Cool Pavements Research and Technology

Requested by
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September 1, 2011

Abstract: Urban heat islands are caused by the heat absorption and reflectance from solar energy with dark surfaces, which can cause the temperature in urban areas to be significantly warmer in the summer months. This excess heat increases the peak energy demand, as people rely on air conditioning to cope, which contributes to elevated levels of greenhouse gas emissions and air pollution. Efforts to mitigate these adverse effects focus largely on increasing the reflective or radiative properties of the built environment, such as cool pavements. Cool pavement technologies create cooler surfaces through convection or higher reflectance. Some research has been conducted on the benefits and methods of using cool pavements, but there has been little implementation. While there is interest from public agencies, academia, and private industry, currently no states within the U.S. are using or researching the implementation of this technology to combat urban heat islands. Not enough information exists to make policy recommendations for cool pavement use in California. Little if any research has been done on the cost benefit of cool pavement use in urban areas versus the cost benefit of green buildings, the cost benefit of cool pavement use in different California climate zones, the technical characteristics of high albedo pavement such as durability, longevity and life-cycle costs.

Executive Summary

Background

The built environment in urban areas can cause the temperature to be 6-8°F hotter than the surrounding undeveloped areas, a phenomenon described as an urban heat island (UHI). UHIs affect the air quality, peak energy consumption, public health, and water quality for a region, as residents cope with the increased temperature. Contributing factors to the built environment include building geometry, the prevalence of dark surfaces, and a lack of vegetation - conditions whereby infrared energy from the sun is absorbed and retained. Efforts to mitigate the UHI effect focus on trees and vegetation, cool roofs, and cool pavements, which mitigate and prevent the absorption of solar radiation. This reflective property, known as albedo, measures the percentage of solar energy reflected by a surface. The albedo of pavement surfaces differs greatly by the materials used in construction:[1]

[1] "Albedo: A Measure of Pavement Surface Reflactance", *R&T Update: Concrete Pavement Research & Technology*, American Concrete Pavement Association, June 2002, www.pavement.com/Downloads/RT/RT3.05.pdf

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)

The solar reflective index (SRI) is the scale most used in measuring the effectiveness of cool technology, and incorporates both solar reflectance and thermal emittance in measuring the thermal effects from the sun.

Cool pavements describe pavements which either have a more reflective surface than traditional pavements, enable evaporative cooling, or other methods that allow the paved surface to remain cooler than traditional pavements. All of the research and developments are based upon the work of the Environmental Protection Agency (EPA) and the Heat Island Group from Lawrence Berkeley National Laboratory (LBNL). Their research established the definition of cool pavements which is now part of the Leadership in Energy and Environmental Design (LEED) certification system:

- Shading hard surfaces with landscaping or design elements.
- Using materials with a SRI of 29 or greater.
- Using an open-grid paving system that is at least 50% pervious. [2]

Techniques for increasing albedo include resurfacing, sealing treatments, and white-topping. Research has shown that permeable pavements lower surface temperature through enabling evaporation to happen close to the surface.

The projected energy savings of increasing solar reflectance of urban areas is not insignificant. For every 10-25% increase albedo, surface temperatures could decrease by at much as 1°F.[3] A comprehensive approach to mitigating urban heat islands, through cool roofs, vegetation and cool pavements, can lower the the temperature 1.5°F. In 1998 the Heat Island Group projected that Los Angeles could save $90 million per year if they improved albedo of the city's pavements.[4]

This Preliminary Investigation includes the literature for current research in the field, including

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[2] *LEED 2009 For New Construction and Major Renovations* USGBC Member Approved November 2008 (Updated August 2011) http://www.usgbc.org/ShowFile.aspx?DocumentID=8868

[3] Pomerantz, M., Pon, B., Akbari, H., Chang, S-C. *The Effect of Pavements' Temperatures on Air Temperatures in Large Cities.* paper LBNL-43442, Lawrence Berkeley National Lab, 2000. http://eande.lbl.gov/HeatIsland/PUBS/2000/43442rep.pdf (Accessed on 09/01/11)

[4] Rosenfeld,A. H., Akbari, H., Romm, J.J., Pomerantz, M. "Cool Communities: Strategies for Heat Island Mitigation and Smog Reduction", *Energy and Buildings*, v. 28 no.1, August 1998, pp 51-62, http://www.sciencedirect.com/science/article/pii/S0378778897000637 (Accessed 09/01/11)

different methods for reducing the heat of paved surfaces. This investigation sought information about implementation of these strategies from different agencies, either through pilot projects or surveys.

