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FIELD STUDIES OF A SULPHUR/ASPHALT COMPOSITE POTHOLE REPAIR SYSTEM

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RÉSUMÉ

Cette note résume les résultats de deux études in situ portant sur une nouvelle méthode de réparation des nids-de-poules des chaussées au moyen d'un mélange de soufre et de bitume ainsi que sur les propriétés du matériau et de l'équipement utilisés. Plus de 100 nids-de-poules dans les localités de Ville Saint-Laurent (Québec) et de Winnipeg (Manitoba) ont été réparés en hiver et en été. À titre de vérification, quelques nids-de-poules ont été réparés avec un matériau à froid traditionnel, lorsque cela était possible. Les types de routes réparées incluaient des chaussées en béton avec ou sans couche d'asphalte ou des revêtements d'asphalte sur une sous-couche à base de gravillon. Les nids-de-poules étaient préparés avant leur réparation en utilisant diverses méthodes de nettoyage, de découpage et de préchauffage, un enduit d'accrochage, des treillis de renforcement et un matériau de remplissage à base de pierres concassées. Le nouveau produit composite s'est nettement mieux comporté que les matériaux à froid traditionnels.

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ABSTRACT

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The results of two field studies on the performance of a novel sulphur/asphalt composite pothole repair system are described, as well as the material properties and equipment development. More than 100 potholes at each location (Ville St-Laurent, Quebec, and Winnipeg, Manitoba) were repaired under both summer and winter conditions. Control patches using conventional cold patch material were made whenever possible. Road types repaired included concrete pavement with and without asphalt overlays and asphalt pavement on a granular base. The potholes were prepared using various methods of cleaning and preheating, tack coat, wire mesh reinforcement, crushed stone filler and edge cutting. The composite system performed better, by far, than the conventional cold patch material.

INTRODUCTION

Pothole repair constitutes a significant part of annual road maintenance expenditures. Estimates of $3 billion to $3.5 billion for North American road maintenance costs in 1980 have been cited (Anon, 1978). One major reason for the high cost is the lack of a material which can produce a permanent repair, i.e., a repair that lasts through at least one spring thaw (U.S. Army Corps of Engineers, 1981). The most common material currently in use, *cold mix* (an emulsion or cutback-based mix), results in a poorly compacted patch which does not adhere well and lasts from only a few hours to a few weeks. Industry is attempting to develop other materials. One promising material, a unique reinforced sulphur/asphalt composite (SAC) system developed at the National Research Council Canada (NRCC) (Beaudoin and Sereda, 1978, 1979, 1980), has advantages absent in many other patented materials: it is self compacting, fast setting and has high early strength. This paper reports the results of two field trials using the NRCC pothole repair material, including a description of the

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material, requirements for pothole repair such as preparation and placing techniques, a discussion of equipment developed, and a performance evaluation of repairs.

POTHOLE REPAIR REQUIREMENTS

A pothole can be considered as a pavement defect, involving the surface or surface and base, potentially hazardous to motor vehicle transport. Potholes are usually the after-effects of differential heaving and settlement which are often attributed to poor design, poor drainage and poor maintenance aggravated by freeze-thaw effects. One such example is shown in Fig. 1.

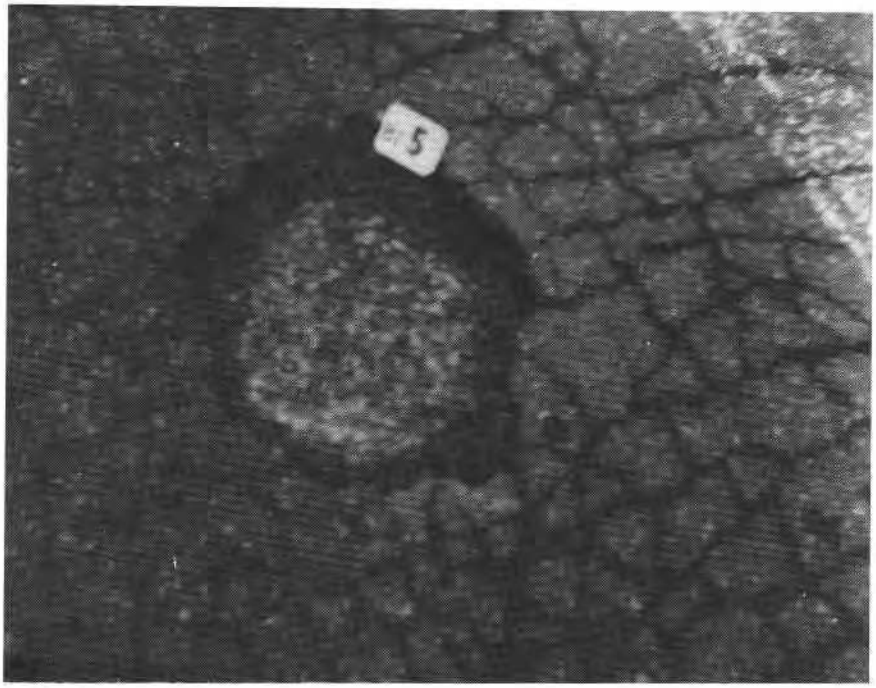


Fig. 1. Typical pothole formed when surrounding pavement has badly deteriorated. Pavement type is concrete base with asphalt overlay. Pothole is approximately 40 cm in diameter.

