Performance of the Glass Fiber Reinforced Asphalt Shingle

By Ray L. Corbin

IN THE UNITED STATES, INDIVIDUAL SHINGLES are generally used on steep-slope applications (slopes greater than 2" in 12"). Of these shingles, 80% are asphalt-based. Of that number, more than 75% are glass fiber felt reinforced. These shingles provide beauty and style as well as performing their primary function, which is to protect the interior of the structure.

The continuing success of the glass fiber reinforced asphalt shingle has been attributable to two key factors—its material properties and application. Both are equally important.

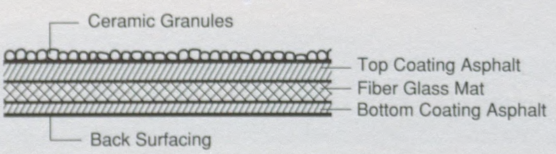
It is a known fact in the "Flat Roof Commercial Roofing Industry" that even the best manufactured sheet membrane is only as good as its application. Sloped roofs (generally, the steeper the better) are more forgiving than flat roofs. A poorly-applied shingle roof, however, will also leak, regardless of slope.

Shingle Construction

The glass fiber reinforced asphalt shingle is constructed with the following key components: flexible coating-grade asphalt; proper amount and type of mineral stabilizer; the fiber glass mat itself (which consists of the type and amount of glass fiber); the binder and sizing used to coat the fiber, as well as the location of the glass mat within the shingle itself; the protective granular surfacing; the back surfacing (to some extent); and the amount and type of sealing adhesive and its release film system.

Whenever a composite product such as a glass fiber reinforced asphalt shingle is judged, all of its various components must be considered. These components must function together for the shingled roof to perform properly over its expected life term.

Cross Section of a Shingle Matrix



The percent or amount of each component necessary to accomplish this longevity has been difficult to establish. Because of their interaction with each other, an increase in any one component could allow or result in a decrease in one or more of the other components. For example, a lower weight fiber glass mat, constructed with proper sizing, binder and type of glass fiber, could perform properly when coated with a more flexible, longer weathering filled asphalt.

There are two major factors that are key to how the shingle performs its intended function to shed water and protect the interior of the building. The first factor is how the shingle is constructed to resist aging. This resistance to aging or the weathering characteristic of the shingle, along with the second factor—that of the correct application of the shingle—are the keys as to how the shingle may be expected to perform.

Non Product-related Failures

There is a myth that an improperly manufactured shingle is the sole reason for a roof to leak. Actually, an improperly manufactured shingle generally takes many years to result in a roof leak; whereas, improper application can cause a roof to leak during the very first rain storm. Glass fiber reinforced asphalt shingles, like any other type of roofing, need a properly designed structure and correct application to work properly. The following are the major contributors to non-product related shingle failures.

I. Deck Movement

The type and stability of the deck are critical to the performance of the shingled roof. Decks that are too light or that deflect contribute to excessive tensile forces upon the shingle that can induce a form of cyclical fatigue stress that will eventually lead to the splitting of a properly manufactured shingle.

The stability of the deck can be affected by many factors, such as exposure to moisture (improper job site storage, not dried-in properly), improper attachment of the deck to the structural supports, lack of proper joint spacing, inadequate structural support and the use of weaker or improper decks. All of these will adversely affect the performance of the shingle.

While almost all "steep" roofing is applied to nailable wood decks, occasionally some of these substrates are supported by metal decks more commonly associated with "low slope" commercial/industrial roofing. Again, as with all structural support, proper attachment of the metal deck to its supports and then the proper attachment of the nailable surface to it, is critical to the proper performance of the shingled roof.

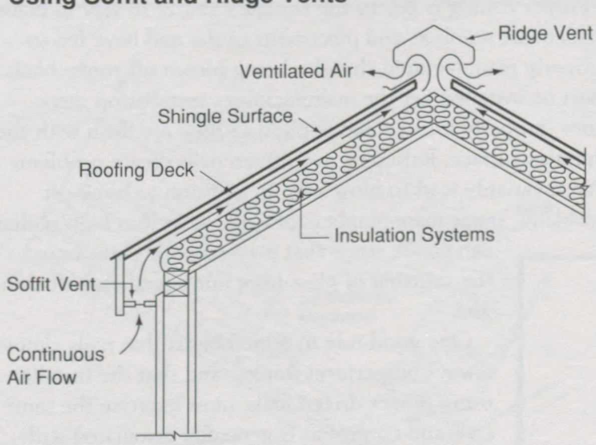
II. Lack of Proper Ventilation

The lack of proper ventilation can lead to excessive heat and moisture build-up which can adversely affect the short-term as well as the long-term shingle performance. Initially, the designer must consider the added moisture present during the construction phase which can result in buckled underlayment felt and shingles, and if severe enough, could adversely affect the deck (substrate) as well. Over time, excessive heat and moisture can lead to premature aging, resulting in a hardening of the coating asphalt as indicated by brittle shingles, visible crazing, or fine, alligator-type cracking of the shingle's surface and the eventual splitting or cracking of the shingle itself.

