Industrial Revolution

Every home makes compromises among different and often competing goals: comfort, convenience, durability, energy consumption, maintenance, construction costs, appearance, strength, community acceptance, and resale value. Often consumers and developers making the tradeoffs among these goals do so with incomplete information, increasing the risks and slowing the adoption of innovative products and processes. This slow diffusion negatively affects productivity, quality, performance, and value. This department of Cityscape *presents, in graphic form, a few promising technological improvements to the U.S. housing stock. If you have an idea for a future department feature, please send your diagram or photograph, along with a few well-chosen words, to elizabeth.a.cocke@hud.gov.*

Glass-Modified Asphalt Shingles for Mitigation of Urban Heat Island Effect

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Abstract

This study aims to use recycled glass cullet (broken or waste glass suitable for remelting) and titanium dioxide powder in asphalt shingles to increase a roof's solar-reflectance index while maintaining high performance levels. The study also uses cullet-modified asphalt shingles to alleviate the harmful effects of the urban heat island, and it evaluates the reduction in heating and cooling loads when the new class of asphalt shingles is used.

The Status Quo

The urban heat island (UHI) phenomenon is becoming increasingly intense as summertime temperatures continue to rise. In the United States, many cities with a population of 1 million or more experience an annual mean air temperature of 1.8 to 5.4 °F (1 to 3 °C) warmer than its surroundings (EPA, 2014). Elevated temperatures during the summertime lead to thermal discomfort, human health issues, and increased consumption of energy for cooling purposes. Development of the Earth's surface and the use of high-solar-radiation-absorbing materials, including asphalt roof shingles, are causes of UHI effect, especially in areas with a high density of buildings and urban structures. The surface temperatures of a traditional asphalt roof system may reach upwards of 160 °F on a 90 °F day (NRCA, 2013), thus intensifying UHI phenomenon.

Asphalt shingles are true composites made from a variety of materials, including fiberglass or organic felt, asphalt binder, mineral filler, and aggregate granules. By weight, shingles may be made of 80 percent mineral and rock, and, despite being called asphalt shingles, asphalt represents a very small yet important element of the material (Leavell, 2006). In an attempt to continue to use asphalt shingles while mitigating UHI phenomenon, this research project proposes the use of a new type of asphalt shingles that contains recycled cullet coated with light-colored titanium dioxide (TiO_2) powder in place of the mineral filler.

Experimental Program

Implementing sustainable materials into current manufacturing processes can reduce costs, conserve energy, and lower pollution. For a material to be considered sustainable, it should be cost efficient to the consumer and perform comparably or better than conventional materials. As an approach for mitigating the harmful effects of UHI, the use of cullet in the production of asphalt roof shingles has the potential to become a cool-roof strategy.

The objective of this study is to test the hypothesis that the use of recycled glass increases the solar-reflectance index (SRI) without affecting the performance of asphalt roof shingles. To evaluate the feasibility of using recycled glass in this application, the engineering properties of cullet were measured and compared with conventional aggregates used in the production of asphalt roof shingles. Laboratory samples were then prepared and the solar-reflectance properties and strength characteristics of conventional and recycled-glass roof shingles were measured.

Laboratory results showed that the use of recycled glass (see exhibit 1) as a replacement to standard ceramic-coated black roofing granules on the top surface of asphalt shingles resulted in an increased SRI. Further, the addition of white pigment TiO2 powder (anatase ultrafine particles passing mesh #320), which is mixed and applied with the surface granules, improved reflectance values to a level that met the cool-roof threshold. Results also showed acceptable tear strength for the laboratory-manufactured shingles.