Good pothole repair can extend the life of pavements by several years. The material used should:

(a) be compatible in strength and density with the surrounding pavement, and be capable of supporting variable wheel loadings over a wide temperature range;

(b) adhere adequately to concrete and asphalt surfaces;

(c) have thermal characteristics similar to those of portland cement and asphalt concrete;

(d) be self-compacting to maximum density when cast into the hole. Preferably, it should be easy to apply in any season using relatively simple equipment and no special skills;

(e) be safe to handle;

(f) be inexpensive; and

(g) be easily stockpiled and readily transported in required quantities. Many of these desirable characteristics do not exist in the materials currently available on the market.

Success of any repair or patching material depends on three basic principles:

(a) the repair or patching material itself must withstand environmental conditions and service loads;

(b) the base to which the repair material is applied must be sound; and

(c) the base material must be clean and dry; that is, free of loose debris, soil and water.

To prepare the pothole properly before repair, the following techniques should be considered. Debris and water can be removed from the cavity using steam, compressed air or mechanical implements. Preheating the surfaces of the hole and applying a *tack coat* improve adhesion with the repair material. Filling deep holes with a crushed stone layer prior to applying the repair material lowers cost. Reducing and modifying cracking by placing wire screening in the pothole before adding the repair material is another possibility (Fig. 2).

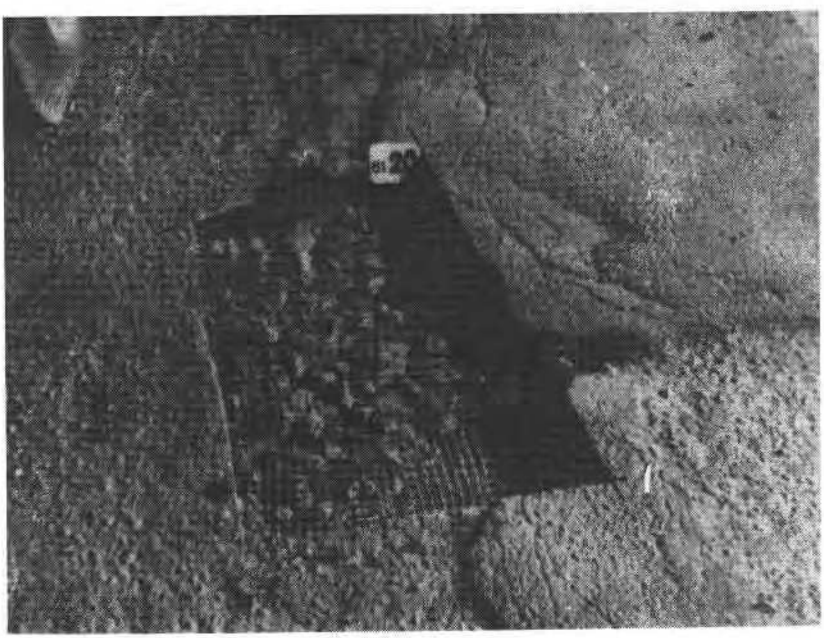


Fig. 2. Pothole shown contains wire screening to reduce cracking. Edges have been saw-cut and crushed stone has been utilized to economize on repair material.

NRCC SULPHUR/ASPHALT COMPOSITE (SAC)

Composition

The SAC developed by NRCC contains sulphur, asphalt, mica flake reinforcement and aggregate. Sulphur and asphalt are present as continuous phases in approximately equal volumetric proportions. A small amount of mica flakes is embedded in both sulphur and asphalt to reinforce the material. Aggregate (maximum size 6.5 mm) content is about 50% by volume.

Production

The method of producing both sulphur and asphalt as continuous phases, which involves shearing a molten mixture at high speed, is described elsewhere (Beaudoin and Sereda, 1978). Prototype production equipment was built by an independent organization under contract to NRCC (Fig. 3) (Gibbons et al., 1978). The main components consisted of two heating kettles, a high shear blending unit, and an aggregate blender unit.

