



Influence of Pavement Composition and Pore Structure on Water Infiltration

Ria Bachuvala

Abstract

Water scarcity and stormwater runoff are growing concerns, especially in regions such as Southern California where water resources are limited. This study investigated how the composition of pavement materials influences water infiltration by comparing conventional concrete, asphalt, and brick with permeable alternatives. Six material samples were tested using a consistent experimental setup, and recorded water-transmission measurements were compared over time. The results showed noticeable differences among the materials, with the porous asphalt sample producing the greatest recorded transmission during the experiment. However, not every permeable material performed better than its conventional counterpart, indicating that pore size, pore connectivity, sample preparation, compaction, and water retention may influence performance. Overall, the experiment suggests that properly designed permeable pavement materials can improve infiltration and may help reduce surface runoff, while also demonstrating that greater expected porosity does not automatically produce greater permeability.

Keywords: porosity, permeability, water infiltration, pervious concrete, porous asphalt, permeable pavement, stormwater management



Introduction

Water scarcity has become a growing concern in many parts of the world because of drought, population growth, climate change, and increasing demand for water. Shemer et al. [1] describe global water scarcity as a major challenge that requires both improved water management and new approaches to water supply. In Southern California, where water resources are limited, groundwater and other stored water supplies play an important role in supporting communities. At the same time, urban development has replaced many natural land surfaces with asphalt, concrete, brick, and other relatively impermeable materials. Although these materials provide strength and durability for roads, sidewalks, parking areas, and buildings, they can reduce the amount of rainwater that infiltrates into the ground.

When rainfall cannot infiltrate into the soil, more of it becomes surface runoff and is directed toward gutters and storm-drain systems. This can reduce opportunities for groundwater recharge and may contribute to flooding and the movement of pollutants into receiving waters. As urban areas continue to expand, improving the way rainfall is managed has become increasingly important.

One possible solution is the use of permeable pavement. Unlike conventional pavement, permeable systems are designed to allow water to pass through the pavement surface and into underlying layers. Kayhanian et al. [2] reported that permeable pavement has been used in parking areas and transportation applications to reduce runoff and provide water-quality benefits. These applications demonstrate the potential for pavement design to become part of a broader stormwater-management strategy.

Two important properties of permeable materials are porosity and permeability. Porosity describes the amount of void space within a material, while permeability describes how easily a fluid can move through it. A material may contain pores without transmitting water effectively if those pores are isolated or poorly connected. Childs and Collis-George [3] showed that permeability depends on the geometry and connectivity of pore spaces, not simply the total amount of empty space.

Conventional concrete and asphalt are generally designed to be dense and durable. Pervious concrete contains a network of interconnected voids created by reducing fine aggregate, while porous asphalt uses an open internal structure that provides pathways for water movement. Permeable brick or paver systems may manage water through pores in the material, joints between units, or both. To support the design of better materials for water management, this study asks: How does the composition of pavement materials influence porosity, permeability, and water infiltration? The hypothesis is that materials with greater and better-connected pore spaces will allow more water to pass through than their conventional counterparts. The study compares three material pairs—conventional and pervious concrete, conventional and modified porous asphalt, and conventional and modified permeable brick—using one small-scale testing procedure.

Literature Review

Previous research has shown that permeable pavement materials can improve stormwater management by allowing rainfall to move through the pavement rather than immediately

becoming surface runoff. Kayhanian et al. [2] reviewed permeable pavement applications and reported benefits related to runoff reduction and water quality. Obla (2010) explained that pervious concrete contains interconnected voids that permit water to pass through the material and reported typical void contents in the range associated with highly porous concrete.

Research also shows that permeability depends on more than the total amount of pore space. Yang and Jiang (2003) found that the porous structure of pervious concrete supports water penetration, while also identifying a tradeoff between high porosity and material strength. Childs and Collis-George [3] explained that pore geometry and connectivity influence permeability. More recently, Ortiz-Marqués et al. (2025) reviewed porosity and permeability in construction materials and emphasized the importance of pore structure in controlling fluid movement.

Methods used to measure porosity can also affect reported results. Dotson et al. (1951) compared porosity-measurement methods across laboratories, demonstrating the importance of consistent testing procedures. Research on porous asphalt similarly emphasizes the role of internal structure and open-graded aggregate in creating pathways for water movement (Chen & Yang, 2020; Król et al., 2018; Liu & Cao, 2009). Studies of permeable brick materials have also examined how composition affects water transmission [9].

