Urban Climate Research Center
Arizona State University

Cool Pavement Pilot Program

Joint Study between the City of Phoenix and Arizona State University

A report prepared for:
The City of Phoenix
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Streets PHX
STREET TRANSPORTATION DEPARTMENT

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HUE

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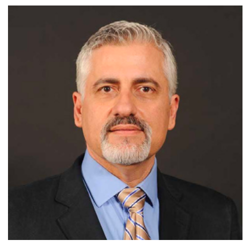

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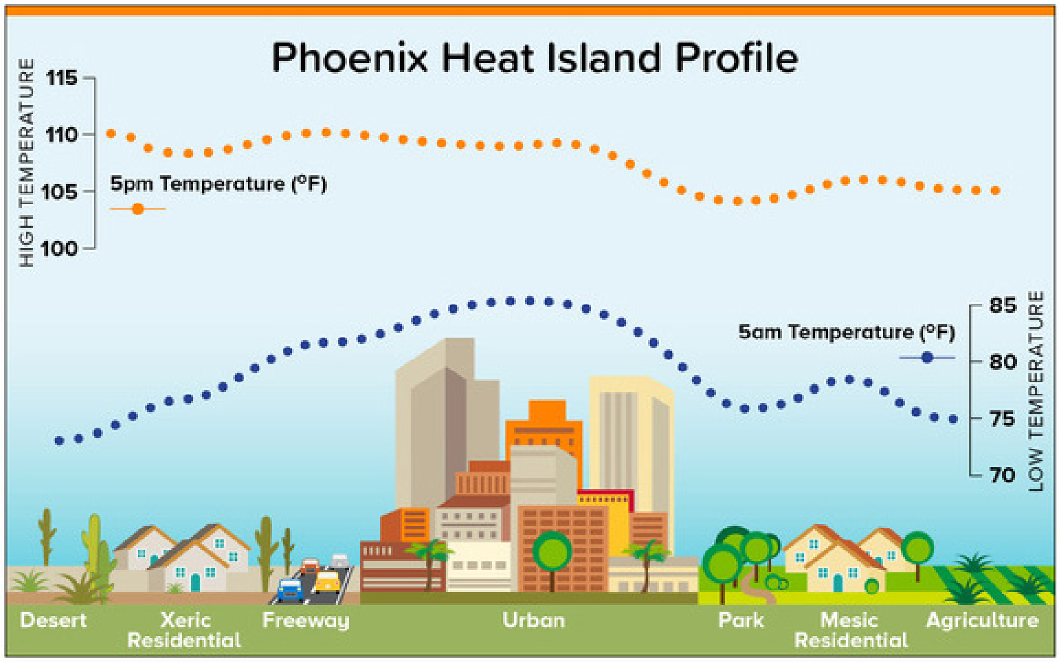
BACKGROUND

Many cities around the world, including the City of Phoenix, are experiencing elevated temperatures due to the built environment that are exacerbated by climate change. Paved surfaces with impervious materials, such as asphalt concrete (roads, sidewalks, parking lots, etc.), absorb and store heat during the day and release this heat overnight creating higher temperatures than surrounding rural areas. This phenomenon is known as the Urban Heat Island (UHI) effect (Figure 1). With paved surfaces comprising about 40% of the urban land area in Phoenix, they are often considered one of the primary causes of the UHI.

One of many strategies to mitigate increased temperatures and reduce heat storage in pavements is the use of coatings that reflect (rather than absorb) solar radiation to reduce the heat absorbed by the pavement, thus reducing surface temperatures. Lowering surface temperatures and the heat retained in the built urban environment may help reduce elevated day and nighttime air temperatures. Such reflective coatings are easy to apply to existing paved surfaces and, in most cases, use light-colored pigments and materials to increase reflectivity compared to traditional asphalt concrete roads.

The City of Phoenix recently initiated the Cool Pavement Pilot Program in which the City applied the product CoolSeal by GuardTop® to 36 miles of residential neighborhood roads and one public parking lot. This effort resulted in the most miles of road surface coverage with a reflective coating of any municipality globally. It is designed to achieve lower pavement surface temperatures through its lighter color and reflectivity. One neighborhood in each of the eight council districts of Phoenix was chosen for application of CoolSeal in consultation and with the support of the City Council Offices (Figure 2).



Urban heat profile of Phoenix showing air temperatures during daytime maximum (afternoon) and daytime minimum (overnight) based on weather station data in the region. This profile also demonstrates intraurban heat variability across the city, as affected by types of land cover (e.g., xeric landscape versus parks) and urban design.

Design by Lisa MacCollum / City of Phoenix.

