Where Has All the Asphalt Gone?

Colin Murphy, RRC, FRCI, LEED AP BD+C, PRA;

AND

Darbi Krumpos, CDT, BECxP, CxA+BE

TRINITY/ERD

80 Yesler Way, Seattle, WA 98104

Phone: 206-467-0054

E-mail: colinmurphy@trinityerd.com and darbikrumpos@trinityerd.com
Abstract

Since the 1860s, asphalt and coal tar have been key elements in multi-ply, low-slope roof assemblies. Over the years, asphalt has been refined and graded to better suit applications in various regions and roof slopes. It has been modified with polymers, waxes, and additives. Asphalt has also been modified for use solely as an adhesive to apply both built-up and single-ply systems.

Beginning in the 1970s, concerns were voiced over the use of asphalt (primarily due to health and safety—specifically odor and fire/burn issues), resulting in product evaluation by industry, government, and unions. This scrutiny ran parallel with the rise of the single-ply industry, which rarely used asphalt in assemblies.

The rise in the market share of thermoplastic polyolefin (TPO), and the marketing of TPO by major built-up manufacturers, further depressed the use of asphalt. The development and promotion of low-rise polyurethane foams used as a substitute for asphalt products also impacted the use of asphalt.

While the asphalt industry made strides in kettle technology, the methods of delivery and application have remained relatively constant and cost effective, and yet its use remains in decline.

Does asphalt have a role in the industry today, or has it been overtaken by technology, making it no longer relevant, similar to the evolution of reinforcement from cellulose to asbestos to fiberglass?

This presentation will trace the history of the product in the industry, review the enhancements and changes that are relevant today, and look at the strides made by the asphalt industry to maintain a role in the application side of the industry.

Speakers

Colin Murphy, RRC, FRCI, LEED AP BD+C, PRA — Trinity | ERD, Seattle, WA

Colin Murphy is the principal of Trinity | ERD, which he founded in 1986. His education is in law (Scotland) and mechanical engineering. He is an author, educator, and inventor. Murphy has authored and presented many papers on roofing and building envelope subjects throughout the U.S. and Canada. He has received awards for outstanding publications and service to industry organizations. He holds 15 U.S., and European patents for roofing and building envelope components and systems. Murphy’s work within the firm includes forensic analysis of building envelopes, design of building envelope systems, and the testing of building envelope components and systems.

Darbi Krumpos, CDT, BECxP, CxA+BE — Trinity | ERD, Seattle, WA

Darbi Krumpos has over 20 years of experience at Trinity | ERD. She has worked with product manufacturers regarding code compliance and warranty support, coordinated projects worldwide, worked directly with condominium associations and owners through litigation and remediation, investigated and researched construction deficiencies and litigation, written specifications, and performed contract administration for new construction and remediation for both commercial and residential projects. She also has experience in building envelope commissioning, field testing and quality assurance, and quality control program management.
Ever since the days of Samuel Barrett and Michael Ehret—the recognized early pioneers of built-up roofing—asphalt and coal tar pitch have been used as both adhesives and waterproofing agents. The derivatives of heated coal and crude oil were applied in combination with “felts” or textiles to form a multi-ply built-up assembly that bonded to the roof deck with the same hot material.

Roof decks of the day were typically thick wood plank or concrete supported by wood or iron superstructures. The advent of built-up roofs allowed for the reduction of roof slope and an overall reduction in the cost of construction. As an example, a larger manufacturing facility may have been planned with a sawtooth design, creating a vertical plane into which windows were placed; and a steep-slope section, creating a suitable substrate for the application of a discontinuous roof assembly such as slate, tile, or the newly developed composition shingle (Figures 1A-1C).

The built-up assembly allowed for a reduction of the roof area that required covering and created a homogeneous membrane layer that could minimize the roof slope to near dead flat. Most roof decks during this period were not flat or low slope as we know them today. Pitches of three to four in twelve were common. Many of the early built-up assemblies maintained some slope to shed water off the roof plane quickly and to ease building owners into a radical change in construction. See Figure 2.