Previous studies generally examine one pavement family at a time and often use professionally manufactured materials, specialized laboratory equipment, or field installations. This study builds on that work by directly comparing six samples representing three material families in one experiment under the same small-scale procedure. Using the same apparatus, timing interval, and comparison method makes it possible to observe how different composition changes affect water movement across concrete, asphalt, and brick within a single study.

Methodology

Materials

The experiment compared six samples: conventional concrete, pervious concrete, conventional asphalt, a modified porous asphalt sample, conventional brick, and a modified permeable brick sample. The conventional brick contained 1 cup of clay and 1 cup of sand. The modified permeable brick used the same mixture plus 2/3 cup of sawdust; the sawdust served as a pore-forming material intended to leave additional void space. The modified asphalt mixture included an additional 2/3 cup of sand to investigate how changing particle composition affected water movement. The concrete samples were prepared as conventional and pervious mixtures, with the pervious sample intended to contain more connected void space than the conventional sample.

The modified asphalt sample was a simplified experimental model rather than an exact reproduction of commercial porous asphalt. Commercial porous asphalt is typically designed with an open-graded aggregate structure and fewer fine particles, while this study intentionally altered the mixture so that its behavior could be compared with the conventional asphalt sample [6,7].

Additional testing equipment included a measuring cup, digital scale, stopwatch, clear testing container, collection container, and mesh screen or filter. The measuring equipment was used to keep the general testing procedure consistent among the six samples.

**Figure 1.** Example of experiment process**Table 1.** Material preparation

Material	Main composition / role	Expected behavior
Conventional concrete	Cement, sand, gravel	Control; relatively low connected void space
Pervious concrete	Cement and coarse aggregate with little or no fine aggregate	Greater connected void space
Conventional asphalt	Dense asphalt mixture	Control; relatively low permeability
Modified porous asphalt	Experimental asphalt mixture with added sand	Test effect of altered composition
Conventional brick	1 cup clay + 1 cup sand	Control sample
Modified permeable brick	1 cup clay + 1 cup sand + 2/3 cup sawdust	Additional void-forming material

Experimental Setup and Procedure

A consistent testing apparatus was used for all six pavement materials. A clear container held each sample, a mesh screen or filter prevented loose particles from entering the collection container, and a separate container below the sample collected the water that passed through. Equal sample volumes were used so that differences in sample quantity would not affect the comparison. The same apparatus and general configuration were maintained throughout testing.

Each material was tested individually. An equal volume of test material was placed in the apparatus and the sample was weighed before water was introduced. The experiment plan specified 200 mL of water for each trial. Water was poured as uniformly as possible across the sample surface, and a stopwatch was started when the water contacted the material. Measurements were recorded every 10 seconds until the value stopped changing or the trial ended.

After drainage, the sample was weighed again so that wet and dry measurements could be compared. The same procedure was used for all six materials. Because the final recorded dataset is reported in ounces and contains values larger than the stated 200 mL starting-water

quantity, the original measurement label should be verified against the laboratory notes before submission. The analysis below preserves the recorded values exactly and treats them as comparative measurements rather than converting them into an absolute infiltration percentage.

Data Collection and Calculations

The recorded measurements were entered into a spreadsheet and compared over time. The digital scale was reported to have an accuracy of ± 0.01 g. The study also identified the following relationships for processing water measurements:

$$m = \rho V \quad (\text{Eq. 1})$$

where m is water mass, ρ is the density of water (approximately 1 g/mL), and V is water volume. The planned porosity calculation was:

$$n = (V_v / V_{\square}) \times 100\% \quad (\text{Eq. 2})$$

where n is porosity, V_v is void-space volume, and $V_{\square}$ is total sample volume. The available dataset does not include the complete void-volume or dry/wet-mass measurements required to calculate experimental porosity for all six samples. Accordingly, the paper does not invent measured porosity values; instead, a literature-based porosity comparison is provided in the Results section.

Results

The experiment showed clear differences in the recorded mass-of-water measurements among the six pavement samples. Measurements were recorded every 10 seconds. The strongest separation occurred in the asphalt pair, while the concrete pair remained relatively close and the brick pair produced an unexpected result.

Concrete

At 10 seconds, conventional concrete recorded 23.58 oz of water passed through and pervious concrete recorded 23.12 oz. The measurements remained close throughout the trial. Conventional concrete eventually reached 31.16 oz, while pervious concrete reached 30.84 oz. Because the final difference was only 0.32 oz and no replicate-based uncertainty was available, the concrete comparison is inconclusive.

