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CONCRETE AND CLAY TILE

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THE JOURNAL OF RCI, THE INSTITUTE OF ROOFING, WATERPROOFING, & BUILDING ENVELOPE PROFESSIONALS

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About This Issue: For most of the 20th Century, concrete and clay tile roofs were used primarily in the southwestern United States. Over the last decade, however, their use has become popular throughout the U.S. and Canada.

On The Cover: The photo on the cover was taken in St. Petersburg, Florida, and it is Ludowici's Spanish tile in 65% clay red, 25% briar brown, and 10% Hawaiian gold. Courtesy of the Tile Roofing Institute and Ludowici Roof Tile.

Gary R. Cattel, RRC, PE
President

What's the Question?

At the risk of personal injury, I have delayed writing this message until the conclusion of the tenth annual Building Envelope Symposium (BES) that RCI held in Washington D.C. these past two days. (The physical harm comes from my deadline with the tenacious Kris Ammerman, the unflappable editor of *Interface*.) Under the selfless efforts of Tom Hutchinson and Bill Waterston, co-chairs of the BES event, we had two jam-packed days of high-quality programs worth a total of 12 CEHs. It was a timely event in that many of us don't obtain sufficient continuing education credits early enough in the year to fulfill our professional requirements. The theme was, "Maintaining the Building Envelope of Aging Buildings" and delivered on all counts, thanks to the efforts of the many presenters. Total attendance came in at 164, with participants from across the continent.

Just another successful BES, you might be thinking. Not so fast. What this actually represents is RCI's commitment to the waterproofing and building envelope professions that fulfills its updated thinking and new charge. More importantly, this symposium clearly illustrated to me how RCI has been tremendously beneficial to professional growth in the roof consulting industry all along and is now moving forward in the related fields of waterproofing and the building envelope.

When I first joined RCI, I was naïve enough to think I knew it all (or at least a good bit of it) and was primarily concerned with being left behind if I didn't obtain the professional credentials RCI offered. Boy, was I wrong! Through the programs, networking, and opportunities presented by being an active member of the Institute, my technical knowledge and understanding of this profession have grown considerably over these past 18 years.

When my involvement with RCI began, not only did new ideas, information, clarity, and confirmation ensue, but more important than answering questions, RCI provided exposure to questions I previously didn't even know to ask. The recently concluded BES program drove home this point all too clearly. Although closely related to roofing, the disciplines of waterproofing and building envelopes are intricate subjects that will take further commitment to understand in order to become a competent consultant in selected areas of these vast fields of endeavor. RCI has once again come through with the programs that help educate our members. Although there was a lot to learn by attending, it was vividly apparent that there are far more questions yet to be asked.

Bottom line: although there is a myriad of questions still to be discovered, there appears to be a universal answer to all of those questions. That answer: RCI.

Through the continued effort of many volunteers and our dedicated staff at headquarters, we can be confident that our Institute will continue to educate and meet the challenges of the complex and demanding professions of the waterproofing and building envelope disciplines.

See you next November 8 and 9, 2007, in Boston, where we'll answer some more questions revolving around the theme of "Designing, Detailing, and Specifying the Building Envelope Today and Tomorrow."

All the best,

Gary

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Doorways to the Future

22nd International Convention & Trade Show

RCI, Inc. - The Institute of Roofing, Waterproofing, & Building Envelope Professionals

Trade Show
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TILE ROOF SYSTEMS:

Analysis and Inspection Techniques for Roof Consultants

By Robert L. Fulmer

Known throughout the world as one of the most enduring and classic roof systems, tile has a global popularity and history that is unlike any other roofing material.

While some basic elements of tile roofing have been a part of the world's architectural legacy for thousands of years, our more recent past has seen significant growth and change within the industry (*Photo 1*).

In the United States, areas of regional popularity were established by colonial settlers where tile still dominates today. However, tile has traditionally been less common here than in many other countries. For example, tile products comprise 86% of the European residential roofing market compared to 6% of the U.S. market.

In the comparatively young American roof tile industry, the popularity of the material within the past two hundred years has fluctuated. The changing popularity of specific architectural styles, the development of the slate roofing industry along the east coast, and competition from new roofing products that are lighter and less expensive, all have adversely affected the popularity of tile at times.

However, the U.S. tile market is again changing as the use of tile increases with its versatility. Technological improvements have combined with tile roofing's classic aesthetics to create more versatile products with some of the longest service lives in the industry. For example, new underlayments and cold roof construction technology now make tile suitable for use in cold climates with heavy snowfall. Tile's excellent seismic

Photo 1 – Flat clay tile on a dome at the Pantheon, Rome, Italy. Photo by Robert L. Fulmer.

Photo 2 – Flat clay tile in the Piazza del Popolo, Rome, Italy. Photo courtesy of Robert L. Fulmer.

performance characteristics make it useable in earthquake-prone regions. Although large urban conflagrations are not the threat they were during the eighteenth and nineteenth centuries, tile's lack of combustibility makes it an ideal material in areas susceptible to wildfires. A tile system's excellent wind resistance combined with modern attachment methods make it suitable for use in regions with hurricane potential.

The increased versatility of the product and technological progress have created greater market growth potential than ever before in the U.S. tile market. The result of this growth is the creation of new materials, testing procedures, codes, and standards. For consultants and other industry professionals, now more than ever it has become essential to obtain the specialized education and training to keep current with the changes in tile roofing. But to understand where we are now in the industry, it is necessary to know the basic history and evolution of tile roofing.

A BRIEF HISTORY OF TILE ROOFING

The origin of clay roofing tile is linked to the development of pottery within two of the world's greatest early civilizations. The first was in China during the Neolithic Age (the last phase of the Stone Age) at about 10,000 BC, and the second was in the Middle East by 6,000 BC. During these periods, humans began to move from life in small groups to large tribal clan communities. For the buildings within these larger, more densely-populated communities, tile roofing played a vital dual role that remains valid today. First, it was an effective means to shed water from buildings, and secondly, it reduced the spread of fire.

From China and the Middle East, the use of clay tile spread throughout Asia and Europe. Although tile roofs were used by the Assyrians, Egyptians, and Babylonians, it was the Greek and Roman civilizations that elevated roofing tiles (known as Tegula) from crude, hand-made objects in clay to an art form (*Photo 2*).

We tend to think of some attributes of tile roofing, such as the ability to re-lay or re-use the material from one roof to another or the manufacture of tile in materials other than clay as relatively modern developments. In reality, the Greek Byzes of Naxos first introduced tile made of Pentelic marble in 620 BC for use on the great temples such as the temple of Jupiter at Olympia and the Parthenon at Athens. Even more spectacular tile was created from solid bronze and gilt for the construction of the Pantheon in Rome. These tiles survived until the seventeenth century before being melted down by Pope Urban VIII to make cannons. This was not the first, but certainly one of the most poorly engineered reuses of tile, as the quality of the precious metals content turned out to be too high (soft) for cannons.

The first documented (and semi-legitimate) re-use of tile occurred in 231 when the Roman censor Fulvius Flaccus removed some marble roof tile from the Greek temple of the Lacinian Juno for use on another temple he was building in Rome. Hence, not all of our "modern" techniques are new. The Romans used tile roofing throughout their empire. In Europe, the popularity of clay tile grew due to an abundance of clay deposits

providing the raw materials and again offering a level of protection against the spread of fire.

Later, as European settlers came to America, they brought their roofing trades with them. Clay tiles have been found in the ruins of the 1585 settlement of Sir Walter Raleigh on Roanoke Island, North Carolina. This was England's first settlement in the "New World." The Spanish used tile in their early settlements at St. Augustine, Fla., and New Orleans, La.

At first, Dutch settlers on the east coast imported clay tiles from Holland. By 1650, however, they had established a production facility in the upper Hudson River valley, shipping tile down the Hudson to "New Amsterdam." By the beginning of the Revolutionary War, there were several tile manufacturers in the New York City area offering colored, glazed, and terra-cotta tile. On the west coast, tile was being produced by 1780 at Mission San Antonio de Padua in California by Spanish missionaries.

In Colonial America, tile was popular for the same reasons that were relevant during the Neolithic period. The materials were readily available and they were fire-proof. The latter helped address a near hysteria about fire in colonial American cities. After devastating fires in London in 1666 and Boston in 1679, the first building and fire codes were established in New York and Boston. These codes encouraged the use of tile roofs and remained in effect for almost two hundred years. By the 1830s, however, clay tile was temporarily out of fashion. Competition with slate along the east coast and new metal products that looked like tile became significant (*Photo 3*).

But the mid 19th century brought the popular new architectural style of "Italianate Villa," and with it, new popularity for clay tile. New production facilities sprang up. Gladding, McBean and Co. in California in 1875, the Celadon Roofing Tile Co. in Alfred, New York in 1888, and Heinz Co. in 1911 were a few of the larger, enduring producers.

The Industrial Age brought a flurry of new patents and industry changes. In 1870, the first tile-making machines were patented, along with the first of the interlocking tiles by J.G. Hughes in 1871. Refinements were being made in production of metal "tile."

But by far the most significant development in the tile industry since the Greeks and Romans occurred in 1848, when a German farmer named Adolph Kroher

Photo 3 – Process of replacing original Ludowici Celadon clay Spanish tile (initially installed at the turn of the 20th century) with new tile by the same manufacturer on an historic hotel in upstate New York (the original tile came from Celadon's plant in Alfred, NY). Photo by Robert L. Fulmer.

introduced concrete tile. Commercial production began in Bavaria shortly thereafter. Concrete tiles were introduced to England, Holland, and other European countries by the early 1900s. Automated production began, along with the practice of adding coloring pigments to imitate clay tile. By the late 1920s, concrete tile was a permanent part of the American tile industry, competing as a product that was lighter and less expensive than clay.

Today, both concrete and clay constitute the roof tile market. Our current technologies, new products, codes, and standards continue to be developed with both products in mind.

These relatively recent developments within the industry have created a changing and increasingly complex environment, developing new challenges for the consultants and others who will be evaluating tile roof systems.

THE ROLE OF THE ROOF CONSULTANT

Roof consultants may become involved with tile systems in a number of ways. A client may request an inspection to locate current leakage or to evaluate remaining service life of a tile system. Owners of larger tile roofs may require maintenance planning or project management. Problems that occur in tile systems prior to the end of their service life may be the result of installation errors or extreme environmental occurrences. In many cases involving construction defects, the consultant may testify as an expert witness in arbitration or litigation.

In all of these scenarios, the consultant must fulfill two primary responsibilities. First, he or she must understand the system and product involved. Secondly, all of the facts must be gathered correctly and objectively. In conducting any tile roof inspection, there are four essential questions that, when answered, will provide the basis for our observations and opinions:

1. What is the problem and how did it happen (i.e., installation errors, material defects, design flaws, lack of maintenance, etc.).
2. When were the tiles installed? The age of the building is a good but not absolute indicator.
3. How was the roof installed? Which method(s) and materials were utilized?
4. What are the applicable codes and manufacturer's installation instructions?

In finding the answers to these basic questions, other relevant information is often discovered that creates a complete assessment. The result should be a thorough, accurate, well-documented opinion or report.

Next we'll discuss some tile basics for background information as well as identifying sources for specific and detailed information.

Photo 4 – Clay overlapping (flat shingle) tile exhibiting signs of water absorption. Photo by Robert L. Fulmer.

TILE TYPES AND SYSTEMS

Knowing the type, the manufacturer, and the age of the tile are among the most critical pieces of information one can obtain from an inspection. Determining the type and manufacturer can be as simple as reading the inscription on the underside of the tile or it can be as frustrating as trying to identify a small regional manufacturer that went out of business 75 years ago.

Predominantly, there are two types of roofing tiles – overlapping and interlocking. Interlocking tiles are designed to be installed in pairs with an extrusion on one tile that is designed to "lock" over the other tile, securing both. Overlapping tiles don't have a locking side and are generally nailed in place. There are a number of tile shapes and profiles, but most fall into two categories – pantiles and flat tiles. Pantiles consist of two half cylinders, where one is attached to the roof deck or battens and the second is inverted and overlaps the upturned edge of the first. These comprise the most common profiles associated with tile roofing – i.e., Spanish, mission, or barrel tile. Flat tile can be either completely flat (no extrusion or lock), or it can be interlocking on the top and one side (*Photo 4*).

These standard shapes may be known by different names in a different part of the country or the world.

Over the past 100 years, roof tiles have been made from a variety of materials, including clay, concrete, sheet metal, fiber cement, and composites. Of these, clay and concrete are the most popular and predominantly used materials.

All this information about tile types, shapes, materials, and manufacturers can be confusing. Remember that there are few individuals who can correctly identify all tile manufacturers at a glance. The important concept here is to use all these individual tile characteristics in our forensic investigation to correctly identify tile type, condition, and manufacturer. While the significance of type and condition are obvious, why is identifying the manufacturer important?

Almost every manufacturer has historically published installation instructions for its products. In cases of problematic tile systems where installation errors are suspected, these guides provide documentation of recommended or published procedures. In addition, tile manufacturers can help determine the approximate age of a particular tile, based on their production records. Manufacturers also provide a key piece of information for maintenance planning when they publish the service life for their products. Knowing the service life of the tile is critical for maintenance cost projections and determining repair or replace options.

When identifying tile and tile manufacturers, look at the obvious first. Is this a familiar looking tile? Are there other tile roofs in the area that look the same and may be well documented? In the case of newer concrete and clay tile, construction records may be available. If not, consider the geographic location. Tiles are heavy and expensive to ship; consider the manufacturers and distributors closest to the building. Most tile manufacturers will evaluate a sample tile or identify with close-up photos. In the case of older or historic tile, one of the best references available is the book, *Historic and Obsolete Roofing Tile* by Vincent Hobson and Melvin Mann. [Editor's Note: This book is available from RCI's publications list.] The book contains histories of all the early major tile manufacturers in the U.S. as well as hundreds of scaled, color photographs of individual tile.

By determining tile type, condition, and manufacturer, we should have sufficient information to answer three of the essential inspection questions. The remaining question is, "what are the applicable codes and manufacturer's installation instructions?"

INDUSTRY STANDARDS AND INSTALLATION METHODS

Industry standards and installation guidelines are the tools consultants use to evaluate the integrity, quality, and code compliance of a tile roof installation. The purpose of these guidelines is to provide a level of quality and standardization for the manufacture, testing, and installation of tile. They are also critical elements in construction litigation, often validating the consultant's position and observations. Roofing tile has more than its share of acronyms for the myriad codes, standards, and organizations representing the industry. While addressing all of the standards organizations that include tile roofing would be overwhelming, a chronology of some of the more relevant organizations is as follows.

ASTM International (American Society for Testing and Materials) is one of the oldest and largest voluntary standard development organizations in the world. Founded in 1898, over the years, ASTM developed ASTM C-1167 standards for clay tile roofing and ASTM C-1492 for concrete tile. The written standards for both include standard specification for materials and manufacture, tests for wind uplift, and standards for terminology. In addition, a grading system is established for "resistance to frost."

The ICC (International Code Council) was established in 1994 as a non-profit organization that develops comprehensive natural model construction codes. It was founded by BOCA (Building Officials and Code Administrators International), the ICBO (International Conference of Building Officials), and SBCCI (Southern Building Code Congress International). These three organizations had been operating independently since the early part of the last century, developing regional codes. The formation of the ICC combined their expertise into one source. Consultants and other industry professionals benefit by working with one set of codes (ICC) as opposed to three different sets of standards prior to 1994. One of the most relevant ICC services is its evaluation report (ICC-ES). The ES reports objectively evaluate code-compliant materials and installation methods and are available on the ICC Web site.

In 1987, the Roof Tile Committee of FRSA (the Florida Roofing, Sheet Metal and Air Conditioning Contractors Association) and the NTRMA (National Tile Roofing Manufacturers Association) co-wrote consensus standards for the installation of concrete and clay roof tiles. This effort, over the course of ten years, produced the *Concrete and Clay Roof Tile Installation Manual*, one of the most comprehensive sets of tile standards. Prior to 2001, individual manufacturers wrote their own installation standards. At that time there were 58 separate standards. The NTRMA manuals consolidate them into one source. The NTRMA also produced the manuals, *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions* in conjunction with the Western States Roofing Contractors Association (WSRCA) and also the *Moderate Climate Installation Guide*.