A combination of factors fed the explosion of built-up roofing in the latter 19th century; these included:

- Expansion west in the United States
- The growing industrial revolution
- The discovery of oil in Pennsylvania
- The expansion of iron and steel use in building construction
- The large production of coal tar as a byproduct from the manufacture of coal gas used to light newly developed urban areas

Felts or textiles were derived from many available materials that would absorb the hot waterproofing agent and were consistent enough to be applied in multiple layers. Felts were typically recycled cotton that came from old clothing, bed linens, towels, and other household textiles. Organic felts were first introduced in the U.S. in 1844 and were primarily composed of a mixture of wood, mixed paper, corrugated paper, and rags.

Figure 1A-1C – The advent of built-up roofs and new designs.

Figure 2 – Built-up roof in Chicago, circa 1930.
Roofing felt, as a standardized industry product, had its beginnings in Finland in the 1870s. By the turn of the century, asphalt-saturated felts were in production for both coal tar and asphalt roof assemblies.

In summary, the origin of built-up roofing included recycled rags, a byproduct from coal gas that could not be given away in most cities, and the residue of the petroleum distillation process that created a sludge byproduct. From this odd alliance of “leftovers,” the built-up roofing industry was born. See Figure 3.

From these creative yet humble beginnings, the demand for the product expanded, rapidly changing the dynamic of the supply chain. Coal tar pitch found other uses in the pharmaceutical, dye, and photography businesses, providing a monetary value to what was once an unwanted waste product. Uses for this readily available and inexpensive material grew due to its low price and supply availability. Once there was a market value for the material, and the cost increased, alternate materials were sought as a viable replacement.

Asphalt had limited applications in early days; however, it became an economic and technically viable alternative to coal tar. The early development of the road business, a segment of the market that did not escape Barrett, expanded the demand and made the product more accessible in both the Midwest and on the Eastern Seaboard.

Product refinement was also under way. Felts, which had little consistency in early days, became a mass-produced product developed initially in Finland. By the turn of the century, as capacity for production rapidly grew, asphalt roofing was in direct competition with both sheet metal and shingles. As fire safety regulations became more nuanced and complex, the product’s popularity only grew. This culminated in the first officially branded roofing felt, “Tar Boy,” being developed, marketed, and mass produced by Asfallti Osakeyhtiö Lemminkäinen in 1920. See Figure 4.

Throughout the late 19th and early 20th centuries, the low-slope
built-up business grew, with major producers and suppliers in most urban areas. Roofing companies were established in urban centers with crews travelling relatively significant distances to complete major projects. A good example is Michael Ehret of Philadelphia, Pennsylvania, a major built-up roofing installer who travelled to other urban centers to complete work. Ehret left a portfolio of work in photographs documenting travel greater than 100 miles from his home base. The distance covered speaks to the unique aspect of the application and the demand for the new product. See Figure 8.

During this 60- to 70-year period, many advances took place that impacted both coal tar and asphalt. Coal gas was made virtually redundant with the introduction of electric light, and the new automotive industry created an ever-growing demand for gasoline. The discovery of huge oil deposits in Texas created what was seen to be an “endless” supply of oil to feed the combustion engine. With more refining of gasoline, more asphalt became available for roads and roofs.

Coal tar pitch had its promoters and supporters. While the primary source was disappearing, the uses that had been developed maintained a demand for the product. Coal was still plentiful; however, coal production had shifted its focus to the production of a former waste byproduct that now had uses in roofing, pharmaceuticals, and photography.

Asphalt originally used in roofing was “flux”: the bottom of the refining process that was difficult to further refine. Through the evolution of the refining process, more of the asphalt could be turned into salable products, changing the base material used for roofing and road building. Around 1890, the industry developed blown or oxidized asphalt. Oxidation is a process where oxygen is blown through the asphalt, hardening the end product. Air blowing is the process of passing air through heated asphalt to raise the softening point of the asphalt while maintaining much of its flexibility at lower temperatures.