Asphalt

The asphalt pair showed the clearest difference. At 10 seconds, conventional asphalt recorded 21.06 oz of water passed through, while the modified porous asphalt recorded 33.84 oz. At 20 seconds, the values were 28.42 oz and 43.45 oz, respectively. At 30 seconds, conventional asphalt reached 30.92 oz while the modified porous asphalt remained at 43.45 oz. Within this experiment, the modified asphalt sample therefore produced the greatest recorded water transmission.

Brick

The brick samples produced the opposite pattern from the original hypothesis. Conventional brick increased from 24.98 oz at 10 seconds to 33.36 oz at 120 seconds. The modified permeable brick recorded 13.00 oz at 10 seconds and 17.34 oz at 70 seconds, after which no additional values were recorded. The added sawdust may have created voids that were not well

connected, or it may have retained some water within the sample. This result illustrates the difference between creating pore space and creating continuous pathways that allow water to pass through a material.

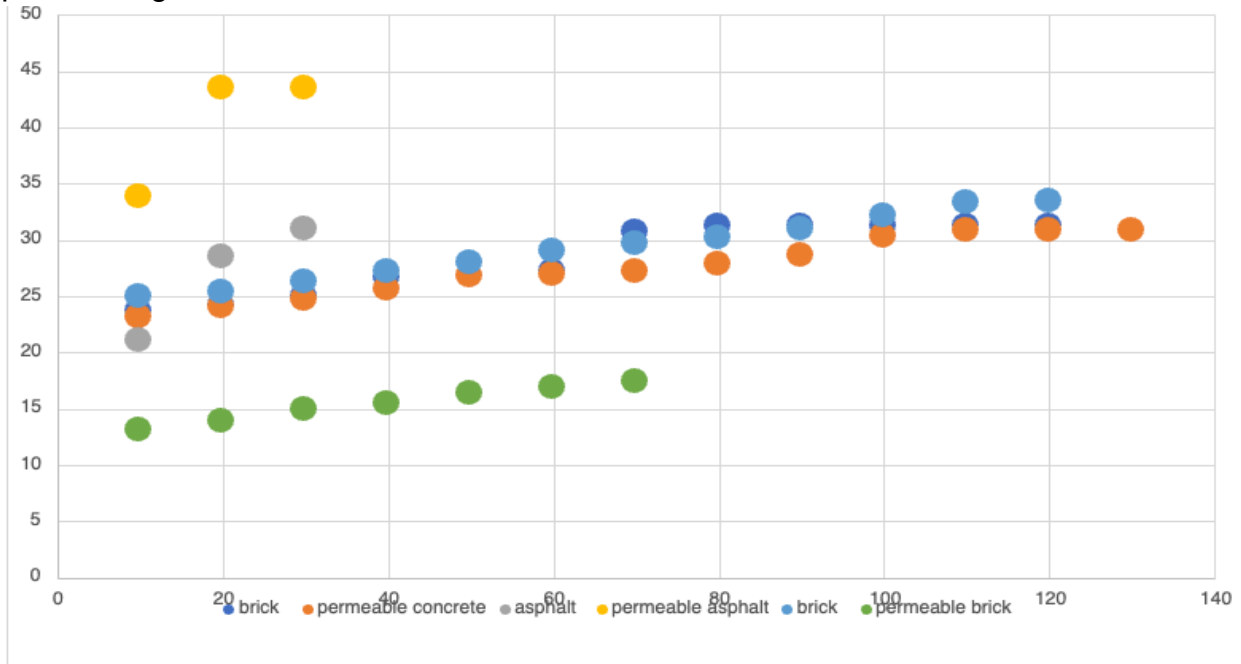


Figure 2. Mass of water passed through each pavement sample over time. For trials that ended early, the final recorded value is carried forward so all series can be compared on the same time axis.

Table 2. Recorded mass-of-water measurements at 10-second intervals. Final values are repeated after early-ending trials for consistent comparison.

Time (s)	Concrete (oz)	Pervious concrete (oz)	Asphalt (oz)	Porous asphalt (oz)	Brick (oz)	Permeable brick (oz)
10	23.58	23.12	21.06	33.84	24.98	13
20	24.14	24.04	28.42	43.45	25.32	13.78
30	24.94	24.72	30.92	43.45	26.28	14.88
40	26.6	25.6	30.92	43.45	27.12	15.44
50	27.96	26.74	30.92	43.45	27.92	16.28
60	27.16	26.92	30.92	43.45	28.98	16.78
70	30.74	27.12	30.92	43.45	29.68	17.34
80	31.16	27.78	30.92	43.45	30.18	17.34
90	31.16	28.58	30.92	43.45	30.96	17.34
100	31.16	30.24	30.92	43.45	32.14	17.34
110	31.16	30.84	30.92	43.45	33.34	17.34
120	31.16	30.84	30.92	43.45	33.36	17.34
130	31.16	30.84	30.92	43.45	33.36	17.34

Porosity and Literature Comparison

Experimental porosity could not be calculated from the available dataset because complete void-volume measurements were not recorded. Table 3 therefore distinguishes the study's unmeasured experimental porosity from literature-based benchmark ranges. Literature shows that pervious concrete and porous asphalt are intentionally designed with substantially more connected void space than dense conventional pavement, while brick and paver behavior depends strongly on composition, pore connectivity, joints, and construction [4-6, 10].

