Environmental and Cost Benefits of High Albedo Concrete

By Erin Ashley, PhD, LEED AP, Director of Codes and Sustainability, NRMCA

The use of light colored exposed concrete in our urban areas and roadways can aid in the overall energy savings, safety, comfort and ambience of the general public. This is a guiding principle of Low Impact Development (LID). Light colored concrete absorbs less heat and reflects more light than dark-colored materials, therefore maintaining a low surface temperature. High albedo concrete has been demonstrated to have a positive impact on the localized ambient temperatures and can reduce energy requirements to cool buildings. Light colored pavements also require less site lighting to provide safe night-time illumination levels, whether on parking lots, driveways or sidewalks. Less sight lighting requires less energy. The net effect from light colored surfaces does result in a reduction in energy to help reduce the environmental impact of our built environment.

Concrete's ability to reflect solar radiation is governed by the material's albedo or measure of the solar reflectivity of the material. An object's albedo is the extent to which the material diffusely reflects light from the sun. Although not always an indicator, materials with a light color have a high albedo, where materials that appear darker typically have a lower albedo. A material's ability to reflect infrared light is directly proportional to a material's ability to reflect heat from the surface. During the hot summer months, the ambient air surrounding dark colored paving or cladding materials can be up to 10 °F warmer[1] than material with a light color, or high albedo. Several studies have been made which illustrate this point. One such study analyzed temperature differentials in California at an ambient temperature of 55 °F for various colored materials[2]. The study found that the maximum temperature differential between a material covered with a black acrylic paint and a material covered with a white acrylic paint was 68°F. A second study measured the temperature of various pavement types during a hot 90°F summer day, and found that weathered concrete had a temperature of 155°F at the material surface where dark asphalt had a temperature of 195°F, 40 degrees higher than the lighter colored concrete pavement.[3]

The effect of increase in ambient temperatures in metropolitan areas is apparent when you compare the health of those who reside in the city versus those who reside in more rural areas. Compared to rural areas, cities experience higher rates of heat related illness and death. Heat islands, or areas of dark colored roofing and pavements where ambient temperature is increased, can exacerbate hot weather events or periods, which may cause heat stroke and lead to physical discomfort, heat stroke, organ damage and even death – especially in vulnerable populations such as the elderly[4]. The Centers for Disease Control and Prevention (CDC) says that excessive heat claims more lives in the United States each year than hurricanes, lightning, tornadoes, floods and earthquakes combined. Between 1979-1998, the CDC estimates that 7,421 deaths resulted from exposure to excessive heat in the U.S. By reducing the temperature of the pavements through the use of concrete, one may be able to reduce the ambient temperature of our cities, therefore reducing the temperature exposure to its residents, as shown in Figure 1. This idea is further solidified when you look at one of 13 "cool communities" sponsored by the Department of Energy[5]. By simply replacing

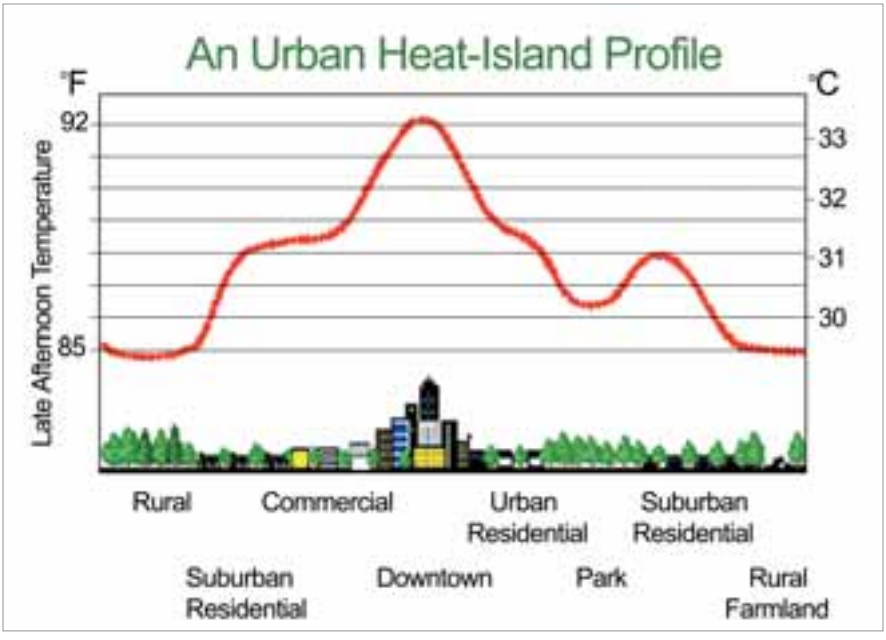

Figure 1. Urban Heat Island Effect for various localities [6]