The industry responded with specifications for the production of oxidized asphalt (ASTM D312 1929). While coal tar pitch had been in use for more than 100 years, an ASTM standard was not published until 1978. These standards identified grades of asphalt and coal tar for specific applications.
Coal tar pitch was broken into two types: Type I, which is generally used for roofing or damp-proofing, and Type II, which has a lower softening point (106°F to 126°F or 41°C to 52°C), which is too low for roofing, but is generally a key agent in waterproofing. Blown asphalt was broken into four types: Types I through IV, the most common in roofing being Types III and IV. Each type had a different softening point, creating a grade of asphalt for various applications and slopes.

By the 1920s, asphalt production had increased to 4.7 million tons with approximately 80% of the production going into road building. Approximately ten percent went to built-up roofing, with a growing percentage of the remainder going into the new composition shingle industry. Both road building and roofing were growing at a fast pace until the onset of the depression in the early 1930s, at which time the demand for asphalt slowed significantly. Demand picked up once again during the war years, further growing during the post-war construction boom. Built-up roofing dominated the low-slope roofing industry with few or no competitive products on the market. By 1960, asphalt production had increased to 64 million tons with ten percent slotted for built-up roofing and five percent used for the production of composition shingles.

The built-up roofing industry dominated the low-slope roofing market with a few dominant suppliers in the asphalt market and one primary supplier of coal tar pitch. Felts were produced from cotton rags and asbestos. Asphalt and coal tar provided the adhesive and the waterproofing to form multiply built-up assemblies. Specifications were developed for three- to five-ply systems with varying life expectancy, depending on the specification.

In the 1960s, the material producers introduced coated roofing felts that prematurely failed. The coated felts gave the industry a black eye and reduced the overall life expectancy of a built-up roof. This opened the door for the acceptance of alternate systems to compete with the primary low-slope system.

While the United States market maintained a singular path in the first half of the 20th century, Europe embarked on a different road, beginning in the late 1920s. The first patents for asphalt modification were issued in Scandinavia in 1929. Modification was not with a “breakthrough” plastic polymer, but with whale oil. The sheet good or membrane was applied with a crude torch, producing a dreadful odor.

Products remained relatively consistent, with few changes made until the late 1950s and early 1960s, when Great Britain, France, Italy, and Germany developed various methods of asphalt modification. Rubberoid obtained a U.K. patent in 1960 for a modified-bitumen membrane, followed in 1965 by successful modification with APP in Italy and SBS throughout most of Europe in 1970. Plants were producing membranes by 1967, servicing multiple European markets. Unlike conventional built-up roofs, these membranes were marketed as single-layer roofs applied over a mechanically attached coated base sheet. The quantity of asphalt required for the roof assembly was drastically reduced. The waterproofing was now in a single layer of membrane that was applied by melting the backside of the sheet and fusing the laps together. SBS membranes could be applied by torch, cold adhesive, or hot asphalt and were marketed in one- and two-layer systems. While more akin to conventional built-up roofing, using hot asphalt and redundant layers, the systems still used less asphalt than conventional built-up systems.

The modified-bitumen systems made their way into the U.S. market by way of private label sales promoted by major U.S. suppliers and start-up companies that eventually began producing membranes domestically.

In 1973, global oil prices increased four-fold as the OPEC exporting nations cut off supply of oil to North America and Europe. This political retribution for support of Israel in the 1973 Arab-Israeli war forever changed the formula for oil-based commodities. The 1979 “Energy Crisis” brought on by the Iranian revolution further solidified the upward spiral of crude oil pricing.

As the asphalt market was evolving with the introduction and further development of membranes, new thermoplastics and thermosets were in development in both North America and Europe. Germany and Switzerland focused on the development of PVC and PIB, while North American manufacturers focused on thermosets such as neoprene and EPDM. Other polymers were also brought to market, such as CPE and CSPE, to name but a few. The poor performance of coated felts in the built-up market opened the door for these new membranes, developing and growing market share despite having warranties of only five to ten years. German and Swiss
manufacturers entered the market with reinforced and non-reinforced PVC, competing with both neoprene and EPDM initially in the East Coast and Midwest markets. Neoprene quickly dropped out of the market due to pricing, and EPDM dominated the single-ply market.