In addition, NTRMA teamed up with the University of Southern California to conduct studies and tests of the seismic performance of concrete and clay roofing tile. In the only study of its kind, earthquake conditions were reproduced on four of the most commonly used tile systems. The results revealed that when installed in accordance with current code, these systems cannot only meet UBC (Uniform Building Code) standards for seismic load requirements of tile, but they are capable of withstanding a quake almost double the intensity of the 1994 Northridge quake, which measure 6.7 on the Richter Scale.

The NTRMA has recently changed its name to the Roof Tile Institute (RTI) and it continues to be one of the best sources for tile information and technical support. No discussion of tile standards would be complete without mentioning the SBC (Standard Building Code) and the FBC (Florida Building Code). The SBC has been the fundamental basis for tile installation for quite some time, and because of the hurricane exposure, the FBC has some of the most stringent "wind uplift" requirements in the nation.

The number and quality of standards and code organizations provide an excellent benchmark for materials, manufacture, and installation, and are valuable technical and documentation resources for the consultant.

THE INSPECTION PROCESS

Tile systems are unique, and as a result, their inspection presents challenges and characteristics unlike any other roof. All roofing tiles are not created equally, nor do they fail equally. One of the most critical challenges before the tile expert is the accurate determination of the reasons behind a tile system's failure. In other words, "what

is the problem and how did it happen?"

As with most forensic roof investigations, the inspection begins by accessing the roof in order to evaluate its components. Again we need to answer the questions, what type of tile is it? What point has the system reached within its service life? Are there problems, and if so, are they normally occurring, the result of environmental factors, or premature failure.

One of the more common misunderstandings about tile is how various systems age. For the most part, this is a direct result of the hardness of the tile. Both concrete and clay tile are porous in varying degrees. It is porosity and the resulting water absorption that weaken the tile over time. Water saturation in concrete tile increases over the life of the tile, accelerated by erosion of the cement and exposure of the mix aggregate. Toward the end of the concrete tile's service life, efflorescence can form on the underside of the tile prior to complete saturation. After saturation, water then drips off of the underside of the tile. In the latter portion of this process, most concrete tiles are too soft to walk on. Clay tiles exhibit different characteristics toward the end of their service lives.

Clay tiles also absorb water; however, porosity is a function of the density of the clay used and the vitrification process. Vitrification is the process that turns clay to glass by applying heat (firing). Clay tiles that are not thoroughly vitrified are softer and consequently possess a shorter service life. Freeze/thaw cycles in colder climates cause spalling when moisture expands as it freezes. Spalling and flaking are the result of normal water absorption and wear process. Flaking begins on the surface of the tile and continues throughout the life of the tile until the flaking wears completely through. The presence of these elements is sometimes incorrectly diagnosed as tile failure. During examination of a representative number of tiles, the flaking should be dislodged. If algae or lichen are present under the flaking, the process is a slow, natural one. If bright, clean clay is exposed, the process is accelerated and newer. This could be the result of environmental factors (i.e., hail damage, excessive hot and cold temperature variation), or it could indicate premature tile failure.

Another common "normal" failure peculiar to clay tile is cracking in older tiles. Occasionally, the clay may not have been properly worked prior to firing. During firing, the clay will then shrink, causing small cracks – some barely visible. As these tiles age, the cracks can become pronounced, providing sources of increased water absorption and possibly breakage.

A key point of misunderstanding in diagnosing a clay or concrete tile system is that any of the potential reasons of failure discussed thus far do not necessarily represent a system failure. Too often, an inspector will encounter one or more of these conditions in a single test area or small section of the roof. The erroneous assumption is made that the entire system has failed, when in fact the problems may be isolated. Examples of isolated failures could be the result of improper aggregate/mortar mixes in a single batch of concrete tile, improper vitrification in a single batch of clay tile, or repairs to a roof section using older salvaged tile. This underscores the importance of testing multiple areas of the roof system upon discovery of these problems to verify whether they are systemic or isolated issues. This could mean the difference between recommendations of spot repairs versus an entire roof replacement, a particularly important consideration on historically significant buildings.

Tile systems overall have excellent resistance to environmental effects. However, severe environments can affect tile in varying degrees. For example, small hail doesn't affect most tiles. However, large hail has different effects on various types of tile. Both concrete and clay tile in the latter portions of their service life are softer and large hail can pass entirely through or knock out large sections of the tile. Hard clay tile are normally completely shattered or cracked; hail will seldom pass through them. Newer concrete tile may exhibit chipped edges or broken corners from medium to large hail.

Wind damage to a tile roof is fairly evident. Tile that have shifted out of place or have blown completely off are an indication. The consultant should verify proper exposure of the tile courses in the case of wind uplift damage, as excessive exposure increases the "overturning" moment of the tile. Proper fastening methods in compliance with RTI and applicable regional standards should also be verified.

Certain environmental factors that adversely affect other roof systems have only aesthetic effects on tile. For example, algae or moss growth can be pressure-washed off the tile. Efflorescence of soluble salts is fairly common on concrete tile. It is the result of lime and water reactions in the material that release calcium hydroxide. The reaction with carbon dioxide and rain eventually washes it away.

Other significant components included in an inspection are the methods of tile attachment, type of underlayments, and flashing details. The focus should again be on obvious indications of age and condition, viewing these components through multiple test areas. Although there are regional variations of installation methods and types of materials for these components, they should be compliant with RTI or the manufacturer's specific installation guidelines as well as any applicable regional codes or standards.

Having discussed potential problems and proper diagnosis of tile roof systems, how should the roof be physically accessed to perform the forensic testing? As mentioned earlier, some tile roofs can be walked on and some can't. But as in any roof inspection, personal safety is the first priority. People inspecting any steep slope system should utilize a body harness and a properly secured lifeline. Once on the tile, however, proper weight distribution is key to minimizing damage. Walk as little as possible on the tiles themselves. When walking on tile becomes necessary, step only on the butts or lower three inches of the tile. This is the "headlap" area with the most supporting material. To access the roof system for test areas, some sort of scaffold or work area is often required. On lower roof pitches, sandbags supporting secured plywood can provide a stable work area. On steeper pitches, roof brackets designed for slate roofing work well, providing a continuous 1x10 or 1x12 is placed under the metal brackets to distribute the weight.

Again, the key premise to any roof inspection is personal safety as the first priority.

HURRICANE CHARLEY

As discussed, tile roof systems have one of the best performance records in the industry. This is also one consultant's opinion after an extensive inspection of tile systems following an extreme weather event.

On Friday, August 13, 2004, at 3:45 p.m., Hurricane Charley made landfall at Cayo Costa, Florida (just west of Cape Coral) as a category 4 storm. Its winds were estimated at 145 mph and measured at 111 mph before an equipment failure at Punta Gorda airport. Charley continued its northeast track across De Soto, Hardee, Polk, and Osceola counties. The storm emerged off the Volusia County coast and back into

Photo 5 – Example of a ridge tile failure in a concrete tile roof system. Photo courtesy of Warren French.

the Atlantic on Saturday, August 14. Taking just nine hours to traverse the Florida peninsula, it was the strongest hurricane to make landfall in the state since Hurricane Andrew in 1992.

Shortly after the storm, RCI member Warren French, PE, of French Engineering retraced the path of the storm to study tile performance during the hurricane. As part of the RICOWI (Roof Industry Committee on Weather Issues) team, Warren began his assessments in the Port Charlotte/Punta Gorda areas and provided the following information. The most destruction to buildings from Charley occurred within a narrow band following the storm track from Punta Gorda northeasterly across the state to Daytona Beach. One to two miles from the center of the storm track, most damage went from heavy to moderate. Virtually all of the tile encountered was concrete with only one clay tile roof examined. Of particular interest was how the various attachment methods of the tile performed in such a severe wind event. Because Punta Gorda is an older community, most tile roofs were older, mortar-set concrete tile. Overall, system performance of the older, mortar-set tiles was the poorest. Mortar deterioration and subsequent loss of adhesion resulted in either substantial numbers of tile blown from the roof deck, or completely missing rakes and ridges (*Photo 5*).

Mechanically fastened tile systems fared better than the older mortar set. They performed well, up to 110 mph. However, above those wind speeds, wind uplift failure occurred, with the resulting impact damage (damage caused by airborne tile and tile debris impacting the roof). On one four-story building inspected, the tile lost to wind uplift blew over the ridge and broke tile on the opposite side of the roof. As the hurricane passed and the wind direction changed, the debris was blown back over the ridge, further damaging the tile on the roof elevation from which they originated.

Overall, new "foam-set" tile systems performed well. Most properly installed systems only received impact damage from other flying debris. Exceptions in this system's performance occurred for two reasons:

1. Failure of the ridge tile occurred on roofs that did not use a ridge nailer board, but relied on mortar without fasteners.
2. The second failure source was an installation error occurring when the two-part foam mix was improperly mixed, resulting in the foam being either "part A rich" or "part B rich" (*Photo 6*).

For the most part, on the roofs inspected, installation problems were minimal. In addition to the problems described above, the other significant installation error occurred when exposure of the tile courses was stretched. This resulted in an excessive overturning moment with the resulting uplift loss.

Photo 6 – Upper concrete tile roof exhibiting partial failure of the "foam-set" system, possibly due to an improper foam mix. Lower roof exhibiting damage from flying debris. Photo courtesy of Warren French.

Observations of the surviving tile were made in comparison with ASCE (American Society of Civil Engineers) standard 7-02. The wind load provision within this standard addresses "corner conditions" damage to tile as well as wind force and uplift moment effects on ridges, rakes, and eaves.

Overall, while tile systems did sustain damage, they outperformed most other roofs within the path of one of the fiercest hurricanes in Florida's recent weather history. Extreme weather events like Hurricane Charley highlight some of the best characteristics of tile roofing. Excellent performance and versatility combined with classic aesthetics separates tile as a truly unique roof system.

The inspection and reporting process for tile roof systems can be challenging and interesting. A working knowledge of the product and its qualities, as well as the effects of age, weather, and other factors, will allow professionals to accurately diagnose the issues involved in tile roof system failures.

Editor's Note: This article was originally published as part of the Proceedings of the RCI 20th International Convention & Trade Show *from March 31- April 5, 2005, in Miami Beach, Florida.*

Robert Fulmer

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Steep-Slope Assembly Testing of Clay and Concrete Tile Roofs

Part I of II

By William A. Miller, PhD, PE

This is the first of a two-part series. This section addresses the effects of cool color pigments on solar reflectance and reviews the effects of climatic soiling. The reasons and methods behind a three-year regimen of testing of sample roof systems are discussed and performance metrics will be presented in a second article showing the effectiveness of cool color pigments on clay and concrete tiles. The study was done for the California Energy Commission and is published with the approval of CEC. An abbreviated report from the study was delivered at the RCI Foundation's 2005 Cool Roofing...Cutting Through the Glare Symposium in Atlanta. The second part of this article will be published in the January 2007 issue of Interface.

A new generation of roofing products is being introduced that will bring relief to homeowners and utilities alike. Cool color pigments used to color paints are reducing the amount of energy needed to cool buildings, which in turn helps power companies to reduce hot-weather energy consumption. Cool color pigments will also positively impact the environment by helping reduce carbon dioxide emissions, metropolitan heat build-up, and urban smog.

Industry researchers, including those working with the Department of Defense, developed the first prototype cool color pigments for military camouflage to closely match the near-infrared reflectance of background foliage. The high infrared reflectance of these pigments can be exploited to manufacture roofing materials that reflect more sunlight than conventionally pigmented roofing products. Therefore, Oak Ridge National Laboratory (ORNL) and the Lawrence Berkeley National Laboratory (LBNL) initiated a three-year project to bring cool-colored roofing materials to the roofing market. The sister laboratories, in conjunction with pigment (colorant) and roof manufacturers, selected appropriate cool color pigments, applied them to roofing materials, and field tested the roof products. Testing occurred at demonstration homes and seven weathering farms in California and at the campus of the Buildings Technology Center (BTC), using the steep-slope attic assembly on the Envelope Systems Research Apparatus (ESRA).

ABSTRACT

Cool-color pigments and above-sheathing ventilation of clay and concrete tile roofs significantly impact the heat flow crossing the roof deck of a steep-slope roof. Field measures for the tile roofs revealed a 70% drop in the peak heat flow crossing the deck as compared to a direct-nailed asphalt shingle roof. The Tile Roofing Institute (TRI) and its affiliate members are keenly interested in documenting the magnitude of the drop for obtaining solar reflectance credits with state and federal "cool roof" building efficiency standards. Tile roofs are direct-nailed or are attached to a deck with batten or batten and counter-batten construction.

S-Mission clay and concrete tile roofs, a medium-profile concrete tile roof, and a flat "slate" roof were installed on fully instrumented attic test assemblies. Temperatures of the roof, deck, attic, and ceiling; heat flows; solar reflectance; thermal emittance; and the ambient weather were recorded for each of the tile roofs and also on an adjacent attic cavity covered with a conventional pigmented and direct-nailed asphalt shingle roof. ORNL measured each tile's underside temperature and the bulk air temperature and heat flows just underneath the tile for batten and counter-batten tile systems and compared the results to the conventional asphalt shingle.

INTRODUCTION

Parker, Sonne, and Sherwin (2002) demonstrated that a Florida home with a "white, reflective," barrel-shaped concrete tile roof used 22% less annual cooling energy than an identical and adjacent home

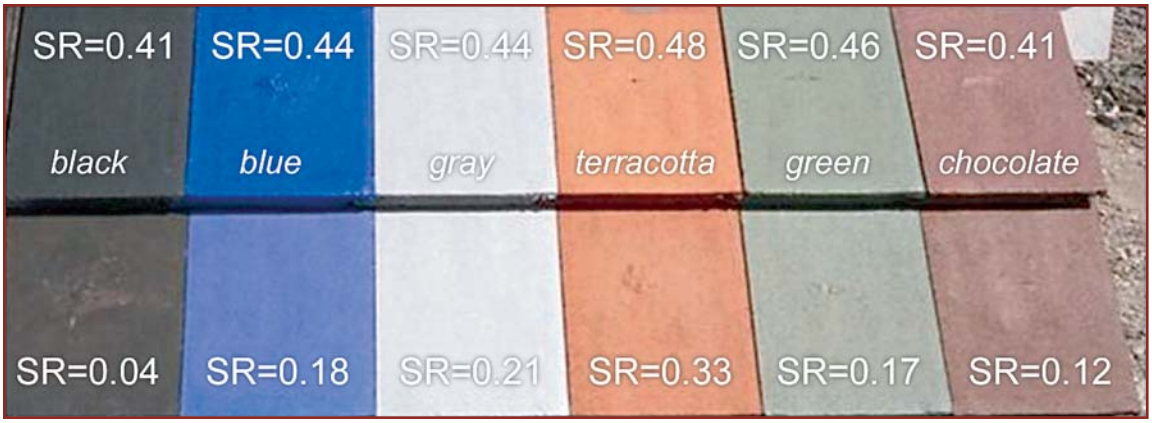


Figure 1 – Cooltile IR Coatings™ developed by American Rooftile Coatings and LBNL increase the solar reflectance of coated tiles by as much as 0.37 (black tile) without changing color.

having a dark, absorptive, asphalt shingle roof. The annual cost savings due to the reduced use of comfort-cooling energy was about $120, or approximately 6.7¢ per square foot per year.

The energy and cost savings reported by Parker *et al.* (2002) for white reflective concrete tile are promising; however, in the residential market, the issues of aesthetics and durability have limited the acceptance of "white" residential roofing. To homeowners, dark roofs simply blend better with the surroundings than their counterpart, a highly reflective "white" roof. What the public is not aware of, however, is that the aesthetically pleasing dark roof can be made to reflect like a "white" roof in the near-infrared spectrum. Miller et al. (2004), Akbari *et al.* (2004b), and Levinson *et al.* (2005a and 2005b) provide further details about the potential energy benefits, identification, and characterization of dark, yet highly reflective, color pigments.

Coating tile with cool pigmented colors has been successfully demonstrated by American Rooftile Coatings, which applied its Cooltile IR Coating™ to several samples of concrete tiles of different colors (*Figure 1*). The solar reflectance for all colors tested exceeded 0.40. Most dramatic is the effect of the dark colors. The black coating increased the solar reflectance from 0.04 to 0.41, while the chocolate brown coating jumped from 0.12 to 0.41, a 250% increase in solar reflectance! The coating can certainly help tile roof products comply with legislation being proposed for California's Title 24 building energy efficiency standards for residential buildings. Levinson, Akbari, and Reilly (2004) found that applying the Cooltile IR Coating™ yielded measurable reductions in roof surface temperature, attic air temperature, and ceiling heat flux for scaled buildings field-tested in Riverside, California (*Figure 1*).