THE PROJECT

July 15, 2020–July 14, 2021

The City of Phoenix Street Transportation Department partnered with the Rob and Melani Walton Sustainability Solutions Service at Arizona State University (ASU) and researchers from various ASU schools to evaluate the effectiveness, performance, and community perception of the new pavement coating. The data collection and analysis occurred across multiple neighborhoods and at varying times across days and/or months over the course of one year (July 15, 2020–July 14, 2021), allowing the team to study the impacts of the surface treatment under various weather conditions.

ON-SITE DATA COLLECTION

Numerous types of platforms and sensors were used to collect data, with further analysis completed in ASU laboratories.

In the field, a mobile human-biometeorological cart (MaRTy, short of Mean Radiant Temperature) and a vehicle completed traverses across three neighborhoods treated with CoolSeal and directly compared the measurements to untreated roads.

» **MaRTy** measures mean radiant temperature, air temperature, relative humidity, and wind speed and direction at pedestrian height at two-second intervals. MaRTy measurements were performed for 45–60 seconds at pre-defined stops.

MaRTy engages 12 radiometers that measure incoming radiation from six directions. This includes shortwave radiation (visible sunlight and UV radiation) and longwave radiation (heat emitted from hot surfaces). The shortwave and longwave radiation can be integrated into mean radiant temperature, the sum of all the radiation that hits a person's body from 360 degrees.

» **A vehicle** was equipped with fast-response, shielded, and naturally aspirated thermocouples to measure air temperature at 6 feet above the surface and an infrared radiometer attached to the bottom front of the vehicle (12 inches from the ground) to measure surface temperature of the pavement. These instruments collected readings at one-second intervals.

These mobile measurements were conducted for one hour at four times of day in each of the three neighborhoods: Before sunrise (~4:30–5:30am), solar noon (~12:00–1:00pm), afternoon at maximum daily air temperature (3:00–4:00pm), and after sunset (~7:30–8:30pm).

Long-term (7–10 months) assessments of performance indicators were also completed in the field:

» **iButton** sensors were buried within the pavement at 0.5 and 3in depth at 10 sites to determine sub-surface temperature across treated asphalt concrete roads.

» **A spectroradiometer** was used to measure changing solar reflectivity across treated asphalt concrete roads.

FINDINGS

The main research findings, outlined below are organized into three categories based on field campaign type and temperature metrics of importance. Together, these findings guide the holistic understanding of how the applied Cool Pavement (CP) treatment impacts the environmental temperatures and the people of the residential neighborhoods.

❶ Assessment 1

Detailed on-site, full-day assessments of local microclimates in three newly treated neighborhoods on extreme heat days, using both vehicle traverses and ASU's proprietary human-biometeorological mobile platform MaRTy, completed August & September 2020.

- » **Surface temperatures** of the CP were systematically lower than non-treated asphalt concrete across all times of day. The CP surface temperature was, on average, 12.0°F and 10.5°F lower than the asphalt concrete at noon and afternoon hours (ranging from 9–16°F lower), and 2.4°F lower, on average, at sunrise. These lower surface temperatures indicate that the CP-treated roads are not absorbing as much heat as asphalt concrete roads, which helps to reduce overall levels of urban heat.
- » **Air temperature** at 6 feet height was lower above the CP than the non-treated surface in the evening by approximately 0.5°F (ranging from 0.9°F lower to 0.1°F higher), which may help reduce the nighttime Urban Heat Island. Daytime differences averaged 0.3°F lower above the CP (ranging from 1.2°F lower to 0.2°F higher).
- » **Mean radiant temperature**, representing a human's total radiant heat exposure walking on the surfaces, was increased at noon and afternoon hours by approximately 5.5°F, on average (ranging from 2.6 to 9.2°F higher), due to higher surface reflectivity. These higher values, which cause a reduction in human comfort, may be a necessary tradeoff to reduce surface temperatures using a reflective surface. These values were lower than the traditional asphalt concrete at sunrise and sunset (-0.5°F), and overall were similar to that experienced if walking over a concrete road.

