Sustainability is Nothing New

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Keywords

Clay tile units, copper, life-cycle cost, durability, university, historic, recycling, embodied energy, Cradle-to-Cradle, LEED®

Abstract

In a world filled with buzz words such as sustainable, green and energy-efficient, many building owners and homeowners only consider the most recent, high-tech innovations when shopping for a high-performance roof system. However, sustainability and high performance are not defined by the most recent products or most innovative chemistry. One must never lose track of the historic techniques that provide quality roof systems from highly recyclable materials that can outlast so many of the “modern” advancements in the roofing industry, providing a life-cycle cost savings with a minimally invasive imprint on nature. Using the recent reroofing of Few Hall at Duke University, Durham, N.C., as a case study, this article explores the real value of returning to historic precedent to satisfy modern roof system performance requirements. Few Hall was constructed during the late 1930s as a residential dormitory for students. In 2009, the original Ludowici Roof Tile™ (Ludowici) brand clay tile roof system was removed and replaced with a new Ludowici clay tile roof system in the same style. The new tile carries a 75-year warranty. Although much has changed in the roofing industry since the first installation, the new roof system incorporates principles of sustainable

design while remaining true to the time-honored craftsmanship of the early 20th century, creating a product that could conceivably last long into the 21st century with a combination of good design, quality materials, proper installation and appropriate maintenance. New ASTM International standards have been developed to ensure tiles can withstand whatever challenges nature presents. More designers know about the effects of harvesting new materials, the captured energy contained in their processing and shipping, as well as their eventual reintegration into new products at the end of their lives on a structure.

The new roof system began as raw materials harvested from Ohio; formed by hand only miles from where the clay was taken from the ground; cured in large batches in a natural gas-fired kiln; and delivered to the site as needed by the construction scheduled. The copper on the old roof system—right down to the nails—was recycled and the value returned to the project budget. The tiles were separated and recycled into road base. In another 75 to 100 years, the same process can begin again.

Few Hall is a prime example of learning from the past rather than relying on untested technology. It once again proves that sustainability is nothing new.

Authors

Larry Meyers joined Wiss, Janney, Elstner Associates Inc. in 1987 and has gained national expertise in the areas of roofing and waterproofing by managing and participating in the investigation, inspection, repair design and construction observation of more than 700 building structures. As a registered architect and a professional and structural engineer in Illinois, Meyers often has been called upon to provide expert testimony in cases involving roofing and waterproofing issues. He serves on several ASTM International technical committees, including ASTM D08—Roofing and Waterproofing, ASTM E06—Performance of Buildings and ASTM E60—Sustainability. As chair of ASTM D08.24—Sustainability, Meyers has been guiding the development of many sustainable roofing techniques and standards.

Carole Ceja has gained roofing and waterproofing experience since joining Wiss, Janney, Elstner Associates Inc. in 2006. As a registered architect in Illinois, Ceja has been participating in the investigation, inspection, repair design and construction observation of more than 100 roofing projects. Her participation in the ASTM D08.22 subcommittee is advancing the practice on electric-based nondestructive investigation techniques for roofing and waterproofing. Ceja recently authored and presented an article for the RCI Building Envelope Symposium in San Antonio in 2010.

Introduction

In a world filled with buzz words such as sustainable, green and energy-efficient, many building owners and homeowners only consider the most recent, high-tech innovations when contemplating high-performance roof systems. However, sustainability and high performance are not defined by the most recent products or most innovative chemistry. High-performance roof systems could be defined as cost-effective, long-lasting, leak-free roof systems that are as gentle on the environment as they are on the bottom line. In other words, high-performance roof systems seek a balance between durability, reliability and sustainability without ignoring cost. Sustainable roofing is the result of manufacture, installation, repair and disposal techniques that lead to the creation of top-performing roof systems without limiting future options for roof design.

Expectations of high-performance roof systems reach beyond those associated with typical roofing. Energy loss or gain must be controlled; longevity beyond typical service life is a must; the negative impact on the environment through its production, transportation, installation and disposal of roofing components should be minimized; and maintaining the aesthetic qualities where the roof system is an integral part of a building's overall visual expression are all high priorities.

