Asphalt Roofing Shingles— Composition, Performance, Function, and Standards

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ABSTRACT

This paper describes the composition and function of each of the layers of a shingle. The various types of shingles and their application are discussed. The more common problems associated with asphalt shingles and the probable causes for these problems are reviewed. The various standards pertaining to asphalt shingles are also discussed.

Introduction

Asphalt shingles have been in general use for the last 85 years. The original shingle was an asphalt saturated felt (made from cotton rags) coated with asphalt and surfaced with slate.

Prior to the introduction of self sealing shingles, strip shingles were tabbed by hand using plastic cement. Nailing was the same as current methods. By the 1940s, defibrated wood had replaced cotton felts, and overall weights had started to come down.

In the last 25 years, dramatic changes have taken place in the shingle industry. Until the early 1980s the industry standard was a 210-pound-per-square, three-tab, strip shingle. Starting with the 1980s, a heavier (225 pound) strip shingle was introduced. Also available are T-locks for high wind areas and two-tab, low-slope shingles designed specifically for roof slopes between 1:6 and 1:3. The early 1980s also saw the introduction of no cutout, random-edge shingles. The latter could be deemed the forerunner of modern "architectural" shingles. In the mid '80s, shingles based on a fiberglass felt were introduced. The late '80s and early '90s saw the introduction of true designer shingles. These include laminated, overlay, and various tab configurations. Today there is a wide variety of styles, patterns, and colors available to the consumer.

Production efficiencies have allowed the cost of shingles to remain at or near the same price as twenty years ago, in spite of rising raw material costs.

In the U.S., shingle contracts amounted to $2.73 billion in 1991. This represented approximately 65% of the total residential roofing market. In 1998, asphalt shingle contracts were worth $4.64 billion.

Shingle composition

A roofing shingle is a composite material. With conventional three-tab, organic (wood fiber), felt shingles, the felt is first impregnated with a saturant asphalt. The saturated felt is then coated on both sides with a mineral-filled, coating grade asphalt. The coating on the weatherface (exposed) side is thicker than that on the reverse side. Granules are applied to the weatherface side and pressed to ensure good bonding to the coating asphalt. The reverse side has an application of a backing dust above the cutouts on the weatherface side. This strip is thermally activated and serves to hold the tabs down to reduce blowoffs. A release tape is applied to the reverse side of the shingle to prevent sticking of the self seal line in the bundles. The shingles are then fully or partially wrapped in kraft paper and palletized for shipment. The process just described is essentially the same for fiberglass shingles except that the filled coating asphalt is also used to impregnate the glass web.

Asphalt

Asphalt is obtained as a by-product in the refining of crude oils. Not all crudes will produce an asphalt acceptable for use in producing shingles. The asphalt must have good weathering characteristics as it will be expected to perform for 15 years or longer under very severe conditions. It must be supple enough to allow bending (for hips and ridges) without cracking, yet stiff enough to allow normal foot traffic during installation. Good performance is determined by using a durable asphalt. A durable asphalt will be pliable and slow to harden. This is not to say that asphalt alone determines good performance. The reinforcement, type and particle size distribution of fillers also play important roles.

Organic felts

Organic reinforcements (or felts) are composed of a combination of virgin wood pulp and recycled cellulosic products primarily from corrugated and paper products. The usual felt weight for shingles is 0.44 kg/m.sq. Heavier weight shingles may use 0.50 kg/m.sq. felts. The base felt is then saturated with a bituminous saturant to a minimum of 165% of its weight. The saturated felt then passes through a coating section where filled asphalt is applied to the top and reverse side of the sheet.

There are advantages and disadvantages to organic felt materials. The advantages are high tear and nail pull through resistance. Organic-based shingles are generally fairly rigid and less susceptible to wind blowoff. The soft saturant used to impregnate the felt enables the shingle to retain toughness, pliability, and mechanical properties at low temperatures. Conversely, the thick organic felt maintains stiffness, even at higher roof surface temperatures. Organic felts show good performance under thermal cycling conditions as found in most of Canada and the northern U.S.

