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Analysis of the Infiltration and Water Storage Performance of Recycled Brick Mix Aggregates in Sponge City Construction

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Abstract: With the gradual advancement of urbanization, urban hardened roofs and pavements are increasing, and the rainwater cycle is being seriously damaged; sponge city construction has become an inevitable trend to address this problem. The analysis of the infiltration and storage performance of recycled brick aggregate, which is highly absorbent and can be used as a permeable paving material in sponge cities, is of great significance. The study firstly designed a simulated rainfall test device, then carried out tests in terms of aggregate gradation, aggregate type, and aggregate grade, and finally analyzed its effect on the void structure and infiltration and water storage performance of recycled brick mix aggregates. The outcomes demonstrate that the particle size of recycled brick concrete aggregate is positively related to the water storage capacity, and the volume water storage rate of recycled sand is close to 26%. The fitting result of 1 h water storage rate under different dosage is 0.984. After 1 h of rainfall, the water storage rate is 3 times that of natural aggregate, and the volume water absorption rate is 2.5 times that of natural aggregate. This indicates that recycled brick concrete aggregate has strong permeability and water storage properties and has great potential for application in sponge city construction, and the study provides a reference for the optimal design of subsequent cities.

Keywords: recycled brick aggregate; infiltration; water storage; sponge city

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1. Introduction

Amid accelerating socio-economic development, the urbanization process has accelerated and the construction of facilities such as ground, roofs, and roads has led to a serious hardening of the road sub-base and a significant reduction in rainwater infiltration into the ground [1]. As this situation intensifies, the natural ecology has been seriously damaged, flooding is frequent in every rainfall, the whole natural rainwater cycle system is out of balance, and water pollution, ecological degradation, and a series of other problems have become more and more obvious. To effectively retain limited rainwater and drain it through more natural forces, the construction of sponge cities, with natural purification, natural infiltration, and natural storage as the main concepts, has gradually emerged, and the development of permeable water storage materials with absorption and infiltration functions has become an important breakthrough [2]. On the other hand, the urbanization process has brought about a large amount of construction waste, including waste soil, waste concrete, and waste bricks, which can mostly be reused in the form of recycled aggregate resources through layers of processing and screening. Recycled aggregates are in line with the concept of green building materials, have the advantages of being recyclable and energy efficient, and fit in with the objectives of sponge city development; they can be used as a base material to optimize the urban hydrological cycle [3].

As a form of structural layer laying, graded crushed stone structure layer is widely used in the construction of permeable pavement facilities in sponge cities [4]. Unlike the cement-stabilized macadam and pervious concrete structure layer, its biggest advantage is that the aggregate will not be wrapped by foot binding material, so the aggregate will be exposed in the rain. This special situation enables the interspace between particles to penetrate and retain rainwater, and the water absorption interspace on the aggregate surface enhances the above effects. The recycled aggregate itself has the characteristics of strong adsorption capacity, large specific surface area, and many pores on the particle surface, which will have great application potential in the graded crushed stone structure layer [5]. Therefore, it is of great significance to analyze the application of recycled brick concrete aggregate in sponge city construction by taking it as the main application material of graded crushed stone structure layer to analyze its permeability and water storage performance.

The permeability performance of geomaterials has reaped a lot of attention from scholars at home and abroad, and many professionals have explored many aspects such as material void structure, average material particle size, void connectivity, etc., and have thus introduced a series of performance improvement measures. Tavakoli et al. analyzed the application of waste clay bricks in concrete pavements and prepared a silica fume containing 5–15%. The design was used to find the optimum amount of silica fume in concrete pavements and to use it in the brick mix. The outcomes demonstrated that there was no significant damage to the concrete pavement by substituting sand through 25% of the waste bricks, while amounts above 50% affected the concrete's performance [6]. Guo's team upgraded the performance of recycled aggregate concrete in terms of the mixing process based on the high water absorption of recycled aggregates, proposing a premixed cement slurry. The outcomes demonstrated an increase in compressive strength of 7.8–15% and a significant improvement in frost resistance [7]. Rahmani et al. looked at the production of new concrete from coarse aggregates and used 50%, 75%, and 100% recycled concrete aggregates in place of coarse aggregates to create different recycled concrete aggregates, which were demonstrated to be suitable for structural concrete and able to provide a valuable resource for the concrete industry's bone section, providing a valuable resource [8]. Chen's research group conducted experiments on the optimal mixing ratio of permeable bricks for a hot topic in science and technology, i.e., sponge city construction. The results showed that the optimal mixing ratio of cement was 2%, the water–cement ratio was 0.38, and the water–cement ratio of aggregate was 3.5; all three could meet the permeability coefficient and the compressive strength of single brick for the sponge city [9]. Wang analyzed the cost-effectiveness of sponge city construction according to the climatic characteristics of China by using the lifecycle cost theory and the storm flood management model and simulated six rainfall design scenarios; the results showed that the method has high application benefits [10]. Bhashya et al. used recycled fine aggregates with water–cement ratios of 0.45, 0.50, and 0.55 to replace sand to prepare concrete and evaluated its durability performance; the outcomes indicated that it had higher water absorption and lower compressive and tensile strengths than natural aggregate concrete [11]. It can be observed that recycled aggregates have a wide range of applications in recycled concrete and concrete pavements, and by adjusting their mix ratio, they can better serve the construction of sponge cities.

