

EFFECT OF ROOFING MATERIALS ON BUILDING ENERGY EFFICIENCY

*Sandra A Nunez and Dr. Robert W. Peters, University of Alabama at Birmingham,
Birmingham, AL*

Abstract

With the energy cost rising 11.7% seasonally adjusted annual rate (SAAR), companies and people are concerned about their energy cost and consumption. Many companies seek to be environmentally friendly and are very conscious about their energy consumption and the related costs. One environmental friendly option is to explore different roofing materials such as white thermoplastic polyolefin (TPO), solar panels, and green roofs, and their use as an alternative to reduce the consumption of energy in existing and new buildings, as well as reduce the amount of contaminants from runoff. Our research project addresses the effects of at least 15 roofing materials in reducing energy consumption and impacting runoff leachate. The interaction between energy consumption and runoff is currently being studied. This project is a collaborative effort involving UAB's Facilities Management Department and the Department of Civil, Construction, and Environmental Engineering. Fifteen mini roofs have been constructed using diverse roofing materials and data are being collected (since early March 2008), in terms of both energy efficiency and runoff characteristics. An evaluation of pollutants from runoff (focusing primarily on heavy metals) using these roofing materials is being conducted, as well as an assessment of energy efficiency. Preliminary results of reducing energy transfer using white roofs and green roofs is being addressed and evaluated. A model of energy consumption for white and green roof materials is being characterized by using the visual DOE-2 tool and the results are being compared with data obtained from the mini roofs. It is anticipated that white roofs reduce the amount of energy consumption about 20% compared to green roofs. However, green roofs may reduce the amount of runoff about 20% compared to white roofs, and therefore reduce the amount of pollutants discharged as runoff. The energy and environmental characteristics and trade-offs will be evaluated and compared for the different roofing materials.

Preliminary results indicate that clean white roofs resulted in consistently lower temperatures inside the mini roof than the other roofing materials, while black roofs resulted in the highest temperature readings. Green roofs resulted in temperatures typically ~2–3 degrees higher than the white roofs; however, they will dampen the drainage of rainfall during a rain storm through the retention of water onto the soil. White and green roofs both significantly reduce the roofs surface temperature and therefore, the air temperatures above and around the roof, thereby reducing the heat load being transferred into the buildings.

Introduction

The surface temperature of a roof can be between 140 and 180 degrees in the summer. It's also not very helpful to the environment, especially when you add the number of buildings in Birmingham to the mix. Surrounding buildings also are radiating this heat, making the temperature downtown higher than nearby rural areas. This phenomenon is known as heat-island effect and many believe it contributes to global warming.

UAB's Facilities Department and researchers from Civil Engineering are currently undertaking a green-roof research project in an effort to evaluate energy-efficient roofs for campus and lead the charge in the southeast in combating this problem.

Our goal is to get enough data that we can create new standards for UAB roofs that will be more energy efficient and cost effective. We want anybody in this climate region to be able to use our data and apply it to their roofs. We're doing our part to promote green at UAB, but we also believe we should be the leader in setting the example and providing data to others.

Heat-island reduction

For millions of Americans living in and around cities, heat islands are of growing concern. This phenomenon describes urban and suburban temperatures that are 2 to 10°F (1 to 6°C) hotter than nearby rural areas. Elevated temperatures can impact communities by increasing peak energy demand, air conditioning costs, air pollution levels, and heat-related illness and mortality. The Environmental Protection Agency (EPA) recommends installing cool or vegetative green roofs, planting trees and vegetation and switching to cool paving materials as a way of reducing the negative effects of heat islands. The EPA says green roofs, if installed widely in a city, can contribute to heat island reduction by replacing heat-absorbing surfaces with plants, shrubs, and small trees. The vegetation cools the air through evapotranspiration (or evaporation of water from leaves). Planted rooftops remain significantly cooler than a rooftop constructed from traditional heat-absorbing materials. Further, green roofs reduce summertime air conditioning demand by lowering heat gain to the building.

Test roofs

UAB's Facilities Management Department recently installed 15 miniature test roofs with different types of green or sustainable roof systems on the Chemistry Building. Researchers and students in Civil Engineering are constantly monitoring the test roofs. Each test-roof box measures 4-foot-by-8-foot, is constructed of plywood and insulated similar to most UAB buildings. Inside each plywood box is a wireless temperature sensor that is continuously being recorded and trended by a remote computer. Data is recorded every 10 minutes for all 15 mini-roofs. Temperatures are monitored over the course of the day and during seasons. Many different types of existing green roof systems, including vegetative and white reflective roofs, are being evaluated in comparison to traditional roofs for their effectiveness in conserving energy and sustainability. The results will be used to determine the type of roofs to be used on future UAB buildings and when roofs are replaced on existing UAB buildings. Due to the cost of energy, we believe this research is very important in UAB's efforts to reduce energy consumption.