Summary of Findings

Most of the strategies to reduce pavement temperature deal with either treating the surface of existing pavements or the design and construction of new pavements. The investigation found these topic areas :

- Pavement preservation and rehabilitation
    - Reflective coatings and seals
    - Whitetopping
- Construction of new pavements
    - Modified mixes
    - Permeable pavements
    - Vegetated pavements

Pavement Preservation and Rehabilitation

Traditional pavements, particularly asphalt pavements, have a low albedo and retain the captured heat quite well. The most cost effective way to make these existing pavement "cool" is to treat their surfaces, which can also preserve the life and improve the performance of the pavement, due to less thermal and environmental stresses for the pavement.

Reflective Coatings and Seals

Treating the pavement surface with lighter colored material to increase reflectance is a relatively straightforward procedure. There are a number of different techniques, but the overall approach is the same. By covering the exposed surface, typically of existing pavements, the albedo is increased without reconstructing the whole roadway or parking lot. In many cases these applications can be part of regular pavement maintenance and preservation.

- Chip seals are commonly used as a low cost and quick method of resurfacing roads. Using a light-colored aggregate with polymers, emulsion or resin for the binder, these chips seals create a marked improvement of the pavement's SRI as measured for the top coat. They also extend the life of the road surface.
- Scrub seals can also be used to raise the SRI of a surface by using light-colored aggregates for the application.
- Microsurfacing, or sealing the surface of the pavement with a thin layer of high albedo material, can increase the reflectance of the pavement and extend the life of the the pavement. Many of these coatings have been engineered to provide enough friction to remain safe in wet conditions. Products, like Emerald Cool Pavements, are available on the market.[5]

Whitetopping

The traditional approach to resurfacing pavements through a concrete overlay, known as whitetopping, can dramatically increase the pavement's albedo. The reflective benefits of

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[5]*Cool Pavement Properties*, Emerald Cool Pavements, http://www.emeraldcoolpavements.com/pressrelease/ASTM.pdf

normal whitetopping, where the layer of concrete is greater than 4 inches thick, and ultra-thin whitetopping, where the application is only 2-4 inches thick, are comparable. The benefits of using this technique include[6]:

- Avoids traditional stresses of an asphalt overlay
- Can be used on existing pavement systems
- Quick to apply and reopen to traffic
- Less sensitive to seasonal variations
- Easily serviced

Construction of New Pavements

For new pavements, there are different techniques that can be used during construction to reduce the temperature of the surface, either through increasing the albedo or promoting evaporative cooling. These strategies go deeper than the surface, and require the use of different materials and techniques than traditional methods. Some of these techniques have other environmental benefits besides reducing the temperature of the pavement, such as using less hazardous binders, using a waste material from other industries as binders, and generating less erosion through water runoff.

Modified Mixes

Modifying the mix of both asphalt and concrete pavements can increase their reflective properties.

- Modified Asphalt Pavements: Using a lightly colored aggregate will raise the albedo to .15-.20 when it's freshly laid.[7] Another technique to be considered is the addition of colored pigments to the mix. Non-bituminous binders, such as tree resin, are clear and therefore depend on the aggregate for overall reflective property. Resin pavements are suitable for walkways, bikepaths, and parking lots. One resin-based product currently on the market is NaturalPave[8].
- Modified Portland Cement Concrete Pavements: While unmodified concrete pavements are moderately reflective, steps can be taken to improve their overall reflectivity. Using lightly colored aggregates and white cement can increase the albedo to .70.[9] Using recycled materials in concrete mixes can also improve the reflectance. Fly ash, a byproduct of coal fueled powerplants, and slag, a byproduct of blast furnace production of iron ore, can be used as aggregate. Slag is noted for its reduced heat generation, as well as higher strength and improved durability. The use of fly ash and slag qualifies projects for LEED credits.[10]

