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How Do Roofs Wear Out?

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ABSTRACT

There are many different systems and components in a building envelope, each composed of physically and chemically diverse materials. Yet roofs, unlike even those components that have moving parts, seem to wear out more quickly than most other assemblies of the building. Water pipes, plumbing fixtures, air handling ducts, electrical wires, and exterior walls all have predicted and proven service lives considerably longer than a roof's.

Over the past 25 years, the author has conducted fundamental research designed to study the physical and chemical stresses placed on roofs and roofing materials. We have chemically analyzed bitumen, metal and single ply membranes, both when new and after years of weathering, and have elucidated proposed mechanisms for degradation for each type of roof. The mechanisms typically include infrared (heat) and ultraviolet radiation from the sunlight ("good" weather is actually "bad" for roofs), oxygen from the air, and precipitation. Freeze/thaw cycling and thermal stresses also have been shown to increase the rate of roof degradation. These mechanisms predict how a roof wears out, not when it will wear out or need maintenance or replacement.

Understanding how roofs work and how they wear out, both from a physical and a chemical perspective, can assist the consultant in determining whether a roof can be maintained or if it has truly reached the end of its service life. Furthermore, this information is valuable when estimating the remaining useful life of a roof and considering maintenance alternatives and schedules to extend the roof life, increase sustainability, and lower life cycle costs.

SPEAKER

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Bill is a Registered Roof Consultant (RRC) and was on the faculty of the Roofing Industry Educational Institute. He is active in ASTM D-08 and E-06 and currently chairs the Technical Committee and is on the board of directors of the Cool Roof Rating Council.

How Do Roofs Wear Out?

BACKGROUND

Analyzing roofing options and choosing a roof system are complicated. Because of this, a building owner/facility manager should retain a professional roof consultant to assist in this task. The owner will want to get the most value for the cost of this very expensive asset. Typical questions for the consultant are, "How long is the warranty?" and "What is my responsibility as the roof owner?" These often-asked questions are certainly important to the building owner, but are not as sophisticated or incisive as "How long will this roof be expected to last?" This question and "How will this roof wear out?" are clearly the most salient issues regarding roof longevity. This question should be of keen interest to the professional roofing community and is the focus of this paper.

This paper does not purport to offer explanations for catastrophic roof failures, but rather is restricted to the general weathering process of roofing materials.

"Everything is chemistry"

In a typical roofing bid process, a sample of the roofing material is included with the construction contract documents as part of a submittal package. This submittal package is usually filed away in a cabinet with the warranty and other pertinent documents relating to the job. If that roofing material sample were to be examined ten years after the roof was installed, and compared to the same material exposed on the roof, there would be a noticeable change in the appearance of the exposed roofing material. The exposed material would probably show dirt accumulation and, depending on the type of roofing material, granule loss, chalking, shrinkage, splitting, cracking, exudation, discoloration, delamination, bacterial growth, etc.

The quote, "Everything is Chemistry" is attributed to Dr. Ralph Paroli, director of the Building Envelope and Structure, with the Institute for Research in Construction, National Research Center, in Canada. If we consider all changes in construction materials – especially roofing – to be the result of chemical reactions, then this axiom is true. Dr. Paroli's sweeping generalization to roofing materials on exposure postulates that there is an underlying physical/chemical process of roofing material degradation.

Finally, if the degradation mechanism can be elucidated, this information can assist the roofing professional in developing maintenance protocols for increasing roof life and reducing life cycle costs of this asset.

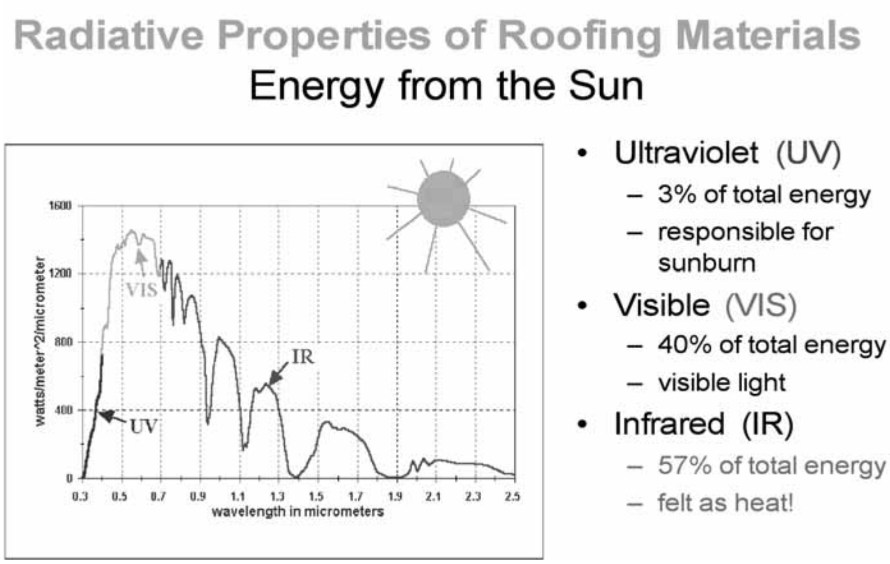


Figure 1

Roof degradation mechanisms (a/k/a "stuff" that makes roofs wear out faster!)

Consider again the comparison of the submittal sample to the sample of the same product after years of exposure on the actual roof. This illustration will highlight some key factors that contribute to roof degradation.

Sunlight

The first factor contributing to roof degradation is sunlight. The same energy that causes sunburn and skin cancer on our bodies can also have a tremendous effect on roof deterioration. Roof membranes protected with granules, foil, ballast, etc, see less effects from UV, while exposed membranes receive the full force of the radiation. It has been said that "good weather is bad for roofs," meaning that the effects of sunlight are detrimental to the roof's watertight integrity and long-term service life. Water coming into a building is merely a consequence of the roof deterioration process. Consider the chart (*Figure 1*) showing the solar spectrum.