Exhibit 1

Recycled Glass Shingle Produced in the Laboratory

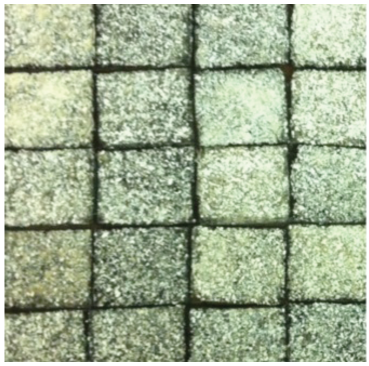


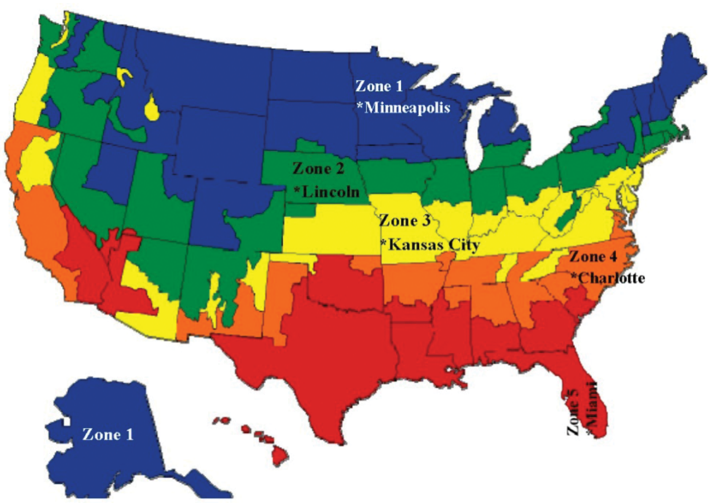
Photo courtesy of Marwa Hassan

Quantification of Energy Benefits

A three-dimensional (3-D) transient finite element (FE) model was developed and validated to quantify energy savings provided by the proposed recycling process under various climatic conditions. Simulations were carried out for three cities located in three of the five climate zones in the United States. The U.S. Energy Information Administration (EIA) categorized the climate regions in the United States into five main zones based on the last 30-year average heating degree days (HDD) and cooling degree days (CDD) (EIA, 2011; NOAA, 2012). Exhibit 2 shows the five main climate zones in the United States. For this study, Zones 3, 4, and 5 were simulated. The three cities representing each region were Kansas City, Missouri, for Zone 3; Charlotte, North Carolina, for Zone 4; and Miami, Florida, for Zone 5.

Exhibit 2

Climate Zones in the United States



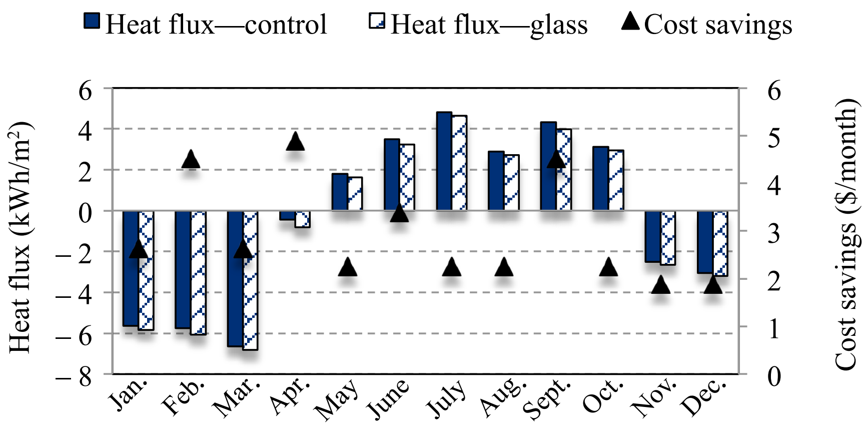
Source: http://energyiq.lbl.gov/EnergyIQ/tooltips/CBClimateMap.html?width=650&height=700

Results for each of the climate zones are shown in exhibits 3, 4, and 5. Exhibit 3 shows the monthly heat flux for a simulated two-floor building's attic in Kansas City—the first simulation using the proposed shingles and the second simulation using conventional shingles—as well as the monthly cost savings in energy consumption. The expected total energy savings per year is approximately $35.

