HIGH-PROFILE ROOFING:

Advancements in Fluoropolymer Top-Finishes for Roofing Membranes

By Jerry Beall

Photo 1 – Beth El Temple, St. Petersburg, Florida. Kynar-coated single-ply.

Technology advancements in industrial coated fabrics are leading the way for new opportunities in the single-ply membrane market. Factory-applied high-performance coatings, combined with gravure printing technologies, are breaking typical roofing paradigms and offering architects solutions to previously unmet customer needs. This article will discuss these advancements and their transition into today's single-ply roofing market.

THE PREMISE

In the 1970s, the roofing industry borrowed reinforcement technology from the polymer-coated architectural fabric market to lay the foundation for most of today's single-ply roofing membranes. These two markets are merging again. As these platforms merge, additional advancements are happening on both fronts.

Since their conception, thermoplastic roofing membranes, initially designed for low-slope roofing applications, have been used for high-profile, highly visible steep-slope roofing solutions. It was a natural evolution. The versatility of these membranes, combined with their exceptional weathering characteristics and watertight integrity, allowed designers and architects to express their creativity in new ways.

Monolithic coverings brought dynamic shape and aesthetics to the structures that rigid materials such as stone and metal or even shingles, for that matter, could not accommodate. It soon became clear that architects were not just designing buildings; they were creating art (*Photo 2*).

The single-ply membranes did an excellent job from an initial installation perspective; but dirt pickup, which had nothing to do with the overall performance of the products, soon diminished the aesthetic value of

Photo 2 – The Ascent at Roebling's Bridge, Covington, Kentucky.

Photo 3 – University of Florida O'Connell Center, September 2005.

Photo 4 – University of Florida, O'Connell Center, May 2008, after cleaning. The white structure below the roof area is a Teflon-coated fiberglass.

the structure and the overall appeal of the membranes. Even though the roofs could be cleaned and restored to their as-new appearance, the expense was not something the owners anticipated or appreciated.

In spite of all the positive attributes afforded these single-ply materials, there was something lacking. The materials themselves were not specifically designed to provide the optimum solution to the designers' overall expectations.

A study of the "high profile" market's needs revealed that there were some significant customer satisfaction gaps when measured against current product offerings. Sure, watertight performance, attractive warranties, and overall ease of installation were givens. But over time, fading colors and dirt pickup diminished the aesthetics of the structures' as-new appearance (*Photos 3* and *4*).

What was really needed was an architectural roofing solution specifically engineered to address the long-term need to maintain aesthetics without sacrificing the inherent performance attributes of these materials. To determine the optimum solution, a thorough analysis of the customer satisfaction gap was in order.

A dynamic study was undertaken that included extensive interviews and opinion surveys of architects, roof consultants, and roofing contractors. The gap is a measure of their satisfaction with currently available membrane solutions and characteristics compared with their preferred or optimum desires (*Figure 1*):

- Color that doesn't fade
- Membranes that stay clean
- Patterns to create depth and break up color monotony
- A broad range of color options
- Warranties

