Increasing groundwater replenishment through environmentally friendly parking lot pavement model

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Abstract. Paving blocks are basically permeable pavements, which can reduce surface runoff by infiltrate rainwater into the ground. So that the installation of paving blocks on parking lots has an environmental function for filling groundwater. However, what is happening in the field today is that paving blocks behave like an impermeable layer. When it rains, it cannot absorb water or only absorbs a little water so that inundations occur. This can be caused by, among other things, the installation of paving blocks or the improper pavement structure. Therefore, it is necessary to develop a model of the parking lot pavement structure that is environmentally friendly, while contributing to groundwater filling, and reducing the surface runoff. The research was conducted by making a physical model of the permeability test. Parking lot pavement structure with arrangement permeable paving block, bedding layer and graded based layer will be placed on a test kit equipped with a control valve. With the system of partly filtration, it will be possible to know the amount of discharge absorbed by the model. So that the parking lot pavement structure will be obtained that can contribute to groundwater filling and its application to various types of subgrade.

1. Introduction
Regional growth followed by rapid development has resulted in reduced water recharging areas and increased potential for flooding. Due to the impermeable surface of the soil, it will further increase the surface runoff and cause puddles because water cannot infiltrate into the ground [1]. So that the drainage load will also increase. Increasing the capacity of the drainage system is not effective, because it does not address the source of the problem. One solution to overcome this is to apply the concept of environmentally friendly drainage. Environmentally friendly drainage is defined as an effort to manage excess water by infiltrating water as much as possible into the soil naturally or draining water into rivers without exceeding the capacity of the previous river [2]. The application of environmentally friendly drainage, among others, can use the construction of infiltration wells, biopore, rainwater harvesting, or permeable pavement systems.

According to Suripin et al. [3] road pavements and impermeable surfaces associated with vehicle movement, such as driveways and parking lots contribute up to 70% of the existing impermeable soil cover in urban areas, where these areas are a source of increased drainage loads. Many parking lots, driveways, neighborhood roads and parks are currently being built using paving blocks. Paving blocks are basically permeable pavements, which can reduce surface runoff by infiltrate rainwater into the ground. So that the installation of paving blocks on parking lots, neighborhood roads or parks has an environmental function for filling groundwater. However, what is happening in the field today is that paving blocks behave like a impermeable layer. When it rains, it cannot absorb water or only absorbs a
little water so that puddles occur. This can be caused by, among other things, the installation of paving blocks or the improper pavement structure. Therefore, it is necessary to develop a parking lot pavement system that is environmentally friendly, which can contribute to groundwater recharge, and reduce the potential for flooding by reducing surface runoff. Suripin et al. [4] developed a permeable paving block system for parking lots with zero runoff of storm water, and conclude that permeable pavement with zero runoff can be developed. Factors that play a role include permeability of paving blocks, porosity of open graded base, permeability of subgrade, and rainfall intensity. The thickness of open graded layer needed is highly dependent on its porosity, and subsoil permeability, while rainfall duration has insignificant influence.

Permeable Pavement System is not only defined as a sustainable drainage system solution, but also as a technology for controlling surface water runoff pollutants from areas used as roads or parking lots, where contaminated water can infiltrate into the ground below. Permeable pavements have been shown to reduce harmful pollutants such as heavy metals, particulates such as suspended solids (sediment) and ammonia levels without the significant maintenance normally required for road ditches [5-6]. Hazardous pollutants in surface runoff have the potential to harm soil and groundwater resources if not adequately degraded and/or removed during infiltration. Therefore, the purpose of this research is to develop a parking lot pavement system that is environmentally friendly and can increase groundwater replenishment in various subgrade conditions.

2. Materials and Method

2.1. Materials. The main structure of the permeable pavement system consists of a permeable surface, bedding layer, aggregate storage base, subgrade, geotextile (optional) and underdrain (optional) (Figure 1). While the arrangement of the permeable pavement layers used in this study can be seen in Figure 2.

Permeable surface is the top layer that serves to absorb rainwater. There are several alternative permeable pavement layers, including porous concrete, porous asphalt, and permeable paving blocks. In this study, permeable paving blocks made from recycled concrete waste were used with an infiltration rate of 858 mm/hour. This infiltration rate is greater than the usual design rainfall intensity.

The bedding layer is the layer under the paving block that functions as a cushion as well as a base layer to ensure a flat surface. Based on ASTM 2017, the bedding layer generally uses aggregate with the size of ASTM no. 8 or ASTM 89 stone coarse (3/64” to 3/8”). The use of aggregate for the bedding layer is recommended to use aggregates of uniform size, meaning that the aggregate must be free of dust and other particles. Aggregate in the bedding layer is often called washed stone because its use must be washed first to remove fine particles and dust from the aggregate, this is intended to prevent clogging.
of the underlying layer, namely the open graded base layer [7]. In this study, a bedding layer with a size of < 5 mm was used.

