Cool Pavements to Reduce Urban Heat Island Effect: Literature review & Finite Element Modeling

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JOURNEES TECHNIQUES ROUTE 2023

Université Gustave Eiffel — University of New Hampshire

Context: Recently, surface temperatures in urban areas of Nantes reached more than 12° C higher than in rural areas [1]. This phenomenon has been identified as urban heat island (UHI) [2]. UHI reducing pavements (cool pavements), have gained an increasing attention from city officials and researchers to mitigate UHI effect. This poster presents a literature review followed by finite element analysis as a first step of the co-tutelle PhD (2022-26) between University of New Hampshire (USA) and Univ. Eiffel (France). This PhD aims to improve the durability of UHI reducing pavements that currently exist and are under development by focusing on their structural optimization (interface performance, layer arrangements, geometric extents).

Urban temperature > Rural temperature

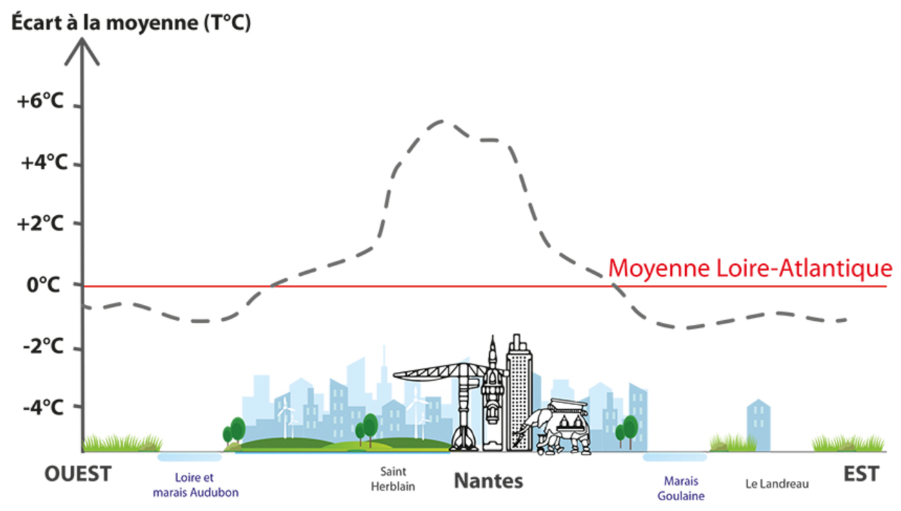


Figure 1 - Temperatures in Nantes [1]

Urban surface temperatures are significantly greater than rural surface temperatures