Liu et al. designed sponge city facilities such as multi-functional ponds, eco-roofs, and bioretention flower beds to address the problem of poor permeability in certain sections of the metro and simulated and calculated their water retention capacity and effects through stormwater management models and volumetric methods, which demonstrated that they could achieve a zero-water flow effect [12]. Zhu et al. started from the planning of green ecological plots in sponge city construction, based on the sponge city construction concept, evaluated its significance and value in terms of economic, social, and ecological benefits, and provided new and feasible ideas for sponge city planning and design [13]. Peng et al. applied the sponge city approach to a wider watershed to respond to water problems in cities with a natural solution and assessed the flood control effect by modelling flood, hydraulic, and hydrological loss curves; the outcomes demonstrated that the approach validates the effectiveness of the flow strategy and contributes to the efficiency and quality of natural flood management [14]. Feng et al. proposed the use of auxiliary cementing materials in concrete to solve the problem of limited strength of silica-upgraded concrete and to explore the effect of factors such as recycled coarse aggregate on the lightness of recycled concrete; the results proved that this method can effectively enhance the strength of concrete [15]. Marthong used recycled coarse aggregate to replace natural coarse aggregate to produce recycled aggregate concrete with appropriate admixture of ethanol benzodicarboxylate in the joint area. Comparative outcomes indicate that the recycled concrete has superior structural performance under cyclic loading and has higher principal tensile stresses and stronger seismic performance [16]. Rosca developed recycled brick concrete with sand and coarse aggregate containing fine aggregate based on the eco-friendly characteristics of recycled brick aggregate and used the same size of sand. Fine brick aggregate of the same dimensions as sand was used as a substitute for sand, and the outcomes demonstrated that the method had some influence on the standard test age strength [17]. The summary of current research work is shown in Table 1.

Table 1. Summary of current research work.

Author	Year	Achievements
Tavakoli et al.	2022	More than 50% will affect the concrete performance
Guo et al.	2020	7.8–15% higher compressive strength
Rahmani et al.	2020	Suitable for structural concrete
Chen et al.	2021	Meet the requirements of permeability coefficient and compressive strength
Wang	2022	High application efficiency
Bhashya et al.	2020	Higher water absorption
Liu et al.	2021	Achieve zero river flow effect
Zhu et al.	2021	New feasible ideas
Peng et al.	2022	Improve the efficiency and quality of natural flood management
Feng	2022	Improve concrete strength
Marthong	2018	Strong seismic performance
Rosca	2022	Influence on the strength of standard test age

In summary, the existing research can improve the strength and compressive capacity by adjusting the ratio of recycled aggregates and has been applied to sponge city construction with good results. However, most studies have not conducted actual tests on the permeability and water storage performance of recycled aggregate and have not concluded its specific role in rainfall water storage. At the same time, although the construction of facilities in sponge cities in China has been gradually promoted, the application of recycled brick concrete aggregate is still low. Therefore, starting from the construction of a sponge city, the research took recycled brick concrete aggregate as the experimental object and tested the permeability and water storage performance of recycled brick concrete aggregate through the self-made permeability and water storage test device and simulated rainfall test, in order to provide theoretical support for the further development of permeability and water storage performance.

2. Experimental Design for Testing the Permeability and Water Storage Performance of Recycled Brick Concrete Aggregate

2.1. Test Material Selection and Device Design

The recycled brick aggregate consists of crushed tile blocks, recycled concrete aggregates, recycled brick aggregates, wood chips, and waste mortar blocks and other impurities. Among its components, waste mortar blocks, recycled concrete aggregates, and recycled brick aggregates play a major role in water absorption because of the presence of adsorptive voids on their surfaces and their high number and specific surface area, which enables them to absorb rainwater well [18–21]. The numerous voids on the surface of the aggregate particles are closely related to the particle characteristics. Different aggregate gradations, aggregate types, and aggregate grades affect the water absorption capacity of the structural layer and thus the infiltration and water storage capacity of the material. Therefore, based on the relationship between the water absorption capacity of particles and the particle characteristics of recycled aggregates, the volume of recycled aggregate mix, aggregate grading, and average aggregate size were used as test variables to investigate the infiltration and water storage performance of the material under different test factors. The recycled brick aggregate selected for the test was produced by Beijing Shougang Environment Industry Co., Ltd. for processing, and the mechanism aggregate was prepared by Beijing Elm Structure Co. In this study, the 0–5 mm particle size aggregates were excluded under the CJJ/T 188-2012 regulations below 0.075 mm particle size, and their performance indices are exhibited in Table 2. The physical property indices of raw materials in Table 2 were obtained according to GB/T 14685-2011 standard, and the apparent density of the material was determined by the wide-mouth bottle drainage method. The water-absorbing pores of the orthopedic particles affected the void fraction of the recycled brick aggregate, resulting in large values, and the porosity of the studies done were obtained by this method.

Table 2. Performance indices of raw materials.

