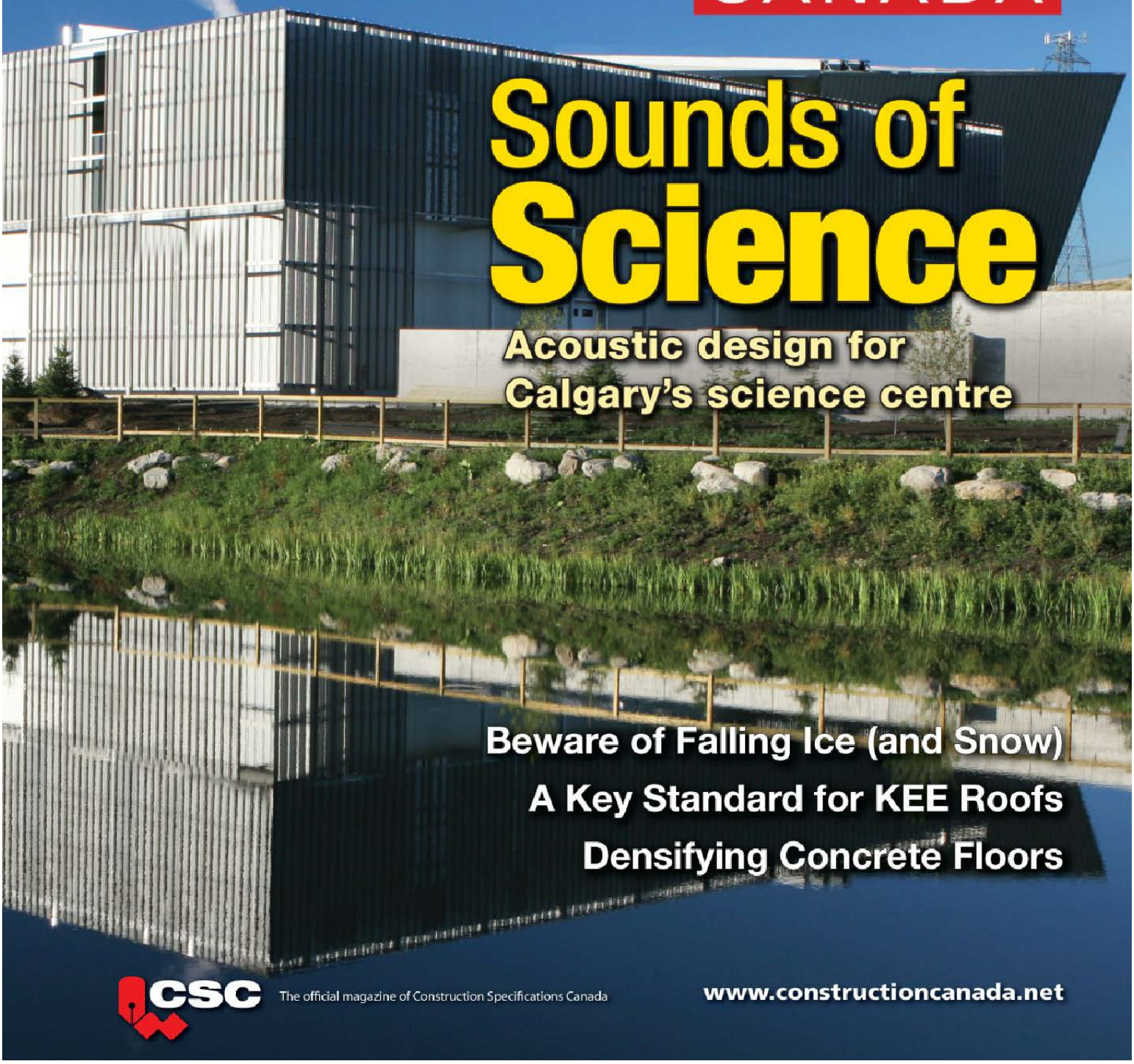
Construction CANADA

$7.95

January 2012 Vol. 54 No. 1



Sounds of Science

Acoustic design for Calgary's science centre

Beware of Falling Ice (and Snow)

A Key Standard for KEE Roofs

Densifying Concrete Floors

CSC The official magazine of Construction Specifications Canada

www.constructioncanada.net

Feature

All images courtesy Seaman Corp.

