Long-Term Field Monitoring and Evaluation of Maintenance Practices for Pervious Concrete Pavement in Vermont

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Pervious concrete pavement (PCP) is used because of its unique properties that allow water to infiltrate into the surface. The objectives of the study reported in this paper were to observe the performance of PCP in the field, determine the effectiveness of cleaning methods to restore infiltration rates, and compare field observations with laboratory results when possible. Two PCP sites in Vermont were monitored over a year through the measurement of infiltration rates at several locations. Facility-wide cleaning operations, such as street sweeping and vacuum-truck cleaning, were tested for their capability to restore infiltration rates. Spot-cleaning methods, such as hand vacuuming, pressure washing, and a combination of the two, were also tested. Infiltration rates decreased gradually during the monitoring period, with average reductions of 59% at the first facility and 26% at the second. Street sweeping and vacuum-truck cleaning restored infiltration rates by 21% and 30%, respectively, but could not restore severely clogged areas. Spot-cleaning methods increased infiltration rates by 85% after pressure washing, 10% after vacuuming, and 100% after pressure washing followed by vacuuming. Vacuum-truck cleaning was recommended. Either method, however, should be used for maintenance operations and should be started after construction. Spot-cleaning methods, with the exception of vacuuming, restored infiltration rates of severely clogged areas and were recommended for localized cleaning. Long-term monitoring compared reasonably well with that of earlier studies, whereas the results associated with cleaning were substantially lower than those found in the literature.

The use of pervious concrete pavement (PCP) has been identified by federal and state agencies as a management practice for the treatment of stormwater through the reduction in volume of runoff from impervious surfaces (*1*). PCP incorporates an open-pore structure, which allows water to travel from the surface into a gravel subbase and subsequently into the native soil. PCP provides added benefits, such as reduced noise from vehicles, improved skid resistance, and reduced heat island effects (*2–4*). Because of its open-pore structure, the use of PCP is limited in general to areas in which lower strength is acceptable, such as parking lots, low-volume roads, driveways, and sidewalks.

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How to ensure the long-term performance of PCP is a major concern of designers and maintenance personnel. PCP can be compromised through (*a*) clogged pores, which reduce the infiltration capacity, or through (*b*) damage to the structure of the PCP, which leads to failure of the pavement. The open-pore structure of PCP gradually accumulates inorganic and organic materials; this leads to reduced infiltration rates. This reduction could cause PCP to become an impervious surface unless periodic, facilitywide maintenance is performed, such as street sweeping or vacuum-truck cleaning, or unless handheld spot-cleaning methods are used, such as hand vacuuming or pressure washing (*1*). Several researchers have attempted to model the effects of clogged pores and maintenance on PCP in the laboratory. Only a few field studies are available, however, to compare with laboratory results.

To ensure the long-term performance of PCP, the practices used to maintain it must be understood. The purpose of the study reported here was to evaluate the effects of typical maintenance practices used on PCP through the conduct of field investigations and then to compare the results with those of laboratory studies. The specific objectives were to (*a*) monitor the infiltration rate of two PCP facilities in Vermont, (*b*) determine the effectiveness of various methods to restore the infiltration rate in the field, and (*c*) compare field observations with laboratory studies.

BACKGROUND

This section presents a literature review related to the effects of maintenance activities on PCP. Studies related to the clogging and cleaning of PCP in the field and in the laboratory are also presented.

Field Infiltration Measurements and Restoration

The field infiltration rates of various pervious pavement surfaces, including PCP, have been investigated with the use of single- and double-ring infiltrometers modified from soils testing (*5*). The results reported by Bean et al. (*5*) from various PCP facilities showed infiltration rates that ranged from 5 to 2,750 in./h (0.003 to 1.91 cm/s). Areas with visible signs of clogging had much lower infiltration rates than areas that showed no signs of clogging. On the basis of those results, regular cleaning was recommended to prevent clogging.

Henderson et al. (*6*) measured infiltration rates with a Gibson asphalt permeameter at 16 locations at each of the three PCP study sites in Canada during summer 2007, winter 2008, and summer 2008. Sites were classified into areas that received sand for winter maintenance and areas that did not. The infiltration rate decreased over time at two of the tested locations. On the basis of the results, it was determined that sand did not significantly increase the clogging of PCP. Sites were cleaned with a 6-hp, wet–dry vacuum to restore the infiltration rate at one facility. Prevacuum infiltration rates ranged from 4.2 to 150 in./h (0.003 to 0.106 cm/s), whereas post-vacuum rates ranged from 190 to 5,200 in./h (0.139 to 3.72 cm/s); infiltration rates increased by a factor of 1.3 to 287. On the basis of these results, vacuuming was recommended as a rehabilitation method.

Chopra et al. (*7*) conducted field and laboratory investigations into various methods to restore infiltration rates of PCP. Eight facilities were selected in the southeastern United States, where infiltration rates were measured in the field with a modified, single-ring infiltrometer. This infiltrometer penetrated both the PCP and the subsoil, which reduced lateral flow during testing. The infiltration rates of the PCP and subsoil were measured. The PCP section was then removed and measured for hydraulic conductivity in the laboratory. On the basis of the results of the field and laboratory testing, it was possible to determine if the limiting factor for infiltration was PCP or the subsoil. Several PCP cores were found to have infiltration rates lower than the underlying soil and were classified as limiting sections. These cores were vacuumed, pressure-washed, or cleaned with a combination of both methods. They were tested for hydraulic conductivity before and after they were cleaned to determine treatment efficiencies. Results indicated that hydraulic conductivity values could be increased by a factor of 10 by vacuuming; by a factor of 56 by pressure washing; and by a factor of 66 if a combination of the two methods was used. It was concluded that these rejuvenation methods should be useful in the field.

Laboratory Studies

Montes and Haselbach (*8*) covered PCP specimens with fine sand of known permeability and simulated various rain events and slopes in a flume. Infiltration rates decreased significantly during testing, with preclog values that ranged from 280 to 1,400 in./h (0.2 to 1.0 cm/s) and postclog values that ranged from 3 to 7 in./h (0.002 to 0.005 cm/s). It was concluded that the observed infiltration rates were sufficient to handle the expected 100-year storm event.