Of a more immediate concern, improper ventilation can contribute to greater deck movement which, in turn, can cause splitting of the shingle. Studies conducted within the roofing industry during the mid 1990s indicated that shingles applied directly to insulation or to decking which has been applied directly to insulation may accelerate the splitting phenomenon or even result in splits to shingles that otherwise might never have manifested this problem.

Recently, ventilation systems have been recommended which utilize continuous ventilation between the deck receiving the shingles and the rigid insulation. Proper design of these systems is important as continuous and adequate ventilation from eaves to ridge is necessary. Other considerations must be designed into the ventilation system whenever hips, valleys, dormers and other such constructions would impede the ventilation flow from eaves to ridge.

Air Flow Through Roof Systems Using Soffit and Ridge Vents



(Most vent systems manufacturers recommend that ridge ventilation/ventilation ratios should be between 1/300 and 1/150 with a max. of 50% at the ridge.)

ARMA "Residential Asphalt Roofing Manual," 1997 Edition.

III. Application-related Problems

Whenever a leak occurs soon after installation, it invariably is caused by improper application rather than a manufacturing defect, a problem that generally requires a few years or more to manifest itself. In most cases, the leak or leaks can be attributed to one of the following details that have either been omitted in the design stage and/or are poorly installed during the application of the roof.

A. Slope of the Roof

Shingles, while themselves watertight, are individual units, and they function to shed water from the roof. The lower the slope, the less likely the shingles are to perform this function. The standard slope for asphalt roofing shingles is 4" in 12" (4:12). On this slope and higher, manufacturers require one layer of underlayment felt. Some manufacturers will allow their shingles to be installed on slopes as low as 2" in 12", but only when extra precautions are followed, such as using two plies of underlayment and/or the use of a self-adhered membrane (commonly referred to as ice and water sheets).

One good rule to remember on slopes is that the longer the run from ridge to eaves, the more water will accumulate and, therefore, the increased need for extra precautions, perhaps even to limit the minimum slope to 4" in 12". Also, certain thick butt types of shingles may require a higher slope as well.

On mansard slopes, 21" in 12" and above, and in areas of higher wind conditions, extra fasteners and hand tabbing (sealing the shingle tab with cement at installation) are always a good procedure and generally are required by most shingle manufacturers.

B. Eaves Detail

Installation of a proper eave detail is always important, but is critical in areas of high rainfall or where leaves and/or snow are likely to accumulate on the roof. First, install a drip edge to protect the wood from possible deterioration. Where water dams can occur, either from snow and ice or leaf accumulation, a self-adhered membrane must be installed, at least a minimum of 24" inside the interior wall line, further for extreme conditions.

Additional information on the use of "Self-Adhered Membrane" in wet or snow areas, is contained in the section on "Weather Conditions" (also refer to "Proper Eaves Details for Asphalt Shingles," *Interface*, Nov. 1993).