Sustaining a KEE Standard for Roofing Membranes

By Jerry Beall

Ketone ethylene ester (KEE) is a flexible, high-molecular-weight thermoplastic co-polymer. When properly compounded with polyvinyl chloride (PVC), the resulting single-ply membrane can be bonded or 'fused' to itself with hot air, requiring neither torching nor adhesives. Among its many performance benefits in roofing assemblies, the polymer promotes chemical resistance and remains highly flexible with age.

In the September 2003 issue of RCI's *Interface* magazine, this author wrote an article discussing the then-new ASTM standard for KEE sheet roofing membranes.[1] In the eight years since, those products have received a lot of attention. If imitation really is the sincerest form of flattery, then the original manufacturer of KEE should be overjoyed. However, growing use of this polymer as a vinyl modifier for roofing membranes and subsequent manufacturers claiming they too are KEE have clouded the premise of the ASTM standard.

ASTM D 6754-02, *Standard Specification for Ketone Ethylene Ester-based Sheet Roofing*, was predicated on the KEE polymer being the backbone or primary polymeric component of the membrane. While having KEE should surely improve any vinyl product (assuming the manufacturer understands its unique processing variables), this does not justify coat-tailing the historical record or claims of compliance to the specifics enumerated within the ASTM standard.

A brief history lesson

In March 2002, ASTM assigned a number to a new thermoplastic roofing membrane standard. At that time, ASTM D 6754-02 was the exclamation point to a 15-year saga associated with its development. The journey began in the late 1980s as an effort to assure the roofing industry it was possible to manufacture a sustainable 'vinyl' roofing membrane less than 1.14 mm (0.05 in.) thick capable of meeting or exceeding the performance expectations of thicker membranes.

The specification has been revised and now carries the reference ASTM D 6754/6754M-10. However, before this, the only official option for evaluating and/or characterizing vinyl membranes was ASTM D 4434, *Standard Specification for Polyvinyl Chloride Sheet Roofing*.

Published in 1985, this was the first consensus standard for thermoplastic single-ply membranes. It was the result of a due process procedure that produced consensus among roofing industry professionals for characterizing PVC sheet roofing. The development of ASTM D 4434 came at a time when PVC membranes, as roof

coverings, were recovering from the stigma associated with early failures. The standard established a nationally recognized definition for PVC roofing membranes.

Section 4.1 of ASTM D 4434-96 defined the applicable material as follows:

The sheet shall consist of poly (vinyl chloride) resin in amounts greater than 50% of the total polymer content suitably compounded with plasticizers, stabilizers, fillers, pigments, and other ingredients to satisfy the physical property requirements and accelerated durability tests.

The standard also cited physical properties intended to characterize a 'good' PVC roofing membrane; it evolved to include a couple of grades and types of PVC roofing that offered different considerations toward internal reinforcements, resistance to heat aging, and resistance to ultraviolet (UV) light. While these are significant considerations, the industry eventually adopted an overriding paradigm that focused on thickness as a prerequisite for performance, and the ultimate measure of viability for a vinyl, or any polymeric, membrane. This theory is just as pervasive today—there are single-ply roofing membranes being offered in thickness up to 3 mm (0.12 in.).

Since its conception, ASTM D 4434 had been the benchmark for the competitive evaluation of vinyl membranes. Although invaluable in its own right for establishing minimum characteristics for a particular segment of vinyl/PVC membranes, it is not necessarily applicable to all vinyl roofing membranes.

A mechanically fastened 25-year-old nominal 0.9-mm (36-mil) ketone ethylene ester (KEE) roofing system in Naples, Fla.

There were various vinyl roofing membranes in existence at the time the standard was adopted in 1985. In addition to 'liquid' polymeric materials (*i.e.* plasticizers) used to impart flexibility, solid

A 26,477-m² (285,000-sf) KEE roof installed below an artificial turf 'garden roof' at Yankee Stadium Parking Garage in New York.

polymers such as vinyl acetate, nitrile, and chlorinated polyethylene were also being used as alternative modifiers for vinyl membranes. Was it appropriate to lump all the variable fabric, compounding, and production technologies available under one universal standard for thermoplastic vinyl roofing membranes? The adoption of ASTM D 4434 had an unintended consequence of doing just that.

