Lowering the ceiling on heat loads

The picturesque Greek archipelago of Santorini is one of the world's most photographed landscapes. Now the whitewashed homes high on its coastline could stand as a signpost to a future of lower building heat loads and reduced urban heat island effects in some of the world's greatest cities. Sean McGowan reports.

We've all been reading about passive cooling in the pages of this magazine and our sister publication, *Ecolibrium*, for many years. They're the techniques synonymous with sustainable buildings, like façade shading, thermal mass and of course natural ventilation.

But more recently, the construction industry has turned its attention to the dark rooftops of buildings, which have traditionally received little consideration as to their role in solar penetration and the overall heat load of a building.

Modern city areas typically feature more dark than lighter surfaces. Just take a quick look at the sprawling CBDs and surrounds of the major capital cities on Google Earth and you'll see just how many dark surfaces surround us, most remaining virtually out of sight from ground level.

These dark surfaces, including bitumen roofs on commercial buildings and tiled roofs on houses, are heated by the summer sun and impact on the heat load of the building below, increasing cooling demand. Research has shown that the difference between the ambient temperature and the temperature of a highly absorptive roof can be as much as 50°C.

This is in stark contrast to roofs which are less absorptive, such as the white roofs of Santorini in Greece, which can be as little as 10°C higher than the ambient temperature.

It's little wonder then that cool roofs have come under close scrutiny in the US and Europe, where research has supported the theory that simple colour changes in roofing materials can have a significant impact on both heat loads and energy use, ultimately playing a role in mitigating the effects of climate change.

Scientists at the Florida Solar Energy Centre have measured cooling energy savings as a result of colour changes in the range of US$10 to US$100 per 100 sq m in several residential and commercial buildings. Similarly, experiments in California have shown that by simply painting a roof white, the air conditioning load can be decreased by between 10 per cent and 50 per cent.

It wasn't until NASA weighed in on the topic, however, that the concept of cool roofs finally attracted the attention of the wider public.

Having undertaken research at its Goddard Space Flight Centre, in collaboration with the Lawrence Berkeley National Laboratory, NASA found that increasing the reflectivity – or albedo – of the country's roofs by an average of 25 per cent, and pavements by 15 per cent, could have the same effect as cutting CO_2 emissions by around 57 million tonnes.

"Increasing urban albedo is something that should be done now to buy time for implementing other near-term and long-term climate mitigation strategies," says Durwood Zaelke, president of the Institute for Governance & Sustainable Development.

He says that by introducing cool roofs and more reflective pavement materials, the built environment could replace some of the albedo lost due to the melting of Arctic sea ice.

"Although it does not solve the root of the climate change problem – substantial reductions in CO_2 and other climate forcers are essential for that –

New York City's rooftops are being covered in a special cool roof coating.

urban albedo can delay the onset of more severe climate impacts, and reduce the risk of passing the thresholds for abrupt and irreversible climate changes."

Lifting the roof in Virginia

Surprisingly, the cool roof concept has been around much longer than the world has been seriously discussing climate change.

For example, one case study which proved the immediate benefits of changing a roofing colour from dark to light is still referenced in cool roof material today, sixteen years on.

Originally built in 1970, the single storey 25,000 sq m Jefferson Houston Elementary School building in Alexandria, Virginia, had for many years managed its heat load by electric air conditioning and heating; but with temperatures varying between a humid 38°C in summer to a freezing – 12°C in deep winter, energy costs had spiraled alarmingly.

Recognising the need to reduce these energy costs, and with an aging EPDM (ethylene propylene diene monomer) roof requiring replacement, the school saw the potential in adopting cool roof technology in 1994 and specified a white, insulated, reflective 60mm EP (ethylene propylene) roofing replacement.

This new material increased the roof's reflectivity from 20 per cent to 78 per cent, and its insulation value from R-10 to R-20. Furthermore, the cost of this material was no more expensive than several other traditional options, such as built-up modified bitumen and metal.

With the new roofing installed, the school immediately realised significant energy savings, with energy costs falling by US$31,000 per annum, or approximately 26 per cent – and usage cut by 514,000kWh a year. This was the equivalent of taking 122 cars off the road.

Such was the success, that other public schools in the area followed suit.

Volunteers are covering up to 30,000m² of New York City's rooftops.

Achieving credibility

Despite mounting evidence over the years showing significant heat load improvement and energy efficiency gains where white roofs were adopted, the building industry around the world has only just begun to take what was once considered a fanciful idea more seriously.

What has followed is a proliferation of interest in the subject, with cool roofs now joining other passive cooling techniques in new building design.

While the EU Cool Roofs Council has been established to work with the European Union's Commission on taking cool roof technology from the lab to the top of European buildings, the US has moved even further.

Not only has its Cool Roof Rating Council established a 'fair, accurate and credible' rating system for the radiative properties of roofing products (solar reflectance and thermal emittance), with over 1000 products now rated, but the CRRC is now widely referenced in building codes and green building programs across the US.

This includes the *Californian Building Energy Code* (Title 24) which has covered low-slope, air conditioned commercial buildings since 2005, and more recently expanded the cool roof requirement to include residential buildings as well as commercial buildings with steep-slope roofs in certain climate zones. Federal tax credits have also been made available for US Energy Star qualified metal roofs and reflective asphalt shingles being installed on existing homes.

