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Durability of fluoropolymer top coat systems related to standards

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ABSTRACT

Many tall and large structures have been constructed and operated under harsh environmental conditions. It has been required to protect steel structures from a variety of corrosive environments over their service life. In order to meet such requirements, continuous research has been aimed at increasing coating system durability, extending service life, and reducing life-cycle costs.

The solvent-borne FEVE (Fluoro-Ethylene Vinyl Ether) type fluoropolymer coatings were invented as top coats of protective coating systems in 1983. Since then, much data has been gathered concerning FEVE system performance data were collected in actual service on steel structures, and by laboratory testing in simulated service environments. In-service performances of FEVE systems have been excellent even after 30 years of outdoor exposure. The FEVE top coats are highly resistant towards exposure to ultraviolet rays, where they significantly outperform the conventional polyurethane top-coat coatings in gloss retention and chalking resistance (also termed "weathering resistance"). These characteristics of fluoropolymers come from their strong chemical bonding between carbon and fluorine atoms in the molecular structure of FEVE. Because of its outstanding and desirable properties, the Japan Road Association specified the FEVE top coat system for C5 class service; i.e., atmospheric corrosivity category type environments as defined by ISO 12944-2 and ISO 9223. In 2014, the FEVE fluoropolymer was also included in the ISO12944-5-2018 standard.

This paper describes performance of FEVE top-coated coating systems, cost reduction of coating system material and installation, reduction of VOC (Volatile Organic Compounds) emissions, and improvements of LCC (Life Cycle Cost). Thick FEVE top coats reduce the number of required

coats per coating system, improve coating system service life (due to improved top coat durability), and further reduce LCC. These benefits were verified by testing in actual outdoor environment, and laboratory testing in simulated environments. The performance results were compared with the past design solvent-borne (S/B) fluoropolymer coating systems. FEVE top-coated systems had been successfully applied to large steel structures such as bridges, railway bridges, and storage tanks, etc.

Key words: "Fluoropolymer topcoat", " FEVE", " Water-borne", "Solvent-Borne", " VOC", " Protective performance", "C5 class service coating system" "LCC" "Weathering performance"

INTRODUCTION

FEVE topcoats have been adopted in the ISO 12944-5-2018 standard. In 1992, FEVE topcoat coating systems were adopted by JIS as the standard. In Japan, solvent-borne (S/B) FEVE topcoats have been adopted for large-scale government construction projects, where high durability protective coating systems are required.

In 1983, FEVE top-coat coatings were developed and are in increasing use in Japan ever since. They were successfully applied at the famous Akashi Kaikyo Bridge in 1998. A thick top-coat FEVE coating system was selected for the largest radio tower in Japan and, in recent years, its water-borne (W/B)-based version was adopted for road bridges.

In 1985, extensive testing of FEVE top-coat coatings was initiated at a national institution, to verify their performance in C5 class service exposure. In 2014, following successful testing, it was adopted by the Japan Road Association for C5 class service.

In 2006, FEVE top-coat coatings were first introduced as chalking resistant / gloss retaining (weatherable) Fluoropolymer Top-Coats.¹⁾ The fundamental chemistry and basic durability of FEVE top-coat system was mentioned in NACE Corrosion 2011.²⁾

This paper describes progress in performance evaluation of FEVE top-coated coating systems, cost reduction of coating system material and installation, reduction of VOC emissions, and improvements of LCC.

FEVE Coating Systems

FEVE Composition

The ambient-cure FEVE systems were developed in 1983, as highly durable polymers for top-coat coating applications. The polymer structure of the FEVE resin is shown in Figure 2.³⁾ It comprises regularly alternating fluoro-ethylene and vinyl-ether segments. While FEVE resins derive its durability from the strong C-F bonds, this regularly alternating sequence is the main reason for the high level of durability compared with conventional polymers like acrylics.

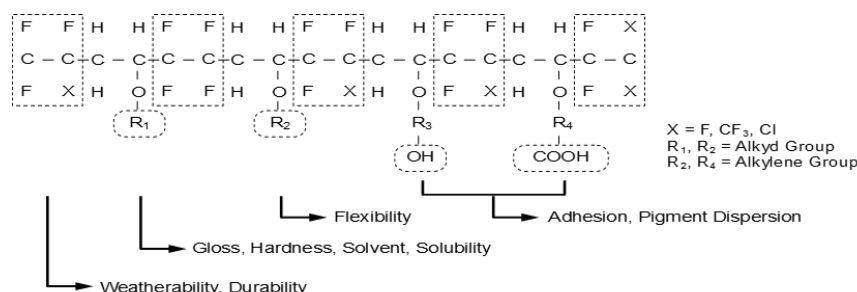


Figure 1. Typical structure of fluoropolymer resin²⁾

Fundamental Chemistry of Fluoro-polymers

Table 1 shows the bond energies of the fluoro-polymer compound compared with conventional polyurethane (commodity) compounds. The bond energies found in the alternating copolymer of the FEVE resin are higher than the energy in natural UV light. This property makes the fluoro-polymer difficult to decompose by natural UV radiation. When UV radiation decomposes a chemical bond, free radicals are formed. These free radicals can initiate degradation of other coating components, including the reacted resin, pigments, and other additives. Generation of these free radicals in the FEVE resin is very difficult. Therefore, the degradation of the crosslinked FEVE coating, which contains several types of chemical bonds, is more difficult than in common polymers like standard polyurethanes and acrylics.

Table 1. Bond energy of Fluoro-polymer Chemicals and Commodity-Chemicals⁴⁾

Resin	C-C Chain	KJ/mol	C-F, C-H	KJ/mol
Fluoro-polymer Chemicals	CF ₃ -CF ₃	414	F-CF₂-CH₃	523
	CF ₃ -CH ₃	424	CF₃CH₂-H	447
Commodity Chemicals	CH ₃ -CH ₃	379	CH ₃ CH ₂ -H	411

Comparison between FEVE and Conventional Polyurethane Coating Systems

Long-term Exposure Trials in Marine Station Environment

The S/B FEVE top-coat coating system and the conventional S/B polyurethane coating systems underwent 30-year exposure in C5 class environment at Suruga Bay, which is characterized by 17.4 °C average temperature, and 69% average RH (relative humidity). The tested systems are described in Table 2, whereas the results of 20-year exposure to corrosivity category C5 in ISO12944 are shown in Figures 3 and 4.