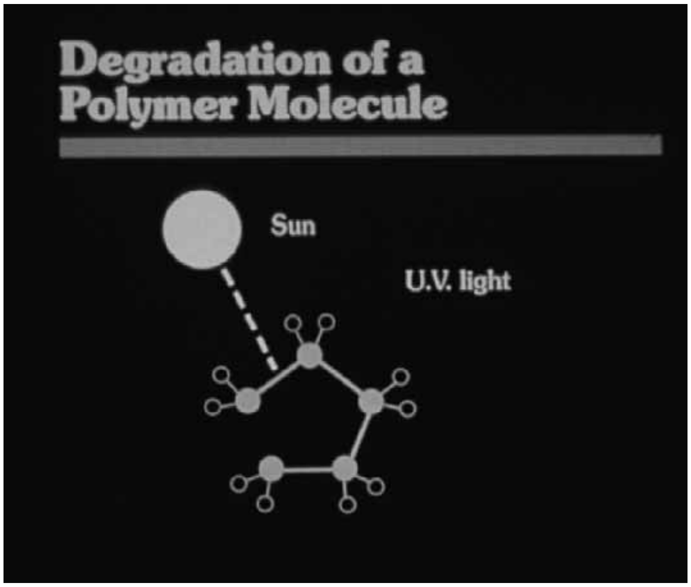


Figure 2

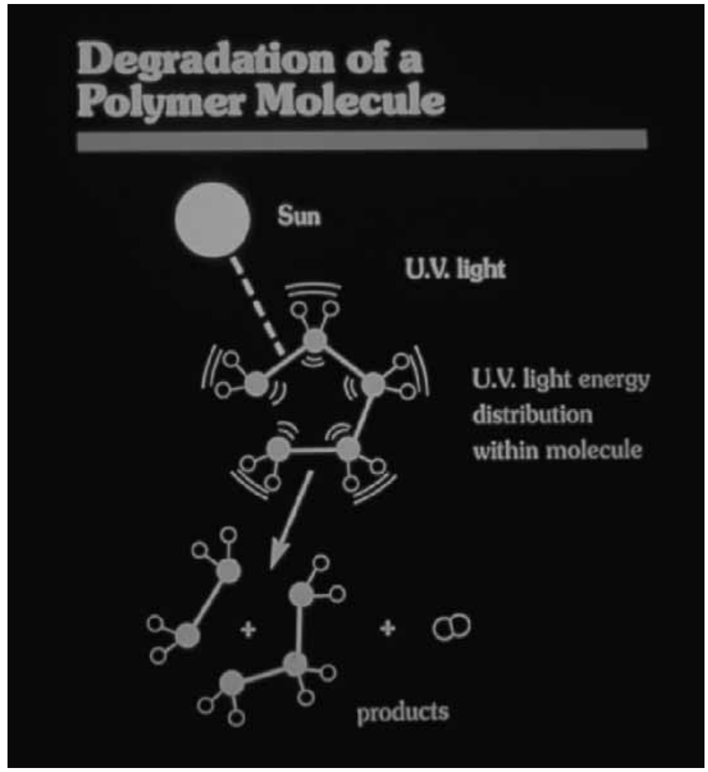


Figure 3

Interestingly, while only a small percentage of the sunlight's energy is in the ultraviolet (UV) portion of the solar spectrum, UV has a dramatic effect on roof deterioration, especially unprotected membranes. The reason for this is that as the wavelength gets shorter (lower number), its actual energy is greater. The UV portion of the solar spectrum is so intense that it can actually penetrate certain materials. So, even though a material appears opaque to visible light (and to our eye) it can actually allow UV radiation to go through it.

Fundamentally, UV deterioration is caused because UV energy strikes a material (the roof membrane). This energy is absorbed by the material and that material becomes "excited" on a molecular level. This excitation energy causes the molecule to destruct. Simply stated, if outside energy is added to a system or material, that energy must be dissipated or it will cause damage to the system. Consider a car moving swiftly on a bumpy road. The tires, springs, shock absorbers, and the entire suspension system, including the seat cushions, are designed to reduce that mechanical energy (the car bumping up and down on the road) and provide a smoother ride for the occupants. Without these energy-damping components, the car would be damaged severely, and the occupants would possibly be injured.

Some materials have "built-in shock absorbers," while others are easily damaged by UV energy. *Figures 2* and *3* show the effect. This chemical process is known as "chain scission" and is responsible for the degradation of the polymer molecule. The effect of chain scission will be discussed in more detail in later sections. Simply stated, the sun's energy cuts larger molecules into smaller ones. This process reduces the strength properties of the affected material, its pigment binding capability (the ability of the polymer to adhesively hold individual pigment particles), and its water resistance.

Heat

In addition to the adverse effects of the UV portion of sunlight, the infrared portion of the solar spectrum must also be considered. This is the "heat" portion of the solar spectrum. It is generally accepted that heat is a natural enemy of most engineered pieces of equipment. For example, the automobile has a radiator to keep the engine from being damaged by the heat of the continuous combustion taking place in each cylinder head. Many cars with automatic transmissions have transmission coolers to reduce the heat build-up and prolong the life of this part.

From a more fundamental standpoint, all chemical reactions are accelerated by adding heat to the process. Depending on the specific type of chemical reaction and its kinetics (i.e., the rate of the process), heat can have a massive impact on the speed with which the reaction takes place.

If we recognize that roofing material degradation is, at least in part, a chemical reaction, then we can conclude that heat is a contributor and accelerator in the deterioration of a roof.

The surface temperature of a low-slope, black-colored roof in the summertime can easily exceed 180°F. If the roof is heavily insulated, there is nowhere for the heat to be transferred by conductivity into the roofing envelope. Thus, all the heat energy remains trapped in the roof membrane. This allows chemical processes such as solvent evaporation and plasticizer transport to occur more quickly.