The design of the two 0.45 m^3 capacity heating kettles (one each for

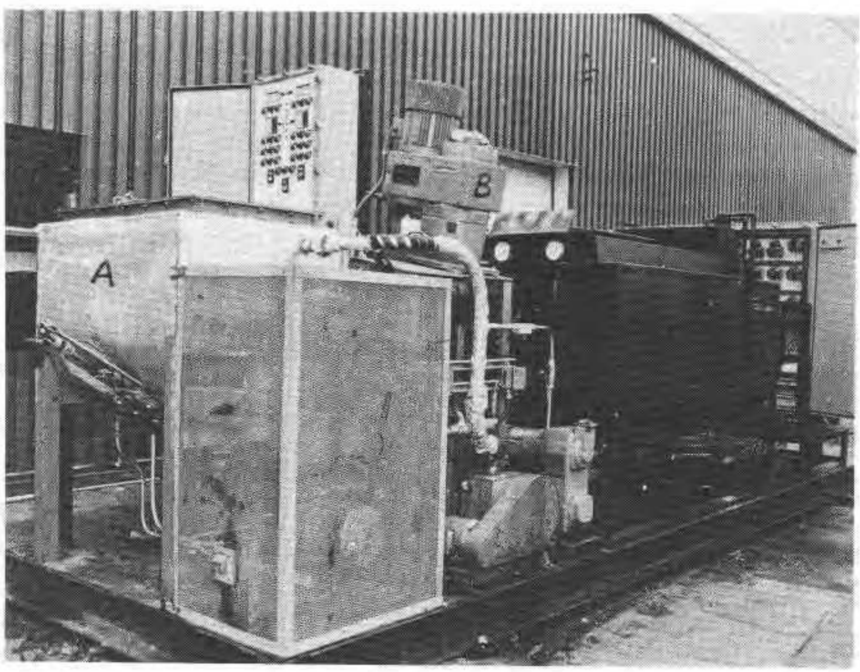


Fig. 3. Prototype production equipment designed to produce NRCC sulphur/asphalt composite pothole repair material: A — Aggregate blender, B — High-speed shear mixer, C — Heating kettles for sulphur and asphalt.

sulphur and asphalt) was based on standard equipment used in applying rubberized asphalt roofing membranes. The heating kettles were oil jacketed. The oil was heated by a burner that used liquid propane and was rated at 3×10^8 J/h at 0.14 MPa inlet pressure. Kettle features included electric motors for oil circulation and agitator drive and automatic temperature control.

The high shear blending unit consisted of a 56.25 W variable speed agitator unit mated to a custom-manufactured mixing tank with 0.09 m^3 capacity. Thermostatically controlled heaters were an integral part of the unit.

The aggregate blender was a standard paddle mixer incorporating a custom-designed heating jacket. The thermostatically controlled unit had 0.28 m^3 capacity and was driven by a 56.25 W motor.

The pump and lines used to transfer sulphur and asphalt from the kettles to the high shear blending unit and from the latter to the aggregate blender were temperature controlled with specially designed trace heating systems and in-line thermostats.

The final product was cast in thin layers, 2 to 5 cm thick, on large sheets of plywood. After cooling, the material could be broken into small chunks and stored in bags until required.

Properties and characteristics

A SEM photomicrograph, illustrating the continuous sulphur network in the SAC is presented in Fig. 4. Mechanical properties of the SAC have been determined and reported previously (Beaudoin and Sereda, 1979). Two important characteristics are the relatively short set time and the ability of the material to be remelted without segregation. Five simple tests were used to determine the quality of the binder: appearance and colour, density, stability (sulphur separation), hardness (cone penetration) and compressive strength (Sereda and Beaudoin, 1980). Hardness perhaps indicates best the quality of the final product since its value decreases by a factor of more than 2 when the sulphur is not continuous.

FIELD TRIALS

Field trials were conducted at two sites: Ville St-Laurent, Quebec, and Winnipeg, Manitoba (I.D. Engineering, Ltd., 1982; Asphalt Labs Ltée, 1982). The contractors were Asphalt Labs Ltée and I.D. Engineering Ltd., respectively. At each site, more than 100 potholes were repaired. Additional control potholes at the two sites were repaired with conventional *cold patch* material whenever possible. Material was shipped to each contractor in small chunks 5 to 10 cm in diameter to facilitate remelting prior to pothole filling.

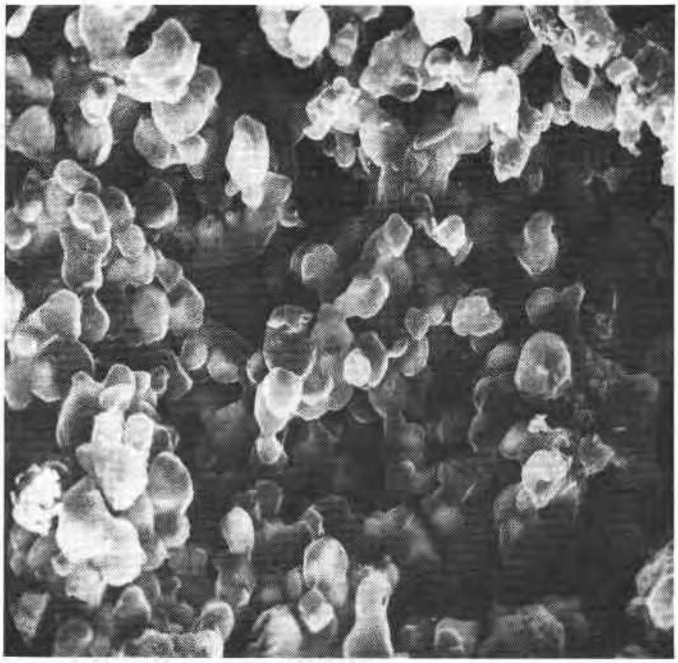


Fig. 4. Continuous sulphur network revealed by leaching continuous asphalt phase from NRCC sulphur/asphalt material. Sulphur nodules are approximately 5 μm.