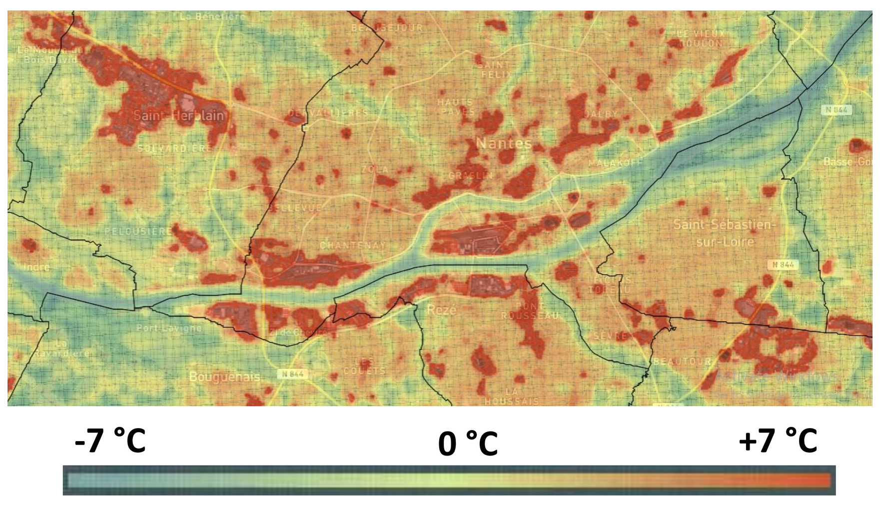


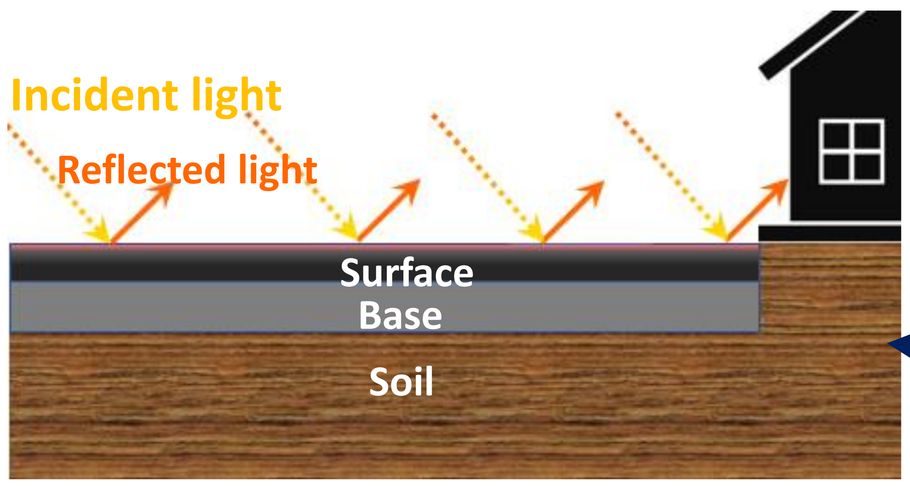
Figure 2 - Surface temperatures in Nantes [3]

Literature review : **> 150** papers from WOS & Scopus

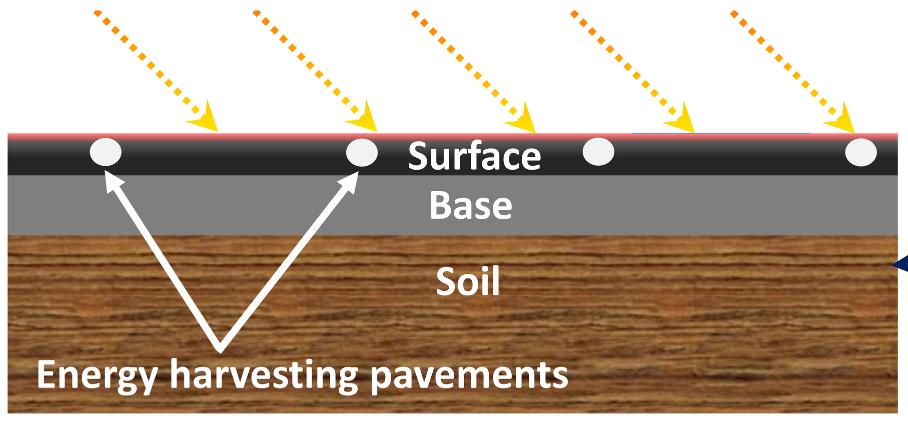
Figure 3 – Geographical locations of the collected papers