The technology to produce vinyl membranes, defined within D 4434, uses a typical platform that begins with a high molecular weight PVC resin but extends it and makes it flexible with a lower-molecular-weight liquid plasticizer. The challenge for this process is to produce a material that sustains its flexibility, even though the lightweight plasticizers tend to volatilize and drift away from the PVC polymer over time, exiting the sheet.

Certain environments can accelerate this process, leaving a membrane prone to in-situ shrinkage and stiffening. A minimum polymer thickness is required to function as a reservoir to prolong the time it takes for these liquid polymeric materials to migrate to the surface and erode away.

KEE and PVC: chemistries and standards

In this author's 2003 article, the roofing industry was cautioned not to "win the battle and lose the war." At the time, the meaning of this sincere warning was not fully grasped. Eight years later, it is important to recognize all vinyl membranes, though significantly different in their technological platforms, offer many sustainable advantages. This is especially poignant in light of those that that have set their sights on the complete elimination of PVC. On the other hand, it is also true some of these technologies have proven to be more effective than others.

The original acronym used to differentiate KEE technology from conventional vinyl technology was EIP (*i.e.* ethylene inter-polymer). The few parties associated with the development and introduction of EIP roofing membranes in the early 1980s contended that thicker was not necessarily better—rather, 'better' was better. This claim was not without precedent. The actual foundation for EIP roofing was laid in 1974 with the introduction of a geomembrane that pioneered the use of a proprietary KEE vinyl modifier to create a high-performance and chemical-resistant membrane for environmental applications.

The EIP acronym and its associated performance record began to catch on and was eventually recognized by the National Roofing Contractors Association (NRCA) in its *Low Slope Guide*. In the late 1980s and early 1990s, additional manufacturers introduced new versions of membranes under the EIP banner.

Was the difference between EIP and PVC technologies significant enough to warrant the development of a separate standard? ASTM was petitioned to take a look and agreed to initiate a committee to evaluate EIP roofing membranes. The subcommittee for the development of a standard specification for ethylene-inter-polymer sheet roofing was formed in 1987.

The term 'EIP' was used to differentiate membranes manufactured using a hot melt vinyl coating technology with the proprietary KEE modifier—DuPont Elvaloy—as the foundation for the vinyl compound. Elvaloy is a flexible co-polymer containing ketone, ethylene, and ester monomers all within the backbone of the polymer. Simply put, it is a high-molecular-weight, solid, and flexible thermoplastic polymer. PVC resin is added to and alloyed with the Elvaloy to impart its more desirable properties such as strength, abrasion resistance, and flame retardancy.

Elvaloy and PVC are completely miscible, becoming a single-phase polymer when mixed. They disperse within each other and, since both polymers are high in molecular weight, they will not migrate away from each other when properly alloyed. Their affinity for each other ensures membrane flexibility in severe environments that would otherwise accelerate the loss of liquid plasticizers in conventional PVC membranes.

Realizing EIP coating technology used Elvaloy instead of PVC as the backbone for the polymer matrix, the title for the standard was changed to better reflect the chemistry. The standard's title was subsequently changed to "Ethyl Vinyl Acetate Carbon Monoxide Terpolymer Sheet Roofing." (Subjecting the roofing industry to EVACMT as a reference acronym would have been cruel.)

In 1997, the standard's title was changed again as the subcommittee refined its understanding of the chemistry and technology associated with the manufacture and processing of Elvaloy. 'KEE' was eventually agreed on as the appropriate acronym to describe the polymer and chemical backbone of the compound. Hence, the proposed ASTM specification for a KEE sheet membrane was defined, but stood in contrast with the conventional definition and description for a PVC sheet membrane within ASTM D 4434-96:

3.3 Polymer Content: In this specification, polymer content shall be defined as polymeric materials which are in the solid state at room temperature, and are high (greater than 50,000) in molecular weight. Other ingredients, known to the art of polymer compounding, such as certain waxes, stabilizers, and other additives, while polymeric in nature are not considered to be part of the base polymer system.

4.1 The sheet shall be formulated from the appropriate polymers and other compounding ingredients. The KEE polymer shall be a minimum of 50% by weight of the polymer content of the sheet.

