The evolution of asphalt shingles: Survival of the fittest?

Research has helped to provide the technology to produce high-quality, serviceable asphalt shingles

by **William C. Cullen**

How long do asphalt shingles last? The answer to this question could be from a few years to approximately 30 years. It all depends on how the state-of-the-art asphalt shingle technology is applied during manufacturing and application.

Research has helped provide for the technology to produce high-quality, serviceable asphalt shingles.

It is up to asphalt shingle manufacturers to incorporate this technology in their selection of raw materials and in the manufacturing processes to produce quality products for consumers.

Only then will the designer and applicator have a significant impact on the product's performance.

This article offers highlights of the 100-year history of asphalt shingles.

It emphasizes the role that researchers have played over the years to create today's technology and describes some projects of the 40-year-old National Bureau of Standards (NBS—now the National Institute of Standards & Technology) and the Asphalt Roofing Manufacturers Association's (ARMA) comprehensive research program, and its influence on today's asphalt shingles.

Asphalt shingles

ASTM defines asphalt shingles as small units of prepared roofing designed for installing with similar units in overlapping rows on inclines normally exceeding 25 percent (3-in-12).

In my opinion, asphalt shingles are the roofing material of choice for residential dwellings in the United States. NRCA's Annual Market Survey revealed that contracts for the application of asphalt shingles totalled $2.73 billion or 64 percent of the 4.26 billion total in the 1991 residential roofing market. The market share for fiberglass-based shingles accounted for 87 percent (of the 64 percent) of those applied.

Several reasons can be cited for the predominance of asphalt shingles in the residential marketplace: availability, ease of application, attractiveness, cost and a history of acceptable performance.

The desirable characteristics of asphalt shingles did not occur by chance. Research played a vital role not only in the development of shingle technology, but also in the solution of performance problems that occasionally faced the shingle industry. In addition, research provided, and still provides, the technical basis for voluntary standards for product and test methods.

The first shingles

The forerunner of asphalt shingles, asphalt prepared roofing, was first marketed in the United States in 1893. The material consisted of a felt base that was impregnated and coated with asphalt. Four years later, in 1897, mineral surfacing was applied for additional weather protection.

The first asphalt shingles appeared in 1901; slate granules were used as surface protection. Asphalt shingles did not come into general use until about 1911. During the ensuing years, these products continued to grow in quality, use and popularity. By 1939, 32 manufacturers produced over 11 million squares of shingles, enough to cover about 45 percent of U.S. residential homes.

Organic felts

Asphalt shingles are a composite of three essential components: reinforcing felt, asphalt and surfacing granules. The performance of the shingles depends upon the quality, quantity and compatibility of these components.

Until the late 1920s, shingle reinforcing felts were made from cotton rags, with or without the use of substitutes. However, due to the increased cost of cotton in the 1920s, substitute materials were used more often in a mixture with the surplus rag stock to produce felts. Questions arose as to what effect this change could have had on the performance of shingles.

In 1926, the Asphalt Shingle and Research Institute (now called ARMA) established a research associate program at NBS to investigate the role of materials in the performance of asphalt shingles. This relationship between shingle manufacturers and a federal laboratory was to endure for the next 40 years.

Three years later, a technical report was written describing the production and composition of 22 experimental felts containing various fibers and the weathering qualities of shingles made from these felts. The conclusions drawn from this early work indicated that no significant difference in the weathering qualities of felts could be attributed to the kind of fiber used. Early shingle producers used this information to select appropriate felt bases for their shingle stock.

The asphalt shingle industry faced another crisis in 1941 when World War II resulted in the increased production of asphalt roofing for military construction, coupled with a growing shortage of imported rags. A quest for substitutes identified defibrated wood (cellulose matter), produced from a recently developed process, as a viable alternative.

A comprehensive outdoor exposure program was then started to evaluate hard- and soft-wood fibers in combinations of up to 60 percent of dry felt weight. After 25 years of exposure, it was concluded that durable shingles can be made from organic felts irrespective of the type and quantity of the defibrated wood fibers used. This study provided the basis for organic felts used in asphalt shingles currently being produced.