The disadvantage to organic felts is moisture related. Inadequate saturation and exposure to moisture can result in curling and fishmouthing as a result of dimensional changes as the shingle absorbs and releases moisture. Even an adequately saturated felt can, under certain conditions, exhibit the same problems.

The problems outlined above can be minimized by 1) ensuring proper saturation of the felt and 2) the application of heavier coatings on both sides of the felt (to provide greater moisture protection and guard against cold curl) to help the shingle to lie flat.

Fiberglass felts

Fiberglass felts (or mats) are produced in a wet process similar to that used in the making of paper. Glass fibers are blended with a binder resin, (usually urea formaldehyde), formed, and cured in an oven. The resulting material (depending on base weight) has excellent tensile strength, good tear resistance, and flexibility. Tensile strength, tear, and flexibility can be modified by formulation with various surface treatments, binders, fiber type, and by including random reinforcing fibers throughout the felt. Generally, the heavier the mat by weight the tougher the product.

The main advantages of fiberglass felts are their excellent resistance to moisture absorption and fire. Fire resistance can be important, as organic-based shingles will only rate class C, while fiberglass can achieve class A.

The main disadvantage to fiberglass-based shingles is a reduced resistance to cracking. This will be discussed in more detail later in this paper.

Mineral stabilizers (fillers)

The selection of the filler for the asphalt coating is of prime importance. Filler type, particle size distribution, and loading levels all impact on shingle performance. First and foremost, fillers "stabilize" the asphalt. They do this by supplying a reinforcing effect on the coating asphalt by stiffening the base asphalt to provide resistance to flow 1) during the shingle manufacturing process and 2) after application at roof service temperatures. The filler also increases asphalt ability to resist potential shrinkage during the aging process. The lower coefficient of expansion of the filler allows the asphalt to better resist cracking when subjected to thermal cycling. Finally, the incorporation of fillers adds weight to the finished product.

A key aspect in the use of fillers is to compound them into the asphalt at levels high enough to both "do the job" and reduce costs. For organic shingles, a level of 60-65% is currently the norm. For fiberglass shingles, 65-70% is used. It should be understood that these levels are not to be taken as "gospel." Fillers increase the stiffness of asphalt, and their use in harder asphalt would obviously be at lower levels than those mentioned. In addition, the use of a lower level of filler in an acceptable asphalt may not give the stiffness characteristics required, while the use of a higher level can cause rapid deterioration of the shingle in service.

The roofing industry, particularly ARMA (the Asphalt Roofing Manufacturers Association) has undertaken several studies to determine the optimum particle size distribution for fillers. Manufacturers have improved filler handling and mixing techniques. These moves have helped to further improve the quality of coatings applied to shingles today.

Roofing granules

Granules are applied to the weatherface (exposed) portion of the shingle to provide resistance to ultraviolet light. Granules have a particle size distribution that allows them to be applied to the asphalt coating in a manner so as to minimize exposed coating. In addition to this technical function, granules provide weight to the shingle and allow the product to be blended in a wide range of colors.

Asphalt sealant

The asphalt sealant used in the self-seal strip is placed on the shingles to provide sealing of the shingles when the sealant is thermally activated. Although small in terms of overall weight (approximately 114-151 grams) per bundle, the sealant strip is critical to the general performance of the shingle. The sealant must be able to provide sealing at lower temperatures and allow stress relief when the shingle undergoes thermal cycling and mechanical stresses in service. It must perform as well when aged as when fresh from the plant. The sealant must not be too aggressive, especially when used on lighter weight shingles. Too aggressive a seal coupled with poor shingle nail-through resistance can contribute to blowoffs.

Backing dust

The backing dust used on shingles has one function only—to prevent sticking of the shingles in a bundle during storage. One of the problems associated with backing materials, especially talc, has been "talc staining." This probably is the result of stacking bundles higher than recommended by the manufacturer over long periods of time and particularly in the summer. Fortunately, in almost all cases, a year or two of exposure on the roof eliminates all evidence of staining.