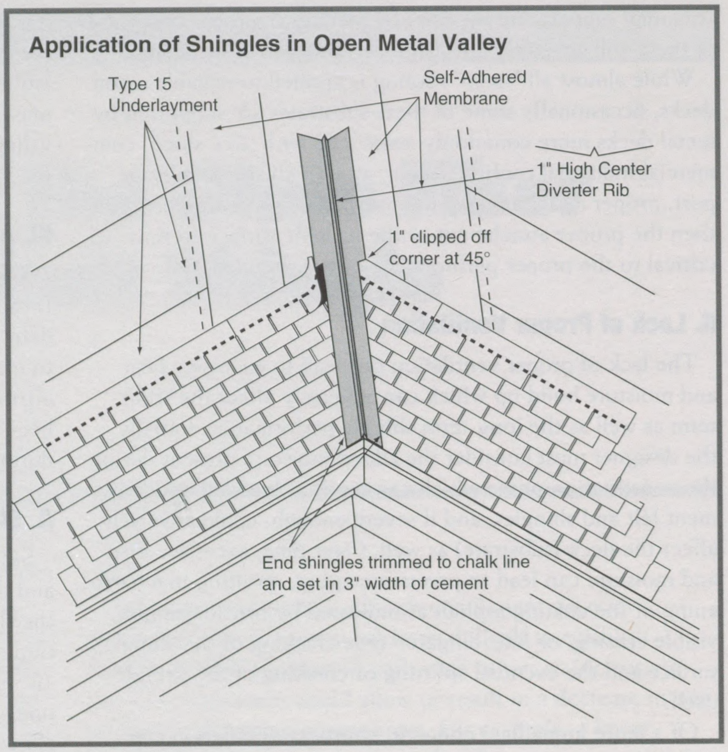
C. Valley Construction

Valleys are formed wherever two intersecting planes of the roof come together. The resulting flow line has less slope than either of the two roof planes. Proper valley construction is essential to the water tightness of the roof as the valley channels water from both slopes. The longer the roof slope, the more water will flow through the valley, making its construction even more critical.

While most applications favor the "closed-cut" valley for its durability and matching color, the open metal valley with its center diverter rib offers more control of the water flow and allows the valley area to drain better. For either valley construction, it is important to use a self-adhered membrane through the valley and at least 3 feet on both sides. For lower sloped valleys or where the run is longer, always increase the use of the self-adhered membrane to either side (see adjacent diagram).

A good rule to remember for valleys is that every shingle corner that intersects the valley must be clipped at least one inch to prevent water from flowing from the valley and running along the head lap of the shingle and ultimately causing a leak. On lower slopes, it is recommended to use mastic alongside and/or under the shingles intersecting the valley.

Additional information on the use of "Self-Adhered Membrane" is contained in the section on "Weather Conditions" (also refer to "Construction and Maintenance of Valleys in Residential Roofing," *Interface*, Jan. 1992.)



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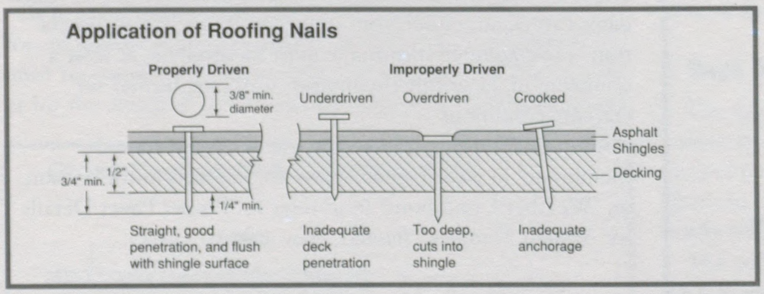
D. Flashing Details

Key areas of concern other than eaves and valleys are flashing details on roof penetrations and vertical walls, especially those associated with chimneys and skylights. When installing a flashing penetration boot or "jack," it is important to have the lower flange on top of the shingle below it so that water will be carried off on top of the shingles.

Side walls must always be flashed with individual flashing pieces of sheet metal referred to as step flashing. This is important because shingles are individual units and a continuous single piece of metal used for side wall flashing could not handle the change of thickness on succeeding rows of shingles.

Chimneys that are in the field of the roof must have a cricket installed on their high side to divert the flow of water to either side. Skylights must be installed on a curb high enough to raise them out of the field of the roof. This is important so that all key flashing details such as step flashing and crickets may be installed. A good rule to remember with flashing details is that proper use of self-adhered membranes will assist in keeping water from accessing the deck at terminations and penetrations.



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E. Proper Nailing

Proper nailing is key to the shingle's ability to stay in place. Inadequate numbers and placement of the nail have led to properly manufactured shingles being blown off roofs. Nails must be installed per the manufacturer's installation directions, properly located and applied so they are flush with the shingle's surface. Raised or overdriven nails create problems that invariably lead to blow-offs. In addition to blow-off problems, inadequate numbers of nails, as well as high nailing, can create stress that may cause or contribute to the splitting of glass fiber reinforced asphalt shingles.

One good rule to remember is that nails almost always outperform staples, and that the installer, using power-driven nails, must exercise the same care and control as is generally associated with hand nailing. The subject of "Proper Fastening" is very important. Please refer to "Proper Fastening for Self-Sealing Shingles" *RIEI Information Letter*, Spring 1992 or the *Canadian Roofing Contractor Magazine*, July 1992.

IV. Weather Conditions

Glass fiber reinforced asphalt shingles can be applied in areas of extreme conditions; however, some additional precautions need to be taken to achieve their maximum effectiveness.