Melting equipment

The melter used by Asphalt Labs Ltée consisted of a 1 m^3 oil-jacketed container mounted on wheels. It was equipped with a sliding-type, stirring apparatus and could be towed by truck. The operating temperature was maintained between 150 and 160°C (see Fig. 5(a)).

The melter designed and used by I.D. Engineering Ltd. (Fig. 5(b)) was not oil-jacketed. It was a rotating drum with spiral ribs inside, and was heated by direct flame against the rear wall. It had a charge capacity of 360 kg and took about 2 hours to melt the charge. The material was discharged from the drum by reverse rotation of the mixer, then directed into the pothole by means of a chute.

Trial 1 - Ville St-Laurent

The pavement type was in most cases granular base with asphalt overlay.

Fifty holes were repaired during the summer of 1979 and 50 in March 1980. The contractor's methods during ideal summer weather were followed for the spring repairs. Of the potholes cleaned in the summer, 10 were steam cleaned, 35 broom cleaned and 5 cleaned with compressed air. The boundaries of the repaired hole were either left alone or saw-cut with a

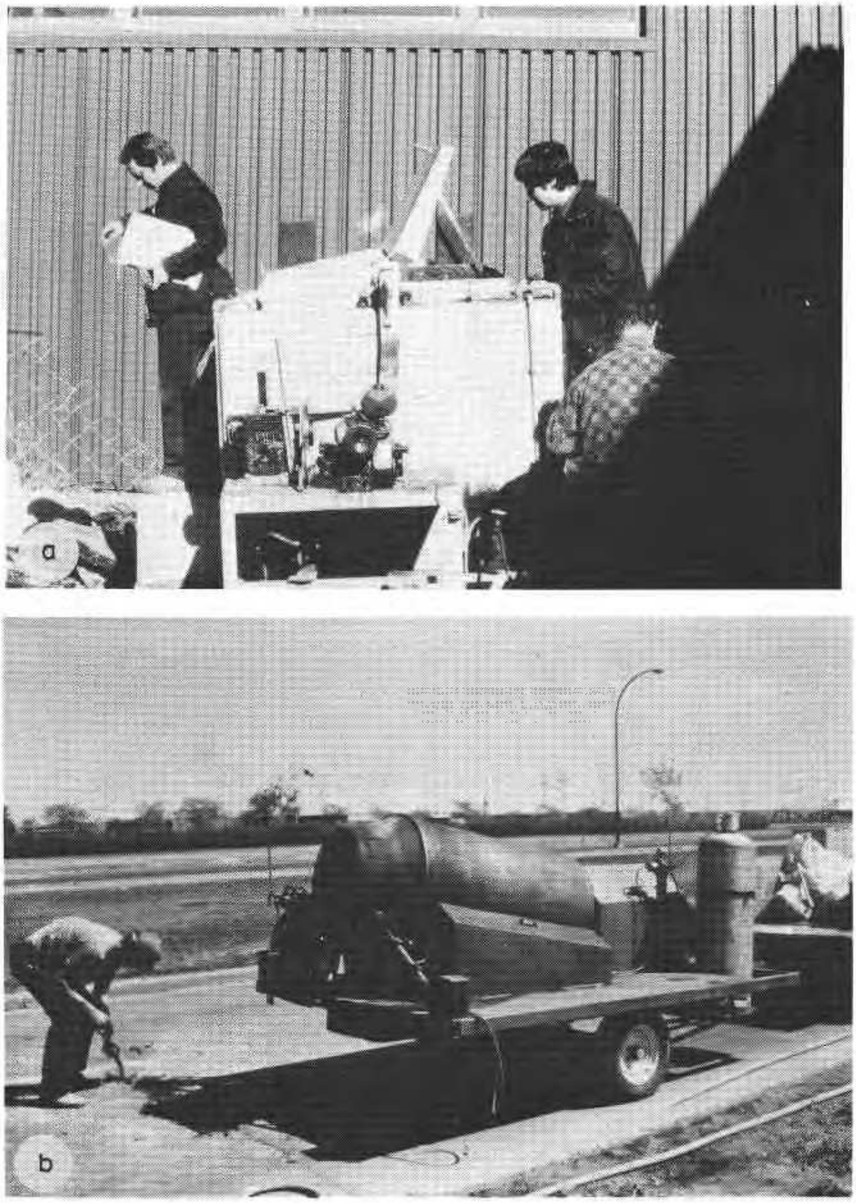


Fig. 5. (a) Melter used to remelt NRCC pothole repair material at Ville St-Laurent, Quebec; (b) Melter used to remelt NRCC pothole repair material at Winnipeg, Manitoba.

portable hand saw (a dry-cut carborundum saw blade was used). Thirty-eight holes were preheated; 28 with propane torch and 10 with steam. An asphalt emulsion tack coat was applied to 40 holes. The potholes were located on residential and industrial streets, as well as main arteries.