Problems associated with shingles curling

Curling is generally a moisture-related problem. The shingle absorbs moisture, either during the manufacturing process (water is used to cool the shingles before cutting), as a result of improper storage, or because of poor ventilation in the dwelling on which the shingles are installed. Curling, which is a result of dimensional change when the absorbed moisture is released after application, generally will show up within the first two years after installation. If the curling is not too severe, the problem can be solved by tabbing down the shingles—preferably with a hot glue. If analysis shows undersaturation, the roof should be replaced, as there will, in all likelihood, be repeated absorption/dying cycles that will only exacerbate the condition.

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Fishmouthing/Buckling

This is also a moisture-related problem. It used to be more prevalent in three-tab 210 shingles than is found today. The increase in overall weight, coupled with heavier backcoating, has reduced the occurrence of this problem in shingles manufactured today. It tends to be restricted to random butt shingles (those with no cutouts) as dimensional change is not relieved by any cutouts. The problem can generally be solved by breaking the seal and regluing the shingles. In severe cases, replacement of the roof is necessary.

Clawing

Clawing was a problem associated with 210 lb.-shingles in the late 1950s. As with fishmouthing, heavier shingle weights and increased backcoating have all but eliminated the problem. Clawing is now more an indication of old shingles (210 lb.-weight) which have 15 years or more of service.

Shading

Shading is a perceptible variation in color of shingles when installed. Shading can be caused by a number of factors. Mixing production runs is one of the most prevalent causes. Granules are produced in a batch process. While granule manufacturers make every attempt to control color within certain specifications, there will be some variation from batch to batch. In addition, during the shingle process, press effort may vary from production run to production run. This can cause a shading variation on installed shingles. Racking the roof as an application procedure can also produce shading. The use of blended color shingles will reduce shading; however, solid color shingles will be more prone to show shading if a roof is racked.

Blowoffs

Shingles, if installed properly, are capable of withstanding wind gusts to 90 km/hr. The critical statement is "properly installed." Over the last few years, numerous studies have evaluated the wind uplift resistance of shingles. These evaluations have shown that shingles installed with the proper fasteners, the correct number of fasteners, and their proper placement have a very good chance of staying on the roof during high winds. Improper and insufficient fasteners will contribute to blowoffs. It has been shown that fasteners placed 1 inch above the self-seal buttons can increase blowoff potential by 20%. Fasteners placed higher substantially increase blowoff potential. The proper type of roofing nail is preferred to staples. Study has shown that one roofing nail is equivalent in tearing resistance to two staples. Study has also shown that it is easier to improperly drive a staple than a roofing nail. ARMA has established a position that "properly driven and applied roofing nails are the preferred fastening system for all asphalt shingles."

Cracking/Splitting

Cracking is a problem that has intensified with the introduction of fiberglass shingles. Shingles, to resist cracking, must have sufficient toughness to overcome the stresses that are applied to them when in service. These stresses can be the result of temperature changes, deck movement, or movement of the shingle caused by wind. Such stresses are present singly or in combination on all roofs and basically do not change from year to year. The one exception would be during periods of high wind gusts in excess of 90 km/hr.

Organic shingles generally are well equipped to resist cracking. The heavy felt allows the shingle to resist wind uplift. If the asphalt matrix does crack, the propagation of the crack is stopped at the felt and does not penetrate the saturated "backbone" of the shingle. The organic felt provides excellent resistance to cracking that does not allow the integrity of the shingle to be compromised.

Fiberglass reinforcements react somewhat differently. Depending on the placement of the mat, the shingle will present greater or less resistance to cracking. If the mat is in the middle of the composite, it will allow greater flexibility during tab uplift as a result of wind. If the mat is closer to the back of the shingle, any crack propagation will continue until it reaches the mat. With the reinforcement being at the back of the shingle, this means the crack can travel through almost the entire thickness of the shingle. Because the fiberglass mat is lower density and lighter weight than organic felt, it presents less resistance to cracking. Cracking in fiberglass shingles is exacerbated by improper fastening and cold weather application.