A. Heavy Rainfall Areas

Shingle installation in known areas of heavy rainfall requires some extra precautions. Valleys, because of the increased volume of water, need to have special considerations.

Open valley construction using a metal valley allows water to flow better. All valleys should have self-adhered membranes installed beneath the metal valley liner as well as running a minimum of three feet to either side. For lower-sloped valleys, and where the run is longer, always increase the use of the self-adhered membrane to either side. The metal liner should be constructed of 26 gauge (min.) galvanized (or comparable), corrosion-resistant metal designed with a 1" high center diverter rib to prevent water from one slope running into and possibly under the shingles on the other side of the valley. Refer to the diagram in the section on "Valley Construction."

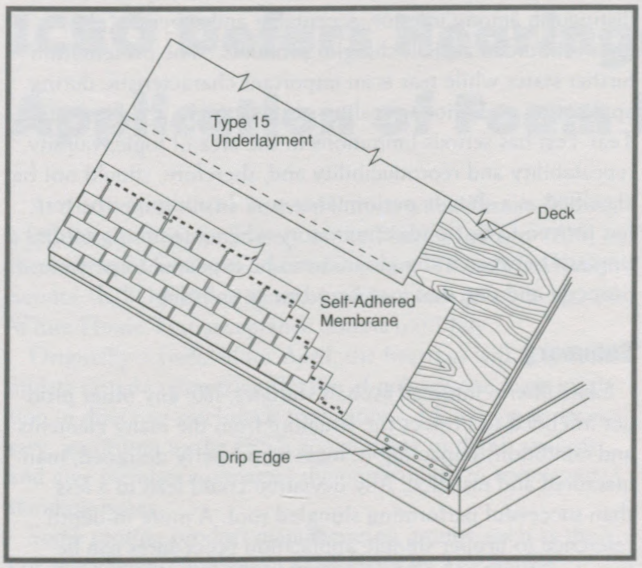
Homeowners should also be alerted to keeping leaves and other debris off of their roof, especially in valley and gutter areas. Additional information is contained in the section on "Application-Related Problems."

B. Warmer Climatic Areas

Shingles installed in warmer climatic areas can have their surfaces scuffed and damaged during pre-job storage and application. Shingle bundles should be stored in a covered area and not stacked any higher than the manufacturer's recommendation.

In hotter weather, the installer must take care not to work from or walk on previously-installed shingles. Where slopes will permit, the applicator should install the shingles from above. On higher-sloped roofs, the applicator should plan the installation to avoid the hotter temperatures of the day, typically from noon to two o'clock in the afternoon.

A good rule to follow in warm, moist climates is to use algae- (more commonly referred to as "fungus"-) resistant shingles which inhibit most algae growth (a dark brown or black surface discoloration) for a number of years.



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C. Colder Climatic Areas

In colder climatic regions, the asphalt in the shingle reaches its glass transition temperature, becoming somewhat brittle, in temperatures below 20°F and may be damaged by excessive foot traffic or abuse by flexing of the shingle during its installation. Most manufacturers recommend that their products not be installed in temperatures below 40°F.

Because of the increased potential of ice damming, self-adhered membranes must be used in all areas that ice dams could occur. These areas are typically along the eaves, around any roof penetrations and through and along the valleys. In colder climates, additional or wider applications of self-adhered membrane should be used (see drawing on this page).

Other areas where ice damming could occur should also have self-adhered membrane installed. Anticipated areas are where the sun will intersect a shaded portion of the roof such as around dormers, clerestory areas, or on sawtooth constructions, as well as other areas where local wind conditions may cause snow drifts to occur.

Snow drifts (or areas where concentrated snow loading may occur) can cause deck deflection which will lead to increased stresses upon the shingles that can ultimately lead to splits within the shingle itself. Roofs in heavy snow areas should be designed to shed the snow rather than allow it to accumulate. Possible designs could be steeper slopes or even using roofing products with slicker surfaces such as metal roofing.

In areas of extreme loading conditions, the deck should be designed with increased structural support to accommodate the expected additional loading. Under certain conditions, it may be advisable to construct a "cold roof" which would keep the snow from melting from below (which could lead to ice dams and resultant roof leaks). Ice dams, in addition to causing roof leaks, can also create a "scouring" effect through a glacier-type movement. This movement not only will dislodge the shingle's protective granular surface, it will put the shingle itself under tension and ultimately cause it to split.