Permeable Pavements

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[6]Sultana, S. *Extending Asphalt Pavement Life with Thin Whitetopping,* Kansas State University, 2010 http://krex.k-state.edu/dspace/bitstream/2097/4324/3/SharminSultana2010.pdf

[7]"Cool Pavements" *Reducing Urban Heat Islands: Compendium of Strategies*, Environmental Protection Agency, 2008 http://www.epa.gov/heatisland/resources/pdf/CoolPavesCompendium.pdf

[8]*Cool Pavements for Cool Communities*, NaturalPave Resin Pavement, http://sspco.com/images/stories/PDF/2176.072610.pdf

[9]*LEED 2009 For New Construction and Major Renovations*

[10]*ibid.*

Permeable pavements achieve a cooler surface through convection. Both asphalt and concrete pavements can be constructed with an open graded mix of larger aggregate, which is bound. Below that rests a layer of crushed stone, which enables water to flow through and away. These pavements are cooler than traditional pavements due to the increased surface area exposed to air. The porous quality also allows water to evaporate, thereby lowering the temperature through evaporative cooling. Regular maintenance is required to prevent dust and other particulates from clogging the pavement, making it less porous. Noise reduction is an added benefit of open graded pavements.

Vegetated Pavements
Vegetated pavements describe surfaces that have plants, typically grass, growing on them. A plastic, metal, or concrete lattice is installed on the ground, which allows vegetation to grow through the interstices. Vegetation has quite good reflectance which lowers the temperature, but there is also the added benefit of cooling through transpiration. Vegetated pavements are also permeable, which is is good for water runoff. They do require more maintenance though, particularly through winter and the dry season.

Gaps in Findings

There has been considerable research into the environmental factors that create UHIs, and there is research related to strategies to mitigate UHIs, such as cool pavements. The excitement and enthusiasm of five years ago has not materialized into anything beyond research and speculation. By contacting various members of the pavement and civil engineering community, it is evident that the field of of cool pavements has not progressed much past the laboratory and is ripe for demonstration projects to provide more concrete data and information about the real benefits and cost-savings of cool pavements.

Most of the research points back to the work of the EPA and LBNL's Heat Island Group, but both groups have focused more on the benefits and effects of cool roofs, landscaping, and other urban design elements rather than pavements. The EPA outlines some of the factors why cool pavements have not been promoted as much[11]:

- Pavements are complex with more factors affecting their reflectivity and heat retention.
- Cool pavements are affected by both radiative and thermal characteristics, unlike cool roofs.
- Pavements serve a variety of functions, with different design specifications and materials.

These constraints are evident in the lack of demonstration projects and hard figures on the use of cool pavements in communities. The few case studies that have been conducted rely on computer simulation to project the benefits of cool pavements based upon existing data sources, such as the census and satellite images. While these studies have projected the benefits and potential impacts of adopting cool pavements, there needs to be data forthcoming from actual demonstration projects. There is also a focus on parking lots, rather roadways, as the barriers will be lower.

There is interest from other states and organizations about the implementation of cool pavements, but no group has worked much past the research stage. There has been work from the National Center for Asphalt Technology (NCAT) and the National Concrete Pavement Technology Center (CPTC), in cooperation with the National Asphalt Pavement Association

[11]"Cool Pavements" Environmental Protection Agency

(NAPA) and the American Concrete Pavement Association (APCA) respectively, which is still largely exploratory. The Transportation Research Board (TRB) has formed the Paving Materials and the Urban Environment Subcommittee to investigate the impact of design and policy decisions on the environment; it has issued a position piece and call for papers, but has yet to produce any research or recommendations. Currently there are no recommendations or guidelines about the design and implementation from the Federal Highway Administration (FHWA) or the American Association of State Highway and Transportation Officials (AASHTO), though FHWA is considering a national review of some kind. There is no detectable evidence that any other states have any research on the topic. (In fact, several of the states that responded to our queries assumed we were investigating cold mix asphalt instead of reflective pavements.)

Outside of a few studies from Japan and Korea, there has been very little from the international community.