STEEP-SLOPE ATTIC ASSEMBLY

The ESRA is a one-story building used to expose large areas of low-slope and steep-slope roofs to East Tennessee's climate. Two sides of the building are mostly below grade, while the other two sides are mostly above grade. The interior of the ESRA is conditioned to a constant temperature of 70˚F year-round. The long axis of the building is oriented east to west, and the test roofs on the ESRA face directly south to receive full exposure from the sun.

Members of TRI installed clay and concrete tile on a fully instrumented, steep-slope attic assembly (*Figure 2*). High-profile S-Mission clay and concrete tile, medium-profile concrete, and a flat concrete "slate" tile were exposed to East Tennessee's climate for two full years. The clay S-Mission tile and the medium-profile concrete tile were direct-nailed to the roof deck; high-profile S-Mission concrete tile was spot-adhered with foam to the roof deck; the flat concrete "slate" tile was fastened to a batten and counter-batten system; and another concrete S-Mission tile was fastened to battens (*Table 1*). The sixth lane (see far left lane in *Figure 2*) has a conventional asphalt shingle roof for comparing energy savings. The tile roofs are approximately 5 ft wide with 16 ft of length. *Table 1* provides the salient features of the test concrete and clay tiles. All tiles, whether direct-nailed or installed on battens, have above-sheathing ventilation along the underside of the tile traveling from soffit to ridge and transversely along the width of the test roofs. Parapet partitions with channel flashing were installed between lanes to keep transverse airflows within a given type of tile (*Figures 2* and *3*).

Each test roof has its own attic cavity, with 11 inches of expanded polystyrene insulation installed between adjacent cavities. This reduces the heat leakage between cavities to less than 0.5% of the solar flux incident at solar noon on a test roof. Therefore, each lane can be tested as a stand-alone entity. Salient features of the ESRA facility are fully discussed by Miller et al. (2002).

As mentioned, above-sheathing ventilation occurs on the underside of the tile roofs because of the design of the tile and the construction of the roof deck. The batten and batten with counter-batten installations provide a unique inclined air channel running from the soffit to the ridge. The bottom surface of the air channel is formed by the roof deck and 30# felt and is relatively in plane and smooth. The top surface is cre-

Roof Cover	Attachment to Deck	Reflectance Emittance
		SR*xx*E*yy*[1]
S-Mission Clay	Direct to Deck	SR54E90
Medium-Profile Concrete	Direct to Deck	SR10E93
S-Mission Concrete	Spot Adhered to Deck Using Foam	SR26E86
"Slate" Concrete	Counter-Batten and Batten	SR13E83
S-Mission Concrete	Batten	SR34E83
Asphalt Shingle	Direct to Deck	SR10E89

[1] SR*xx* states the solar reflectance of a new sample. E*yy* reports the thermal emittance of the new sample. For example, the asphalt-shingle roof is labeled SR10E89; its freshly manufactured surface properties are therefore 0.10-reflectance and 0.89-emittance.

Table 1 – Clay and concrete tile placed on the ESRA's steep-slope attic assembly.

Figure 2 – An assembly of steep-slope attics was placed on top of the ESRA. Clay and concrete tiles were installed by the Tile Roofing Institute.

ated by the underside of the roofing tiles and is broken at regular intervals by a batten[1] wood furring strip (into which the tiles are fastened).

For batten and counter-batten construction, the counter-batten is fastened to the roof deck and run from soffit to ridge, and the batten is nailed on top of the counter-battens (*Figure 3*). The underside of the roof tiles establishes the upper surface of the inclined air channel. Tiles are designed with a gap at the respective overlap where one tile lies atop the other. The design allows wind pressures to equalize, reducing uplift. The design further complicates solution of the heat transfer because an accurate prediction of the airflow is required to predict the heat transfer crossing the roof boundary.

SOLAR REFLECTANCE AND THERMAL EMITTANCE INSTRUMENTS

A Device and Services solar spectrum reflectometer was used to measure the solar reflectance (near normal, hemispherical reflectance of sunlight) of the roof samples. The device uses a tungsten halogen lamp to diffusely illuminate a sample. Four detectors, each fitted with differently colored filters, measure the reflected light in different wavelength ranges. The four signals are weighted in appropriate proportions to yield the total hemispherical reflectance. The device was proven accurate to within ±0.003 units (Petrie et al., 2000) through validation against the ASTM E-903 method (ASTM 1996). However, because the cool color pigments exhibit high near-infrared reflectance, some of the field samples were also measured at LBNL using a spectrometer to check the portable reflectometer. The average absolute difference between the Device and Services reflectometer and the spectrometer was about 0.02 points of reflectance.

The impact of emittance on roof temperature is almost as important as that of reflectance (Levinson 2005). A portable Device and Services emissometer was used to measure the thermal emittance using the procedures in ASTM C-1371 (ASTM 2004). The device has a thermopile radiation detector, which is heated to 180°F. The detector has two high-e and two low-e elements and is designed to respond only to radiation heat transfer between itself and the sample. Because the device is comparative between the high-e and the low-e elements, it must be calibrated *in-situ* using two standards, one having an emittance of 0.89, the other having an emittance of 0.06. Kollie, Weaver, and McElroy (1990) verified the instrument's precision as ±0.008 units.

Figure 3 – Construction of the roof deck showing battens and counter-battens for attaching the slate tile. The parapets are used to limit airflow on the underside of the tile to within a given test roof.

SOLAR REFLECTANCE AND THERMAL EMITTANCE

The solar reflectance and the thermal emittance of a roof surface are important surface properties affecting the roof temperature, which, in turn, drives the heat flow through the roof. The solar reflectance (ρ) is the fraction of incident sunlight that is reflected by the surface. The thermal emittance (ε) characterizes the efficiency with which a surface cools itself by emitting radiation. It is the ratio of the total flux (power per unit area) radiated by the surface to that radiated by a black body (perfect absorber of radiation) at the same temperature. Our emphasis on the long-term benefits of cool roofing systems recognizes the potential for a significant loss in solar reflectance in the first few years of service life. Surface contamination and climatic exposure cause the loss. If a roof product is severely soiled, then the benefits of cool color pigments diminish.

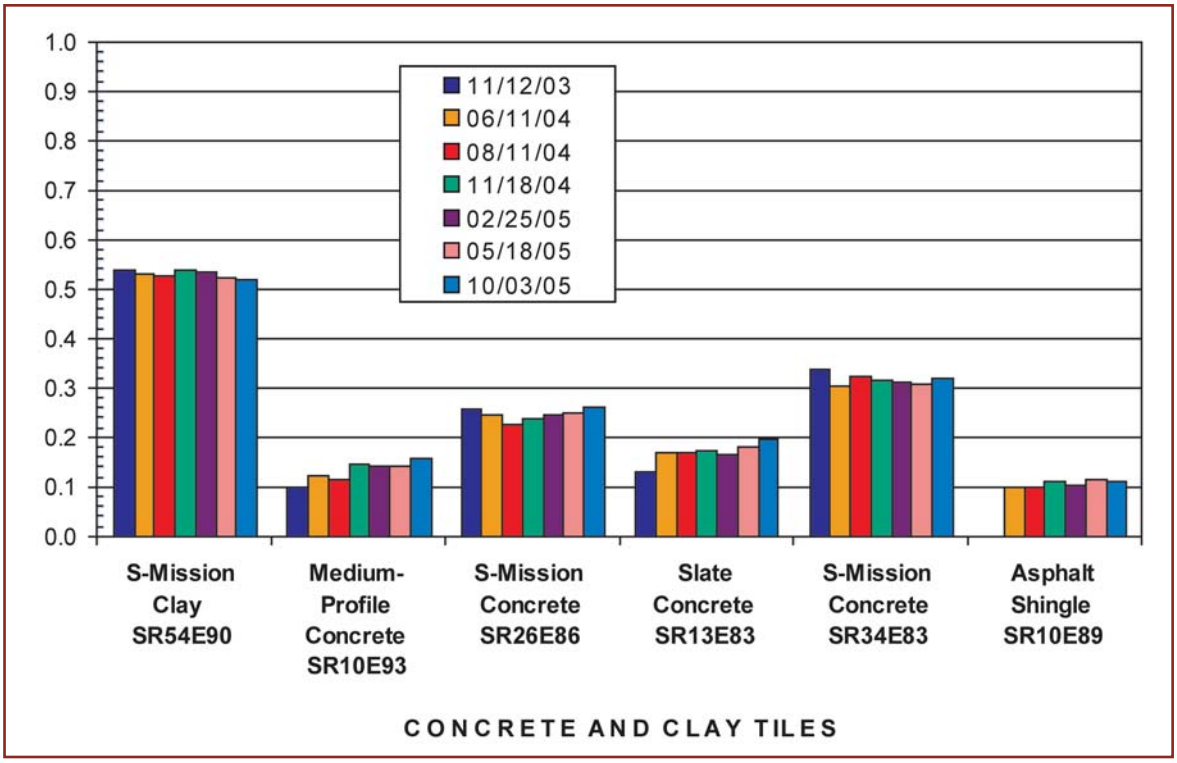


Figure 4 – Solar reflectance of the clay and concrete tile exposed on the ESRA.

EFFECTS OF CLIMATIC SOILING

The initial solar reflectance and initial thermal emittance are identified for each tile using the abbreviation SRxxEyy described in *Table 1*. After two years of exposure, the S-Mission tiles (SR54E90, SR26E86, and SR34E83) show little drop in solar reflectance (*Figure 4*). The clay tile (SR54E90) exceeds the solar reflectance of all the other tiles (*Figure 4*), because it contains cool color pigments that boost its reflectance in the near-infrared spectrum. A slurry coating process is used to add color to the surface of a clay tile. Once coated, the clay is kiln-fired, and the firing temperature, the atmosphere, and the pigments affect the final color and solar reflectance [Akbari, et al. (2004a)].

Data for clay tiles are also shown for field exposure testing in three of the 16 climatic zones of California. The clay samples are identical to those tested at ORNL. They show a loss of solar reflectance that occurs because of climatic soiling. The worst soiling observed occurs in the urban area of Colton and the desert area of El Centro (*Figure 5*). However, the crisp and clear alpine climate of McArthur shows the lowest loss of solar reflectance, because fewer contaminants pollute the air.

Roof slope appears to affect the loss of solar reflectance (*Figure 5*). Testing at the slope of 8 inches of rise per 12 inches of run (33.7˚ slope) has less reflectance loss compared to testing at 2 inches of rise per 12 inches of run (9.5˚) for all three exposure sites (*Figure 5*). Precipitation is not believed to be the dominant player, especially when one considers that El Centro has less than 3 inches of annual rainfall! Rather, wind may be causing the different losses of solar reflectance as roof slope changes from 9.5 to 33.7 degrees.

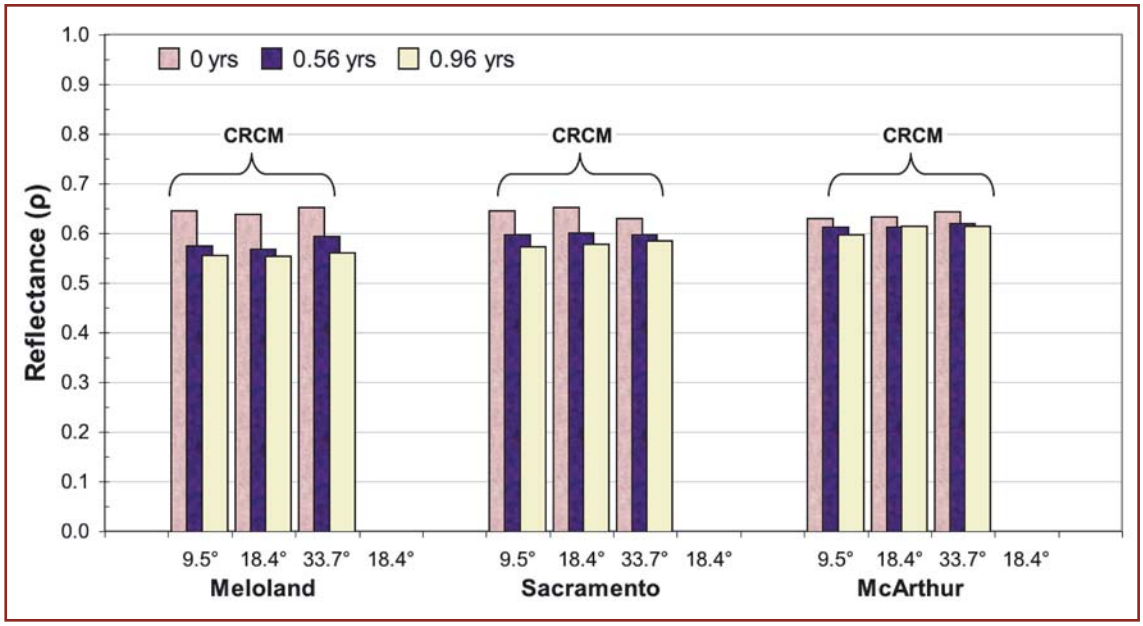


Figure 5 – Solar reflectance of clay tile exposed at weathering sites in California.

The results in *Figures 4* and *5* show that exposure testing differed between the western and mid-eastern climates of the United States, possibly because of differences in precipitation and wind. East Tennessee's climate caused little, if any, soiling of the non-white tiles.

The thermal emittance of the clay and concrete tile has not changed much after two years of exposure in California or Tennessee. It remains relatively constant at about 0.85.

Part II of II will appear in the January issue of *Interface* and describe field test results, conclusions, and recommendations.

William A. Miller, PhD

Dr. Miller is a specialist with 25 years of experience in vapor compression refrigeration systems, absorption heat, and mass transfer and building science technologies. He has a PhD in mechanical engineering and works for the Engineering Science and Technology Division of the Oak Ridge National Laboratory. He has conducted cool roof studies for the California Energy Commission, SPRI, and a consortium of metal industries to quantify the energy savings and affordable cost premiums for highly reflective roof products as compared to dark, absorptive roof systems. He has expertise in finite difference heat conduction for application to forced convection, natural convection, and mixed convection finite-difference simulations.

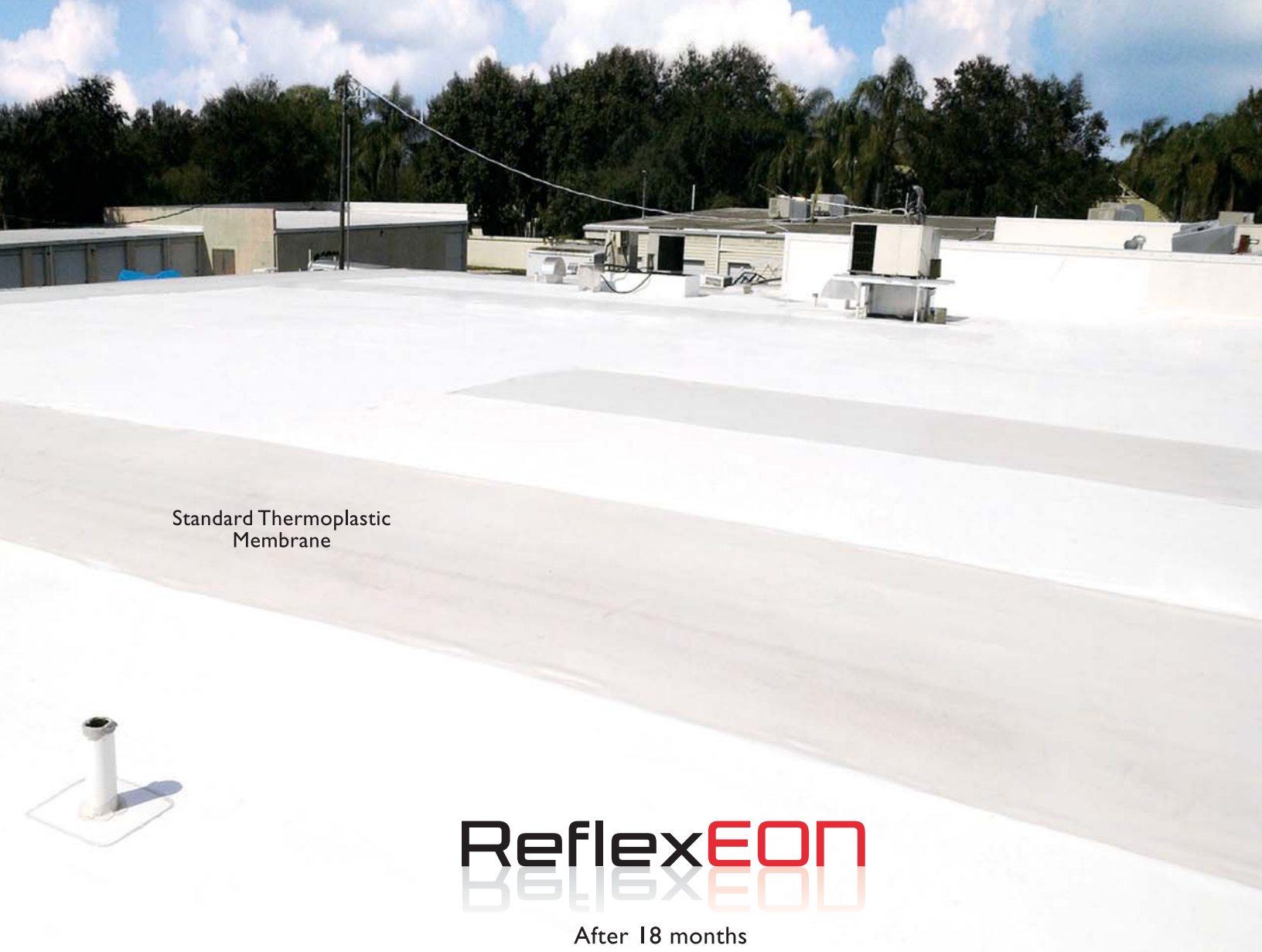
FOOTNOTES

[1] Battens are either fastened directly to the roof deck or fastened atop a counter batten. Battens run parallel to the roof's ridge.

