POLYASPARTIC COATINGS: REDUCING THE COST OF SHOP PAINTED STEEL BRIDGES THROUGH IMPROVING PAINTING EFFICIENCY

Introduction

Protective coatings have been used to mitigate corrosion of steel bridges for more than a century. As health and environmental regulations have changed, so have the coating systems that have been used to protect steel bridges. Gone are the days of using oil-based coatings with lead and chromium pigments (1). Now, sophisticated zinc-based coating systems are used to protect steel bridges. For several decades, the standard coating system for steel bridges has been a three-layer system consisting of an organic or inorganic zinc-rich primer, epoxy intermediate coat, and polyurethane finish coat or commonly abbreviated ZEU (2-4). Each layer provides specific protection mechanisms to prevent corrosion. The zinc-rich primer provides galvanic protection, with the zinc preferentially "sacrificing" itself to protect the steel. The epoxy layer provides barrier properties by reducing the permeability of water, oxygen, and salts through the coating. The polyurethane topcoat provides protection from the sun's ultraviolet rays while providing abrasion and chemical resistance.

Economics and schedule impacts have driven more Departments of Transportation to apply all three coats in the shop for new steel bridges (5). This has shifted the painting responsibility to steel fabricators and / or blast and paint shops. For fabricators, painting is an additional revenue stream that also creates additional scheduling complications.

Applying three coats of paint is a time and labor intensive process for fabricators. Each layer of paint has a minimum recoat time, or the minimum amount of time before another layer can be applied. Drying times can be significant depending on the coating and environmental conditions. For instance, inorganic zinc-rich primers typically require 16 - 24 hours (temperature and humidity dependent) to cure before applying subsequent coats reducing productivity. The total time to apply a ZEU system in a shop setting can vary quite significantly depending on the available shop space and number of painting shifts per day. Depending on the current work load and scheduling, a fabricator may subcontract out painting due to the bottleneck that applying multi-layer coating creates in the paint shop.

Advancements in coating resin technology have improved painting efficiency. More than 20 years ago, polyaspartic (PAS) coating resins were invented by Covestro (6-7). This new coating resin replaces the "polyol" or paint resin in the "A-side" of two-component polyurethanes (Figure 1).

