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No More Broken Pavement Around Manholes

By Henry Knoll and Jim Gallagher

It's a problem seen all around Ottawa streets every winter and it's not a pretty sight. And it doesn't please drivers who must endure a bumpy ride because of it.

The ugly sight is broken pavement around manholes, a costly problem caused by frost heave and one that frustrates city engineers and officials and leaves taxpayers coughing up for the extensive, disruptive repairs that must be carried out.

Help may be on the way thanks to an innovation developed at the National Research Council's Institute for Research in Construction (IRC). The key to this innovation, the brainchild of researcher Dr. Otto Svec, is to channel the natural heat flowing through sewers to the area around manholes, thereby preventing the surrounding pavement from breaking up.

"When you consider how many municipalities throughout Canada and the northern United States experience frost damage to the pavement around manholes, and when you think of the number of manholes in each municipality, you can see how costly this problem can be,"says Svec.

The pavement around manholes cracks when frost penetrates down to such frost-sensitive soils as clay or silt. The resulting vertical deformation, the frost heave, can be up to 10 cm high. Under such stress the pavement inevitably breaks.

For frost heave to occur requires three conditions: sub-zero temperatures, availability of water, and frost-sensitive soil. Svec's innovation aims to remove sub-zero temperatures by channeling heat to the area around the top of a manhole. An energy barrier would then be created preventing the downward movement of frost. The source of the heat is not only the water flowing through sewers but also the heat from the soil deep around manholes.

Inside a manhole during winter, the air temperature is usually quite warm at the bottom and cold at the top. "We can sometimes see temperature gradients of up to 20°C between the bottom and the top of a manhole," Svec notes. Indeed, inside the manhole the air temperature at the bottom can be +10°C, yet -10°C at the top. Such a temperature difference generates air convection. And there lies the key to this new technique: the warm air carried upward by convection can be used to warm the pavement around manholes. Normally, the heat energy in manholes is simply lost through the holes in the steel cover or simply by conduction without ever being of any benefit.

The IRC innovation allows the warm air to be distributed to the area around the manhole. This is achieved by substituting the top manhole ring with one that has eight narrow slots, 51 mm wide and 254 mm high, radially through it. With such a modified ring at the top of the manhole, warm air can then flow through the holes into a special aggregate layer placed under the pavement structure. As a result, frost cannot migrate below the pavement layers, that is, it cannot move down into the frost-sensitive soil below, where it would cause frost heave.

This new technique was tested first during the winter of 1998-99 in the former City of Nepean. Svec and several of his IRC colleagues carried out field tests in colloboration with Wayne Newell, then General Manager of Design and Construction in Nepean's Public Works Department.

"We were delighted with the whole experience, the positive outcome," says Newell. "Even with fluctuating temperatures over the course of our winters, and with all the salt and wear and tear, it is clear that this new technique works."

"The beauty of this solution is that it is so accessible," says Dr. Svec.

A brief description of the reconstruction carried out that winter shows just how accessible it is. The pavement and soil were first removed for about 2 m from around the manhole, thus creating a circular hole 5 m in diameter. The depth of excavation was about 1 m. During excavation, the existing rings of the manholes were removed to approximately the same depth. To obtain the proper level for placing a modified manhole ring, another new (conventional) ring is placed on the remaining manhole as a spacer. On top of that, the modified ring was placed and properly cemented. Around this modified ring, galvanized steel mesh was placed to prevent small stone chips from falling into the manhole.

The bottom of the excavation and its peripheral sides were then covered with a geotextile blanket forming, in a sense, a radiator bag. The excavation was then filled with clean, 51-mm stone aggregate to a layer about 400 mm thick. The top of this 400-mm thick layer was covered with another sheet of geotextile, creating a complete bag (a natural radiator) full of clean, well compacted stone aggregates. This special layer allows movement of warm air through the large, connected air voids. The air circulation transfers heat from inside the manhole to the "bag" and back. Another conventional ring was placed on top of the modified ring. A subbase was then created by placing crushed-stone aggregate over the geotextile bag and properly compacting it. On top of that, a regular stone base and asphalt pavement were placed and compacted. Two-inch thick circular insulation was placed at the top (and inside) of the modified ring to prevent the heat from escaping.

The next step in the research – another test being carried out during the winter of 2000-01 – has focused on making the new technique as cost-effective and easy to use as possible.

"Cost was not a major concern in the first trials, as our main objective was to prove the concept," says Svec.

Cost effectiveness is being addressed by testing a smaller radiator bag, one that is not as high or as wide as the one tried in the tests two years ago. "This means less excavation and easier installation by the contractor," says Svec.

To manufacture the slotted manhole rings does not present any difficulty. When the rings are mass produced, their costs are only slightly higher than the standard rings. Geotextiles are inexpensive materials and in the future the radiator bag can be fabricated to fit the size of the designed pit. Otherwise, all the materials used in a manhole rehabilitation method are standard.

The tests during 2000-01, which are taking place on a different street in the same general area of the former City of Nepean, have also addressed a concern expressed by many engineers. Their concern was that the slots in the modified manhole rings could lead to water infiltration into the manholes, and thus increase the overall sewage volume. Results of casual evaluation of this new technique showed, however, that no water passed through the open slots into the manhole. At least, water was neither observed in the slots nor as stains on the concrete below the slots because of past infiltration. According Svec, water infiltration can be expected to occur only if the ground water level were to reach the top of the open slots. This is highly unlikely.

Because this new technique has performed very well thermally and thus generated considerable interest in Canada and the United States, the possibility of a water infiltration had to be disproven in earnest. The results are as predicted: no water infiltration.

There was another significant difference between the test conducted in 1998-99 and the one being conducted this winter. This winter the manhole innovation was installed by contractor crews at the same time they were reconstructing the sewer system on the residential street in question. Svec says this showed that installing the manhole innovation is much less disruptive and costly when done in tandem with a sewer system change.

A small, but very important, change in the design of the modified ring will ultimately be the geometry of the holes. For better structural strength and for avoiding stress concentration in sharp corners in vertical rectangular holes, the shape of the holes will be rounded at the top and bottom. In addition, the bottom of the holes will be outwardly slanted down, so that any potential water around the manhole will not flow into the manhole.

Figure captions

Figure 1. Special modified manhole ring with vertical holes as provided by precast concrete manufacturer.

Figure 2. Crew fills the bottom of the geotextile "bag" with large aggregate. Steel mesh prevents stones from falling through the slots

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