Major U.S. roofing manufacturers took the competition seriously and expanded product offerings to include modified bitumen and EPDM. Warranties for single-ply systems were extended beyond ten years, with some offering 20-year durations.

By the turn of the century, asphalt production had increased to 104 million tons, with 85% going into the road business and less than ten percent sold to the roofing business. Composition shingles increased product share, with a decrease in mopping asphalt usage.

The mopping asphalt producers clearly saw asphalt modification as a benefit. In the early 1980s the Canadians began modifying asphalt with rubber to produce a waterproofing system that has become an industry standard.

Asphalt was also modified for the road industry in the 1980s with very positive results. SEBS was first produced for road work and subsequently added to the roofing market. The product was heavily marketed for use in cold climates. Wax additives were also mixed with flux to produce a low-temperature mopping asphalt used primarily as an adhesive. Both products now have ASTM specifications and are used in both built-up and single-ply applications. See Figure 9.

As described by Tim Barret in his 2000 article, the SEBS polymer was developed by Shell Chemical as a “second generation” of the SBS-type polymer. Through a process called hydrogenation, the SBS polymer undergoes a chemical transformation, developing into SEBS. In very simple terms, the ethylene molecules add significant thermal stability and ultraviolet resistance to the SBS polymer. SEBS polymers have been widely used in the adhesive and automotive industries for more than two decades.

SEBS was first sold in the U.S. roofing industry as a mopping bitumen by two competing companies in the early 1980s. By the time an ASTM specification was established, more than 50 variations of the product were on the market, sold by better than 20 roofing manufacturers. Prices ranged from $1400 to $2300 per ton, whereas Type III was selling for $200 per ton. The industry had recognized that the addition of SEBS created an “engineered enhancement” to standard mopping-grade asphalt, but at a significant price increase. The development of an ASTM standard established nine minimums and maximums for the product, eliminating the wide performance spread in the market prior to its introduction.

In the mid-1980s, a proprietary wax-modified mopping asphalt was developed by a major manufacturer that was also developed for use in the paving industry. The newly developed material had a softening point similar to Type IV; however, application temperatures were more akin to Type II, resulting in application temperatures ranging from 80°F to 100°F lower than standard Type IV. This lower application temperature reduced fume exposure. An ASTM standard was established in 2016, ASTM D8051/D8051M-16.

One of the most significant changes to the asphalt market in the late 20th century was the introduction of TPO membrane. TPO initially entered the European market in the late 1980s as FPO. The product was first promoted in the United States in the late 1980s by two major suppliers, with introductions to the marketplace by the primary suppliers of EPDM and built-up roofing. While early formulations did not meet their anticipated life expectancies, TPO formulations were modified over the next 20 years to increase service life performance. An ASTM standard was not published for TPO until 2003, after many years of development in committee. The current standard was amended and published in 2011 with changes to performance criteria.

The initial product offerings focused on thicknesses of 45 and 60 mils, following the most common thicknesses offered by the PVC industry. In recent years, the 60-mil and the more recently introduced 80-mil product have been more common.

Like most new products offered into an industry, there were many cautions offered in the first 15 to 20 years of sales; however, the market expanded in double-digit growth each year. Much has been written about the remarkable growth of TPO and the changes it has brought to the U.S. roofing market, some of which are worth noting:

- The PVC and CSPE industries had introduced the basic installation concepts, tooling, and adhesives required for TPO 35 years before the introduction of TPO. While the membrane may have been new, the methods of installation had been well developed and were familiar to the industry in general.
- The concept of both thermoset and thermoplastic single-ply membranes was a major part of the North American and European markets by the later 1980s. While Europe favored thermoplastics and the U.S. thermosets, single-ply systems represented significant shares in both markets. Built-up roofing was losing market share on both sides of the Atlantic; however, both APP and SBS modified-bitumen systems were seeing continued growth. More conventional multilayer systems were losing popularity.
- By the first decade of the new millennium, the primary suppliers of BUR were also the major suppliers of TPO. Only Johns Mansville was the “odd man out” until they introduced TPO in 2008. Built-up roofing was facing environmental, safety, and pricing issues that brought the TPO option to the forefront. North American manufacturers invested heavily in new production, making the product readily available, cost effective, and heavily marketed.