Civil Engineering students tackled the question of what kind of roof should be used as part of their senior design course last fall semester. The course culminates four years of study as a civil engineering student, tying in all of their sub-disciplines. The Facilities Management Department identified the Hulsey Building as a potential test case to retrofit a green roof. The students divided into two teams and had to look at design codes of the building, figure out what kind of load it could support and then design a vegetative or white reflective roof that could retrofit the building, factoring in how the runoff from rain impacts the surroundings. Both groups advocated green roofs to help save energy. One looked at a conventional green roof and the other looked at using soil that had broken up brick. They also had to incorporate some architectural design and looked at plant species that might be involved.

In the current research project, we want to identify which roof is the best candidate for retrofitting out of all of the models we have. We are using different soil materials and plant materials. We are also capturing samples of the runoff and looking to see if metals and other substances may be present in the runoff from the roofing materials.

Do it yourself

Chicago and parts of Arizona and Wisconsin have incorporated green roofs into their structures. There has been a good amount of research done on green roofs for those climates to determine what type is best suited for those weather climates. However, there is not much research being conducted on which green roof systems are best suited for the southern climate, especially through university research. The research team at UAB finally decided the only way to get this information was to do it ourselves. Fortunately we are at an institution with the kind of resources at our disposal to make this happen and to do it the right way. We have put a vegetative roof on one of the buildings on the UAB campus as a pilot program (on top of Hulsey Building). In retrofitting a green roof on any building, the structural strength of the building must be sufficient to support it. As a result, some buildings may be suited for it, and others not.

RESULTS AND DISCUSSION

Figure 1 shows several of the mini roof systems being studied in the project. A listing of the fifteen roofing materials being studied is provided below in Table 1. All roofs are insulated with 2.0-in. of extruded polystyrene which has an *R*-value of 0.10.

Table 1. Mini-Roof Descriptions.

| Mini-Roof No. | Mini-Roof Description |
|----------------------|--|
| 1 (Sensor B) | White TPO/PVC/Elvaloy fully adhered, FiberTite Membrane. |
| 2 (Sensor C) | Black 60-mil EPDM fully adhered/coated/white urethane, Mule Hide Membrane. |
| 3 (Sensor D) | Black 60-mil EPDM fully adhered, Mule Hide Membrane. |
| 4 (Sensor E) | Beige TPO/PVC/Elvaloy fully adhered, FiberTite Membrane. |
| 5 (Sensor F) | White granular modified, Firestone SBS Modified Membrane. |
| 6 (Sensor G) | Black granular modified, Firestone SBS Modified Membrane. |
| 7 (Sensor H) | Black granular modified coated/white urethane, Firestone SBS Modified Membrane. |
| 8 (Sensor I) | Bituthene IRMA with lightweight “T Clear” pavers. |
| 9 (Sensor J) | Bituthene IRMA with river rock ballast. |
| 10 (Sensor K) | Bituthene IRMA with vegetative green roof, ½-in. drain mat, 350-lbs dry soil. |
| 11 (Sensor L) | Bituthene IRMA with vegetative green roof, 1-in. drain mat, 350-lbs dry soil. |
| 12 (Sensor M) | Black 60-mil EPDM loose, ballasted with river rock, Mule Hide Membrane. |
| 13 (Sensor N) | Black 60-mil EPDM loose, ballasted with #300 marble chips, Mule Hide Membrane. |
| 14 (Sensor O) | White TPO/PVC/Elvaroy loose laid, ballasted with river rock, FiberTite Membrane. |
| 15 (Sensor P) | Bituthene IRMA with vegetative green roof, ½-in. drain mat, 350-lbs dry soil. |
| Sensor S | Sensor inside mini-roof No.10 (inside the soil of the green roof). |
| Sensor T | Sensor under the white TPO/PVC/Elvaloy loose laid, ballasted with river rock. |