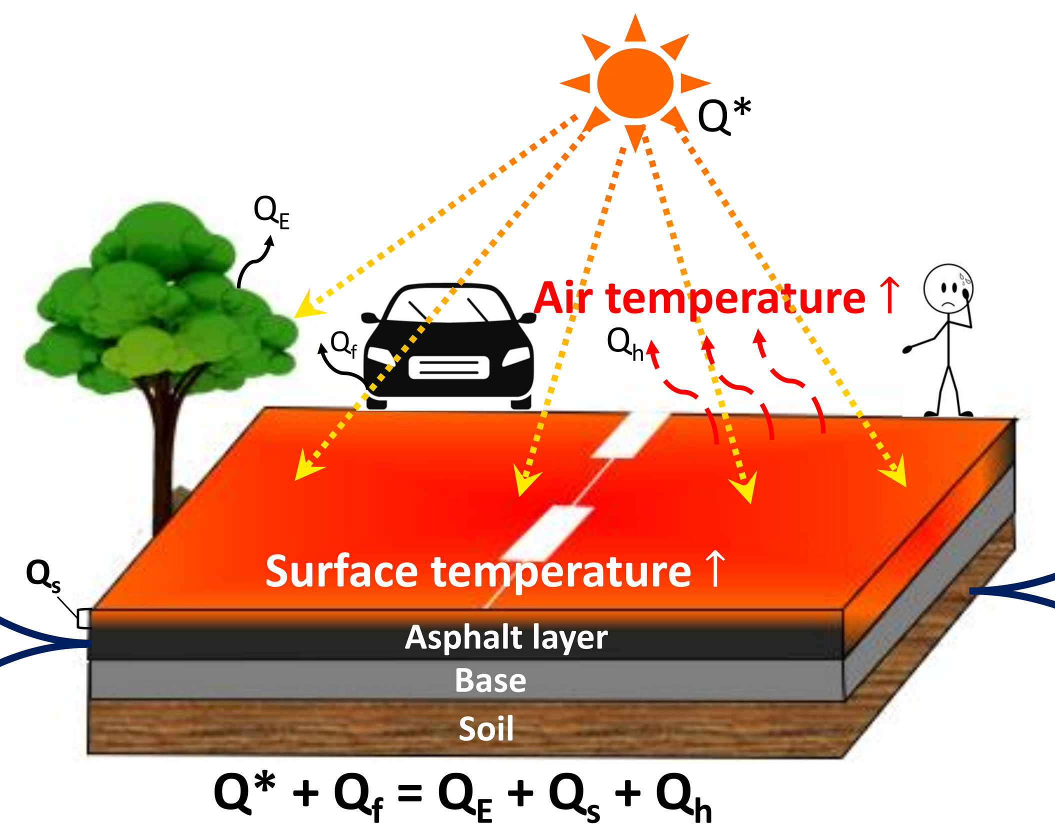
Solutions to decrease pavements' surface temperature proposed in literature

Family 1- Increasing pavements' reflection



Family 3- Energy harvesting systems

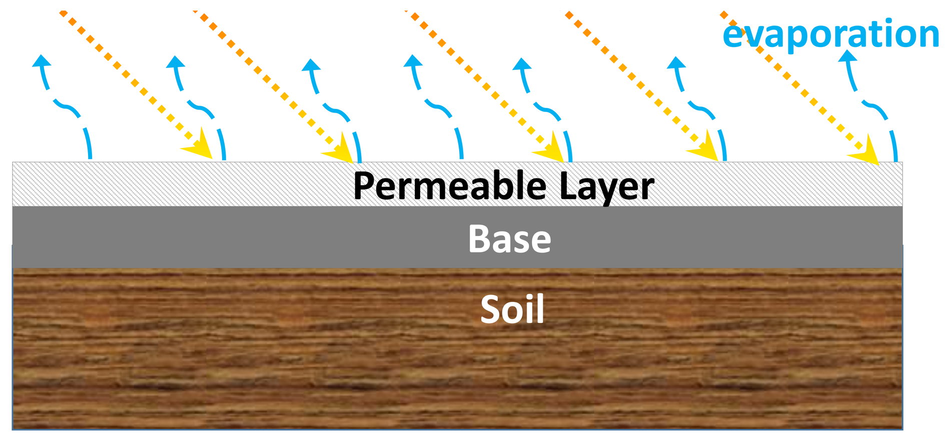




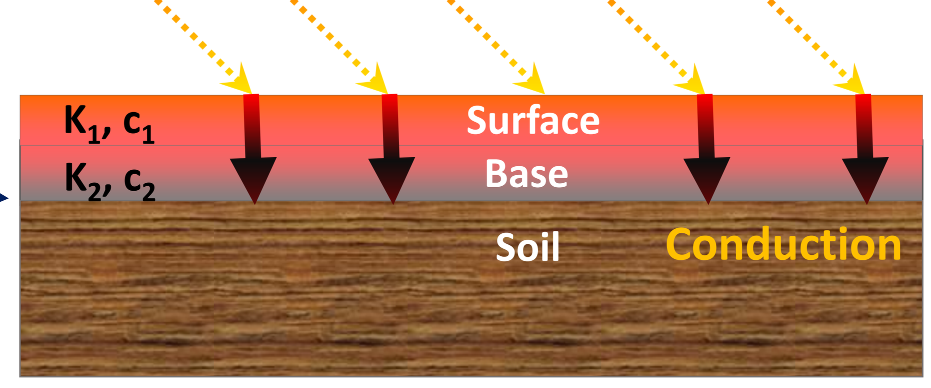
$Q^* + Q_f = Q_E + Q_s + Q_h$

Asphalt materials tendency to absorb and retain heat → increases surface and air temperatures