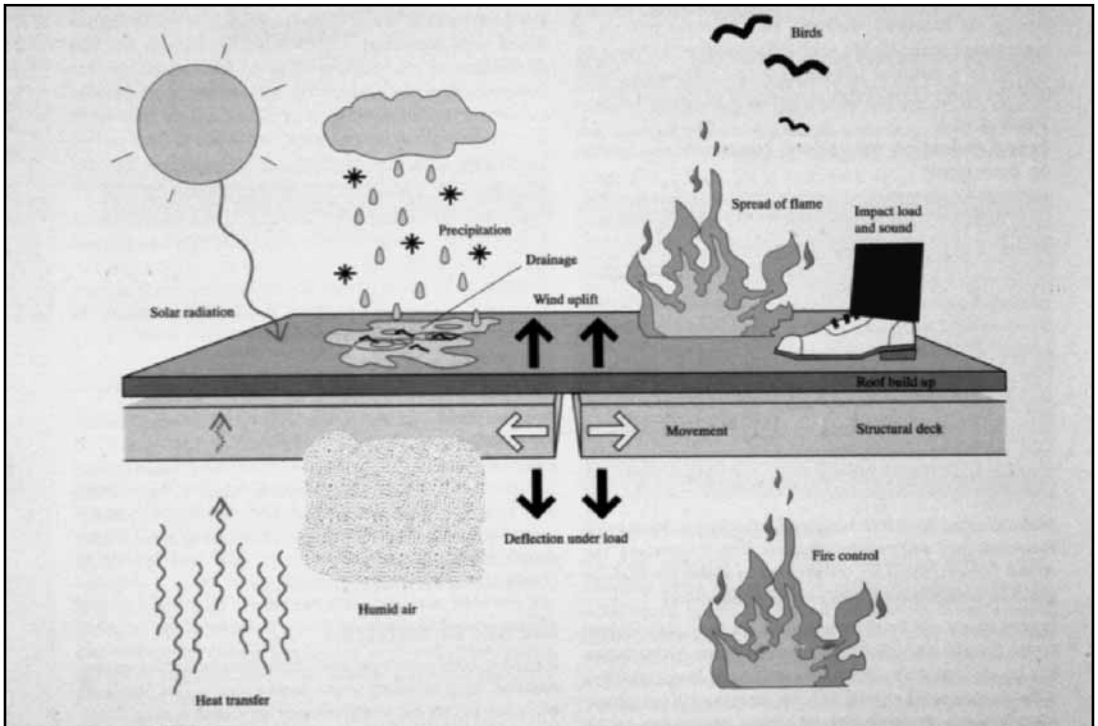


Figure 4.13.1
Performance of the roof

Figure 4

Thermal shock

The roof temperature of the same low-slope, black-colored roof in the summer time, when there is a mid afternoon thundershower approaching, may exceed 180°F just prior to the cloud burst. But the cooling effect of the rain will reduce the membrane temperature by as much as 100°F in 15 minutes or less. This phenomenon, known as "thermal shock," causes the membrane to contract. Remember some simple physics. As solid materials are heated, they expand. As they cool, they contract. This rapid change in size of a rigid object (the roof) stresses the membrane and shortens its life. This process happens sometimes daily throughout the service life of a roof.

Freeze thaw cycling

Anyone who has experienced a water leak caused by water freezing in a pipe understands quite well the fact that when water solidifies and forms ice, it expands very slightly. This expansion has sufficient force to cause a pipe to rupture. This same force has a similar impact on roofing materials, causing microscopic splits, cracks, and fissures. Water fills these microscopic voids and channels. As it freezes, it contracts, then just prior to solidifying, it expands and causes the cracks to enlarge. This process happens repeatedly and contributes to the propagation and growth of surface cracks. In the most severe cases, this process also creates stress on the reinforcement used to make the roofing material. This scrim may be fiberglass, polyester, a combination of both, or organic felt. These cyclic stresses can weaken the reinforcement and ultimately adversely affect roof life.

Other cyclic stresses

It is quite common for mechanically-fastened, single-ply roofs to "flutter" in the wind. The unseen wind uplift forces are trying (hopefully unsuccessfully) to suck the membrane off the roof. The repeated bending and flexing of the membrane causes weakening in the membrane reinforcement and contributes to shortening its useful service life.

When inspecting an asphalt or modified bitumen roof, a roof observer may sometimes see the roof begin to develop wrinkles as the roof heats up during the day. The wrinkles then disappear as the membrane cools during the night. Again, over years of exposure, this effect weakens the reinforcement and shortens the roof's useful service life. This same phenomenon an also be observed as isocyanurate insulation board "cups" and curls when subjected to heat. This flexing causes a similar deformation on the roofing membrane, causing stress and deterioration of the reinforcement.

Another somewhat cyclic stress is the live load stress on the roofing membrane that results from intermittent water, ice, and snow buildup on the roof. These

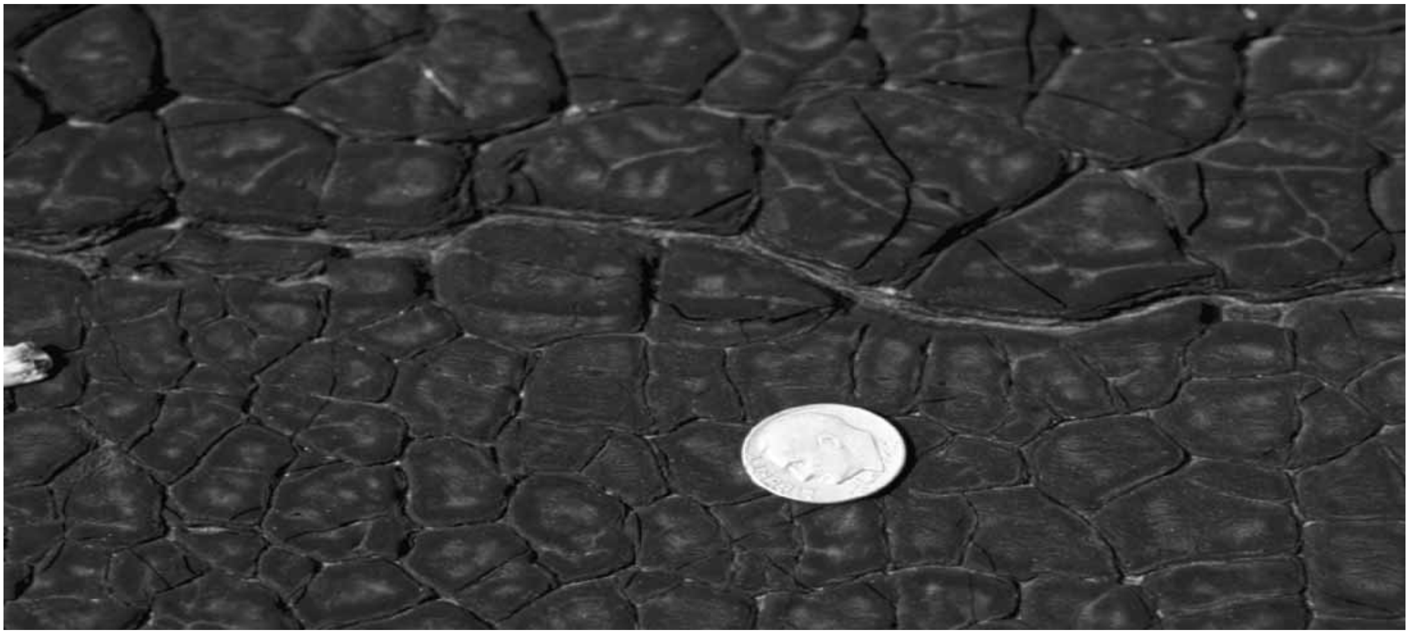


Photo 5: Alligator cracking of aged flood coat of built-up roof.