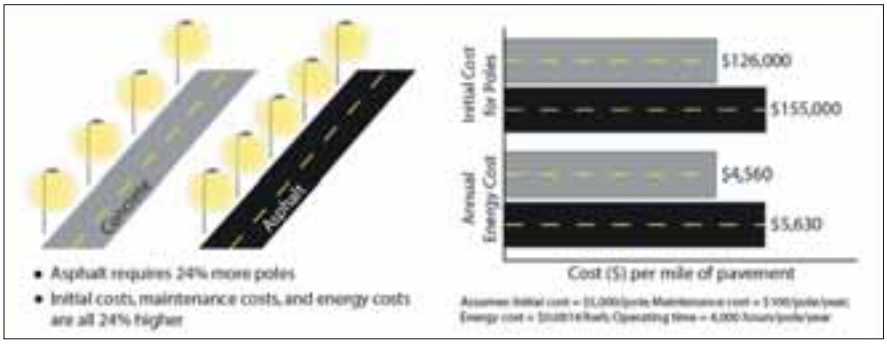

Figure 2. Cost and light pole differential between concrete and asphalt roadways. Reprinted from "Enlightened" (QD-010P), a publication of the American Concrete Pavement Association. ©2007, American Concrete Pavement Association. All rights reserved.

dark colored pavements with light and heat-reflective concrete-based materials, along with careful planting of trees, the average summer afternoon temperature was reduced by as much as 5°F, cutting the need for air conditioning by 18% and even reducing air pollution.

When it comes to green building, concrete pavements may aid in achieving specific LEED credits related to the heat island effect. A point is awarded if the requirements of LEED Sustainable Sites Credit 7.1 Heat Island Effect – Non Roof are achieved. The intent of this credit is to reduce heat islands (thermal gradients between developed and undeveloped areas) to minimize impact on microclimate and human and wildlife habitat[6]. This credit requires high albedo materials and/or open-grid pavement for at least 50% of the site's non-roof impervious surfaces such as sidewalks, parking lots, driveways and access roads; or by providing shade through vegetation, within five years, on at least 50% of non-roof impervious surfaces on the site, including parking lots, walkways, plazas, etc. Concrete surfaces help reduce the heat island effect by absorbing less heat from solar radiation than darker pavements, therefore meeting the intent of this credit.

Concrete's ability to reflect light increases the safety on highways and roadways by allowing for increased illumination during the nighttime hours. This increased illumination allows for a decrease in energy use by reducing or eliminating electric lighting. Studies have shown that concrete pavements reduce the required lights per unit length of roadway (or possibly parking area) to achieve the same level of illumination of dark colored pavements[7]. The results of the study indicate that the cost savings in initial energy consumption and ongoing maintenance of light poles is reduced by 31% where concrete pavements are used. Operational energy costs to illuminate a concrete roadway compared to a dark colored roadway were 33% less. To maintain the specified illumination of a roadway, an asphalt roadway will require 24% more light poles, an increase in project costs of $30,000. The annual energy consumption of these extra light poles equates to a cost of $1100 per mile of roadway as shown in Figure 2. Simply by constructing a roadway of concrete, one can significantly reduce the first costs, as well as the ongoing energy costs and consumption. When these costs and impact are quantified to an owner, changing a decision or paradigm of pavement type selection can be easily facilitated and justified.

With the inevitable rise in outdoor temperatures leading to higher energy use, additional CO2 emissions, and more expensive heating and cooling bills, decreasing urban heat islands through the use of concrete is a viable option to mitigate the environmental burden of our pavements. By providing concrete pavements on roadways, the first and operational costs of our pavements are reduced and our public is provided a safe, sustainable, well lit environment to operate their vehicles. ■

For more information, contact Erin Ashley at easley@nrmca.org.

The net effect from light colored surfaces does result in a reduction in energy to help reduce the environmental impact of our built environment.

[1] LEED 2.2 Reference Guide, United States Green Building Council, 2007.
[2] Berdahl, P. and Bretz, S., "Spectra Solar Reflectance of Various Roof Materials," Cool Building and Paving Materials Workshop, Gaithersburg, Maryland, July 1994.
[3] Rosenfeld, A. H.; Akbari, H.; Bretz, S.; Sailor, D.; and Taha, H., "Mitigation of Urban Heat Islands: Materials, Utility Programs, and Updates," Submitted to the Journal of Energy Efficiency, Vol. 1, No. 1, 1993.
[4] Cutler J. Cleveland (Topic Editor). 2007. "Heat island." In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [First published in the Encyclopedia of Earth August 17, 2006; Last revised February 3, 2007; Retrieved August 13, 2008]
[5] www.eere.energy.gov/state_energy_program/project_brief_detail.cfm/pb_id=102 Accessed August 10, 2008
[6] http://www.climatescience.gov/Library/sap/sap4-5/sap4-5prospectus-final.htm Accessed August 10, 2008.
[7] Gadja, J.W., and M.G. Van Geem. 1997. A Comparison of Six Environmental Impacts of Portland Cement Concrete and Asphalt Cement Concrete Pavement. PCA R&D Serial No. 2068. Skokie, IL: Portland Cement Association.