Historic roofing techniques have provided durable roof systems that performed admirably from highly recyclable materials for generations. Historic builders intrinsically knew the value in sustainable roofing before the term took on its current acceptance. The philosophy was simple: use the materials at hand, do it well, make it last and take pride in your work. Builders took advantage of locally available materials and the craftsmanship needed to perform the work. There were no expressways to ship in new tiles or an Internet full of suppliers ready to send out the latest prefabricated sheet product.

As labor costs have increased considerably, many of the "modern" advancements in roofing material were created with the sole intention of saving money by reducing installation time. Using the recent reroofing of Few Hall at Duke University, Durham, N.C., as a case study, this paper explores the value of returning to historic precedent to satisfy modern roof system performance requirements, and it shows that sustainability is nothing new.

Building Description

Few Hall was constructed in the late 1930s as a residential dormitory for students staying at the Duke University campus. See Figure 1 for an overall view of the building. The building is a complex series of wings oriented primarily around two interior courtyards. Each wing contains a primary gable running along the long axis. A series of secondary gable and smaller dormers intersect the main gable at the student rooms. The gables and dormers are roofed in Ludowici Roof Tile™ (Ludowici) Yale style clay tile units. Hanging copper gutters and built-in copper gutters collected rain water runoff and directed it to elaborately crafted copper conductor heads and downspouts before entering the below-grade storm water system. The 14:12 (average) pitch roof uses closed valleys and copper baby tin flashings and counterflashings which were molded against the rough-hewn Duke Stone exterior building walls to reflect the texture of the stone's surface below (see Figure 2). Few Hall is a large building with an approximately 54,600-square-foot roof, but it is also a part of a larger collection of buildings that comprise the West Campus of Duke University. The roof lines are a vital piece of the campus's architectural expression, and the scale of Few Hall with its textured dormers sets it apart as a residential building among the greater campus of education buildings (see Figure 3). The enduring institution of Duke University is etched into the rock of the walls, which ties successive generations of students together in a common living and learning experience.

In addition to the clay tile clad gables, there are two towers on Few Hall that originally had roof systems of sheet metal copper and two low-sloped roof areas between wings that also consisted of sheet metal copper. Some dormers with small copper sheet metal lined balconies exist at several locations near the roof level.

The clay tile roof system and copper sheet metal roofing materials were supported on precast gypsum planks with integral welded wire reinforcing. These panels were about 2 feet wide by 3 feet tall and hung on steel angle purlins spanning between steel roof trusses.

Pre-Replacement

The roof system replacement began like many projects and included an evaluation of the existing roofing materials and construction. The existing roof system dated from original construction of the building and had experienced generally minor repairs and maintenance during its service life. Black EPDM membrane had been installed over the majority of exposed copper sheet metal roofing materials and at transitions to some of the gutters, indicating that previous experience with leakage had occurred at the copper details. Exterior surveys from grade, close-up survey and inspection openings at selected locations from a manlift and interior surveys from the accessible attic spaces were conducted in fall 2007. About 10 to 15 percent of the existing tile was observed to exhibit some distress, such as chipped corners, cracks or entirely missing tiles (see Figure 4). The highest concentration of damage existed at locations where students could access the roof surface, such as from dormers and small balconies. Staining was observed on the interior of the gypsum planks supporting the tile in patterns consistent with the welded wire fabric reinforcement. Only the upper two-thirds of the underside of the roof deck are accessible from the attic space. The lower third, including the eave line, is concealed by the finished spaces and ceilings of the dormitory rooms.

During the investigation, several tiles were removed and tested for breaking strength according to ASTM C1167, “Standard Specification for Clay Roof Tiles” and for water absorption as referenced in ASTM C67, ”Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile.” These two tests evaluate a clay tile’s weathering resistance. The testing revealed that although all of the tile samples passed the water absorption criteria, more than two-thirds of the samples failed to meet current standard requirements for breaking strength. There were no ASTM International standards for fabrication or performance of clay roof tiles at the time a roof system first was installed on Few Hall. In fact, there was no ASTM International standard (for clay roof tiles) adopted before 1990. Because there was no attic stock available from the original installation, it could not be determined whether the existing tile units had lost strength over time or that the original fabrication values were less than current standard requirements.