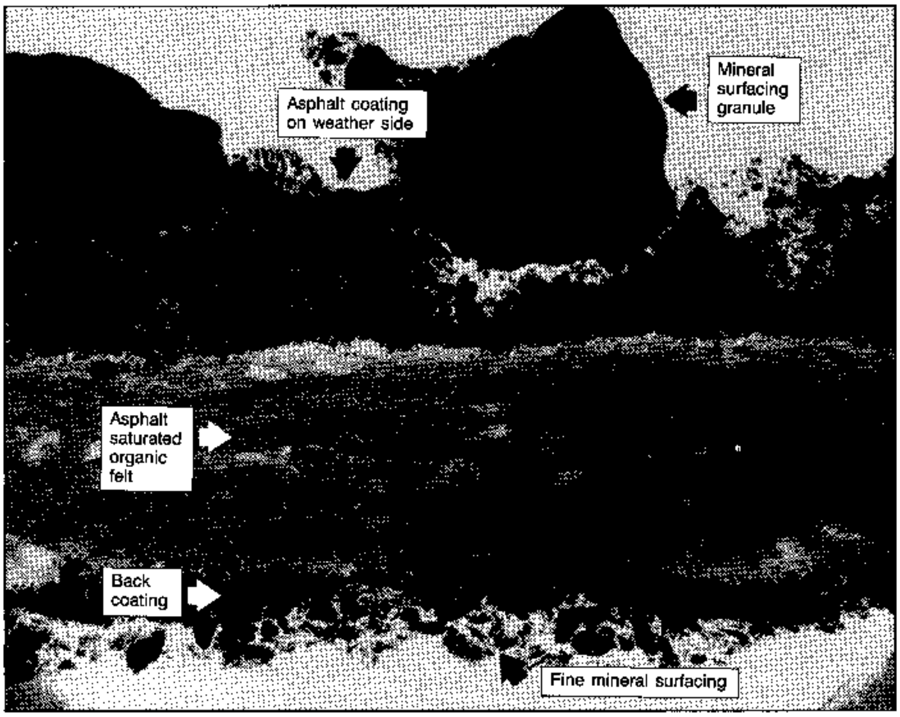

Figure 1: This is an X-ray taken of the interior of an unexposed 210-pound asphalt shingle. The photo demonstrates the value of this non-destructive technique to observe latent failures in newly manufactured shingles, such as adhesion of granules, saturation of felt and asphalt coating thicknesses.

Fibrous glass felts

In the early 1950s, fibrous glass mats were impregnated with asphalt to form roofing felts that were employed as alternatives for the inorganic products used in built-up roofing.

In the 1960s, the first experimental asphalt shingles using glass fiber "felt" were exclusively developed and produced in California. The shingles consisted of a two-layer arrangement of thin, fibrous glass mats saturated and coated with a filled asphalt and surfaced with mineral granules. These products met with limited success; however, they did provide the basis for the fibrous glass shingles now being marketed.

In general, the weight and thickness of glass felts is less than that of organic felts. They are considerably less susceptible to moisture absorption than their organic counterpart. In addition, they possess better fire-resistant characteristics. On the other hand, there have been some recent complaints about the questionable performance of some fibrous glass shingles with respect to breakage, cracking and splitting (see "Q & A," January issue, page 44).

Research and development of glass reinforcement felts have been generally proprietary. Consequently, little information appears in "open" technical literature. Nonetheless, glass shingles have been such successful performers, they now command a large percentage of the U.S. residential roofing market.

Asphalt

Asphalt, an extremely complex chemical compound, is the second important component of shingles. It is a residue material produced in the oil-refining process. Each crude oil has a unique physical and chemical make-up that effects its behavior for use as a roofing material. Simply stated, shingle quality depends on the quality of asphalts used in production. In turn, coating grade asphalt quality not only depends on its source, but also on the quantity and characteristics of the mineral additives used as fillers.

In shingle production, organic felts are first saturated with a soft flowing asphalt, called a "saturant" (similar to a Type II asphalt). The felts are then coated with harder, mineral-filled asphalts (coating grade asphalts). Coating grade asphalts are used exclusively in manufacturing glass-based shingles for both saturation and coating.

The effects of weathering on the composition and durability of coating grade asphalt was the primary thrust of the ARMA/NBS research associate program. In the early 1920s, accelerated weathering test methods were developed to simulate the effects of outdoor weathering on roofing asphalts. These test procedures were adopted as standard test methods by ASTM in 1933.