Aggregate Type	Crushing Index (%)	Water Absorption (%)	Bulk Density (kg/m^3)	Particle Size Fraction (mm)	Brick Content (%)	Void Fraction (%)	Apparent Density (kg/m^3)
Recycled brick concrete aggregate	34	11.8	1186	0–5	29.8	51.7	2457
	/	10.4	1086	5–10	25.7	51.2	2451
	24.5	8.3	1103	10–20	24.2	50.2	2474
Natural machine-made stone	4.8	0.8	1429	0–5	/	45.6	2629
	/	0.6	1495	5–10	/	41.6	2845
	13.6	0.2	1511	10–20	/	41.0	2838

The determination of the permeate storage performance of the material was then determined and carried out under a simulated rainfall test designed by a home-made permeate storage test device, the sketch of which is exhibited in Figure 1. The constant speed pump in Figure 1 is a BT100LC type, the internal volume of the infiltration storage device is 250 × 250 × 500 mm^3, the maximum water feed rate is 290 mL/min, and the material is provided with uniform permeable holes in the material's laying substrate, the aperture of which is 5 mm, so as to ensure the flow of precipitation. Sensitive sensing of permeability is achieved by wetting and diverting the diversion funnel in advance of the infiltration device being used [22]. A layer of geotextile is provided at the base of the device to prevent blockages caused by leakage of small granular materials.

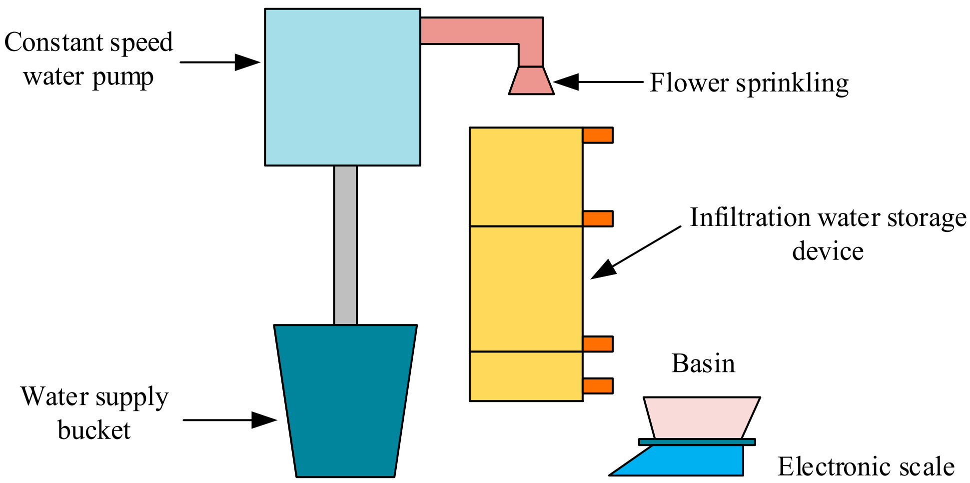


Figure 1. Schematic diagram of seepage storage test.

2.2. Test Methods and Procedures

The aim of the test was to simulate the water absorption, retention, permeability, and storage properties of a layer of infiltration storage material under rainfall conditions. The rainfall is simulated by means of a constant speed pump, and to compare the infiltration and storage capacity of the different structural layers, the test is carried out at a fixed feed rate, with a rainfall intensity of 180 mL/min. The timing starts at the beginning of the rainfall simulation. The time was recorded at the first drop of water from the outlet at the bottom of the device, and then every minute of rainfall was recorded thereafter. The rainfall is then simulated continuously, with the material of the infiltration aquifer in a steady state of permeability, i.e., the volume of water discharged per minute is closer to the rate of water supply, with a floating difference of 0 to 5 mL/min. The rainfall is continued for a period of time and then stopped, and the quality of the water received for 1 h after the stop is recorded at minute intervals. The outflow rate (mL/min) was obtained by converting the volume of water discharged per minute recorded at the end of the test to the outflow rate per minute. The outflow rate is then used to describe the water permeability of the material and to obtain the infiltration performance curve. This curve characterizes the stages through which the material passes under rainfall conditions. The first stage is impermeable at the bottom of the material and only adsorbs rainwater, i.e., the material is infiltrated. In the second stage, water permeability appears at the bottom, and the rate of outflow increases until it is very close to the intensity of the rainfall, i.e., the permeability enhancement stage. In the third stage, the bottom outflow rate is consistent with a fixed rainfall intensity, and the outflow rate remains stable over time, i.e., the fully permeable stage. The fourth stage is the water storage stage, when the material's own properties are used to store rainwater. A diagram of the infiltration curve is shown in Figure 2, which characterizes the first three stages of material infiltration and water storage.

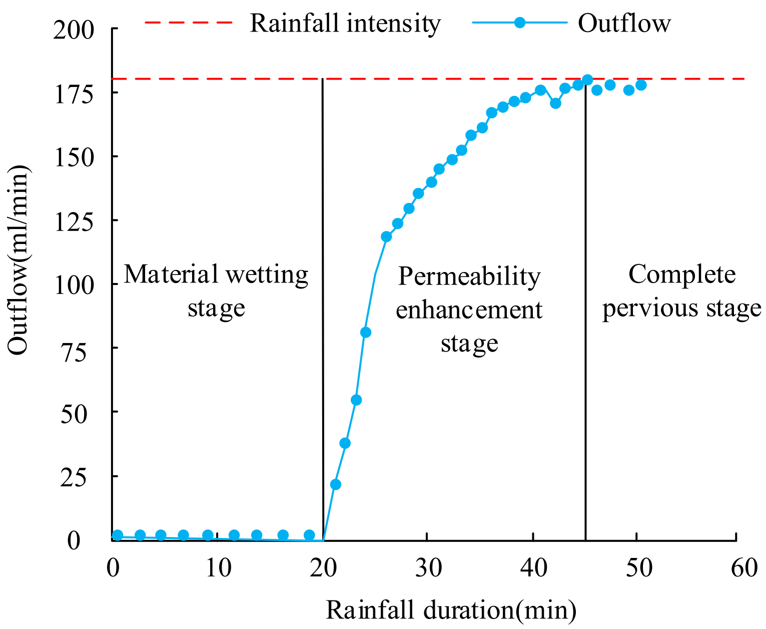


Figure 2. Schematic diagram of permeability curve.