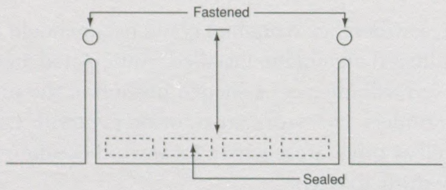
One good rule to remember for colder areas is to never get up on the roof during cold, snowy conditions. It is not only unsafe, but any action such as shoveling the roof will lead to direct damage of the shingle itself. (Also refer to "Water Dams: Up North It's Ice, Down South It's Pine Needles," *Interface*, Jan. 1997.)

The Fiber Glass Splitting Phenomenon

The roofing industry has experienced a splitting or cracking phenomenon of the glass fiber reinforced asphalt-based shingle. This splitting has occurred in a relatively small percentage of the shingles produced. A survey conducted by the Asphalt Roofing Manufacturers Association (ARMA) indicated that during a 10-year period from 1981 to 1990, less than 0.1 percent of the glass fiber reinforced asphalt shingles had any problems and that less than 0.03 percent were identified as having split or cracked. This splitting phenomenon is a result of the shingle's inability to withstand the thermal and/or mechanical cycles of stress exerted upon it. This stress induces a shingle split, either from a weakness within the shingle itself or, more likely, caused by a number of non-shingle related problems. Over a period of time, these cycles of stress cause the shingle to fatigue and finally result in a splitting of the shingle. This repeated stress is called cyclic fatigue, with stress cycling between tension and compression.

The occurrence of diagonal splits may or may not be significant due to the random nature of the fiber glass reinforcement strands in the fiber glass mat. The direction taken by splits can be further confused by high and/or missing fasteners. However, vertical and/or horizontal splits can almost

Cyclic Fatigue.
Cycling between tension and compression.



always be traced to deck (substrate) movement.

Because shingles are nailed to the deck and then sealed between adjoining courses, their movement is restricted. As a result, cyclic fatigue stress loads occur within the shingle as it expands and contracts due to either thermal or mechanical stress. The shingle's ability to withstand splitting from this cyclic fatigue stress is a function of the shingle's resistance to tensile stress. This ability continues to decrease as the shingle ages from exposure to natural conditions such as heat, cold, water and ultraviolet rays. How successful the shingle resists this stress is also controlled to a greater degree by factors which are non-shingle related and are external to the shingle's own construction. These non-shingle factors that contribute to or cause splitting of the shingle are substrate movement, lack of proper ventilation and moisture control, and incomplete and/or high fastening.

Investigations have shown that the splits in the shingles have no correlation to the underlayment felts which may not have split. Reasons for this lack of correlation are because shingles are designed to be fairly rigid, constructed with a harder asphalt and filler, are nailed and sealed in place and are exposed to the elements. Felts, on the other hand, are designed to be rolled out, contain a soft, saturating asphalt, are not sealed, and are protected from the weather.

The industry continues to pursue a test procedure that will demonstrate a shingle's ability to resist splitting when properly manufactured and applied. Among these tests are those for flex tensile strength/elongation and tensile cyclic fatigue.

(Also refer to "Cyclic Fatigue Test As a Method for Distinguishing Between Cracking and Non-cracking Shingles,," by M.M. Datta and R.L. Corbin, *ASTM STP 1224, Roofing Research and Standard Development*, 3rd Volume.)

Tear Test Myth

The tear test was first developed to identify fiber glass mats that could reduce or eliminate the tearing of the shingle during its application and prior to its sealing.

The Elmendorf Tear Test, originally used by the paper industry, was adopted by one or two manufacturers in the roofing industry in an attempt to distinguish between the earlier-dry process fiber glass mats themselves, and later, the shingles containing the dry process mat. The test was somewhat difficult to read even with the fairly linear, machine-direction oriented dry process mat. Test repeatability was also difficult, as the mat would tend to tear (zipper) off to the side, giving a false reading.

In ASTM D 3462, the Elmendorf Tear Test is listed as 1700 grams minimum tear for "as manufactured" shingles. A minimum tear has not been developed for aged shingles.

The 1700 gram guideline, while a somewhat reasonable guideline with the earlier dry process mats, became meaningless with today's wet process mat with its superior distribution of the glass fiber and "square" characteristics of almost equal strengths in both machine and cross machine directions.

As the industry moved from the dry process to the superior wet process mat, the tear test proved to be inadequate in determining the strength of the improved reinforcement that is now an integral part of today's glass fiber reinforced asphalt shingle. The tear test, while difficult to achieve consistent readings with the dry mat, became nearly impossible to read with the wet process mat.

