BY TOM KUENNEN

TRB: Albedo change study quantifies role in climate change; PCC overlays perform

The 97th annual meeting of the Transportation Research Board in January drew 13,000-plus transportation engineers and specialists from across the country, and around the world to Washington, D.C. More than 5,000 presentations in over 800 sessions addressed topics in multimodal transportation, including materials and design involving ready mixed concrete and precast/prestressed products. *Concrete Products* was there and this month presents a report on new research findings in cast-in-place concrete. We'll look at precast/prestressed related research from TRB 2018 in an upcoming issue. For more information, visit www.trb.org.

PCC ALBEDO CHANGES VARY URBAN HEAT ISLAND EFFECT

MIT CSHub researcher Xin Xu weighs the result of changes in albedo of pavements and structures in different urban contexts.

Quantifying radiative forcing and building energy demand impacts due to pavement albedo changes is essential to understanding the role of concrete pavements in keeping urban areas cooler and forestalling global warming, say Xin Xu, Dr. Jeremy Gregory and Dr. Randolph Kirchain in their TRB paper, The Impact of Pavement Albedo on Radiative Forcing and Building Energy Demand: Comparative Analysis of Urban Neighborhoods.

Albedo is a ratio expressed on a scale from zero to one that describes how much solar radiation any given surface reflects: a surface with an albedo of "zero" would be impossibly dark, taking in 100 percent of the sun's energies, where a surface with an albedo of "one" would be completely reflective. This should benefit concrete as its lighter color is more reflective than other building materials, for example, giving it an advantage over dark asphaltic concrete in keeping urban areas cooler, and even deferring presumed climate change.

The amount of solar energy absorbed or reflected by surfaces in urban environments impacts the energy demand of surrounding buildings and also has an impact on the climate—locally, regionally, and globally. Researchers developed an approach to quantify the impacts of changes to pavement albedo in different locales, and then translate those changes into global warming potential.

"The albedo effect applies to any type of urban surface, not just concrete," says Gregory, author and executive director, Concrete Sustainability Hub [CSHub] at Massachusetts Institute of Technology. "Considering albedo, there are differences in how that can impact the climate. A change in albedo can change the radiative forcing, that is how much radiation enters the atmosphere versus how much leaves. Deforestation causes albedo changes too, for example. With this paper we quantify that radiative forcing impact."

He and fellow authors also quantify the impact of changes in albedo in the energy consumptions of buildings near those surfaces. That's because, they say, benefits of a high albedo material like concrete, depending on the location, actually can force adjacent buildings to consume more energy for air conditioning.

"In a hot climate, if the [pavement] albedo is increased, it can increase the amount of radiation that strikes nearby buildings," Gregory tells *Concrete Products*. "It can increase the cooling demands on the building, which leads to more energy generation, which can impact the climate. We're quantifying both those mechanisms and looking at their net effects."

Like white concrete pavements, use of white roofs to mitigate urban heat island effects is all about balancing net effects, he adds, noting: "If you do that in a northern climate it decreases the amount of cooling air required, but increases the amount of heating required. You have to look at what the net benefit will be and where those applications make the most sense.

"It's the same with pavements, but the other complicating factor with concrete pavements—particularly in the urban environment—is there are 'canyoning' effects [of building shadows] that change the amount of shading there is on the pavement. In this paper we have quantified the impact of the change of albedo on different locations, and the geometry of different urban configurations."

Thermal mass of a building—optimized by cast-in-place or precast concrete construction—can mitigate urban heat island effects. That's why the design of the building and how much energy is absorbed by the reflection of the pavement both have an impact on the energy consumption of the building, dubbed the building energy demand, or BED. "If it's a well-designed, energy-efficient building, and certainly one with thermal mass, that can mitigate any effects of energy being reflected off horizontal surfaces onto the building's vertical surfaces," Gregory observes.

