Can vacuum cleaning recover the infiltration capacity of a clogged porous asphalt?

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ABSTRACT

The clogging of porous asphalts is the major threat for their sufficient performance. In this study, the effect of vacuum cleaning to recover the infiltration capacity of clogged porous asphalts was investigated. Two residential roads in Luleå and Haparanda, northern Sweden, were evaluated which had been in use for 17 and 24 years, respectively.

The infiltration capacity of the two pavements was measured using replicate double ring infiltrometer tests before and after cleaning the clogged asphalt with an industrial vacuum cleaner/sweeping truck. The results of the tests in Luleå showed that vacuum cleaning has the ability to recover the infiltration capacity of porous asphalt depending on the extent of clogging. In Haparanda, however, no effect was shown.

Furthermore, it was shown that the long term behaviour of the infiltration capacity depends largely on the street maintenance, thus regular maintenance is crucial to counteract clogging.

KEYWORDS

Clogging; infiltration capacity; long term performance; Porous asphalt; vacuum cleaning

INTRODUCTION

Urbanization causes increasing imperviousness. Thus, compared to natural catchments, infiltration of precipitation water decreases causing significantly higher surface run off to the receiving water body. This involves a higher risk for flooding and high flows in the receiving waters and furthermore, discharge of pollutants (Walsh, 2000). Consequently, concept like Water Sensitive Urban Design (WSUD) has been developed as an alternative management option for stormwater in urban areas (Chocat, et al. 2001).

Within these concepts, the use of porous pavements is one option. Porous pavements have the ability to efficiently control runoff volumes and flows, reduce or avoid downstream flooding, recharge natural groundwater, and remove pollutants (Shackel B. 2010).

However, as with many alternative stormwater management systems, the long term performance might be critical and a lack of regular maintenance actions has been shown (Lindsay, et al. 1992). The main threat for the sufficient function of porous pavements is their tendency to become clogged if they are not maintained regularly (Dietz, 2007).

A reason for clogging of these pavements is the accumulation and deposition of sediments on the surface.

Despite the availability of many studies about the performance of porous pavements, but there is still a lack of studies which address their long term performance focussing on clogging and its effects on hydraulic conductivity (Yong, et al. 2008). Furthermore, there is a need to identify measures to recover the infiltration capacity of already clogged surfaces. Our hypothesis is that it is possible to enhance the infiltration capacity of clogged porous asphalts by cleaning the surface by e.g. vacuum cleaning, depending on the extent of clogging (Baladès, et al. 1995). Thus, the objective of this study was to investigate the potential of vacuum cleaning to recover the infiltration capacity of two clogged permeable asphalts in northern Sweden, which have been in operation for 17 and 24 years. Furthermore, we aim to identify reasons for the clogging and the efficacy of vacuum cleaning.

MATERIALS AND METHODS

Site description

In this study two residential streets located in northern Sweden were investigated, one in Luleå and the other one in Haparanda. Both streets are covered with porous asphalt (Figure 1) underlain by a coarse macadam layer.

Figure 1: Asphalt cores sampled at Kockvägen, Luleå (left) and Åkergatan, Haparanda (right).

Luleå site. The first road (Kockvägen) is located in a housing area in the outskirts of Luleå. It was constructed in 1993/94. This site has previously been described by Stenmark (1995) and Bäckström (1999). The porous pavement structure of the layers is illustrated in Figure 2. The initial porosity of the porous asphalt was 15-20%. A drainage pipe was placed in the sub-base to allow drainage of the infiltrated water. The coarse material used in the sub-base consists of macadam and partly blast furnace slag; this layer had a porosity of 35-40%.

The infiltration capacity of the asphalt was evaluated shortly after construction of the road by Stenmark (1995) and after about two years of operation by Bäckström and Bergström (2000). Stenmark (1995) measured the initial infiltration capacity using asphalt test pieces (0.4 x 0.4 m) which were cut out from the field study site. The mean infiltration capacity was 290 mm/min at room temperature and 130 mm/min at a temperature between -1.1 and -1.9°C. Bäckström and Bergström (2000) used the same method to investigate the infiltration capacity during a simulated snowmelt period after about two years of operation. The infiltration capacity at +20°C was 19 mm/min which was reduced close to the freezing point to 7.4 mm/min.

During each winter, fine gravel (2-4mm) is applied two to four times (depending on the weather conditions) on the road surface as an anti-slip agent. The gravel is removed with a mechanical sweeper each spring after snowmelt (approximately in May). No de-icing salt is used.