During the infiltration phase, the adsorption and storage capacity of the material can be calculated by the equation in Equation (1), if the length of the material phase is known.

$$a_c = \frac{t_1 \cdot i_w}{V} \cdot 100\% \tag{1}$$

In Equation (1), a_c represents the water adsorption rate of the material (%), i_w represents the water feed rate of precipitation (mL/min), t_1 is the infiltration phase duration (cm), and V is the volume of the structural layer of the material (cm^3). It was observed from several tests that all the test groups selected were able to infiltrate rainfall after 20 min of rainfall application, with the fully permeable phase occurring after 45 min. The study selected the ratio of precipitation time to water output when the time is 30 min of rainfall as an indicator to characterize the permeability of the material and to further compare the difference in material permeability performance; at this time recorded as permeability efficiency after rainfall of 30 min, the calculation process is exhibited as in Equation (2).

$$K_{30} = \frac{m_{30}}{30\rho_w} \tag{2}$$

In Equation (2), K_{30} represents the infiltration efficiency of rainfall for 30 min, m_{30} represents the water output (g) at this moment, and ρ_w represents the density of water, which is taken as 1 g/cm^3. The test definition of water retention is the material particles between the voids existing and surface water absorption pores in the rainfall stagnation of rainwater, using volume water retention rate to characterize [23–29]. Volumetric water retention is the ratio of the volume of the structural layer of the material to the amount of water retained, while the amount of water retained is the difference between the total amount of water that comes out and the total amount of rainfall at each moment. Material water retention is characterized by the volumetric water retention rate in the fully permeable phase, as shown in Equation (3).

$$a_z = \frac{i_w \cdot t_2 - m_z/\rho_w}{V} \cdot 100\% \tag{3}$$

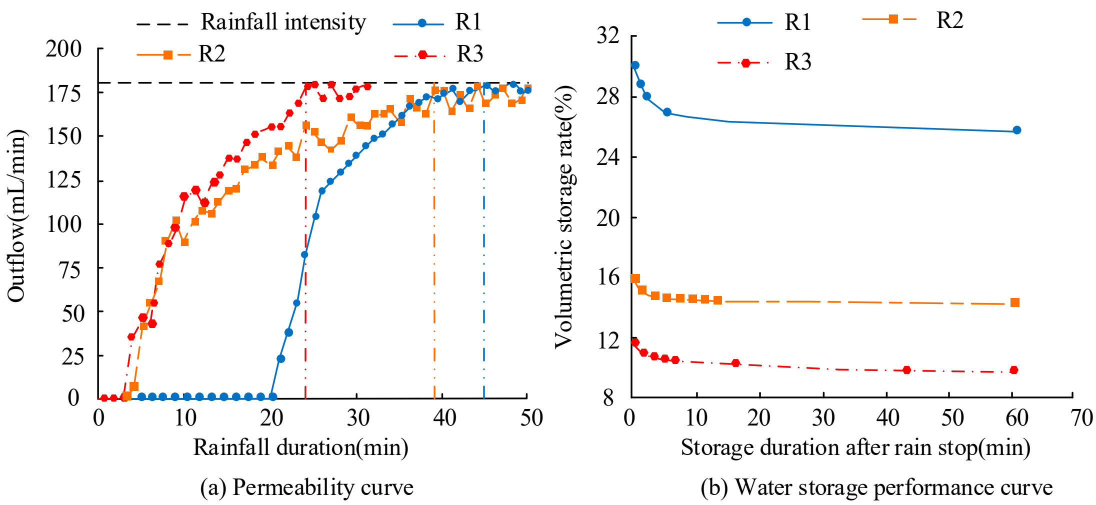
In Equation (3), a_z represents the volumetric water retention rate at the fully permeable stage, t_2 represents the rainfall ephemeris at this stage, and m_z represents the total water quality at t_2 during the rainfall ephemeris. The water storage capacity, defined experimentally as the capacity of the inter-granular void structure and the water-absorbing pores on the surface of the granules to store rainwater after the end of the rainfall, is characterized by the volumetric water storage rate, which is the ratio of the volume of the structural layer to the volume of water stored, with the volume of water stored being the difference between the total volume of water discharged and the total volume of rainfall at each moment. The test was carried out by monitoring all outflows at key time points within 1 h of rainfall cessation, from which the volumetric storage rate was calculated. By plotting the volumetric storage rate at each point in time, the water storage performance after the cessation of rainfall is characterized. The volumetric storage rate at this point is calculated in Equation (4).

$$a_x = \frac{i_w \cdot t_3 - m_x/\rho_w}{V} \cdot 100\% \tag{4}$$

In Equation (4), a_x represents the water storage rate after 1 h of rainfall has ceased, t_3 is the total simulated rainfall duration, and m_3 represents the total volume of water discharged after 1 h of rainfall has ceased. After establishing the method for determining the infiltration storage performance and explaining the definition and calculation of the indicators required in the test, the analysis of the infiltration storage performance of recycled brick mixes in sponge city applications was carried out.

