Better Pavements Make Better Communities

The Promise of Cool Pavements

A White Paper for ePAVE, LLC

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Executive Summary

Paved surfaces play an important role in modern life: from providing sturdy roads to move goods and people, to creating community spaces for people to live and grow. They are an indispensable part of our lives. However, paved surfaces also absorb more heat than natural vegetation, leading to the development of the Urban Heat Island (UHI) effect. This has several negative consequences: increased air temperature, higher greenhouse gas emissions, higher near-surface ozone, heat-related ailments, lower quality of stormwater runoff, etc. The UHI effect is further exacerbated by climate change.

Cool pavements are a solution to mitigate the UHI effect. With a high solar reflectance, they absorb less solar radiation and thus have a lower surface temperature than typical paving materials. However, in order to maximize their benefits, cool pavement solutions need to be long-lasting, use environmentally-sustainable materials, and not be energy-intensive. ePAVE is one such solution that converts existing pavements into cool pavements by providing a thin coating of a polymer-cement composite.

In addition to a cool pavement solution ePAVE provides a variety of benefits. It uses environmentally-sustainable materials while being easy to install without the need for any energy-intensive or specialized equipment. ePAVE is long-lasting, providing a high surface reflectance as well as good ride quality for a significant amount of time before needing reapplication. It absorbs ultraviolet (UV) radiation, reflects Intrared (IR) radiation, and traps Volatile Organic Compounds (VOCs), further improving the urban environment. Finally, ePAVE is also available in a variety of colors to meet the cool pavement requirements of various of communities.

Introduction

Paved surfaces are all around us. From roads to tennis courts, they are an indispensable part of civilization. In ancient Rome, road networks covering hundreds of thousands of miles were built to enable trade and commerce. Similar road systems developed in the ancient civilizations of Egypt, India, China, among other parts of the world (Jacobson, 1940). Today, virtually every country in the world has a road network to facilitate the movement of goods and people. Many paved surfaces such as public squares, private patios, basketball courts and parking lots can be found in every community. In the future, the fraction of paved surfaces in cities will only rise, as more than half of humanity shifts from rural areas to dense urban ones (World Bank, 2015).

However, as much as paved surfaces benefit communities by enabling commerce and providing spaces for work and leisure, they also have negative consequences for the urban microclimate. One of these is the Urban Heat Island (UHI) effect. In hundreds of cities across the world, the average air temperature has been observed to be higher than adjacent rural areas. Thus, when the temperature profile is plotted on a map, the temperature of cities rises above its surroundings, like an island in a sea, giving the UHI effect its name.

The UHI effect adversely impact several aspects of human life. The US Environmental Protection Agency (EPA) lists four impacts from the UHI effect[1]:

1. Increased building cooling loads, leading to higher energy consumption
2. Increased greenhouse gas emissions and deteriorating air quality
3. A decline in human outdoor comfort and public health
4. Reduction in the quality of stormwater runoff

To make matters worse, climate change may further intensify the UHI impact on communities[2]. Climate change is caused by the emission of greenhouse gases, trapping solar energy inside the earth's atmosphere causing worldwide air temperatures to rise. The growing number of UHIs is raising the air temparture of cities and making life in urban areas uncomfortable.

Paved surfaces have been blamed as one of the factors that lead to the development and increase of UHI in cities[3]. These surfaces typically have a lower solar reflectance (albedo) than natural vegetation. The solar reflectance or albedo is a property of paved surfaces that determines the fraction of incoming solar radiation that is reflected from them, while the rest is absorbed and increases the surface temperature. As paved surfaces usually have a low albedo, it implies that they absorb a greater fraction of incoming solar energy. This absorbed energy remains stored and slowly emitted out of the pavement, increasing the surrounding air temperature and thus leading to the UHI effect. In addition, this increases the use of air conditioning, which further heats up the urban environment.

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[1] US EPA: https://www.epa.gov/heat-islands/heat-island-impacts
[2] US EPA: https://www.epa.gov/heat-islands/climate-change-and-heat-islands
[3] Arizona State University: https://www.epa.gov/sites/production/files/2014-07/documents/2scientificoverview-pavements-heatislands-kaloush-asu.pdf

While paved surfaces are essential to modern life, they also have a negative effect in the form of UHI. Cool pavements, which reflect a greater fraction of incoming solar radiation (Lawrence Berkeley National Lab, 2017), is a pavement solution that reduces the UHI effect while still allowing communities to enjoy the benefits of paved surfaces. These pavements are characterized by a higher solar reflectance than typical paved surfaces and have been shown to have a lower surface temperature, which in turn leads to a lower air temperature in their vicinity. Large-scale adoption of cool pavements in communities has the potential to mitigate UHI, reverse some of the effects of climate change by decreasing greenhouse gas emissions and create a healthier living space.