Joung and Grasley (*9*) investigated the hydraulic conductivity of clean and clogged PCP samples with a falling head permeameter. Clogging was accomplished by passing a mixture of sand and water through the sample multiple times. After water had drained from the sample, hydraulic conductivity tests were performed a second time to measure the reductions. The results showed that the sand did not clog PCP samples, with a void ratio of 33% or greater. Samples with a lower void ratio were affected, with the hydraulic conductivity reduced by approximately 40%.

Deo et al. (*10*) investigated the clogging of PCP of varying aggregate sizes and measured hydraulic conductivity with a falling head permeameter. Clogging was accomplished through the addition of 25 g of sand to the top of the sample and the performance of additional permeability testing, which allowed water to transport sand into the PCP sample. This process was repeated until additional sand applications did not result in further reductions in the infiltration rate. After clogging, 30% reductions were observed in hydraulic conductivity.

RESEARCH METHODS

Field investigations were conducted to determine (*a*) how the infiltration rate of PCP changes over time; (*b*) how facilitywide cleaning operations, such as street sweeping and vacuum-truck cleaning, restore infiltration rates; and (*c*) how spot-cleaning methods, such as hand vacuuming and pressure washing, restore the infiltration rate of PCP in severely clogged locations.

Surface Infiltration Capacity

A falling head infiltrometer was designed and built at the University of Vermont, Burlington, to monitor the long-term infiltration rate of two PCP facilities. A sheet of PVC, which measured 2 ft by 2 ft by ¾ in. (60.9 cm by 60.9 cm by 1.90 cm) with a circular opening for a standpipe, was used as a base. The standpipe was made with PVC pipe with a thickness of 0.25 in. (0.63 cm) and an internal diameter of 4 in. (10.1 cm). Milled viewports on the standpipe made it possible to monitor water levels during testing. A foam-rubber ring was attached to the underside of the device around the standpipe to create a seal between the infiltrometer and the PCP surface. Weights of about 120 lb (55 kg) were placed onto the device to compress the foam during testing (Figure 1).

To determine the infiltration rate, the standpipe was filled and the time was measured for the water level to drop from 15 in. (38.1 cm) to 3 in. (7.6 cm) above the PCP. Earlier research indicated laminar conditions would exist for the head values used during testing (*8*). Measurements were taken three times at each location to ensure consistent results. The infiltration rate was determined with Equation 1. This falling head infiltrometer method has been found to correlate well with the ASTM standard (single ring) for infiltration measurements of PCP and with saturated hydraulic conductivity measurements that had a relation of 1:1.8:9 (hydraulic conductivity: ASTM standard: falling head infiltrometer) (*11*).

$$I = \frac{c(h_1 - h_2)}{t} \tag{1}$$

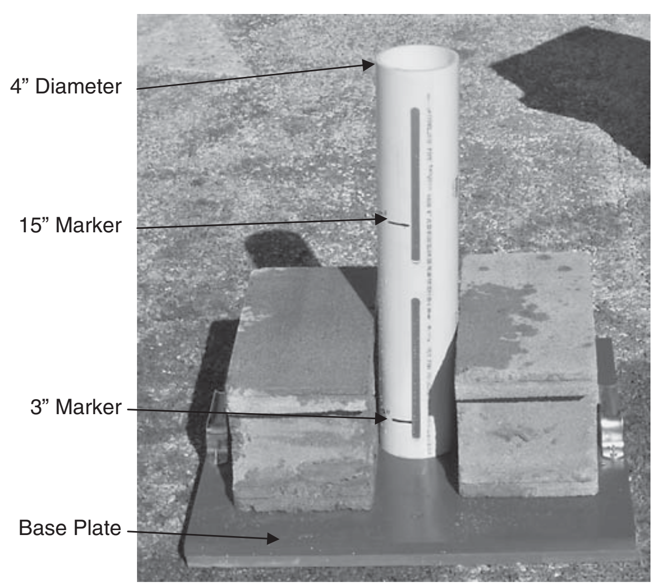


FIGURE 1 Falling head infiltrometer in use.

where

I = infiltration rate (in./h),
t = recorded time (s),
h_1 = initial water level (in.),
h_2 = final water level (in.), and
c = conversion factor = 3,600 s/h.

Field Facilities

Infiltration testing was performed at two PCP facilities. The first facility was located at College Street in Burlington, Vermont, and was constructed in June 2009. PCP was used in the central portion of the parking area, and traditional asphalt was used in the rest of the lot. Figure 2 shows an outline of the site, with infiltration monitoring sites listed alphabetically and cleaning locations listed numerically. The site was graded to direct water to the central PCP section. Below the pavement surface was a 34-in. layer of gravel used as a storage reservoir and perforated pipes that removed the collected stormwater. No cleaning operations were performed on the facility before this investigation. Winter maintenance consisted of plowing with little use of sand or salt, although both were used on a nearby road with runoff from the road that led into the facility.