Next Steps

The barriers to implementing cool pavements are still quite high, and there remains a great need for more research on the policy side of the actual implementation. To help the field progress, three steps should be taken:

1. Submit a Research Needs Statement to TRB about cool pavements projects, perhaps in collaboration with the TRB Subcommittee on Pavement Materials and the Urban Climate. Securing NCHRP funding will not only help move the research forward, the corresponding report will be something other agencies can refer to when considering cool pavements.
2. Work with federal agencies and national organizations, such as FHWA or AASHTO, in developing a national framework for implementing cool pavements and other techniques to mitigate the UHI effect from a transportation standpoint.
3. Partner with a vendor on a demonstration project to more accurately gauge the costs and benefits of using cool pavement technologies. A demonstration project could be mutually beneficial, such that the vendor could show the effectiveness of their product at a reduced cost for the agency, and other barriers to implementation, such as policy and regulations, could be clarified as well.

National Guidance

Currently, most of the recommendations on cool pavements are coming from the EPA or the LBNL Heat Island Group. Research from groups like NCAT and CPCT are built largely on the Heat Island Group's work. FHWA currently does not have any formal investigation of cool pavements, though they are considering them.

EPA and Heat Islands

The EPA has been the primary source of information for the public about heat island mitigation. (http://www.epa.gov/heatisland/index.htm) Their reports and workshops are regarded as a definitive resource in the field. The 2008 report *Reducing Urban Heat Islands:Compendium of*

Strategies[12], particularly chapter 5, which focuses on cool pavements, provides a lot of the values and strategies commonly used in discussing cool pavements. They also produced the Mitigation Impact Screening Tool (MIST)[13], which assists in calculating the potential gains from mitigation, either through cool pavements, landscaping, or cool roofs. The tool only differentiates between mitigation by affecting the albedo of surfaces and mitigation through landscaping.

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LBNL and the Heat Island Group

The Heat Island Group has produced research which is the foundation of scientific information and specifications for cool pavements. (http://heatisland.lbl.gov/) Their research includes the effects of heat islands on the the atmosphere, air quality, and energy consumption. They have determined the defacto standard cost and energy savings from the city-wide application of cool pavements using Los Angeles as a test case.[14]

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TRB Subcommittee AF000 (2): Pavement Materials and the Urban Climate

Established in 2008, the subcommittee works towards developing a better understanding of how paving materials interact with the environment, contribute to UHIs, and technologies that can be used to mitigate the impacts of UHIs. Their objectives include technology transfer, contributing to the NCHRP research program, and promoting UHI research within TRB. They have already sponsored workshops, conferences and poster sessions related to the field, including impacts on the green construction codes. Future plans include webinars with the EPA, submitting a research needs statement, and compiling a synthesis on the topic.

Contact: Kamil E. Kaloush, Ph.D., P.E., Director - National Center of Excellence for SMART Innovations, Chair of TRB Subcommittee AF000(2), kaloush@asu.edu

NCAT at Auburn University

Created through an agreement with NAPA and Auburn University, NCAT has researched techniques and technologies to improve asphalt pavement performance. (http://www.eng.auburn.edu/research/centers/ncat/) They have researched different ways to manufacture more reflective pavements, culminating in the report *Strategies for Design and Construction of High-Reflectance Asphalt Pavements*[15] A new researcher, Dr. Carolina Rodezno, will investigate their data related to reflective pavements and temperature.

Contact: Dr. Randy West P.E., Director, westran@auburn.edu

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[12]*Reducing Urban Heat Islands: Compendium, of Strategies*, Environmental Protection Agency, 2008 http://www.epa.gov/heatisland/resources/compendium.htm

[13]Mitigation Impact Screening Tool (MIST) http://www.heatislandmitigationtool.com/Introduction.aspx

[14]Pomerantz, M. *Benefits of Cooler Pavements*, Heat Island Group, Lawrence Berkeley National Laboratory http://eetd.lbl.gov/HeatIsland/Pavements/Overview/

[15]Tran, N., Powell, B. *Strategies for Design and Construction of High-Reflectance Asphalt-Pavements*, National Center for Asphalt Technology, 2009 http://www.eng.auburn.edu/research/centers/ncat/files/reports/2009/rep09-02.pdf

CPTC at Iowa State University

Part of the Institute for Transportation at Iowa State, the CPTC is sponsored by APCA and the Portland Cement Association (PCA). (http://www.cptechcenter.org) They focus on working with agencies to bring advances in concrete technology to the field, and implemented by agencies. They have issued a number of reports about concrete overlays. A new study examining pervious concrete pavements should be published Fall 2011.