Photo 6: Loss of light fractions of APP modified bitumen roof.

loads cause deflection of the roofing membrane and, as with the examples above, cause deterioration of the reinforcement or mat.

SUMMARY

Shown pictorially in *Figure 4* are the effects of roof degradation mechanisms that cause roofs to wear out.[1] This graphic also shows the predominant design considerations that must be considered for any low-slope roof.

SPECIFIC ROOFING MATERIAL DEGRADATION MECHANISMS

The following describes the mechanisms of degradation as they affect the main types of roofing membranes. These mechanisms do not pertain to catastrophic deterioration due to wind events, hail, or seismic effects, but rather the natural processes of weathering and deterioration.

Asphaltic roofing materials

Asphaltic and modified bitumen roofing membranes comprise the largest segment of the low-slope roofing market. The asphalt used for roofing is usually blended with reinforcing agents such as calcium carbonate to increase strength and decrease flow. If the material is modified bitumen, the asphalt is blended with a polymeric modifier such as atactic polypropylene (APP) to create APP-modified bitumen or styrene-butadiene-styrene (SBS) block copolymers to create SBS-modified bitumen. Two variants are SEBS (styrene-ethylene-butadiene-styrene) and SIBS (styrene-isobutylene-styrene) block copolymers.

Asphalt is a by-product of the crude oil refining process. After the “lighter fractions” are distilled off, the remaining crude oil, called flux, is the basic building block for asphalt and modified bitumen. While asphalt has excellent waterproofing properties, it is extremely susceptible to attack by UV radiation. The deterioration that is observed as cracking and chalking is a direct result of this attack. The underlying mechanism is twofold. Depending on the source of information, chemical analyses of asphalt have shown it to be composed of hundreds of different chemical components. Some of these components are liquids at room temperature, but when dispersed in the asphalt matrix, They appear to be solids. Over time and with the addition of heat, these light fractions leach out. This has two effects. First, the loss of this material slightly reduces the size of the roofing material (i.e., volume reduction). This loss of dimension, or shrinkage, may cause stress on the seams and fasteners, reducing the service life of the roof. Moreover, these light fractions also act as plasticizers, making the membrane more flexible, especially at low service temperatures. These materials can be thought of in the same way as plasticizers used for improving the flexibility of PVC thermoplastic single ply roofing membranes.

As asphalt shingles weather and degrade, they begin to curl and become embrittled. This condition is exacerbated by the use of certain types of reinforcements. This is a direct result of the loss of these components. Moreover, some of the stone granules that protect the shingle or bitumen cap sheet can collect in the gutters and low spots on the roof as a result of the loss of these asphalt fractions that act as “glue” to adhere the granules. As the granules become dislodged, more asphalt is exposed to the harmful effects of the sun's UV and IR (heat) radiation. This, in turn contributes to a more rapid degradation of the asphalt membrane.[2]

Asphalt is generically characterized by “Type,” increasing from Type I through Type IV. Different geographies and contractor preferences dictate that the most widely used are Type I and Type III. The difference is these asphalt material is the degree of “blowing” or oxidation that takes place as the asphalt flux is processed. The longer the processing time, the higher the (number) asphalt type that is created. However, this blowing also increases the softening point and makes the asphalt harder. On exposure, as asphalt is continually heated by the IR portion of the sunlight, this same chemical reaction continues. Because these temperatures are much lower than those in the “blowing” process, the reaction happens more slowly. Nevertheless, it still occurs. This makes the asphalt more brittle. Consider walking on an aged asphalt shingle roof versus a new one.

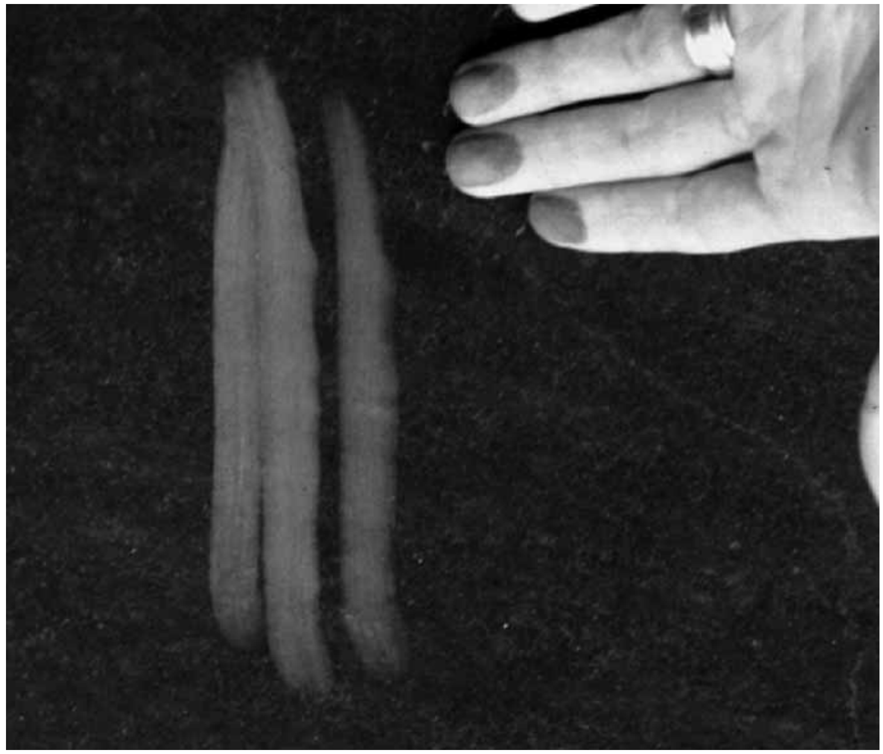


Photo 7: Degradation of APP modified bitumen roof.

An additional weathering related reaction is that of oxygen in the air with some of the components of the asphalt. This chemical reaction causes the asphalt to become less hydrophobic, as hydroxyl radicals are created on the component chains. This reaction can be observed by wetting aged asphalt with water and checking for a soapy feel.

Photos 5, 6, and *7* show the physical evidence of the exposed asphalt roof deterioration.

Reinforcement

Asphalt and modified bitumen roofs work because asphalt is an excellent waterproofing material. However, to function successfully as a roof system, the asphalt must be held stationary and not permitted to “flow” when it experiences summertime temperatures on a roof. The asphalt roof composite must tolerate the physical and mechanical stresses induced by movement of the building and roof deck.