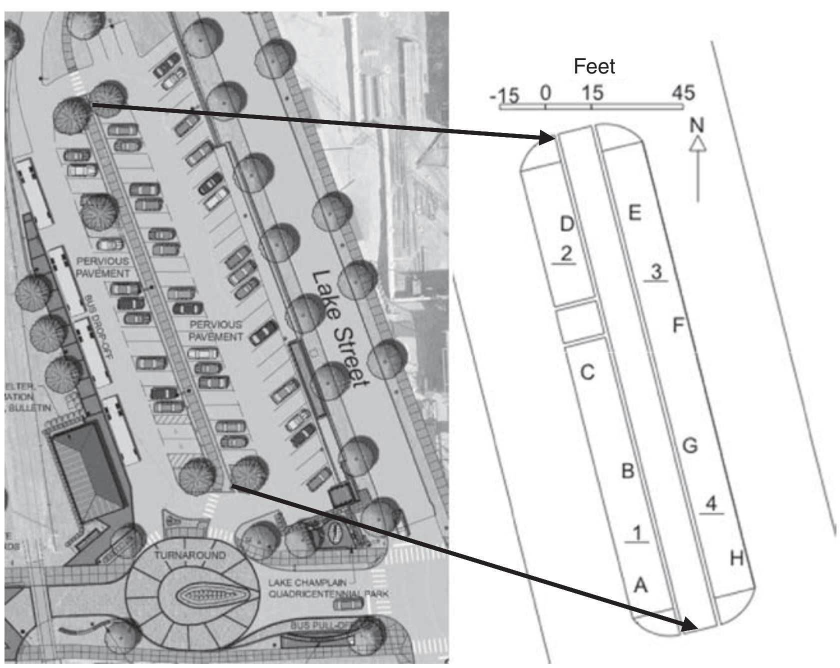
The second facility was located at Heritage Flight in South Burlington, Vermont, and was constructed in September 2009. The lot there was made solely of PCP. An outline of the facility is shown in Figure 3, with infiltration monitoring sites and cleaning sites included. The area was used primarily as a parking facility, although a small amount of truck travel occurred to deliver fuel. The facility was graded flat with minimal runoff from the adjacent, impervious surfaces. The PCP overlay a gravel base with a thickness of 32 in. (81.2 cm) and with water infiltration into native soils. The facility was cleaned by street sweeping biannually: once in the fall after foliage had dropped and once in the spring after winter maintenance ended. In winter, the area was plowed with a rubber-tipped blade; no sand or salt was applied.

Long-Term Field Monitoring

The infiltration rate was measured at eight locations at the College Street facility. Sites A, C, F, and H were located near the divide between PCP and asphalt. Sites B, D, E, and G were located near the inner island. Fourteen locations were selected at the Heritage lot, with sites (*a*) outside the wheelpath, which experienced little traffic (Sites A, C, N, and P), (*b*) inside the wheelpath, which experienced traffic (Sites B, D, O, and Q), (*c*) parking areas not under tires (Sites E, G, and I), and (*d*) parking areas under tires (Sites F, H, and K). Infiltration measurements were made in August 2010 at both locations, with subsequent measurements taken every month. Infiltration data immediately after construction were not available. Infiltration rates of slabs created in the laboratory with an identical mix design and similar placement methods were used therefore to estimate a range of postconstruction infiltration rates.

Infiltration Recovery Methods

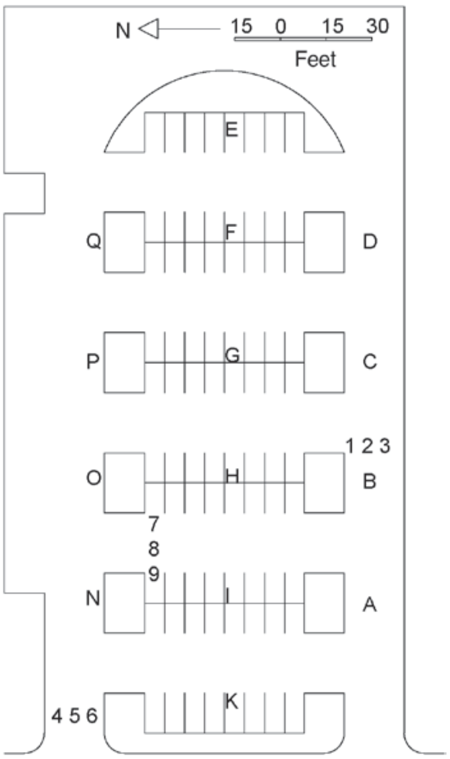
Cleaning operations were separated into two categories: (*a*) facilitywide cleaning operations, which included street sweeping and vacuum-truck cleaning, and (*b*) spot-cleaning methods, such as vacuuming by hand, pressure washing, and a combination of the two methods. Street sweeper cleaning was performed with an Elgin Whirlwind air sweeper, which brushed material from pores and carried it to a central vacuum. This vacuum removed material but did



(a) (b)

FIGURE 2 College Street PCP facility: (*a*) overview of facility and (*b*) location of testing sites.

(a)



(b)

FIGURE 3 Heritage PCP parking facility: (*a*) Heritage Flight lot and (*b*) location of testing sites.

not, however, form a tight seal with the pavement surface. Vacuum cleaning was performed with a Tymco 500x regenerative air vacuum truck. The Tymco vacuum system provided a better seal to the pavement surface and included pressurized air to dislodge material from the pores and remove it from the surface. Street sweeping was performed as part of regular maintenance at the Heritage facility in September 2010, and vacuum-truck cleaning was conducted at both facilities in October 2011. To determine the effectiveness of these maintenance operations, infiltration rates were measured before and after cleaning at eight locations per facility. Handheld methods were tested to determine their effectiveness to restore infiltration at four locations at the College Street facility and 10 locations at the Heritage facility. At selected sites, a 5-hp, wet–dry vacuum was used to clean an area that measured 2 by 2 ft (61 by 61 cm) for 30 s in one direction, and then for another 30 s in the perpendicular direction. At selected locations in which a 3,500-psi pressure washer was used, the method of cleaning was identical to that of the vacuum procedure. At sites at which the combined method was used, the areas were pressure-washed first and then vacuumed. Pre- and post-cleaning infiltration rates for all methods were determined with a falling head infiltrometer.

RESULTS AND DISCUSSION

Long-Term Field Monitoring

The results of long-term monitoring of the College Street facility are presented in Figure 4. Figure 4*a* shows the sites monitored, along with the infiltration rate (in./h) at the beginning and end of the monitoring period (August 2010 to July 2011) and the percentage of decrease. Infiltration values reported as “CLG” indicated complete clogging. The infiltration rate likely ranged from 1,400 to 2,800 in./h (1.0 to 2.0 cm/s) immediately after construction.