The proponents of KEE sheet membranes were about to shatter the 'thicker is better' ethos that evolved from ASTM D 4434. Since it takes consensus among committee members to move the process along, satisfying all the concerns raised took time.

A 12,820-m² (138,000-sf) adhered KEE roofing assembly on an airport.

State-of-the-art hot-melt calendar for manufacturing KEE membranes.

There were two KEE issues that stood in stark contrast to the ASTM D 4434 PVC standard. Although KEE membranes exceed the majority of the physical property requirements of D 4434, they were significantly thinner than the 1.14-mm (0.045-in.) minimum and exhibited a higher water absorption characteristic when evaluated under the 'high temperature' exposure requirements within the D 4434 test methods.

Apart from the technical discussions on how to statistically analyze and display the data assembled, thickness and water absorption were the most significant objections toward adoption of the standard within the subcommittee. The KEE proponents were asked to prove that thickness and water absorption as historically defined within ASTM D 4434 were not appropriate mandates for performance.

How thick is thick enough?

Depending on the internal fabrics or reinforcements, initial impact resistance may be improved with the additional mass when testing new membranes. However, roofing membranes anchored to low-molecular-weight liquid polymeric technologies are known to be prone to loss of flexibility due to plasticizer migration. This has been, and will continue to be, a factor affecting in-situ performance of PVC roofing systems.

Today, the thickness paradigm is rampant and crosses all polymeric materials. Is the push for thicker membranes really necessary? When consideration is given to the roofing industry's new obsessions with sustainability, the question is not just whether these thicker materials are relevant to performance, but also if they can be stewards of our limited natural resources.

By definition, a true KEE membrane does not have to be thick to exhibit very desirable membrane attributes or retard the loss of some migratory component. The material does not migrate, and a bonafide KEE membrane with a minimum thickness of 0.81 mm (0.03 in.) has demonstrated its ability to remain flexible and endure in harsh environments for more than 25 years. The membrane's strength attributes come from the fabric, not its thickness. If the fabric is properly engineered, then the coating's purpose is to protect the fabric's inherent attributes. Of course, the coating does have to endure the effects of time—and with roofing, time is brutal.

ASTM D 4434 prompted the adoption of a 1.14-mm (0.045-in.) standard within the industry, but the trend has been for many manufacturers to promote even thicker materials ranging from 1.27 to 2.29 mm (0.05 to 0.09 in.). Curiously, the increase in thickness rarely yields a corresponding increase in physical properties.

To a certain degree, some additional thickness is understandable in light of the ever-increasing expectations with regard to the tenure of commercial roofing warranties and their associated liabilities over the same period. To assume 'two times the thickness' equates to 'two times the design service life' may just be wishful thinking. The empirical data regarding the actual service life of these thick (and generally overweight) sheets is lacking.

As the roofing industry continues to grapple with sustainability, there needs to be brutally honest evaluations. The most recognized definition of a sustainable roof comes from the Proceedings of the Sustainable Low-Slope Roofing Workshop, held at Tennessee's Oak Ridge National Laboratory (ORNL) in October 1996:

A roofing system that is designed, constructed, maintained, rehabilitated, and demolished with an emphasis throughout its life cycle on using natural resources efficiently and preserving the global environment.

Are the overweight single-ply roofing membranes truly using natural resources efficiently? The epitome of sustainability is getting more with less. Durability is at the centre of this paradox.

Water absorption

Water absorption was the second comparative issue between ASTM D 6754 and D 4434. The much thinner KEE membranes had the proven ability to endure and sustain their performance within a broad spectrum of the hostile rooftop environments. However, when immersed in a high-temperature water bath, they exhibit absorption characteristics higher than conventional PVC membranes defined within the context of D 4434.

In addition to variable fabric densities within the membranes, different polymers exhibit different affinities to water. Properly compounded KEE membranes, as defined within the context of ASTM D 6754, may appear to have increased high-temperature water absorption characteristics, but they are proven to excel as waterproofing membranes.

ASTM D 4434 allows for membranes to experience a three per cent weight gain or loss after the water absorption test. ASTM D 6754-02, on the other hand, did not allow for any weight loss. Since water is not chemically reactive or degrading to either PVC or Elvaloy, the increase in water take-up for KEE roofing membranes, when evaluated at high temperature, does not translate into a detrimental performance factor.