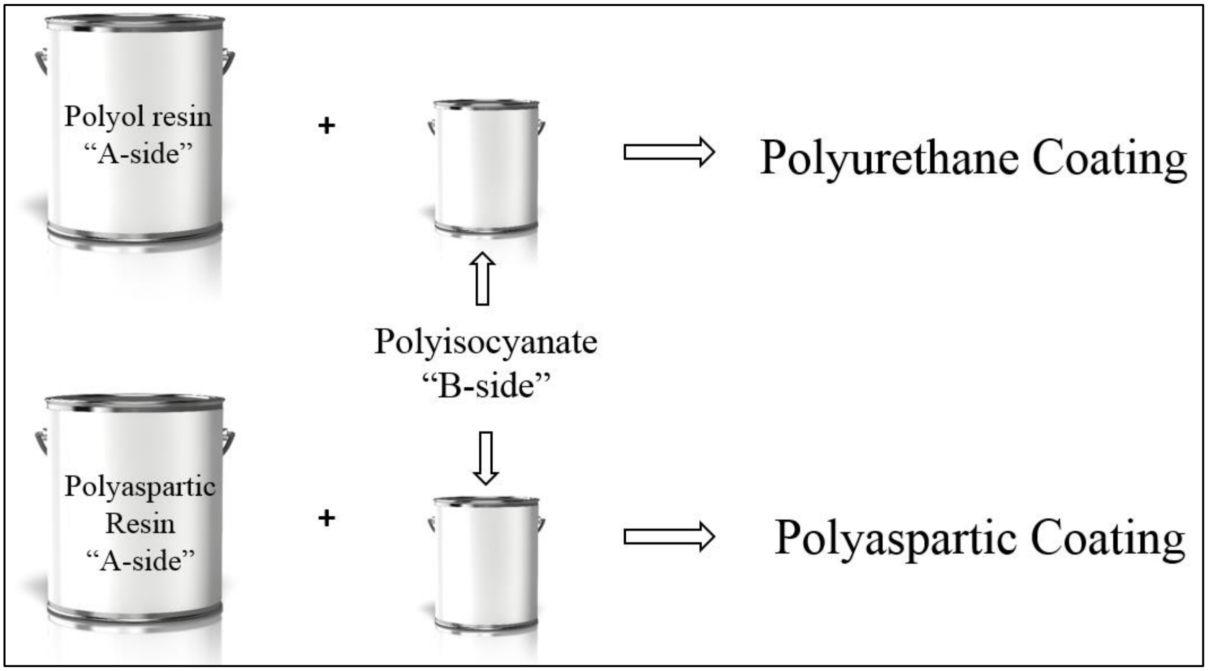

Figure 1. Raw material difference between a polyurethane and PAS coatings

Polyaspartic coatings offer a number of application and physical property advantages. In general, PAS coatings offer fast cure with a reasonable potlife (useable time to apply the coating). Typically these coatings are dry-to-handle in one to two hours at 75 ^{o}F and 50% relative humidity, while having a potlife between two to three hours. By comparison, polyurethane coatings are dry-to-handle in six to eight hours with a two to four hour potlife. Polyaspartic coatings can be applied at higher dry film thicknesses (6-10 mils) when compared to polyurethanes (2-5 mils). The larger film build tolerance of PAS coatings allows for more forgiving application when painting complex geometries. The high film build characteristic of PAS coatings also allows for the reduction in number of coats to provide corrosion protection. For instance, a ZEU three-coat system can be replaced by a two-coat system of zinc-rich primer with a PAS topcoat at the same overall film thickness (Figure 2). PAS coatings are applied by the same means and methods as polyurethane coatings: spray, brush, and roll. Several key physical properties are color and gloss retention equivalent to polyurethanes, while delivering better edge retention and cure significantly faster. These application and physical property advantages of PAS coatings have been documented to increase painting productivity (8-13), while reducing project costs (10, 12, 14) without sacrificing corrosion protection (15-19). PAS coatings have been used for more than a decade in a number of different markets that shop paint steel including oil and gas, stadiums, railcars, and structural steel (Figure 3).

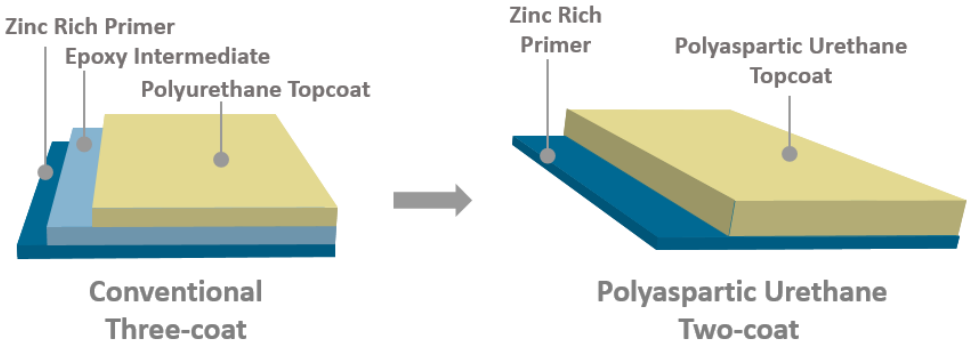

Figure 2. Layers of the standard three-coat system and PAS two-coat system. Both systems have total dry film thicknesses ranging from 9-14 mils

Figure 3. Several shop-applied end use applications where PAS coatings lower overall project costs