The performance results of the potholes were derived from visual inspection and are thus qualitative only. The first inspection, in November 1979, of repairs made that summer revealed that in the main the material was still serviceable. Some general observations are as follows. Material at the edges of potholes that had been difficult to feather was severely cracked or had broken off. Although the patches at bus stop locations were severely cracked, the material still adhered well, as evidenced by the difficulty in removing it mechanically. One patch, which had been placed with some water remaining in the hole, stayed in place, probably due to keying action with the sides of the pothole, and showed only slight edge failures. The patches applied to the saw-cut potholes appeared to give best performance. The cracks in distressed areas of pavement tended to propagate through the patches placed over them; however, the patches adhered well and remained serviceable. It was concluded from the experience with the first 50 holes that the best procedure was as follows: saw-cut the sides of the hole to remove deteriorated material; use compressed air to clean the hole, if necessary; dry and preheat the hole with propane; apply a tack coat of asphalt emulsion or cutback to the hole; fill the hole and finish with a steel trowel.

The second inspection, on February 6, 1980, of the potholes repaired in the summer indicated all the patches were in place but one. Most patches had cracks but remained intact and serviceable. (All 50 patches were thin *skin* patches, as the potholes were those remaining in summer after the regular city maintenance program in spring.) Normally the cracking would be more excessive with a thin skin patch.

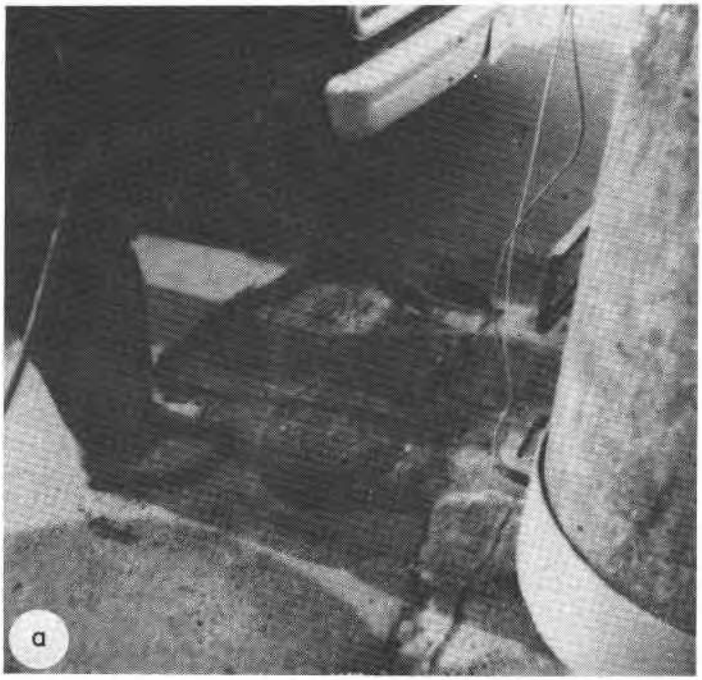
An additional 50 potholes, wider and deeper than the first lot, were repaired in March 1980. The work on each was done in about 45 minutes. All holes were prepared by saw-cutting and heating; tack coating was used in some of them. When inspected on June 9, 1980, all the patches were serviceable and performed well in spite of some cracking. There were no edge failures. Fourteen had multiple cracking (often due to base failures), 17 had slight cracking, 14 were in good condition (no cracking) and 5 were covered during resurfacing by the city. In general, all 100 potholes remained filled during the critical spring period with only 10% showing signs of severe deterioration; that is, loss of adhesion and material from the hole.

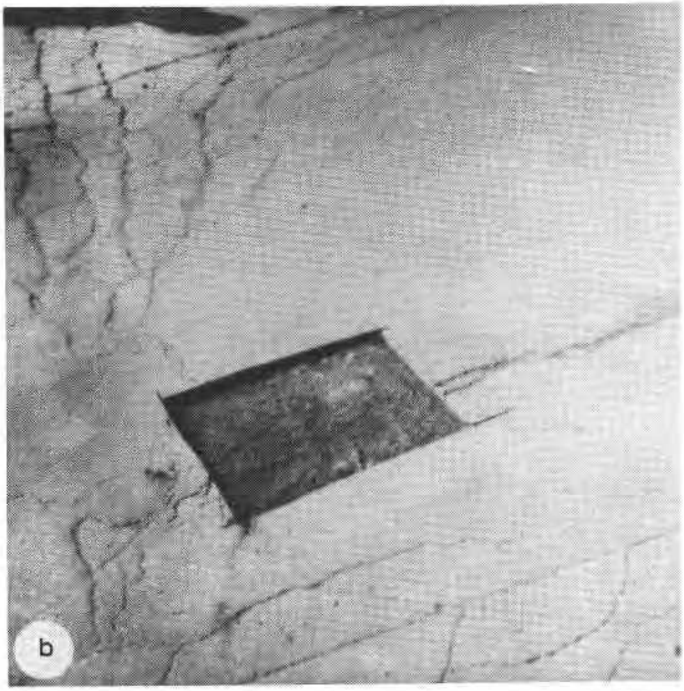
All the potholes were inspected again on December 1, 1980. Of the first 50, all the saw-cut patches were performing well. Of the second 50, thirty-six were covered during resurfacing operations by the city. Normally other patching materials are removed prior to resurfacing. Of the remaining 14 patches, 10 had some cracks and 4 had no visible signs of cracking.