There are a few additional tests and property limits recognized within the KEE standard that should not only characterize minimum values for KEE membranes, but should also be considered essential to the overall performance of all roofing membranes. Adhesion of the coating to the reinforcement and resistance to hydrostatic pressure, fungi, and abrasion may all contribute to the 'design service life' of a membrane roofing system, but are conspicuously absent in ASTM D 4434.

KEE membranes are also characterized with having excellent chemical resistance. The rooftop environment is one of contamination. In addition to direct exhaust exposure, areas of ponding water can accumulate all forms of fallout. Even seemingly benign contaminants like oils, greases, and fats can accelerate the aging process for PVC membranes by accelerating plasticizer loss. Properly formulated KEE membranes begin with flexibility, creating a permanent phased-polymer, and they are not prone to having this flexibility extracted.

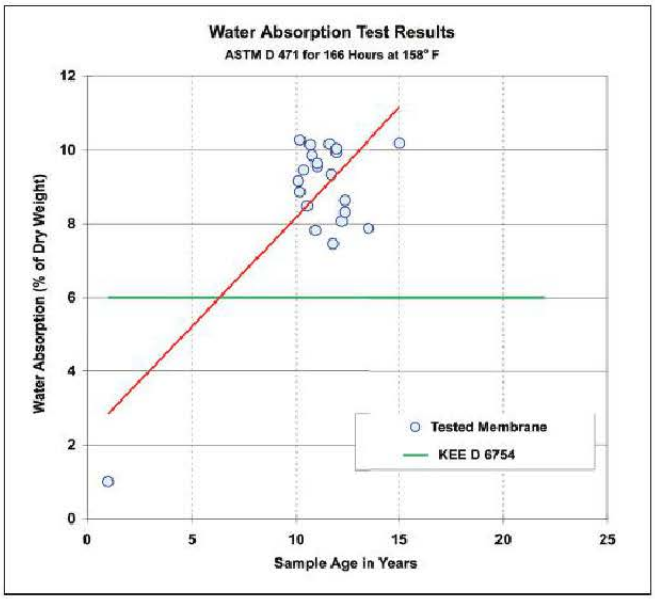
Durability discussions

All roofing systems have some hidden Achilles heel. KEE membranes can be vulnerable to low-molecular-weight liquid polymeric plasticizers. While formulations do not rely on liquid plasticizers for flexibility, some liquid plasticizers may be used during processing. High molecular weight KEE and PVC polymers have a natural affinity for lightweight plasticizers. Consequently, exposing KEE membranes to these low molecular weight polymerics can promote over-plasticization and softening of the membrane under warm exposure.

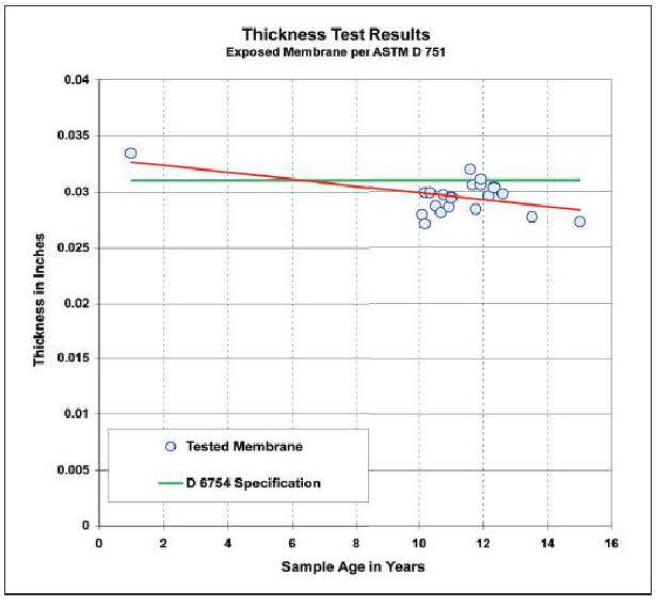
To address the committee's concerns once and for all, a 10-year history of performance for KEE membranes was assembled and presented to the subcommittee. The history included a certified sampling of roof systems over a decade old in Florida, Ohio, Colorado, Wisconsin, and Texas. This sampling was supported by a 1997 study and evaluation of KEE roofing systems by Exterior Research & Design LLC.