Largest Roofing Companies Listed

ENR has released its "Top 600 Specialty Contractors" list. Ranked by 2005 revenue, the top 20 roofing contractors are listed below:

Rank	Firm	2005 Revenue ($ Mil.)	Chg. % '04-'05
1	Centimark Corp., Canonsburg, PA	347.5	+14
2	Tecta America Corp., Skokie, IL	334.6	+42
3	Latite Roofing & Sheetmetal Co. Inc., Pompano Beach, FL	108.4	+43
4	Baker Roofing Co., Raleigh, NC	100.1	+40
5	Best Roofing & Waterproofing Inc., Gardena, CA	65.0	+49
6	Crowther Roofing & Sheet Metal of Fl. Inc., Fort Myers, FL	56.4	+33
7	Holland Roofing, Florence, KY	52.0	+11
8	The Campbell Cos., Memphis, TN	48.2	+27
9	Advanced Roofing Inc., Fort Lauderdale, FL	46.4	+37
10	Beldon Enterprises Inc., San Antonio, TX	36.0	NA
11	Schreiber Roofing Corp., Detroit, MI	33.8	+2
12	Kalkreuth Roofing & Sheet Metal Inc., Wheeling, WV	33.1	+27
13	The Young Group Ltd., St. Louis, MO	32.6	+29
14	Douglass Roofing Co., Commerce City, CO	32.0	+20
15	The Fred Christen & Sons Co., Toledo, OH	30.8	NA
16	All-South Subcontractors Inc., Birmingham, AL	29.8	+31
17	Orndorff & Spaid Inc., Beltsville, MD	29.4	+16
18	Commercial Roofers Inc., Las Vegas, NV	25.5	NA
19	Hamlin Roofing Co. Inc., Garner, NC	22.8	+20
20	Burns & Scalo Roofing Co. Inc., Pittsburgh, PA	18.5	+1



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– Investigation and Rehabilitation

By Nicholas A. Piteo and Niklas W. Vigener

1. INTRODUCTION

Traditional clay tile roofs combine both modern and time-proven materials with traditional craftsmanship to produce what can be one of the most durable, aesthetically pleasing, and architecturally distinct steep-slope roofing systems. On the downside, designing and constructing clay tile roofs present technical and aesthetic pitfalls that can defeat the most durable materials. For example, an inappropriately selected tile color or finish can unacceptably alter the appearance of a building, and a poorly designed or constructed roofing system can be quickly destroyed by material failure, leakage, or wind uplift.

Achieving maximum durability requires careful material selection, meticulous detailing, and construction by knowledgeable and diligent craftsmen. This paper presents practical advice to help designers and builders conceive, design, and construct durable clay tile roofs. Several aspects of clay tile roofing are covered in a restoration and rehabilitation context, including investigation of existing clay tile roofs to determine causes of failure; selection of tile materials, geometries and finishes; selection and detailing of flashing and membrane underlayment; and review of attachment methods. Advice and recommendations based on the authors' experience are also included to illustrate successful design and building practices for clay tile roofs.

2. INVESTIGATION

Prior to beginning rehabilitation design, a careful investigation of the clay tile roof is required. The purpose of this step is to document the condition and performance of the roof and collect necessary product information for the design. Field investigations typically include an interior condition survey to locate roof leaks; water testing to track leakage paths into the building; and exploratory openings in the roof to document the configuration and condition of its components. We discuss the critical steps for a field investigation below.

2.1 Document Review and Preparation for Field Work

In preparation for field work, the designer should collect and review existing documentation, such as original construction documents, photographs, maintenance logs, and repair histories pertaining to the roof. Pre-planning for field work is a comprehensive process involving multiple tasks:

- identification and coordination of appropriate access equipment;
- selection of exploratory opening locations;
- selection of water test locations;
- coordination with a skilled roofing contractor to assist with access and make and repair openings;
- review of building plans, photographs, and
- a pre-investigation visit.

Information shown on existing building drawings (such as details, roof slope, tile manufacturer, or prior repairs and modifications) is helpful for preliminary planning, but must be verified during the field investigation.

2.2 Field Investigation

Once the pre-planning work is complete, the first step of the field investigation is an interior building survey, starting with interviews of building occupants to locate roof leaks. The information collected during this survey will serve as a "road map" to help plan water tests and sample openings of exterior roof features.

Exploratory openings are required to document the roof's as-built construction and will make up the bulk of the field investigation. Documentation of sample openings must include necessary information to design and detail roof repairs and should include photographs, notes, and sketches. The designer should make openings at all typical roof locations, including roof eaves, rakes, valleys, hips, ridges, roof penetrations, and rising walls, as well as at unique roofing features that will require special detailing. Generally, the larger an exploratory opening is, the more information it reveals and the easier it is to view the detail configuration. In areas that have been subject to water leakage, sample openings will reveal concealed damage, such as deteriorated deck, that must be accounted for during design.

During the investigation, clay tile specimens should be removed for identification of tile type and configuration, manufacturer, exterior finish, and color range. Preparation of custom tile finishes and geometries to match existing tiles requires considerable lead times, so starting this process early in the rehabilitation design is prudent. Tile specimens can also be tested to determine relevant material properties (see below). This step is necessary to evalu-

ate the tiles' in-service performance and their potential for reuse in repairs or re-roofing. Although a discussion of the requirements for re-using tiles is beyond the scope of this paper, we note that as a result of the significant market for finding matching replacement tiles and relative ease of salvage, a large cottage industry has arisen for salvaged, re-used clay tile. Advertisements for used tile brokers can be found in restoration magazines and Web sites. We recommend laboratory testing of any salvaged tile, prior to bulk purchase, to assess its anticipated residual durability. If the tile tests well, it may provide an economical approach to finding durable, well-matched replacements to tile that are no longer available.

In some cases, water tests that track existing leakage paths to the interior are required in order to determine the causes of premature roofing failures and to pinpoint roof details that must be reconfigured during the rehabilitation design.

3. COMPONENTS OF CLAY TILE ROOFING SYSTEMS

Multiple individual components make up clay tile roofing systems, including slope, deck, underlayment, flashings, and attachments. Each component can impact the overall performance of the roofing system, and it is important to understand the role that each plays.

3.1 Roof Slope

All clay tile roofs must have sufficient slope to shed rainwater off the assembly. Minimum slope requirements vary by manufacturer and tile geometry but generally range from 3:12 to 5:12. While the 2003 edition of the International Building Code (IBC 2003) requires a minimum slope of 2-1/2:12, we recommend a minimum roof slope of 4:12, consistent with National Roofing Contractors Association (NRCA) tile slope recommendations, to promote drainage and improve the reliability of the assembly in regions that are subject to snow accumulation. At lower slopes, water does not drain as promptly, more water is prone to bypass the outermost surface of the tile and reach the underlayment, and thus, the performance of the roofing assembly becomes more heavily reliant on the performance and reliability of the underlayment, particularly at fastener locations. Consequently, where existing roof slopes are 4:12 or less, providing self-adhered membrane underlayment is especially important to limit the risk of leakage; see the discussion below.

Most tiles do not have maximum slope limits. However, tiles installed over very steep slopes – 18:12 or greater – are prone to "chatter" (i.e., they rattle in windy conditions) unless special attachment provisions, such as wind clips and adhesives at the nose of the tiles, are included in the design to restrain movement. Chatter may also occur due to local wind conditions on roofs with lesser slopes.

3.2 Roof Deck

Proper selection of the deck is critical to the installation and performance of a tile roof assembly. The deck must support construction loads along with code-required dead and live loads, provide a continuous substrate for the membrane underlayment, supply adequate structural capacity for the tile attachment, and meet code-required fire resistance. Fire code considerations are not discussed in this paper. In historic buildings, we commonly encounter lightweight cinder concrete decks, pre-cast concrete planks with or without lightweight cinder topping, continuous wood plank decks, discontinuous wood "skip" sheathing, or discrete metal or wood bars.

3.2.1 Concrete Decks

Poured-in-place lightweight concrete decks and pre-cast concrete planks provide both continuous support and a stable work platform and may even add some insulation value to the roof assembly. Unfortunately, while lightweight concrete readily accepts nails, it provides little resistance against nail withdrawal and frequently cannot provide code-specified wind uplift resistance without more complex fastening arrangements, such as screws or adhesive anchors. We have seen other instances where the concrete deck was too hard to accept roofing nails or fractured during nail driving. Because of these limitations, we prefer to cover existing concrete decks with plywood to facilitate better nail pull-out resistance.

3.2.2 Wood Decks

In older buildings, decks commonly consist of tongue–and-groove wood decking. For new design, plywood is typically used. Both make for an excellent roof deck.

- Plywood must be rated for structural use as roof sheathing by the Engineered Wood Association, formerly the American Plywood Association (APA) and conform to standard PRP-108. Other panelized wood products, such as oriented strand board (OSB), are much less durable than plywood and are not appropriate for use in heritage buildings.

  Even though designers intend sheathing to remain dry in service, we recommend kiln-dried, preservative-treated plywood to provide protection against unintended leakage or exposure. Use of preservative-treated wood requires additional fastener considerations; see the attachment section below. The plywood attachment, span, and thickness must be designed to withstand wind uplift and accommodate service loads. Traditional rules for plywood installation still apply, including providing slight gaps between adjacent sheets to accommodate wood expansion and avoid buckling of the sheathing. Plywood also requires special considerations when installed below vapor impermeable substrates, such as self-adhered membrane underlayment, and should be kiln-dried to avoid trapping moisture within the roof assembly. See also our discussion of self-adhered membrane underlayment below.
- Wood plank decking and/or tongue-and-groove wood decking must accommodate many of the design considerations discussed above for plywood. Historic tongue-and-groove decking ranges from 3/4-inch thick on many residential applications, up to between 2 and 3 inches thick on some mills and other industrial buildings. Tongue-and-groove sheathing tends to have narrow, shallow gaps between individual boards, whereas plank or skip sheathing often has wide gaps (often up to 1 inch wide) between boards. Large gaps and "skip sheathing" are not acceptable substrates for new or rebuilt roof assemblies because the mem-

Photo 1 – Torn felt membrane underlayment. Asphalt-saturated felt embrittles with age and becomes prone to tearing.

brane underlayment sags into these voids and causes membrane seams to open, which leaves the membrane vulnerable to leakage. Further, out-of-plane irregularities and sharp edges of boards can cut or stress and prematurely wear membrane underlayments over time. In cases of skip sheathing or plank sheathing with wide gaps, we recommend covering with plywood to provide a smooth, clean, uniform substrate for membrane underlayment. For optimum adhesion of the membrane, prime the plywood and seal gaps between boards to prevent bridging and provide for continuous adhesion. Similarly, clean, prime, and seal gaps in tongue-and-groove sheathing prior to membrane installation for optimum adhesion and performance.

3.2.3 Other Decking Systems

In some historic buildings, clay tiles are wired directly to horizontal metal or wood bars that span continuously between roof trusses or rafters. These traditional systems, which have no continuous substrate sheathing or underlayment membrane, are inherently less reliable in their waterproofing performance than similar systems with continuous underlayment and sheathing. In some cases, depending upon the interlocking geometry and watertightness of the particular tile, they can provide sufficient waterproofing performance over unoccupied and unfinished areas, such as attics, which have some tolerance for water leakage. However, they are vulnerable to wind-driven rain, particularly at flashing transitions. In rehabilitation work, it is advisable to add continuous sheathing and membrane underlayment to improve the reliability of the system; however, the additional weight of the sheathing and underlayment must be considered during the design.

3.3 Underlayment

Clay tile roofs are water-shedding systems. The tiles interlock and/or overlap to intercept and shed most water off of the roof assembly. However, most clay tile installations alone are far from watertight and inevitably allow some water to pass through the tile joints, particularly at roof perimeter conditions, such as hips, valleys, ridges, and eaves, and at roof penetrations. Membrane underlayment is typically needed to collect this water and conduct it to the exterior along the roof eaves and valleys.

When evaluating roof underlayment, durability of the membrane is an important design consideration. Good quality clay tiles have a typical service life of 75 years or longer; ideally, the quality of the membrane underlayment must match this life expectancy. We have seen instances where non-durable or poorly detailed and installed membrane underlayment resulted in leakage and required reconstruction of the entire roof well before the clay tile reached the end of its service life.

3.3.1 Asphalt-saturated Felt

Asphalt-saturated felt is a traditional choice for clay tile roof underlayment and has a long track record of performance. Felt is straightforward to roll out, install in shingle-lap fashion, and attach to the roof deck. For attachment, we prefer button cap nails over staples because staples penetrate in two places and frequently tear the felt at fastener locations, which reduces the reliability of the membrane underlayment.

IBC 2003 requires that underlayment conform with ASTM D 226, Type II (No. 30 asphalt-saturated felt), ASTM D 2626, or ASTM D 249 Type I mineral-surfaced roll roofing. Furthermore, IBC 2003 requires two layers of underlayment for low-slope applications. Low slope is defined as between 2-1/2:12 and 4:12. We prefer two layers of ASTM D 226, Type II membrane underlayment for increased durability and redundancy against leakage. Asphalt-saturated felts will embrittle with age, particularly if they have been exposed for an extended time prior to clay tile installation, and are prone to tearing, especially at ridge, hips, and other details where the membrane is creased; see *Photo 1*.

For roof slopes of 3:12 and greater, IBC 2003 also requires an additional layer of 36-in.-wide [ASTM D 226] Type I membrane underlayment at valley locations. This additional layer is intended to provide added protection from leakage and membrane erosion. We prefer self-adhered membrane

underlayment, regardless of the roof slope, below roof perimeter conditions, and areas that conduct large volumes of water, such as valley flashings. Self-adhered membrane underlayment, when properly lapped and installed, provides a more reliable waterproofing layer than loose-laid felt, and resists erosion of asphalt oils from frequent runoff or standing water that contribute to premature, asphalt-saturated, felt degradation. See below.

3.3.2 Self-Adhered Membrane

Self-adhered membrane underlayments (typically rubberized asphalt on a polyethylene or fiberglass carrier) for roofing applications may include features such as slip- or abrasion-resistant surfaces, reinforcement to resist tearing, or formulations to resist ultraviolet degradation. Due to the wide variety of available self-adhered membranes, we limit our discussion to general principles applicable to most self-adhered membranes.