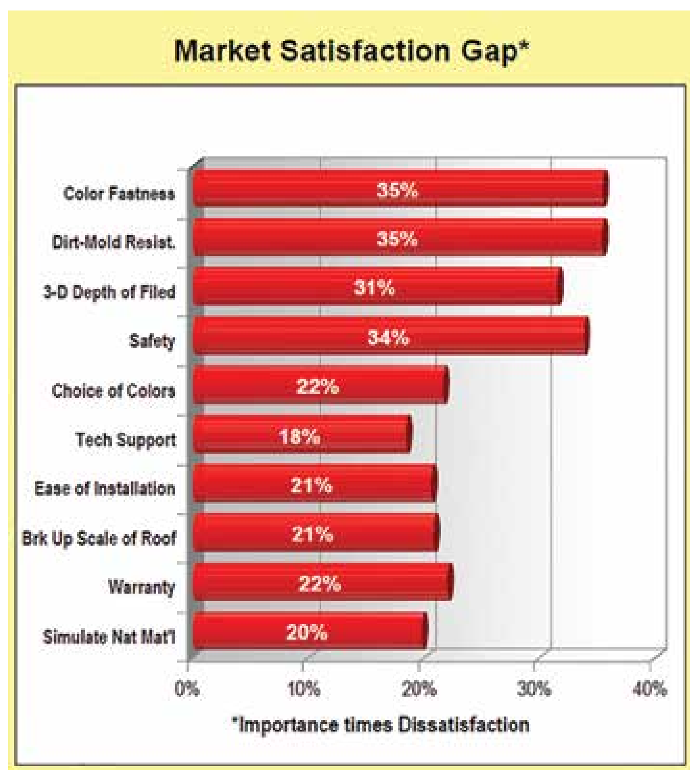

Figure 1 – The gap is a measure of building professionals' satisfaction with currently available membrane solutions and characteristics compared with their preferred or optimum desires.

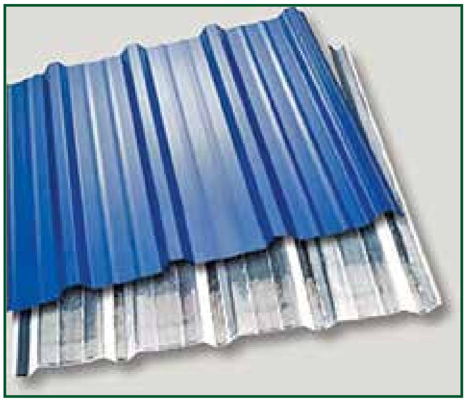

Photo 5 – Fluoropolymers were metal roofing's solution for corrosion and aesthetics.

Photo 6 – Field-applied coating.

Photo 7 – Factory-applied top finish.

The solutions also had to meet a host of standard external requirements for fire, wind, and general weathering performance. So the ultimate solution could not overlook the many givens required for commercial roofing in general. These external requirements can be summed up by just saying Factory Mutual (FM) and UL approvals.

While this challenge may have been new to commercial membrane roofing, it had been addressed long ago in the architectural fabric structure market. In these markets, the vinyl membrane is the roof, and initial and long-term aesthetic performance is critical to the satisfaction of the customer.

And, similar to today's highly visible commercial roofing, these single-ply materials offered an endless opportunity for architects to express themselves in shape and color; and, just like commercial high-profile roofing, maintaining aesthetics over time is an important consideration in the selection of materials.

For their ultimate solution, the architectural fabric industry borrowed a page from the metal roofing industry. By using a fluoropolymer film or top finish applied during the manufacturing process, the architectural fabric industry was able to offer the ultimate solution to the aesthetic expectations of their customers (*Photo 5*).

These coatings and/or top-finishes protected the metal from corrosion as well as promoted unlimited color options with minimal dirt pickup. Hence, a top finish (factory-applied coating) was applied to protect vinyl membranes from ultraviolet radiation (UV) and its effects. The top-finish could restrict plasticizer migration, prevent colors from fading, and repel dirt. Early top-finish solutions utilized acrylics, which offered a solution—albeit temporary at best. Acrylic resins contain esters and incorporate other functional groups that are susceptible to photochemical degradation and hydrolysis, both of which are prominent during typical environmental exposure. These conditions contribute to the ultimate breakdown of the protective acrylic layer. Eventually, degradation of the top finish left the vinyl exposed to the effects of UV. Plasticizers would begin to migrate, colors would fade, and dirt would collect on the structures.

COATING FUNDAMENTALS

The performance of many materials can be enhanced with an exterior barrier that preserves the inherent properties of the base material. Paint, which is essentially a coating, has been used for this purpose for hundreds of years. This technology has advanced to include some pretty high-tech solutions for the construction market, whether field-applied (*Photo 6*) or in the form of factory prefinished materials (*Photo 7*).

