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Investigating the use of hydro-geothermal energy from tunnel drainage system for de-icing roads: results from a pilot study

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De-icing roads is a complex process that requires careful consideration of multiple factors, as traditional de-icing methods can have significant environmental and economic impacts. Therefore, the use of sustainable methods such as renewable energy, can potentially help to mitigate some of these issues. In order to investigate this concept, a thorough investigation into the use of hydro-geothermal energy from a tunnel drainage system for preventing the accumulation of ice and snow on traffic areas at the tunnel portals was conducted.

As part of this investigation, a pilot system consisting of nine fields with underlying heat pipes was constructed being monitored by several temperature sensors and further equipment. The fields utilise the readily available mountain water from the 1.284 m long road tunnel ´Füssen´ at the German/Austrian border as a natural heat source [1], eliminating the need for a heat pump. The sensor readings were then compared to the results obtained from a coupled hydro-thermal numerical model (Figure 1). The model considers all heat fluxes acting on the free surfaces (e.g. short and long-wave radiation), and determines the heat flux density required to keep the ice and snow free by means of the energy balance formed at the surface of the field. The validation of the simulation is carried out on the basis of the measurement data which were recorded in periods in which the external atmospheric boundary conditions can be determined as precisely as possible.

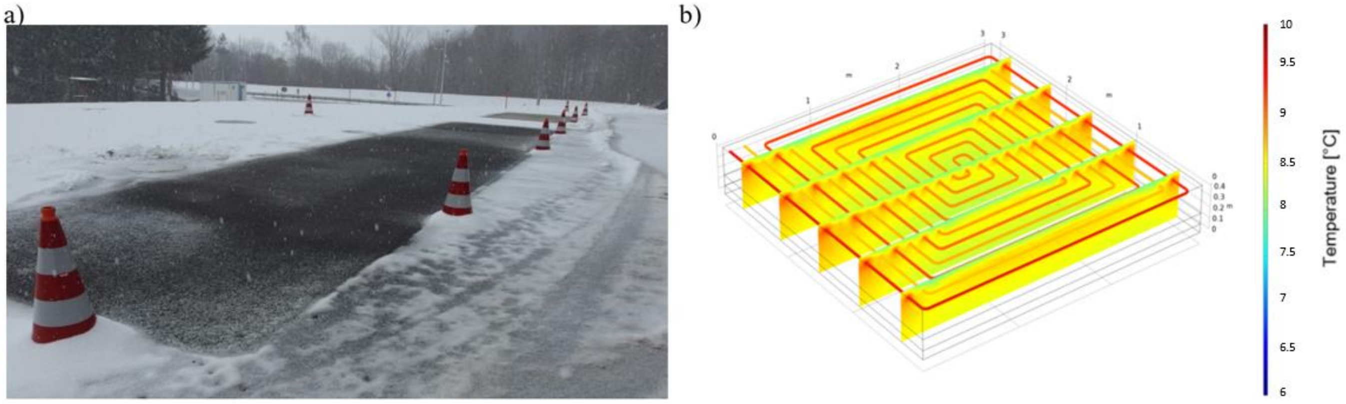

Figure 1: (a) Testing area equipped with the heat pipe system, (b) Numerical model of the heat pipe system.

A parameter study was also conducted that included different weather conditions, variable field geometry, pipe materials, and surface materials such as concrete, or asphalt, as well as the minimum field activation times, the results of these studies confirmed, among other things, that the utilization of copper pipes results in higher temperatures on the surface of the road [2]. Furthermore, it was determined that an activation time of 9 hours prior to the forecast of a weather event is sufficient to raise the temperature of the road surface to remain ice-free.

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The results of this study provide compelling evidence for the efficacy of the direct, passive outdoor temperature control concept in mitigating snow and ice accumulation on traffic areas adjacent to tunnel portals. This pioneering approach not only safeguards winter safety by maintaining hazard-free surfaces but also presents the opportunity to extend the lifespan of the traffic areas through the implementation of cooling strategies during the summer season. Notably, upon activation, the road surface consistently achieves the necessary temperature to effectively melt snow and ice during moderately intense snowfall within a relatively short timeframe of approximately 5 to 9 hours. These results highlight the practical viability and efficiency of the direct, passive outdoor temperature control method in combatting snow and ice-related challenges.

It was concluded that the findings of this study have yielded positive results and have served as proof of concept for the utilization of hydro-geothermal energy from tunnel drainage systems but also from other sources as e.g. BHE as a viable means of preventing ice and snow accumulation on roads. The data obtained from numerical simulations and measurements were found to be in agreement. This method holds the potential to greatly enhance the safety and accessibility of roads during the winter months, while also reducing the dependence on traditional de-icing methods that can have detrimental environmental impacts, on top of that, the method has an added benefit of being used in the summer to cool down the roads to prevent heat deformations. The results of this pilot project provide a foundation for further research and development in this field, with the ultimate goal of implementing this technology on a larger scale.

Data Availability Statement

The measured and used data are available from the authors on request.

Contributor statement

Conceptualisation: Mustafa Mustafa, Christian Moormann; Data Curation and Formal Analysis: Mustafa Mustafa; Investigation: Mustafa Mustafa; Supervision, Project Administration: Christian Moormann; Resources and Visualtisation: Mustafa Mustafa; Writing Original Draft: Mustafa Mustafa; Writing and Review & Editing: Christian Moormann, Mustafa Mustafa, Funding acquisition: Christian Moormann

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