3. Analysis of the Infiltration and Water Storage Properties of Recycled Brick Mix Aggregates

Firstly, the granularity of the recycled aggregates was varied to investigate the changes in the infiltration and water storage performance of the structural layer with different average granularity. Three grades of recycled brick aggregate, R1, R2, and R3, were set up, all with a structural layer thickness of 250 mm, aggregate grades of 0–5 mm, 5–10 mm, and 10–20 mm, structural layer masses of 17.42 kg, 16.95 kg, and 15.81 kg, respectively, and structural layer void ratios of 54.6%, 55.7%, and 59.3%, respectively. With a fixed rainfall rate of 180 mL/min, the obtained infiltration and water storage performance curve variation outcomes are shown in Figure 3.



(a) Permeability curve (b) Water storage performance curve

Figure 3. Seepage storage performance curve of different recycled brick concrete aggregate size fractions.

From Figure 3a, the recycled brick mixed coarse aggregate, i.e., the R2 and R3 groups, entered the permeability enhancement phase earlier, with both initial and full permeability times significantly earlier. The outflow rate was also higher than that of the recycled brick mix sand under the same rainfall calendar conditions. The 30 min water permeability of two groups of recycled brick mixed coarse aggregate is more than 3 times that of recycled brick mixed sand. The recycled brick mix layer has a strong capacity to adsorb and store water before permeability begins, and the resulting volumetric water attachment rate is five times higher than that of the recycled coarse aggregate, indicating that the permeability of the material is significantly influenced by the average particle size of the recycled aggregate. In Figure 3b, during the permeability enhancement phase, the better water retention effect was achieved by the recycled brick mix sand, which was able to achieve a volumetric water retention rate close to 30% at full permeability, indicating that most of the voids in the recycled sand layer were able to retain rainwater, while the recycled coarse aggregate voids had a poor water retention capacity. At the end of the rainfall, the 1 h volumetric water retention rate of the recycled brick mix sand was close to 26%, more than 1.5 times that of the recycled coarse aggregate in the R2 group and 2.5 times that of the recycled coarse aggregate in the R1 group, which has a stronger water retention capacity. By comparing the saturated water absorption rates obtained from the three grades, it can be observed that the recycled coarse aggregate has large voids, it is easy to form directly connected upper and lower void channels between the voids, and the degree of curvature is low, making rainwater infiltration relatively easy. The recycled sand, on the other hand, has a large degree of curvature and poor connectivity between the upper and lower voids, making it less susceptible to rainwater infiltration, but more conducive to locking in water. A comprehensive analysis of the infiltration and water retention performance of the different granular materials was carried out, and the relationships obtained are exhibited in Figure 4.

From Figure 4, different recycled aggregate grades have different effects on water storage and permeability performance. The two types of recycled coarse aggregates have a large difference in permeable water storage performance compared to the recycled brick mix sand. There is a cross-balance between the water storage and permeability variation lines for the different grades. From this, it can be observed that extremes in infiltration water storage performance occur with single-grain recycled brick mix aggregates. Based on the differences in infiltration storage capacity of the grain-level aggregates, a reasonable design can be made in the infiltration storage material ratio to achieve a balance of infiltration storage in rainfall of the structural layer materials. The influence of the layered gradation of recycled aggregates on the infiltration storage performance of the material under multi-layer single-grain conditions is then investigated. The infiltration storage performance of graded aggregates under different conditions was investigated by varying the volume share of the single-grain sand layer, planning different aggregate gradations at a rainfall of 180 mL/min, and stratifying the filler for each single-grain graded aggregate. The test numbers are L1, L2, and L3 respectively. The recycled brick concrete aggregate parameters of the three are 100%. The particle size of the upper filler is 10–20 mm, and the layer thickness is 100 mm, 75 mm, and 50 mm, respectively. The particle size of the middle layer filler of the three is 5–10 mm, and the layer thickness is consistent with that of the upper layer filler. The particle size of the lower layer of the three is 0–5 mm, and the layer thickness is 50 mm, 100 mm, and 150 mm, respectively. The mass of the three structural layers is 16.71 kg, 16.57 kg, and 16.25 kg, respectively, and the void fraction of the structural layers is 56.9%, 57.2%, and 57.9% respectively. The obtained material permeability and water storage performance curve is shown in Figure 5.