Family 2- Using permeable pavements

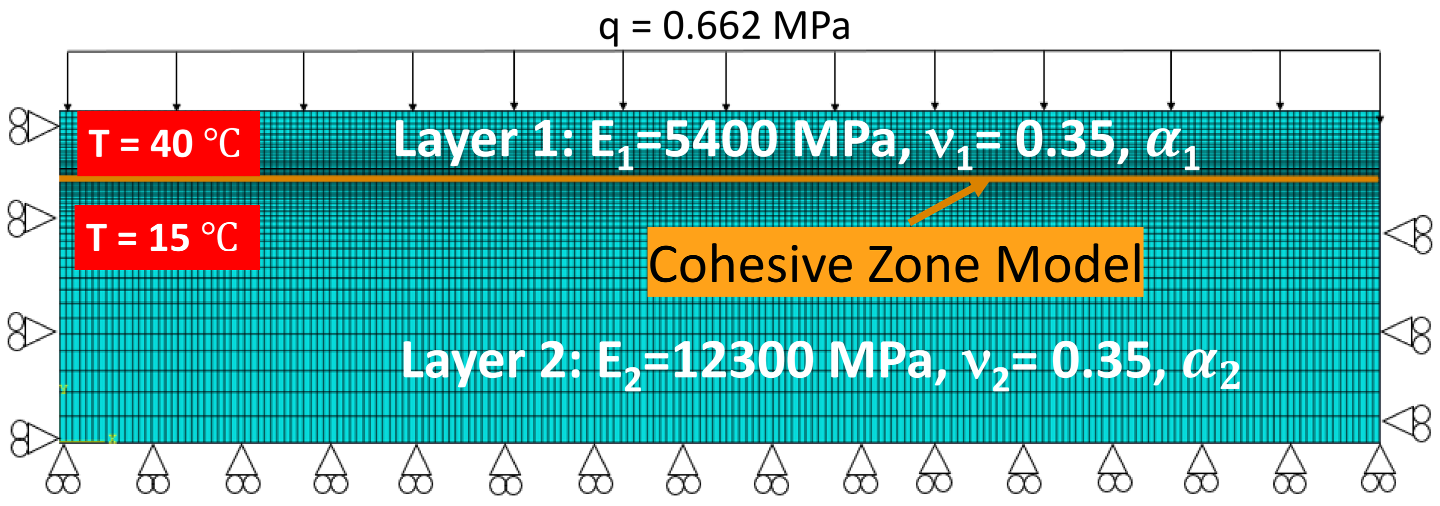


Family 4- Modifying thermal properties



Including *use of phase change materials*

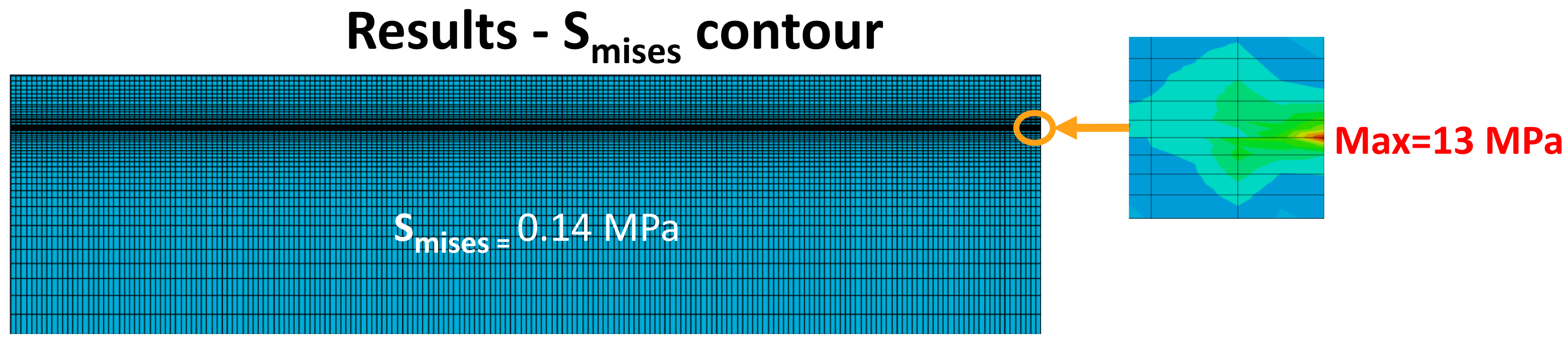
Preliminary FEM Exploration: Effects of bilayer UHI pavement properties on global response



