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Unlike other fluoropolymer resins, FEVE resins are thermoset, which means they can be applied in the field or in the shop and cured under ambient conditions.

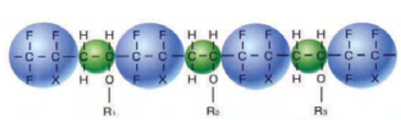
Long-life fluoropolymer resins for bridge coatings

By Winn Darden

Fluoroethylene vinyl ether (FEVE) resins were developed in the early 1980s in Japan. Unlike other fluoropolymer resins, FEVE resins are thermoset, which means they can be applied in the field or in the shop and cured under ambient conditions. Fluoropolymers offer a number of desirable properties, among them excellent stability against UV light and the elements, corrosion resistance, and chemical resistance. FEVE resins are no different; they are used to formulate coatings that offer 20 years or more of resistance to weathering and corrosion in the most severe environments. Because they can be field-applied, coatings made with FEVE resins are used for structures such as bridges, water towers, monumental buildings, and other assets that are difficult to paint.

FEVE coatings derive their properties from the chemical structure shown below in Figure 1.

Figure 1: Chemical structure of FEVE polymer.



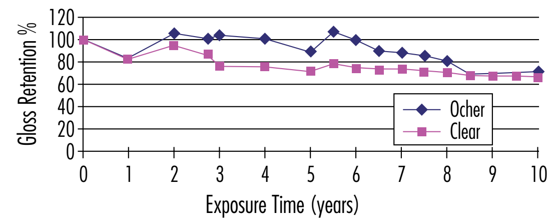
Fluoroethylene Segment
Weatherability, durability, chemical resistance

Vinyl Ether Segments
R1 = Clarity, gloss, hardness
R2 = Flexibility
R3 = Crosslinking site (-OH) Solubility

The fluorinated segment of the molecule imparts weather resistance, durability, and chemical resistance to the polymer. The vinyl ether segments allow the polymer to be dissolved in solvents commonly used in coatings, and to be chemically set with standard coating crosslinkers. Physical properties like hardness, chemical resistance, flexibility, and toughness can be altered by changing the structure of the polymer.

FEVE-based coatings offer excellent weatherability under the worst of conditions. The weather resistance of coatings often is tested by placing coated metal coupons on a test rack in South Florida for extended periods of time. The high levels of UV light, humidity, and salt in this environment will degrade many coatings inside of a year. There are several architectural coating specifications that require at least 50-percent gloss retention after 10 years of South Florida weathering. As shown in Figure 2 below, FEVE-based coatings offer excellent gloss retention, even after 10 years.

Figure 2: South Florida weathering test results for FEVE-based coating.



The traditional reasons for using FEVE resins in coatings have been aesthetic: The coatings retain their appearance and gloss for more than 20 years in many cases. Minimizing changes in coating appearance over time is of interest in markets other than architectural. For industrial maintenance applications, such as coatings for bridges, protection of the structure from corrosion also is important.

Recent test results from panels coated with fluorourethane coatings made with FEVE resins indicate that these coatings offer superior corrosion resistance as well. A marine platform off the coast of Japan near Tokyo has been set up by Japan's Ministry of Land, Infrastructure and Transport. This platform is used by coating manufacturers to get real-time corrosion data on their products. Coated panels were placed on the platform in 1988, and were periodically inspected. The coating system was a four-coat system: an inorganic zinc primer (75µm, 3 mils), two epoxy midcoats (120µm, and 30µm, total of 6 mils), and a fluorourethane topcoat (25µm, 1 mil).

Coating thickness was monitored carefully during the 16 years of exposure on the platform. As UV light degrades a topcoat, the degraded products will be removed from the surface of the coating by wind and rain. If enough of the topcoat is lost, the likelihood of corrosion is increased. In the platform test, it was determined that the fluorourethane coating suffered no change in thickness for the first seven years of exposure. In years 8-16, the average change in thickness was 0.38µm (0.015 mils) per year. This means that the average remaining coating thickness of the FEVE-based coating after 16 years was 21.6µm (0.85 mils). By comparison, the average change in coating thickness for a urethane coating was more than 2µm (.079 mils) per year, beginning in year two, meaning that a 2-mil-thick urethane topcoat would lose more than half of its thickness during the time span of the test. Because of variability in coating thickness and phenomena such as inadequate coating thickness on edges, reducing topcoat thickness by this amount can lead to initiation of corrosion.