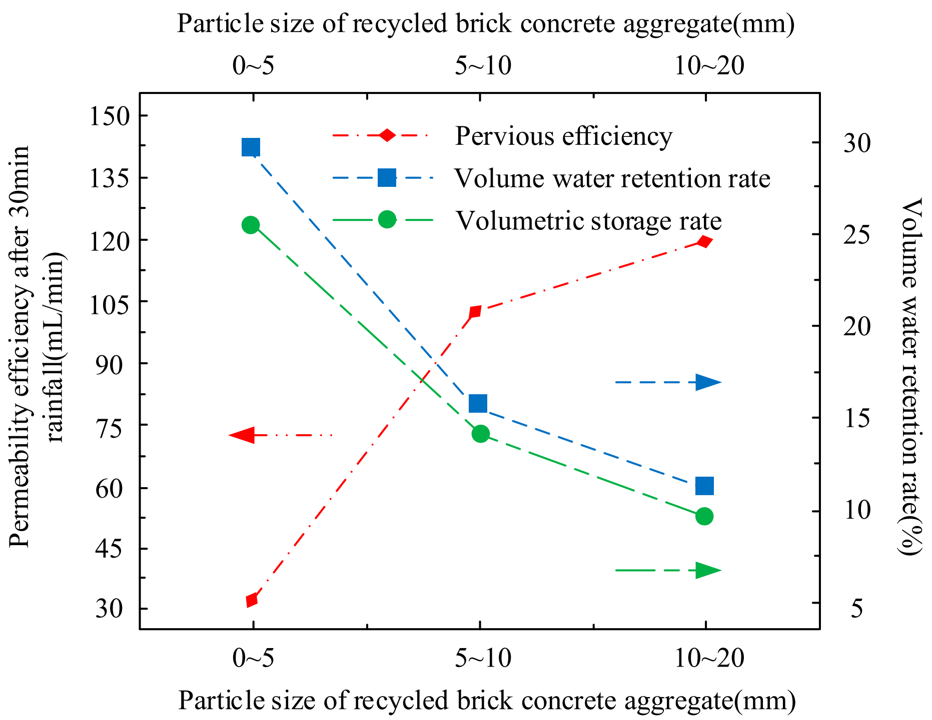


Figure 4. Influence of different gradation on permeability and storage performance of materials.

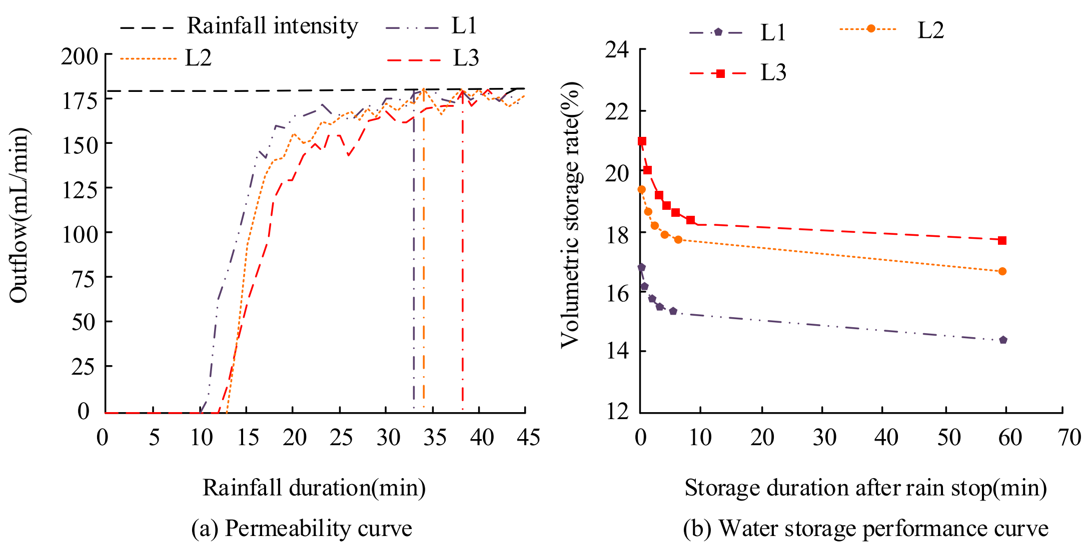


Figure 5. Infiltration and storage performance curve of materials with different multi-layer single-particle size gradation.

In Figure 5, L1, L2, and L3 all represent tests of different groups, and their recycled brick concrete aggregates have different gradations. From Figure 5, there are significant differences in the permeable water storage properties of the material depending on the gradation of the recycled brick mix aggregates. As the volume share of the recycled sand layer gradually increases, there is a corresponding delay in the fully permeable state and initial permeability time, and the volumetric water attachment rate also increases. At the same time, the 1 h volumetric water storage rate and volumetric water retention rate also increase as the sand layer percentage increases. The 1 h volumetric water retention rate increased by roughly 1.7% as the sand layer was gradually increased from 20% to 40%. The 1 h volumetric water storage rate increases by approximately 1.1% when the sand layer is gradually increased to 60%, thus indicating that the infiltration and storage performance of the structural layer is significantly influenced by the change in gradation. The reason for this is that the water storage performance of the recycled brick mix sand is stronger than that of the recycled brick mix coarse aggregate, and the lower limit of the overall water storage capacity in the stratified fill structural layer is determined by the amount of sand layer. The greater the volume share of the recycled brick mix sand layer, the more void structure is required to retain rainwater and the more easily rainwater can be stored in this structure. Therefore, when the volume share of the recycled sand layer is increased, the permeability is reduced, and the water storage and retention capacity is increased. A comprehensive analysis of the infiltration and water storage performance indicators for materials with different sand layer volume ratios results in the relationships demonstrated in Figure 6.

