PROJECT SUMMARY REPORT

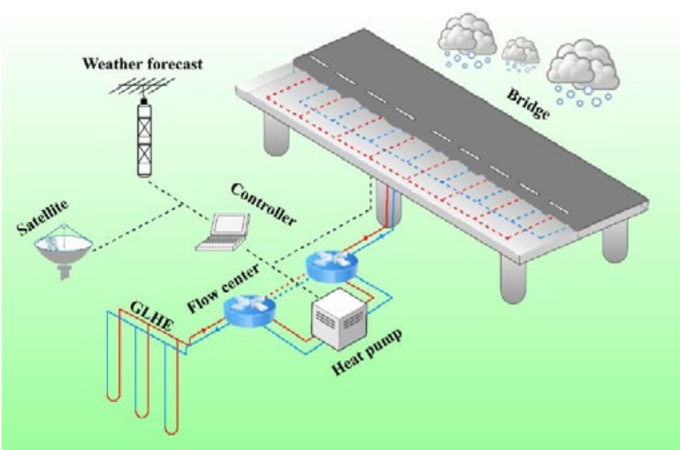
0-6872-01: Use of Geothermal Energy for De-Icing Approach Pavement Slabs and Bridge Decks – Phase II

Background

Bridges in many parts of Texas are prone to icing on the bridge deck during winter events, which poses severe travel disruptions and potential accidents to the drivers. Therefore, bridge deicing is critical to ensure roadway safety, mobility, and productivity reasons. However, the commonly used chemical deicing methods are considered less effective in certain weather conditions, often energy-intensive, corrosive to the bridge materials and substructure elements, and potentially dangerous to the surrounding environment. Geothermal energy, or ground-source heat, is a reliable and green energy source that can be utilized by ground-source heat pumps for heating bridges to prevent bridge icing. In phase II, this research aimed to develop and test a geothermal-bridge deicing system for in-service bridges in Texas. As shown in the schematic for the geothermal bridge de-icing system, the bridge geothermal de-icing system consists of ground loops, bridge loops, heat pumps, and water pumps. The loops are closed-loop pipes filled with a heat-carrier fluid circulated from the ground to the bridge via heat pumps and water pumps. The heat pumps can extract heat from the ground at a high efficiency, e.g., 3-5 watts of heat output with 1 watt of electricity and supply warm fluid to the bridge loops as high as 110˚F.

What the Researchers Did

The research team developed and optimized a geothermal bridge deck deicing system that can be installed onto in-service bridges through retrofitting. To meet the installation and bridge inspection challenges, the research team tested various bridge heating loop designs considering heating fluids (water-based vs. CO2), insulation materials (spray-on polyurethane vs. geofoam), and loop configurations (geometry and insulation coverage). Prototypes of various bridge heating loops were evaluated and tested at different scales in the laboratory and field under simulated and real winter weather scenarios. Selected bridge heating loop designs were tested on a mock-up model bridge constructed in Fort Worth with one geothermal borehole in 2019, 2020, and 2021 winter events. Following the successful



Conceptual diagram of the geothermal heat pump de-icing system (GHDS) (HabibzadehBigdarvish et al. 2019)

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deicing performance of the mock-up geothermal bridge, the geothermal bridge deicing system was implemented on an 8-span, in-service flat-slab concrete bridge with 16 geothermal boreholes in Fort Worth as a pilot geothermal bridge and tested successfully in the 2024 winter events. Also, the environmental impacts and cost-benefits of the geothermal bridge deicing system were also analyzed using historical and newly collected data on geothermal bridges.

What They Found

At the test site, the ground temperature below 25 ft. is approximately constant at 72˚F year-round. During the deicing operations, the supplied fluid temperature from the 430-ft. geothermal borehole is about 63˚F. The mock-up geothermal bridge performed satisfactorily in deicing during all winter events and snow-melting during most of the winter events observed from 2019-2024. The pilot-geothermal bridge was observed to be ice and snow-free during the winter events of January 2024 when the air temperature was below 14˚F, and the accumulated snow was less than 1 inch. The bridge heating loop temperature can be maintained at around 110˚F maximum for deicing operations. The observed average heat flux was 230 W/m 2 for the mock-up geothermal bridge of 8-in. deck thickness and 90 W/m 2 for the pilot-geothermal bridge of 19 in. deck thickness. The geothermal heat pumps were found to have an average coefficient of performance (COP) of 4.5 during deicing operations. The construction cost per unit heating deck area for the pilot geothermal bridge is $42/ft 2. The life cycle cost-benefit analyses of the pilot- geothermal show a benefit to a cost ratio of 7, yielding substantial savings in corrosion prevention and safety enhancement, notably in reducing traffic delay times and accidents.

What This Means

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