Table 3. Experimental porosity status and literature-based porosity benchmarks for the six pavement-material categories. Ranges are contextual benchmarks, not measured values from this experiment.

Material	Literature-Reported Porosity	Interpretation
Conventional concrete	~3–8%	Dense control; relatively low connected void space
Pervious concrete	~15–30%	Higher void content when pores are well connected
Conventional asphalt	~2–8%	Dense-graded control; low air-void content
Porous asphalt	~18–25%	Open-graded structure creates connected flow paths
Conventional brick	Varies by brick	Depends on composition and internal pore structure
Permeable brick/paver	System-dependent	Depends on connected pores, joints, bedding, and construction

Discussion

The results only partially supported the hypothesis. The modified porous asphalt sample showed substantially higher recorded measurements than conventional asphalt, but the pervious concrete sample was similar to conventional concrete and the modified permeable brick recorded lower values than conventional brick. These differences indicate that composition influences water movement, but the effect depends on pore size, distribution, connectivity, compaction, and water retention. For the concrete pair, the final difference was only 0.32 oz (31.16 versus 30.84 oz). Because replicate trials and measurement uncertainty for the complete apparatus were not recorded, such a small difference should be treated as inconclusive rather than evidence that one concrete definitively performed better.

The concrete results are consistent with the literature emphasizing pore connectivity. Pervious concrete is normally designed to contain interconnected voids [4](Obla, 2010; Yang & Jiang, 2003). If the experimental sample was compacted differently or its voids were not connected through the full sample depth, water movement could have been limited. The brick

result provides a similar lesson: adding sawdust may have increased empty space, but the resulting pores may not have formed continuous channels.

The asphalt result most strongly supports the study's central idea. Research on porous asphalt has shown that internal structure and aggregate gradation influence permeability [6](Chen & Yang, 2020; Król et al., 2018; Liu & Cao, 2009). The experimental asphalt sample also produced the highest recorded values. However, because the modified sample was prepared differently from commercial porous asphalt, the result should be interpreted as evidence that changing composition affected the sample, not as a direct performance test of commercial porous asphalt.

There are several limitations. The samples were prepared on a small scale rather than manufactured under controlled pavement-production conditions. Differences in compaction, sample thickness, particle distribution, and water application could have affected the results. The data also contain different trial lengths, and the draft does not provide repeated trials for each material. Most importantly, the paper's notes contain inconsistent descriptions of the starting water quantity, and the complete measurements needed to calculate experimental porosity are not included. These limitations mean that the study is best interpreted as a comparative demonstration rather than a precise engineering characterization of the materials.

Conclusion

This study investigated how changes in pavement-material composition affected observed water movement. Conventional concrete, asphalt, and brick were compared with pervious or modified permeable alternatives. The results showed that composition influenced the samples, but they did not fully support the prediction that every permeable material would outperform its conventional counterpart.

The modified porous asphalt produced the clearest difference, recording 43.45 oz at 30 seconds compared with 30.92 oz for conventional asphalt. The concrete samples finished at similar values, approximately 31.16 oz for conventional concrete and 30.84 oz for pervious concrete. The modified permeable brick recorded lower values than conventional brick. Together, these results suggest that pore connectivity may be as important as the amount of pore space in determining how readily water moves through a material.

The experiment also demonstrates the importance of careful sample preparation and consistent measurement. Future work should use commercially manufactured pavement samples or precisely controlled mix designs, repeat each test at least three times, maintain identical sample dimensions and compaction, and record complete dry mass, saturated mass, discharged water volume, and infiltration time. Those measurements would make it possible to calculate average infiltration rates and experimental porosity more reliably.

Overall, the study supports the broader idea that pavement design can influence stormwater behavior. Properly designed permeable surfaces may help reduce runoff and create additional opportunities for rainfall to infiltrate. The experiment itself evaluates material behavior under small-scale laboratory conditions and does not directly test regional field performance.

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