The reinforcement provides for this resistance to movement in BUR and modified bitumen systems. As a part of the aging, weathering process, the reinforcement begins to degrade and its

Photo 8: Degraded base flashing.

tensile strength diminishes over time. The reinforcement, which can be organic, polyester, fiberglass, or a combination of two different materials, begins to degrade and its tensile strength diminishes over time. This loss of strength is observed as cracking and splitting of the felts. This can be seen in *Figure 8* in the significant deterioration of the asphalt base flashing.

Photo 9 shows a microscopic cross section of a granule-surfaced bitumen roof membrane after years of exposure. Notice how the asphalt has eroded away and the granules are now more exposed. As this erosion continues, the granules begin to dislodge from the membrane, exposing more asphalt to the harmful effects of UV and IR from the sun. This accelerates the rate of roofing membrane deterioration.

Thermoplastic single plies

Thermoplastic single ply membranes typically include PVC, PIB, CPE, and TPO. These materials range in thickness from 0.045" to 0.090" and are most often reinforced with a woven scrim. The scrim is sandwiched between two layers of thermoplastic film, and is designed to provide the necessary tensile strength for the membrane. The basic composition of the membrane includes the polymer, such as one of the chemical acronyms listed above, plus pigments to provide opacity, pigment extenders, fire retardant additives, plasticizers to improve flexibility, catalysts to provide secondary crosslinking, processing aids to increase membrane manufacturing efficiency, and other "salt and pepper" ingredients.

Unlike the basic components of asphalt, thermoplastic roofing membranes are composed of one basic polymer. These polymers are unique in that they have molecular weights in the millions, versus molecular weights in the hundreds for pure asphaltic materials. Think of these polymers as bundles of very long strands of spaghetti, while the asphaltic components are merely short strands of chopped pasta. Intertwined with these strands are the pigments, plasticizers, and other additives described above. The bundling of these individual molecules provides some tensile strength to the "plastic" film, which is significantly reinforced by the woven scrim.

As the membrane is exposed to sunlight, the solar radiation begins to break down the polymer chains. This phenomenon, known as chain scission (and described earlier) is responsible for chalking, loss of pigment adhesion to the polymer (glue) in the membrane, loss of watertight integrity, and general breakdown of the membrane. These chemical reactions can actually be initiated and catalyzed by additives in the membrane itself. When a membrane exhibits excessive wear and

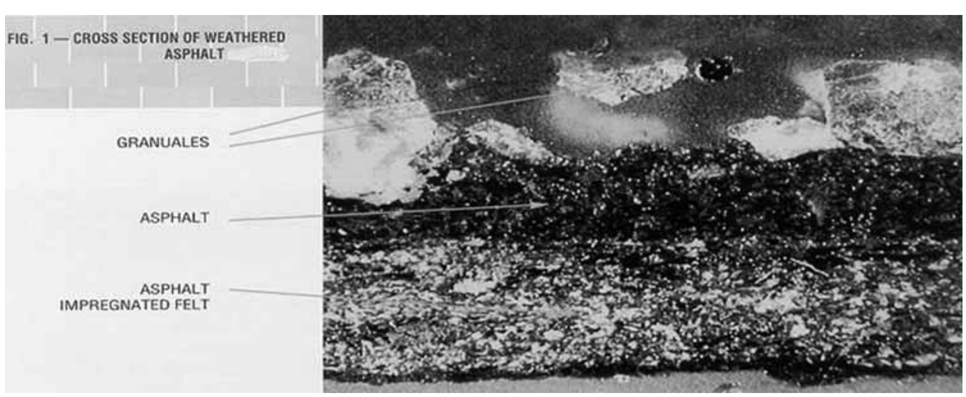


Figure 9: Cross-section of asphalt cap sheet.

Figure 10: Surface deterioration of a thermoplastic single ply.

deterioration early in its life, it usually means that there is a destructive chemical reaction taking place internally that is destroying the membrane.

The most widely used thermoplastic single ply in roofing is PVC. However the base polymer, while having excellent waterproofing and fire retardancy properties, is very brittle, especially at low service temperatures. This brittleness (due primarily to plasticizer migration), was responsible for shattering of some PVC roofing, particularly unreinforced, in the early years of this product's market life. However, the addition of plasticizers that are slow to migrate out of the membrane has dramatically improved the low temperature properties and especially the low temperature service life of this type of membrane. Plasticizers used today have a much higher molecular weight, are less mobile, and do not move through the membrane as easily as their lower molecular weight predecessors. Plasticizer content can exceed 30% of the total membrane composition, and on weathering this level slowly drops. Slip sheets are placed under the PVC membrane in a roofing assembly to retard the migration of the plasticizer into the roofing assembly. The level of plasticizer is high in order to create a reservoir of additional plasticizer to ensure that the membrane remains flexible during its service life. However, as the plasticizer migrates out, the membrane's flexibility is reduced. In addition, since there is loss of material in the membrane, it begins to shrink, putting stresses on the seams and fasteners.

Studies conducted on other thermoplastic single ply membranes[3] have shown the polymer to degrade via chain scission. This causes chalking, as the polymer, which acts as a glue to hold the pigments in place, loses its ability to hold the pigment. The photomicrograph below shows the surface erosion and deterioration of a single-ply membrane.

Thermoset single plies

EPDM is the single most notable example of this class of roofing materials. The EPDM formula consists of the EPDM polymer, carbon black pigment, catalysts such as stearic acid and zinc oxide, vulcanizing agents such as peroxides and sulfur containing additives, and paraffinic and naphthenic and other oils and fire retardants.[4]

A weakness of EPDM and mechanism for some EPDM deterioration has been the improper selection of the oils used as extenders and plasticizers in the membrane. If these oils are too low in molecular weight, they can mi-

Photo 11: Stress on accessory due to membrane shrinkage.

Photo 12: Stress on accessory due to membrane shrinkage.

Photo 13: Stress on termination due to membrane shrinkage.

grate out of the membrane in the same fashion as some plasticizers in PVC single ply roofing. Just like PVC plasticizer migration, the effect is membrane shrinkage, which puts stresses on field seams, fasteners, and termination bars. This problem is exacerbated if the roof is ballasted with river rock, as the rock, because it is in direct contact with the membrane, can absorb the oils as they migrate from the membrane.

Photos 11 through *14* show shrinkage and stress on accessories and terminations caused by oils leaching out of the membrane. Notice how the rubber boots are stretched in one direction, toward the center of the roof. This stress also creates tension on the field seams, causing premature failure and tearing away from the termination bar.