Because of the high potential for ongoing deterioration of the existing tile units, the recommendation to Duke University was for full replacement of the clay tile roof system and copper accessories within the next two to five years. Duke University had planned a major interior renovation project for Few Hall and determined that commencing the roofing work immediately would be beneficial and protect the new interiors. Completed design drawings and specifications were provided to Baker Roofing (Baker) who had engaged in a negotiated contract with Duke University. Construction began in January

2009 and continued through October 2009. A total of 54,600 square feet of clay tile was removed and replaced.

The new roof system was to carry with it a 75-year warranty. Although much has changed in the roofing industry since the first roof system installation, the new roof system incorporates the same principles of sustainable design while remaining true to the time-honored craftsmanship of the early 20th century, creating a finished product that conceivably could exist long into the 21st century incorporating good design, quality materials, proper installation, and appropriate maintenance.

Minimally Invasive Demolition

Demolition of the old roof system began at the balconies, which were clad in copper sheet metal. Copper is one of the easiest metals to recycle given its relatively low melting point. Copper has been used in the construction industry for thousands of years. Ancient Egyptian copper piping has been discovered by archeologists. It is estimated that 700 billion pounds of copper currently are being used across the globe. This represents only 12 percent of the estimated copper reserves available for mining[i]. Nearly three-fourths of the copper used in the U.S. (other than for use in copper wire production) is formed from recycled scrap. Copper wire is more sensitive to impurities and therefore requires newly mined ore. The mining process uses considerable time and energy, so there is a high demand and value for recycled copper.

The copper gutters, downspouts, flashings, balconies, limited sections of flat roofs and even the copper nails were collected and sorted on-site for recycling. All copper was recycled, and the profits of the sale were returned to Duke University. The copper returned about $1 per pound, so the 50,000 pounds of copper removed from Few Hall translated into $50,000 paid back to Duke University. It also resulted in 50,000 pounds of building debris diverted from the landfill—a double dip for sustainability as the old copper now can be incorporated into new copper elements such as the new gutter, downspouts, sheet-metal pans and nails for future roofing projects.

The existing clay tiles were broken on-site to fist-sized pieces and provided to WCA Waste System Facility in Raleigh, N.C.,[ii] for use in road base. Below the high-quality pavement that supports traffic, there are several layers of fill and other aggregates to level road surfaces or spread load over weak soil conditions. These can be filled with many types of recycled materials, including broken clay tile. In all, more than 526 squares at 1,800 pounds per square, or 946,800 pounds, of clay tile were salvaged from Few Hall. The material would have otherwise gone to a landfill but instead found new life taking the place of newly mined gravel, which could have been used as road base.

The dormer windows were constructed with wood frames. At some point, the maintenance of these windows necessitated the installation of aluminum covers to minimize the ongoing deterioration of the wood and peeling paint (see Figure 5). The reroofing project included replacing these aluminum frames. Aluminum also is a highly recyclable material, and the aluminum window casements were sold to TT&E Recycling rather than ending up in a landfill.

The only component of the existing roof system that went to a landfill was the felt underlayment and the shrink wrap used to keep the clay tiles on the pallets during shipping.

Embodied Energy

The clay tile units for the new roof system were created using a multifaceted sustainable approach. Clay is excavated from property about 5 miles from the Ludowici plant in New Lexington, Ohio. Ludowici's geologists have determined there is enough clay on hand nearby to cause no problems sourcing clay for at least a few hundred years[iii]. This clay is found below the topsoil layer on what would otherwise be farming land. Following strict EPA guidelines, after the clay layer is removed from a section of land (about 6 to 8 feet), the topsoil is replaced in its original topography, and the land returns to farming functions.

The raw clay is mixed with water and formed into tiles either by hand or by mechanical press. The unique tiles for the closed valleys at Few Hall created a considerable amount of hand-forming work for Ludowici manufacturing personnel.

Once tiles are formed, they are sent to drying rooms until specified moisture content is reached. From the drying rooms, they are given a glaze of color and then enter the kiln. The kilns currently run on natural gas. When the first set of tiles was created for Few Hall, the kilns also ran on natural gas. Excess exhaust heat from the kilns is captured and reused in the drying rooms. Ludowici is certified Cradle-to-Cradle Basic. The Cradle-to-Cradle certification process is a holistic approach to a wide variety of manufacturing products with requirements in the following categories: material health, material reutilization, renewable energy use, water stewardship and social responsibility.

