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Introducing Smart Materials in Granular Roadway and Pavement Foundation Systems for Mitigating Freeze-Thaw Damage

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Abstract

Seasonal frost heaving and freeze-thaw weakening have a significant effect on granular roadways and pavements. Roadways in the northern plains are routinely subjected to seasonal freeze-thaw cycles, resulting in extensive damage from frost-related problems such as frost heave, frost boils, thaw weakening, rutting, and potholes. This damage increases maintenance costs and adversely affects public safety and mobility. The current findings from an article published by the Transportation Research Board`s 2019 State Partnership Visits Program observes that many states, especially in the norther plains (e.g. Minnesota, Iowa, North Dakota), have been researching and developing new methods to overcome the negative impact of freeze-thaw cycles on roadways.

It is well-established that three conditions are required to form ice lenses in soils, (a) subfreezing temperature, (b) frost susceptible soils with capillary action, and (c) water supply to the frost fringe from a high groundwater table or other source of water. We expect that controlling the soil freezing temperature will be the most effective solution in reducing the freeze-thaw impacts on subgrade soils.

While some conventional techniques have had success, their applicability and efficiency are limited, particularly within frost-susceptible (e.g., silt rich) subgrade soils. As an alternative, this study proposes to keep the subgrade soils temperature above freezing via use of phase change materials (PCMs) as additives to reduce damage that occurs due to freeze-thaw cycles. It is hypothesized that PCMs will help keep the soil temperature above freezing (0°C) for longer which will minimize the existing and capillary water in soils to freeze and form ice lenses thereby preventing frost heave and strength loss in subgrade soils. This, in turn, prevents ice formation and minimizes the freeze-thaw damage to roadway systems.

This research is addressing the following questions: (a) What PCMs are available and ready to test for minimizing freeze-thaw damage to the roadway subgrade soils? (b) What are the optimal mixing ratios and inclusion methods of PCMs to the subgrade soils for the various type of Iowa soils to achieve reduction in freeze-thaw damage?