Cool Roofing

Analysis of Energy Consumption for Cool Roofing

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For more than 30 years, roof coating products have been available to the roofing market in the form of asphaltic-based mastics and coatings, emulsion coatings, fibered and non-fibered aluminum, acrylic coatings, polyurethanes, polyureas, epoxies, methyl methacrylates, and polyvinylidene difluorides, to name more than a few. For just as many years, modified bitumen membranes have existed in the form of mineral, smooth, foil-faced, and film-surfaced with base chemistries of SBS, APP, and a variety of other chemistries. There are single ply options (such as EPDM, TPO, KEE, and PVC) and metal options, most notably, standing seam solutions in a myriad of colors. Built-up roofing systems with asphalt or tar, cold or hot applied, with aggregate or mineral surfaces are also prevalent. Each product has its specific advantages, performance attributes, economic impact, life-cycle expectations, and limitations.

Given these facts, product selection and design decisions can be highly complex and, in some cases, risky. It is therefore critical to work with industry experts, roofing professionals, and reputable companies when selecting a roofing solution. Furthermore, using independent agencies (like ASTM, UL, FM, CRRC, CCMC, DIE, etc.) or independent test laboratories to assist in verifying quality and performance helps to validate product claims and performance. New and existing qualifying agencies (such as IBC, USGBC-LEED, IgBCC, CEC, ASHRAE, etc.) help building owners and facility managers make appropriate decisions by offering design requirements and establishing building codes. Over the last decade, much of the development, design, and code alterations have focused on enhancing overall construction sustainability, the use of green product solutions, and an emphasis on cool roofing solutions.

The cool roofing initiative was the result of studies performed in the 1980's establishing a phenomenon known as the urban heat island effect. The urban heat island effect is the thermal property of metropolitan areas to remain hotter longer than areas of less building density. Academic studies and discussions regarding how to solve these issues include creating more green space, replacing parking lots with grass surfacing, utilizing the roof top as a passive solar heater, additional shading for window designs, and finally the reduction in black surfaces by removing dark surfaced roofs, roads, and parking facilities and replacing them with more reflective surfaces.

Energy Calculators

There are a variety of calculators available for public use. In most cases, users have the ability to input data for a broad group of variables including but not limited to location, facility use, HVAC efficiencies and type, product selection, reflectivity, emissivity, and level of insulation. Based upon the information provided, the calculator uses mathematical models that return energy usage based on specific climatic conditions for the selected location. The most common environmental conditions used in typical analysis are solar irradiance, cooling-degree days (CDD), and heating-degree days (HDD). Cooling-degree day is a measurement designed to reflect the demand for energy needed to cool a building to a baseline temperature of 65°F (approximately the zero house load temperature), while heating-degree days relate to the amount of energy necessary to heat a building to 65°F.

The solar irradiance is a measure of the amount of solar radiation that is received at a specific location. Hotter climates, like Phoenix, have higher solar irradiance than a more temperate climate like Chicago. By

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combining such environmental factors with building-specific inputs (such as reflectivity, level of insulation, etc.), one can use the algorithmic simulation engines of these calculators to generate energy consumption figures. By systematically comparing different simulation conditions, one can calculate the potential savings created by making specific construction changes to the roofing system.

For the purposes of this discussion, the Roof Savings Calculator hosted at the Oak Ridge National Laboratory was used to establish all data. This, among several calculators, is a well-recognized standard in the industry and allows for input and manipulation of a wide range of the most common building-specific variables.

ASHRAE Standard 90.1 allows reduced insulation if cool roofing is used in Zones 1, 2, and 3. Cool roofing is defined as a reflectivity of 70% and an emissivity of 0.75 (SRI of 83). ASHRAE 90.2 Energy Efficient Design of Low-Rise Residential Buildings allows for reduced insulation for a reflectance level of 0.65 (SRI 75). LEED provides credit for the use of reflective coatings (higher than 78 SRI) in all areas. Many states, locations, and power authorities provide credits, rebates, and incentives to utilize reflective systems. A lengthy list of these opportunities can be found on the CRRC (Cool Roof Rating Council) website at: www.coolroofs.org/codes_and_programs.html#rebate.