PAS coatings have been used in the steel bridge market for more than the last 15 years. However, the vast majority of these applications have been in field maintenance painting. Since the early 2000s a number of State Departments of Transportation (DOT) used PAS two-coat systems for field maintenance painting including Virginia, Maine, Connecticut, Michigan, Maryland, Pennsylvania, North Carolina, and Kentucky. In terms of total structures painted with PAS coatings, Virginia DOT has the largest number for any one state with over 150 bridges (19). Figures 4 through 6 show field maintenance painting projects from Virginia, Michigan, and Maryland. The Connecticut DOT quantified the cost benefit for field applications of PAS coatings to show a cost reduction of up to 20% and greater than 30% improvement to maintenance painting efficiency when compared to ZEU systems (10). The long term corrosion resistance of PAS coatings on steel bridges has been documented to show corrosion resistance equivalent to ZEU systems (19). PAS coatings have been used on new steel structures, but to a far less degree than maintenance painting. This article will present cost and throughput advantages of PAS coatings specific to shop painting of steel bridge structures compared to ZEU systems. These advantages generate significant value for both steel fabricators and bridge owners.

Figure 4. Virginia DOT; I-64 over Simpson Creek in Clifton Forge, VA. Repainted with PAS system in 2005. After 12 years in-service, <0.1% rusting over entire structure


Pictures taken 2017

Figure 5. Connecticut DOT; I-75 over Starr Ave in Danbury, CT. Repainted in 2002 with PAS system. After 15 years in service, <0.1% rusting across entire structure.


Pictures taken 2017

Figure 6. Michigan DOT; West Road over I-75 in Woodhaven, MI. Repainted with PAS system in 2017.

Maine Department of Transportation (DOT) PAS Project

The Maine DOT replaced bridge #5160 that carries Main St. over the Little Madawaska River in Stockholm, ME. The replacement structure selected was a simple span bridge design with four steel girders spanning ~100 ft. The bridge was constructed with weathering steel girders with painted beam ends approximately five feet from both abutments. The coating system originally selected was ZEU. Maine DOT showed interest in PAS coatings after using the technology for field maintenance painting and allowed a change order for the coating system. A two-coat system consisting of an organic zinc-rich primer with a PAS topcoat was selected.

Beam ends were blasted to SSPC-SP 10 prior to primer application. Following surface preparation, the zinc-rich primer was applied per manufacturer's requirements at 3-5 mils dry film thickness. After the primer was applied and inspection was complete, the PAS finish coat was applied using a single component airless pump. The final inspection on the finish coat was started four hours after completion of the application. After final inspection, the beams were loaded and moved outside to the laydown yard. The total cycle time for blasting and painting and moving the finish product outside was 36 hours. Table 1 below shows a detailed timeline.

Table 1. Timeline of Epoxy Zinc Primer / PAS Finish Coat

Process	**Timing**
Blasting starts on beam ends	Monday 3:00pm
Zinc application starts on first two girders	Monday 8:30pm
Zinc application complete on all four girders	Tuesday 7:00am
Application of PAS coat starts	Tuesday 1:00pm
Application of topcoat completed	Tuesday 4:30pm
Final inspection started on 3rd shift	Tuesday 8:30pm
Inspection completed	Tuesday 10:30pm
Girders loaded and moved outside finished	Wednesday 3:00am
Total cycle time for four beam ends painted	**36 hours**

In order to provide a comparison between the two-coat PAS system and the traditional ZEU, a second timeline was put forward (Table 2) based on years of experience with ZEU systems. Both timelines assume the paint bay has three shifts. The total cycle time for the ZEU system for the same beam end project would be 58 hours. This timeline for the ZEU system also assumes ideal environmental conditions (temperature and humidity). Using the two-coat PAS system reduces the cycle time by 22 hours compared to the ZEU system. This 61% increase in throughput is attributed to reduced curing time and one less coating layer. The PAS system has a combined ~6 hours of curing "downtime", while ZEU has ~26 hours of curing "downtime". One less layer for the PAS system also requires one less inspection, saving an additional ~2 hours in cycle time. The PAS systems enables a significant improvement in the throughput and painting efficiency of the paint shop. This increase to shop efficiency essentially increases a fabricator's painting capacity without having to add additional shop space or resources. In periods of high demand, PAS coatings can improve scheduling as well as require less painting work subcontracted out to third parties. Figure 7 shows a graphical representation on the cycle time difference between PAS and ZEU systems.