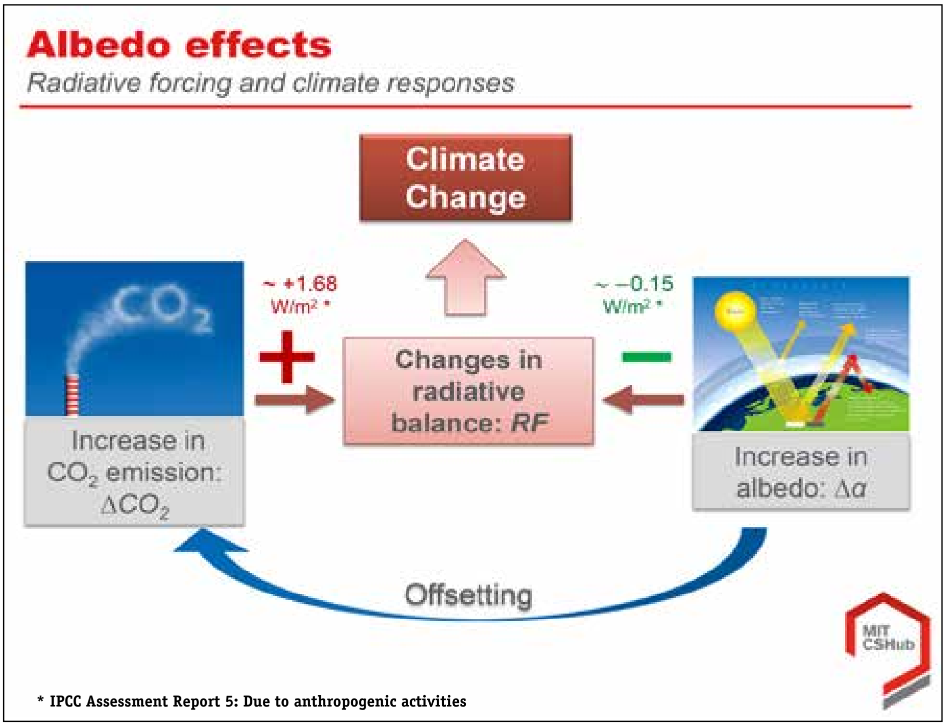
To be fair, a nonreflective structure can be made reflective just by cladding it in a reflective surface. "Knowing the reflectivity of the building is very important," he says. "Any surface—regardless of its natural color—can be made reflective with a coating. It's not just about concrete or asphalt, it's about anything that is reflective. Concrete is being made with lighter aggregate, and in some places, asphalt is being coated to increase its albedo. There are a lot of different solutions."

This research's benefit for the industry is that for the first time practitioners can understand quantitatively what role a concrete structure will play in its urban context.

"A big challenge associated with this is measuring the albedo of different surfaces," Gregory explains. "We know initially concrete has a higher albedo than asphalt, but over time, concrete darkens, while asphalt lightens. We need better research on how that process unfolds over time, and how that depends on their locations. But for researchers, the starting point is very clear: Concrete starts out with a naturally higher albedo, which depending on its location or urban context, can benefit the environment.

"The takeaway for us is that higher albedo surfaces where there isn't an urban environment are definitely going to be a benefit. We have calculations that show exactly how much of a benefit that is in mitigating climate change. When it comes to urban environments, we see that having higher albedo surfaces in places with a lot of dense, tall buildings might not be the best solution, that it can actually increase the heating and cooling demands on the buildings more than any benefit you would get in the climate.

"But on the average those situations aren't that common; most areas will have low-rise buildings that are further apart and in those places we show a net benefit," he concludes. "Part of our research is to explore more context, more locations, and make sure that if that's the case, that some early results show that higher albedo surfaces can mitigate the impact of climate change and the urban heat island."



