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Infiltration performance evaluation of a 15-year-old concrete grid paver parking area (Italy)

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ABSTRACT

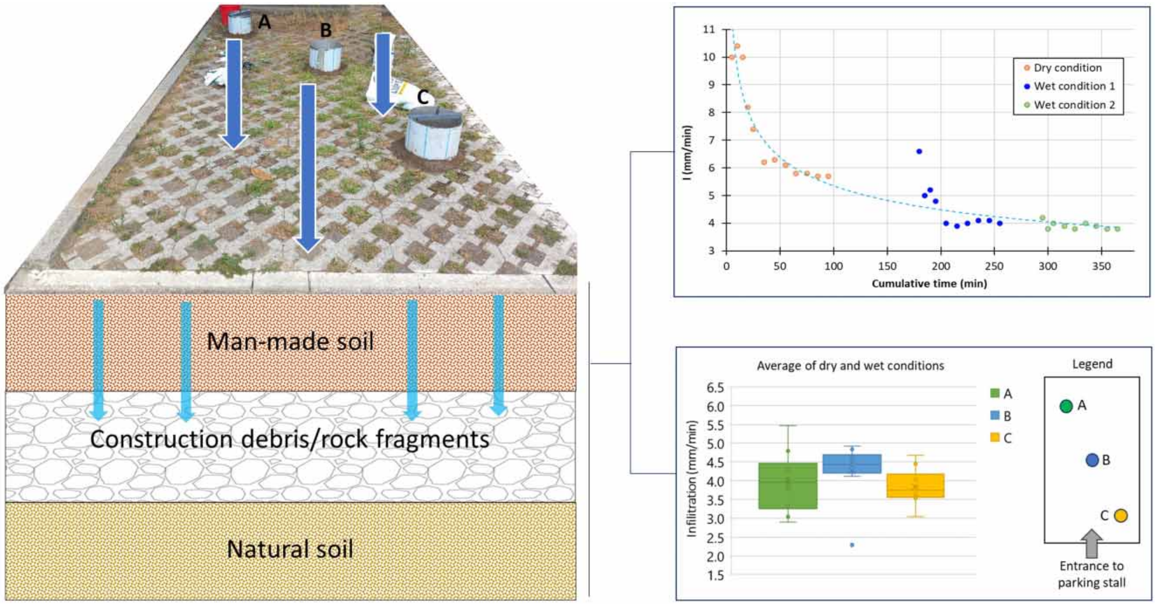
The management of urban stormwater needs a wide array of environmentally friendly solutions to safeguard water resources and improve the quality of the urban environment. In that, permeable pavements, a type of sustainable drainage system, are designed to reduce the volume and peak flow of stormwater on-site, improve infiltrating water quality, and combat the urban heat island phenomena. In this study, we tested the infiltration capacity of 15-year-old concrete grid pavers (CGPs) using single ring infiltrometer tests. We investigated how various factors, including location within the parking space, affect infiltration rates. Despite no maintenance and 15 years of operation, the infiltration capacity of the CGPs still exceeds the minimum infiltration capacity of 1.62 mm/min as required in many European regions. This may be due to the presence of soil cracks and the development of plant roots and insect/microorganism activities within the pavement voids. Indeed, this 'living soil system' continuously develops and counteracts the formation of clogging, interacting with the compaction process. Our study demonstrates that incorporating CGPs is effective in addressing emerging challenges associated with urban hydrology. Due to effectiveness and limited maintenance requirements, CGPs could be successfully included in long term climate adaptation measures.

Key words: adaptation, concrete grid pavers, nature-based solutions, single-ring infiltrometer test, sustainable drainage system, urban hydrology

HIGHLIGHTS

- We provide data on 88 single-ring infiltration tests in concrete grid pavers (CGPs).
- Infiltration in CGPs meets the technical standards even after 15 years of operation.
- Wheel passing on CGPs causes reduced infiltration due to soil compaction and reduced development of root apparatus.
- The role of vegetation in CGPs is substantial in maintaining high infiltration with time.
- Selection of rustic/drought resistant grass species is important to assure maintaining vegetation in the long run in CGPs voids.

