R&T UPDATE
Concrete Pavement Research & Technology

ALBEDO: A MEASURE OF PAVEMENT SURFACE REFLECTANCE

Paved surfaces (such as highways, roads, runways, parking areas, sidewalks, and driveways) typically constitute about 30 to 40% of developed urban areas. In the past few decades, the bane of urban cities has been the increased heating of the city by sunlight due to dark, heat-absorbing materials used in the construction of pavements and buildings. Urban areas are oftentimes up to 8°F warmer than the surrounding rural area, creating "urban heat islands." If the urban surfaces were lighter in color, more of the incoming light would be reflected back into space, cooling the surfaces and ambient air. Cooler surfaces and air reduce the need for air conditioning, saving energy and reducing power plant emissions. Cooler air can also reduce air pollution by slowing the chemical reactions that produce smog.

What is albedo?

Solar radiation includes visible light (typically 43% of solar energy), near-infrared light (52%), and ultraviolet light (5%). Albedo, or solar reflectance, is the ratio of *reflected* solar radiation to the total amount that falls on that surface, known as *incident* solar radiation. Albedo values range from 0, for perfect absorbers, to 1, for perfect reflectors. In pavement structures, the topmost surface is the only layer which affects albedo. Therefore, pavement type selection should also include a consideration of albedo where heat generation is a concern.

Field measurements indicate that new, cured gray-cement concrete pavement has an albedo in the range of 0.35 - 0.40. As concrete ages, it tends to darken because of dirt and tire wear, so most older concretes have albedos in the range of 0.20 – 0.30. The use of white cements and slag cements can also influence a concrete's albedo immensely. White cement concrete pavements have albedos in the range of 0.70 - 0.80 when new, and 0.40 - 0.60 when aged. Asphalt, on the other hand, tends to get lighter as it ages, due to oxidation and wearing of the binder, revealing the lighter-colored aggregate. New asphalt is very dark, so it has an albedo of 0.05 - 0.10, and aged asphalt has an albedo of 0.10 – 0.15 [see Table 1].

Examples of albedo

In a recent study, sponsored by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA), researchers in the Heat Island Group at the Lawrence Berkeley National Laboratory investigated methods to develop cool concrete pavements by using white portland cement and reflective aggregates [Ref 1].

Table 1. Albedos (reflectance) of pavement surfaces

Pavement Type	Albedo
Asphalt	0.05 – 0.10 (new) 0.10 – 0.15 (weathered)
gray portland cement concrete	0.35 – 0.40 (new) 0.20 – 0.30 (weathered)
white portland cement concrete	0.70 – 0.80 (new) 0.40 – 0.60 (weathered)

American Concrete Pavement Association
5420 Old Orchard Rd.
Suite A100
Skokie, IL 60077
Phone: 847-966-2272
Fax: 847-966-9970
www.pavement.com

In urban situations, most sidewalks and a varying percentage of roads and parking areas are paved with portland cement concrete, which can be made even more reflective through suitable choice of cement and aggregate. Variations in mix design and environmental exposure of portland cement concrete pavements were explored in the Berkeley study through laboratory fabrication and exposure of 32 different concrete mixes.

Excluding substandard samples that exhibited poor mixture characteristics, the albedos of the concrete mixes ranged from 0.41 to 0.77. Simulated weathering, soiling, and abrasion each reduced average concrete albedo, though some samples became slightly more reflective through weathering or soiling. Simulated rain (wetting) strongly depressed the albedos of concretes until their surfaces were dried. Concrete albedo grew as the cement hydration reaction progressed, but stabilized within six weeks of casting.

White-cement concretes (albedos 0.69 – 0.77) were on average significantly more reflective than gray-cement concretes (albedos 0.41 – 0.52). The albedo of the most-reflective white-cement concrete was 0.18 to 0.39 higher than that of the most-reflective gray-cement concrete, depending on state of exposure. Concrete albedo generally correlated well with cement albedo and sand albedo, and, after abrasion, with rock albedo. Cement albedo has a disproportionately strong influence on the reflectance of concrete.

Costs

Even though concrete pavements can be made lighter than they already naturally are, the benefit of using light-colored aggregates and white cement (as compared to normal aggregates and standard gray cements) needs to be weighed against the additional cost of obtaining these materials. Concretes made with white cement, for example, may cost up to twice as much as those made with normal gray cement. However, certain blended cements (slag cements) are very light in color and may reflect similarly to white cement at an equivalent cost to normal gray cement.

The cost savings, however, from switching from *asphalt* pavements to normal gray *concrete* pavements can save a city millions of dollars a year. Simulations of the influence of pavement albedo on air temperature in Los Angeles predict that increasing the albedo of 1,250 km of pavement by 0.25 would save cooling energy worth $15M per year, and reduce smog-related medical and lost-work expenses by $76M per year [Ref 2].

Conclusion

The selection of materials that comprise a concrete mixture can greatly affect the reflectance of the finished concrete surface. Although concrete surfaces are already more reflective than asphalt surfaces, they can be made even more reflective with the use of white cement and lighter coarse and fine aggregates. This helps make concrete a very attractive pavement surface choice for urban areas.

References (reprints available from Lawrence Berkeley National Laboratory, tel. 510-486-7437, MAShiffman@lbl.gov)

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2. Pomerantz, M., H. Akbari, A. Chen, H. Taha, and A.H. Rosenfeld. 1997. “Paving Materials for Heat Island Mitigation,” Lawrence Berkeley National Laboratory Report LBL-38074, Berkeley, CA.

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