Initial infiltration rates of sites near the inner island were significantly lower than other locations. Sites B, D, and G had the lowest infiltration rates at the start of testing. The initial infiltration of other sites was higher, and ranged from 574 to 1,442 in./h (0.41 to 1.03 cm/s). Figure 4*b* shows areas clogged with sand or organic matter, which were visible at the end of the monitoring period. Clogging was identified by standing water after storm events, and occurred primarily at locations near the inner island. Clogging was present on both sides of the facility. Clogging near Site G consisted mostly of sand. Near Sites D and B, clogging consisted of a combination of organic matter and sand. Visibly clogged areas covered approximately 15% of the facility. Figure 4*c* shows locations that appeared to be raveling during the monitoring period. These locations closely matched areas of severe clogging. These observations supported earlier laboratory studies, which indicated that clogging could accelerate freeze–thaw damage in PCP (*12*). As a result of the high, initial clogging, these sites did not show significant change over the testing period. Other locations showed decreases in infiltration rates between 42% and 64%. Average infiltration values determined at each location are presented in Figure 4*d.* Infiltration measurements were not recorded in December and May because of poor weather conditions. In general, infiltration rates decreased continually throughout the monitoring period. The rates decreased the most at Sites A, C, and E. This gradual decrease suggested that clogging material was transported constantly to the site, with little variation over the yearlong period.

Results of long-term monitoring at the Heritage facility are presented in Figure 5. When the monitoring began, there was clogging observed at Sites B and D (Figure 5*a*). Delivery trucks, which could compact sand and other materials into pores, regularly traveled on these sites. Infiltration rates were an order of magnitude higher at sites in a similar location that did not have truck traffic (Sites A and C). This difference was not as drastic at sites that had a similar distribution inside and outside of the travel lane but no regular truck traffic (Sites N though Q). Not only traffic but also the type of vehicle in traffic could have an effect on the clogging of PCP, as indicated by these findings. Sites located in the parking areas showed the highest initial and final infiltration values, with little difference between sites inside or outside the travel lane. Figure 5*b* shows visible clogging near the entrances to the facility. Clogging material was found to consist mostly of asphalt particles from the nearby road. Raveling, shown in Figure 5*c,* was not correlated with clogging at the Heritage facility and was observed to be more random in location. Both clogging and raveling were observed on less than 5% of the surface. In similar fashion to the College Street facility, unclogged

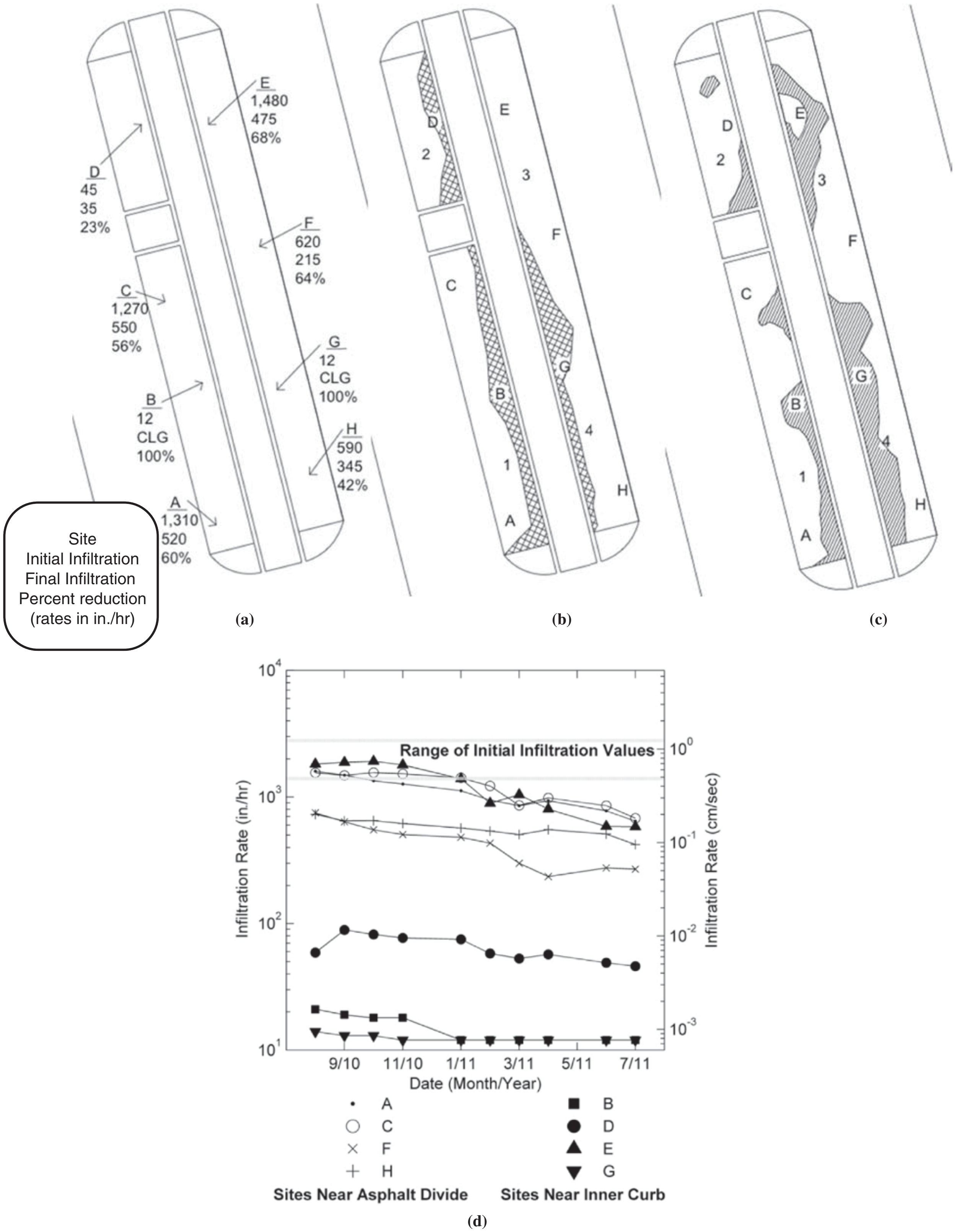


FIGURE 4 Results of field monitoring at College Street facility: (*a*) infiltration sites, (*b*) visual signs of clogging, (*c*) visual signs of raveling, and (*d*) infiltration measurements.