GRAPHICAL ABSTRACT



1. INTRODUCTION

The effective management of urban stormwater needs a wide array of environmentally friendly tools to assist in safeguarding water resources and land against escalating pollution and flood hazards (Gomez-Ullate *et al.* 2011; Gimenez-Maranges *et al.* 2020). Blue/green infrastructures gained growing attention in the last decade from authorities and professionals (Piacentini & Rossetto 2020; Lupp *et al.* 2021) in order to reduce residual flooding risk and improve water quality (Campisano *et al.* 2017; Barbagli *et al.* 2019). Permeable pavements (Scholz & Grabowiecki 2007) are a form of sustainable drainage system (or green infrastructure) designed to reduce the volume and peak flow by retaining stormwater on-site, promote infiltration, augment evapotranspiration (Elhadi *et al.* 2021), and combat the urban heat island phenomena (Peluso *et al.* 2022). Moreover, permeable pavements, as a sustainable drainage solution, may play a role in improving water quality through filtration or retention and water conservation and harvesting (Shackel *et al.* 2008; Lentini *et al.* 2022). Permeable pavements may be used in roads, parking lots, and pedestrian areas instead of standard low-porosity/permeability pavements.

Despite permeable pavements having been in use for decades, the evaluation of how different types of permeable pavements and their conditions allow infiltration and how infiltrated water quantity and quality are affected continues to be an ongoing effort. From the infiltration rate (water quantity) viewpoint, the infiltration capacity of permeable pavements can vary significantly depending on site-specific factors such as the forms/structures of the pavement (Lucke *et al.* 2014), pavers bedding and jointing materials, the soil porosity and saturated hydraulic conductivity (Shackel *et al.* 2008), clogging (Sansalone *et al.* 2012; Zhang *et al.* 2023), maintenance practices (Winston *et al.* 2016; Selbig & Buer 2018), age (Boogaard *et al.* 2014a), vehicle type, and traffic counts (Cipolla *et al.* 2016).

Besides permeable pavers are competitive in terms of costs and maintenance with time respect to traditional paving materials (i.e. concrete and asphalt), in order to support and spread their application, it is important to present infiltration data in their real operation conditions and in time.

Various techniques have been used in previous studies to measure the infiltration rate of permeable pavements, including single- or double-ring infiltrometers (Al-Rubaei *et al.* 2015; Cipolla *et al.* 2016; Winston *et al.* 2016; Chen *et al.* 2019; Zhao *et al.* 2019; Zhang *et al.* 2023), full-scale infiltration tests (Boogaard *et al.* 2014b; Lucke *et al.* 2014; Boogaard & Lucke 2019; Veldkamp *et al.* 2022), and the use of a rainfall simulator (Borgwardt 2006).

Single- or double-ring infiltrometers are widely used for *in situ* determination of the infiltration rate of permeable pavements. Ring infiltrometer tests were originally developed to ascertain the hydraulic conductivity of soils in their natural field conditions (Bouwer 1986). Two prevalent methodologies for conducting the ring infiltrometer tests are the constant- and falling-head methods. In the constant head method of ring infiltrometer testing, the water level within the rings is consistently maintained at a predetermined level throughout the entire duration of the test. In the falling-head method, a relatively substantial amount of water is introduced to the rings at once, and the time it takes for the water to descend between two pre-established points inside the rings is measured. Due to the challenges of maintaining a constant flow rate of water in field conditions, the falling-head method is more commonly employed to estimate the infiltration rate through permeable pavement surfaces (Boogaard *et al.* 2014a). As keeping a consistent water supply to two rings under such conditions can be challenging (Boogaard & Lucke 2019), the falling-head method in a single-ring infiltrometer test is particularly advantageous for pavements with high infiltration rates.

Concrete grid pavers/pavements (CGP; or green parking lots) are open concrete units placed in the ground to support car parking and appeared for the first time in 1961 in Germany (Urban Innovation Abroad 1978). ICPI (1999) presents a technical bulletin providing guidance on the design, specification, construction, and maintenance of CGPs for a wide range of applications. Moreover, ASTM C1319-21 (ASTM 2021) covers the requirements for concrete grid paving units proposed for use in vehicular trafficways, parking areas, soil stabilization, and revetments.

However, few authors report data on the infiltration rate at concrete grid pavements in real operational conditions, while the surface infiltration rate is a key performance indicator for the efficiency of this pavement type. The infiltration capacity of CGPs in operation can vary significantly depending on site-specific factors. ASTM C1701 (ASTM 2009) describes the single-ring infiltrometer method to test the surface infiltration of CGP and pervious concrete. Smith *et al.* (2012) confirmed that ASTM C1701 (ASTM 2009) is suitable for measuring the surface infiltration rate of CGPs.