In a presentation at the Fourth International Symposium on Roofing Technology, A. Phillips indicated that the results from the Elmendorf Tear Test make it "extremely difficult to distinguish among inferior, acceptable and superior (glass fiber reinforced asphalt shingle) products." The presentation further states while tear is an important characteristic during application and prior to sealing of the shingle, the Elmendorf Tear Test has serious limitations in the area of logic, validity, repeatability and reproducibility and, therefore, should not be classified as a shingle performance test. In addition, the test has proven to be nondiscriminatory when attempting to distinguish between a shingle that can be expected to perform properly and one that may be prone to splitting.

Summary

Glass fiber reinforced asphalt shingles, like any other product intended to protect the structure from the many elements and conditions impacting it, must be properly designed, manufactured and installed. Any deviation could lead to a less than successful performing shingled roof. A more in-depth reference to proper shingle application procedures can be found in the *Residential Asphalt Roofing Manual*, 1997 Edition, by the Asphalt Roofing Manufacturers Association.

Articles for Further Reading

"Cold Weather Recommendations for Application of Asphalt Roofing Shingles," *ARMA Technical Bulletin*.

Corbin, R. L., "Construction and Maintenance of Valleys in Residential Roofing," *Interface*, Jan. 1992.

Corbin, R. L., "Proper Fastening for Self-Sealing Shingles," *RIEI Information Letter*, Mar. 1992.

Corbin, R. L., "Let's Pay Attention to Shingle Flashing Details," *Interface*, Sept. 1992.

Corbin, R. L., "Proper Shingle Application— How Important Is It?" *Interface*, July 1993.

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Corbin, R. L., "Cyclic Fatigue Test as a Method for Distinguishing Between Cracking and Non-cracking Shingles," *ASTM Roof Research and Standards Development*, 3rd Volume, STP 1224, May 1994.

Corbin, R. L., "Sealing of Asphalt Shingles," *Interface*, Nov. 1994.

Corbin, R. L., "Today's Asphalt Roofing Shingle," *Interface*, Jan. 1995.

Corbin, R. L., "The Need for Underlayment Felt with Asphalt Shingles," *Interface*, Aug. 1995.

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Phillips, Aaron, R., *Residential Asphalt Roofing Manual*, 1997 Edition, ARMA.

Phillips, Aaron, R., "The Apt Model for Assessment of Prospective Shingle Performance Test Methods," NIST/NRCA, *4th International Roofing Technology Symposium*, Sept., 1997.

"Preventing Damage from Ice Dams," *ARMA Technical Bulletin*.

"Ventilation for Residential Roofing, Heat and Moisture Control," *ARMA Technical Bulletin*.

About The Author

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***Ray Corbin** is Director of the Better Understanding of Roofing Systems Institute (BURSI). A 25-plus year national educational program on roofing systems, designed for architects, engineers, and building owners, BURSI is sponsored by Johns Manville.*

Corbin holds four US patents for roofing shingle design and application. He is a faculty member of the Roofing Industry Educational Institute (RIEI) and has served as Chairman of the Code Committee for the Asphalt Roofing Manufacturer's Association (ARMA). He has published numerous technical articles and is a regular contributor to Interface.

This article is based upon the author's years in the roofing industry since 1961 as a research specialist, a shingle designer and one who has also applied a large number of roofs while researching shingle design and proper application procedures. Corbin was personally involved in the original development of the glass fiber reinforced shingle and was one of the earlier developers of the process, style, color and application of the multidimensional laminated shingle. He actively participated in the change from the dry process mat to today's wet process mat. He is one of two people responsible for developing and using the tear test.

ICBO Defers Hearings on Direct-to-deck Application of Foam Plastic Insulation

At the request of the Foamed Polystyrene Alliance (FPSA), a business unit of the Society of the Plastics Industry (SPI), the International Conference of Building Officials Evaluation Service (ICBO ES) has agreed to defer hearings on proposed White House Test acceptance criteria until July.

Originally scheduled for April, the hearings will help to formulate criteria permitting the use of polystyrene foam insulation in direct-to-steel-deck applications. More time is necessary, according to the FPSA, to complete in-depth analysis and give member companies the opportunity to review outstanding issues.

Some roofing product manufacturing groups, such as the Polyisocyanurate Insulation Manufacturers Association (PIMA), have opposed ICBO ES acceptance of new fire testing methods for such application (See "Letters to the Editor," July 1997 issue, *Interface*).

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