Cracking in fiberglass shingles can be reduced by using higher basis weight mats as well as the use and proper compounding of durable asphalts. Close attention to the installation procedures recommended by manufacturers will help to minimize this problem.

Blistering

ARMA has defined blisters as "hollow raised areas of variable size and shape which develop on the exposed surface of asphalt roofing upon exposure to the weather." Blisters are normally of two types—small rash blisters and large blisters in which the entire thickness of the coating asphalt is raised from the felt and contributes to the deterioration of the roofing.

The evidence to date indicates that blisters are formed as a result of the behavior of entrapped air and moisture when subject to certain heat or temperature conditions. When excess amounts of solvent-based roofing adhesives are used, the shingle will absorb the solvent and the process is the same as for moist air. Dry air expands, on warming, in direct proportion to the increase in temperature.

Water, on the other hand, expands approximately 1,244 times in changing from a liquid to a vapor. Thus, if a shingle absorbs moisture which is trapped in the small voids in the coating asphalt, this air will, at roof temperatures, expand and form blisters.

Blister formation can be minimized by ensuring the use of dry felts, saturating to the maximum possible without creating "wet spots" of saturant, ensuring the finished product is stored in a dry environment, and by minimizing moist air accumulation in attic areas by proper venting. The use of recommended amounts of roofing cement for tabbing and low slope shingle application is, of course, a necessity.

Rash blisters generally will not vent and should not pose a threat to the integrity of the roof. Large blisters (greater than 6.5mm in diameter) will, in all likelihood, vent, and roofs in this condition should be replaced.

Specifications for shingles

There are, currently, in Canada, two specifications for asphalt roof shingles. Both are under the auspices of the CSA (Canadian Standards Association). The specifications are CSA A123.1-98, "Asphalt shingles surfaced with mineral granules" (this is for organic shingles); and CSA A123.5-98, "Asphalt shingles made from glass felt and surfaced with mineral granules." There are also two standards for the application of shingles—one for roof slopes 1:6 to less than 1:3; and the other for slopes more than 1:3. The CRCA (Canadian Roofing Contractors' Association) also includes a guideline for shingle application in its roofing specifications.

The CSA standards have recently been revised. The standard for organic shingles now has requirements for tear strength, tensile strength, fastener pull through, dimensional stability, cold curl resistance, and coating stain tendency. The temperature for pliability has been lowered from 25° C to 0° C. The standard for glass shingles has been similarly "beefed up." There is, in addition, a requirement for shingle mass.

ASTM (American Society for Testing and Materials) has nine standards that deal with shingle testing. There is currently a standard under development to evaluate the effectiveness of sealing asphalt. As with the Canadian standards, these methods all deal with fresh product.

Conclusions

Asphalt shingles provide excellent watershedding characteristics at a reasonable cost. Coupled with varying appearances and colors, shingles represent good value for residential and commercial applications. In fact, they are probably the best value for most steep roofing applications.

For shingles to perform, two things must happen. One: the shingle manufacturer must provide a product that will withstand the severe thermal and mechanical stresses that occur on a roof. The shingle must have the ideal combination of composition and processing to be tough and pliable, especially as the shingle ages. Two: shingles must be applied correctly on the roof. There are sufficient guidelines from CSA, CRCA, and the manufacturers for there to be no reason for improper application. The long-term reliability depends on these two areas.

The future development of standards for shingles must take "roof performance" into account. Test methods (such as heat aging and low temperature aging) on how stresses affect long-term performance are required to determine if a shingle is of merchantable quality when manufactured. Continued demands by the market for lower-cost roofing materials can have adverse effects on products, from manufacturing down to application. While it is not unreasonable for consumers to request lower-cost materials, steps must be taken to assure these demands do not compromise product quality, performance, and application.

Shingles have proven to be a successful roofing material for nearly 100 years. With the advances in material science, processing, and evaluation, there is no reason to doubt the ability of the shingle industry to continue to improve the product while maintaining an acceptable performance-to-cost relationship. End users should expect continuing performance improvement through the technical expertise of the industry. ■

About the Author

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