The increase in TPO usage took market share from areas of North America where built-up roofing had remained strong during the growth of single-ply systems. Regions of the United States, such as the West and Southwest, saw significant reductions in built-up usage and a dramatic rise in TPO applications. The last strongholds of conventional built-up roofing saw major decreases in market share as the economy came out of the 2008 recession. Many large roofing companies fell out of business during the recession, and as the economy started to come back, TPO was easier to begin installing than BUR, which required a high capital investment for equipment.

Reducions in built-up systems meant a reduction in the use of mopping asphalt and the reduction in ply and cap sheets.

The modified-bitumen market remained a strong market presence, even during the 2008 downturn. Based on figures from the Single-Ply Roofing Industry (SPRI), APP usage grew in market share during periods of the recession. Many of
The TPO producers also produced modified-bitumen membranes, adding self-adhered systems to their product offering. See Figure 10.

The self-adhered market began as an “add-on” product to the residential market, quickly growing into the small commercial market as the products and application techniques evolved. Speed of application and the elimination of asphalt and adhesive found favor with both owners and installers. The reduction in the use of mopping asphalt motivated the asphalt suppliers to look closely at safety, environmental, and application issues in the downturn.

The primary method of asphalt application is the heating of the product—either in a roofing kettle on site or delivery of hot asphalt to the jobsite in heated tanks. The hot asphalt is pumped to the roof where it is transported in luggers to mop carts or felt layers. The asphalt must remain at application temperature until the time it is applied. Asphalt temperatures range from 350°F to 500°F (177°C to 260°C), depending on type and EVT. The material must be carefully handled for a safe and successful application. Heated asphalt creates fumes and odors that can be a harmful nuisance. Conventional kettles are open, allowing fumes and odors to impact a significant area. The method of heating and delivering the product has not substantially changed since the inception of built-up roofing. Kettles have become insulated, covered, and have modern pump systems added, but the basic concept of delivery to point of application remains the same.

In 2004, a study was published identifying that exposure to asphalt fumes resulted in unacceptably high benzene levels at...
16 out of 42 roofing sites. The paper also concluded that the introduction of a small quantity of polymer to the asphalt, creating a seal at the surface, reduced fumes by greater than 70%. The study later concluded that temperature reduction further reduced fumes emitted by hot-mopping asphalt.

The industry went to work on two fronts: the first in the heating and delivery equipment, and the second in the asphalt itself. Kettles were developed with hoods, fans, and afterburners to capture and burn off fumes at the kettle. Efforts to reduce fumes can be documented as far back as the 1920s; however, the efforts were not very successful until the development of the hood and the afterburners. See Figures 11 and 12.

In recent years, equipment has been developed to heat the asphalt at the point of application, completely eliminating the need for tankers, kettles, luggers, and mop carts. While still in developmental stages at this point, a point-of-application heating delivery system would revolutionize the asphalt industry. See Figures 13 and 14.

Asphalt is still used in the production of both conventional and modified-asphalt products. APP- and SBS-modified membranes in one-, two-, and three-layer applications make up a significant component of the market share. Based on data from the Asphalt Roofing Manufacturers Association (ARMA), market share for 2018 indicates a 9% increase in the second quarter of 2018 as compared to the second quarter of 2017, for production of modified sheet goods.

Self-adhered membranes continue to expand as material usage continues to make headway in the commercial market. The use of multi-layer systems also expands the category. SBS membranes are both mopped in place, primarily with Type IV oxidized asphalt, and torched. Combination systems of both mopping base layers and torching cap sheets is common. Asphalt continues to be used to saturate and coat felts and membranes for the built-up market. While market share has decreased, strong regional pockets still exist in California, Texas, and Florida.