Twenty new holes were repaired on February 26, 1981. Two 1.25 cm diameter rebars were placed in 14 of the holes before patching. Three holes contained wire mesh and 3 contained no reinforcing. Four of the holes were prepared with a crushed stone base. After about 10 days the patches were reinspected visually for performance. All the patches were performing well, with the exception of one which had not been reinforced, but which was still completely intact. The repairs containing wire mesh were in good condition.

On October 7, 1981, all patches were inspected. Of the first 50 patches there were 11 edge-type failures after 2 years service. Only 2 of the repairs, both made at bus stop zones, ceased to be serviceable. Among the second 50 repairs, only 1 failed in service. This patch, placed in a hole containing water, went through two spring breakup periods before final failure occurred. Among the final 20 holes, no failures were observed. In contrast, all the control *cold mix* patches were replaced several times.

Some methods of pothole preparation and differences in performance of various repairs are illustrated in Figs. 6(a) — (h). The captions give specific details about each repair. Some general observations are as follows: the smaller patches cracked less than the larger ones; the weaker the road base, the sooner the patch cracked; the patches that were saw-cut appeared to undergo less deterioration and cracking than those that were not; repairs made in spring performed as well as those made during summer; cracking of patches in potholes less than 0.2 m^2 in area can be eliminated by using wire mesh reinforcing; potholes more than 15 cm deep can be partially filled with granular material to reduce the quantity of the repair material needed without adversely affecting performance. Using a minimum thickness of 7.5 cm of the patching material produced no adverse effects.

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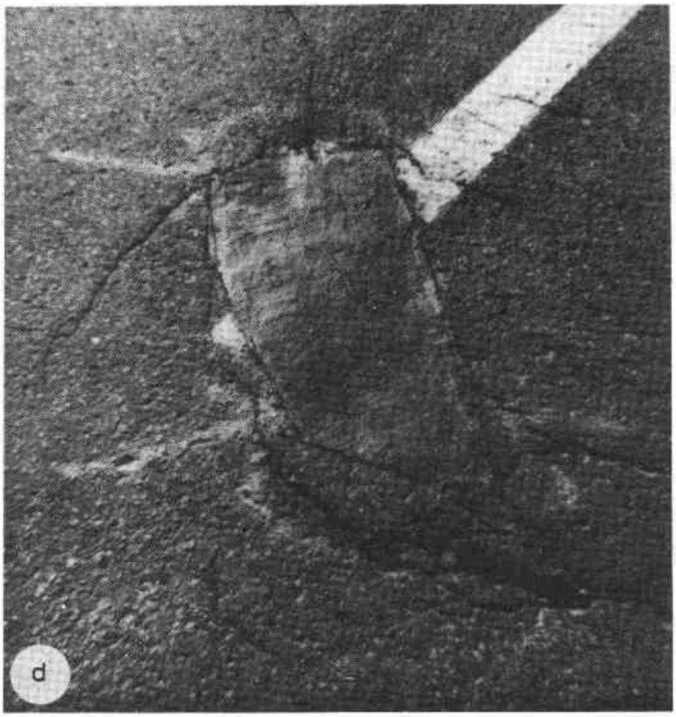