Background

In the US, even though paved surfaces cover less than 1% of the overall land surface (ATRBA), 45 million people still live within 300 ft of a major road[4]. The distribution of paved surfaces is highly uneven. In typical urban areas, 40-70% of surfaces are paved (Akbari et al, 2003). These surfaces are made of man-made materials, almost always asphalt and concrete, and are very important for modern society. Some examples of urban surfaces include:

1. Sturdy and durable **roads** that facilitate the movement of people and goods from one place to another. According to the CIA World Factbook[5], the United States, China, and India have over 2.5 million miles (4 million km) of paved roads each, the European Union has over 6.2 million miles (10 million km), while Australia has a little over 600,000 miles (1 million km). Some of these countries are actively building new roads and increasing the length of their systems, others are rehabilitating and preserving their existing systems. Roads also include **airport** taxiways and runways, which also cover significant areas, such as Denver International Airport in Denver, CO, which covers an area of about 34,000 acres.
2. **Parking lots** that are a must for businesses, schools, and residential areas. A fascinating tool developed by Moovel Lab's 'What The Street?!' project (Moovel Lab) shows the vast amounts of area devoted to parking spaces in major cities in the US. The EPA (EPA, 2006) investigated parking design methods and found that over half the area of a typical commercial development is occupied by parking lots. Urban planners have blamed parking lots for increasing urban sprawl, creating larger cities and reducing green spaces.
3. **Buildings**, comprising walls and roofs, are perhaps the most important use of paved surfaces. Building provide shelter from the elements, giving communities safe places to carry about their business. Indeed, cities are characterized by their buildings, which can be large and majestic structures like Chicago's Willis Tower or Tokyo's Metropolitan Government Building, smaller but no less important ones like schools, homes, and public libraries, or factories and industrial areas like docks.
4. **Recreational surfaces**, including playgrounds, basketball courts, tennis courts, and race tracks. This also includes recreational areas like **theme parks** that see many tourists.

Paved surfaces are a defining feature of all cities making concrete the most-used man-made material in the world. However, these surfaces are known to be a cause of the UHI effect. According to the US Environmental Protection Agency (EPA, 2014), conventional pavements in the US can heat up to a surface temperature of 115-155ºF (48-67ºC), which is 18-36ºF warmer than the surrounding air temperature. In turn, these hot surfaces gradually heat up the surrounding air and make the adjoining environment warmer. Globally, urban air temperatures have been measured to be over 18ºF (10ºC) higher than adjoining rural areas.

As pavements tend to be concentrated in cities, this heating effect becomes pronounced in urban areas with a large fraction of paved surfaces. Anthropogenic (human generated) heat, such as from vehicles or air conditioning, further adds to this effect. With climate change, UHI can lead to

[4] US EPA: https://www.epa.gov/sites/production/files/2015-11/documents/420f14044_0.pdf
[5] CIA World Factbook: https://www.cia.gov/library/publications/the-world-factbook/fields/2085.html

increasingly intense heat waves. For example, the 1995 Chicago Heat Wave led to over 700 deaths, and according to the Illinois State Water Survey (ISWS)[6], it was exacerbated by the UHI effect in the city. Another example is the European heat wave of 2003[7], which killed about 35,000 people. As the climate continues to change, such dangerous heat events can become more common.

The EPA lists four major impacts of the UHI effect in cities, which are discussed below.

Energy Consumption

Increasing outdoor air temperatures because of the UHI effect forces residents of a city to use more energy in the form of air conditioning and refrigeration. An expert study (Doddaballapur, 2011) examined the effect of UHI on several types of buildings and found almost all of them to be susceptible to higher cooling loads due to the UHI effect. Other studies from around the world have also reported similar results. The increased energy usage not only increases costs for users but requires increasing power generation capacity.

Air Pollution

According to the International Energy Agency (IEA)[8], despite the increasing push towards renewable energy, a clear majority of energy production in Organization for Economic Cooperation and Development (OECD) countries comes from fossil fuels like coal and natural gas. OECD countries have the most energy-intensive economies in the world. Another major source that raises safety and environmental concerns is nuclear energy. The increasing cooling loads in cities indirectly increases greenhouse gas emissions, further damaging the environment. According to the EPA, coal-fired power plants release dangerous gases, such as carbon monoxide, sulfur dioxide, and particulate matter, into the atmosphere.

Human Health and Comfort

Increasing outdoor air temperatures can be very dangerous to health, especially for vulnerable populations such as children, the elderly, and construction workers. Heat-related stress can cause dehydration, heat stroke, and even death. Increased air temperatures have also been correlated with higher pollen content in the air, leading to a deterioration in comfort for those affected by allergies[9].

