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Cool Pavement Analysis and Techniques

Vivek A. Nilawar

Government Engineering College, Aurangabad
E-mail: viveknilawar0303@gmail.com

Abstract—*Urban heat islands are caused by the heat absorbance and reflectance from solar energy with dark surfaces, which can cause the temperature in urban areas to be significantly warmer in summer months. This excess heat increases the peak energy demand as people rely on air conditioning to cope which contributes to elevated levels of green house gas emissions and air pollution. These all effects are because of increasing the reflective and radiative properties of built environment[2]. Pavements are considered as an important factor that contributes heat islands, whereas cool pavement technologies create cooler surface through reflectance, thus reduce contribution to localized increased temperatures and minimize storm water runoff by adopting different techniques in pavement design .Researches are going on for the benefits and methods of using cool pavements. There is a brief analysis of cool pavements.*

1. INTRODUCTION

Cool pavement refers to a range of established and emerging materials. these pavement technologies tend to store less heat and has lower temperatures compared with the conventional pavements. This technology can help in the problem of urban heat island. Urban heat island is the phenomenon in which built environment in urban areas has more temperature than surrounding undeveloped areas. UHI affect air quality, energy consumption ,Water quality for a region etc.

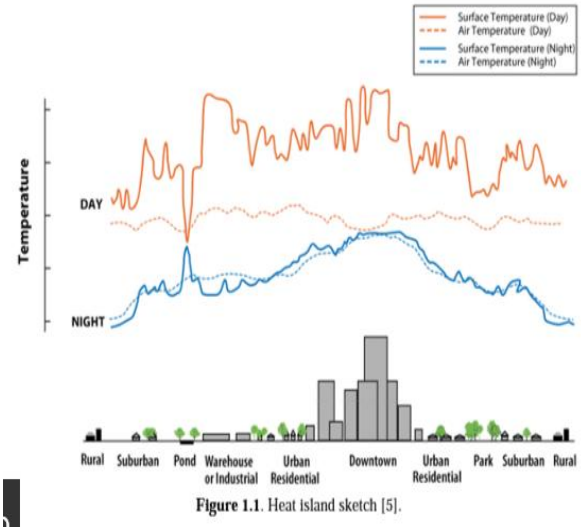


Figure 1.1. Heat island sketch [5].

Heat island sketch

To mitigate UHI effect we have to focus on increasing tress, vegetation, cool roofs, cool pavements, which prevent the absorption of solar radiations. There is a large contribution of pavements in urban heat island so a brief analysis on this is necessary.

There are several causes of urban heat island. The principal reason in that is the short wave radiation is still within the concrete, asphalt, and buildings that absorbed during the day. Concrete and asphalt are the common materials used in construction of pavements, so that pavements has large contribution to urban heat island.

2. IMPACTS OF URBAN HEAT ISLAND

The IPCC stated that " It is well known that compared to non urban areas urban heat island raise night time temperature more than day by time temperature up to 5 F [8]. there is also impact of UHI on energy consumption. Increased local urban temperatures typically lead to higher electrical loads and more resultant energy use and emissions. For every 1 F increase in summer time temperature, peak utility loads in medium and large cities increase by an estimated 1.5-2.0 % (EPA) a reduction of 1.8-3.6 F in regional average temperatures can result in 10% decrease of the peak energy demand, hence lessen annual cost and impact related to energy extraction[4].

3. STRATEGIES OF UHI MITIGATION MEASURES FOR HEAT ISLAND

1. Increasing trees and vegetation cover
2. Creating green roofs
3. Installing green roofs
4. Using cool pavements
5. Introducing water bodies to urban area
6. Reducing atrhographic heat
7. Amending urban geometry to improve air flow and natural ventilation.

As mentioned above pavements are considered as an important factor that contributes to heat island. There are several potential strategies to make pavements cooler with different cooling mechanism[5].

1. Modification of thermal properties of pavements

There are several properties which influence temperature variation such as thermal conductivity, pavement heat capacity, pavement surface reflectance (albedo).

Thermal conductivity is the ability of material to transmit heat. It determines how fast heat transfers from high temperature to low temperature, therefore reducing thermal conductivity could slow or reduce heat flow causing lowering the temperature.

Pavement heat capacity is the amount of energy required to raise temperature of one unit weight of substance by one degree Celsius without change of phase. In case of pavements it determines how much energy is absorbed and stored in pavement. The higher heat capacity of conventional urban materials contributes to heat island at night, however increasing the specific heat capacity as well as density and thickness of pavement could increase the effective heat capacity of the whole pavements and reduce the daytime high temperature and increase in nighttime low temperature[5].

Pavement surface reflectance (albedo) is the percentage heat energy reflected by the pavement. Most existing studies on cool pavements have focused on solar reflectance. High albedo also could help to reduce pavement subsurface temperatures. It is easy and convenient to increase the albedo of construction materials such as asphalt and concrete. In asphalt pavements albedo can be modified with high albedo materials such as cool colored aggregates or by using light colored tree resin in place of asphalt. These are some techniques to improve albedo of pavement materials.