As such, in this research, we tested the infiltration capacity of a 15-year-old CGP parking area using single-ring falling-head infiltrometer tests to investigate how various factors, including location within a single parking lot, influence the infiltration capacity of a CGP. The objectives of our work are (i) to analyze the infiltration dynamics of a specific kind of CGPs 15 years old in the dry season as saturation proceeds; (ii) to check the robustness of data gathered through single-ring infiltrometer tests; (iii) to compare these data against infiltration rates at vegetated manmade soil and asphalt at the same place and against data from previous studies; and (iv) to verify if car parking conditions may bring different infiltration rates at a single parking stall.

2. MATERIALS AND METHODS

We tested CGPs, asphalt parking, and vegetated manmade soil at a parking place located in the San Giuliano Terme municipality (Italy; Figure 1). It consists of a large parking area serving a student residence and a kindergarten, and it is largely covered by asphalt and partly, on a limited area, by CGP parking stalls. The parking place was built in 2008, and since then, the only maintenance operation run was weed cutting at CGP, when necessary, with no regular schedule.

Infiltration tests were run between July 18 and August 4, 2023, during the dry season, so our data refer to summer dry soil conditions. During the testing period, the average daily air temperature was 26 °C (with a maximum peak of 33.8 °C and a minimum of 17.8 °C). One rainfall event occurred during the experiment with about 8 mm cumulated rainfall (Figure 2). The amount of rainfall was so low, and the air temperature high, that the site conditions were not affected by this event.

Figure 3 shows a schematic description of the stratigraphy at the site. In the parking area, above the natural soil (silty/loamy soil), the manmade part starts with construction debris/rock fragments. Upon it, manmade silty soil was set in the permeable pavements and in the green areas (flowerbed areas). CGPs are present at 11 parking stalls (Figure 1). In the green areas, during the test period, the soil was dry, and several open cracks (up to 5 mm large) were present. Vegetation was largely characterized by grass in the flowerbed areas. Mauve (*Malva sylvestris*) was also present in the CGP voids. Areas where the asphalt had been dismantled showed about 5 cm thick asphalt cover laid over a gravel bed.

The following design was selected to assess the positions subject to varying parking traffic loads. At each tested parking stall (Figure 4(a) and 4(b)), three different positions were tested: one on the center of the parking stall, one at the side end, and another at the entrance side end (Figures 1 and 4). In order to test positions subjected to different traffic loads: (A) position, located on a side at the end of the stall, hence subjected to the passage and stationary of a single wheel of a car; (B) position, in the center of the stall, and hence not subjected to wheel transit; and (C) position, on a side at the beginning of the stall, hence subjected to passage of two wheels.

Figure 1 | Geographic setting of the test area, position of the TOS01000544 meteo-station, and position of the tested pavements.