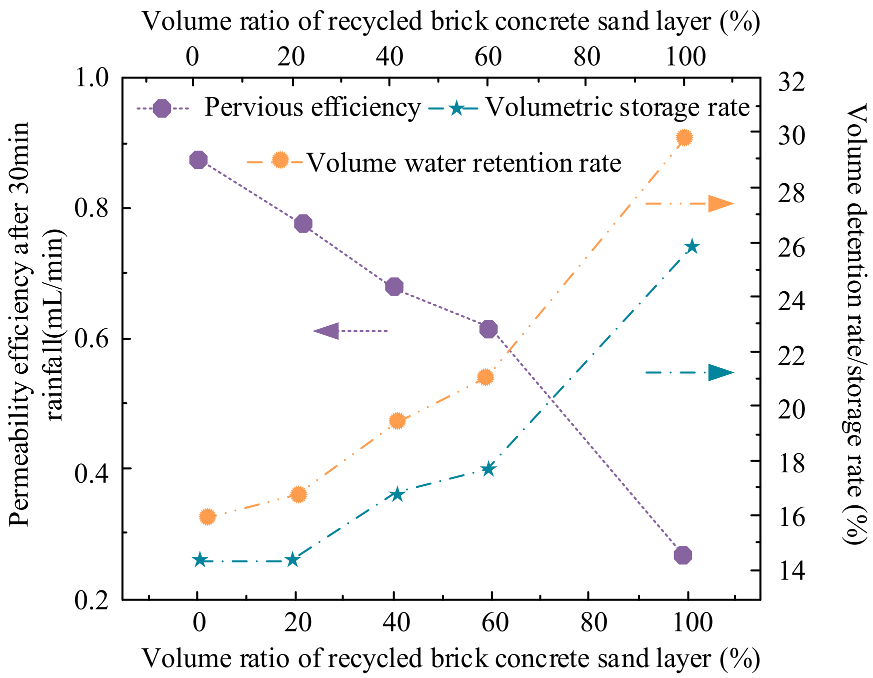


Figure 6. Influence of different gradation on permeability and storage performance of materials.

In Figure 6, as the volume share of the sand layer continues to increase, the water storage capacity and water retention effect of the material gradually increases, and the permeability decreases. The specific surface area of the overall aggregate changes as the gradation of the stratification changes and, more importantly, the voids between the particles change as well. The analysis of the outcomes combined with the average particle size demonstrates that the voids between the 0–20 mm single-graded particles store approximately 1.4% of the structure's volume of rainwater, 2.9% for 5–10 mm, and 12.5% for 0–5 mm single-graded recycled sand. This demonstrates that in a layered structure, the amount of water storage capacity is directly related to the volume share of the sand layer, so the infiltration storage performance can be adjusted by varying the volume share of the sand layer when adopting single-grain graded layered fill. The relationship between the volume of recycled aggregate and the infiltration storage capacity is then analyzed. The major difference between natural mechanism aggregate and recycled brick mix aggregate is the water absorption capacity of the aggregate particles, with the latter particles having a stronger water absorption capacity. The natural mechanism aggregate and the recycled brick mix aggregate were mixed evenly and divided into five groups according to different volume admixtures, and the filler situation is presented in Table 3.

Table 3. Filler of test structural layer.

Test No.	Void Ratio of Structural Layer (%)	Structure Layer Thickness (mm)	Recycled Brick Concrete Aggregate Content (%)	Quality of Structural Layer (kg)	Orthopedic Grade (mm)
T1	47.5	250	0	23.36	5–10
T2	49.7	250	30	21.43	5–10
T3	51.3	250	50	20.15	5–10
T4	53.9	250	80	18.23	5–10
T5	55.7	250	100	16.95	5-10

The rainfall rate for the fixed simulation was still set at 180 mL/min, and the outcomes obtained for the five different sets of volumetric admixtures of infiltration water storage performance are shown in Figure 7.