Exhibit 4 shows the monthly heat flux for a simulated two-floor building's attic in Charlotte—the first simulation using the proposed shingles and the second simulation using conventional shingles—as well as the monthly cost savings in energy consumption. The expected total energy savings per year is $62.

Exhibit 3

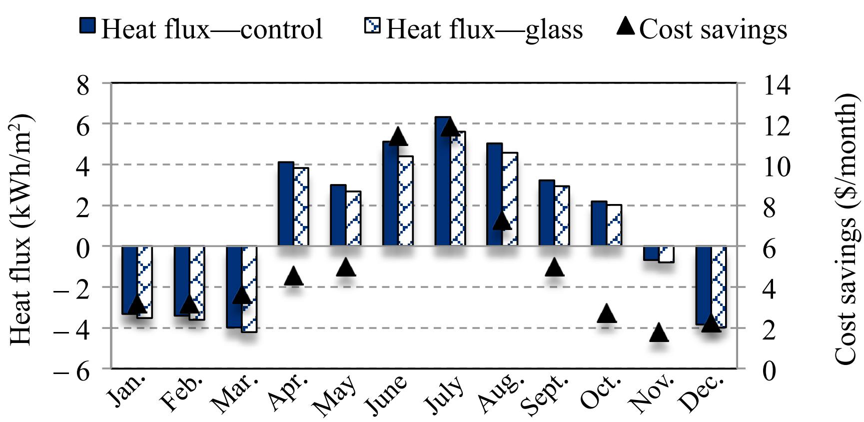
Simulated Heat Flux and Energy Savings for Kansas City, Missouri—Zone 3



kWh/m² = kilowatt-hour per square meter.

Exhibit 4

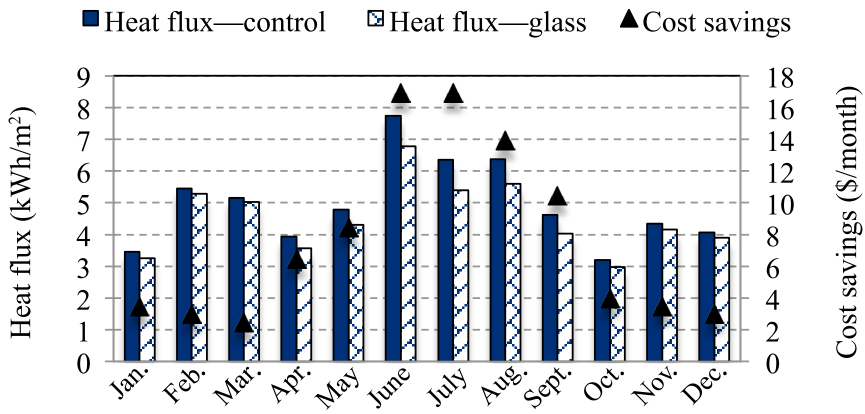
Simulated Heat Flux and Energy Savings for Charlotte, North Carolina—Zone 4



kWh/m² = kilowatt-hour per square meter.

Exhibit 5

Simulated Heat Flux and Energy Savings for Miami, Florida—Zone 5



kWh/m² = kilowatt-hour per square meter.

Exhibit 5 shows the monthly heat flux for a simulated two-floor building's attic in Miami—the first simulation using the proposed shingles and the second simulation using conventional shingles—as well as the monthly cost savings in energy consumption. The expected total energy savings per year is approximately $93.

As demonstrated by the FE results, more energy savings are attained in warmer climates. This technology is very well suited for use in Miami and locations with similar hot weather in the United States.

Conclusions and Recommendations

From the results of this study, we learned that cullet can be successfully blended with conventional materials to produce a sustainable asphalt shingle that has a solar-reflectance property that is 25 percent greater than conventional materials without compromising performance. This shingle design was patented and proven to result in significant annual energy savings especially in hot climate zones, including Florida and Louisiana.

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Additional Reading

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