Heat island effect

The US EPA has also thrown its support behind cool roofs, including the technology as part of its urban heat island mitigation strategy.

According to the US EPA, the term "urban heat island" describes built-up areas that are hotter than nearby rural areas.

"The annual mean air temperature of a city with 1 million people or more can be 1–3°C warmer than its surroundings. In the evening, the difference can be as high as 12°C. Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality," it explains.

Cool roofing is now seen as a serious solution to the problem of the urban heat island effect in major cities and towns across the US, not only saving energy and money by reducing air conditioning needs, but also by lowering a community's ambient temperatures by several degrees.

Results from a study conducted recently at the National Centre for Atmospheric Research (NCAR), has revealed that painting roofs white is an effective mitigating technique for reducing the urban heat island effect.

"Our research demonstrates that white roofs, at least in theory, can be an effective method for reducing urban heat," says NCAR scientist Keith Oleson, the lead author of the study.

"It remains to be seen if it's actually feasible for cities to paint their roofs white, but the idea certainly warrants further investigation."

Cool roof case studies

Retailer, Home Base
Vacaville, California

Installing a cool roof at this store helped solve the problem created by an incorrectly sized cooling system. This store used an undersized evaporative cooling system that was unable to meet the building's cooling loads. Indoor temperatures above 32°C were recorded, even with the building coolers working around the clock. After adding a cool roof, peak indoor temperatures were reduced to 29°C or lower, and 10 more shopping hours a week were deemed comfortable (below 26°C and 60% humidity) inside the store. Although the evaporative coolers were still not powerful enough to meet the hottest conditions, the cool roof helped reduce temperatures inside the store.

Apartment Complex
Sacramento, California

Adding cool roofs at these residences lowered indoor air temperatures, improving resident comfort. These non-air conditioned buildings were composed of two stories and an attic, with an R-38 level of insulation above the second story and below the attic space. Adding a cool roof lowered peak air temperatures in the attic by 17-22°C. Generally, the higher the insulation level, the less effect a cool roof will have on the space beneath it; however, in this case, even with high insulation levels, the cool roof reduced second-story air temperatures by 2°C and first-floor temperatures by 1°C.

Private elementary school
Cocoa Beach, Florida

Cool roof coatings at this school improved comfort and saved energy. This 930 sq m facility had an asphalt-based roof – grey modified bitumen – over plywood decking, with a measured solar reflectance of 23 per cent. The dropped ceiling was insulated to R-19 levels, and insulated chiller lines were used in the hot roof plenum space. Once the roof was covered by an acrylic white elastomeric coating, the solar reflectance rose to 68 per cent. The classrooms became cooler and the chiller electric use was reduced by 10 per cent. School staff noticed improved comfort levels due to the new roof.

Image credit: www.akarienergy.com

The study team used a newly developed computer model to simulate the amount of solar radiation that is absorbed or reflected by urban surfaces. The model simulations, which provide scientists with an idealised view of different types of cities around the world, indicate that, if every roof were entirely painted white, the urban heat island effect could be reduced by 33 per cent.

This would cool the world's cities by an average of about 0.7°F, with the cooling influence particularly pronounced during the day, especially in summer. Interestingly, the research also indicated that some cities would benefit more than others from white roofs, depending on such factors as roof density, construction and climatic regions.

"White roofs tend to have a larger impact in relatively warm climates that receive strong, year-round sunlight," the study concluded.

While the model did not have enough detail to capture individual cities, it did show the change in temperatures in larger metropolitan regions. The New York area, for example, would cool in summer afternoons by almost 2°F.

The future looks bright

Although the challenge of painting every roof in every city seems an insurmountable one, the introduction of cool roofs in new building regulations in the US, combined with a series of pilot programs already under way in many cities, indicates that it might just happen.

One such program, launched in New York by the city's mayor, Michael Bloomberg and supported by climate change advocate, former Vice-President Al Gore, is seeing volunteers covering over 30,000 sq m of the city's rooftops in a special cool roof coating.

It's an idea that at least two of Australia's major cities are also considering.

Despite receiving wide derision from media commentators when making his announcement, Melbourne's mayor Robert Doyle has indicated that the Melbourne City Council are investigating how a similar program to that of New York's could be adopted in its CBD. The Cairns Regional Council are also on record as considering the concept.

Whether or not the scientific theory can be replicated in the field remains to be seen, but to paraphrase a one-hit wonder from the 1980s, the future's so bright we'll have to wear shades. ■

Stop Press

ASHRAE adopts cool roofs

ASHRAE and IES are working to strengthen the requirements in ANSI / ASHRAE / IESNA Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings which provides minimum requirements for the energy-efficient design of non-residential buildings.

ASHRAE's goal for the 2010 standard is 30 per cent energy savings over the 2004 version.

The proposed standard contains new mandatory prescriptive requirements for cool roofs, including a minimum three-year aged reflectance of 0.55, and a minimum aged emittance of 0.75. The 2010 standard is expected to be released later this year.