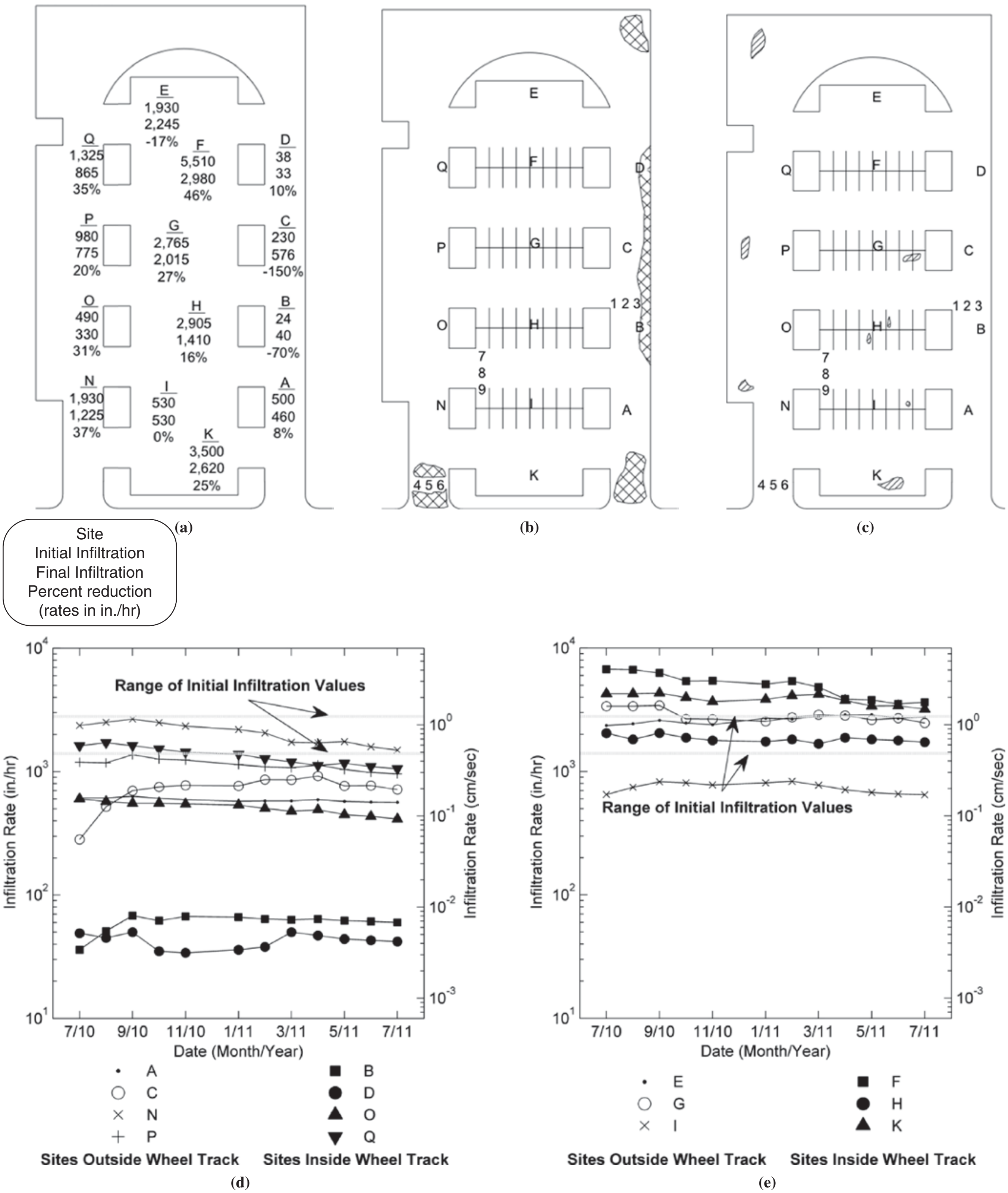


FIGURE 5 Results of field monitoring at Heritage facility: (*a*) infiltration sites, (*b*) visual signs of clogging, (*c*) visual signs of raveling, (*d*) infiltration measurements in travel lanes, and (*e*) infiltration measurements in parking areas.

areas also showed similar reductions in infiltration rate; most sites decreased 10% to 30% over the testing period. Figure 5, *d* and *e,* shows the range of infiltration rates observed in travel lanes and parking areas, respectively. All sites, with the exception of Site C, showed a gradual decrease over time; infiltration values remained high at the end of testing. Differences existed between infiltration rates at sites located inside and outside the wheel track (Figure 5*d*). Several sites showed infiltration rates above the range of initial infiltration values (Figure 5*e*) and probably were the result of variability in construction (i.e., low compaction resulted in higher infiltration rates). In the parking areas, little difference appeared between the sites inside and outside the wheel track.

Infiltration Recovery Methods

Facilitywide Cleaning

The effects of facilitywide maintenance practices are presented in Figure 6. Bars show the initial infiltration value measured at the beginning of the monitoring period, with measurements before and after cleaning performed by street sweeper and vacuum truck. For each cleaning method, the absolute increase to infiltration rate (in./h) and percentage increase are presented above the bar plots. A range is shown of the estimated postconstruction infiltration values and the infiltration rates associated with the 100-year, 24-h storm event for the region. Cleaning was performed by sweeper only at the Heritage facility (Figure 6*a*). Sweeping primarily collected dislodged aggregate and cement paste along with large inorganic and organic material on the PCP surface. The average increase to infiltration values was 28% as a result of cleaning. However, this value included results from clogged sites that showed large increases in the infiltration rate as a result of low precleaning infiltration rates. These sites did not accurately represent the average conditions of the facility and inflated the average recovery value. Removal of these sites (B and D) from the analysis resulted in an average increase to infiltration rate of 21%, which more accurately represented the effect on nonclogged areas. During postcleaning observations, material was still present in the pore structure, which indicated that cleaning was incomplete.

Vacuum-truck cleaning was performed at both sites, with differences in effectiveness. At the Heritage facility, vacuum-truck cleaning was found to be more effective than sweeping. The average increase in the infiltration rate was 89% for all sites and 30% when Sites B and D were removed from analysis. Both of these numbers were greater than the increase after sweeper cleaning. The addition of pressurized air resulted in the removal of additional material from the pores, which increased infiltration recovery rates. Vacuum-truck cleaning was less effective at the College Street facility than at the Heritage facility. Infiltration rates were restored at only three of the six sites, with an average increase to infiltration rates of 17%. Material still trapped in the PCP was observed at the site after cleaning, which indicated a limit on the extent to which vacuum-truck cleaning could be used effectively on clogged PCP.