A secondary impact of the UHI effect is the increase in concentration of ozone (O_3) gas near the earth's surface (Swamy et al, 2017). This is a greenhouse gas that can be toxic to humans at elevated levels. Yet another effect of UHI is that it makes cities unlivable during heat waves. Residents are often warned not to venture outside, thus locking them up indoors. As these increase in frequency and magnitude, people would be further discouraged from using outdoor spaces.

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[6] ISWS: https://www.isws.illinois.edu/statecli/General/1995Chicago.htm
[7] New Scientist: https://www.newscientist.com/article/dn4259-european-heatwave-caused-35000-deaths/
[8] IEA: https://www.iea.org/newsroom/energysnapshots/oecd-electricity-production-by-source-1974-2016.html
[9] Brian Stone: http://uci.umn.edu/sites/g/files/pua2696/f/urban-warming-management-and-health_final_stone.pdf

Unfortunately, Heaviside et al (2017) predicts that as society urbanizes and ages at the same time, the health-related aspects of the UHI effect will continue to get worse unless mitigation measures are adopted.

Stormwater Runoff Quality

Stormwater runoff is rainfall that flows on paved surfaces and eventually reaches natural water bodies like lakes and seas. With the increases in the area of impervious paved surfaces, more runoff is generated. This can cause localized flooding if not managed properly. Furthermore, aquatic vegetation and wildlife are extremely sensitive to water temperature. When stormwater flows over hot pavements, it heats up and eventually reaches natural water bodies. This warm water adversely affects the aquatic ecosystem (Houston Advanced Research Center, 2009).

In addition, asphalt roads (which constitute over 95% of roads in the US), also contaminate stormwater with chemicals. The American Society of Civil Engineers (ASCE) has identified 28 harmful chemical compounds that are emitted from traditional hot-mix asphalt (HMA) pavements. These chemicals come from vehicle exhaust, tire wear, lubricating oils, deicing chemicals, etc. (Nemeth, Ward & Woodington, 2010) that contain heavy metals and other potentially toxic compounds. These are deposited on the paved surfaces during use or are a part of the asphalt binder itself, and are washed away by stormwater into natural water bodies, contaminating them and putting the natural aquatic ecosystem in danger

Climate change is a continuing threat to urban areas as it can further aggrevate the UHI effect. Even as cities continue to grow with more area being paved, they need to address the risks from uncontrolled growth of UHI and climate change.

Solution: Cool Pavements

Cool pavements are a popular technique to mitigate UHI and fight the effects of climate change. The property that makes a pavement 'cool' is its solar reflectance or albedo. The solar reflectance of typical asphalt pavement is only about 5-20%. 5-20% of incoming solar radiation is reflected by the pavement while 80-95% is absorbed. This absorbed radiation increases surface temperature of the pavement and hence the surrounding air temperature.

Cool pavements have a higher solar reflectance than typical asphalt pavements. Cool pavement solutions like white cement concrete or white coatings can have an initial solar reflectance of 50-80%, which can lower the surface temperature significantly and thus mitigate the UHI effect. The Leadership in Energy and Environmental Design (LEED) system defines a cool pavement as one that has a Solar Reflectance Index (SRI) of 29 or more.

Cool pavements provide several benefits. These are summarized by Lawrence Berkeley National Lab (LBNL) as follows:

1. Lower air temperature around the cool pavements. It is predicted that an increasing in the solar reflectance of all roads in California can reduce summertime air temperatures by 1.0-2.5ºF (0.5-1.5ºC).
2. Reduced building cooling loads and a consequent reduction in greenhouse gas emissions due to lower demand on electricity generation.
3. Improved human comfort and public health, including a reduction in heat-related illness and near-ground ozone
4. Improved water quality by lowering stormwater runoff temperature
5. Reduced street lighting cost and driver safety as cool pavements reflect more light from cars

However, despite the many benefits of cool pavements, there are several concerns regarding their use. The two most important ones are:

1. **Longevity:** While cool pavements have a high solar reflectance at the time of installation, this decreases over time. The reason behind this varies: some cool pavement solutions may degrade chemically over time due to exposure to UV radiation from sunlight, while others may simply accumulate dirt and tire debris on top. Still others, most prominently thin coatings, may undergo severe abrasion over time and require reinstallation at regular intervals of time.
2. **Installation:** Nearly all existing paved surfaces are not cool. Replacing them with cool ones would not just be prohibitively expensive, but would also lead to a large amount of greenhouse gas emissions. Cool pavement solutions that are energy-intensive to manufacture or install can cause unintended environmental damage.

