Title

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ASTM Standards for Measuring Solar Reflectance and Infrared Emittance of Construction Materials and Comparing their Steady-State Surface Temperatures

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Numerous experiments on individual buildings in California and Florida show that painting roofs white reduces air conditioning load up to 50%, depending on the thermal resistance or amount of insulation under the roof. The savings, of course, are strong functions of the thermal integrity of a building and climate. In earlier work, we have estimated the national energy savings potential from reflective roofs and paved surfaces. Achieving this potential, however, is conditional on receiving the necessary Federal, states, and electric utilities support to develop materials with high solar reflectance and design effective implementation programs. An important step in initiating an effective program in this area is to work with the American Society for Testing & Materials (ASTM) and the industry to create test procedures, ratings, and labeling for building and paving materials. A subcommittee of ASTM E06, E06.42, on Cool Construction Materials, was formed as the vehicle to develop standard practices for measuring, rating, and labeling cool construction materials.

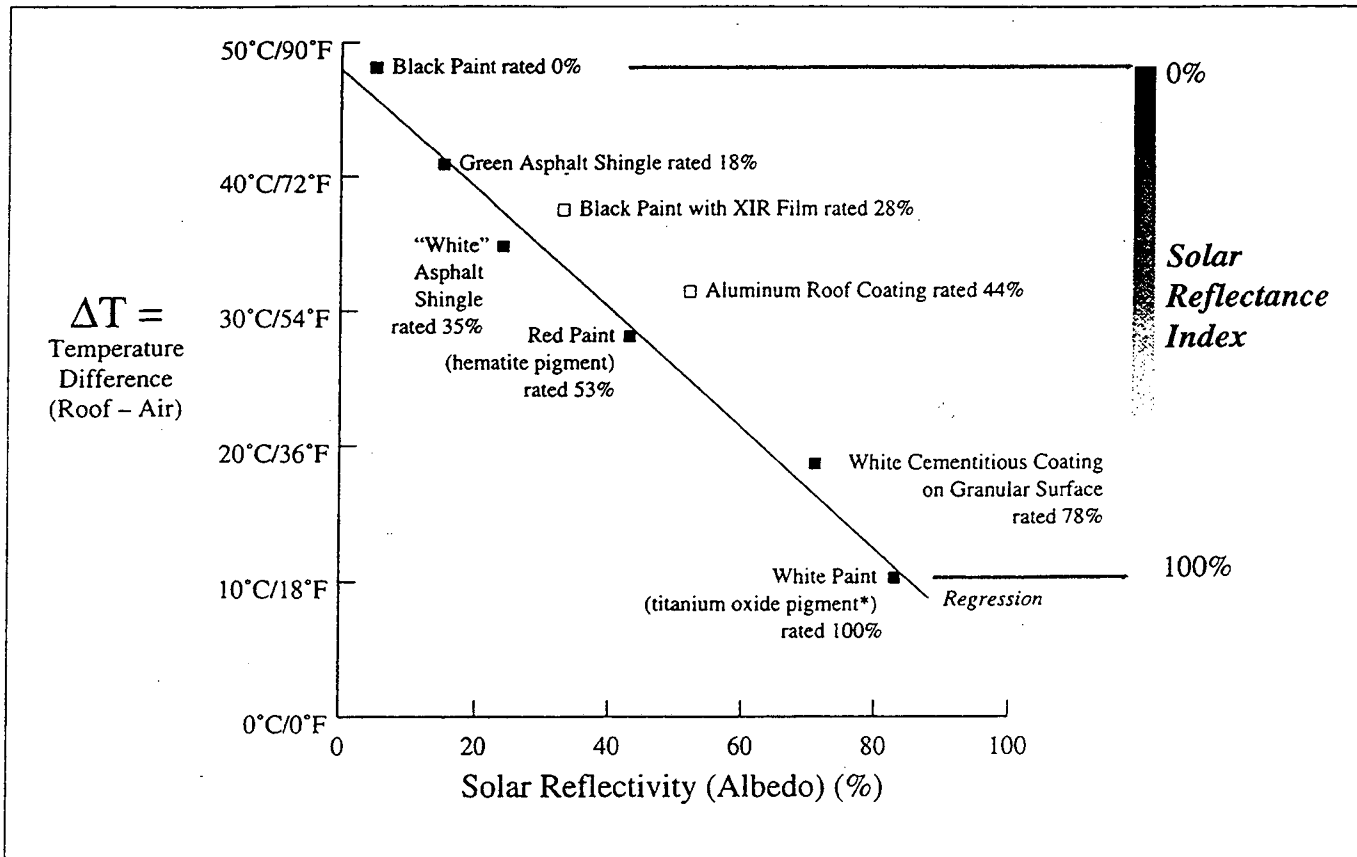
The subcommittee believes that two existing ASTM standards ''E 903—Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres'' and ''E 408 - Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques'' meet the present needs for laboratory measurement of these properties. The subcommittee has determined that these two optical properties (solar reflectance and infrared emittance) also need to be measured in the field. In response to lack of standards for field measurements of solar reflectance, the subcommittee has drafted a test method for measuring solar reflectance of horizontal and low-sloped surfaces. The subcommittee has not yet proposed a method to measure infrared emittance in the field.