![Figure 2. The structure of the permeable pavement system model](image)

Aggregate storage base or open graded base (OGB) is an aggregate layer below the bedding layer and above the subgrade which functions as a reservoir or storage area for surface water runoff. Base on Suripin et al. [4] various aggregates can be incorporated into a permeable pavement system as open graded base, as long as the voids between the particles are relatively large when compacted. In this experiment, the aggregate made of crushed stone passed through 19 mm sieve and retained on 9.5 mm sieve was used as open graded base.

Geotextile serves to limit the movement of fine grains into the open grade base and subgrade [9-10]. The geotextile used is non-woven geotextile with a weight of 250 g/m².

2.2. Test methods. In this research, partial infiltration flow system is used. Partial infiltration means that not all of the rainwater runoff is absorbed into the subgrade, but some of the runoff is absorbed into the soil and part of it is discharged through the underdrain which is then channeled into the nearest drainage channel or directly into the river (Figure 3). Therefore, an underdrain of PVC pipe with a diameter of 38 mm is required. For infiltration is also used PVC pipe with a diameter of 19 mm.

The study was conducted by measuring the permeability that occurs based on a certain rainfall intensity using a permeable pavement system model (Figure 4). The experiment was carried out 3 times with the same amount of rain intensity and underdrain capacity while the type of subgrade was different (Table 1). Rainfall will stop when inundation begins. The permeability was measured in terms of its intensity, which indicates the time taken for a specified depth of water permeate through the system. Outflow is the intensity of water that comes out through the underdrain. Infiltration is the intensity of water that infiltrate into the subgrade.
3. Results and Discussion

Based on the experiments conducted (Table 2), it can be seen that the start time for outflow in the three scenarios is almost the same, ranging from 6-8 minutes with OGB porosity between 42.02 % - 44.13 %. The relationship between pressure head and outflow in the three experiments resulted in the same trend, the higher the pressure head the greater the outflow produced until it reached the maximum outflow capacity limit (Figure 5). This similarity is due to the arrangement of permeable pavement layers, rainfall intensity and underdrain capacity used in each scenario is the same. This proves the model has a good performance.
Table 1. Research scenario

| Test | Rainfall Intensity (mm/hour) | Underdrain Capacity (mm/hour) | Subgrade type | Infiltration rate (mm/hour) based on [4,11] |
|------|-------------------------------|-------------------------------|--------------|-------------------------------------------|
| 1    | 254.2                         | 174.14                        | Loamy sandy  | 72.0                                      |
| 2    | 254.2                         | 174.14                        | Sandy loam – loamy sandy | 25.2 – 72.0 |
| 3    | 254.2                         | 174.14                        | Sandy loam  | 25.2                                      |

Table 2. Experimental results

| Test | OGB Porosity | Infiltration rate (mm/hour) | Time of onset of outflow (minutes) | Time of start of inundation (minute) | Outflow (%) | Infiltration (%) |
|------|--------------|-----------------------------|-----------------------------------|--------------------------------------|-------------|-----------------|
| 1    | 42.93        | 73.41                       | 6                                 | 81                                   | 63.10       | 36.90           |
| 2    | 44.13        | 52.93                       | 8                                 | 72                                   | 66.72       | 33.28           |
| 3    | 42.02        | 25.10                       | 6                                 | 53                                   | 74.29       | 25.71           |

Figure 5. Pressure head and outflow relationship graph

In different types of subgrade, it will have different infiltration rates [4,11]. The effect of the type of subgrade can be seen at the time of the start of inundation, the higher the infiltration rate, the slower the start of inundation (Table 2). The effect of subgrade can also be seen from the infiltration produced, the higher the infiltration rate, the greater the infiltration produced (Figure 6 and Figure 7). From Figure 6 it can be seen that the higher the pressure head, the greater the infiltration.

To get the same starting time for inundation, soil types with lower infiltration rates require a larger underdrain capacity or a thicker open graded base. However, so that more water infiltrate into the soil,
the subgrade with a low infiltration rate should have a thickened open grade base so that the water will stay in the storage longer and provide an opportunity to infiltrate into the soil.

![Pressure head and infiltration relationship graph](image1)

**Figure 6.** Pressure head and infiltration relationship graph

![Graph of infiltration and outflow that occurs](image2)

**Figure 7.** Graph of infiltration and outflow that occurs
Soil types with low infiltration rates require a thicker open graded base than soil types with higher infiltration rates [4]. This permeable pavement system model with partly filtration gives good results, some of the water can be absorbed into the soil (Table 2). The length of time it takes for water to infiltrate into the ground is longer than the time it rains [4]. Therefore the existence of an open graded base that functions as a temporary reservoir will provide a longer opportunity for water to infiltrate into the ground.

4. Conclusion
The permeable pavement system model with partly filtration flow can increase the amount of water that infiltrates into the ground so that this system can be used as a permeable pavement system in environmentally friendly parking lots. The amount of water that infiltrates into the soil depends on the rate of soil permeability. The existence of OGB which serves as a temporary reservoir provides more opportunities for water to infiltrate into the ground. Further research is needed to determine the difference in OGB thickness to the percentage of the resulting infiltration.

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