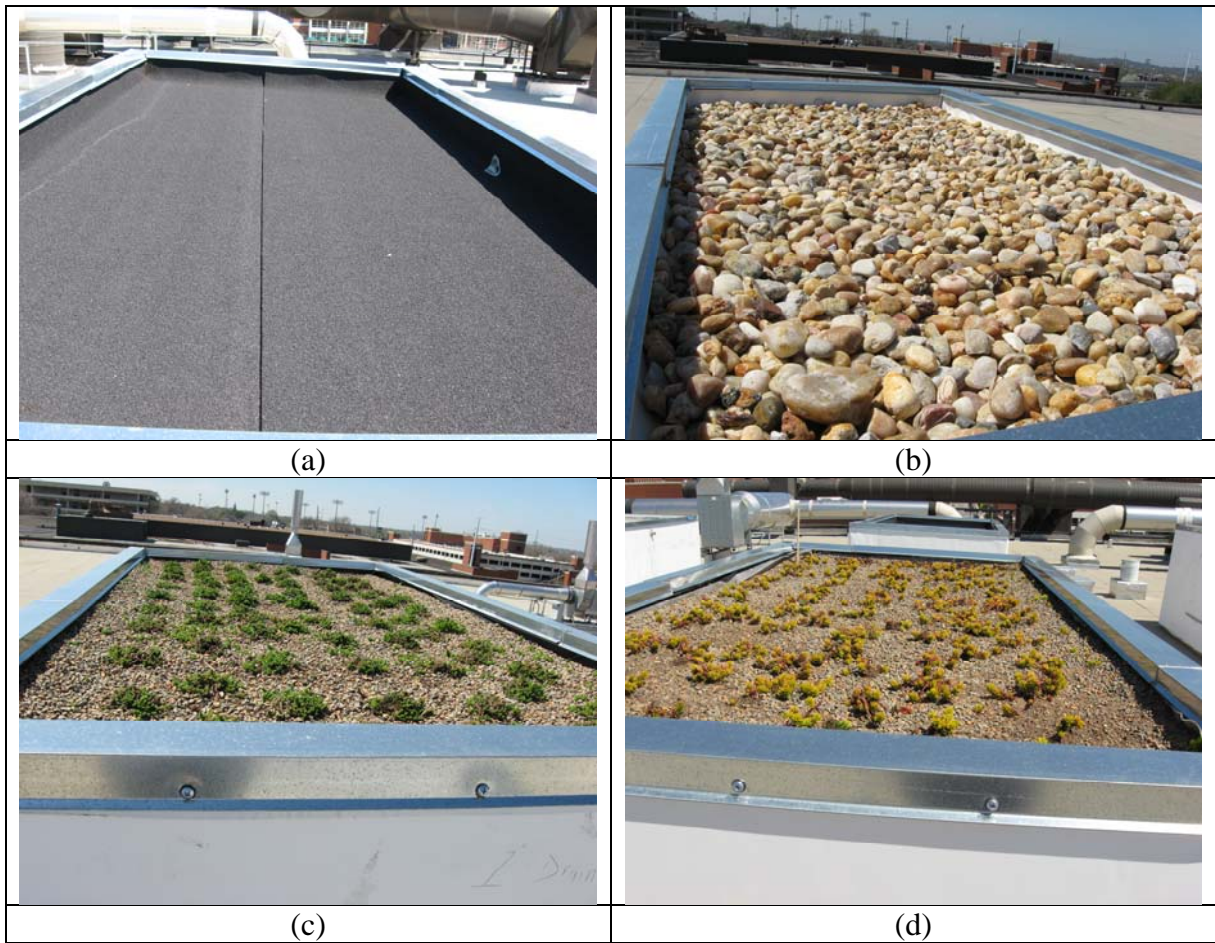


Figure 1. Examples of the mini-roofs constructed on the UAB campus: (a) black roof; (b) river rock; (c) vegetative (green) roof; and (d) second different vegetative roof.

Figure 2 shows an example of a temperature sensor installed inside one of the mini-roof structures. Temperature measurements were recorded every 10 minutes. Typical results for the 15 roofing materials during the course of three different days (May 26th, May 28th, and June 5th) are also shown in Figure 2.