Albedo effects

Radiative forcing and climate responses

Climate Change

~ +1.68 W/m² *

+

Changes in radiative balance: *RF*

~ −0.15 W/m² *

−

Increase in CO_2 emission: ΔCO_2

Increase in albedo: $\Delta\alpha$

Offsetting

MIT CSHub

* IPCC Assessment Report 5: Due to anthropogenic activities

Due to changes in radiative balance, increases in surface albedo can offset increases in carbon dioxide emissions, effecting climate change. IMAGE: Xu, Gregory and Kirchain

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NEARLY THREE DECADES ON, WHITETOPPING STILL PERFORMS

Portland cement concrete unbonded overlay test sections are still doing their job after nearly 30 years, say James Greene, Ohhoon Kwon, Abdenour Nazef, and Bouzid Choubane, State Materials Office, Florida Department of Transportation, in their TRB paper, A Long-Term Performance Evaluation of an Experimental Concrete Overlay.

The standard response to a distressed asphalt pavement is a mill and overlay with hot mix asphalt. Wishing to compare performance of a concrete overlay to an asphalt overlay in a same-type situation, Florida DOT designed and constructed a 1.9-mile unbonded concrete overlay on U.S. 1 between Daytona Beach and Titusville in 1988. The concrete overlay was part of a larger eight-mile milling and resurfacing of a deteriorated asphalt pavement.

"[T]here are many reported benefits to concrete overlays as a rehabilitation and preservation technique," the authors write. "In addition to being cost-effective, properly designed concrete overlays can be constructed quickly, can be easy to maintain, and extend the life of the original pavement for 30 years or more."

Concrete overlays may be bonded or unbonded, with the design dictated by the condition of the existing asphalt pavement. "In the United States, more than 200 concrete overlay projects have been constructed each decade since the 1980s," say Greene, Kwon, Nazef and Choubane. "Of these projects, nearly 80 percent were unbonded concrete overlays and approximately 30 percent of these unbonded concrete overlays were constructed over an existing asphalt pavement rather than a concrete or composite pavement."

The DOT took the opportunity to evaluate different designs. Test sections were divided into three groups based on 6-, 7- and 8-in. design thicknesses. Each of these groups included six 500-ft. subsections with three joint spacing levels, and two dowel bar configurations consisting of standard 12-in. spacing and wheel path only.

"This project successfully demonstrated the effectiveness of a concrete overlay as a rehabilitation method for distressed asphalt pavements," the authors say. "After 28 years of service and more than 2.25 million trucks, the experimental concrete overlay sections on U.S. 1 have outlived the design life by almost 20 years without the need for major repair or rehabilitation. While all of the sections performed well over the original design life, thicker sections, as one would expect, were found to have less cracked slabs at the end of the study."

Researchers found:

- The asphalt base in the concrete overlay sections served as a non-erodible base which reduced faulting and slowed the increase in pavement roughness.
- Despite being designed as an unbonded overlay, a bond between the concrete overlay and asphalt was confirmed after construction. After 28 years of service, the bond was still evident in nine of 19 cores. Debonding occurred at the corners more often than the slab center. Joint spacing likely played a role in bond retention.
- Corner deflections may be controlled through a combination of slab thickness and dowel configuration. Corner deflections for the 8-in. overlay with standard dowels were reduced by nearly 50 percent compared to the 8-in. overlay with dowels only in the wheel paths.
- Sections with a standard dowel configuration had average joint load transfer efficiency (LTE) values of approximately 80 percent and differential deflections of 2 mils, while the sections with dowels in the wheel paths only had average LTE values of 46 percent and differential deflections of 7 mils.
- In general, most sections exhibited good cracking performance. The section with 20-ft. joint spacing had the most overall cracked slabs (20 percent), and 20-ft. joint spacing no longer is recommended. Of the 25 slabs within this section, two were found with transverse and longitudinal cracks and one was found with a corner crack. No corner cracks were observed in any 8-in. overlay sections.
- Dowel configuration and base type had the biggest impact on pavement smoothness. International Roughness Index readings increased by more than 60 percent for sections with dowels in the wheel path only, and more than 15 percent for sections with standard dowels. IRI increased approximately 75 percent in the control section, which included standard dowels and a lime rock base.