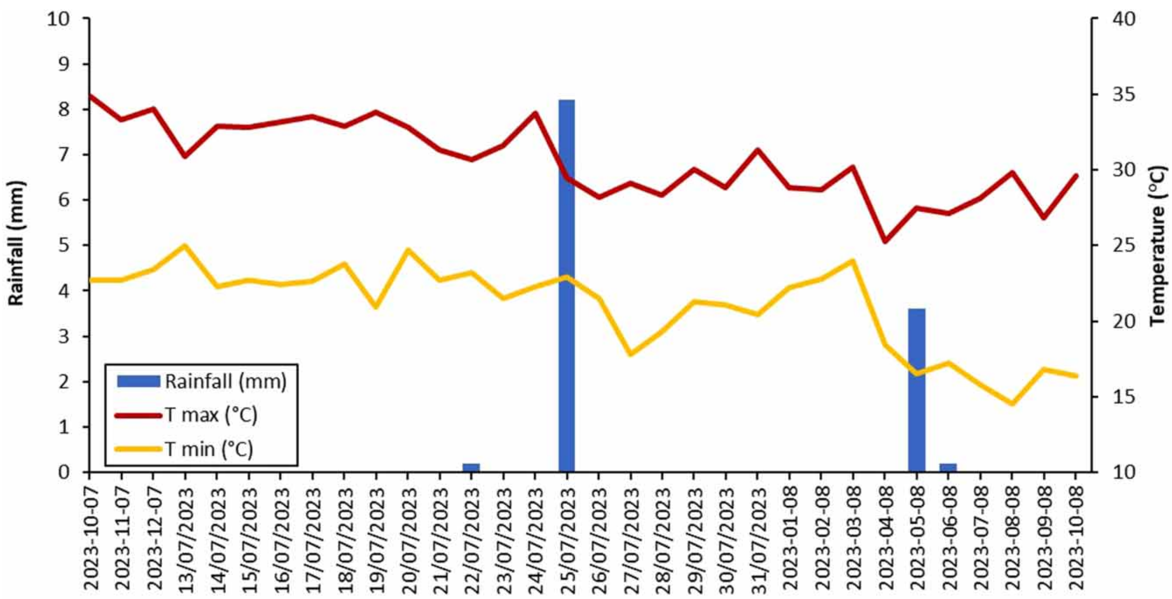


Figure 2 | Rainfall and air temperature recorded at the TOS01000544, Pisa (Fac. Agraria) meteo-station (data from the Hydrological and Geological Service of Regione Toscana; http://www.sir.toscana.it/). The position of the meteo-station is presented in Figure 1.

2.1. Infiltration test

The field infiltration rate is examined using a single-ring infiltrometer test, which is a modified form of double-ring infiltrometer test methods described in ASTM D 3385-18 (ASTM 2018), by means of a falling-head test. The

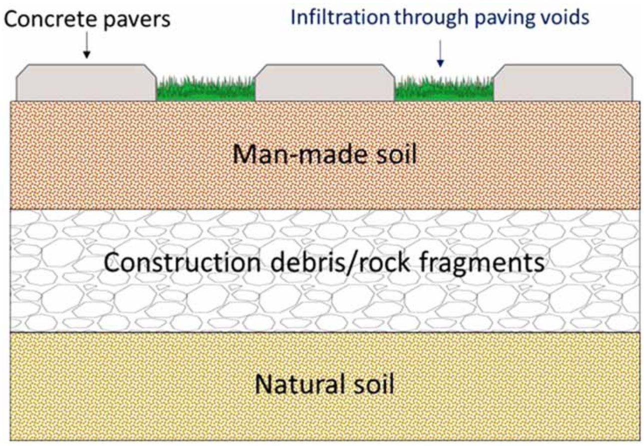


Figure 3 | Schematic representation of the stratigraphy of the CGP at the investigated site.

Figure 4 | CGP parking area (a) and experimental set-up (b).

falling-head single-ring infiltrometer test is useful for pavements with a high infiltration rate that cannot sustain a hydraulic head (Boogaard *et al.* 2014a). The experimental equipment consisted of steel rings with inner diameters of 28, 30, and 32 cm (Royal Eijkelkamp, the Netherlands), a synthetic measuring bridge, and a measuring rod with float and sealing material (Figure 4(b)).

The test, in short, involved sealing the ring to the soil/pavement, filling it with water and then measuring the water level reduction over a specific time to assess the infiltration rate. While setting the ring on vegetated/natural soil is rather straightforward, the primary challenge in using the infiltrometer test to assess the infiltration capacity of asphalts/permeable pavements is that the rings cannot penetrate the test surface to create a leak-proof seal. Consequently, to conduct the test accurately, it becomes necessary to seal the rings against the pavement surface using a waterproof sealant (Boogaard *et al.* 2014a). If water leaks or bypasses around the ring, it can lead to overestimations or significant fluctuations in the measured infiltration values. After testing different solutions and sealing materials, we used a double-sealing approach. A first sealing was set using TEC7[(R)], a high bonding capacity glue that adheres to both wet and dry substrates (Novatech International nv., Belgium). Further to this, after the initial filling of the ring, we disposed around the outside of the ring Lamposilex[(R)] powder (MAPEI, Italy) to stop eventual residual outflow. Lamposilex is a pre-blended powder binder composed of high-strength cement and special admixtures. Mixed with water, Lamposilex produces a paste with a plastic-thixotropic consistency with a very fast setting time, waterproof and water-repellent. Using this approach, a strong sealing solution was achieved, and no losses were observed within 30 min from the test set-up. Once this was achieved, the test started.

Table 1 presents information on the tests run. At each CGP position, three infiltration tests were run. The first test was then conducted after the said initial filling and sealing procedure at a high infiltration capacity. However, as several causes during infiltration can hinder the achievement of maximum saturation, we then repeated the tests two more times at the same point within 1–2 h from the end of the first test. Each test continued until no large changes were observed in the infiltration rate between the following time intervals and a quasi-steady state constant infiltration value was achieved. The average of the results of the two following tests is referred to as the 'wet condition test'. At points 6A and 6C, only one wet condition test was applied following the dry test. For the statistical analysis, at these two points, we included a second replicate with the assumption that its results would match those of the first wet condition test.