Additional analytical tests, such as scanning electron microscopy and electron dispersive X-ray analysis, indicate that the FEVE topcoat prevents corrosion initiators like chloride, water, and oxygen from penetrating to the epoxy middle coats and the zinc-rich primer. This means that corrosion of the steel substrate is not able to occur, even after 16 years on the test platform. Corrosion resistance is particularly important for structures such as bridges that span salt water. The impervious nature of the FEVE topcoat may allow for development of two-coat systems, which would result in substantial decreases in coating application time and costs.

FEVE coatings have been in use in Japan since the mid 1980s. In the United States, the primary use for FEVE resins has been in the formulation of architectural coatings, and increasingly, of industrial maintenance coatings. However, the same properties that make FEVE-based coatings useful on bridges in Japan make them useful for this country. Shown below are a number of examples of FEVE-based coatings applied to bridges in Japan and in the United States.

Tokiwa Bridge, Hiroshima, Japan

This bridge is in a mountainous area near

Tokiwa Bridge in 2006, coated in 1987.

Hiroshima. Because of the prevalence of snow, the extensive use of calcium chloride for deicing the bridge is common. The old chlorinated rubber coating was removed by blasting, and then a three-coat system of epoxy primer/epoxy midcoat/FEVE topcoat was applied. The new coating system, a portion of which is shown in the picture above, was applied in 1987. After 19 years, the gloss retention of the FEVE topcoat is greater than 90 percent.

Amadori Bridge, Wakayama Prefecture, Japan

The Amadori Bridge was recoated in 1994. The bridge is located in a seaside environment, and thus is exposed to large amounts of chloride. Additionally, it is exposed to the typical climate in Japan: hot, humid summers and moderate winters with rare snowfall. The previous coating was removed by blasting to bare metal. A three-coat system of a zinc-rich primer/epoxy/topcoat was applied to the bridge. Two topcoats were used for comparative purposes: one a FEVE-based topcoat and a second of chlorinated rubber. The FEVE topcoat has outperformed the other coating in both gloss retention and corrosion prevention after 11 years of weathering.

Akashi Kaikyo Bridge, Kobe, Japan

The Akashi Kaikyo Bridge (or Akashi Strait Bridge) currently is the world's longest suspension bridge (12,828 feet), spanning the water between Japan's main

The Akashi Kaikyo Bridge in 1997.

The same properties that make FEVE-based coatings useful on bridges in Japan make them useful for this country.

Table 1: Coating procedure for Akashi Strait Bridge.

Treatment	Coating dry film thickness, µm (mils)	Elapsed time before next treatment	Coating location
Abrasive blast	-	-	Shop
Inorganic zinc-rich primer	15µm (0.6 mils)	6 months	Shop
Abrasive blast	-	-	Shop
Inorganic zinc-rich primer	75µm (3 mils)	7 days	Shop
Epoxy mist coat	10µm(0.4 mils)	7 days	Shop
Epoxy midcoat	60µm (2.4 mils)	7 days	Shop
Epoxy midcoat with MIO	60µm (2.4 mils)	12 months	Shop
FEVE-based fluorourethane topcoat	30µm (1.2 mils)	7 days	Shop/onsite
FEVE-based fluorourethane topcoat	25µm (1 mil)	-	Shop/onsite
Total coating thickness	275µm (11 mils)	60 years	

To determine the cost effectiveness of FEVE resin topcoats, lifecycle cost analysis for the entire coating project must be used.

island of Honshu and the island of Shikoku. The longest, single span of the bridge is 6,527 feet, while the towers stand at 928 feet. The coating system used on the bridge is more complex than those typically used in the United States, consisting of a number of coatings both field- and shop-applied. The application of the coating system is given above in Table 1 (page 17). Elapsed time is the time period between treatments.

The estimated life of the Akashi Strait Bridge is 120 years. During that time, the Honshu Shikoku Bridge Authority is planning to recoat the bridge only once. To accomplish this, the fluorourethane topcoat was applied at 55µm (2.2 mils), or about twice the normal thickness. The Akashi Strait is the site of frequent typhoons, with substantial wind and rain common in the area, which may lead to higher erosion rates than discussed above. However, this coating thickness should allow the authority to reach its goals.