Table 2. Timeline of Epoxy Zinc Primer / Epoxy / Polyurethane Finish Coat

Process	**Timing**
Blasting starts on beam ends	Monday 3:00pm
Zinc application starts on first two girders	Monday 8:30pm
Zinc application complete on all four girders	Tuesday 7:00am
Application of epoxy starts	Tuesday 1:00pm
Application of epoxy is completed	Tuesday 3:00pm
Epoxy curing complete	Wednesday 3:00am
Inspection of epoxy coat completed	Wednesday 5:00am
Polyurethane topcoat application starts	Wednesday 5:00am
Polyurethane topcoat application completed	Wednesday 6:30am
Polyurethane topcoat curing completed	Wednesday 6:30pm
Polyurethane inspection completed	Wednesday 8:30pm
Girders loaded and moved outside to yard	Thursday 1:00am
Total cycle time for four beam ends painted	**58 hours**

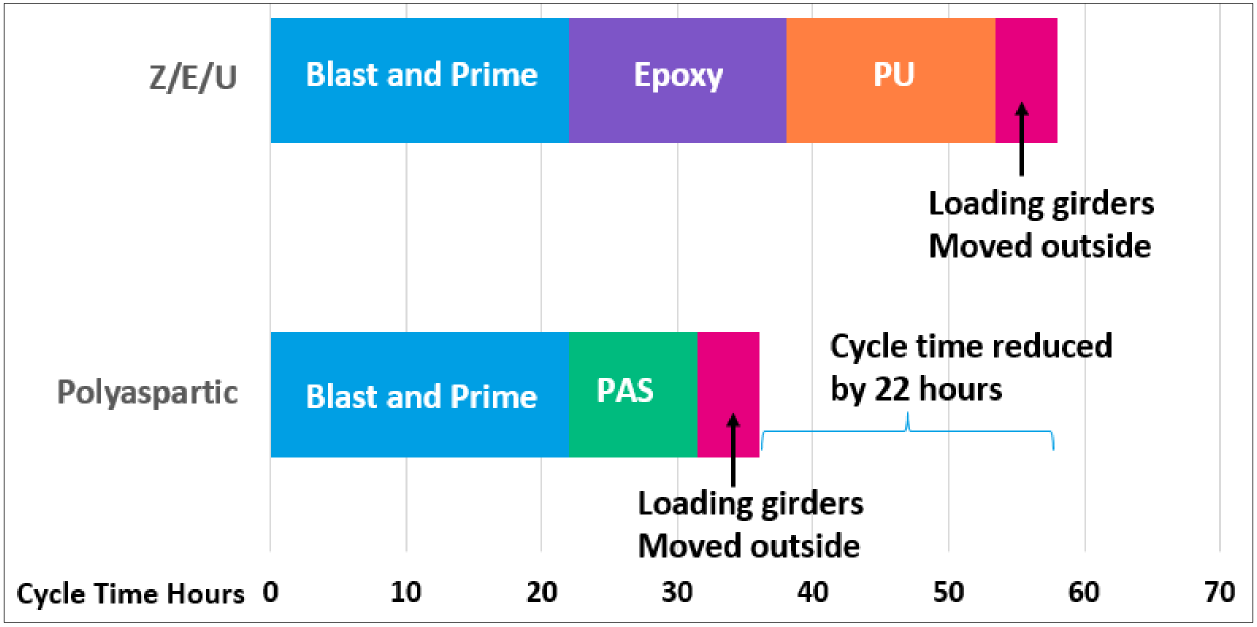

Figure 7. Graphical representation on cycle time difference in ZEU and PAS systems based on the data in Tables 1 and 2 has been grouped into buckets. Each block of time represents all processes for that step. For example: the Blast and Prime block represents the hours to blast, apply primer, inspection, steel handling, and curing of the zinc.