The succeeding pioneering work for determining asphalt durability included the following: various ultraviolet radiation sources; moisture and temperature effects; sample preparation techniques; exposure conditions; evaluation methods; and interpretation of results in terms of the in-service performance of asphalt shingles. This work provided the information on which numerous voluntary standards have been established.

Another comprehensive NBS/ARMA investigation studied the effects of mineral additives on the durability of asphalts produced. The findings revealed that concentrations of up to 60 percent of *some* additives resulted in substantially increased durability of asphalts. It also showed that particle size distribution of additives had a significant influence on the durability of coating grade asphalts. Further, thorough mixing of additives with asphalts was of primary importance. The research demonstrated that Mica, oyster shell and blue-black slate were most effective in increasing asphalt durability. Dolomite and fly ash were of less influence, and silica and clay the least. In brief, minerals with plate-like particle shapes were the most effective in increasing durability.

Perhaps the most important conclusion of the investigation was that in determining durability, in general, the asphalt was the most important component of stabilized coating. However, shingle durability could be greatly improved by incorporating selected mineral additives.

The contributions of these research efforts are numerous, as exemplified by publications dating from the 1920s to the 1970s. These research findings still play a key role in asphalt shingles currently being manufactured.

Shingle performance

Shingle investigations have not been restricted to studying composition. In reality, some of the pioneering research looking into on-the-roof performance provides today's industry with information to make improved products. Solving problems using applied research is perhaps more visible and produces a faster pay-off to the producer and consumer.

The following are examples of investigations undertaken by NBS. Prior to 1962, the type of shingle that was predominately used was referred to as the 210-pound shingle. Unfortunately, a rash of shingle failures referred to as "clawing" (where the shingle tabs curl under) shook the industry. Shingles were failing after only two to four years of exposure. Clawing was a serious and costly problem; not only to homeowners, but also to the armed services, which used asphalt shingles extensively at military bases. Facing clawing failures, the armed services requested assistance in solving the problem.

A field and laboratory investigation was conducted by ARMA, ASTM and UL. The research identified the causes of clawing as under-saturation of shingle felts and insufficient back coating. The mechanism of failure was the expansion and shrinkage of the shingle due to the alternate wetting and drying of under-saturated organic felts causing distortion of the shingle. This was accelerated by the porous shingle back coating, allowing moisture to freely penetrate to the felt. Clawing was classified as a material failure.

Subsequent testing revealed that greater saturation of the felts and a heavier asphalt back coating could provide protection from moisture penetration to prevent clawing. Recommendations were adopted by the roofing industry that encouraged the early acceptance of new shingle standards with requirements for additional felt saturation and thicker back coatings. Consequently, the industry acquired a heavier shingle, called the 235 shingle. By 1963, the 235 shingle essentially replaced the 210 shingle. The clawing problem disappeared and shingle life was appreciably extended.

Self-sealing shingles

Prior to the mid-1950s, the most frequent cause of premature failure of asphalt shingles was wind damage. To prevent extensive wind damage, most shingle manufacturers applied heat-sensitive adhesives to seal shingle tabs. With one exception, the adhesives were activated by solar heat to seal tabs to the surface below.

The armed services again asked NBS to undertake an investigation to determine the effectiveness of the adhesives. In response, NBS carried out a three-phase program consisting of laboratory work, including outdoor exposure, field observations and wind-resistance testing. Ten manufacturers provided 12 samples of their self-sealing shingles that were included in the laboratory and wind resistance phases.

NBS developed and constructed an apparatus to measure the force required to break the adhesive bond under individual tabs after conditioning at preselected times and temperatures. First, the area and thickness of adhesive spots were measured. The measurements varied widely among the shingles from .5 to 3.5 inches^2 in area and from 8 to 40 mils in thickness.