The subcommittee has also undertaken the development of a standard practice for calculating a solar reflectance index (SRI) of horizontal and low-sloped surfaces. SRI is a measure of the relative steady-state temperature of a surface with respect to a standard white surface (SRI = 100) and a standard black surface (SRI = 0) under standard solar and ambient conditions. This paper discusses the technical issues relating to development of these two ASTM standards.

INTRODUCTION

Modern urban areas usually have darker surfaces than their surroundings. Use of dark roofs and pavements affects the climate, energy use, and habitability of cities. At the building scale, dark roofs are heated by the summer sun and this raises the summertime cooling demand. Figure 1 shows the midday temperatures of various horizontal surfaces exposed to sunlight. For highly absorptive (low-solar reflectance) surfaces, the difference between the surface and ambient air temperatures may be as high as 50°C (90°F), while for less absorptive (high-solar reflectance) surfaces, such as white paint, the difference is only about 10°C (18°F). For this reason, ''cool'' surfaces (which absorb little ''insolation'') are effective in reducing cooling energy use. Cool surfaces incur no additional cost if color changes are incorporated into routine re-roofing and resurfacing schedules (Akbari et al. 1989). Scientists at the Lawrence Berkeley National Laboratory (LBNL) and the Florida Solar Energy Center have measured cooling energy savings in the range of 10 to 50% (ranging from $10 to $100 per year per 100 m^2) in several residential and small commercial buildings (Akbari 1994, Parker 1994). Numerous experiments on individual buildings in California and Florida show that painting roofs white reduces air conditioning load between 10 and 50%, depending on the amount or thermal resistance of insulation under the roof. The savings, of course, are strong functions of the thermal integrity of a building and climate conditions. Most surfaces with high solar reflectance are light-colored, although selective surfaces—which reflect a large portion of the infrared solar radiation but absorb some visible light—may be dark colored, yet have relatively high solar reflectance. This phenomena is better explained by inspecting the spectral reflectance of black acrylic paint and the same paint covered with XIR selective coating (Figure 2). On a clear sunny day, over 40% of the incoming solar radiation is

Figure 1. The midday temperatures of various horizontal surfaces exposed to sunlight.



near-infrared. As a result, covering the black surface with a selective (XIR) film has lead to an increase of 0.28 in the solar reflectivity of the surface and to a reduction of 10°C in surface temperature (see Fig. 1). Hence, it is possible to develop cool materials that are highly reflective in the near infrared band with a choice of light colors in the visible spectrum.

Darker surfaces also more quickly warm the air over urban areas, leading to the creation of summer urban ''heat islands.'' On a clear summer afternoon, the air temperature in a typical city can be about 1–5°C (2–9°F) hotter than the surrounding rural area. Akbari et al. (1992) have found that peak urban electric demand in five American cities (Los Angeles, CA; Washington, DC; Phoenix, AZ; Tucson, AZ; and Colorado Springs, CO) rises by 2–4% for each 1°C rise in daily maximum temperature above a threshold of 15 to 20°C. The additional air-conditioning use caused by this urban air temperature increase is responsible for 5–10% of urban peak electric demand at a direct cost of several billion dollars annually.

Scientists at LBNL have examined the impacts of using cool surfaces (cool roofs and pavements) on reducing the urban air temperature and hence further reducing cooling energy use and smog. At the community scale, increasing the solar reflectance of urban surfaces can limit or reverse an urban heat island effectively and inexpensively. Increasing the solar reflectance of urban surfaces can be implemented by a program which 1) rates and labels roofing materials by their temperature rise on a cloudless summer day; 2) adopts relatively mild standards (for example, new roofs run cooler than halfway between the surface temperature of typical white and black surfaces) and 3) offers incentives to beat the standards such as electric utilities offering rebates on new roofs (or re-roofs).

LBNL researchers have simulated the cooling achieved by increasing the reflectance of roofs and roadways in the Los Angeles Basin (Taha 1995b). About 17% of the urbanized area in the basin is covered by roofs and roads which can realistically have their solar reflectance raised by 30% when they receive their normal repairs. The result is an overall reduction in temperature peaking at about 2°C (4°F) by 3 pm. This summertime temperature reduction has a significant effect on further reducing building cooling energy use. An estimate of the national impact of cool surfaces (combining the cooling effect at the building level and community-wide cooling) is summarized in Table 1.