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State Practices

Currently, there are no known states seriously investigating cool pavements.

Oregon and Greenroads

The Oregon DOT participates in the Greenroads rating system for sustainable transportation. (http://www.greenroads.org/) Currently, the rating system does not give any credits for cool pavements, instead focusing on promoting the use of recycled materials and minimizing the production of greenhouse gasses during road construction.

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New York and GreenLITES

The New York state DOT began it own sustainability rating system known as GreenLITES (Green Leadership In Transportation Environmental Sustainability). (https://www.nysdot.gov/programs/greenlites) Though the program does not specifically give credits for the use of cool pavements, they do give credit for "the selection of materials and detailing that reduces the overall heat island effect."[16] The acceptable materials and techniques are pulled from the EPA recommendations.

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Relevant Research

Will supply full-text on request.

"Cool Pavements as a Sustainable Approach to Green Streets and Highways"

[16] GreenLITES Project Design Certification Program https://www.nysdot.gov/portal/page/portal/programs/greenlites/repository/Green%20LITES%20Certification%20Program%20-%20Full%20Doc%20-%20Final.pdf

Lee, K.W., Craver, V.O., Kohm, S., Chango, H. *Green Streets and Highways 2010: An Interactive Conference on the State of the Art and How to Achieve Sustainable Outcomes*, American Society of Civil Engineers, 2010
http://dx.doi.org/10.1061/41148(389)20

> The urban cityscape is covered with man made materials that absorb the suns light. Darkly colored roads and roofs have replaced surface area which was once predominantly vegetated lands. For these reasons summertime ambient temperatures in cities are typically warmer than those of rural areas. This phenomenon is known as the heat island effect. Heat islands lead to increased air conditioning use which puts a strain on a cities energy grid. To supply this extra wattage municipal power plants must work harder and as a result emit more carbon. Therefore, the heat island effect contributes to environmental problems including air quality and climate change. Dark impervious pavements cover a large amount of urban surface area, typically 30–45%. One solution to this problem is the implementation of cool pavement technologies in pavement areas of less stringent structural requirements such as parking lots and low volume roads. Cool pavements are a class of materials that exhibit enhanced cooling by means of increased reflectivity or increased convection. This study correlates heat island effect to climate change as well as outlining the different cool pavement technologies which may help to mitigate climate change effects. © 2010 *ASCE*

"Mix Design and Benefit Evaluation of High Solar Reflectance Concrete for Pavements"
Boriboonsomsin, K. and Reza, F. *Transportation Research Record*, v.2011, Transportation Research Board, Washington D.C., 2007
http://trb.metapress.com/content/5682542g550x74vr/

> The use of cool paving materials, or cool pavements, has been identified as one strategy that can help mitigate the urban "heat island" effect. One method of creating a cool pavement is to increase the solar reflectance, or albedo, of its surface. This increase can be achieved by many existing paving technologies. This study explores alternative ways of creating high-albedo concrete for use in pavement applications. The key approach is to make concrete whiter by replacing cement with whiter constituents. Fly ash and slag are used as the main constituents because they are environmentally friendly, readily available, and already familiar to the concrete industry. Compared with a conventional concrete mix, concrete mixes containing fly ash have lower albedo, whereas concrete mixes containing slag have higher albedo. Of all mixes tested, the mix with 70% slag as cement replacement achieves the highest albedo of 0.582, which is 71% higher than the conventional mix. It also has better compressive strength as tested at 7 and 28 days and modulus of rupture as tested at 7 days. The production of high solar reflectance concrete consumes 43.5% less energy and results in less emission of pollutants and greenhouse gases (by 20% to 60%). Furthermore, the analysis of some urban cities shows that the implementation of this high solar reflectance concrete could increase the city albedo by 0.02 to 0.07. This amount of albedo modification has the potential to benefit economics and the environment in many ways, ranging from decreasing energy demand to improving air quality.