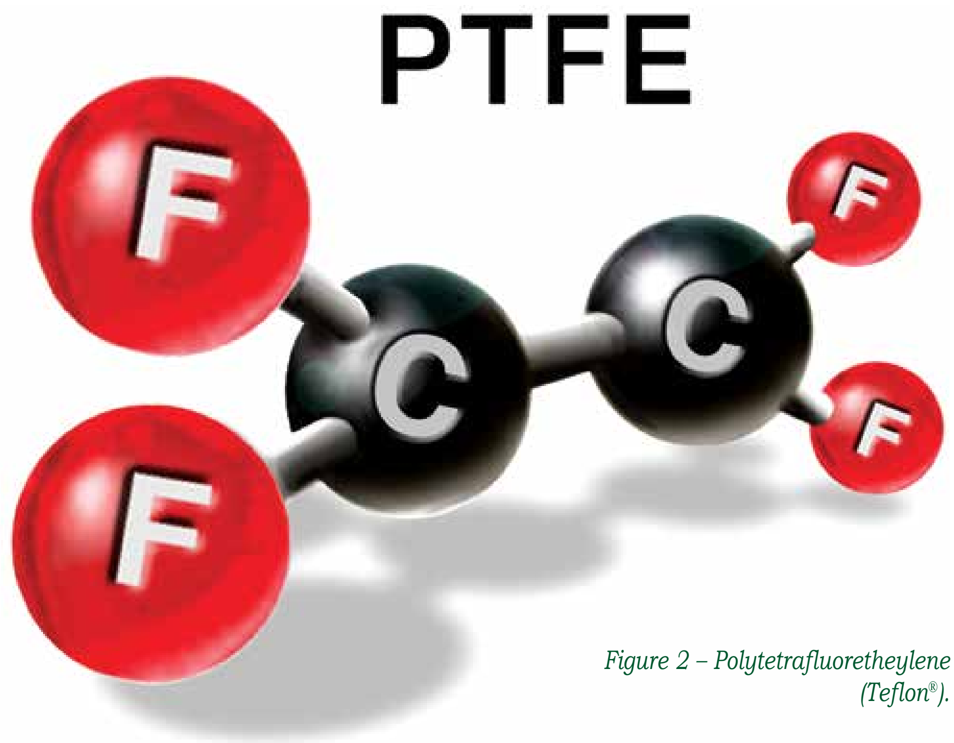

Figure 2 – Polytetrafluoretheylene (Teflon®).

In general, coatings—whether factory- or field-applied—have the same functional requirements. Yet in certain cases, such as architectural fabrics, coatings can be used to protect the primary waterproofing, coatings, and/or polymers. These factory-applied coatings are often referred to as top-finishes.

Paints or coatings in this context are generally classified into two categories: water-based and solvent-based. Solvent-based coatings use a carrier consisting of volatile organic compounds (VOCs). VOCs can cause smog, ozone pollution, and indoor air quality problems. Newer formulations contain more solids and less solvent or environmentally friendly solvents such as water.

Additives may be used in small amounts in comparison to the main ingredients. They include flatting agents, rheology modifiers, wetting agents, and curing agents.

Binders allow for curing of the coating, which increases physical strength and chemical resistance of the coating film. The binder is the primary source for the coating's durability and physical properties. Binders differ in their ability to withstand UV exposure. The type of binder used is one of the most significant criteria in choosing an exterior coating.

Acrylics are one of the most common binders used for coatings. For field-applied roof coatings, we see a lot of acrylics (and now, urethane) being used to coat not only metal, but single-plies. We also have new fluoropolymers blended with acrylics entering the roofing market.

The better the binder or "resin," the better the coating or top finish will perform.

Solvents are chosen based on system compatibility and evaporation rate. Environmental concerns have pushed the technology toward water-based materials that now perform as well if not better than solvent-based ones.

FLUOROPOLYMERS

Fluoropolymers share the properties of fluorocarbons in that they promote a high surface tension phenomenon that contributes to their non-stick and friction-reducing properties. In addition, they are stable due to the strength of their multiple carbon-fluorine bonds. Fluoropolymers may be mechanically characterized as thermosets or thermoplastics. Fluoropolymers can be homopolymers or copolymers.

In 1938, polytetrafluoroethylene (PTFE) was discovered by accident by a recently hired DuPont chemist, Roy J. Plunkett (*Figure 2*). While working with tetrafluoroethylene gas, he noticed missing weight. While scraping down his container, he found white flakes of a new-to-the-world polymer. Testing showed that the substance was resistant to corrosion from most substances and had better high-temperature stability than any other plastic known at the time. By early 1941, a crash program was making commercial quantities of this unique plastic: Teflon.[1] See *Photo 8*.

Fluoropolymers make excellent protective coatings because of their inherent chemical and UV resistance. In many cases, they are the preferred choice for protective coatings.

