of 90°F (32°C), EPC is 250°F (121°C).

Carcinogen Hazard:
EPC is epoxy based and 100% solids. There are zero known carcinogens.

VOC respiratory irritation:
EPC contains no VOC's. With no VOC's or extreme smells, contractors do not have to wear respirators around this product and there are no public phone calls/ concerns (a common situation with PPC) during use of installations.

Performance and chemistry issues:
EPC is a 2:1 ratio material with no chemistry in the field. There are no special directions on mixing or concerns of explosive reactions. With the ease of mixing and overall product mix, contactors prefer the installation of EPC due to the ease of placement, workability, and lower PPE requirements.

EPC/PPC Comparison

Composition:

- PPC: PPC overlays are composed of polyester styrene resin, initiators or inhibitors, and aggregates. With the use of a HWMA pre-treatment, polyester resins provide excellent bonding properties, chemical resistance and mechanical strength.
- EPC: EPC overlays are composed of epoxy resin, hardener and aggregates. Epoxy resins provide superior bonding properties, chemical resistance, and mechanical strength.

EPC/PPC Comparison
(continued)

Adhesion:

- PPC: PPC requires a primer to provide a suitable chemical bond to concrete. Without this primer, PPC's will eventually debond due to a process called saponification.
- EPC: EPC offer excellent adhesion to the substrate to the existing concrete surface. High alkaline substrates are no issue for EPC.

Durability:

- PPC: PPC overlays offer good durability and resistance to abrasion, freeze-thaw cycles, and chemical exposure. Known failures (cracking, etc.) have occurred at larger depth applications and when bonding to rebar, etc.
- EPC: EPC overlays are highly durable and resistant to a wide range of chemicals, including deicing salts and corrosive substances. They also exhibit excellent resistance to abrasion and wear. EPC has shown no early cracking or issues bonding to rebar, etc.

Application:

- PPC: Flammable. Contains H.A.P.'s
- EPC: Not flammable. Does not contain H.A.P.'s.

Environmental impact:

- PPC: Hazardous to the environment. Contains VOC's.
- EPC: VOC compliant
- Cost:
- PPC: Overlays are generally more costly due to PPE requirements and environmental monitoring concerns.
- EPC: Tend to be more cost effective due to the epoxy resin ease of use and friendlier installation requirements.

Other EPC benefits over PPC

EPC is non-flammable and contains zero VOC's. EPC is 100% solids, bonds to concrete surfaces and provides a more durable binder than PPC-styrene resin. Contractors prefer the installation of EPC instead of PPC due to the ease of mixing, workability, cleanup, and lower PPE requirements.

According to Elkins, there are two types of concrete in the world—the kind with cracks in it and the kind that's going to crack. How you deal with this inevitability is up to you. With the development of EPC, you now have a choice.

For more information, review the following Meridian/E-Chem project profiles:

- Grade Correction, I-25 Cerrillos, Santa Fe, New Mexico
- U.S. Route 54 over the Canadian River, Logan, New Mexico

Conclusion

The evolution of bridge deck protection has been driven by the need to safeguard critical infrastructure from the deteriorating effects of weather, traffic, and de-icing chemicals. For decades, Polyester Polymer Concrete (PPC) systems have served as the primary defense, providing waterproofing and durability for bridge decks. However, as we have examined, the use of PPC comes with significant drawbacks, including flammability, hazardous material handling, environmental risks, and health concerns. These issues have raised substantial safety and sustainability challenges for departments of transportation, contractors, and engineers.

The introduction of the Epoxy Polymer Concrete (EPC) system by Meridian Adhesives' E-Chem division marks a significant advancement in bridge deck protection technology. EPC offers a safer, more environmentally friendly alternative that eliminates many of the risks associated with PPC. With no flammable components, zero VOCs, and superior ease of use, EPC not only meets but exceeds the requirements for modern infrastructure protection. Its excellent adhesion, durability, and cost-effectiveness make it a preferred choice for bridge deck overlays, ensuring longer-lasting protection with fewer environmental and health-related concerns.

In conclusion, as infrastructure continues to age and the need for robust, sustainable solutions grows, the EPC system represents the future of bridge deck protection. By choosing EPC, transportation departments and contractors can ensure safer working conditions, reduce environmental impact, and extend the service life of critical infrastructure. The development and adoption of EPC offer a clear path forward, providing an effective and responsible solution to the challenges of bridge deck preservation.

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