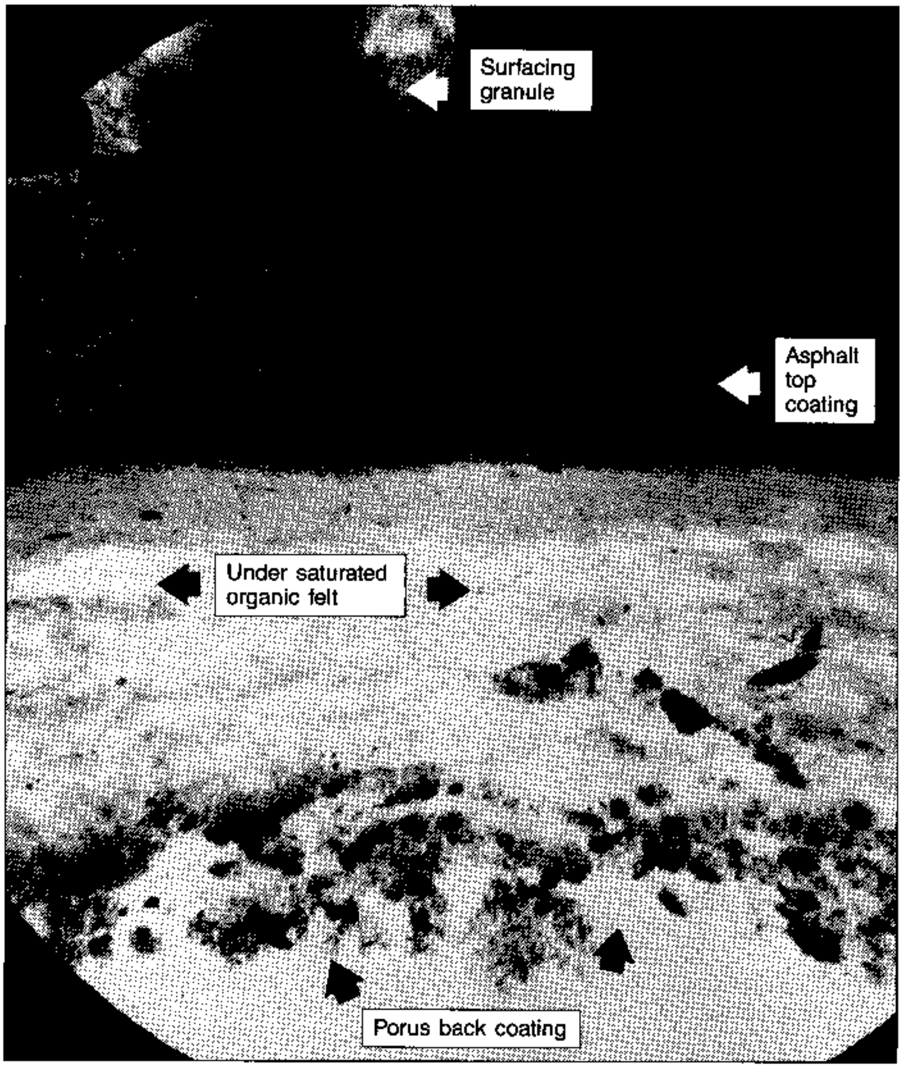

***Figure 2:** In the case of a "clawed" shingle, the X-ray clearly shows moisture deterioration of the saturated felt base and the porosity of the shingle's back coating, which allows moisture to penetrate the felt.*

Bond strengths ranged from about 3 pounds/force to 16 pounds/force, depending on the manufacturer. Researchers found:

- All shingles tabs sealed after exposure to 140 F for 16 hours.
- Bond strengths increased with increased area and thickness of adhesive.
- Water had no appreciable effect on bond strength once the sealant had been activated.

Field observations were made of more than 40 self-sealing projects located in nine states representing both warm, moderate and cool climates. Observations indicated that self-sealing shingles performed adequately on slopes varying from 2 to 6 inches per foot in both Northern and Southern climates. Self-sealing shingles applied during cold weather cannot be expected to seal immediately.

A storm test machine was employed to measure the relative resistance of heat-activated, self-sealing systems on 4-by-3-foot panels with shingles applied according to manufacturers' instructions. The test panels were conditioned for five hours at temperatures of 120, 140 and 160 F prior to testing at air speeds of 40, 50 and 60 mph for two hours. Lifting of one or more tabs constituted failure.

Results showed that only two systems passed the 60-mph criterion when conditioned at 120 F for 16 hours. Five of the 12 passed when conditioned at 140 F, and 10 of the 12 systems passed the 160 F conditioning period. Conclusions included:

- The development of self-sealing shingles represented a major improvement in asphalt shingles by the industry.
- Criteria for the performance of these systems should be established, stating that shingles, conditioned for 16 hours at 140 F, be required to withstand air velocities of 60 mph for two hours.