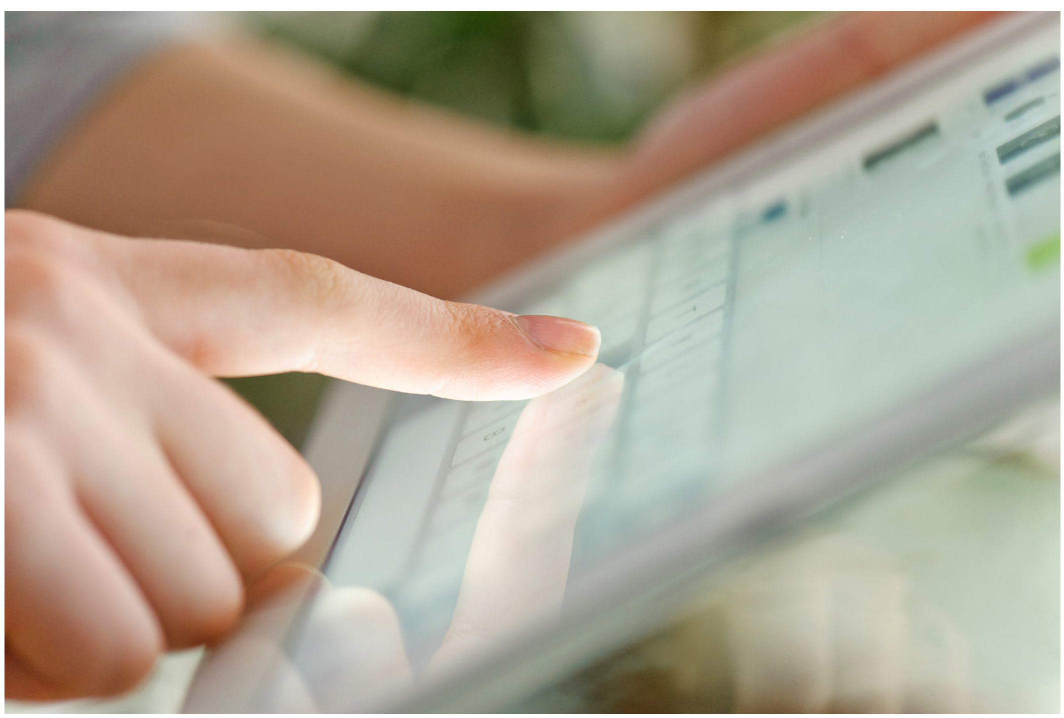
❷ Assessment 2

Long-term (7–10 months) assessments of sub-surface temperature and solar reflectivity across treated asphalt concrete roads.

- **Sub-surface temperatures** beneath the CP were lower (4.8°F on average) than beneath the untreated asphalt concrete surfaces.
- **Surface solar reflectivity** of the CP was around 33–38% when installed and declined over time. The solar reflectivity 10 months after installation ranged from 19–30% across the eight neighborhoods. These reductions in reflectivity can result in less decreases in surface and sub-surface temperatures. For comparison, an untreated asphalt concrete surface had a consistent reflectivity of 12%, hence absorbing more solar radiation.

❸ Resident interviews (early 2021) and surveys (June 2021) were conducted to understand the community perception and impact of the Cool Pavement. Survey results will continue to be tabulated through summer 2021. Preliminary findings include:

- **Satisfaction** with communication from the City about the CP pilot program and **interest** in learning more from the evaluation.
- **Divergent opinions** were expressed among residents concerning visual appeal and aesthetics, impacts on property values, the longevity of the coating, and surface friction.
- Collectively, the interview and preliminary survey results point to **opportunities** for additional resident engagement and education concerning CP.



RECOMMENDATIONS

Numerous important topline takeaways and recommendations arise from these initial Year 1 findings of the Cool Pavement Pilot Program. These include the following:

» The reductions in surface and sub-surface temperatures are positives for improving the lifespan and performance of the pavement. These factors are particularly important if the treatment is applied in the early years when the road is in very good condition. It is recommended that longer-term testing is completed to assess the changes in reflectivity, traction/skid, degradation, and subsurface temperature over time, particularly as the CP ages.

» While surface temperature reductions were strong, air temperature reductions were minor, yet influenced by numerous factors in an uncontrolled environment. It is recommended that enhanced fine-scale, precise assessments of air temperature changes are conducted, particularly to determine the energy, water, and health impacts of any temperature differences. Further work is also required to provide Phoenix-based guidelines to mitigate surface dirt, tire markings, and degradation due to a lack of precipitation and the hot climate.

» There was a wide range of resident opinions and perceptions that provided important insight into other CP considerations, which cannot be quantified using atmospheric sensors but are also important. Additional exploration of the potential use of this technology and other pavement coatings with similar performance yet a darker color may help improve public perception.

Additional and more detailed recommendations are provided as part of the full report based on study findings. A broad assessment of these physical and social indicators of the pavement coating at various timescales will provide critical insight and valuable information for the City of Phoenix to better understand how CP technology will impact street construction and maintenance operations, while also reducing the impact of asphalt concrete on urban heat levels in a hot desert climate.