Tests on asphalt and on vegetated soils were only run in dry conditions, that is one test per position. Out of several trials on the vegetated manmade soil, only three tests were completed and allowed to get infiltration results. Because of the presence of the above-mentioned large cracks in the soil, we could not achieve the building of a head in the cylinder in the several positions tested. Practically, as the water was poured into the ring, it infiltrated through the cracks.

2.2. Data analyses

We performed exploratory data analysis and summary statistics to get a general insight into the pattern of the data. We used the box and whisker plot (Tukey 1977) to create a graphical representation of a dataset and to compare infiltration rates. Moreover, to analyze the difference between the results of the test at various locations in the parking lot, the Mann–Whitney U test was employed. This non-parametric statistical test was run using the PSPP free software (Pfaff *et al.* 2007).

As the infiltration capacity of soil decreases rapidly over time during the infiltration process until it reaches a quasi-constant value, we considered the average of infiltration values from the last three measuring time steps as the representative infiltration rate in each test.

In each test, the exposure of the CGP (paving voids) could vary due to differences in the rings' size and the small diameters of the rings in relation to the paving voids. Therefore, for each test, the percentage of paving voids area inside the ring (ring paving voids index) was estimated and the infiltration rate was rescaled using the following formula:

$$I_{\mathrm{RS}} = I \times \frac{\mathrm{PV}_l}{\mathrm{PV}_r}$$

where I_{RS} is the rescaled infiltration rate (mm/min); I is the measured infiltration rate (mm/min); PV_l is the large-scale paving voids index which is 48% for the study site (–); and PV_r is the ring paving voids index (–).

The rescaled values were used in data analysis, which enabled us to compare infiltration rates across various locations and under both wet and dry conditions.

Table 1 | The number of the testing location and infiltration tests on each land cover type

Land cover type	No. of testing location	No. of infiltration tests
CGPs	30	88
Asphalt	9	9
Green areas	3	3

3. RESULTS AND DISCUSSION

We present data from 88 tests run at 10 CGP parking stalls (Supplementary Material, file data_bgs.2023.043.xls). At the 10 CGP parking stalls, the generally measured infiltration rates under pre-dry and -wet conditions range from 1.89 to 6.31 mm/min, with an average of 4.03 mm/min (Table 2). Despite no maintenance during 15 years of operation, the infiltration capacity of the CGPs exceeds the minimum design infiltration rate requirement of 1.62 mm/min, as specified by some European authorities, such as in the Netherlands, Belgium, and Germany for newly installed permeable pavements (Boogaard *et al.* 2014a). This may be due to the presence of soil cracks and the development of plant roots, as well as insect holes and activities within the pavement voids. Furthermore, the void ratio of the CGP surface is considerably larger compared to other types of permeable pavement, such as permeable interlocking concrete pavers, which decreases the likelihood of clogging (Joshi & Dave 2022).

Infiltration rates at three asphalt parking stalls under dry conditions vary between 0.37 and 0.83 mm/min (with an average of 0.54 mm/min). Tests run on vegetated manmade soils (green spaces) indicate significantly high infiltration rates, ranging from 3.93 to 9.87 mm/min with an average of 6.36 mm/min (and the highest standard deviation value). However, because of the presence of desiccation cracks (detailed in the Materials and Methods section), at several locations tested, infiltration was practically infinite, being not measurable.

The infiltration rate values during the dry season are substantially higher in CGPs than standard asphalt even after 15 years of operation. Values are lower than those measured in vegetated soil because of the soil conditions in the dry season. In both asphalt parking stalls and green spaces, the presence of cracks and preferential flow results in infiltration rates higher than expected.

The average of the last three values was considered the representative infiltration value for each test (Figure 5). As an example, Figure 5 shows the effect of prewetting on infiltration behavior at point 9B on CGP. At the beginning of the test, dry ground typically exhibits a high infiltration capacity due to the presence of preferential flow paths caused by vegetation roots, soil cracks, and insects' holes, but also to significant soil matrix suction. While the test is progressing, in the near-saturated condition, potential differences are reduced. The presence of air bubbles during infiltration can further hinder achieving maximum saturation (Bouwer 1986). Consequently, the infiltration rate typically diminishes, stabilizing at a relatively constant level.

Table 3 shows that by conducting the test under dry and then wet conditions, the measured infiltration rate in CGP land cover can be decreased by 4–40%, with an average of 27%. Therefore, running a single infiltration test on permeable pavements in dry conditions may lead to an overestimation of the infiltration rate. As mentioned by other researchers, the infiltration rate decreases with increasing soil moisture (Bagarello & Sgroi 2004; Ruggenthaler *et al.* 2016).