On the basis of the results from the Heritage facility, it was concluded that cleaning with a vacuum truck led to better restoration of infiltration rates than did cleaning with a sweeper. It did appear, however, that regular (biannual) sweeping at the Heritage facility reduced areas of clogging, which allowed for increased restoration. Severe clogging at the College Street facility was probably the result of no regular cleaning. This clogging reduced the effectiveness of vacuum-truck cleaning. These observations suggested that it would be beneficial to clean PCP facilities regularly: twice a year (spring and fall) and preferably with a vacuum truck. If such a practice was not feasible, the use of a sweeper was expected to be better than no cleaning at all.

Spot Cleaning

Results of spot-cleaning methods performed at the College Street and Heritage facilities are presented in Figures 7 and 8, respectively. Sites are reported with their numerical identifier, precleaning infiltration rate, postcleaning infiltration rate, and percentage restoration; all infiltration rates were calculated in inches per hour. Figures were modified for the Heritage facility to better show the area in which cleaning was performed.

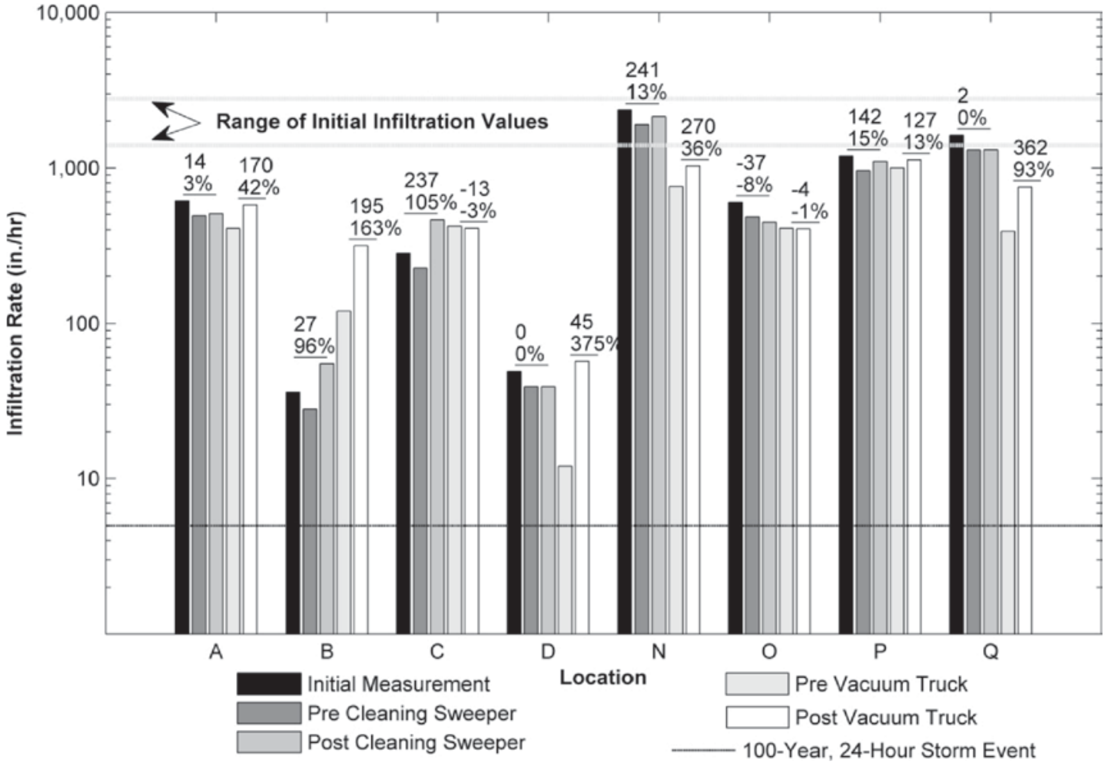
In general, precleaning infiltration rates at a given site were similar across all cleaning methods. The largest variation was observed at College Street at Site 2, which ranged from 700 to 1,120 in./h (0.53 to 0.83 cm/s). At the Heritage facility, the largest variation in precleaning infiltration rates was found at Site 3, which ranged from 42 to 1,000 in./h (0.03 to 0.72 cm/s). Sites at both facilities were found to vary greatly: precleaning infiltration rates ranged from 82 to 1,160 in./h (0.006 to 0.83 cm/s). These values indicated that cleaning procedures were tested on a wide variety of clogging conditions.

Pressure washing increased infiltration rates at all sites, except at Site 1 at the Heritage facility, with increases of 4% to 591% and an average increase of 85%. The largest increases to infiltration rates were observed in areas such as College Street Site 4 and Heritage Sites 4 to 6, which indicated that pressure washing could restore areas of severe clogging. At Site 8, pressure washing was observed to cause a small amount of raveling. At all other sites, however, no such raveling was observed. Vacuuming was also found to restore infiltration rates from 4% to 28% with an average value of 10%. However, College Street Sites 2 and 4 and Heritage Sites 4 and 6 showed no increase, which indicated that vacuuming alone could not remediate severe clogging. The combination of pressure washing and vacuuming resulted in restoration of infiltration rates at all sites, including severely clogged sites. Increases to the infiltration rate ranged from 6% to 1,070% and averaged 100%. Results of spot cleaning indicated that different methods resulted in different treatment efficiencies. Although these methods were impractical for facilitywide cleaning operations, (*a*) pressure washing and (*b*) the combination of pressure washing and vacuuming resulted in successful remediation of severely clogged areas that street sweepers and vacuum trucks could not clean. Pressure washing, followed by vacuuming, would be ideal to prevent the migration of material into PCP. However, pressure washing alone could be effective if small areas (rather than the overall site) were cleaned.