The tiles are fired and allowed to cool. Then, they are packaged and shipped to the site. The Few Hall project was organized in such a way that only the tiles necessary for the week's work were packaged and delivered to the site by truck. Duke University is less than 500 miles from the Ludowici manufacturing plant, a requisite for LEED® local materials credit.

Another benefit of using clay tile units is they do not leach chemicals during their service life that would contaminate water runoff from the completed roof system. There are minimal chemical additives included in the production of clay tile units to enhance their performance. Because there are fewer additives, there are fewer elements to leach out of the units over time.

Sustainable Installation Action

Once the materials arrived on-site, several methods of installation developed by the project contractor, Baker Roofing Company (Baker), assisted in the project's overall sustainability. Scaffold and other access equipment were reusable, which reduced construction waste. Demolition of the existing clay tile units used gravity to rapidly move the existing materials from the roof to sorting bins closely located at grade for recycling. Items that could not be recycled were carried down the scaffolds and taken to bins located centrally on site. This extra step of collecting nonrecyclables away from demolition areas encouraged the laborers to take sorting seriously. New clay tiles were moved around on-site in small batches by hand or small lift carts.

Baker supplied two portable metal fabrication shops on-site to assist in the creation of the copper and aluminum details. Precise measurements could be taken at each unique copper detail and then built to suit in the field. This reduced the waste created by poor fitting copper details and improved the overall performance of the copper work.

One of Duke University's greatest concerns was the effect construction would have on the mature plant life, especially the trees immediately adjacent and in some places hanging over the roof. Before construction, Duke University installed snow fencing around the root bulb of each tree on-site. No construction personnel or equipment was permitted around the base of the trees. Scaffolding was erected over bushes and smaller trees, and access to the scaffolds was limited to areas where no trees were present. Special additional measures also were undertaken to prevent damage of the in-ground irrigation systems. Planking was installed over permitted construction paths to prevent the small equipment carts from damaging the grounds.

Sustainable Communities

One aspect of sustainable construction that often is underappreciated is the sense of community created by these projects from the sheer volume of labor, as well as the pride of craft in the labor force. Maintaining the historic appearance and texture of institutions such as Few Hall adds an additional link through time between the various students who have called it home during their university experience and the larger collection of Duke University alumni who have for generations been able to reconnect with their education experience through visits to the campus.

Ludowici is the largest employer in Perry County, Ohio, and Baker employed more than 70 men on-site. By the time each tile was in its final position, at least eight hands had helped it along its path (see Figure 6). Each tile was created for a specific location on the roof and production followed installation scheduling. During the 180 days of installation, Ludowici could produce fire and ship only the combination of tiles shapes and colors needed for the area of the roof being completed by Baker at that time. This limited the necessary staging space (in turn, damaging less mature landscaping). Color blending of the tile units was carried out on-site by hand because no machine could achieve the artistry needed to blend the three colors of tiles included in the design (see Figure 7). Installation work also was hand-oriented, from raising the tiles to the roof level 10 tiles at a time to laying out the complex patterns of closed valleys (see Figure 8), each valley requiring more than five different sizes of tile.

The connection created to the past through the continued use of the historic clay tile roof system is one way the project is sustainable even if it is difficult to quantify the effects. The longer a building is in place, the greater importance it develops in the community. With the highly visible roof configuration establishing the character of the campus, Few Hall's roof becomes a symbol of Duke University's commitment to honoring the past. The uninterrupted appearance of Few Hall over what will total more than a century and a half adds value to the project and community as a whole. Duke University also always was cognizant of the roofing project's effect on its alumni network and how alumni often are interested in owning a piece of their past. One of the strategies employed by Duke University to defray the costs of the reroofing project was to save the original ornate copper conductor heads for possible sale to benefactors in the future (see Figure 9).

Performance

A new ASTM International absorption and breakage strength standard provides more reliability for the long-term performance of clay roof tiles. Few Hall's roof system installation included Grade 1 tiles selected for resistance to severe weathering as described in ASTM C1167. Repeated freeze/thaw cycles are the greatest factor in clay tile degradation. Tiles that absorb large quantities of water will experience more damage during these freeze/thaw cycles. The new roof system was designed to not exceed 6 percent water absorption by weight. Breakage strength influences performance because of freeze/thaw, as well as impact resistance. The tiles for Few Hall were to meet or exceed 300 pounds breakage strength to achieve Grade 1 classification. These conditions combined will create a reliable roof for 75 years or more in the North Carolina climate.

