ENERGY SAVINGS FOR EXTERIOR WALLS COATED WITH COOL COLORS

A Summary of the Oak Ridge National Laboratory Report

Solar radiation control is an effective means to decrease building cooling energy. By reflecting sunlight away from an exterior surface before it can be absorbed, solar radiation control keeps the exposed building surface cooler than without solar radiation control. This decreases the temperature difference between the inside and the outside of the roof or wall. Temperature difference drives heat into the building; the smaller the difference, the smaller the heat flow rate. Reduced heat flows mean lower energy costs for the building owner. Reflecting sunlight away also diminishes the effects of high temperature and intense sunlight on the exterior surfaces.

Until recently, options for reducing these energy costs have been limited to using white surfaces. They appear white because they have a high solar reflectance, especially in the range that is visible to the eye. They reflect away the maximum amount of solar radiation leading to the maximum summer cooling savings compared to dark colored surfaces. While these “technologies” provide satisfactory results for out-of-sight surfaces, they are not aesthetically useful elsewhere, or where the consumer desires to use a non-white exterior color.

For steep-slope roofs and exterior walls, the appearance of the surface becomes a significant factor. Building owners want aesthetically pleasing colors for exterior surfaces that will be seen from street level. Specialized pigments referred to as cool colors used in exterior wall finishes are now available and enables walls of any hue to have increased levels of solar reflectance and therefore save energy.

Cool colors are a recent development. They have the same visible appearance as standard colors but have higher solar reflectance in the near infrared range. In the portion of the solar spectrum that is visible, cool and conventional pigments exhibit essentially the same absorption. Cool paints reflect the same amount of solar energy as a conventional paint. To the human eye sensing the light reflected off them, they appear to have the same color. However, the solar reflectance of cool colors is enhanced outside of the visible range as the wavelengths proceed into the near-infrared region. A coating formulated with cool pigments will show far less absorption and have a total solar reflectance that is significantly higher than when using the same colored coating with conventional pigments. This is important because it is the infrared portion of sunlight that supplies more than 50 percent of the sun’s energy. As a result, the cool pigments translate into less heat build-up in the wall. For example, a typical green vs. a cool green surface has 25% vs. 50% solar reflectance, doubling the amount of solar energy reflected off of a surface treated with the cool color.

The measurement of a cool colored paint for a wall system is identical to the procedures that have been defined for measuring roofing products or coatings. The Cool

Roof Rating Council (CRRC) has selected several standardized ASTM tests that are used to evaluate the solar reflectance and thermal emittance of cool roofing products. These are the same key material properties that define the performance of cool colored wall paint. The same ASTM test methods used for roofs can be used for these products. ASTM C1549, Standard Test Method for "Determination of Solar Reflectance Near ambient Temperature Using a Portable Solar Reflectometer" and ASTM C1371, Standard Test Method for "Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers" have been used to characterize cool colored wall products. These procedures are accepted by the CRRC for roofing product certification.

Vertical surfaces do not receive maximum solar load during peak cooling nor do they have solar energy striking their surfaces for as long a time period as a roof system. Still, these surfaces provide an as yet untapped source of potentially significant energy savings. Moreover, coating a wall with cool colors is an energy saving improvement that can be done without any deconstruction and rebuild.

With very limited options available to a homeowner when considering energy efficiency improvements for walls, especially when it comes to improving older homes, a cool color certainly can be considered a viable cost-effective alternative. In existing buildings, improving the energy efficiency of the walls of that building is quite costly. For example, the addition of insulation requires either the removal of the exterior façade to add foam sheathing or literally hundreds of access holes punched through the interior gypsum board to allow for the application of insulation products into the wall's cavities. Quite the contrary, nearly every consumer must paint their exterior walls at some point as part of their routine maintenance. The use of cool pigments (at little to no extra cost) would provide those consumers in the environments described below with substantial energy savings.

To quantify the energy savings, field tests were done at three sites on walls coated side-by-side with and without cool colors. These field tests were performed by Oak Ridge National Laboratory, a nationally recognized leader in the area of building envelope energy efficiency research, under my direction. Data from Phoenix AZ and Jacksonville FL showed the effect of different constructions, orientations and climates. Data from a year of tests in Oak Ridge TN were judged suitable for validation of a model of a south-facing wall.

For the Oak Ridge testing, the two wall sections were placed side-by-side on the south side of a conditioned research lab building and instrumented identically. The wall was comprised of a gypsum board interior, a 2 by 4 inch stud cavity filled with R11 fibrous glass insulation, an oriented strand board exterior sheathing, building paper, and a vented stucco exterior cladding. A heat flux transducer installed in the gypsum board was used to measure the instantaneous rate of heat flow through each assembly. Thermocouples were placed on surfaces in each assembly, including the exterior and interior surfaces, to measure the temperature profile. One of the test sections was coated with a traditional paint (dark aqua color) having an initial solar reflectance of about 25%. The second test section was coated with a visually identical dark aqua cool color paint having an initial solar reflectance of about 50%. Concurrently, weather data including solar radiation striking the test wall was acquired in order to establish the conditions imposed on the assemblies. These experiments were conducted for twelve months. At several times during the long test, solar reflectance of the exterior surfaces was remeasured.

Annual averages of outside surface temperature and annual cooling/heating loads at the gypsum interface were measured to permit quantitative comparisons to predictions by a model. The average yearly temperatures of the traditional and cool colored outside surfaces were 68.0 and 65.3˚F, respectively. For these two systems, the total cooling load measured was 1302 and 1035 Btu/ft^2, respectively or a 20 percent reduction due to the cool color on the south façade of a building in Oak Ridge TN.

The purpose of this project was to estimate cooling load reductions for cool colored paints for a variety of climates in the southern United States or for any building in any climate that has an appreciable cooling load. To accomplish this task the public domain program DOE 2.2 was selected as the modeling tool in this project because it accounts for solar radiation of walls from the sun, sky and ground and can model shading. The south-facing wall in the model of a single-story residence with wood-framed walls was modified to accommodate the features of the test sections. It requires an estimate of the solar reflectance of all exterior wall surfaces and assumes that they are opaque. For the traditional and cool surfaces, the annual average solar reflectance was used. To allow direct comparison of predicted and measured results, the weather and solar conditions to DOE 2.2 were generated from the hourly averages of the measured climatic conditions.

Annual average surface temperatures and cooling loads were computed from the model and compared to the experimental results. The average yearly temperatures predicted by DOE 2.2 for the traditional and cool colored outside surfaces were 69.8 and 65.8˚F, respectively. These temperatures are 1.8 and 0.5˚F higher than the measured results. With respect to total cooling loads, the predicted results were 1593 and 1000 Btu/ft^2, respectively, for the traditional and cool colored walls. The cooling loads are 20 and 5% higher than measured. This agreement is considered good.

The DOE 2.2 model of a single-story residence whose south wall was the focus for validation was reconfigured with stucco-coated wood-framed and concrete masonry unit (CMU) exterior walls with typical overhangs. Standardized sources of data were used to specify schedules for occupants and their energy consumption. The house model including walls with and without cool colors was exercised in seven cooling and mixed climates. Annual cooling energy savings for use of cool colored (solar reflectance of 0.50) instead of conventional coatings with the same aqua hue (solar reflectance of 0.24) were 4% to 22%. Savings are found for all climates having an excess of 1500 cooling degree days (65˚F baseline) and increase with increasing cooling requirements. The higher percentages were for the CMU walls with lower R-value. Energy improvements to uninsulated wall systems may even be higher than these estimates.