MONTAGE: Greene, Kwon, Nazef and Choubane

Distresses observed in the Florida overlay test sections.

UNBONDED ILLINOIS PCC OVERLAYS PERFORM BEST

Portland cement concrete overlays on Illinois interstates have mixed results over a period approaching 50 years, say Laura Heckel, P.E., Applied Research Associates in Champaign, Ill., and Charles Wienrank, P.E., Illinois Department of Transportation, in their paper, Performance of Concrete Overlays on Illinois Interstates 1967 through 2016.

IDOT has been constructing concrete overlays of existing Interstate concrete pavements for nearly five decades, including two bonded and eight unbonded installations. The agency also constructed one thin unbonded concrete overlay as an alternative to rehabilitation with a hot mix asphalt overlay. An evaluation of performance history of the 11 pavement sections was undertaken.

A bonded concrete overlay involves placing new concrete directly on the existing concrete, creating one thicker monolithic pavement slab capable of handling traffic for a normal design life, typically 20 years from the placement of the overlay, Heckel and Wienrank write.

"Bonded concrete overlays are thin, in the range of 3 to 4 in.," they note. "The distresses of the existing concrete pavement will reflect through a bonded concrete overlay. Because of this, pavements in good condition but with insufficient structural capacity for the anticipated traffic levels are the best choices for bonded concrete overlays. A typical application would be in areas with an existing bare concrete pavement where truck traffic increased dramatically, such as in areas of new commercial or manufacturing development."

An unbonded concrete overlay involves placing a fully designed new pavement over the top of an existing pavement. "The design assigns little or no structural value to the existing pavement," observe Heckel and Wienrank. "An interlayer is used between the existing concrete pavement and the new concrete pavement to cause the existing and new pavements to act independently, thereby reducing stresses between the two layers. An unbonded concrete overlay is a good choice for deteriorated pavements at the point of needing reconstruction. An unbonded concrete overlay eliminates the need for pavement removal and construction of a new subgrade/subbase, significantly reducing the cost to construct a new pavement."

The authors conclude:

- Bonded concrete overlay performance on the Interstate system varied widely, and should only be used in the future judiciously, with engineering judgment;
- Unbonded concrete overlays performed consistently well, with all observed pavements exceeding or expected to exceed their design lives and design traffic factors; and,
- The thin unbonded overlay was too new to conduct a meaningful analysis of performance.

ILLINOIS INTERSTATE OVERLAY SURVEY

Route	County	Original Type	Pavement Year	New Overlay Type	In Service? Year
Bonded concrete overlays					
I-80	Rock Island	8-in. CRCP	1965	4-in. concrete 1994-95	No – 2010
I-88	Whiteside	8-in. CRCP	1976	3-in. concrete 1996	Yes
Unbonded concrete overlays					
I-70 WB	Bond	8-in. JRCP	1939	6-8-in. CRCP 1967	No – 1987
I-55	South Sangamon	7-in. JRCP	1933	8-in. CRCP 1970	No – 2001
I-55 NB	North Sangamon	10-in. JRCP	Mid-1950s	9-in. CRCP 1976	No – 1997
I-74 WB	Knox	7-in. CRCP	1969	9-in. CRCP 1995	Yes
I-88	Whiteside	8-in. CRCP	1975	9-in. CRCP 2001	Yes
I-70	Clark	8-in. CRCP	1969	12-in. CRCP 2002	Yes
I-57	Jefferson	8-in. CRCP	1969	10.5-in. CRCP 2014	Yes
I-57	Union/Johnson	10-in. CRCP	1960-61	9.75-in. JPCP 2016	Yes
Thin unbonded overlay					
I-72	Sangamon	8-in. CRCP	1976	6- x 6-ft. x 6-in.	2015 Yes

CRCP: Continuously reinforced concrete pavement
JRCP: Jointed reinforced concrete pavement
JPCP: Jointed plain concrete pavement