Reducing the number of paint layers improves the throughput and also generates cost savings through reduction in coating application and steel handling costs in the painting process. The material cost of the PAS system is ~ 100% more expensive than ZEU. However, the paint material costs are the minority relative to coating application and handling costs. By only having to apply two layers versus three, significant savings are achieved in coating application and steel handling costs. The PAS system generated ~28% in coating application and steel handing savings in the painting operations. These savings are largely attributed removing the processes around the third layer, which would include application of the coating, mixing, and cleaning equipment, inspection of the cured coating, and steel handling costs attributed to moving the steel for painting. Considering both raw material cost increase and coating application and steel handling savings, the PAS system created an overall cost reduction for painting of ~ 14%, which factored to a 2% reduction in the total cost of the new fabricated and painted steel girders. Figure 5 graphically depicts the cost impact from switching from the three-coat ZEU system to the two-coat PAS system.

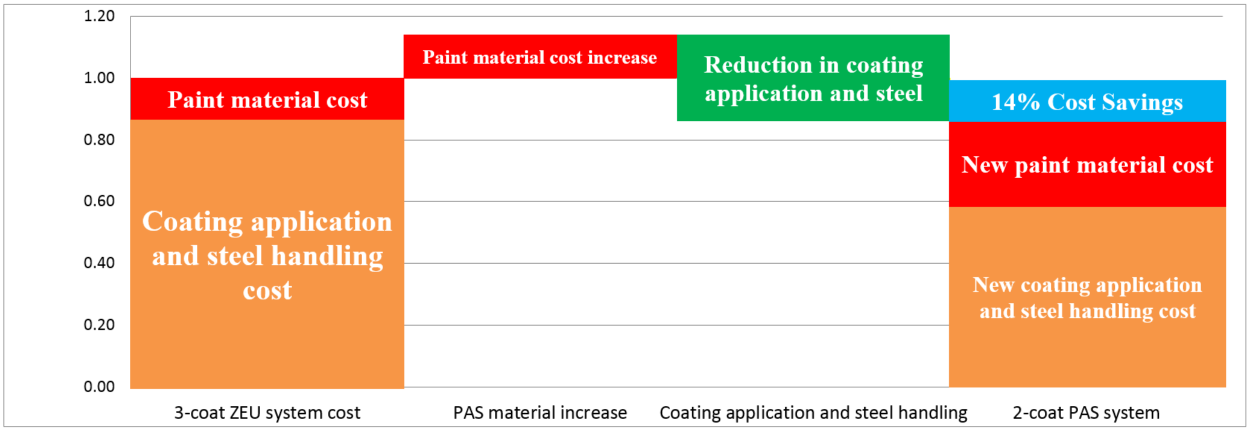

Figure 5. Cost savings waterfall between the three-coat ZEU and two-coat PAS system. Note that the values presented are listed in absolute percentages with the three-coat system being defined as 100%.

Pictures from Maine DOT project

Figures 8-10 show several pictures of the finished structure in place.

Figure 8. Main St. over Madawaska River in Stockholm, ME.

Figure 9. Close up view on one of the painted beam ends.

Figure 10. Close up view on one of the painted beam ends.

Summary

As the trend to shop-apply all coats of paint for new steel bridges continues, PAS coatings can deliver significant value to both fabricators and bridge owners requiring shop painting of new steel bridges. While similar to traditional polyurethanes, PAS coatings have unique features that differentiate them that include fast drying with high film build allowing for an overall reduction in the number of coating layers required for long term corrosion protection. Reducing the number of coating layers from three in ZEU systems to two layers in a PAS system generates significant improvements to shop painting efficiency (~61%) and savings through reductions in both coating application and steel handling costs (~14%). Steel bridge fabricators and DOTs can leverage these advantages into value engineered solutions for new steel bridge structures without having to sacrifice long term corrosion resistance. Polyaspartic coatings have demonstrated more than a decade of field performance on steel bridge structures with equivalent corrosion protection to three-coat ZEU systems in the northeast United States where salt is used liberally in the winter.

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