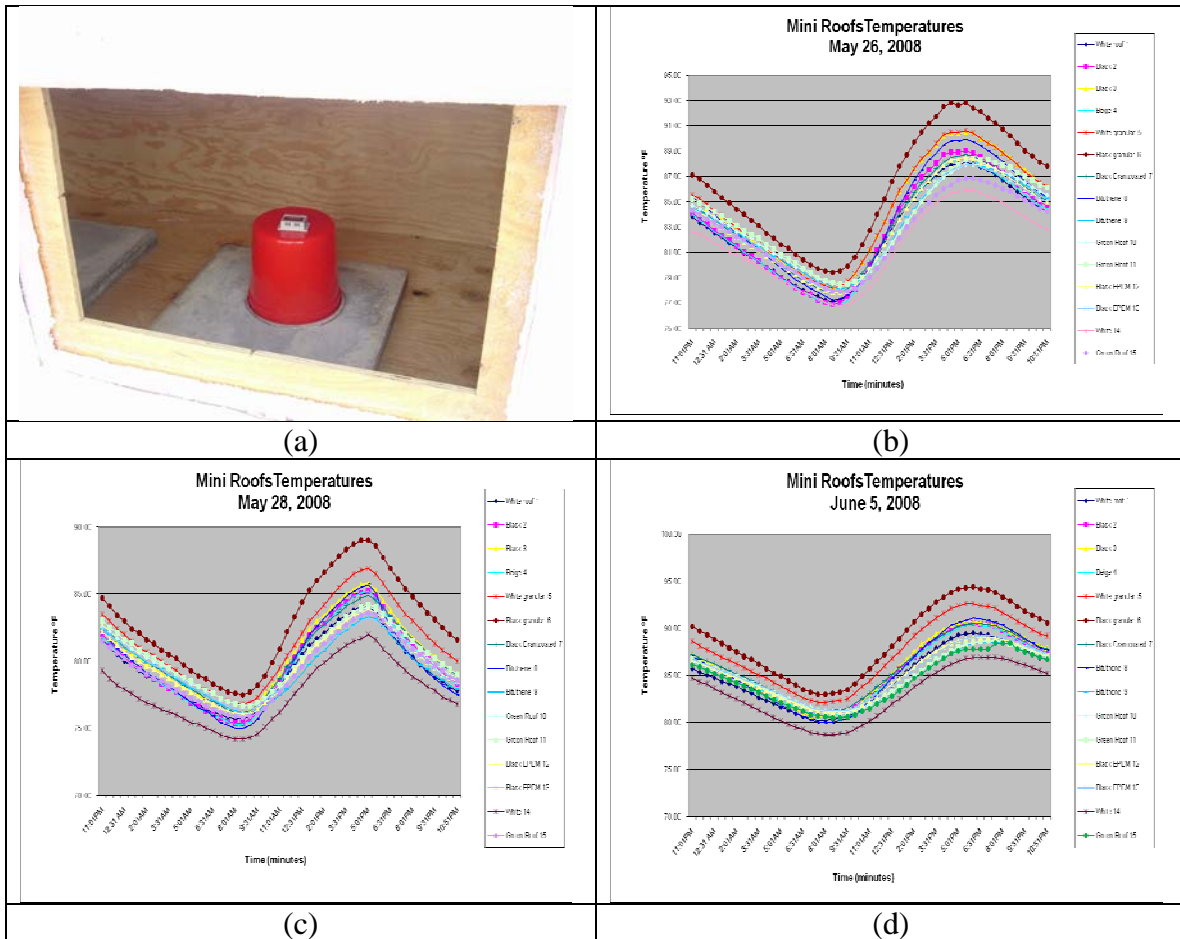


Figure 2. (a) Mini-roof system showing temperature sensor installed inside a mini-roof; and typical results of the temperatures inside the mini-roof structures on three separate days: (b) May 26; (c) May 28; and (d) June 5, 2008.

Surface temperatures of the roofing materials during hot summer days were $\sim 170\text{--}180^\circ\text{F}$ for the black roofs; $\sim 110^\circ\text{F}$ for the clean white roof materials; and $\sim 145^\circ\text{F}$ for the soils of the green roof systems. However, due to transpiration, the temperature of the surface plants was $\sim 115^\circ\text{F}$. Thus, as the plant systems grew and spread, the surface temperature decreased significantly, resulting in a lower heat load being transmitted into the building. Another noteworthy observation is that as the white roof systems became dirty (accumulating dust, etc.), the surface temperature rose considerably, to $\sim 140^\circ\text{F}$.

The results from these mini-roof structures have shown the following trends:

- Clean white roofs resulted in consistently lower temperatures inside the mini roof than the other roofing materials.
- Black roofs resulted in the highest temperature readings.
- Green roofs resulted in temperatures typically $\sim 2\text{--}3$ degrees higher than the white roofs; however, they will dampen the drainage of rainfall during a rain storm through the retention of water onto the soil.

- Bituthane (river rock) performs only slightly better than black roofing materials.
- White granular roofing behaved similarly to black granular roofing materials.
- White marble chips behaved slightly worse than green roofing materials, but considerably better than black roofing and granular roofing materials.
- While it is too early to come to a definitive conclusion, preliminary evaluations indicate that the “white” and “green” roofs both significantly reduce the roofs surface temperature and therefore, the air temperatures above and around the roof.

Conclusions

If we can prove this works, then buildings that are being designed now or in the future – whether it be on campus, in our community, or in the southeast – can be stressed to handle the load of a green roof and it can be a part of the design from the beginning. That could mean those roof temperatures of more than 160°F in the summer may not be as frequent in the coming years. White and green roofs both significantly reduce the roofs surface temperature and therefore, the air temperatures above and around the roof, thereby reducing the heat load being transferred into the buildings.

Acknowledgments

This research activity is being funded by the University of Alabama at Birmingham (UAB), in conjunction with the Facilities Management Department and the Department of Civil, Construction, and Environmental Engineering.