Shelby Street Bridge, Nashville, Tenn.

The Shelby Street Bridge originally was built in 1909. Problems with concrete used in its construction led to repairs in the 1920s and again in 1960.

Photo courtesy of Carboline

Shelby Street Bridge in 2003.

In 1998, the bridge was declared unfit for traffic and was slated for demolition. However, because of its historic nature, the bridge was not torn down, but was converted into a pedestrian bridge linking entertainment venues and the coliseum on either side of the Cumberland River. At 3,150 feet, it is one of the longest pedestrian bridges in the world.

The bridge was repainted in 2003 with an inorganic, zinc-rich primer, a cycloaliphatic amine-cured epoxy middle coat, and a fluorourethane topcoat. The bridge often is lit with lights of various colors, often reflecting the season. A gray topcoat was selected because it shows the color of the lights better.

Gateway Boulevard Bridge, Nashville, Tenn.

The Gateway Boulevard Bridge won the 2005 National Steel Bridge Alliance award for a major span. The bridge's red box structure was coated with a FEVE-based coating on those portions with significant exposure to sunlight.

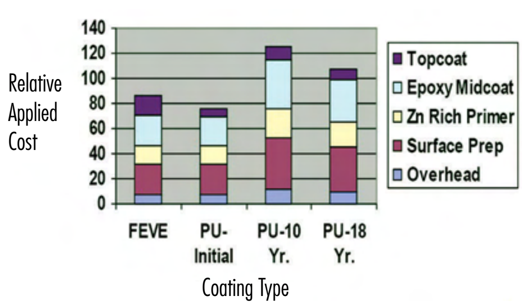
Lifecycle costs

In 2005, the Ministry of Land, Infrastructure and Transport in Japan, revised the requirement for performance of heavy-duty coatings. Fluoropolymer topcoats now are required for use on all bridges in Japan, both for new construction and for repainting. The Ministry has determined through extensive real-time testing that the lifecycle cost of FEVE-based coatings is far lower than that of competitive coatings. It expects a minimum of 30 years of life from the FEVE topcoat.

FEVE topcoats are more expensive than traditional topcoats used on bridges. Paints made from FEVE resins typically sell in the range of $200 to $450 per gallon. To determine the cost effectiveness of FEVE resin topcoats, lifecycle cost analysis for the entire coating project must be used.

Labor typically is 80 to 90 percent of the cost of field-coating a bridge. This means that material costs typically are only 10 to 20 percent of the cost. Bridge coating systems usually are comprised of three parts: primer, midcoat, and topcoat. Because the FEVE resins are used only in the topcoat, application and material costs for the primer and midcoat are the same, regardless of the type of topcoat used. Field experience has shown that the total initial application cost of a FEVE coating system is only 6 to 13 percent more expensive than a polyurethane. When lifecycle costs are taken into account, the FEVE coating system offers a 45-percent cost advantage after 10 years, and a 26-percent cost advantage after 18 years. The lifecycle cost analysis is shown below in Figure 3.

Figure 3: Lifecycle costs, FEVE topcoat v. polyurethane.



This lifecycle analysis doesn't include additional costs that are incurred when a bridge is repainted. Costs to the public, for example, closing lanes on bridges during repainting operations, can also be reduced over time by using FEVE coatings. Further, FEVE coatings can reduce VOC emissions over time. Potential liability can be minimized by reducing repainting requirements for assets such as bridges and water towers that are difficult to access, and by limiting exposure to other costs such as overspray claims. For taxpayer-funded entities such as Departments of Transportation, investing in FEVE coatings today can reduce the use of maintenance dollars in the future, freeing these funds for use on other projects.

FEVE resins have a 20-year history of successful use in the field. FEVE coatings can substantially reduce lifecycle costs for bridges, while offering significant improvements in appearance and corrosion protection over the life of the coating: Coating life of 30 years or more is typical using FEVE coatings. While the majority of projects to date have been completed in Asia, FEVE topcoats are finding more application for bridge coatings here in the United States. ■

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Winn Darden is the business manager for AGC Chemicals Americas line of LUMIFLON fluoropolymer resins. He has been involved in the sales and marketing of coatings and coating raw materials for more than 15 years. Darden has authored more than a dozen papers, including presentations for the Society for Protective Coatings and the National Association of Corrosion Engineers.