Metal

Metal roofing is typically divided into two types: ferrous (steel) and non-ferrous (aluminum, galvalume, galvanized steel). Most metal roofs (with the exception of stainless steel) are prepainted to provide corrosion protection.

As a coated metal roof weathers, the coating slowly deteriorates, succumbing to the harmful effects of dust abrasion, as well as the some of the other factors previously described. As long as the coating is in place to protect the metal roof from corrosion and the metal does not rust through, the roof will provide watertight integrity.

The concept of ferrous metal corrosion is well understood. It is a galvanic process, meaning that a very weak electrical charge is involved. The material is converted from metal to a metal oxide. *Photo 15* shows coating peeling and rusting of the ferrous metal. This process can be greatly accelerated when the roof is in a salty environment, such as near the coast. This process can be accelerated if the roof houses a chemical plant or is down wind of effluent that is corrosive.

Steel, the most commonly used metal for roofing, corrodes into a red iron oxide. This oxide is not well adhered to the underlying metal, and coatings applied to this loose scale will easily delaminate. Thus, the ferrous metal (steel) must be brushed with a wire brush or wire wheel, sand blasted or cleaned thoroughly to remove the oxide scale. Moreover, without special flash rust inhibitors, water-borne primers will actually create an immediate rust scale.

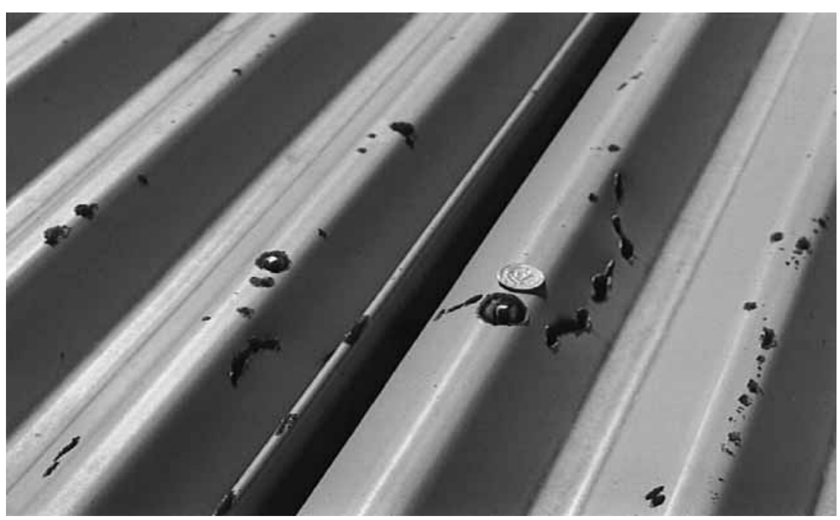
Certain metals such as aluminum, galvanized steel, and galvalume corrode in a unique fashion such that the metal forms an oxide scale that actually protects or "passivates" the remaining metal below the surface. The aluminum oxide or zinc oxide scale, because of its roughness and passivation, also creates an excellent substrate for application of a protective roof coating.

Photo 14: Tear at termination due to membrane shrinkage.

SPF

Sprayed polyurethane foam (SPF) roofs are unique in that the foam, while providing the waterproofing, can also provide additional insulation. The basic chemistry of SPF is an aromatic urethane. This type material, while having excellent low permeance and suitability for in-situ installation, has very poor durability. This should not be confused with aliphatic urethane, which has excellent durability, but at a significantly higher cost. The aromatic urethane must be coated or covered with a UV-resistant barrier. Otherwise, the foam will degrade immediately upon exposure to sunlight. This is manifested as a brown/orange discoloration of the foam surface. As degradation continues, the foam begins to chalk. As the chalking continues, the foam cell walls break and water can enter the open cell cavities. Then, as the roof experiences freeze/thaw cycling, the constant expansion and contraction (described earlier) causes rupture of the neighboring cell walls. This allows the foam to absorb water, thus further diminishing its thermal resistance properties.

Photo 17 shows what happens when a protective coating applied to an SPF roof has eroded away. The aromatic polyurethane foam is exposed to the destructive effects of UV. The cavities created allow for water to wet the foam cell structure and freeze/thaw cycling begins. This further destroys the integrity of the foam cells and accelerates the destruction of the roof. It is worth noting that this degradation could have been prevented if the coating had remained intact. When the foam began to show through the coating, the roof should have been recoated. Recoating would have prevented the costly repairs now required for this roof.



Figures 15 and 16: Galvanic corrosion on metal roofs.

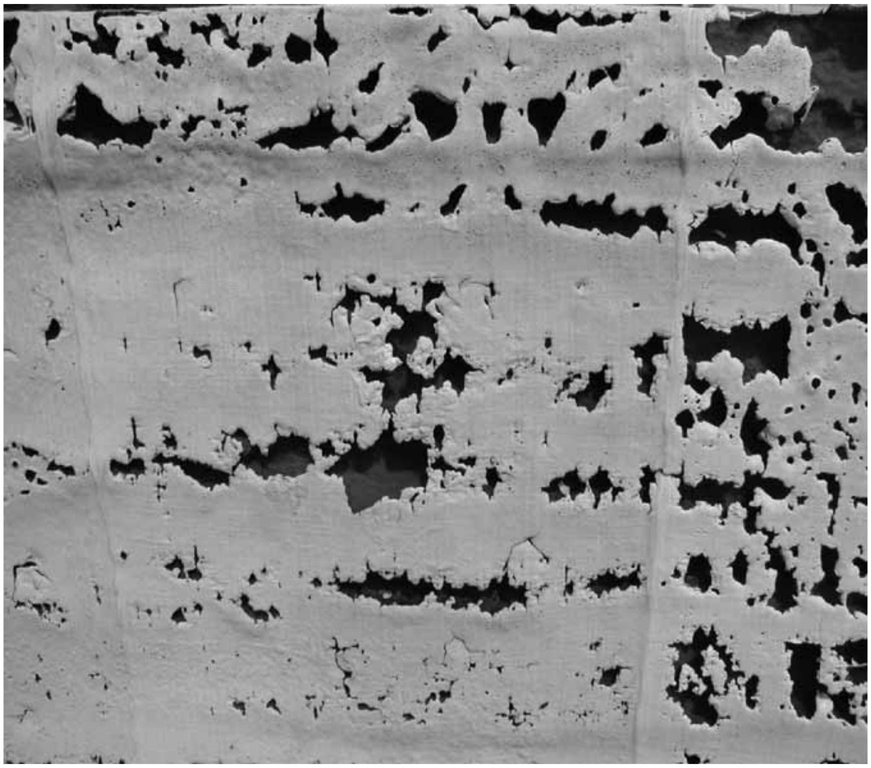


Figure 17: Degraded SPF resulting from coating loss

The "ideal" roofing material

What would the ideal roofing material look like? What would be its composition? What would its attributes be?