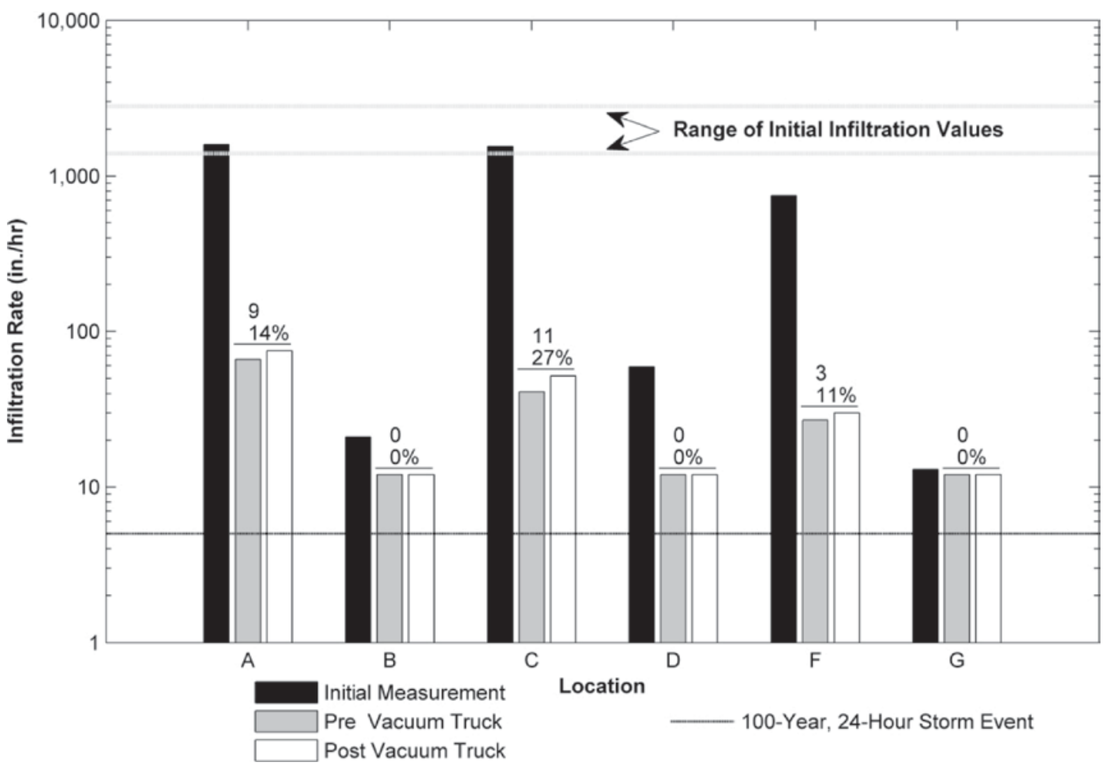
COMPARISON WITH EARLIER STUDIES

Long-Term Monitoring

Henderson et al. (*6*) observed a reduction in the infiltration rate of 87% in the field, which compared reasonably well with values observed in this study at the College Street and Heritage facilities, where reductions were observed of 59% and 26%, respectively. Laboratory reductions were observed to be approximately 40%



(a)



(b)

FIGURE 6 Results of maintenance operations: (*a*) Heritage facility and (*b*) College Street facility.

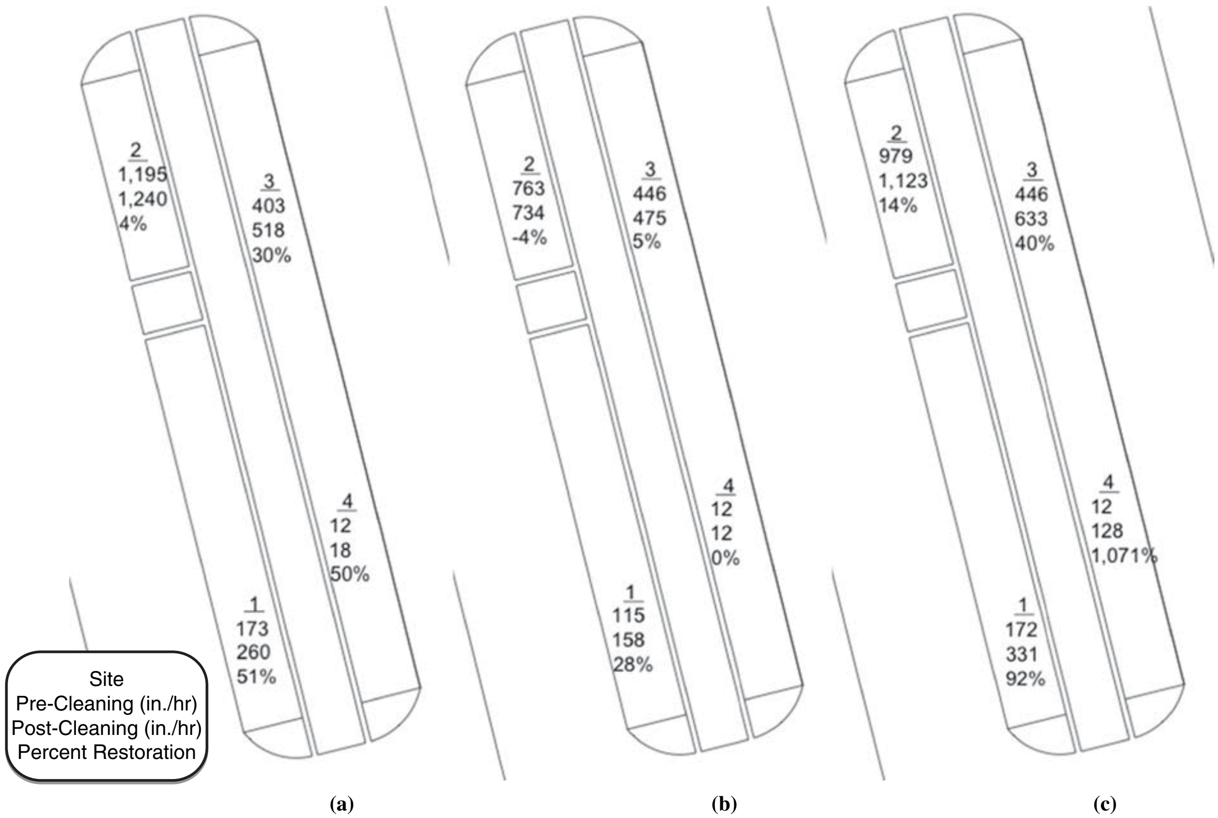


FIGURE 7 Effects of various cleaning methods on infiltration rate at College Street facility: (*a*) pressure washing, (*b*) vacuuming, and (*c*) combined methods.