You will note, upon review of the information on the link above, that there are more than a number of temperate or cool climates that provide incentives, or requirements, for cool roofing, for example: Idaho, Ohio, Colorado, Illinois, and Minnesota. It is important to note that consumers who choose a reflective roofing solution may not receive the same financial benefit, as a result of energy savings, that they might in warmer climates.

Experimental Design

The following experiment represents a snapshot of a selected matrix of data for various building types and locations. This study is based solely on the beta version of the RSC v0.93. While DOE-2.1E and AtticSim ASTM Standard C 1340-04 have been validated with comparison to empirical data, the integrated RSC engine has not. Furthermore, it is known to have discrepancies with previous cool roofing studies, based on engines that didn't incorporate heat transfer through radiation within the attic assembly, which is yet to be reconciled.

In an effort to represent a variety of U.S. geographic locations, nine cities were selected. Both standard ASHRAE climate zone cities as well as several cities that have standing reflective roofing codes were included in the study.

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The final step in all cases was to enter non-variant data such as the base line data, which in all cases was: a black (non-reflective) built-up roof system with 10% reflectance and emissivity of 0.90; R-19 insulation; no above-sheathing ventilation; low slope (<= 2:12); no radiant barrier; and duct location in conditioned space.

The data used represents the most common values for the U.S. building stock. The final step in this experimental design was the input of the higher reflectivity coatings and materials to conduct the energy savings calculations, relative to a common baseline built-up roof. All data was compiled by Oak Ridge National Laboratory and reflects the calculated saving expected.

The results were not surprising: in the climates where CDD's greatly exceeded HDD's, a reflective surface was financially preferable to a non-reflective surface. Conversely, in cooler or moderate climates where HDD's were in excess of CDD's, a less reflective surface provided the best financial savings.

Much of the data indicated that either minimizing the SRI or maximizing the SRI would provide the maximized savings benefit. Cubic curve-fitting equations used in this study were calculated using the Cubic Equation Calculator. Higher-resolution and data analysis would further indicate that the local optimums exist while demonstration buildings could be used to validate this behavior. Based on the previous analysis comparing savings to 10% reflectance and 90% emissivity, we established SRI values for maximum savings performance. Specifically where curves indicated a minimum desired SRI, a value of six was used. For observations where a maximum SRI appears to be optimal, a 107 value was used. There appears to be a logical break between areas where a highly reflective system would be desired and where lower SRI products

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would be more appropriate. This break occurs based on climatic conditions at the transition between a dominance of HDD over CDD. For conditions where HDD's are in excess of CDD's (or where the CDD's are greater than HDD's by more than 3000), the optimum SRI is below 40. Conversely, in areas where CDD's are in excess of HDD's, an SRI in excess of 100 is desirable. This would seem intuitive, but is critical in understanding the function and benefit of alternative surfaces.

In temperate zones, the losses attributed to additional heating demand outweigh the benefit of cooling savings. Internal loading (common in office buildings or retail stores) can affect these results and the current modeling engine is rather conservative regarding internal load for such buildings. As a method of comparison, the same data set (including all cities and material types) was analyzed using the existing DOE Calculator that can currently be found on the Oak Ridge Website. The DOE Cool Roof Calculator compares a fixed black roof with 10% reflectance and 0.90 emissivity. The compiled data showed similarity but also showed some interesting differences. Atlanta, Baltimore, Kansas City, and New York exhibited contradicting trends between the two calculators. The RSC would indicate that a minimized SRI would be appropriate for the four cities, while the DOE Calculator would favor a maximized SRI value for energy efficiency.

Conclusions

Cool roofing in the form of reflective surfacing can provide a benefit in any climate as a result of: potential reduction in energy costs as a result in reduction in cooling costs; reduction in the Urban Heat Island Effect (including increased safety from heat-related illness); reduction in Roof Top Temperature, reducing the rate of aging of the overall roofing system; reduction of the strain on power demand related to facility air conditioning; and increased reflectance of the earth surface to mitigate climate change.

However, it is important to note that based on acceptable industry standard calculations in the current business environment, static reflective roofing does not provide an energy cost savings in cooler or temperate climates. In fact, it can be detrimental to overall energy costs to employ roofing with high SRI values. Clients should consider a broad range of solutions when selecting the environmental surfacing and should not be misled by potential savings. Using available tools, building owners, architects, and facility managers can select the appropriate and best product for overall function.