Based on the foregoing discussion, the ideal roofing material (from a chemistry standpoint) would first have excellent water resistance. It would resist deterioration from UV and the sun's IR heat radiation. Moreover, it would not contain (or at least minimize the amount of) light fractions, plasticizers, flexibility enhancers, and other low molecular weight components that could leach out, causing embrittlement and shrinkage. The material would not be sensitive to corrosive attack or be adversely affected by atmospheric pollutants.

Can these roofs be maintained?

The issues of roof longevity, lowering life cycle costs, and sustainability all revolve around the simple question of roof maintenance. Consider the analogy of repainting an older car. It may have some dents and need body work. It may also have some rust and pinholes as a result of exposure to a harmful environment and severe winters. However, with proper preparation, the car can be restored to its original "like new" appearance.

As stated previously, the external factors that cause roof deterioration and degradation include sunlight (UV and IR), water, and oxygen. If these factors can be eliminated or mitigated, then the roof can be maintained.

When the concept of roof maintenance is considered, the idea of coatings quickly comes to mind. Some maintenance coatings and especially acrylic maintenance coatings have been designed to block the UV radiation that causes membrane degradation. Moreover, if the coating is white in color, the IR (heat portion of the sun) will also be reflected, leaving the membrane cooler.

Can all roofs be maintained with coatings?[5]

This rather difficult question can be easily answered by posing the following scenario. If the degradation that has occurred on the exposed membrane can be halted or significantly retarded, then the roof can be maintained. If the degradation mechanism involves the erosion of the membrane surface, and a coating can replace that lost millage, then the roof may be suitable for maintenance and life extension with a coating.

A caveat to this is if the weathering deterioration of the reinforcing scrim has caused a greater than 50% tensile strength compromise of its original strength, then coating alone will not be sufficient to accommodate the dimensional stresses encountered during the service life of the coating.[6] However, if the coating is reinforced with embedded polyester or fiberglass scrim, then the roof can be maintained with coating/reinforcing scrim system. It is important to note that the coating must now provide significant waterproofing properties.

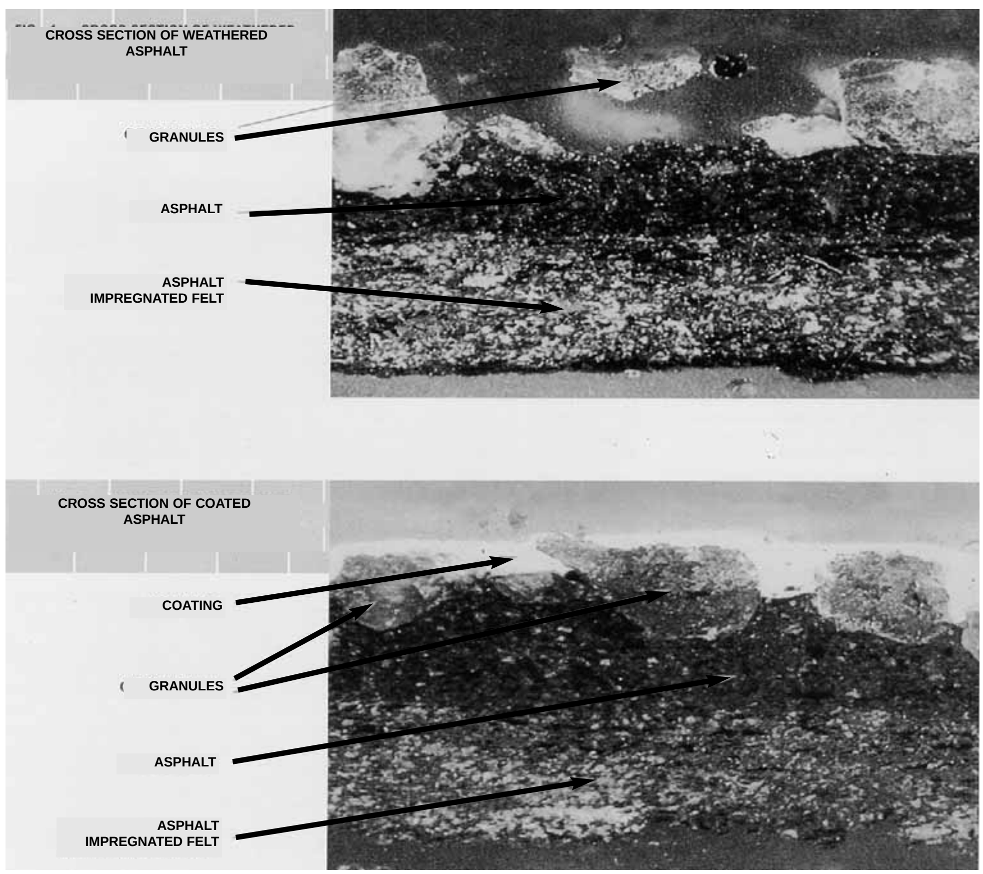
Acrylic roof coatings have been promoted for maintaining low-slope roofing systems since the late 1970s. The early coatings were merely diluted acrylic latex caulks, supplied in brushable or sprayable viscosities. While the need for elastomeric properties was fully understood, little was known about the specific adhesion properties needed. However, over the past 20 years, advancements in understanding how different types of roofs deteriorate and the performance and adhesion requirements for each type, have led to the creation of an entire family of acrylic maintenance coatings specifically designed to prevent further deterioration of the roofing membrane. These coatings contain pigments that have excellent UV resistance, capable of blocking the UV from penetrating to the roofing substrate. The acrylic polymers themselves are transparent to UV radiation and will not be degraded by the sun's radiation. The polymers will not suffer chain scission, embrittlement, and other maladies associated with some polymers used in the original membrane. (Think of this combination of UV transparent acrylic polymer and UV blocking pigment as a form of “sunscreen” for a roof.) If the coating is white in color, it will also reflect over 80% of the sun's IR (heat) radiation. This will cool the membrane and reduce the deteriorating effects of heat on the membrane.

Figure 18: Asphalt shingle showing coated and uncoated sections.