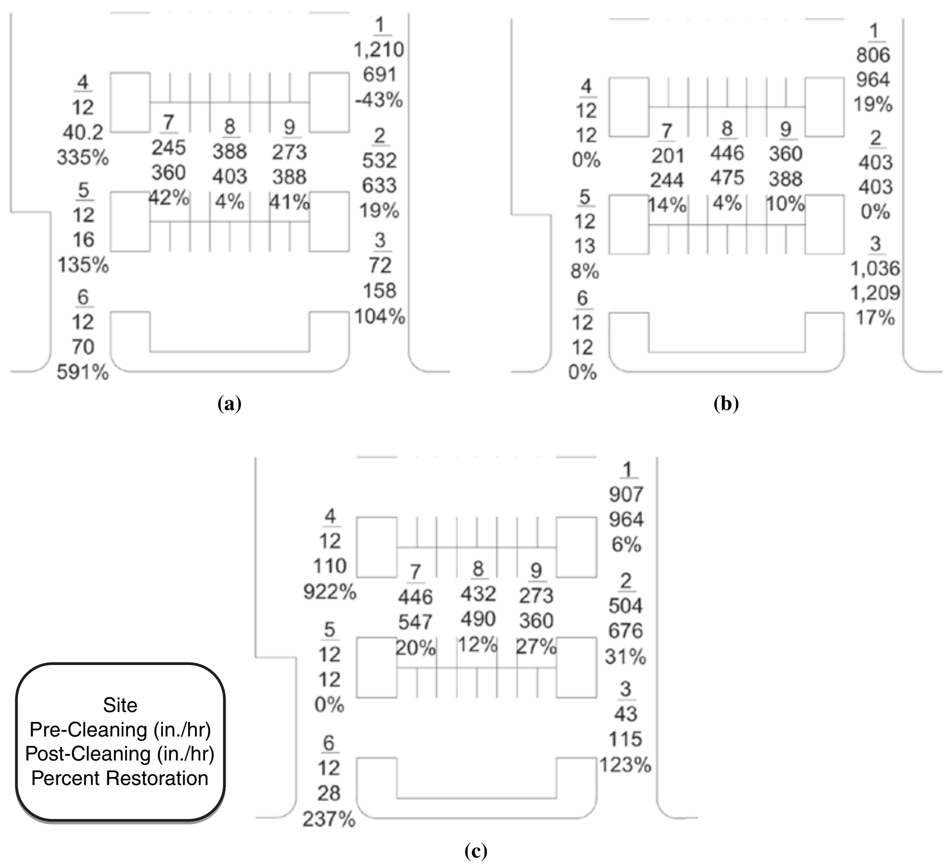


FIGURE 8 Effects of various cleaning methods on infiltration rate at Heritage facility: (*a*) pressure washing, (*b*) vacuuming, and (*c*) combined methods.

and 30% in specimens that exhibited clogging (*9, 10*). Both of these results fell within the range of field observations, which indicated that laboratory studies could be used to estimate the field performance of PCP.

Infiltration Recovery Methods

Field testing of vacuum cleaning performed by Henderson et al. (*6*) showed postcleaning infiltration rates were 100 times greater than precleaning infiltration rates. In another study (*7*), cleaning increased infiltration rates 10-, 56- and 66-fold for vacuuming, pressure washing, and combined methods, respectively. These increases to infiltration rates were considerably larger than the results of this study: vacuuming restored infiltration rates to 1.1 times their original value, on average; pressure washing restored infiltration rates to 1.85 times their original value; and the combined methods restored rates to 2 times their original value. This difference between the efficiency of cleaning methods was significant. In results reported by Henderson et al. (*6*), cleaning was performed 1 year after construction, whereas in this study cleaning was not investigated until after the second year of operation. The additional time between construction and cleaning in this study likely allowed material to be forced into the PCP, which resulted in reduced cleaning efficiency. Different hydraulic testing conditions (saturated hydraulic conductivity rather than unconstrained infiltration) made direct comparisons with the second study difficult and could explain the observed difference. The effectiveness, however, of each cleaning method compared with one another (vacuum versus pressure washing) was similar for both studies.

CONCLUSIONS AND DISCUSSION

The objectives of this study were to observe the performance of PCP in the field, determine the effectiveness of cleaning methods to restore infiltration rates, and compare field observations to available laboratory results when possible. These objectives were accomplished through the monitoring of two PCP sites in Vermont over a yearlong period, and through testing various cleaning methods at several locations within each site.

Infiltration rates measured at the PCP facilities decreased over the 1-year period, with average reductions of 59% for the College Street facility and 26% for the Heritage facility. Reductions in the infiltration rate over time were gradual, which indicated that the clogging process occurred consistently across both sites regardless of the season. Differences were observed between sites within and outside of the wheel track of vehicles. Clogging was observed to be more severe in locations where trucks traveled regularly. Earlier studies that simulated clogging in the laboratory found infiltration rates decreased in a more or less linear fashion as the clogging material was added, with final reductions that ranged from 20% to 40%. These findings suggested that real-world clogging of PCP could be simulated in laboratory studies.

Facilitywide cleaning operations included street sweeping and vacuum-truck cleaning, which resulted in increases to the infiltration rate of 21% and 30%, respectively. Both methods were recommended for regular cleaning operations. Spot-cleaning methods also were investigated, with increases of 85% after pressure washing, 10% after vacuuming, and 100% after pressure washing followed by vacuuming. Cleaning by pressure washing was effective to restore infiltration rates in areas of severe clogging. However, the method forced material into the gravel subbase, which might clog it in the future. The combination of pressure washing and vacuuming was preferred because it restored the infiltration rate and removed material from PCP. These field results yielded substantially less recovery of infiltration rates than did the earlier laboratory studies. All the same, less than 15% of the total PCP area was clogged in both facilities, and in general the infiltration rate of the PCPs remained greater than the infiltration needed to accommodate a 100-year storm event, except in the severely clogged regions.

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