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A SUSTAINABLE SYSTEMS APPROACH TO THE HYSTERESIS LAG EFFECT OF SURFACE MATERIALS & URBAN HEAT ISLANDS

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1. INTRODUCTION

The transition from rural to urban is means for the engineered environment of manmade civil infrastructure to flourish and expand. Urbanization is transitioning communities from the natural rural vegetation to urban infrastructure. The anthropogenic-induced change has manifested itself in microscale and mesoscale impacts for the urban inhabitants. This includes increases in temperatures in comparison to adjacent rural regions, increased environmental and environmental health impacts as well as economic and social consequences. Policy makers from the local regions play an integral part in developing and sustaining policies, incentives and regulations to mitigate the impacts of the UHI. This paper intends to present a case example in Phoenix, Arizona and a research methodology to reduce the hysteresis lag effect of surface materials and to develop policy recommendations based on sound science and engineering.

2. BACKGROUND

The interdependencies and interactions of the built environment with climatic and atmospheric sciences is a driving basis for the variations in the severity of the UHI effect. However, for policies to be developed and implemented at the local level, there must be an understanding of technologies and practices which are under the control of the policy making branch. There currently exists an opportunity within the engineering and scientific communities to develop a robust understanding of the coupled volumetric and material make up of surface materials within an urban region and their impacts to the UHI effect. Over the 20th century, average annual temperatures in the arid subtropical Phoenix region (?33° 26'N / f 112°W) have increased 3.1°F (Brazel et al. 2000). However the urban portions of the region have realized mean annual temperature increases of 7.6°F, a rate of 3x the total region mean increase. On December 5, 2001, the City of Phoenix adopted by City Council Resolution a revision of the General Plan, which promulgated Goal 7 – The Urban Heat Island. This goal obligated the City to "explore options to minimize the impacts of the Urban Heat Island Effect" (Phoenix General Plan, page 271).

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Subsequent to the adoption of the General Plan, numerous editorials in the States largest newspaper, The Arizona Republic were run including a series of four full-page editorials in September 2003.

3. RESEARCH SITE

Beginning mid 2002, researchers from Arizona State University and from the Cambridge – MIT Institute sponsored Engineering for Sustainable Development Programme within the Department of Engineering at Cambridge University initiated a series of meetings in the greater Phoenix, Arizona region with a variety of stakeholders from all levels of government as well as representatives from industry, academics and non-governmental organizations. These discussions resulted in governmental and industrial management stakeholders articulating a need to address the Phoenix regional UHI effect via science and engineering based policies and standards for items for which the stakeholders have direct control. It was identified that those items of control lay primarily within the micro-scale and local-scale (urban canopy layer). However, these layers impact all levels including the meso-scale potentially as well as the global-scale.

The outdoor laboratory utilized for materials encompassing the regional surface urban fabric, is Phoenix Sky Harbor Airport. Sky Harbor is the worlds fifth busiest airport for aircraft movements and serves the two county regions of Maricopa and Pinal of central Arizona (14,600 Sq. Miles / 37,813 Sq. Kilometers), and the large Phoenix metropolitan region (urbanized land area of 1,207 Sq. Miles / 3,126.12 Sq. Kilometers). Phoenix is the largest single city within Maricopa County and is the nation's fifth largest city by population. Its geographic area of 484.521 square miles is larger the City of Los Angeles. Phoenix is projected by 2010 to be the fourth largest City in the United States behind only New York, Los Angeles and Chicago.

As presented in Figure #1, minimum temperatures within the Phoenix region have demonstrated annual increase in comparison to a non-developed rural desert location that has not been influenced by the transition to manmade materials.

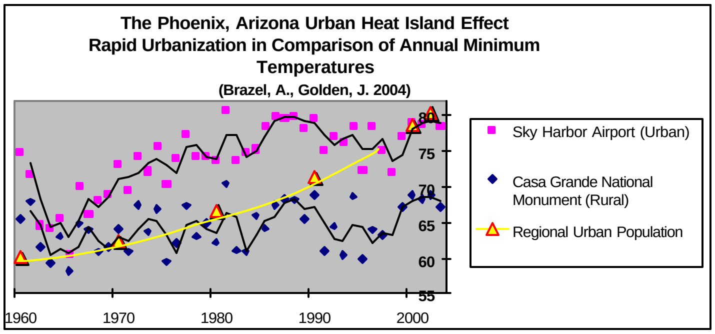

Figure #1: The Phoenix Regional UHI Effect. An evaluation of minimum annual temperatures – Phoenix Sky Harbor vs. Casa Grande Regional Monument.