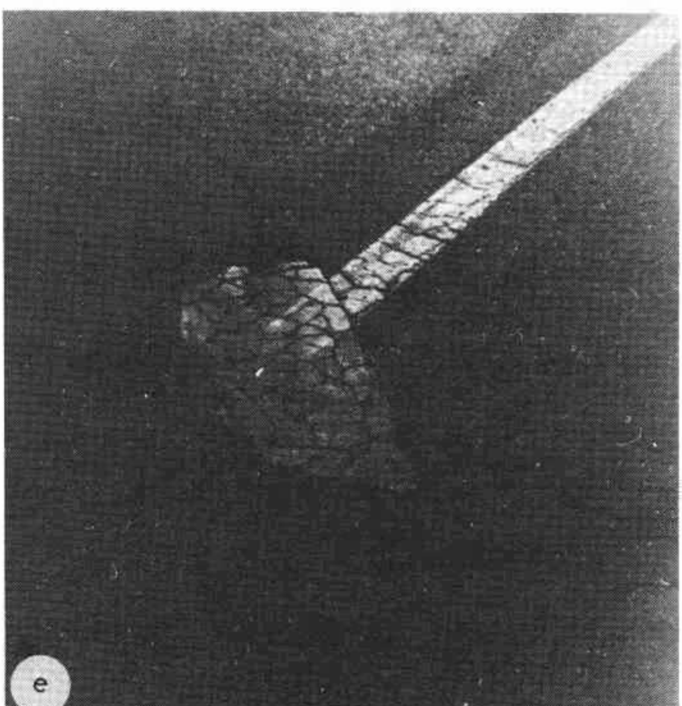

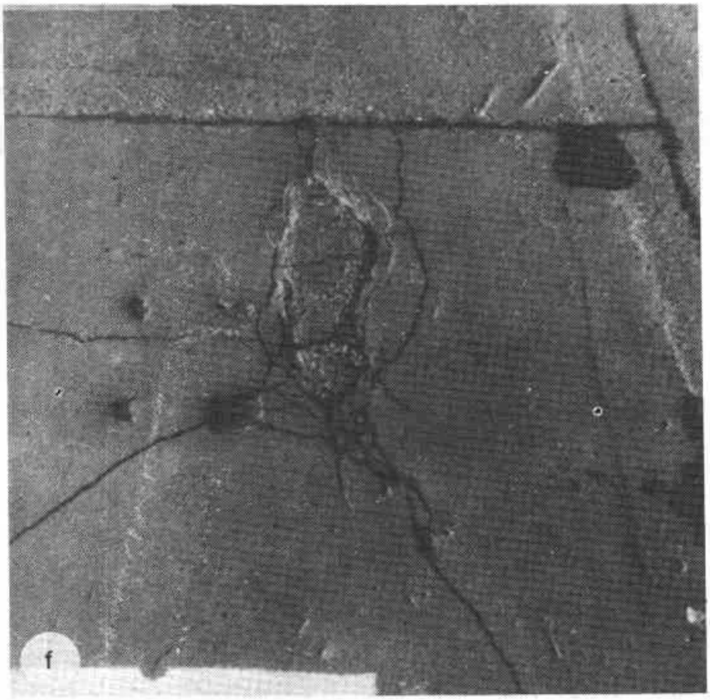
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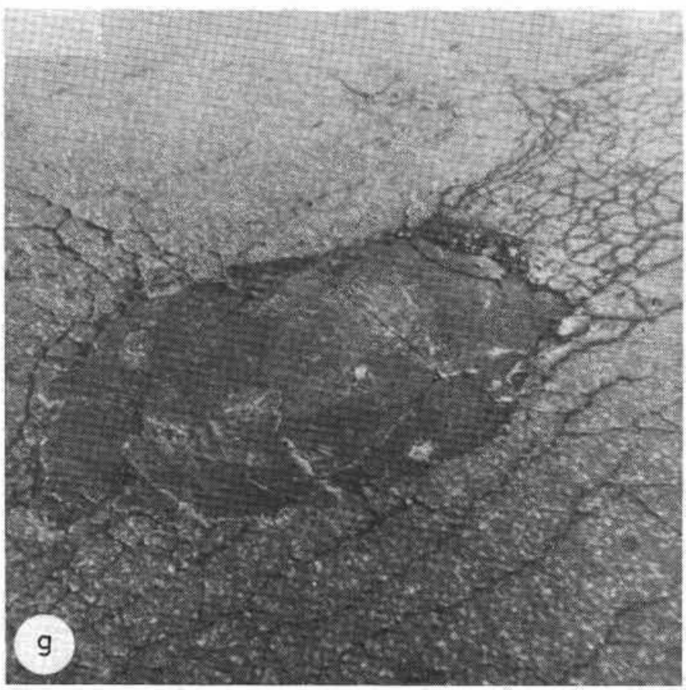
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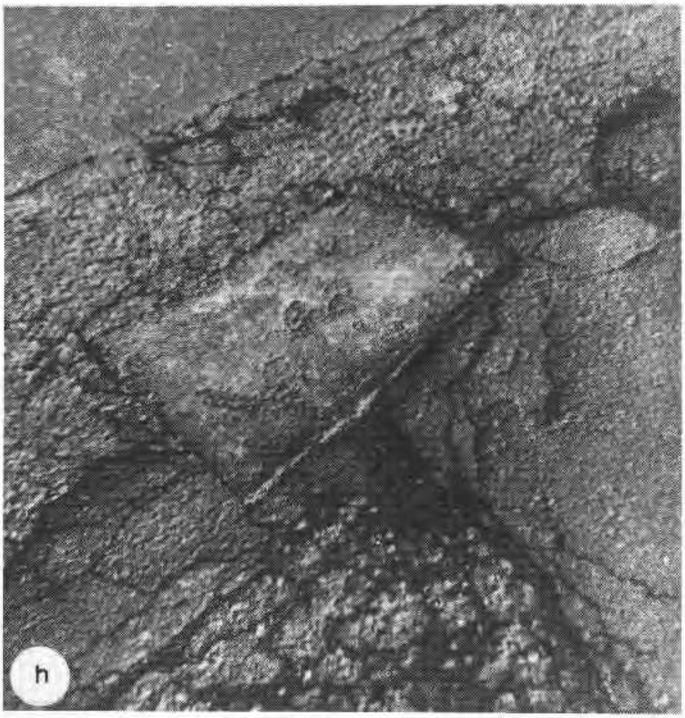

Fig. 6. Pothole repair at Ville St-Laurent, Quebec: (a) Preheat treatment is applied to cleaned pothole using propane torch; (b) Pothole is prepared by saw-cutting boundaries; (c) Surface of pothole repair is troweled; (d) Pothole repair with saw-cutting boundaries is shown shortly after completion; (e) Same pothole as in (d) is shown after 2½ years service. Although extensive alligator cracking has occurred, adhesion and serviceability remain good; (f) Repair installed in March 1980 is shown 1½ years later; (g) Repair containing wire mesh is shown 10 months after installation. Note poor condition of surrounding material and minor cracking of patch; (h) Repair similar to (g) except for saw-cut boundaries is shown.

