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Numerical study of the thermal behavior of a new deicing road structure design with energy harvesting capabilities

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Facing the heavy organisational, financial and environmental constraints imposed by usual winter maintenance salting operations, pavement engineers have been led to look for alternative solutions to avoid ice or snow deposit at pavements surface. Among the solutions, one is self-de-icing heating pavements, for which two technologies have been developed so far: one is based on embedded coils circulating a heated calorific fluid under the pavement surface; the other one relies on the use of embedded resistant electric wires. The use and operation of such systems in the world is still limited and was only confined to small road stretches or specific applications, such as bridges which are particularly sensitive to frost. One of the most significant “coil technology” example in Europe is the SERSO-System (Solar Energy recovery from road surfaces) built in 1994, on a Switzerland bridge. Many of these experiences are referenced in the technical literature, which provides state-of-the art papers (see for instance Eugster) and useful detailed information dealing with the construction and operational management of such installation.
The present study is taking part of the Forever Open Road Concept addressed by the R5G: 5th Generation Road [1], one of the major project supported by IFSTTAR. It considers a different design of self-de-icing road that simplify its mode of construction and maintenance, compared to the two technologies mentioned above. It should also be noted that similar to pavements instrumented with coils, such structure could be used in the reversible way to capture the solar energy at the pavement surface during sunny days and store it, to either warm the pavement at a later stage or for exogenous needs (e.g. contribution to domestic hot water). To complete our study we also considered the use of semi-transparent pavement course wearing in place of the traditional opaque one.
In the present study, a 2D model was developed using FEM approach. It combines 2 numerical models. One is dedicated to the calculation of the heat transfer inside the porous layer between the fluid and the structure according to the geometry studied and the physical properties of the components of the system. The second one addresses the heat transfer inside the different layer of the pavement and was adapted to allow the insertion of a semi-transparent surface layer (for sun radiation). The temperature spatial distribution within the structure and its surface is calculated at different time step according to the evolution of boundary conditions at its surface. Various location in France were selected and calculation of the temperature field was carried-out over a year. Discussion on the performances of such system versus its location is proposed. Influence of a semi-transparent layer is also discussed. Future works will compared numerical simulations with experiments thank to a dedicated test bench under development and that will allow to test various structure in parallel.

References

[1] W. J. Eugster, Road and Bridge Heating Geothermal Energy. Overview and examples, European Geothermal Congress 2007
[2] http://www.ifsttar.fr/en/recherche-expertise/colonne-1/nos-grands-projets/r5g-5th-generation-road/