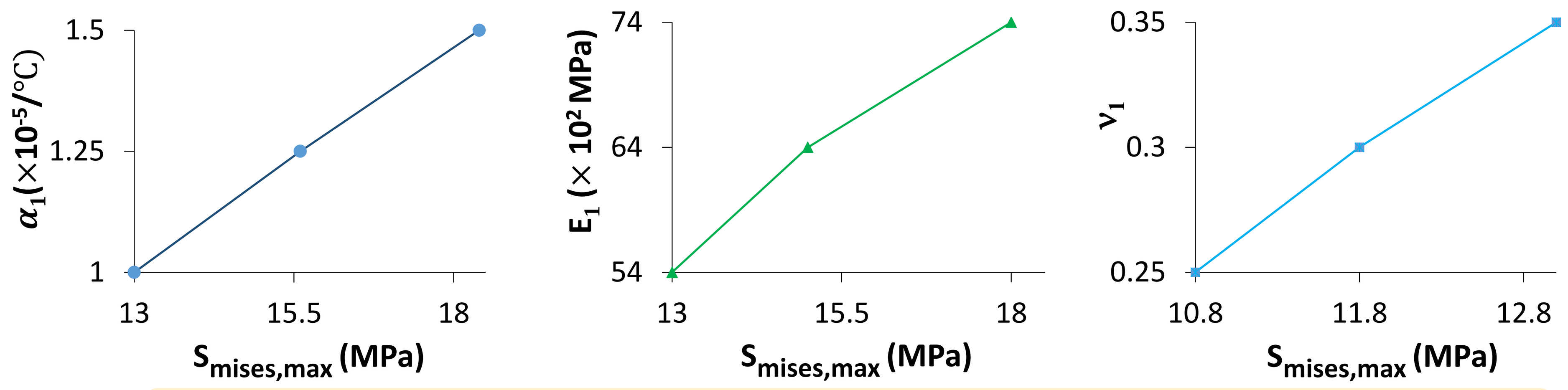
ABAQUS®

Parameter	Layer 1	Layer 2
Thermal conductivity K *(W/m.K)*	2	2.35
Heat capacity c *(J/kg.K)*	880	880
Density *(kg/m³)*	2350	2390
Thermal dilatation α *(/°C)*	Variable	10^{-5}

Results - S_{mises} contour



Effects of and α_1, E_1, and ν_1 on $S_{mises,max}$ at interface



As α_1, E_1, and ν_1 increases $S_{mises,max}$ at interface increases

Conclusions/perspectives: A first literature review has highlighted 4 different families of "cool pavements" used to reduce UHI. UHI reducing multi-material system durability requires high performance of interfaces. To optimize such composite structures, there is an urgent need to adopt and develop fundamental characterization of multi-material interfaces [4]. To this aim, preliminary finite element modeling has been conducted to evaluate effects of thermal and mechanical properties variations on global response using the cohesive zone model (CZM) in ABAQUS®. This work will be followed by experimental testing of interfaces under thermal and moisture loadings, more finite element analysis of the interface behavior using CZM, and life cycle assessment to optimize the UHI reducing pavements.

References

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[3] https://tiles.auran.org/ICUV2/#8.5/47.3569/-1.8144
[4] Buttlar WG, Chabot A, Dave EV, Petit C, Tebaldi G (2018) Mechanisms of Cracking and Debonding in Asphalt and Composite Pavements. Springer International Publishing, Cham. RILEM State-of-the Art Reports 28

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