4. SURFACE MATERIAL HIEARCHY

Roads and highways account for 29 to 39% of the urban fabric (Rose et al. 2003; Akbari et al. 1999). Because many of the urbanizing cities in the Southwest, including Phoenix and Las Vegas, experience a nocturnal UHI effect, material selection for roads and highways needs to address the hysteresis-lag effect, which results in urban areas being significantly warmer than rural areas outside of the urban fringe. This effect increases energy usage, inhibits outdoor activity, and links to significant health risks due to the diurnal high temperatures. Initial research indicates that, in desert climates, albedo is less important than the material design and inclusion of porosity. Utilizing ASTER satellite thermal imagery, hand-held thermography and in-situ thermocouplers, researchers worked to develop a preliminary hierarchical listing of surface materials response to the hysteresis lag effect. As presented in figure 2 below, the use of recycled, rubberized asphalt appears to respond well to the nocturnal UHI effect while providing societal benefits (reduced noise) and environmental benefits (use of recycled materials) and economic positives due to material durability. Other sustainable technologies and material innovations being addressed include the addition of existing and emerging pigments and aggregates to mitigate the UHI effect.

5. SURFACE MATERIAL MITIGATION

As a resultant of the extreme temperatures in the desert southwest, sub-surface soils in the rhizosphere reach levels exceeding 40°C, which reduces the development and health of urban forestry (Celestian, S. & C. Martin. (2003). In addition, the impervious pavements direct any rain events into a sheet flow off-site transport or to drywells. Researchers are evaluating the utilization of coupled renewable energy technologies that can alter the surface energy budget so as to reduce the hysteresis lag while promoting a sustainable systems approach to UHI mitigation. One example is the adaptation of commercial parking canopies fitted with Photovoltaics. A 11,000 ft^2 100kW (ac) system utilizing 768 PV modules was set-up at a mass-transit park & ride facility. Early results of sampling during calm June nights presents evidence that surface materials remain cooler than with conventional sheet metal canopy coverage with the surface of the top of the canopy cooling rapidly after sun-down. Additionally, the system provides an estimated 178,000 kWh per annum and reduces water usage by 1.3L per kW as required by conventional fossil fuel plants. By 2006, researchers anticipate having developed a complete hierarchal mitigation strategy based on climatic, environmental, economic and social ranking scheme – a sustainable systems approach to the UHI.

6. REFERENCES

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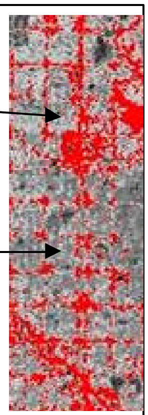
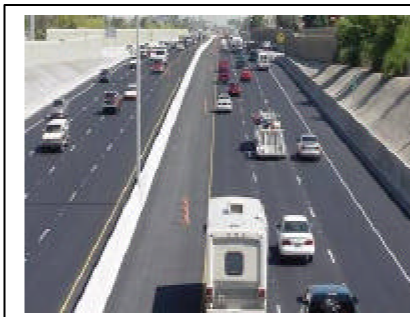
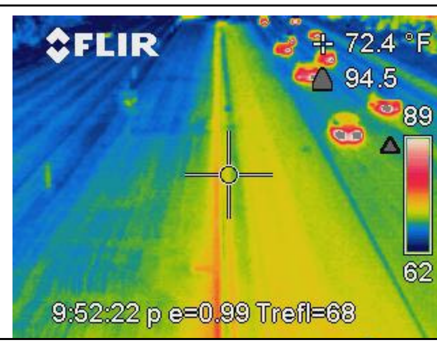
Conventional concrete highway is warmer than recycled rubberized asphalt being used in the West.







Note: concrete median is warmer than the rubberized asphalt highway.