Bottom Line

There is no denying the new roof at Few Hall was a major financial undertaking. With a total roofing budget of about $3.61 million, Few Hall could not be considered sustainable in the manner selected if the final costs were too high. The $50,000 return on the value of the recycled copper resulted in a net fiscal investment for the roof of about $3.56 million, or roughly $65 per square foot. If the material and labor for the copper balconies are taken out of the above figures (because this work was specific to Few Hall and not typical for most steep-slope roof system applications), the total roofing-related project costs are further reduced to $3.305 million, or roughly $60.50 per square foot. The cost of the existing roof system during 75 years translates to about $44,075 each year of service life.

Life-cycle Costing

The cost data for the originally installed roof system could not be determined from research of available documents. Total repair expenditure for the 70-year life of the previous roof system could not be located either to develop costs of the previous roof system before replacement.

The current roofing is warranted for 75 years and can be expected to perform well for that length of time given reasonable annual maintenance. If a more conventional roof system based on current materials and standards was installed with a 20- to 25-year expected service life, it would undergo three replacements before Few Hall's current roof system reached its full anticipated service life. If this hypothetical roof system could be installed and replaced for $15 per square foot in current dollars, and assuming simple 3 percent inflation, the initial investment and three subsequent replacements would total more than $9.53 million of roofing or nearly three times the initial financial cost for the existing sustainable roof system. There also would potentially be an additional 136,800 square feet (54,600 x 3) of roofing materials and waste in local landfills and another 54,600 square feet soon to join them.

Methods and Materials With Improvement Possible

Although traditional pulley systems were used to raise equipment and large copper sections to the level of the scaffolds, smaller gas-powered lifts moved the tiles to the roof. These mechanical lifts ran for long periods of time because they could only lift about 10 tile units at a time to the top of the scaffolds.

With the interior renovation completed, the building needed to be kept watertight during the day and overnight as work on the roof system continued. A self-adhered membrane underlayment was specified rather than the nailed down saturated building felt used with the original tile installation. The surface of the gypsum panels remained dusty following demolition, and the self-adhered membrane would not readily bond to the exposed substrate. Therefore, Baker needed to provide an asphalt primer on gypsum planks to enhance the bonding of the membrane. The chemical makeup of the primer was not selected for its minimal effect on the environment. The application of the self-adhered membrane did not significantly affect the air flow through the roof structure. A half inch of gypsum wall board meets the National Building Code's requirements for forming a part of an air barrier assembly. The two inch thick gypsum panels with interlocking edges and fully grouted joints restricted air flow through the roofing assembly prior to the installation of the new roofing.

Sustainable opportunities missed

A major factor used to judge a roofing project's sustainability is energy gain and loss. Insulation and solar reflectance are two of the largest factors to influence how much heat energy is lost through the roof. These factors were not addressed in the Few Hall reroofing project.

A well-insulated roof system blocks heat loss in cooler months and limits heat gain in warmer months. At Few Hall, an unconditioned attic space exists below a majority of the roof deck. The finished ceiling in the top floor of the dormitory consists of plaster on metal lath. Fiberglass batt insulation was applied over the top of the plaster ceilings in the attic space. The insulating value of the roof system could have been improved by including spray-applied polyurethane foam to the underside of the gypsum planks.

A roof's ability to reflect the sun's energy also is important to a building's overall energy use. The market for pigments is improving for reflectance capability of many roof coverings. White pigments traditionally reflect the greatest amount of solar energy, but new pigments allow a wider range of colors. Obviously the selection of a pigment or surface coloring for the roof coating significantly can affect a roof system's aesthetics. At Few Hall, the color selection of the tiles was determined to most closely match original tile colors rather than what colors would assist in the building's energy use.

For steep-slope roofs, a solar reflectance index (SRI) equal to 29 qualifies for LEED points. Ludowici estimates that the new roof color blend developed to match the historic colors would be in the low 20s. Ludowici currently has 13 standard colors, as well as several custom colors of glazing that would meet the SRI LEED requirements (see Figure 10) and believes a color pallette similar (but not exact) to the historic pallette could have been developed, which would have met the SRI requirements if such a requirement had been specified.