Self-adhered membranes provide improved weather resistance over felt underlayments, mainly because they provide some self-sealing capabilities at fastener penetrations, have reasonably watertight membrane-to-membrane seams, and fully adhere to the deck (creating isolation of any small leak). Together, these characteristics provide greater protection against leakage in low-slope applications in all climates, and from water ponding behind ice dams in cold climates, than does shingle-lapped felt underlayment.

In cold climates, self-adhered membrane underlayments should be used and may be required by code, for ice dam protection. Felt membrane underlayment must overlap the self-adhered membrane underlayment if self-adhered membrane underlayment is used for ice dam protection. A full discussion of ice dams and ice dam protection is beyond the scope of this paper. For maximum waterproofing performance, self-adhered membrane underlayment must be installed without gaps, wrinkles, or fishmouths (small, tunnel-like openings in lap seams at wrinkled membranes).

Most membrane underlayments, and particularly self-adhered membranes with polyethylene carrier sheets and their release paper, are slippery to walk on. Wet membrane underlayment frequently occurs due to rain, dew, or frost. Under slippery conditions, foot traffic should be prohibited, and release paper should always be promptly removed from the roof during installation. Many self-adhered membrane manufacturers also make products with textured facers to improve slip resistance. In hot conditions, we have seen instances where the modified asphalt melted and caused the carrier sheet to slip when stepped on.

Self-adhered membrane must also be protected from exposure to sunlight and must not be used in permanently exposed locations since most membranes will degrade in sunlight. Allowable exposure is generally limited to about 30 days, although limitations vary by manufacturer and membrane type.

Additionally, self-adhered membranes form an effective vapor retarder and may cause condensation unless the roof assembly is properly vented. Although a discussion of vapor retarders in roof assemblies is beyond the scope of this paper, we note that potential applications where a significant proportion of the roof deck is covered with self-adhered membrane should be analyzed during the design phase to assess their condensation potential.

3.3.3 Hybrid Underlayment

Where the potential for condensation does not preclude the installation over the entire deck, we recommend providing a layer of self-adhered membrane installed over the roof deck and covering it with a layer of asphalt-saturated felt. This arrangement provides the advantages of both systems, including tighter seals at fasteners and ice-dam protection provided by the self-adhered membrane.

The felt, on the other hand, has a longer allowable exposure time and protects the self-adhered membrane from UV exposure. To a limited degree, it also protects it from wear and tear during roofing installation (e.g., protection from dropped nails and tools), can provide a more slip-resistant work surface, and provides waterproofing redundancy.

3.4 Flashings

Flashings provide durable waterproofing in exposed locations and avenues that conduct high volumes of water such as open valley flashings, eave flashings, exposed counterflashings, and roof transitions. Flashings are typically exposed and must be UV-resistant. Flashings must also be carefully integrated with the underlayment to provide continuous waterproofing while resisting corrosion and premature wear. Flashings are made almost exclusively from metals and must be carefully selected and detailed for durability.

While IBC 2003 allows a minimum flashing thickness of 0.019 inches, we find that more robust flashings are required to match the expected service life of a clay tile roof. Typically, 16- or 20-oz. copper is sufficient for most flashing areas that are not subjected to concentrated water run-off. High-flow areas, such as valleys, require thicker flashings to provide a reasonable service life.

To be durable and reliable over the long-term, metal flashings should be solderable and non-corroding. Aluminum is not solderable, and galvanized steel flashings readily corrode at cut edges, and thus, do not meet these criteria. Copper (including coated coppers such as zinc-tin, alloy-coated copper) or stainless steel are two metals that meet these criteria and that we recommend and use for flashings.

- Copper is the traditional flashing material of choice for its exceptional workability, durability, and in-service performance record. Unlike aluminum, copper can be soldered to provide watertight and durable flashing connections. "Red" or uncoated copper will turn brown, then greenish blue, and eventually green with patina due to oxidation and natural weathering. (Refer to Revere Copper's *Copper and Common Sense* for a more complete discussion of the patination process.) This process varies by region and exposure and occurs at different rates for different copper surfaces. The green patina can also bleed onto walls or other building components and stain them. Effective management of copper runoff is essential to prevent such staining. Lead- or zinc-coated copper resists patina formation and staining as long as the coating

remains intact. Environmental and health concerns about lead runoff preclude the use of lead-coated copper in most applications. Zinc-coated copper does not have the lengthy performance history of lead-coated copper but provides a similar appearance, supposedly without environmental concerns.

- Stainless steel is another durable flashing material because of its exceptional corrosion resistance, including resistance to the more corrosive wood preservative treatments used today. Unlike galvanized steel flashings, stainless steel is equally durable at all cut edges and at scratches. Stainless steel can be soldered watertight, but is tougher to work with than copper, and some consider its shiny appearance aesthetically objectionable. However, it may be aesthetically appropriate and desirable for modern/contemporary buildings.

IBC 2003 and the NRCA *Roofing and Waterproofing Manual* permit other metals, such as aluminum and galvanized steel, but these lack the durability of copper or stainless steel, and we consider them inappropriate for use in monumental buildings.

We recommend that flashing design include provisions to facilitate maintenance and eventual roof replacement, such as removable skirt components on through-wall flashings.

3.5 Attachment

Clay tile attachment is critical to the overall roof performance and must account for wind loads while maintaining a durable and weathertight roofing system. IBC 2003 offers a methodology to determine the aerodynamic uplift moment acting to raise the nose of the tile and describes limitations for its use, which may be used to determine adequate attachment provisions. Two common methods of clay-tile attachment permitted by IBC 2003 are adhesives and mechanical fasteners. In some traditional applications, clay tiles were simply hung from horizontal battens; in other installations, tiles were fastened or wired to battens.

3.5.1 Battens

Some clay tiles, such as pan and cover tiles, require wood battens (i.e., strips of wood set on or over the structural deck used to elevate and/or attach the tile roof covering) to attach the cover tiles. Wood battens are typically outboard of the roof underlayment, i.e., they are expected to endure some moisture exposure and must be preservative-treated to resist deterioration in service. Today's commonly available wood preservatives are more corrosive than their predecessors and require special fastener considerations; see the attachment discussion below.

Toe-nailing to the deck is the traditional way to secure battens, but we have found that metal angle brackets provide for more reliable attachment because they avoid splitting the wood batten, a common problem where toe nails are installed with little edge distance.

3.5.2 Adhesive Attachment

We have seen mortar, aphaltic mastics, and spray foam used as clay tile adhesives. One drawback of all adhesives is that they inhibit drainage by reducing or eliminating the "drainage plane" free space between the underside of the tile and the underlayment. Spray foams can provide tenacious adhesion to many substrates; many are "Dade County Approved" for use in Florida's high wind hurricane zones. Some foam manufacturers have training programs that address typical challenges of spray-foam adhesive, including a "blind" installation procedure that does not allow a visual review of the adhesive after tile installation, code limitations on the permitted adhesive contact area, unpredictable expansion patterns, and proper clean-up of overspray.

Spray foams have a limited performance history and are not yet proven to match the expected service life of clay tile roofs. Additionally, most spray foams cannot be installed in cold temperatures, which limits their use to a short construction season in cold climates, and they have a limited track record in freeze/thaw exposure. They do not adhere to some underlayments, especially membranes with a polyethylene carrier sheet. Because of their limited track record and the aforementioned difficulties, we recommend using mechanical fasteners to provide adequate tile restraint, and using spray foam only as a supplemental measure to reduce "chatter" of the tiles in strong winds.

On the other hand, mortars and mastics are traditional materials. Their traditional use was typically not as a primary means of attachment, but rather as a "hole filler" for edge tiles at rakes and valleys; to provide a closed, finished appearance; and to reduce nesting of insects beneath open tile edges. Mortars tend to have very limited adhesion to clay tiles. Mortar should not be used as primary clay tile attachment but can be used as a supplement to mechanical fasteners to reduce chatter and reduce nesting of nuisance insects (e.g. hornets, wasps) in edge voids. If left exposed or subject to water run-off, mortar may also produce unsightly white efflorescence staining. Mortar is also susceptible to freeze/thaw damage under these conditions and must be evaluated for durability when exposed to such conditions in service.

Photo 2 – Fastening eave and valley tiles (not shown) with wire ties can avoid penetrations through metal flashings, which would result in less reliable waterproofing performance.

Photo 3 – Nose clips are used to resist uplift forces on tiles. The photo shows both a wire nose clip in the field of the roof (top) and a custom-manufactured nose clip along the roof eave (bottom). Custom-manufactured nose clips may be required to provide adequate stiffness and length to fasten above, rather than through, metal flashing along roof eaves.

Photo 4 – Delamination in clay tile as a result of freeze-thaw damage. Testing of clay tiles prior to selection and installation can help avoid such damage.

3.5.3 Mechanical Attachment

Mechanical fasteners, such as nails, screws, wire ties, and nose clips, have a long performance history with clay tile roofing and they remain the most reliable attachment method. Mechanical fasteners must be installed to achieve sufficient deck penetration but should not strain the tile, which can cause breakage. Clay tiles should "hang" from the fasteners to allow some movement.

Two fastener materials meet the corrosion resistance and durability required with clay tile roofs: copper and stainless steel. Galvanized fasteners typically do not provide reliable corrosion resistance over the anticipated life of the tile (e.g., 75 years), especially when in contact with commonly available, corrosive wood preservative treatments. A full discussion of corrosive wood preservative treatments is beyond the scope of this paper.

Traditionally, clay tiles are held in place with one or two fasteners at the head or along the edge of rake tiles. IBC 2003 has numerous prescriptive fastener requirements, including using a minimum of 11-gauge fasteners, 5/16-inch diameter heads, and sufficient length to penetrate the deck a minimum of 3/4-inch or through the thickness of the deck. IBC 2003 also provides a table to describe the minimum fastener requirements to simplify design efforts at some basic wind speeds and roof heights.

3.5.3.1 Nails and Screws

Nails are generally the most straightforward type of fastener to install. We recommend the use of ring-shank or spiral-shank nails, as they provide additional withdrawal ("pull-out") resistance, at minimal increase in material cost. Copper nails have long been a traditional fastener choice due to their corrosion resistance and ease of installation. Copper nails are also easy to

cut to accommodate later tile removal and replacement. Unfortunately, thin copper nails may bend during installation into hard substrates, such as concrete and plywood decks. Stainless steel nails are a stiffer and more corrosion-resistant alternative to copper, and they rarely bend. However, stainless steel fasteners are tough to remove to allow later piecemeal tile replacement; they usually must be cut off with a hacksaw. Screw fasteners typically provide better pull-out resistance than nails but take longer to install and make later repair or replacement much more difficult and time consuming.

3.5.3.2 Wire Ties

Eave tiles and tiles adjacent to valley flashings are frequently wired into place; i.e., corrosion-resistant wire is fastened to the deck beyond the flashing and the tiles are hung into position (*Photo 2*). This configuration avoids fastening through flashings, which compromises their watertightness.

3.5.3.3 Nose Clips

Supplemental clips to hold down the front edge of the tile, commonly called nose clips, are particularly important in high wind regions because they provide two points of tile attachment – one at the head and one at the nose – to resist uplift force. IBC 2003 requires nose clips at eave tiles under some circumstances. While not required by IBC 2003, we recommend the use of nose clips in the field of the roof to provide greater resistance to tile uplift in high-wind regions. Numerous proprietary nose clip products are available. Designers must select nose clips with adequate stiffness to hold the tile nose in place; long, thin wires or sheet-metal clips are often too flexible for this purpose.

Nose clips along eaves frequently present additional problems because adequate clip stiffness and the desire to fasten the clip away from the eave flashing generally oppose each other. In these cases, we have successfully used custom-manufactured, heavy-gauge stainless steel or copper nose straps to provide tile restraint along eaves (*Photo 3*).

3.6 Clay Tiles

Durability is the most important quality for clay tile selection. The tiles must be appropriate for their intended geographical location and use. Proven performance in similar climates and applications is one way to gauge tile quality and designers should visit such installations if possible. In addition to a review of in-service performance, ASTM C 1167, the Standard Specification for Clay Tile Roofs, includes tests to help gauge the expected durability of tiles. We discuss some of these tests below. (*Photo 4*)

3.6.1 Testing

ASTM C 1167 classifies clay tiles into grades for durability, based on their resistance to frost action. Tile grades range from Grade 1, representing significant resistance to severe frost action; to Grade 3, with only negligible resistance to any frost action. A map in ASTM C 1167 recommends tile

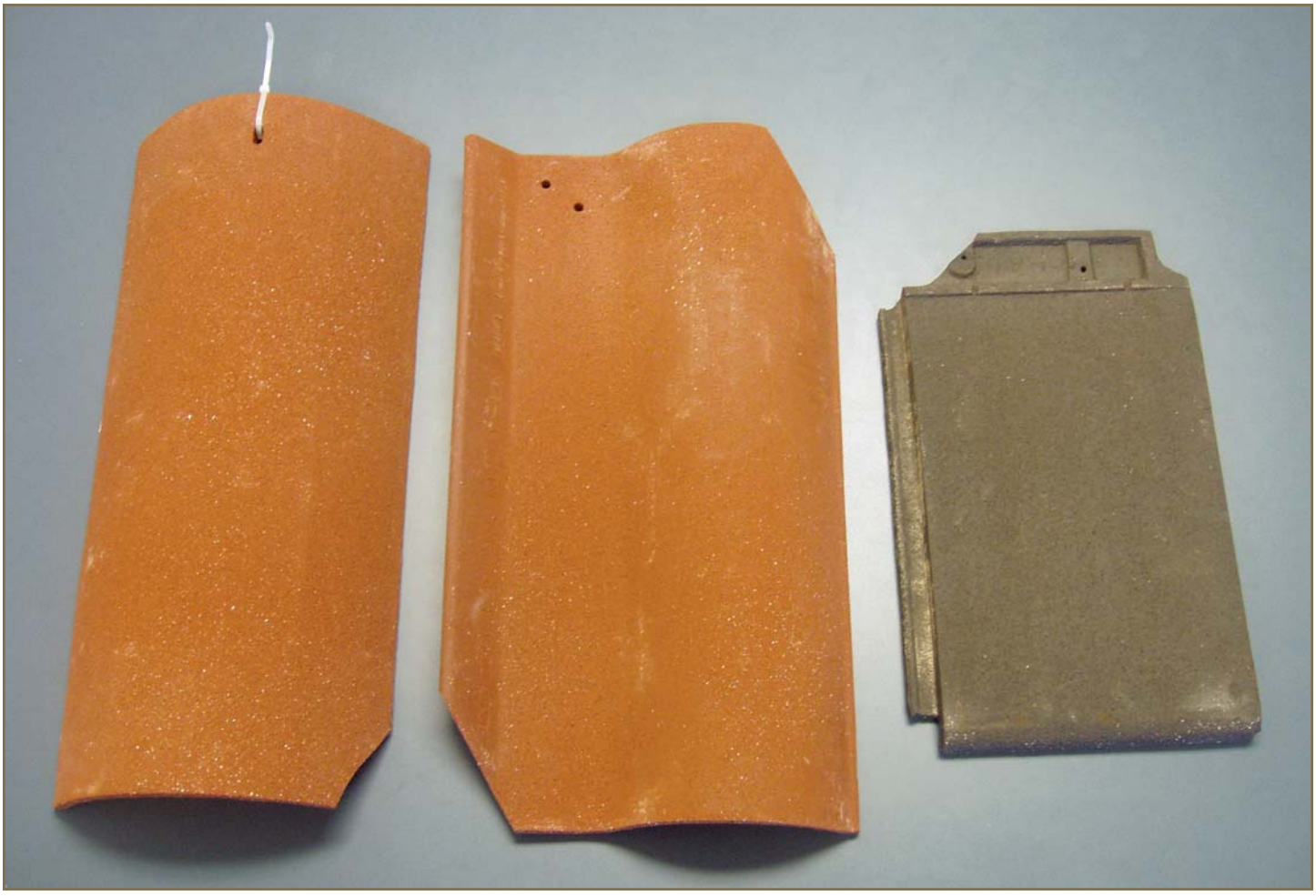


Photo 5 – Some common tile shapes include Pan and Cover or Straight Barrel Mission Tile (left), Spanish or "S" Tile (center) and Flat Interlocking Tile (right). Mission tiles are also available with tapered profiles. Numerous other tile shapes are available. Contact tile manufacturers for information on available shapes.