Samples of the membranes were presented to the committee, evaluated against the proposed KEE standard for new materials, and subsequently found to be in excellent condition. They all retained more than 90 per cent of their original physical property requirements, including thickness. Many of the 10-year-old samples were exposed to additional accelerated weathering tests including QUV (*i.e.* accelerated weathering) and heat aging.

The committee eventually concluded the results from immersing a 25.4 x 50.8-mm (1 x 2-in.) sample of membrane in a 70-C



ASTM D 471, Standard Test Method for Rubber Property–Effect of Liquids: *One-side water absorption testing of aged nominal 36-mil KEE roofing membranes.*



ASTM D 751, Standard Test Methods for Coated Fabrics: *Testing for the thickness of the exposed in aged nominal 36-mil KEE roofing membranes.*

(158-F) water bath for seven days (as described within ASTM D 4434), was not an acceptable test method for the characterization of a KEE membrane. One-side water absorption evaluation—similar to requirements for ethylene propylene diene monomer (EPDM)—was selected as a more appropriate test method.

Conclusion

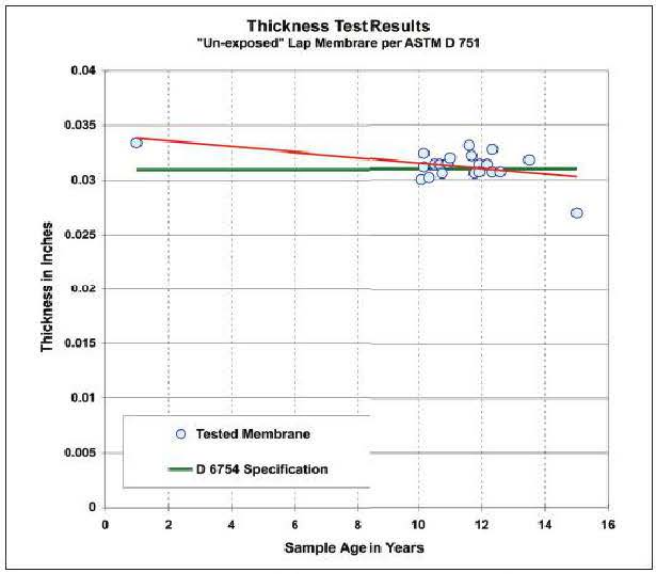
Properly compounded and engineered 0.81-mm (0.03-in.) KEE membranes have a proven performance record. Physical property paradigms that had generated the greatest concern—specifically, thickness and water absorption according to conventional evaluation of PVC membranes—were determined to be of no consequence and non-persuasive. Those challenging the standard had offered no evidence supporting their archaic way of thinking and the supporters of the standard had all the evidence to the contrary.

ASTM D 6754-02 specified a minimum thickness of 0.81 mm. When the first KEE roofing membrane was commercialized in 1979, the model building codes at the time required a minimum 0.8 mm for most forms of sheet roofing. This new standard clearly recognizes a properly formulated and engineered KEE membrane can perform or provide a design service life at 70 per cent of the 1.14-mm (0.045-in.) norm for PVC membranes produced according to the criteria in D 4434.

The permanence of the phased polymer structure, the coatings' adhesion to the base fabric, and superior resistance to UV, chemical, and micro-biological attack are all attributes that have contributed to the historical performance of KEE membranes, and what could arguably be the most sustainable roofing membrane available.

Notes

[1] The article, "A KEE Standard for Roofing Membranes," appeared in the September 2003 issue of *Interface*, a magazine published for RCI International (formerly the Roof Consultants Institute).



ASTM D 751L: Testing for thickness of the unexposed lap areas in aged nominal 36-mil KEE roofing membranes.

Jerry Beall has been in the roofing industry for almost four decades, stemming from a 10-year chapter as a journeyman with Roofers' Local #88, and then developing into work in technical service, commercial roofing sales, estimating, and project and technical management. As national sales and technical manager for FiberTite Roofing Systems by Seaman Corporation, he guides a nationwide team of sales, technical, and manufacturing representatives. Beall regularly makes presentations to audiences including members of the American Institute of Architects (AIA) and RCI International, along with roofing contractors and building owners. He can be contacted via e-mail at jbeall@seamancorp.com.