English:

Title: Mechanical and Thermal Optimization of a Solar Energy Harvesting Pavement

In the current context of energy transition, the exploitation of renewable energy sources is of crucial importance. Utilizing the surface of roadways exposed to solar radiation could capture solar energy, giving a new function to the road which would contributes to the decarbonization of transportation.

By coupling the use of photovoltaic panels with a heat exchanger consisting of a layer of porous concrete through which a heat transfer fluid circulates, Eiffel University has been developing a promising modular solution for the past few years: the hybrid pavement (Vizzari, 2020, 2021a, 2021b). Initial results show interesting yields, notably achieved through the significant permeability of the porous layer (Asfour (2016), le Touz (2018)). The modular nature of the innovation allows the control of construction stages of this complex type of pavement through concrete prefabrication.

This thesis proposes to further these efforts by jointly optimizing the mechanical and thermal aspects of the hybrid pavement. To achieve this, an experimental approach will be adopted, relying on numerical modelling and physical models for thermal considerations."

The objectives of the thesis are as follows:

1. Thermal optimization of the porous material is planned to maximize energy recovery. This will involve the selection of constituents and mix-design. The assessment of thermal exchanges of the generated materials can be carried out using simple laboratory scale prototypes respecting certain dimensionless parameters to compare the energy efficiencies of the chosen materials.

2. Mechanical Optimization of the Hybrid Pavement: This involves assessing the mechanical performance under traffic conditions achievable with this multilayer pavement, which includes a low-resistance porous core. The aim is to maximize mechanical performance while maintaining efficient energy harvesting yields. This will include formulating optimized porous concretes in terms of thermal efficiency/mechanical properties, optimizing the design of the hybrid pavement (thickness, reinforcements, module size, geometry of distributors/collectors...), studying the fatigue behaviour of porous concrete and the multilayer, as well as examining the bonding between layers. If the overall performance is satisfactory, a 1:1 scale traffic simulation test using FABAC machines (available on the campus) may be considered.

3. Multiphysical Topological Optimization of the Porous Medium: This part focuses on optimizing the thermal transfer efficiency by studying different internal geometries and characterizing the two-phase water/air flow within the porous medium. It begins with a precise evaluation of thermal exchanges observed in the developed porous medium for the hybrid pavement. Models and demonstrators already constructed will be provided for evaluation using adapted experimental methodologies. Numerical simulations of the thermal behaviour of optimized topologies will then be conducted to enhance the overall efficiency of the system.

This thesis aims to address current lack of knowledge in the mechanical and thermal behaviour of solar energy harvesting pavements. By developing a holistic solution, this research will contribute to the creation of more sustainable and efficient energy systems, addressing contemporary challenges related to decarbonized transportation and the need for clean energy.

The thesis will take place on the Nantes campus of Gustave Eiffel University, in the MAST/MIT laboratory for mechanical and experimental aspects, with interactions with the COSYS/SII and MAST/GPEM laboratories, also in Nantes, for thermal aspects. The doctoral student will benefit from close supervision by a complementary team of experts in the fields of road mechanics and thermal issues.