Photo 6 – The devolution of tile surface features: Three generations of tile from the same manufacturer show loss of surface articulation from a circa 1951 roof tile (left) to its later (center) and contemporary (right) counterparts. On the earliest tile (left), note the raised hub at fastener hole to protect fastener hole from leakage and deeper drainage channel (indicated by longer shadow from back leg of top channel). These features are muted or eliminated on later tiles to right.

Photo 7 – Accessory tiles, such as the rounded hip closure tile shown above (or tiles for ridges, rakes, and starter courses) are often available from manufacturers for various tile shapes and styles. In some cases, these require special order and have considerably longer lead times than typical field tile shapes. Identify and order accessory or custom tile shapes early to avoid delays during construction.

grade by region. At a minimum, designers should adhere to the grade recommendations of ASTM C 1167. We recommend only specifying and using Grade 1 tile in northern climates, and whenever possible, we prefer to use Grade 1 tiles for increased durability in less severe climates.

The "gateway" grade requirements of ASTM C 1167 are based on the tile's cold-water absorption and saturation coefficient, which compares cold-water absorption to boiling-water absorption and is used to gauge the freeze/thaw resistance of the tiles. Gateway requirements for the performance grades were established to limit the need for freeze/thaw tests, which may take ten weeks or longer to complete and are often too long to allow testing of the actual batch of tiles intended for the project, while still meeting construction schedules. We have found that these gateway absorption and saturation coefficients provide a good indicator of long-term tile durability under freeze/thaw weathering and general exposure. We have conducted laboratory tests on existing tiles that have failed as well as existing clay tiles that have performed well for over 100 years and found the absorption results to correlate well with tile durability.

While not required by ASTM C 1167, freeze/thaw testing according to ASTM C 67, Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile, as modified per ASTM C 1167, subjects tiles to freeze/thaw cycles similar to those expected in service in northern climates. Freeze/thaw testing is allowed by the standard as a means to "prove" tile resistance to severe weathering conditions if they fail to meet the specified gateway absorption grade requirements described above. However, the 50 freeze/thaw cycles may represent only 1-2 years of actual exposure in many northern climates in the U.S.; thus, the passing of this test is not "proof" of long-term durability.

Transverse breaking strength of tiles (i.e., bending strength) offers the best indicator of resistance of the tile to breaking due to impact (e.g., tree branches or ice

falling onto the tile) and point loading (e.g., foot loads from workers walking on the roof). The importance of breaking strength data in selecting and specifying tile for a roof should be assessed by the designer on a case-by-case basis. On roofs with overhanging trees, large roofs above that shed ice to lower roofs, and rooftop elements (e.g., painted dormers, chimneys, etc.) that require frequent maintenance, the roof will be subjected to more frequent and severe field conditions that promote breakage than roofs not having any of these characteristics. While breaking strength is not a direct indicator of durability due to freeze/thaw weathering, on some tests of existing clay tile we have noted an indirect correlation between the two. Tile that are dense and well-fired (highly vitrified) tend to test better in terms of both their breaking strength (creating greater resistance to impact), and their absorption (creating greater resistance to freeze/thaw deterioration).

3.6.2 Tile Profile

The shape and surface profile of an individual tile also affect its durability and waterproofing performance. Many different stock tile shapes are commonly available, some of which are shown in *Photo 5*. Consult tile manufacturers' literature for descriptions and illustrations of available shapes.

Traditionally, many tiles included intricate features to channel water out of the roof assembly and limit fastener exposure to the weather. Such features include ridges to shield fastener holes and drainage channels with weep slots to collect water and direct it downward. Many modern tile shapes either lack these traditional surface features altogether or have muted versions that are less effective at protecting tiles and fasteners than their traditional counterparts. *Photo 6* shows several generations of clay tiles that illustrate the devolution of these surface features.

3.6.3. Reproduction Tiles

Reproduction of traditional tiles to match specific existing tiles for restoration projects frequently presents challenges. Traditionally, clay tile manufacturers often used labor-intensive fabrication methods to produce intricate and irregular tile shapes and finishes. While these techniques can still be replicated, high initial set-up costs and labor costs make large-scale production of custom tiles too costly for most jobs. Today, custom, hand-formed tiles are considerably more expensive and take much longer to procure than mass-produced production line tiles, which may be stockpiled for rapid distribution. For commonly available field tiles, some manufacturers offer "accessory" pieces, specially shaped for common non-field conditions such as hips, ridges, rake closures, etc. The rounded hip closure tile in *Photo 7* is one example of an accessory tile shape. Where custom-shaped tiles are required, plan ahead and allow considerable lead time and additional cost compared to standard tiles to allow for their production and delivery.

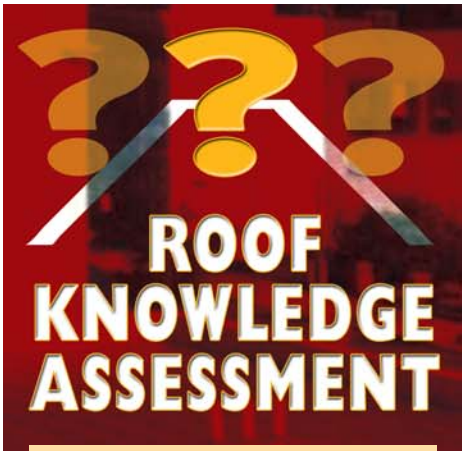
Tiles are often available in many color options and with numerous finishes. Some variations in the finish texture are even available, such as the depth and degree of scored surface textures. Unfortunately, these modern variations do not approach the almost limitless variations available to craftsmen of hand-formed and pressed tiles of the past. As a result, matching traditional tile finishes, while keeping to reasonable production costs and schedules, is often difficult. Existing clay tiles may include formed edges, tile color variations due to antiquated firing techniques, or surface finishes that are no longer commonly used.

Manufacturers are often willing to vary surface textures within the limits of their production equipment, blend different tile colors, or use special firing techniques that introduce trace gasses or mists to produce variation in finishes in an attempt to mimic existing tile roofs. Some other features of existing tiles, such as "battered" edges and custom surface finishes, are more difficult to procure in a cost-effective manner. Generally, appearance options are limited by budget, schedule, and the willingness and capability of the manufacturer to modify its production equipment and process to replicate traditional tile features with reproduction tiles.

4. OTHER CONSIDERATIONS

4.1 Hazardous Materials

Older clay tile installations frequently include roofing cements or mastics containing asbestos fibers. Susceptible locations include hips, ridges, and eaves where roofers relied on cement to adhere tiles or to provide a "finished" appearance to the roof. Similarly, some roofing felts may include asbestos. A discussion of hazardous materials is beyond the scope of this paper. The roof designer should consult a qualified industrial hygienist and the building official for the jurisdiction to specify appropriate precautions and abatement procedures.

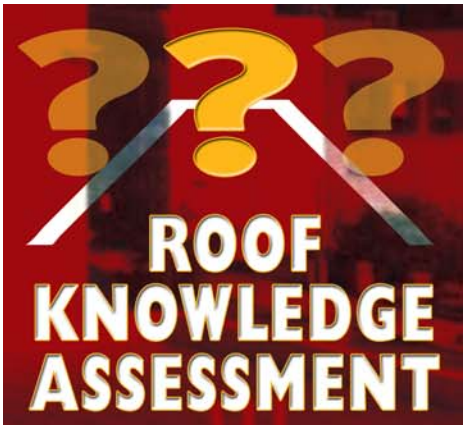


Test your knowledge of roof drainage with the following questions, developed by Donald E. Bush Sr., RRC, FRCI, PE, chairman of the RRC Examination Development Subcommittee.

1. **Which factors must be considered in the design of roof drainage systems for steep-slope roofing systems?**
2. **In sizing downspouts, which considerations apply?**
3. **In sizing gutters, which considerations apply for typical section lengths of 8 - 10 feet?**
4. **The size of rectangular gutters depends on which factors?**
5. **Which procedures are used for scupper sizing?**

Reference: ***Architectural Sheet Metal Manual* — Fifth Edition**

Answers on page 30



Answers to questions from page 29:

1.
   - Area to be drained
   - Size of gutters
   - Size of downspouts
   - Size of outlets
   - Slope of roof
   - Type of building
   - Appearance

2.
   - Downspouts of less than 7.00 sq. in. cross section should not be used except for small areas such as porches and canopies.
   - The size of the downspout should be constant throughout its length.
   - Downspouts should be constructed with conductor heads every 40 feet to admit air and prevent vacuum.
   - Offset of more than 10 feet can affect drainage capacity.
   - The gutter outlet capacity should suit the downspout capacity.
   - The downspout size must suit the bottom dimension of the gutter.
   - Gutter capacity and length.
   - Capacity of the inlet tube.
   - Potential for water freezing.
   - Appearance of downspout system.
   - The greater runoff rate of a pitched gutter.
   - The downspout discharge location.
   - The risk of gutter overflow from insufficient drainage capacity.
   - A scupper serving a designated roof area.

3.
   - Spacing and size of outlet opening.
   - Slope of the roof.
   - Style of gutters to be used.
   - Maximum length of gutters.
   - Gutter support capability.

4.
   - Area to be drained.
   - Rainfall intensity per hour.
   - Length of gutter in feet.
   - Ratio of depth to width of gutter.

5.
   - Determine the head of inches of water (typically 1" minimum by code) at a point six feet back from the scupper opening.
   - Determine the roof drainage area in square feet.
   - Using rainfall intensity in inches per hour (IPH), determine the discharge capacity in gallons per minute (GPM). GPM equals S.F of roof area time IPH times 0.0104. The constant is 7.48 gallons per cubic foot divided by 12 inches per foot divided by 60 minutes per hour.

4.2 Insect Infestation

Clay tile roofs, which typically include large dry and concealed spaces, are notorious as ideal habitats for several insect species, including yellow jackets and hornets. If the re-roofing project is undertaken in the spring and summer when wasps are most active, large swarms can injure workers. If necessary, tile roof restoration projects should include procedures for handling wasp infestations. One proactive management strategy entails baiting for wasps in the early spring to limit the number of "foundress queens," wasps that go on to establish nests and large colonies. Another strategy is to seek out the "clusters" of displaced wasps after roof removal during periods of inactivity between evening and morning to spray and eliminate them. Workers should be prepared to encounter wasps throughout the work and must make appropriate preparations for personal protection.

EDITOR'S NOTE: This article was originally presented as part of the *Proceedings of the RCI 2006 Symposium on Building Envelope Technology* on October 31, 2006 in Washington, DC.

USEFUL REFERENCES

The following references are useful when designing and installing clay tile roofs:

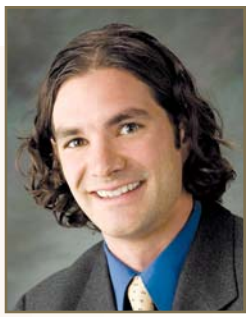
Copper and Common Sense, published by Revere Copper Products, Inc. This reference provides descriptions and illustrations for many metal flashing conditions, including eave flashings, expansion joints, valley flashings, and gutters.

The Clay Tile Installation Manual, published by Ludowici Roof Tile. This reference provides descriptions and illustrations of clay tile installations for many common tile types and includes recommendations related to decking, underlayments, and fastening.

The NRCA Roofing and Waterproofing Manual, published by the National Roofing Contractors Association. This reference provides descriptions of tile roofing components, including clay tiles, with installation recommendations and illustrative figures.

Concrete and Clay Tile Installation Manual for Moderate Climate Regions and ***Concrete and Clay Tile Design Criteria for Cold and Snow Regions***, both published by the Tile Roofing Institute (**www.tileroofing.org**).

Nicholas A. Piteo



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Niklas W. Vigener, PE

Niklas W. Vigener, PE, is a principal with Simpson Gumpertz & Heger Inc. He received his B.S. in civil engineering from Clarkson University and his M.S. in structural engineering from the University of California at Berkeley. Vigener is the project manager on many of SGH's most notable building technology and historic preservation projects. He worked on the rehabilitation of Yale University's Sterling Memorial Library and led the master plan condition assessment, historic consultation, and design of comprehensive envelope rehabilitation at the New York State Capitol Building. Mr. Vigener is also a lecturer in the Department of Civil Engineering at Johns Hopkins University.

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TILE TIDBITS

Compiled by Kristen Ammerman

- Tile products comprise 86% of the European residential roofing market but only 6% of the U.S. market.

- The gilt bronze tiles of the Pantheon survived into the 17th century, only to be removed and melted down by Pope Urban VIII (Maffeo Barberini) to make cannons. It turned out to be a pointless waste; the precious metals content of the tiles was too high for the intended use, so most of the metal wound up in the baldacchino of St. Peter's. It is this act that prompted the famous pasquinade, "*Quod non fecerunt barbari, fecerunt Barberini*" ("What the barbarians didn't do, the Barberinis did"), reminding everyone for centuries of Urban's responsibility for one of the worst depredations of Rome in recent times.

Bill Thayer

- Concrete tiles are made from a mixture of cement, sand, and pigments and extruded into molds and then cured to achieve their strength.
- Clay tiles are made from various mixtures of clay and water and are then fired at a high temperature to attain their strength and color.
- Versatility of tile allows profiles in flat and barrel shapes as well as wood and slate textures.
- Flat tiles (also known as shingle tiles) can overlap or interlock to form distinctive French- or English-style roofs, different from the traditional Spanish, "S," mission, or barrel style.
- Color palettes offer an unlimited array of colors.
- Many tile manufacturers offer light-weight tiles suitable for re-roofing projects.

Tile Roofing Institute

- In Staudach, near Munich, a stationer named Adolf Kroher assembled simple equipment to make the first concrete tile mix in 1844, mixing sand with Portland cement (discovered two years earlier in England). Kroher continued his experiments using different sand grading and different types of cement until he made a valid tile. In 1858, he established the first factory for production and sale of concrete tiles and cement products.

Copyright, "Il Tetto," (the Roof), Consortium of Concrete Tile Manufacturers

Silicosis and Cement Tiles

- Cement tiles are used on roofs across the United States but are more common in the Southern states.
- Cement tiles can contain silica. The silica content of cement tiles should be listed by the manufacturer on a material safety data sheet.
- Cutting, crushing, drilling, or blasting the tiles creates silica-containing dust, which workers breathe in.
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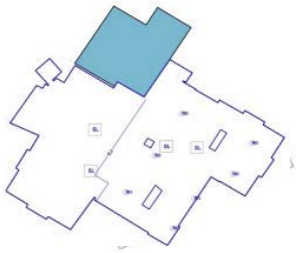

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Tile Roofing Institute Expands and Grows

The Tile Roofing Institute (TRI) was formed in 1971 (originally as the National Tile Roofing Manufacturers Association, and later as the Roof Tile Institute) to support the advancement of concrete and clay tile roof systems. As a non-profit trade association, TRI devotes its time to the technological, environmental, and market advancement of the tile roofing industry and provides manufacturer members, government entities, and building professionals with research, testing, education, training, and technical expertise. TRI's manufacturer members produce 95% of the tile roofing installed in North America.

Through ongoing collaboration with local and federal code bodies, TRI has established standards and guidelines to enhance the quality and installation of tile roof systems. The organization was instrumental in assisting legislation to ban combustible roofing materials in California and has guided successful efforts to revise codes for high-speed winds and to upgrade installation standards following the devastation of Hurricane Andrew.

Formerly comprised mainly of tile roofing manufacturers and related associate producers, it has more recently expanded its reach by increasing membership categories and adding a member contractor database. Associate members include importers, suppliers, distributors, contractors, and those with a general interest in tile roofing. The new contractor database matches prospective tile roofing customers with contractors in their area.

TILE ROOFING INSTITUTE

TRI has developed an Installer Certification Program to impart the requisite knowledge and industry guidelines to install concrete and clay roof tile. Its day-and-a-half course is designed to enhance the knowledge of individuals involved in the construction and installation of tile roofing systems by teaching them material specifications, roof preparation, tile installation, and special conditions. The program is taught by Rick Olson, technical director of TRI, with more than 25 years' experience in the tile roofing industry. Rick acts as the technical liaison for the industry and various code bodies. He has also been instrumental in the creation of TRI's installation guides, research studies, and informational videos. Classes are often taught in conjunction with other industry professionals.

In November, TRI held its 2006 TRI Fall Industry Forum at the Rosen Shingle Creek resort in Orlando (site of RCI's upcoming 2007 convention), featuring exhibiting booths of the leading manufacturers and suppliers of tile roofing products and services. Forum topics included an update from NRCA's Bill Good, one from the Institute of Building and Home Safety, a FEMA overview, a discussion on immigration issues, updates on cool roofing and tile roofs, and more.