The project was completed in 1959. Shortly thereafter, based on recommendations by NBS, UL established a standard test method and performance criteria for wind resistance of self-sealing shingles for labeling purposes. For the most part, these test and criteria are still in effect today.

Hail resistance

In the 1960s, ARMA, in cooperation with NBS, undertook a project to investigate the effects of hail storms on roofing materials.

A test was developed to evaluate the hail resistance of organic-based asphalt shingles. Synthetic hailstones (ice spheres) of various sizes (1½ to 2 inches in diameter) were shot from a compressed air-hail gun at calculated free-fall terminal velocities of 60 to 75 mph. Indentations, granule loss and shingle fractures were observed after impact. Following are the conclusions:

- Asphalt shingles have considerable hail resistance. However, as the size of the hail increases, a level of impact energy is reached at which damage occurs. This level lies in the range of 1½- to 2-inch-diameter hailstones for most asphalt shingles.
- Solidly supported areas of shingles tend to be the most resistant areas. For example, shingles with a 15-pound underlayment were less resistant than those with no underlayment.

- Weathering lowers the hail resistance of asphalt shingles.
- Shingles applied on 1-by-6-inch T & G decks were more resistant than those on plywood decks. Those applied on ⅝- and ½-inch plywood decks performed equally well.
- Heavier shingles tend to be more resistant to hail damage.

Staples versus nails

In 1954, the U.S. Federal Housing Authority asked NBS to evaluate the performance of organic-based asphalt shingles applied with ¾-inch staples in lieu of conventional nailing. The program included field studies of asphalt-shingled roofs in nine states comparing the performance of staples and nails for wind resistance, appearance, corrosion, holding power and positioning of staples.

Laboratory tests were devised to measure the resistance to the tearing of shingles fastened with one and two nails and with ¾-inch staples placed parallel, perpendicular and at a 45 degree angle to the base of the shingle. Following are the conclusions given in a 1955 NBS report:

- Field studies showed that the corrosion resistance, appearance and retention of holding power of stapled shingles compared favorably with nailed shingles, and that staples were more likely to be improperly placed.
- Although staples tended to provide adequate wind resistance, the investigation left some question as to whether stapled shingles performed as well as nailed shingles.
- Regardless of the positioning of the staples (i.e., parallel, perpendicular or at a 45 degree angle), the average tearing resistance of two staples ranged from 21 to 23 pounds.
- The average tearing resistance of two staples (22 pounds) was equal to one nail (21 pounds); the tearing resistance of two nails was 27 pounds.
- Winds of high intensity will damage stapled shingles more than nailed shingles, if the same number of fasteners is used and tabs are not sealed. Further, six staples should give about the same resistance to tearing as four nails.

Projection microscopy

The ability to see within an asphalt product has always been hampered by the opaqueness of the materials. However, in 1962, ARMA's research associate applied point projection microscopy using soft X-rays to see the interior of several asphalt products as thick as 50 mils. The project demonstrated that the technique permits observance of variations within asphalt roofing material as the variations occurred upon undergoing natural- or laboratory-simulated weathering conditions (see Figures 1 and 2).

Looking ahead

This article highlights the 100-year history of asphalt shingles. It emphasizes the critical role that research has played to create today's technology and recalls examples taken from the 40-year-old NBS and ARMA programs that have had a major impact on the performance of asphalt shingles currently marketed. Unfortunately, the ARMA/NBS relationship no longer exists at NBS. In fact little, if any, research is being conducted at NBS that focuses on asphalt shingles.

However, ARMA continues to sponsor and conduct research to improve the performance of asphalt roofing products. For example, ARMA supports a comprehensive program at a major university to better understand wind force and its effects on shingle roofing.

ARMA-member companies conduct ARMA-sponsored in-house research to investigate issues, such as the bond-strength of tab sealants, the effectiveness of fasteners for shingles, etc. ARMA is also sponsoring a program that is conducting research on asphalt as a critical component of shingles.

In other areas, NRCA has joined ARMA in investigating shingle underlayments and their effect on shingle performance, and the Western States Roofing Contractors Association has undertaken an investigation into fibrous glass shingle problems resulting in premature failures. PR

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