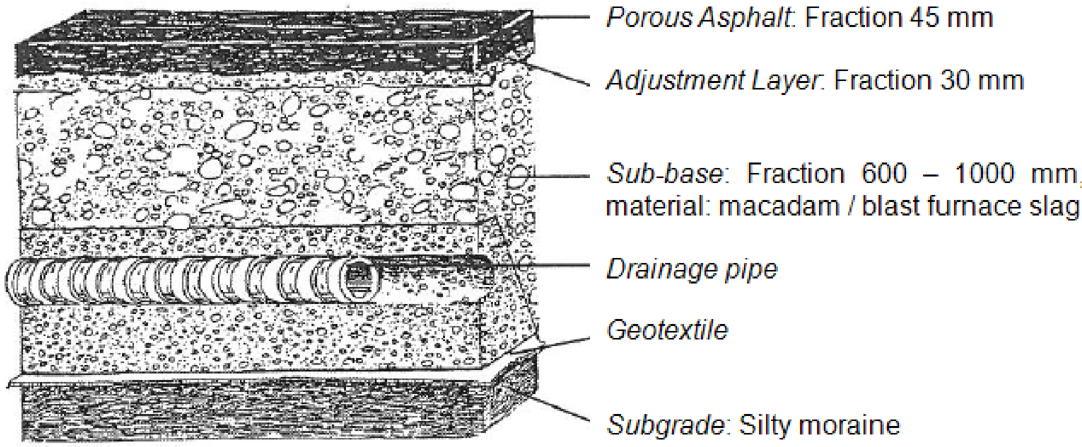

Figure 2. Construction of the porous pavement (Bäckström, 1999)

To maintain the infiltration capacity, initially the porous asphalt was cleaned regularly by vacuum cleaning. However, during at least the least five to six years no vacuum cleaning was carried out. Thus, recently no sufficient maintenance to sustain the infiltration capacity of the porous pavement was conducted

Haparanda site. The second road is located in Haparanda (Åkergatan). The porous asphalt was constructed in 1986/87 (Stenmark 1990). On a length of 140 m a layer of permeable pavement was built over a subgrade of silty clay with a structure similar to the one shown in Figure 2. The porous asphalt had a porosity of 15 to 25 %, the macadam-layer of 20 to 40 %.
The infiltration capacity was measured in laboratory by using test pieces (0.4 x 0.4 m) comparing new asphalt and asphalt which had been exposed to sand applications (Gyllefjord and Kangas 1989). The infiltration capacity was 470 mm/min for new unused asphalt and decreased to 6 to 2 mm/min after application of sand.

Each winter, a sand mixture (0-6 mm, mixed with 2 % road salt) is applied on the road surface as an anti-slip agent at a rate of 5-10 times each winter (depending on the weather conditions. After snowmelt in spring, similar to Luleå, mechanical sweeping was used to remove the sand from the asphalt.

Besides the mechanical sweeping in spring, no maintenance measures were conducted to enhance/sustain the infiltration capacity; the asphalt was never cleaned by vacuum cleaning.

Infiltration measurements
In 2011, replicate infiltration capacity measurements were conducted at three locations in Luleå (B, C and D in in Kockvägen) and two sites in Haparanda (G and H in Åkergatan). The sites are marked in (Figure 3). The three locations in Luleå (B, C and D) were chosen since they represent different conditions of the road. Location B lies on the intersection of two roads; this area is exposed to high traffic and receives additional stormwater runoff from the entering road with conventional pavement. Location C was at a dead end street section; this zone is without traffic and was rarely used as parking. The third location D was placed in the middle of the road as a point which represents conditions for ordinary traffic load like transit and parking. The two locations G and H represent typical conditions, G lies at an intersection.

Double ring infiltrometers were used to measure the infiltration capacity at the five locations before and after vacuum cleaning (see below). Each test included measurements with three replicate infiltrometers sets which were placed on the asphalt with a distance of approximately 1 m at the same time. The three infiltrometers sets were sealed with plumber's putty to the asphalt. Water was filled in the outer ring to control the sealing and leakage points were patched. Then water was filled in the inner and outer ring to a high of approximately 5 to 10 cm. The initial water level in the inner ring was recorded at time zero and then the water level was logged every 2-10 minutes depending on the infiltration rate. The tests were completed when the infiltration rate stayed constant or trended towards zero.

Vacuum cleaning

In between the two infiltration measurement rounds, the roads were vacuum cleaned by using an industrial vacuum cleaner/sweeping truck from BDX Företagen AB. This technology is recommended as a maintenance option for porous asphalt. Vacuum cleaning was conducted once in the sampling areas. The roads were not cleaned with a mechanical sweeper between snowmelt and vacuum cleaning. However, it was not much fine gravel or sand on the roads since during the winter 2010/11 only little anti slip agent was applied due to beneficial weather conditions.

Figure 3. Layout of the field site in Luleå and Haparanda with measuring locations (B, C, D, G, H)

RESULTS AND DISCUSSION

Vacuum cleaning had a positive effect on the infiltration capacity in Luleå which increased substantially. Mean infiltration capacities ranged between from 1.1 to 7.1 mm/min. In contrast, in Haparanda it remained steady around 0.1 mm/min also after vacuum cleaning (Table 1 and Figure 4).

Before vacuum cleaning, the mean infiltration capacities in Luleå ranged between 0.33 to 0.73 mm/min and between 0.1 and 0.3 in Haparanda (Table 1 and Figure 4). Comparing these infiltration capacities (i.e. before vacuum cleaning) with the initial values observed by Stenmark (1995) and Gyllefjord and Kangas (1989) (see above) it becomes clear that the asphalt at both roads was substantially clogged. A clearly visible layer of fine sediment was observed on the surfaces.