The Institute has published three installation manuals for moderate climate, cold weather, and high wind. For more information about tile roofing, visit **www.tileroofing.org**.

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STEEP ROOFING –

UNDERLAYMENT "UPGRADES" THAT SOMETIMES AREN'T

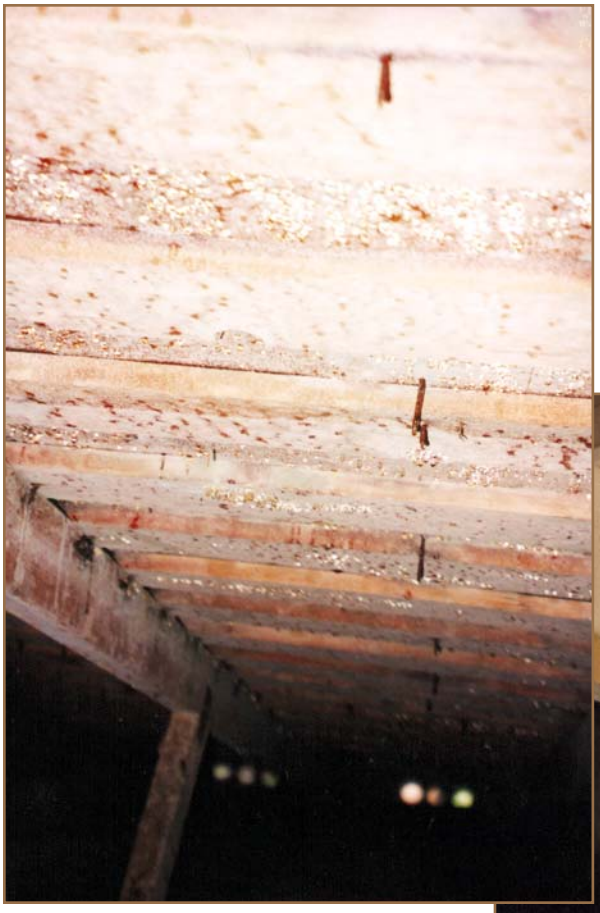
By Philip D. Dregger, RRC, FRCI, PE

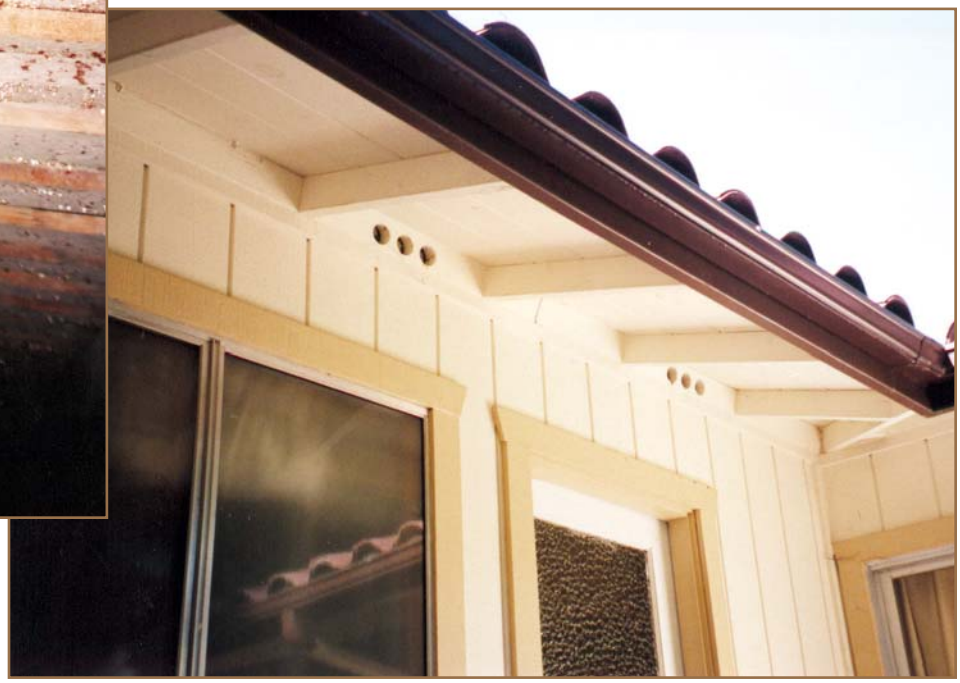
Self-adhering, modified bitumen membranes are often installed as continuous waterproofing layers below steep-roof systems to enhance weather protection. Sometimes these "bullet-proof" roofs develop an unexpected problem – condensation. This article explains why and offers suggestions on how to enhance weather protection and reduce the risk of condensation.

This author acknowledges that self-adhering "ice and water" type underlayment membranes for steep roofing are useful in the marketplace. He has personally specified their installation as part of steep-roofing systems, including copper, slate, clay tile, concrete tile, and asphalt shingles. These products offer excellent waterproofing, and some possess a "self-sealing" characteristic around fastener penetrations. They are particularly useful to protect against ice dam conditions along eaves and to help achieve weather protection at penetrations, complex transitions, and terminations where rigid materials are inherently difficult to make weathertight on a long-term basis.

A problem can be created, however, when these products are installed without considering how they might foster the

Photos 1 (left) and 2 (above) – Steep roofs without conventional attic spaces (e.g., enclosed rafter spaces).





Photos 3 (left) and 4 (below) – Literally thousands of water droplets form on the underside of a plywood and spaced sheathing roof deck despite conventional attic eave vents on a project where a self-adhered membrane underlayment was installed as part of a roof replacement project.

potential for condensation.

Self-adhering, modified bitumen, sheet-type products are waterproof and quite flexible, but they are virtually impermeable to water vapor transmission. The manufacturer of one of the "ice and water" type products publishes a "maximum" water vapor transmission value of about 0.05 perms. In contrast, "15-lb asphalt felt" underlayment is listed in the ASHRAE Fundamentals manual as having a water vapor transmission rate (permeance) of about 1.0 perms (dry cup method) – or about 20 times more vapor permeability than the "ice and water" type product. Materials with perm ratings below about 1.0 or 0.5 perms are usually considered vapor retarders.

It is important to keep in mind that recommendations included in well-known manuals such as *Copper and Common Sense* by Revere Copper Products, Inc.; *Slate Roofs* by Vermont Structural Slate Co., Inc.; and *Architectural Sheet Metal Manual* by Sheet Metal and Air Conditioning Contractors National Association, Inc. discuss conventional felt underlayments but are generally silent in regard to "ice and water" type waterproof membranes, except along eaves with potential ice dam conditions.

Shake Roof Replacement

During an investigation of "leaks" reported the first winter after a wood-shake-roof in the San Francisco Bay Area was re-roofed with concrete tile, this author observed literally thousands of water droplets covering the underside of the roof deck in the attic (see *Photo 3*). The owner reported no leaks (condensation-related or otherwise) from the previous wood shake roof that had been installed over spaced sheathing. The roofer reported that he had installed new plywood throughout and had even "upgraded" the underlayment from a conventional #30 felt to a self-adhered, modified bitumen membrane. Therefore, he was convinced the leaks were not his problem.

Although attic venting was about 50% of the code-required minimum, the old wood shake roof installed over spaced sheathing had been air- and water-vapor permeable just enough to avoid noticeable condensation. Installation of new plywood sheathing and a waterproof membrane changed this. The new plywood and waterproof membrane greatly increased the condensation-producing conditions by virtually eliminating any water vapor migration and "supplemental" attic air exchange that previously occurred directly through the wood shakes.

It is important to recognize that "ice and water"-type underlayment membranes are excellent vapor retarders; as such, if they are installed on the cold (exterior) side of the ceiling insulation rather than on the warm (interior) side, this can sometimes lead to problems.

Other projects where this author has observed very significant condensation conditions created or at least contributed to by the installation of self-adhering "ice and water"-type waterproofing membranes include several non-vented cathedral ceiling assemblies and copper barrel-shaped roofs (see *Photo 5*).

Condensation Basics

During the winter, the air inside a heated and occupied building typically has water vapor (and vapor pressure) in amounts well above that present in the air

Photos 5 (left) and 6 (below) – Saturated plywood sheathing below self-adhering membrane underlayment in a non-vented barrel roof with a standing seam copper covering.

outside. This difference in water vapor pressure works to equalize itself by some of the higher pressure interior water vapor diffusing or migrating outward through the walls and ceilings. (It's like air slowly escaping from a balloon.) As the water vapor migrates, it also cools. And, if it cools to its dewpoint, it will condense on a surface of one of the components within the roof or wall assembly.

Figure 7 shows severe deterioration caused by water vapor migrating through the ceiling of a laundry room and condensing on "cold," underside surfaces of a plywood roof deck above enclosed and insulated (but not vented) rafter spaces in Minnesota. Throughout the winter, water vapor in the air in the laundry room (68˚F, 50% RH) migrated upward and outward through the gypsum board ceilings and into rafter spaces filled with fiberglass batt insulation and covered by the plywood roof deck. Whenever the underside of the plywood was at a temperature less than the dewpoint of the water vapor in the air inside the rafter spaces (for this example, assumed to be about 49˚F), it condensed. Eventually, the plywood became wet enough (and warm enough) to support growth of wood decay fungi.

Mold (A Fungus)

In addition to decay, toxins produced by some molds have been linked to adverse health conditions. Since, among other things, mold requires moisture to grow, limiting condensation-producing conditions (including high-humidity) can help control the growth of mold in roof and wall constructions.

Condensation in Steep Roof Assemblies

Unfortunately, the mechanics of condensation in many situations are more complicated than illustrated in the above example. This is true for condensation in many steep-roof assemblies, with and without conventional attic spaces. (Note: Attic venting helps control condensation in at least two ways: first, by mixing moisture-laden interior air that enters with drier outside air before it contacts a surface below its dewpoint; and secondly, by facilitating drying of moisture that does condense on surfaces in the attic).

Condensation depends not only on how temperature changes along the path of water vapor migration, it also depends on

Photos 7 (left) and 8 (below) – Severe plywood deck deterioration with fungi growth caused by condensation over a laundry room in multi-family apartment building.

how the water vapor pressure changes along this same path. In fact, if a vapor retarding material is installed on the warm (interior) side and the other components of a non-vented roof assembly are sufficiently vapor permeable toward the cold (exterior) side, condensation will not occur, even though the "dewpoint" temperature is reached (i.e., the dewpoint temperature as calculated from the temperature and relative humidity of the interior air).

This is not so hard to believe when considering that the water vapor arriving at such a theoretical "dewpoint" location is "filtered" by each layer it pass-

es through. Each layer – especially the vapor retarder layer – serves to hold back some of the water vapor and then, at the theoretical dewpoint location, the air and water vapor mixture isn't at a 100% saturation level. (Note: The ability of some materials to absorb water vapor is another reason why many steep-roofing systems over wood-frame construction in mild climates avoid noticeable condensation, even though simple dewpoint calculations would suggest otherwise.)

Wall Cladding

Condensation considerations for walls are similar to those for roofs. As with roofs, if impermeable membranes are installed on the cold side, excessive amounts of condensation can sometimes accumulate and fuel deterioration and fungi growth.

Re-Roofs

Consultants are often involved with re-roofing over existing enclosed and insulated rafter spaces that are not vented (e.g, vaulted or cathedral-type ceiling assemblies) or over existing attic spaces that are minimally vented. Local building officials often do not require upgrading to comply with current code venting and vapor retarder requirements. If, in such cases, the new system includes an impermeable membrane above the deck, significant condensation conditions can be inadvertently created where they did not exist before.

Ventilation

When installation of a continuous waterproofing membrane beneath a steep-roof system is desired to enhance weather protection as part of a reroof project, this author strongly suggests checking and enhancing existing roof ventilation, even if not required by local codes. (Note: Also consider asking the owner to confirm that all flue, bath, and kitchen exhaust vents are operational and discharge humid air and combustion products (containing large amounts of water vapor) to the outside – not into attic areas.]

Non-Vented Assemblies

If the existing steep-roof assembly includes enclosed and insulated rafter spaces, and the reroof project does not or cannot include ventilation between the roof deck and the insulation, this author suggests proceeding with caution or considering not proceeding at all. Installation of insulation above the roof deck and installation of continuous vapor retarders on the warm (interior) side would be, in this author's opinion, a prudent practice in such cases in most climates.

Summary

Self-adhering, modified-bitumen membranes can enhance weather protection below steep-roof systems but can also inadvertently increase the risk of condensation by serving as vapor retarders on the "cold" side of roof/ceiling assemblies. Before specifying "ice and water" or other types of impermeable membranes that will completely cover steep roofs, this author suggests designers use caution and, as a minimum, comply with code-stipulated venting and vapor retarder requirements.

For steep roofs that do not have conventional attics (e.g., enclosed and insulated rafter spaces) or that have relatively high interior humidity conditions, this author suggests designers be conservative and, if needed, consider retaining suitably qualified individuals to consult regarding options (e.g., framed ventilation spaces, above-deck insulation, vapor retarders, mechanical

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ventilation systems, and interior humidity control systems) for controlling the accumulation of condensation moisture.

Future articles may address other important considerations such as interior air flow into insulated and non-vented air spaces (e.g., through unsealed lighting fixtures), complications associated with fire-control-related "draft stops" and "wrap backs," and the potential benefits promised by the new generation of watershedding, yet highly moisture-vapor-permeable underlayments.

EDITOR'S NOTE: This article is a revised version of an article of the same title originally published in Western Roofing, *January/February 2001. Reprinted with permission.*

Phil Dregger, RRC, FRCI, PE

Phil Dregger, RRC, FRCI, PE, is president of Technical Roof Services, Inc., a DNG Group Company, in Concord, California, specializing in finding solutions to difficult building moisture problems. Phil received his Masters of Science degree in civil engineering from the University of Minnesota in 1978. He is a past director of RCI, a former faculty member of RIEI, and serves as RCI's representative to the Roofing Industry Committee on Weather Issues (RICOWI). Mr. Dregger has designed roof and waterproofing systems to meet the requirements of a wide variety of clients, including the University of California, SBC Communications (formerly Pacific Bell), Kaiser Hospitals, Mervyn's, and Disney. He has investigated numerous roof and waterproofing problem conditions, including damages sustained after major hurricanes and earthquakes. Phil is the author of several articles on roof technology and has lectured to industry groups, sharing lessons learned from his many investigations.

Roofing Demand to Expand Only 1%/Year Through 2010

U.S. roofing demand is projected to expand less than one percent per year through 2010 to 278 million square feet, with value expected to rise to $14 billion. The nonresidential construction market will provide the best opportunity for gains in the roofing industry, assisted by new office, commercial, institutional, and industrial segment expansion.

Among the various roofing materials, plastic and metal will see the fastest growth in the U.S. through 2010. Thermoplastic polyolefin (TPO) and spray-applied roofing will continue to make inroads. Metal roofing will continue to increase in popularity in commercial applications as well as residential markets, where metal panels, tiles, and shingles are being used as alternatives to roofing tile and asphalt shingles.

In 2005, asphalt shingles accounted for nearly 70% of the total installed square footage and will maintain the lead position through 2010. Demand for asphalt shingles will be constrained, however, by the weak outlook for new residential roofing.

Products designed to mimic asphalt shingles, roofing tiles, wood shakes and shingles, and slate will post gains, as will environmentally friendly products such as recycled roofing materials and composite shingles.