To investigate the impact of vehicular traffic counts on the infiltration rate at CGPs, the infiltration rate values were compared at three points within each parking stall including the center of the parking space (B) and the passages of the wheels (A and C; Figure 6).

The results show that the mean infiltration rates at points A, B, and C slightly differ, measuring 3.99, 4.27, and 3.85 mm/min, respectively, considering the average of all tests (dry and wet conditions). The highest infiltration

Table 2 | Summary statistics for all surfaces and tests run (all values are in mm/min)

Land cover/location		Minimum	Maximum	Median	Mean	Standard deviation
CGPs	1	2.57	5.23	3.57	3.75	0.96
	2	3.01	6.31	4.34	4.41	1.12
	3	3.41	5.71	4.07	4.18	0.84
	4	1.89	3.93	3.04	2.98	0.68
	5	3.32	5.50	4.40	4.42	1.11
	6	2.59	5.22	4.10	4.04	0.84
	7	3.21	5.26	4.13	4.22	0.73
	8	3.04	5.74	4.26	4.23	1.16
	9	2.39	5.82	3.70	3.82	1.19
	10	3.34	5.19	4.32	4.29	0.83
	All points	1.89	6.31	3.95	4.03	0.98
Asphalt		0.37	0.83	0.50	0.54	0.18
Green space		3.93	9.87	6.73	6.36	2.20

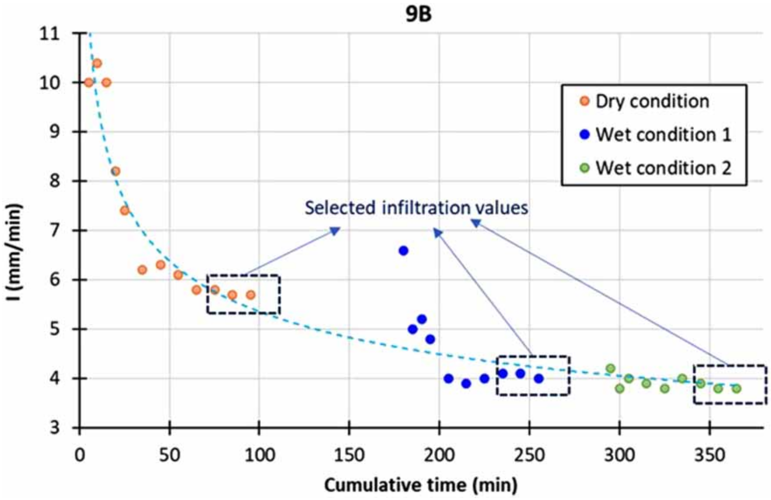


Figure 5 | Measured infiltration rates in three repeating tests at 9B CGP position. Time in minutes (min) from the beginning of the test.

Table 3 | The reduction in the infiltration rate in CGP land cover resulting from the measurement being conducted first under dry and then wet conditions

	Dry condition (mm/min)			Wet (mm/min)			Reduction		
Location	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
1	4.45	5.23	3.51	3.11	3.64	2.57	30%	31%	27%
2	6.31	4.74	4.06	4.61	3.72	3.01	27%	21%	26%
3	4.35	5.71	4.17	3.41	3.96	3.49	22%	31%	16%
4	3.15	2.68	3.93	2.92	1.89	3.31	7%	29%	16%
5	5.28	5.50	5.49	3.32	3.53	3.39	37%	36%	38%
6	4.07	4.21	5.22	2.59	4.02	4.14	36%	4%	21%
7	5.26	4.78	3.94	4.32	3.84	3.21	18%	20%	18%
8	5.05	5.74	4.99	3.04	3.54	3.07	40%	38%	39%
9	3.40	5.82	4.25	2.39	4.01	3.04	30%	31%	28%
10	5.19	5.04	4.84	3.52	3.80	3.34	32%	25%	31%
All	**4.65**	**4.94**	**4.44**	**3.32**	**3.60**	**3.26**	**28%**	**27%**	**26%**

values are observed at point B, which is located in the center of the parking stall, hence with lower traffic counts, followed by point A and then point C (representing one- and two-wheel passages, respectively). The results of the Mann–Whitney *U* test (Table 4) provided also a significant statistical difference in the B and C datasets ($p <$ 0.05). According to the results shown in Table 4, the *p*-values for comparisons between the A and B datasets and the A and C datasets are both greater than $p < 0.05$. However, the larger difference between the A and B datasets acknowledges that there is a disparity between infiltration rates at points A and B, which we assume is caused by different vehicular traffic counts. As such, wheel passing decreases infiltration capacity due to soil compaction (as reported in Cipolla *et al.* (2016)) and at the same time does not allow the proper development of vegetation and root apparatus.