Traditionally, insulation was mopped with hot asphalt to various substrates. However, with the increases in insulation and, therefore, the number of layers, along with the common addition of cover boards, processes needed to change. In the 1960s, attachment of base layers and thermal barrier boards were either augmented or replaced with mechanical fasteners. The first devices for steel decks were “hammer-in” anchors such as Lexsuco clips. These were eventually replaced with screw-type fasteners with metal or plastic plates. See Figure 15.

In the early 1980s, Factory Mutual Research published Loss Prevention Data Sheet 1-28, which mandated the use of mechanical fasteners for the base insulation...
layer to increase uplift performance and to minimize the risk of fire. In terms of fire safety, the watershed event was the Livonia, Michigan, fire in a General Motors plant in 1953. The fire quickly spread through the manufacturing plant, completely destroying the property. Asphalt accumulated in the flutes of the steel deck, contributing to the quick spread of the fire.18

Asphalt, employed as an adhesive, was used to adhere the multiple layers of insulation and coverboard. Types III and IV were commonly used in asphalt and single-ply systems. Thermal transfer concerns reduced the use of mechanical attachment of top insulation layers and coverboard. Asphalt was employed in the top layers to secure the coverboard and membrane(s) to avoid thermal shorts created by mechanical attachment.

Throughout the 1980s and the 1990s, a wide variety of innovative fasteners were developed for attachment of insulation and single-ply membranes for all deck types. Even lightweight decking systems became suitable substrates for mechanical attachment, using fasteners such as the NTB and the TPR. See Figure 16.

By the mid-1990s, new adhesives were developed to adhere insulation and coverboard. Low-rise polyurethane foams were developed as an alternative to asphalt and mechanical attachment. While expensive when compared to alternatives, the concept quickly caught on—primarily in the single-ply market. If mopping asphalt was used for the application of a roof cover, it was logical and cost effective to adhere the insulation layer in hot asphalt, since the equipment was already on site; however, the capital cost of hot asphalt application equipment was higher, with maintenance and servicing a significant factor. Low-rise polyurethane foam had minor capital costs and did not bring with it the potential environmental and safety concerns attributed to hot asphalt.

The continuation of mechanical attachment and low-rise foam significantly decreased the use of asphalt as an adhesive for the insulation and cover board market, notwithstanding its excellent performance.

Many roof cover manufacturers tested fleece-backed systems with solvent water-based adhesives, as well as with asphalt. Notwithstanding the fluctuating price of oil, asphalt used as an adhesive remained cost effective when compared to other adhesive applications. The resistance in usage came from the environmental and safety issues, as well as the lack of equipment within the roofing community for the application.

Considering that the built-up roofing industry began with utilizing waste product and discarded rags, it has come a long way. Changes in the delivery and application systems and the lowering of temperature at the point of application will give mopping asphalt a continuing place in the industry. The product remains most effective in its traditional use as an adhesive and waterproofing agent, but it also has a new role as solely an adhesive to apply SBS and fleece-backed membranes.

The growth of the TPO industry and its adoption as the single-ply choice by the majority of the built-up manufacturers will permanently change the role asphalt plays in the industry. More work is needed to address safety and environmental concerns if it is to build on its more recent role solely as an adhesive. Polymer and rubber-modified systems will continue to use asphalt flux to manufacture membranes, providing the cost structure remains competitive with the single-ply industry.

As the demand for mopping asphalt decreases, there will be (and already has been) a reduction in the equipment suppliers and skilled mechanics needed to load, deliver, and install the material.

New requirements for continuous air barriers may increase the demand for asphalt applications as a component of air and vapor barrier assemblies. Asphalt provides a seal at the roof level, minimizing air and vapor transfer. Adhesives and low-rise foam do not; in fact, low-rise foam is installed in beads and patties, creating gaps that allow air flow.

For the asphalt industry to continue in the mopping asphalt end of the business, there is work to do throughout multiple segments of the industry to keep it from becoming a specialty component in the business.

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8. Chlorosulfonated polyethylene
9. Styrene-ethylene-butylene-styrene
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Figure 16 – Various roofing fasteners.