U.S. Roofing Demand

(million squares)

			% Annual Growth		
	2000	2005	2010	05/00	10/05
Total Roofing Demand	235.0	268.0	278.0	2.7	0.7
Asphalt Shingles	138.1	160.4	161.5	3.0	0.1
Bituminous Low-slope Roofing	34.3	34.5	36.0	0.1	0.9
Metal	18.5	19.9	23.0	1.5	2.9
Elastomeric	17.9	18.4	20.0	0.6	1.7
Other	26.2	34.8	37.5	5.8	1.5

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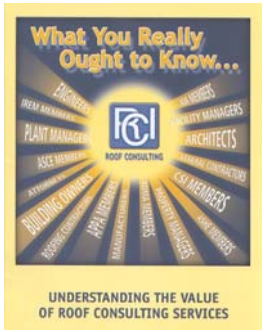

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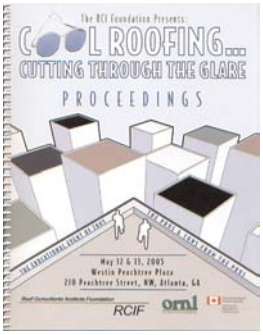

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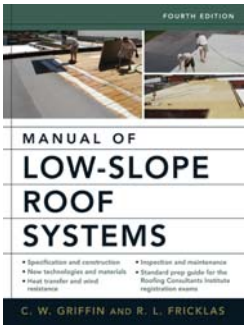

The Manual of Low-Slope Roof Systems - 4th Edition

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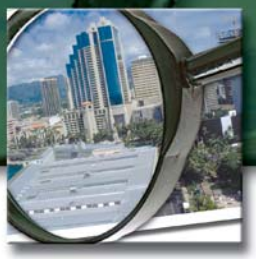
For decades, this manual, by Dick Fricklas and C.W. Griffin, has been the most widely respected guide to designing and specifying low-slope roof systems. This newly-released fourth edition covers major advances in design and materials, as well as changes in building codes, and reviews new procedures in inspection and maintenance.



GDP SHOWS SPLIT IN HOUSING, NONRESIDENTIAL CONSTRUCTION

By Ken Simonson

Gross domestic product, net of inflation (real GDP), grew at a seasonally adjusted annual rate (SAAR) of 1.6% in the third quarter, compared to 2.6% in the second quarter and 5.6% in the first, the Bureau of Economic Analysis (BEA) reported. Real residential fixed investment plunged 17.4% in the third quarter, 11.1% in the second. Real investment in private nonresidential structures rose 14% in the third quarter, 20% in the second.

Construction as a share of GDP was highest in faster-growing states: Nevada, 9.6% of GDP (real GDP growth of 9.0%); Arizona, 7.2% share (growth of 9.1%); Montana, 6.4% share (growth of 5.2%). At the low end, construction accounted for 3.2% of GDP in New York and 3.6% in Connecticut.

Sales of new and existing houses in September were each 14.2% below the September 2005 rate, the government and the National Association of Realtors reported. The median sales price fell 9.7% for new houses and 2.2% for existing houses.

Nonfatal workplace injuries and illnesses occurred at a rate of 4.6 cases per 100 equivalent full-time workers among private industry employers in 2005, down from 4.8 cases in 2004 and 5.0 in 2003, the Bureau of Labor Statistics (BLS) reported on October 19. In construction, the rate fell to 6.3 in 2005 from 6.4 in 2004 and 6.8 in 2003. BLS noted, "Specialty trade contractors…accounted for the majority of both employment (64%) and of injury and illness cases (68%)….Within specialty trade contractors, workers employed in foundation, structure, and building exterior [work] reported the highest rate in 2005 at 8.5 cases per 100 workers. Of the eight industries within [that trade], rates ranged from 6.8…for masonry contractors…to 13.4…for framing contractors."

Diesel fuel and natural gas prices are likely to be lower this winter than last, according to the *Short-Term Energy and Winter Fuels Outlook* that the Energy Information Administration (EIA) released in October.

The Bureau of Labor Statistics revised up its estimates for August (for the second time) and September, and reported that the unemployment rate, which is based on a separate survey, fell to a 5-1/2 year low of 4.4%, from 4.6% in September.

Ken Simonson

This series on the economy and its impact on the construction industry is published monthly in Interface. *This month's column was prepared by Kenneth D. Simonson, chief economist for the Associated General Contractors of America (AGC). Before joining AGC, Simonson spent three years as senior economic advisor in the Office of Advocacy of the U.S. Small Business Administration and 13 years as vice president and chief economist of the American Trucking Association. Simonson may be reached at simonsonk@agc.org.*

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FIRESTONE PURCHASES GENFLEX

Firestone Building Products Company, a division of BFS Diversified Products LLC, purchased GenFlex Building Products, a division of chemicals maker Omnova Solutions Inc. GenFlex was comprised of 100 employees and had been in operation since 1980. The total cash value of the transaction was approximately $40 million. Firestone will acquire a manufacturing plant in Tuscumbia/Muscle Shoals, Ala., a warehouse in Columbus, Ohio, and the GenFlex headquarters office in Maumee, Ohio. GenFlex Building Products will operate as an independent business unit to be called GenFlex Roofing Systems.

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Carlisle Coatings & Waterproofing (CCW) introduces Flexphalt TWF for superior moisture protection in diverse wall flashing applications, especially masonry through-wall flashing. Flexphalt TWF is a 40-mil flashing membrane, which consists of an 8-mil, multi-layered polymeric film over 32 mils of rubberized asphalt adhesive. This flexible membrane is available in four widths. For more information, visit **www.carlisle-ccw.com**

SLATEDIRECT IS SOLD

ElkCorp's (NYSE: ELK) subsidiary, Elk Slate Products, Inc., announced it has completed the acquisition of SlateDirect, L.P., a privately-held manufacturer of TruSlate™, a patented slate roofing system. The company intends to continue operations at the SlateDirect facilities in San Antonio.

SELECTBUILD ACQUIRES WILLIS ROOF CONSULTING

Building Materials Holding Corporation announced that its subsidiary, SelectBuild Construction, has signed a letter of intent to acquire the assets and operations of Willis Roof Consulting Inc. Willis provides roofing services for high-volume production homebuilders in the greater Las Vegas, Nevada market. Willis will be folded into SelectBuild's Las Vegas Division and will do business as SelectBuild.

MRCA ELECTS NEW OFFICERS

The Midwest Roofing Contractors Association (MRCA) has announced a new slate of officers and directors for the 2007 year. New officers are President Kurt Steinkuhler, Geo Groh & Sons, Inc., Emporia, Kansas; First Vice President Rod Petrick, Ridgeworth Roofing Co., Inc., Bridgeview, Illinois; Second Vice President John Daly, Kaw Roofing & Sheet Metal, Inc., Kansas City, Kansas; and Ronnie McGlothlin, Empire Roofing, Inc., Forth Worth, Texas. Four new directors include Kevin Gwaltney, Diamond Roofing, Dodge City, Kansas; John Turner, J. B. Turner & Sons Roofing and Sheet Metal, Topeka, Kansas; Joe Hall, Hall Commercial, Inc., Arlington, Texas; and Tom Miller, The Zero Company, Louisville, Kentucky.

RICHARD CRAMER NEW SMACNA PRESIDENT

Richard J. Cramer Sr. of Dee Cramer Inc., Holly, Michigan, was elected president of the board of directors of the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Board of Directors. Elected president-elect was Ronald J. Palmerick, AABCO Sheet Metal Co., Ridgewood, NY. Keith Wilson is immediate past president.

More *Industry News* on page 46

Industry News

To submit an industry news item to *Interface* *(Note: News must fit journal requirements in order to be published.)*:
E-mail it to: **kammerman@rci-online.org** or Mail to: **RCI, *Interface* Journal, 1500 Sunday Drive, Suite 204, Raleigh, NC 27607**

Ply Gem Buys Alcoa Home Exteriors

Aluminum maker Alcoa Inc. has agreed to sell its home exterior business to Ply Gem Industries, a U.S. manufacturer of new construction or do-it-yourself renovation products, for $305 million in cash. Alcoa Home Exteriors, which makes vinyl and aluminum siding, has 1,400 employees and posted $600 million in revenue for 2005. Its manufacturing facilities are located in Atlanta, Ga.; Denison, Texas; Gaffney, S.C.; Sidney, Ohio; and Stuarts Draft, Virginia.

Window-Wall Interface STP

STP 1484, *Performance and Durability of Window-Wall Interface*, is now available for purchase from ASTM International. The book offers new research, testing data, and material about the creation of installation standards that attempt to identify installation methods and construction sequencing that integrate fenestration products into wall claddings. For information, visit **www.astm.org**.

Metal-Era Improves Arched Coping

Metal-Era Inc. introduces a new version of its popular Arched Coping: Snap-On Arched Coping. The invention uses concealed anchor clips with dual springs, eliminating the need for exposed fasteners and making for an attractive and aesthetically clean arched appearance. Print approvals and installation instructions for Snap-On Arched Coping and its endcaps can be found on Metal-Era's website, **www.metalera.com**.

WJE Purchases Edis Oliver

Wiss, Janney, Elstner Associates, Inc., headquartered in Northbrook, Illinois, has purchased the assets of Edis Oliver & Associates, Austin, Texas. All of the professional and technical staff at Edis Oliver have accepted employment with WJE. WJE's field of expertise is material and structural failure analysis, analysis of building envelopes, and moisture infiltration of all types.

W.P. Hickman Earns First UL ES-1 Classification

W.P. Hickman Co. received Underwriters Laboratory's first ES-1 classification under the new UL evaluation program for roof edge systems. The program incorporates the ANSI/SPRI ES-1 roof edge system wind resistance testing protocols.

Berger Acquires M.J. Mullane

Berger Building Products, Inc., has acquired M.J. Mullane Company, Inc. The Mullane line of products for slate, shake, shingle, and metal roof surfaces will enhance Berger's already extensive offering of snow retention products. Berger will offer these products in bronze, copper, lead-coated copper, aluminum, and polycarbonate. Berger has been in business since 1874. For more information, visit **www.bergerbros.com**.

CMG Relocates

Coated Metals Group (CMG) and its subsidiary, Architectural Metals Inc. (AMI), both formerly located in Madison, Wisconsin, have relocated to a new facility at 300 Yard Drive, Verona, Wisconsin. The company maintains locations in Indianapolis and Denver. For more information, visit **www.cmgmetals.com**.

NRF and Roofing Industry Alliance for Progress Merge

The National Roofing Foundation's (NRF's) board of trustees and The Roofing Industry Alliance for Progress' Steering Committee have combined to form one board. NRF, an educational and research organization of the NRCA; and The Roofing Industry Alliance for Progress, which was established within NRF to create an endowment fund and provide guidance and direction for NRF; will do business as The Roofing Industry Alliance for Progress. NRF will remain a legal corporation but do business as the alliance. For more information, contact Bennett Judson, the alliance's executive director, at (800) 323-9545, Ext. 7513, or e-mail bjudson@nationalroofingfoundation.net.

Advertisers' Index

Calendar of Events

Black print: INDUSTRY EVENTS
Red print: RCI EVENTS
Green print: RCI-AFFLIATED CHAPTER OR REGION EVENTS
Blue print: NON STAFF-INSTRUCTED RCI CLASS

Calendar subject to change without prior notice. Visit **www.rci-online.org** for schedule updates. *A completed application must be received by Headquarters 90 days prior to sitting for an exam.

DECEMBER 2006

1 RRO Exam
Downey, CA

1 Region I Meeting
Poughkeepsie, NY

1 Ohio Valley Chapter Meeting
TBD

2 *RRC & RWC applications due for 3/2/07 exams*

2-3 Exec. Committee Winter Meeting
Orlando, FL

6 *RRO applications due for 1/20/07 exam*

6-7 Ecobuild Federal 2006
Info: ecobuildfederal.com

6 Roof Asset Management
Atlanta, GA

7-8 Rooftop Quality Assurance
Atlanta, GA

9 RRO Exam
Atlanta, GA

11-14 China International Exhibit on Roofing & Waterproofing
Beijing, China
Info: 847-299-9070, Ext. 7586

JANUARY 2007

14 *RRO applications due for 3/2/07 Exam*

15 RRC Review & Update
Seattle, WA

16 Advanced Thermal and Moisture
Seattle, WA

18-19 Rooftop Quality Assurance
Seattle, WA

20 RRO Exam (applications due 12/6/06)
Seattle, WA

17 Region III – Chicago Area Chapter Meeting
Oak Brook, IL

18-19 Chicago Roofing Contractors Assoc. Conf.
Oak Brook, IL

22-23 Region IV Meeting – Winter Technical Program
Honolulu, HI

23-24 Roof Technology & Science 1
Chicago, IL

25-26 Roof Technology & Science II
Chicago, IL
Delivered by Chicago Chapter
Info: www.cac-rci.org

30-31 Wind and Drainage
San Diego, CA

FEBRUARY 2007

1-2 Professional Roof Consulting
San Diego, CA

3 RRC Exam (applications due 11/3/06)
San Diego, CA

7-10 National Home Builders
Orlando, FL

8 Great Lakes Chapter Meeting
Detroit, MI

19 RRC applications due for 5/19/07 exam

MARCH 2007

1-6 RCI Convention & Trade Show
Orlando, FL
Info: www.rci-online.org

1 & 6 RCI Board of Directors Meeting
Orlando, FL

2 RRO, RRC, & RWC Exams
Orlando, FL
(RRC & RWC applications due 12/2/06 & RRO applications due 1/16/07)

3 Region Meetings
Orlando, FL

5 RCI Annual Meeting of the Members
Orlando, FL

6-8 NRCA Convention & Roofing Expo
Las Vegas, NV
Info: www.theroofingexpo.com

APRIL 2007

___ Humber College
Etobicoke, ON

10-11 Roofing Technology and Science I
San Antonio, TX

12-13 Roofing Technology and Science II
San Antonio, TX

26 SPRI Wind Design Meeting
Dallas, TX
Info: www.spri.org

27 Region III Meeting
Dallas, TX

27 Region I Meeting
Mt. Laurel, NJ

29-2 Greening Rooftops for Sustainable Cities
Minneapolis, MN
Info: www.greenroofs.org

MAY 2007

3-5 AIA Convention
San Antonio, TX

9 *RRO applications due for 6/23/07 exam*

15-16 Professional Roof Consulting
New Orleans, LA

17-18 Wind and Drainage
New Orleans, LA

25 *RWC applications due for 8/25/07 exam*

***A complete 2007 calendar will run in the January 2007 issue of* Interface.**

NRCA DESIGN AWARDS PROGRAM

The National Roofing Contractors Association (NRCA) has announced a call for entries for its 2007 SpecRight Excellence in Design Awards program. The award honors long-lasting, energy-efficient, and environmentally friendly roof systems designed according to industry practices. Architects, specifiers, roof consultants, and roofing contractors who are responsible for the design of a nominated roof system are eligible to apply. Nominated roof systems must have been designed and installed after Jan. 1, 2004. The deadline for entries is Dec. 18. The winner will receive a $2,500 cash prize.

For an official entry form, visit **www.specright.net.** For more information, contact Ambika Puniani Bailey at (800) 323-9545, Ext. 7555, or e-mail abailey@nrca.net.

TRICKS OF THE TRADE

A Rapid, Qualitative, Non-Destructive Test for Measuring Adhesion of Fully Adhered Single-Ply Membranes

OR

Something Else to Do with a "PLUNGER"

WILLIAM RUBEL, RRC

AND

WILLIAM KIRN, RRC

When inspecting a fully adhered, single-ply membrane roof, samples are often cut from the roof to determine the degree of adhesion of the membrane to the underlying substrate. However, like all sample evaluations, these data represent only a very small percentage of the actual membrane adhesion. The actual membrane adhesion over the vast majority of the roof still remains unknown. Sampling is also a destructive test, where the membrane must be patched to restore watertight integrity.

Here's an easy-to-use method to qualitatively determine the adhesion of the membrane. All that is needed is a "plumber's helper" (a/k/a, toilet drain plunger) and some cooperation from the weather in the form of a heavy dew or recent rainfall.

With the roof surface wetted by rain, overnight dew, or a garden hose, merely push the plunger down onto the roof so that the suction force holds the plunger to the roof membrane; then pull up. If the membrane is well adhered, it will not "lift up" when upward pressure is applied. If the membrane is not well bonded, the membrane will form a "tent" as it is lifted up. This test can be rapidly repeated many times as the inspector walks the entire roof. Unadhered areas can then be marked for subsequent repair.

DON'T MISS the (occasional) upcoming articles in "Tricks of the Trade for RCI Consultants." A few upcoming "tricks":

- How a spatula for icing pastry can help evaluate and repair a shingle roof.
- How a "Wonderbar" can prevent falls.
- How far will a dollar go?

Please submit your own "Tricks of the Trade for RCI Consultants" to Kristen Ammerman at kammerman@rci-online.org.

22nd International Convention & Trade Show

Doorways to the Future

RCI, Inc. - The Institute of Roofing, Waterproofing, & Building Envelope Professionals

800-828-1902
www.rci-online.org

March 1 - 6, 2007
Rosen Shingle Creek Resort
Orlando, Florida

Outside Back Cover - Cover 4
Full Page Ad
4-Color
GAF
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“Energy Cap”