The carbon-fluorine bond is the key to the thermal, chemical, and UV-resistance properties of all fluoropolymers. The number of fluorine atoms present in a given fluoropolymer has a direct bearing on its performance.

The unique combination of properties of fluoropolymers is attributed to two intrinsic characteristics of fluorine atoms—extremely high electro-negativity and small atomic radius. The atomic structure of fluorine gives rise to some of the strongest chemical bonds known.

As if the roofing industry doesn't have enough acronyms, here are a few more for you.

Polytetrafluoroethylene (PTFE), polyvinyl fluoride (PVF), and polyvinylidene fluo-

Photo 8 – Teflon is the only known surface to which a gecko cannot stick.

ride (PVDF) are the three most commonly used fluoropolymers today. Although best known for their nonstick characteristics, they are also extremely durable materials. In many instances, these are very thin films, measuring no more than a few microns. PTFE (Teflon) is most recognized as a nonstick coating for cookware. It is very nonreactive—partly because of the strength of the carbon-fluorine bond. PTFE is often used in containers and pipe work for reactive and corrosive chemicals.

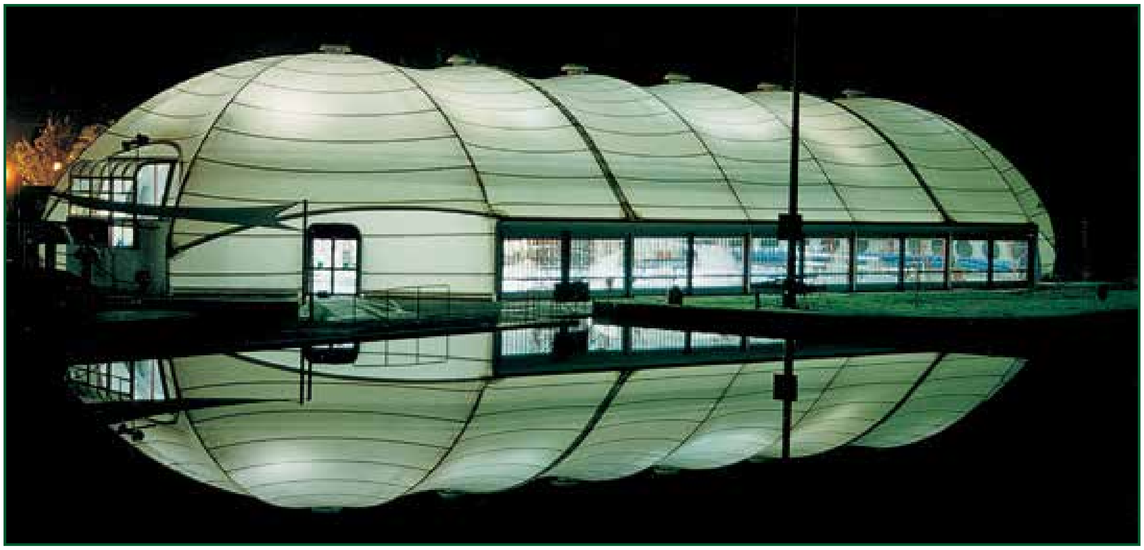

Photo 9 – Tedlar-coated polyester on an aquatic center.

PTFE-coated fiberglass is a popular noncombustible, coated fabric used in the architectural structure market. This is especially true in the U.S., as the structure must pass a similar battery of fire tests to that required for roofing materials: the burning brand test.

PVF (Tedlar)[2] is the predecessor to PVDF in architectural fabric coatings and has performed in the architectural market for over 30 years (*Photo 9*). This film has been used extensively in the construction market on vinyl siding, architectural shingles, and membrane structures.

PVF resin is structurally similar to PVC resin in that it has low permeability for vapors, burns very slowly, exhibits excellent resistance to weathering and staining, and is resistant to most chemicals except ketones and esters.

Low water permeation, high-UV resistance, color stability, and good chemical resistance are properties of this 1-mil film that provide a high-performance, long-term, durable surface in harsh environments. Until recently, this product was the best solution for long-term performance in the architectural fabric market. With the rise in usage of PVF in photovoltaic cells, a new film was needed in the architectural market to act as an alternative and provide yet another superior alternative to acrylics.

