PhD subject 2024-2027

Institut de Recherche en Génie Civil et Mécanique, UMR 6183, Nantes Université – Ecole Centrale Nantes – CNRS

Title: Control of porosity variation in concrete pavements under the influence of evaporative water flow.

Subject: When we talk about urban environments, we imply the development of housing and infrastructure and therefore an increase in soil waterproofing. This concerns, among other things, a change in the pace of biodiversity (filtration of groundwater), the associated risk of flooding, or drought. The city, while renovating itself to reduce the negative impacts on its biodiversity, must be able to continue to develop housing. It must also adapt to environmental changes.

Urban developments are responsible for the formation of "urban heat islands" (UHI). The confined nature of the dense urban environment (urban canyons) can be detrimental in summer. Indeed, radiative trapping (multiple reflections and solar absorption) and aeraulic confinement of urban canyons (recirculation zones) can cause UHIs locally. Global warming will accentuate urban canyons when the temperature difference between areas of the city becomes very large. The greening of building envelopes contributes to the direct cooling of this immediate environment. It has already been shown that planting trees along streets can reduce the shade provided and can modify the albedo of the ground and therefore UHI phenomena. However, their alignment limits street ventilation and recent studies have shown that tree photosynthesis coupled with atmospheric pollution generates poor ambient air quality. The solution for cooling streets on building facades remains the most relevant solution.

We speak of evapotranspiration the combination of the actions of evaporation of water from the soil with the transpiration of plants. The project aims to reproduce this combination with the ground-road couple. For this, the doctoral project proposes to evaluate the evaporation of water circulating under the pavements which should allow this cooling. However, periods of extreme heat are often accompanied by drought and the lack of rainwater therefore does not make it possible to supply the water circuit hoped for for cooling. A continuous water resource solution will first be proposed in the project while respecting the water cycle. Mastering water storage and evaporative flow requires a very good understanding of the phenomena in porous media. Evaporation in a porous medium is a complex phenomenon where water vapor diffusion, liquid water flow and phase change occur simultaneously. The evaporation rate depends on both the atmospheric demand (humidity, temperature and velocity of the ambient air), the porous medium and the transport properties (thermal and hydraulic conductivities, vapor diffusion). The development of an experimental protocol based on this physics is necessary to identify the type of porous materials capable of supporting an evaporative flow in summer.

The control of evaporation by the elastic deformation of pores seems to be the most relevant idea to study. In parallel with the experimental study, the development of a predictive model will be necessary by explicitly taking into account the pores in a representative elementary volume with scaling laws to model the material at the macroscopic scale. For this, a thermo-poro-elastic problem with a pressure relationship taking into account dynamic and fluid-fluid effects will be solved. Tests on concrete pavement samples will be carried out to measure the relationship between swelling and shrinkage deformations with drying and water absorption.

The PhD will be realised in the research team « Approaches for Green Engineering » (UTR INGVER) at the Institute of Civil and Mechanical Engineering. The project takes part of new research topics of the Chair EDYCEM.

Supervising:

- Frédéric Grondin (main supervisor), Full Professor, More details;

- Ahmed Loukili (supervisor), Full Professor, More details;

- Benoît Hilloulin (co-supervisor), Associate Professor, More details.

Required skills: Scientific curiosity, knowledges in physics measurement methods, knowledges in modeling by finite element method, able to work in a French or English speaking environment.

Eligibility: Master's degree or equivalent in civil engineering, or in mechanical engineering, or in materials engineering.

Gross salary: 2100 € / month (net salary around 1750 €) with a regular increase each year. Possibility to teach with additional salary.

Dates: beginning in september/october 2024 ; duration: 36 months.

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