Albedo = reflected heat / incident heat,

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

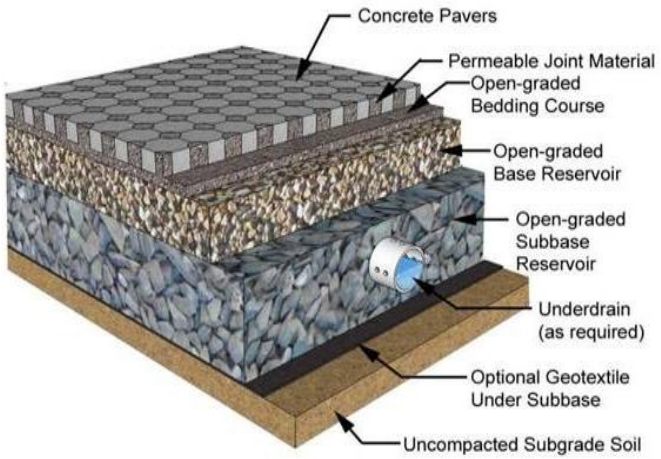
4. MODIFIED PAVEMENTS

- 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, bike paths, and parking lots. One resin-based product currently on the market is NaturalPave8[3].
- 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[3].

Pavement type	Albedo
Asphalt	0.50 - 0.20 (new) 0.10 - 0.15 (weathered)
Grey 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)

2. Enhancement of evaporation from pavements

The use of evaporative cooling could reduce pavement temperature and consequently air temperature[5]. The two types of pavements provide these type of benefits permeable pavements and water retentive pavements. 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[7].



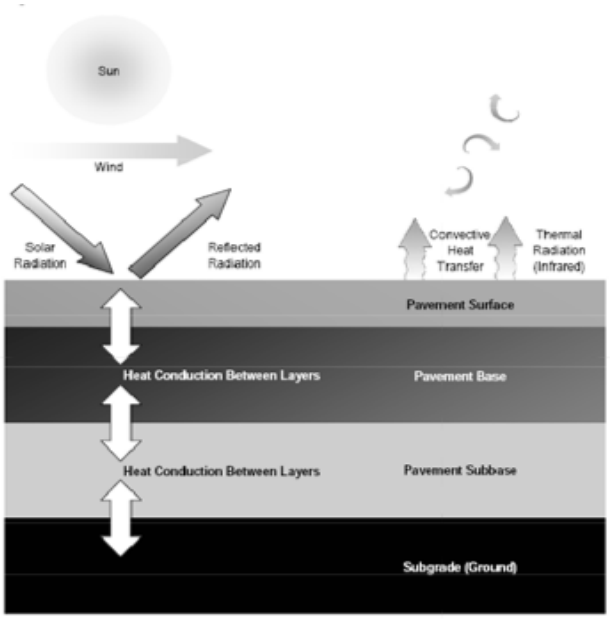
Permeable pavement

5. 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 good for water runoff. They do require more maintenance though, particularly through winter and the dry season.

3. Enhancement of convection

Enhancement of convection between pavement and air as air moves over the warmer pavement surface. If there is more convection of air in surface temperature remains low.



Energy balance of pavement

4. Reducing heat energy in pavement

Other measures to keep pavement cooler include shading pavement surfaces from solar radiations using tress, buildings and canopies etc[1]. Another cooling option is the use of mechanical cooling associated with harvesting and converting heat energy stored in pavement.

(a) shading with tree

(b) shading with canopy and solar panels [65]

The photovoltaic canopies also could generate electricity that can be used to power nearby buildings.

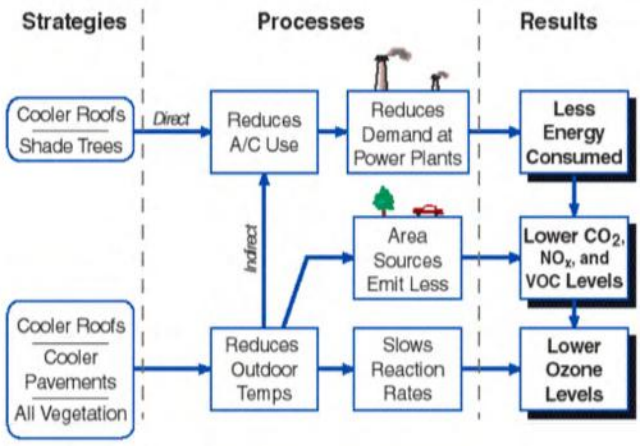
6. SOME COMMON RECOMMENDATIONS ON THE APPLICATION OF COOL PAVEMENT STRATEGIES

- Pave less and plant more for some areas such as parking lots, alleys should be partly paved
- Pave smart if to be paved permeable pavements such as porous asphalt pavement, pervious concrete pavement etc. to manage both storm water runoff and heat island.
- Consider evaporation and shading . these could be very effective strategies to help improve the thermal environments.

7. SUMMARY AND DISCUSSION

Cool pavements have been identified by the US Environmental Protection Agency (EPA) as a major strategy to mitigate heat island effect, with one of the best benefits being that they could lower air temperatures and consequently reduce cooling related energy use and associated greenhouse gas emissions. An integrated model was developed to stimulate the temporal and spatial distribution of temperatures of pavement and near surface air. Both measurements and model show expected effects of albedo, and also show potential benefits of permeable pavements on near-surface temperatures.

The impacts of temperature change from cool pavement technologies on building/vehicle energy use, human comfort, air quality and pavement life need to be evaluated[9].



In the above pathway, we can see clear results that cool pavements has many benefits. It is an eco friendly pavement.

8. COST

Cool pavement costs will depend on many factors including the following

- The region
- Local climate
- Contractor
- Time of year
- Accessibility of the site
- Underlying soils
- Project size

- Exported traffic
- The desired life of pavement

Federal Highway Administration has noted that porous asphalt costs approximately 10 to 15 % more than regular asphalt, and porous concrete is about 25% more expensive than conventional concrete[4].

In countries like India, China in which urbanization is increasing rapidly simultaneously built environment is also increasing so as to produce UHI effect which will become a serious issue in nearby future so there is need to plan mitigation strategies to reduce UHI. There is need of further research in making pavements cool.

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