While cool pavements provide a variety of benefits, they must also be able to provide those benefits over a reasonable amount of time, while also using environmentally-friendly materials and less energy-intensive installation methods.

ePAVE: A better way towards cool pavements

ePAVE, LLC is a cool pavement solution provider based in Los Angeles, California, USA. Our patented product, ePAVE, is an environmentally friendly pavement preservation solution that extends pavement lifecycle, is cost effective, and addresses the challenge of reducing greenhouse gas emissions and lowering the Urban Heat Island. It is a long-lasting, environmentally-sustainable cool pavement solution that has a high solar reflectance at construction of 30-40%. The benefits of ePAVE to the end-users are:

1. Lowers surface temperature, creating cooler stormwater runoff and less damage to local watersheds;
2. Provides energy savings. Cooler air temperatures result in reduced air-conditioning demand lowering both pollution and energy costs;
3. Slows climate change by offsetting warming from greenhouse gases;
4. Reduced street lighting cost due to its higher reflectance of lighting;
5. Improves comfort and health. It cools city air, which in turn reduces smog and heat-related illnesses;
6. Is non-toxic. It allows uncontaminated water to drain from surfaces into downstream collectors and vegetation;
7. Leaves a smaller carbon footprint;
8. Reduces smog and mitigates pollution through cooling pavements; and
9. Is resistant to sunlight UV, rain/snow, salt and de-icing chemicals, lubricants, most aircraft fluids and hydraulic oils.

ePAVE is a novel engineered polymer-cement composite product that preserves both asphalt and concrete pavements, as it bonds well to both types of surfaces. It is a durable product with the ability to restore, maintain and preserve pavements efficiently and cost effectively, making the pavement surface more durable while also being environmentally friendly.

ePAVE is also environmentally sustainable. It lasts longer than asphalt-based treatments requiring fewer applications over the service life of a pavement. It is a polymer-cement composite and requires less cement binder than concrete overlays and can be supplemented by sustainable by-products like fly ash and slag. Furthermore, ePAVE helps mitigate the urban heat island, and provides a pavement preservation-led strategy for communities to meet their intended Greenhouse Gas (GHG) emission reduction targets and sustainable community goals. Yet another benefit of ePAVE is its ability to absorb UV radiation without undergoing severe degradation, thus reducing the amount of UV exposure to the local community while still providing lost-lasting benefits. ePAVE is free of Volatile Organic Compounds (VOCs) like toluene and xylene and helps to contain those compounds by preventing their migration into the environment via stormwater runoff or by off-gassing into the atmosphere. ePAVE is not only a cool pavement solution, but provides an all-round environmentally sustainable solution for communities.

ePAVE is applied as a thin 1/8 to 1/16 inch (1.5-3 mm) coating on top of existing asphalt and concrete pavements. The constituents of the proprietary formula can be mixed on site using existing road construction equipment and without the need to heat the product to high

temperatures. The emissions during this process is greatly reduced. The mixture is then laid out and left to cure for as little as an hour before it is reopened. Furthermore, it can be mixed with various dyes to change its color, thus providing a cool pavement solution with a wide color selection. Pilot projects using ePAVE have shown excellent retention of surface reflectance and ride quality over time, making it an ideal, long-lasting cool pavement solution.

Conclusion

Paved surfaces are the foundation of modern civilization: from transporting goods and people to providing spaces for work and leisure, they are an indispensable part of any city. However, paved surfaces lead to the development of the Urban Heat Island (UHI) effect by absorbing a greater fraction of incoming solar radiation and increasing the surrounding air temperature.

The UHI effect has several negative consequences for communities: increased building cooling loads, higher greenhouse gas emissions and near-surface ozone, higher risk of heat strokes and heat-related fatalities, less livable outdoor spaces, and lower stormwater runoff quality. Furthermore, climate change can be expected to further exacerbate these effects. To negate these negative consequences while still enjoying the benefits of paved surfaces, cool pavements may be adopted.

Cool pavements are characterized by a higher solar reflectance than typical pavements. They reflect a greater fraction of incoming solar radiation and maintain a lower surface temperature. As a result, they create a cooler environment around them, negating the negative effects of paved surfaces while still allowing communities to enjoy their benefits. However, all cool pavements lose their effectiveness over time and need to be reapplied. Some cool pavement solutions need to be reapplied every few months, while others retain their beneficial properties for several years before needing reapplication. Furthermore, a sustainable cool pavement solution also needs to be made of materials that do not harm the environment. Finally, sustainable cool pavement solutions must also be easy to apply, requiring minimal energy for application.

ePAVE is a cool pavement solution that provides a variety of benefits. It can be applied as a thin coating to existing pavements to enhance their service life and decrease their surface temperature. In addition to reducing the surrounding temperature and mitigating the UHI effect, it uses sustainable materials, has a long service life, and can be installed easily without requiring a lot of energy. Moreover, it absorbs UV radiation, further improving the outdoor environment for users. It does not contain volatile organic compounds and can prevent such compounds from being released into the atmosphere by the underlying pavement. Finally, ePAVE is available in a variety of colors. For more information, visit www.epavellc.com.

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