PVDF (Kynar)[3] is a highly nonreactive and pure thermoplastic fluoropolymer produced by the polymerization of vinylidene difluoride. PVDF is a specialty plastic material in the fluoropolymer family; it is used generally in applications requiring the highest purity, strength, and resistance to solvents, acids, bases, and heat and low-smoke generation during a fire event. Compared to other fluoropolymers, it has an easier melt process because of its relatively low melting point of around 350°F (177°C).

It also has a low density and low cost compared to other fluoropolymers. PVDF is available as piping products, sheet, tubing, films, plate, and an insulator for premium wire. It can be injected, molded, or welded, and is commonly used in the chemical, semiconductor, medical, and defense industries, as well as in lithium ion batteries. It is also available as cross-linked closed-cell

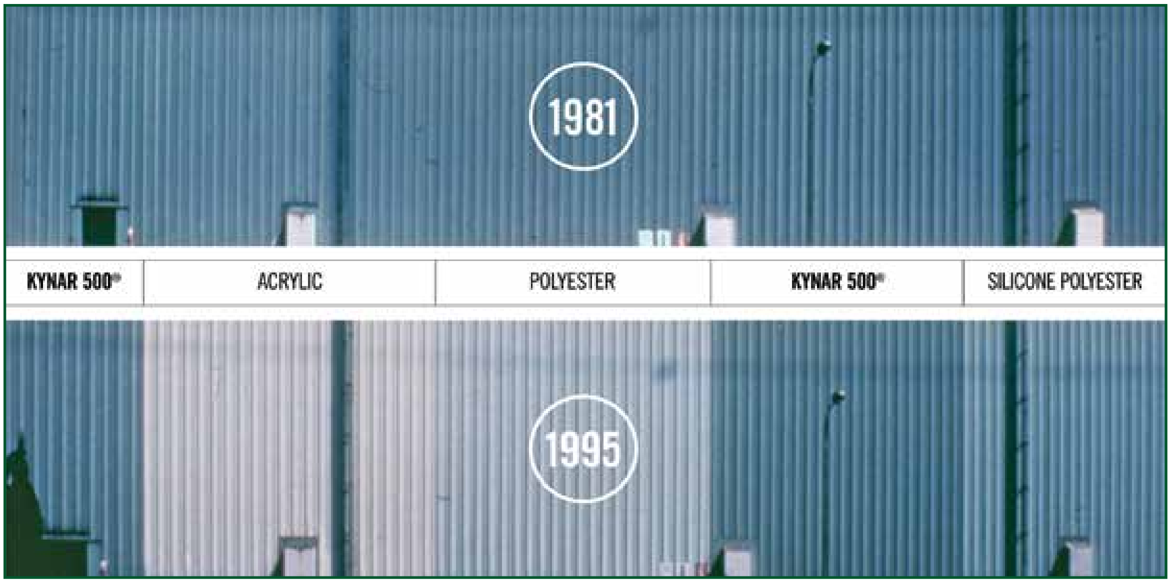

Photo 10 – Field-testing and weathering of PVDF.

foam, used increasingly in aviation and aerospace applications.

Fortunately, and unlike the other two fluoropolymers discussed, PVDF is also used as the principal ingredient of high-end paints for metals (*Photo 10*). These PVDF paints have extremely good gloss and color retention and are used on many prominent buildings around the world, as well as on commercial and residential metal roofing.

The most significant property of PVDF-based coatings is their outstanding exterior durability. The exceptional weatherability is a result of the strength of the carbon-fluorine bond, which is one of the strongest chemical bonds known. The bond strength provides a chemically inert coating with complete resistance to UV light exposure. UV radiation is one of the major causes of deterioration of a coating exposed to the atmosphere.

Commercial coatings can fade over time. PVDF offers unique weathering properties. As it is invisible to UV, it holds up to the sun's energy and doesn't break down. It also allows the use of high-performance metal oxide pigments. These pigments resist fading much better than conventional organic pigments.

MERGING TECHNOLOGIES

The transfer of architectural fabric top-finish technology to roofing has had its challenges. From a purely technical perspective, creating the fabric was a fairly simple transition. The greater challenge was turning the Kynar-coated fabric into a reliable and easy-to-install roofing system.