"Strategies for Design and Construction of High-Reflectance Asphalt Pavements"
Tran, N., Powell, B., Marks, H., West, R., Kvasnak, A. *Transportation Research Record*, v.

2098, Transportation Research Board, Washington D.C., 2009
http://trb.metapress.com/content/0652u8t444730242/

The occurrence of higher air and surface temperatures in urban areas is known as the urban heat island (UHI) effect. Reducing the UHI effect may decrease summer energy use and improve human and ecological health. The Leadership in Energy and Environmental Design certification system has awarded up to three points for construction projects that provide any combination of the following cool pavement strategies for up to 75% of the site landscape: (*a*) shading hard surfaces on the site with landscape features, (*b*) using high-reflectance materials with a minimum solar reflectance index (SRI) of 29, and (*c*) utilizing an opengraded pavement or porous pavement system. Although a guide to the design and construction of porous asphalt pavements has existed for some time, such a guide is not readily available for high-reflective asphalt pavements. The objective of this study is to identify and validate high-reflectance asphalt materials and pavement surface treatments that are suitable for use in parking lots and other large paved surfaces, have a minimum SRI of 29, and are economical. In this study, six technologies exhibited SRI values of 29 or greater: E-Krete microsurfacing, Street-Bond coating, synthetic binder, Densiphalt, and chip and sand seals using light-colored aggregates. Another technology, surface gritting using light-colored aggregate, most likely would have exhibited SRI values of at least 29 if the aggregate had adhered properly to the asphalt mat.

"Cyclic Heat Island Impacts in Traditional Versus Pervious Concrete Pavement Systems."
Haselbach, L., Boyer, M., Kevern, J.T., Schaefer, V.R. *Transportation Research Board 90th Annual Meeting*, Washington D.C., 2011

As the world becomes more urbanized, concerns over the urban heat island are more pronounced. Increased urban temperatures impact energy usage, smog formation, and negatively impact the natural and human environment. Pervious concrete pavement is one technology that may help mitigate increased urban temperatures. This paper presents temperature data from an instrumented site in Iowa and heat storage phenomena for various weather patterns. The site contains both pervious concrete pavement with a solar reflectance index (SRI) of 14 and traditional concrete pavement with an SRI of 37. A high SRI (>29) has been accepted by LEED as one method to characterize a surface as a cool surface. Heat capacities of both systems were studied along with a sensitivity analysis of the inputs. The research presented herein supports the conclusion that even though pervious concrete may have a much lower SRI than traditional concrete made with similar materials, it can be considered a cool pavement option. Additionally, daytime rainfalls combined with the internal high surface area result in significantly more removal of stored heat from the system, with a more rapid mitigation of urban heat island impacts and a reduction in the potential for thermal shock from impervious surface runoff.

"Cooling effect of water-holding pavements made of new materials on water and heat budgets in urban areas"
Nakayama,T., Fujita, T. *Landscape and Urban Planning*, v. 96, no. 2, 30 May 2010, pp 57-67
http://www.sciencedirect.com/science/article/pii/S0169204610000344

People often suffer from the intense summer heat in Japan. This trend is increasing in

urban areas because of the heat island effect and global warming. We evaluated the effect of pavements made of traditional and new materials on water and heat budgets. We expanded the NICE (NIES Integrated Catchment-based Eco-hydrology) model to simulate the water and heat budgets for the various materials and to reproduce the cooling of water-holding pavement (consisting of porous asphalt and water-holding filler made of steel by-products based on a silica compound) by evaporation (NICE-URBAN); the results were compared with those from the simplified empirical model. NICE-URBAN simulated the cooling of water-holding pavement during the intense heat of summer in an urban area more correctly than the empirical model. Because the model estimates that the air temperature above the water-holding pavement is 1–2 °C lower than that above the lawn and 3–5 °C lower than that above the building rooftop, this material has a powerful positive cooling effect in combination with a lawn for a passive cooling effect. The simulation of NICE-URBAN showed that the surface temperature decrease in water-holding pavement is closely related to evaporation from the surface, the water volume of the pavement and the surface reflectance. The procedure used to integrate the model simulation with land use planning to effectively select and use ecosystem service sites is a very powerful approach to create thermally pleasing environments in a megalopolis.