Data on surface infiltration rates in real CGP operations are not commonly published. Table 5 presents and compares data from this study with published data from previous studies. Cipolla *et al.* (2016) conducted a field investigation in Rimini (Italy) to compare infiltration rates in eight different permeable parking lots, five of which were CGPs. Their findings revealed that the infiltration capacity of the pavements was primarily influenced by the position of the ring in the parking lot, the filling material used, and the surface type, rather than the antecedent dry-weather days and the pavement age. Additionally, the study demonstrated that compaction, due to

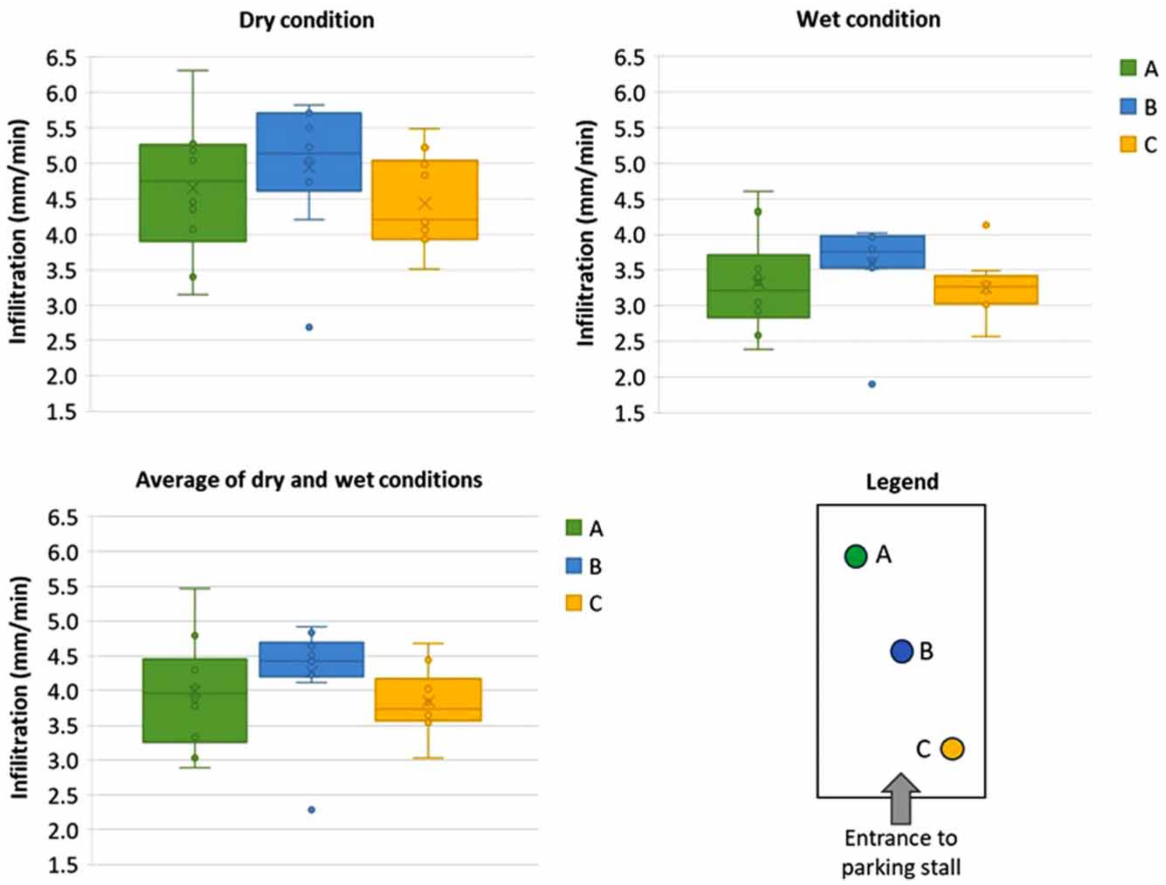


Figure 6 | Comparison of infiltration rate at three points (A, B, C) in 10 parking stalls covered by CGP under dry and wet condition tests.