It has become the general rule of roofing to place a heavy emphasis on aesthetics, but the expectations with Kynar-coated membrane are reaching new heights (*Photo 11*). This challenge is magnified by the fact that the factory-coated top-finish is nonweldable. However, the selvedge edge or coating miss along the edge of the membrane will facilitate the vast majority of field welding.

There are numerous advantages of having a factory-applied finish as opposed to a field-applied finish (*Photo 12*).

This is a unique technological advancement in the art and applied engineering of coated fabrics. The application of the top finish involves more than just applying a layer of coating. It is a multi-step process to

Photo 12 – Working with a preprinted metal profile illusion on a fluoropolymer roofing membrane.

Photo 11 – Plainview Elementary School, Plainview, Texas, with its "Dazzle Blue" Kynar roofing system.

ensure optimum adhesion of the finish to the vinyl membrane.

Roofing membranes with a fluoropolymer top finish offer a broad spectrum of color options that do not fade, and the inherent low coefficient of friction reduces dirt accumulation on the surface of the membrane.

The transfer of this top-finish technology to roofing permits the membrane to have the advantage of thermoplastic seams and a highly durable yet nonthermoplastic finish.

Today's emphasis on energy savings through highly reflective roofing makes a premiere membrane with top-finish very appealing. Imagine a white roof that stays clean or a blue roofing membrane that doesn't fade and also meets 20-year performance expectations.

Fluoropolymer-coated roofing membranes require forethought on the part of the craftsman during layout of the membrane and assembly. Joining the membrane at flashing and roll ends or anyplace else that the fluoropolymer would impede welding is pretty simple, but requires either a removal process for the fluoropolymer or an underlying uncoated base membrane. A masking process is used along with cleaning the fluoropolymer with methyl ethyl ketone (MEK) to ensure straight edge laps. PVDF (with the exception of ketones) is very chemical-resistant.

Photo 13 – Fluoropolymer removed and ready to weld.

Care must be exercised to avoid splashing or spilling the MEK on the unmasked portion of the membrane, as it will damage the fluoropolymer top-finish.

This process is applied to any seam that needs to be made within the fluoropolymer top finish of the membrane, including flashing and repairs.

Once the welding techniques are mastered (*Photo 13*), the other challenge is hid-

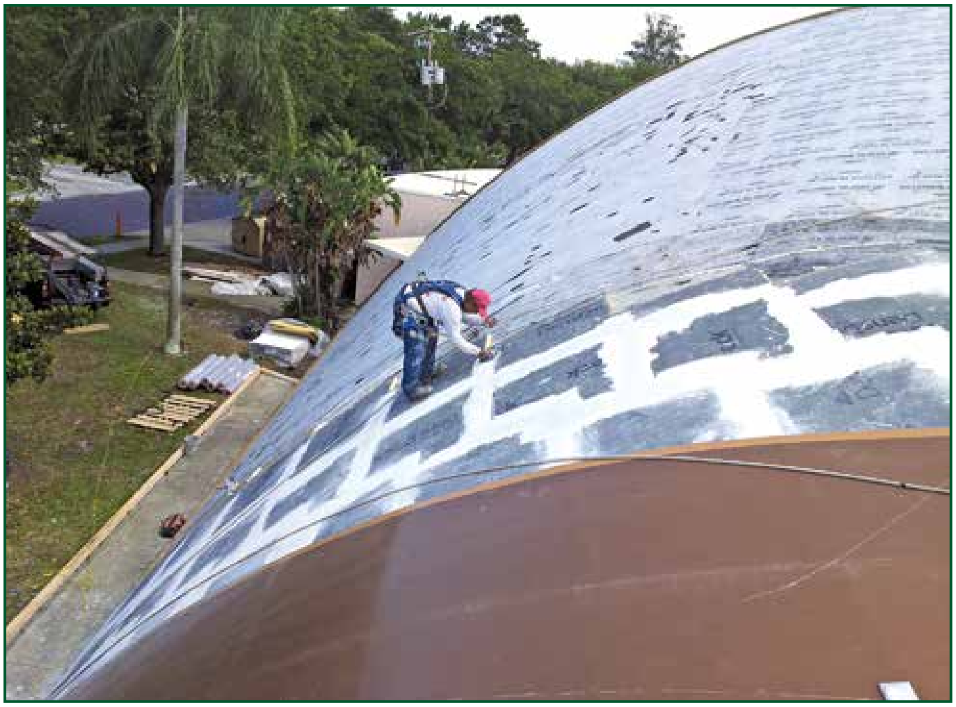

Photo 14 – Substrate preparation and grouting of the underlayment on Beth El Temple, shown in Photo 1.

ing the substrate and preventing it from telegraphing through the adhered membrane.