"Cooling Principle Analyses and Performance Evaluation of Heat-Reflective Coating for Asphalt Pavement"
Cao, X., Tang, B., Zhu, H., Zhang, A., Chen, S. Journal of Materials in Civil Engineering, v. 23 no.7, Association of Civil Engineers 2011.
http://link.aip.org/link/doi/10.1061/(ASCE)MT.1943-5533.0000256

In the experiment, a heat-reflective coating (HRC) was applied to the surface of asphalt pavement. The coating temperature reduction principle and the mechanism to mitigate the urban heat island effect (UHI) were explored by analyzing the material characteristics and features of atmospheric absorption spectrum. HRC features a good waterproof ability, strong oil resistance, abrasion resistance, and aging resistance. When it was painted on the surface of the dense-graded asphalt concrete, the pavement temperature could be reduced by approximately 9°C in hot seasons. The comprehensive pavement performance was evaluated through the following tests: antiskid, accelerated abrasion, freeze-thaw cycle, and permeability. The results show the asphalt concrete pavement with adopting HRC has a strong abrasion resistance, a good resistance to temperature fluctuation, and significantly reduces water damage. The skid-resistant ceramic granular should be added in the dense-graded asphalt pavement with HRC, which was shown to greatly improve the antiskid capability.

"Results from the Phoenix Arizona Urban Heat Island Experiment"
Hedquist, B.C., Di Sabatino, S., Fernando, H.J.S., Leo, L.S., Brazel, A.J., *Seventh International Conference on Urban Climate*, Yokohama, Japan, 2009.
http://www.ide.titech.ac.jp/~icuc7/extended_abstracts/pdf/384812-1-090518233339-002.pdf

A 24 hour Urban Heat Island (UHI) field experiment was conducted in Phoenix, Arizona on April 4-5, 2008. IR thermography was utilized to measure temperatures over a large area ranging from meter to km scales augmented by standard meteorological measurements. Temperature mapping was achieved utilizing field measurements at fixed locations on the ground, with mobile sampling, and via helicopter. Analyses of measurements illustrate the effects that various building façade material and building arrangements have on diurnal air temperatures. The numerical model ENVI-met as well as CFD modeling of the CBD, were used to interpret local flow modifications due to the UHI diurnal cycle. Results are of relevance for devising heat mitigation strategies within large hot and arid cities and developing urban parameterizations for meso-scale model.

"**Reductions in Ground-Level Ozone Pollution Through Urban Heat Island Mitigation Strategies Including Rehabbing Land Occupied for Transportation Related Uses: A Case Study of Fresno, CA**"
Fang, K., Cook, J., Smith, J., Williams, K.*Transportation Research Board 90th Annual Meeting*, Washington D.C., 2011
http://docs.trb.org/prp/11-2304.pdf

The urban heat island effect is the phenomenon where developed areas tend to be warmer than their surrounding countryside. Excessively warm conditions can worsen ground-level ozone air pollution problems as ozone concentrations are dependent on levels of photochemical reactivity affected by temperature. Among the causes of heat islands are the thermal properties of materials used in urban areas, including those used for transportation, such as pavement. Heat island mitigation strategies, including cool pavement technologies and shading of pavement, among others, represent opportunities to tackle ground-level ozone pollution problems through temperature. Two mitigation scenarios for the Fresno, California region, an area heavily impacted by poor ozone conditions, indicate that heat island mitigation strategies can bring modest ozone benefits. Conservative estimates modeled using the Mitigation Impact Screening Tool shows that the two mitigation scenarios could reduce temperature by 0.8 degrees Fahrenheit to 5.7 degrees Fahrenheit and yield 3 to 12 percent reductions in the typical excess of ozone in Fresno over California state ambient air quality standards. Cool roofs provide relatively more benefit in the two scenarios, as does increase vegetation, including vegetation that shades land occupied for transportation uses. Cool pavements provide some benefit, with greater future benefit possible with further developments in technology.

Appendix

Appendix A: List of people contacted for the investigation

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