Table 4 | *p*-values obtained from the Mann–Whitney *U* test by comparing the infiltration rate in A, B, and C points in 10 parking stalls covered by CGP

	Dry		Wet		Average of dry and wet	
	B	C	B	C	B	C
A	0.406	0.450	0.096	0.910	0.151	0.677
B	–	0.070	–	0.019	–	0.034

Table 5 | Comparison among the surface infiltration rate (mm/min) of CGP land cover obtained in different studies

	Minimum	Maximum	Median	Mean	Standard deviation
This study (2023)	1.89	6.31	3.95	4.03	0.98
Al-Rubaei *et al.* (2015)	0.30	11.80	2.60	4.21	3.66
Bean *et al.* (2007)	0.17	3.17	0.82	1.15	0.87
Cipolla *et al.* (2016)	4.12	335.62	51.32	115.60	141.11

vehicular traffic, negatively impacted the infiltration rate, leading to reduced permeability values. Bean *et al.* (2007) tested the surface infiltration rates at 17 CGP sites in the United States using double-ring infiltrometers, single-ring infiltrometers, or combinations in pre- and post-maintenance situations. The pre-maintenance infiltration rates displayed a range of values, spanning from 0.17 to 3.17 mm/min, with an average rate of 1.15 mm/min (Table 5). After maintenance, the average CGP infiltration rates increased to 2.18 mm/min. This study demonstrated that the location and maintenance of permeable pavements played a crucial role in infiltration rates. Al-Rubaei *et al.* (2015) conducted research on the infiltration rates of six CGPs in Sweden. The measured average infiltration rate was 4.21 mm/min (Table 5). This study again highlighted the impact of the type and age of the pavement and the joint filling material on the long-term performance of infiltration capacity.

Our data show the highest minimum infiltration rate value among those presented, while descriptive statistics are in line with those of Al Rubaei *et al.* (2015) and Bean *et al.* (2007). Data from Cipolla *et al.* (2016) show the largest standard deviation and highest values for all descriptive statistics. The extremely high maximum infiltration rate may depend on the soil type occupying the grid voids (i.e. gravels).

4. CONCLUSIONS

This study presents data and findings from field tests, performed during the dry summer season, and carried out on a parking lot covered by CGPs. The research assessed the infiltration rate through the application of a simple and cost-effective single-ring test procedure. Substantial work is needed to set-up reliable infiltration tests in CGPs using ring infiltrometer tests. Running a single infiltration test on concrete grid pavers in dry conditions may lead to an overestimation of infiltration rates. At least two following tests are needed to get quasi-steady state infiltration values.

The values for the surface infiltration ranged between a minimum of 1.89 mm/min and a maximum infiltration of 6.31 mm/min with an average of 4.03 mm/min. The infiltration rate values during a dry season are substantially higher in CGPs than standard asphalt even after 15 years of operation.

The results show that the infiltration rates in a parking stall could spatially vary due to soil compaction and improper development of vegetation and root apparatus caused by traffic counts. The higher infiltration values were observed in the center of the parking stall with lower traffic counts in comparison to the points at the passages for car wheels. The role of vegetation in CGP parking areas is substantial in supporting continuously high infiltration rates with time.

Our study demonstrates incorporating permeable pavements is a potentially effective approach to address emerging challenges associated with urban flooding, drought, and mitigation of urban heat islands as part of climate adaptation measures even in the long run and with limited maintenance.

Several authors report that maintenance is crucial in order to avoid clogging, hence preserving the infiltration rates in permeable pavements (Gerrits & James 2002; Bean *et al.* 2007; Kamali *et al.* 2017). In our case, despite no maintenance and 15 years of operation, the investigated CGP is still effective in favoring infiltration and reducing runoff generation. The infiltration capacity of the CGPs still exceeds the minimum infiltration capacity of 1.62 mm/min as required in many European regions. We infer this is likely due to the presence of soil cracks and the development of plant roots and insect holes and activities inside the pavement voids, which may generate preferential flow paths. This observed 'living soil system' continuously develops and counteracts the formation of clogging by repacking the first layers of the soil and interacting with the compaction process. Maintenance operations should take into account and favor the development of vegetation. Irrigation may then be needed in the dry period, in order to avoid reaching a wilting point and loss of vegetation in the CGPs voids. As such, care should be given in selecting rustic/drought-resistant grass species in order to minimize irrigation needs.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Material (file data_bgs.2023.043.xls).

CONFLICT OF INTEREST

The authors declare there is no conflict.

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