The most likely method to accomplish this is to mechanically fasten the insulation composite as required and bond a coverboard in urethane foam adhesive to the insulation. However, this, too can have its challenges.

The incorporation of a "fleece" on the back of the membrane helps hide substrate imperfections.

For the job shown in *Photo 14*, the contractor had to take additional steps to tape and grout the joints in the gypsum coverboard to minimize any telegraphing in order to please the architect's demand for impeccable aesthetics.

ADVANCING TECHNOLOGY

Breaking up the monotony of a high-profile roof is a desired attribute for a single-ply roofing membrane, according to the architects interviewed. Technology has advanced to the point that printed patterns and/or illusions using fluoropolymer coatings are now possible.

This is a big step up from the current illusions available in the market that simulate shingles or stone and are typically printed with acrylics.

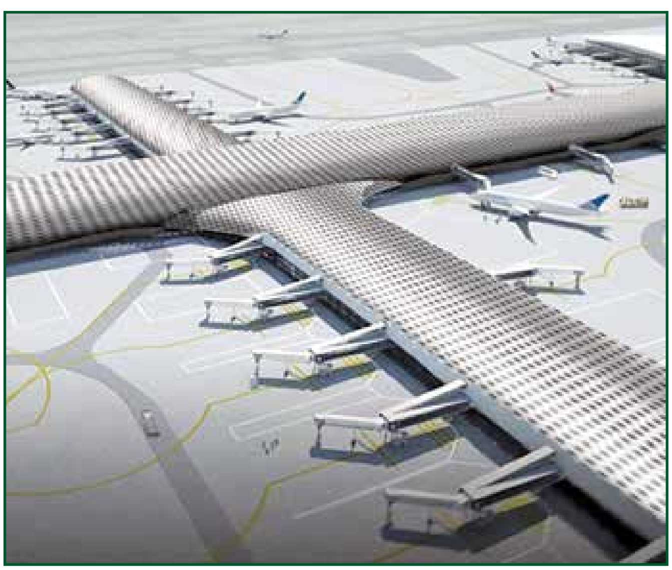

Photo 15 – Patterns allow for unlimited architectural expression, such as on the roof of this airport.

The type and choice of pattern will determine the final aesthetics. The patterns can be fairly intricate, such as the ones shown in *Photo 15*, or larger in their repeat pattern to create some pretty astounding visuals.

Custom designs will open the door for unlimited design options; and, based upon initial studies, the possibilities for artistic expression are endless.

Thermoplastic single-ply roofing has been improving and advancing since its initial conception in the 1960s. As customer expectations expand, fluoropolymers are creating unique opportunities to meet these expectations, as well as interject new creativity into the architectural design process.

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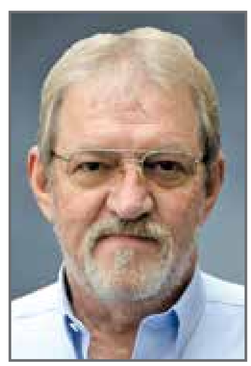
FOOTNOTES

1. Teflon is a registered trademark of DuPont.
2. Tedlar is a registered trademark of DuPont.
3. Kynar is a registered trademark of Arkema Inc.



Jerry Beall

Jerry Beall's roofing industry career spans 40 years, stemming from a 10-year stint as a journeyman in Roofers Local #88. He joined Seaman Corporation in 1984 and spent five years as FiberTite's senior technical service representative. During a three-year absence from Seaman, he worked with a Florida roofing contractor and then returned in 1992 as a FiberTite® Roofing Systems technical manager. In 2000, he became national sales and technical manager for FiberTite. Four years later, Beall assumed his current role as FiberTite technical and product specialist.