Trial 2 - Winnipeg, Manitoba

Two types of pavements were repaired: asphalt overlay on a concrete slab and concrete pavement on a granular base. The concrete was generally 20 cm thick and the asphalt 10 cm thick. The majority of repairs were made on concrete pavement without overlay.

The first field operation began on December 24, 1979. Thirty-five potholes were placed at -10°C in areas where traffic varied from light to very heavy. A second patching operation was carried out on March 21, 1980. Extensive repairs on joint failures in concrete pavement were performed during June, July and August 1981. The distress indicators for inspection included surface cracking, edge deterioration, loss of adhesion and loss of patch material. In general, the performance was very similar to that at the Ville St-Laurent test site. Many of the initial patches survived 33 months service (at last inspection) and the effect of freeze-thaw cycles, salt, traffic and maintenance operations. Despite the great demands placed on material used to repair joints as a result of continual movement and stress reversal at the joint, many of the repairs were still serviceable. Reinforcing was not evaluated at the Winnipeg site. In contrast with the NRCC SAC patches, many of the control *cold mix* patches were replaced 4 or more times. Figure 7 shows some typical repairs at the Winnipeg site.

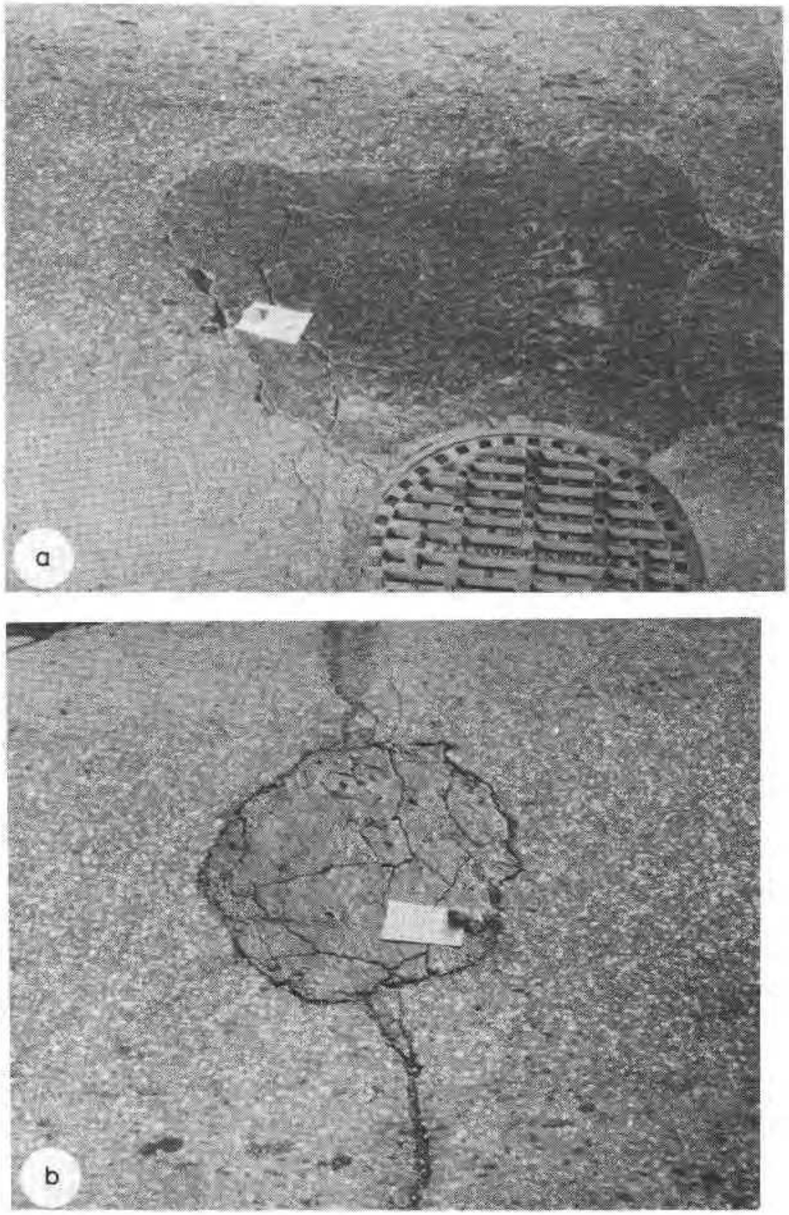

Fig. 7. Some repairs at Winnipeg site: (a) Typical patch at periphery of catch basin shows deterioration after 6 months; (b) Typical pothole repair shows some reflection cracking after 6 months; (c) Example of joint repair is illustrated.

CONCLUSIONS

The field trials at Ville St-Laurent and Winnipeg, in which the NRCC sulphur/asphalt composite was used, indicate that this pothole repair material meets many important requirements, is self compacting, and gives a service life of at least 2 years. Furthermore, it adheres well to the road base, in spite of cracking, and enables repairs to be made during winter. It eliminates the need to remove the sulphur/asphalt composite prior to resurfacing, which is the practice with other temporary repairs. In addition, traffic need only be halted 30 to 45 minutes, long enough to allow the material to cool.

The performance of this repair material exceeds, by far, that of conventional cold patch material.

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