Conclusion

Historic and sustainable roofing are not mutually exclusive nor must they be detached from describing high-performance roofing. Few Hall is a prime example of how the incorporation of historic materials and techniques added to the overall performance and sustainability of the roof systems. Few Hall once again proves the concepts of sustainability are nothing new. The result was a beautiful, high-performance roof system (see Figure 11).

Figures

Figure 1. Overview of Few Hall, Duke University, Durham, N.C.

Figure 2. New copper flashings to Duke Stone at exterior walls and chimneys

Figure 3. Few Hall, a residential building with secondary gables, dormers and balconies

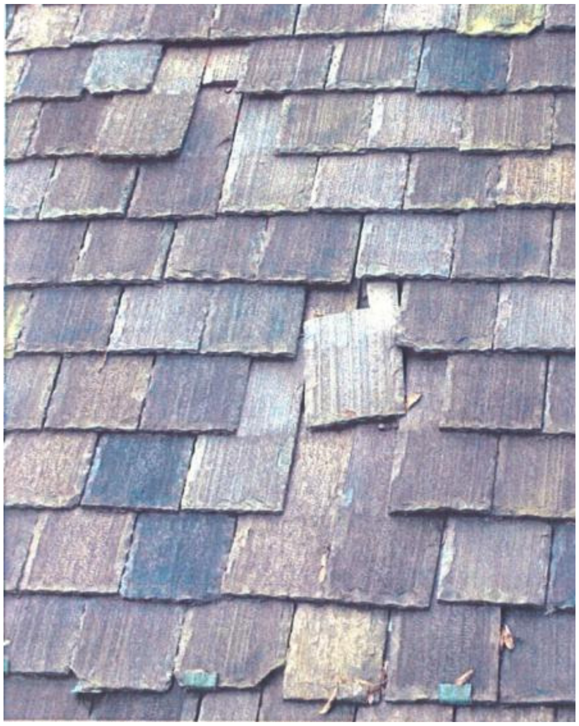

Figure 4. Typical types of observed damage to original tiles in service for more than 70 years

Figure 5. Wood-framed windows below existing aluminum covers

Figure 6. Many hands were involved in tile installation at dormers.

Figure 7. Many hands were involved in tile sorting for color blend and size.

Figure 8. Complex closed valley design and intersection ridges created significant detail work and opportunity for artistry of craft for tile layers, including the even distribution of three tile colors.

Figure 9. New (left) and original (right) conductor heads

Figure 10. Ludowici color options and SRI ratings taken from Ludowici's Sustainable Green Brochure published in 2009 and available for download from www.ludowici.com

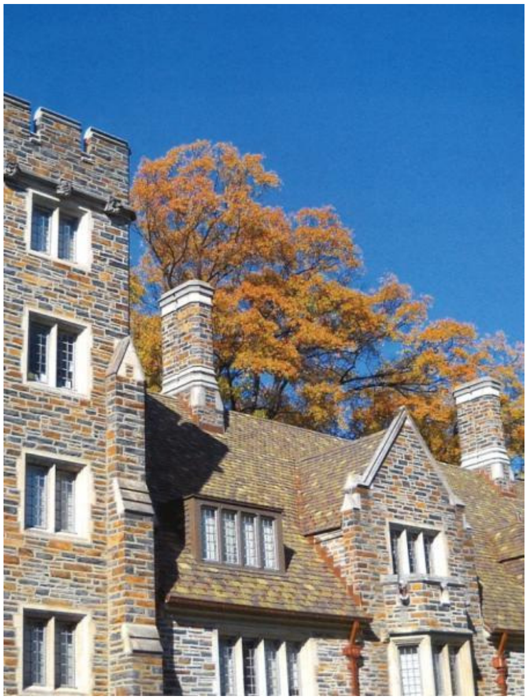

Figure 11. Portion of completed roof line.

[i] Source: http://www.copper.org/environment/homepage.html
[ii] Source: John C. Matthews, LEED AP Baker Roofing
[iii] Source: Tab Colbert, VP marketing and Sales Ludowici