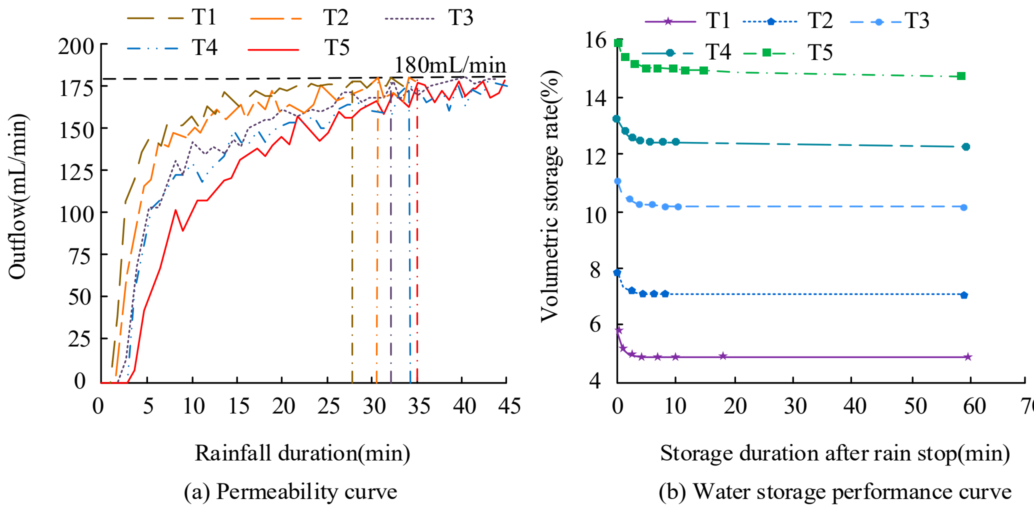
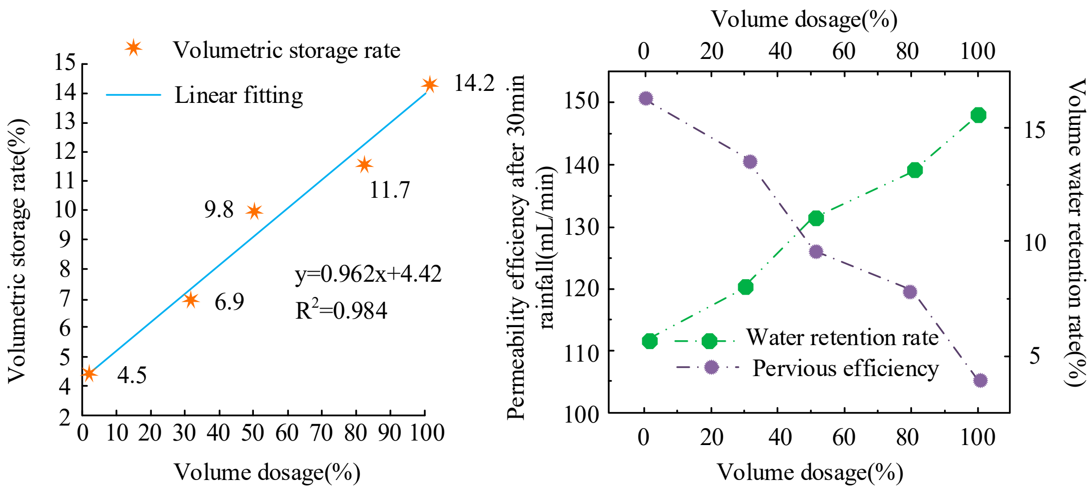


Figure 7. Seepage and storage performance curve of recycled brick aggregate with different volume content.

In Figure 7, as the volume admixture gradually increases, both the time to complete permeability and the initial permeability are delayed. As the volume admixture of recycled brick mix increases by 20–30%, the time required to achieve full permeability is delayed by approximately 2–3 min, and the volumetric water absorption rate increases by 0.2–0.9%. Furthermore in terms of volumetric water adsorption rate, recycled aggregates show close to 2.5 times that of natural aggregates. It can be observed that the permeability is influenced by the admixture of recycled brick aggregate; the greater the admixture, the poorer the permeability and the smaller the outflow rate for the same rainfall calendar time. During the permeability enhancement stage, the volume water retention rate obtained from pure recycled aggregate is close to 3 times that of natural aggregate. After 1 h of rainfall, the recycled brick aggregate exceeds the natural aggregate by a factor of 3 in terms of 1 h water retention rate. Therefore, increasing the volumetric admixture of recycled brick aggregate increases the void ratio, but instead the permeability decreases, and the water retention performance is significantly upgraded. This is because the increase in admixture does not change the void structure, the outflow rate still decreases, and more rainwater is impounded. The outcomes of the effect of different volume admixtures on the 1 h volume water storage rate and infiltration water storage performance indicators are shown in Figure 8.

From Figure 8a, the 1 h water retention rate at different dosing levels is 0.984, indicating that the effect of dosing on the water retention rate is linear and the slope of this linear relationship is 0.0962, thus demonstrating that the increase in dosing increases the volume share of the particles and therefore increases the water retention capacity. In Figure 8b, the water retention effect and the permeability of the material are linearly related to the amount of recycled brick aggregate, and the design parameter required to meet the infiltration and storage balance is 50% admixture. In summary, the infiltration and storage performance of the recycled brick mix aggregate are closely related to the characteristics of the aggregate particles, the amount of recycled aggregate, and the aggregate gradation, and with reasonable adjustments, the maximum infiltration and storage performance of the recycled brick mix aggregate in sponge city construction can be brought into play.



(a) Influence of different volume dosage on 1h volume storage rate

(b) Influence of Different Volume Admixture on Permeation and Water Storage Performance Index

Figure 8. Outcomes of influence of different volume dosage on 1 h volume storage rate and infiltration storage performance index.

4. Conclusions

Recycled brick concrete aggregate has become a material that cannot be ignored in the construction of permeable pavement in sponge cities. On the basis of the design of rainfall simulation facilities, the determination approach of the permeability and water storage performance of materials is determined, and then the permeability and water storage performance are analyzed by controlling the aggregate gradation, aggregate size, and aggregate type. The results show that the water permeability of the two groups of recycled brick mixed coarse aggregate over 30 min is more than 3 times that of recycled brick mixed sand during rainfall. In the stage of water permeability enhancement, the volume water retention rate of recycled brick sand can reach 30%, indicating that the average particle size of recycled aggregate has a positive correlation with the water storage capacity. At the same time, when the proportion of sand layer increases, the 1 h volume water storage rate and volume water retention rate also increase gradually. In the volume mixing test, the volume water absorption rate of recycled aggregate can reach 2.5 times of that of natural aggregate, and the volume water retention rate of recycled aggregate is close to 3 times that of natural aggregate in the stage of water permeability enhancement, which provides a reference for sponge city construction. However, in the process of test design, the consideration of the drainage velocity of the drainage pipe and the seepage velocity of the soil base is relatively insufficient, so it needs to be further optimized in this respect to simulate more real infiltration and impoundment processes.

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