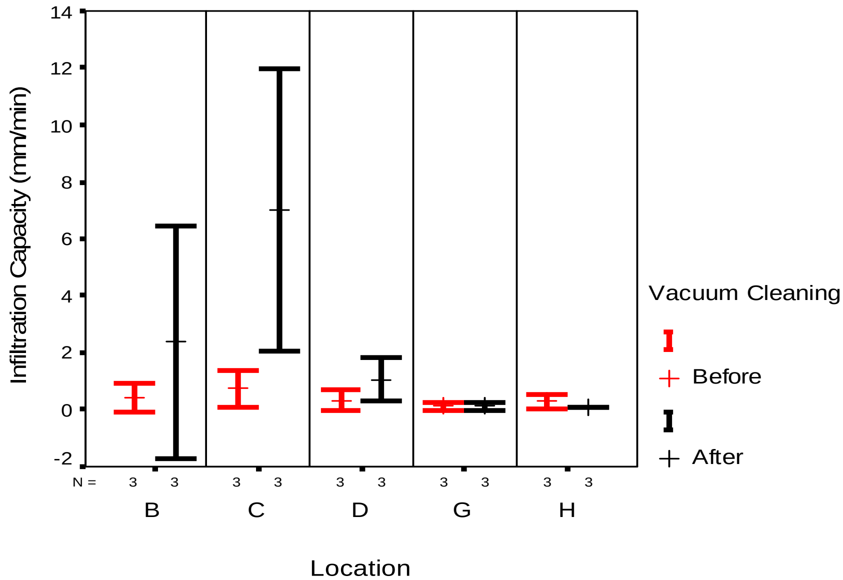

Figure 4. Interval plots of infiltration capacity with 95% confidence interval of the mean at 5 locations before and after vacuum cleaning

A paired t-test was used to determine whether there was a statistically significant influence of the vacuum cleaning on the infiltration capacity (Table 1). Even though the mean infiltration capacities were higher in Luleå after vacuum cleaning, statistical significance was only shown for site C (dead end street with very little traffic). As expected, at Åkergatan no significant difference was shown

Table 1: Mean infiltration capacities for all sampling sites before and after vacuum cleaning and p-value of the paired t-test

Location	Infiltration Capacity (mm/min)		Percentage Increase%	P-Value Paired t-test
	Before	After		
B	0.43 ± 0.21	2.40 ± 1.65	458	0.147
C	0.73 ± 0.25	7.10 ± 2.00	610	0.036
D	0.33 ± 0.15	1.10 ± 0.31	10	0.088
G	0.10 ± 0.10	0.10 ± 0.10	0	0.423
H	0.30 ± 0.10	0.10 ± 0.00	-67	0.074

However, location C seemed to have a tendency towards a higher infiltration capacity compared to other locations. This might be due to the different conditions of the road where location C was at a cul-de-sac as previously mentioned.

The low statistical significance might be due to the low number of samples (three at each location) and the high variation of the data after vacuum cleaning. The highest infiltration capacity before vacuum cleaning and the clearest (and only statistically significant) increase of the infiltration capacity after it was detected at site C which was a dead end road section as previously mentioned. In contrast, at the mostly clogged sites in Haparanda, there was no significant change in the infiltration capacity.

The different results in Luleå and Haparanda might be due to a range of factors. The different age of the two roads might have been influenced the results. Additionally, the de-icing material and its application rate each winter differ between Luleå and Haparanda. The finer material and more often applications in Haparanda might have supported clogging. Same applies to the lack of maintenance in Haparanda, while in Luleå the road was at least vacuum cleaned occasionally (even though not during the last years).

Despite the improvement of the infiltration capacity after vacuum cleaning in Luleå, it was still far lower than the initial infiltration capacity after construction, where it was 290 mm/min (Stenmark 1995) whilst after approximately two years the infiltration capacity was 19 mm/min (Bäckström and Bergström 2000).

Depending on the extent and nature of clogging, vacuum cleaning can be an option to enhance the infiltration capacity of porous asphalts. However, since the infiltration capacity recovery was depending on the extent of clogging, it is recommended, that porous pavements are cleaned regularly to prevent clogging as far as possible.

CONCLUSIONS

The aim of this study was to evaluate the potential of vacuum cleaning to recover the infiltration capacity of clogged porous asphalt pavements. After having been in use for 17 and 24 years (in Luleå and Haparanda, respectively), both roads were clogged significantly; the results of this study show a significantly reduced infiltration capacity compared to studies conducted earlier after 1 and 3 years of operation. Our hypothesis that vacuum cleaning may have the ability to recover the infiltration capacity was only corroborated partly; while the infiltration capacity could be enhanced in Luleå, no changes were detected in Haparanda. This was possibly due to the extent of clogging. Thus, vacuum cleaning can be recommended to recover infiltration capacity of porous asphalt depending on the grade of clogging.

Furthermore, we showed that, the long term behaviour of the infiltration capacity depends largely on the street maintenance, thus regular maintenance is crucial to counteract clogging. Exposure of the road surface to fine sediment should be avoided as far as possible.

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