Typical maintenance coating film thicknesses range from 20 to 40 dry mils (0.020-0.040"). This thickness is sufficient to provide an appreciable increase in the millage of an existing membrane that has suffered surface erosion and deterioration during its years of service life. The coated membrane could now have millage equal to or greater than that of the original membrane.

Consider the asphalt shingle roof shown in *Figure 18*. This coating exposure was initiated in 1986 after the uncoated, 3-tab shingle roof had been exposed for about 10 years. The majority of the roof was coated with an acrylic elastomeric roof coating at 3 gallons per square. The small portion was left unexposed. After 10 years, this photo was taken. The exposed portion of the roof shows significant shingle deterioration, granule erosion, curling, embrittlement, and loss of integrity. By contrast, the coated section shows almost no deterioration.

Note the difference in the cross sections of the granule-surfaced cap sheet in *Figures 19* and *20*. *Figure 19* is a photomicrograph of an uncoated cap sheet, while *Figure 20* is a cap sheet that has been coated with a protective acrylic roof coating. The acrylic coating works to protect the granules and exposed asphalt from deterioration. Moreover, the coating “glues” the granules in place, providing additional protection against granule displacement. The millage of the acrylic coating fills in voids and cracks created as a result of the natural weathering process. This prevents water from filling these voids and prevents cracks from propagating in the asphalt membrane as a result of freeze/thaw cycling.



Figures 19 and 20: Cross section of cap sheet showing the effect of maintenance coating.

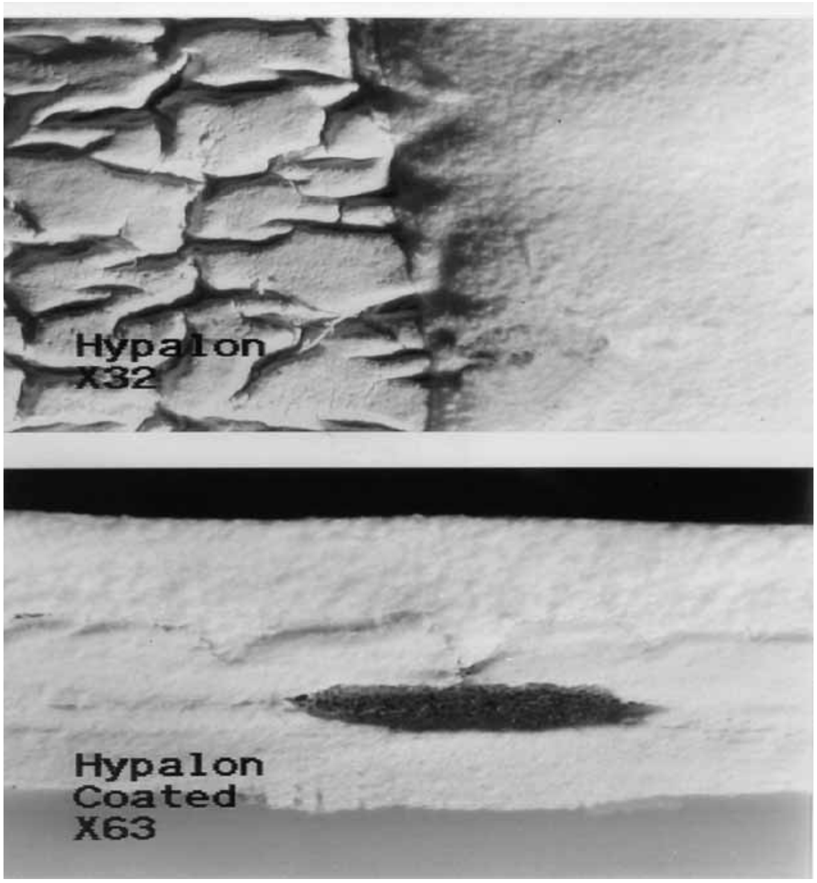


Figure 21: Cross section of thermoplastic membrane showing the effect of maintenance coating.

Note in the photos in *Figure 21* how a thermoplastic single ply roof, shown previously, can benefit from the protection afforded by an acrylic maintenance coating. The voids and interstices are filled with the coating. Moreover, there is now a protective barrier over the membrane created by the acrylic coating that prevents further UV degradation. This barrier also reduces migration of plasticizers out of the membrane, further prolonging its life.

Similarly, a thermoset membrane can benefit from this same protection. The photomicrograph in *Figure 22* shows an EPDM protected by an acrylic coating. Note that the membrane is now white, thereby reducing the heat load on the building.

Conclusions:

Roof deterioration, while complex, can be simplified into key causal factors, including UV and IR from the sun, water, freeze/thaw cycling, and oxidation. While the specifics of the mechanisms differ depending on the type of roofing material, if the membrane can be protected from exposure to these factors, then the roof service life can be greatly enhanced.

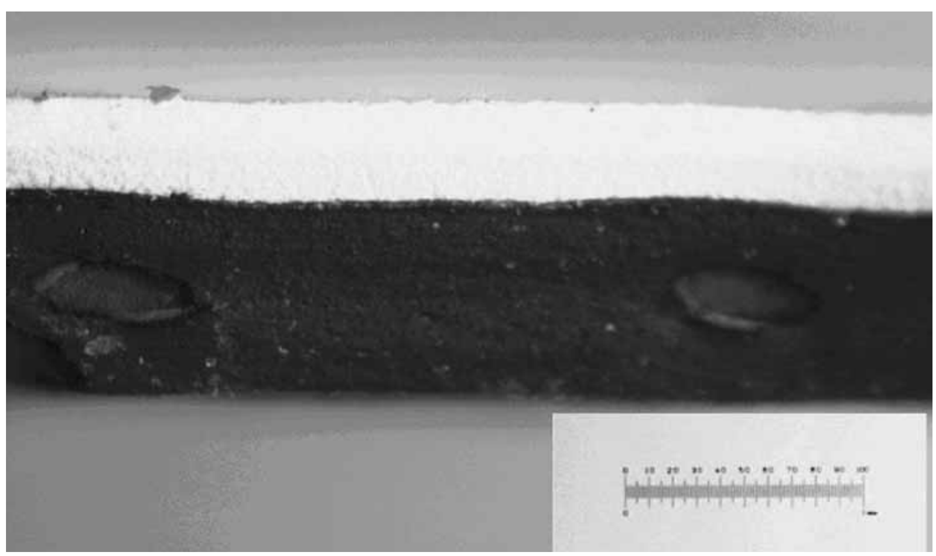


Figure 22: Acrylic maintenance coating applied over thermoset single-ply membrane.

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