The Effect of Permeable Pavement on Pedestrian Walkway for Human Comfort

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Abstract. This paper describes the effect of material selection for the human movement’s comfortable space on pedestrian walkway. Social interaction between humans as well as human interaction with the surrounding environment take place in this pedestrian space. One of the important elements on the pedestrian space is the pavement material. The purpose of this study is to examine the relationship between the selection of permeable pavement material in the pedestrian walkway and the human comfort movement. The study case is conducted in the campus area of the University of Indonesia, where most of the pedestrian walkway is using permeable pavement material. The observation was held during the time before and after the rain. The discussion of this study includes the discussion of the character and performance of the permeable pavement material, the space created by human movement and the activities in the pedestrian walkway, and the effect of permeable pavement material on human comfort movement.

Keywords: Pedestrian Walkway, Permeable Pavement Material, Human Space, Interaction, Human Comfort

1. Introduction
Pedestrian paths are walkways that are specifically aimed for pedestrians. In this street space, social interaction can occur between humans as well as human interaction with the surrounding environment [1]. There are many factors from the environment that can affect the comfort of humans as pedestrian walkway users [2]. Inside the pedestrian walkway, there are elements that support human activities and increase human comfort. One of the factors that make direct contact with human is the base of the walkway made of the paving material. The elements on the pedestrian walkway must be attractive, supportive, and comfortable for the users. The chosen paving material must be considered in terms of its reflectivity, selecting materials that are produced by considering the environment, material that made of nature materials and permeable material [1]. The purpose of this study is to examine the relationship between the selection of permeable pavement material in the pedestrian walkway and the comfort of the human movement space on pedestrian path at the campus of University of Indonesia.

2. Literature Review
Based on its ability to absorb water, paving material can be categorized as a permeable and non-permeable paving material. Permeable paving material is material that allowed water to infiltrate and flow through the pavement surface and/or joints and openings [3]. Research has proven that permeable pavement is an effective method to reduce excess water flow and pollution from urban areas and can function properly with minimal maintenance [4]. Most materials for conventional paving are non-permeable which causes the flow of rainwater and other excess water not absorbed directly into the soil as they are directed straightforward to the sewer. Furthermore, this causes decreased water quantity in the soil and increased mass of water pollutants [5]. Based on the system and properties of permeable paving material, they can be categorized into four categories, namely porous asphalt (PA), pervious concrete (PC), permeable interlocking concrete Pavement (PICP) and grid Pavement systems (plastic/concrete) [6]. Permeable, porous and pervious materials have one thing in common: the installation requires an aggregate layer below the surface to receive rainwater [7].

Porous Asphalt (PA) looked similar to other conventional asphalt. The difference is their aggregates are removed so that they have a larger cavity than conventional asphalt. Usually, additional or aggregate materials of high quality are used that this material is more binding[8]. The rate of porous asphalt is between 18% - 25%. With the ratio of ordinary asphalt of high cavity, 2% to 3% [6].

Pervious concrete is produced by adding aggregate into the cement mixture to form a gap. Its appearance looked rougher than usual concrete [6]. 15 to 35 % of this material is a cavity obtained from removing small aggregate particles so that it is more porous [8]. Pervious concrete has two types of installation: pre-cast and cast in place [9].

Permeable interlocking concrete pavement (PICP) is made of concrete stone structures with some distance among the structures, so that the water flow can enter into the gap between these structures. The gap between materials is usually filled by aggregates [6]. Apart from concrete material, the same system can use burned clay [7]. There are two types of material properties used in this system which are non-permeable in terms of their non-porous surface and porous material [10]. Research has proven that this system is the most effective one to reduce pollutant that enters the soil, particularly hydrocarbons and oil pollution [9].

Grid pavement systems (plastic/concrete) are arrangements in the form of grids made of plastic or concrete which are usually filled by grasses or gravel rocks [6]. Concrete tuft block filled with grass has been available since the 1940s and 1970s to early 1980s, when they began to develop it using plastic material. This system can strengthen grass, stabilize the soil, and store gravel [7].

All types of material pavement could help reduce the volume of rainwater after the rain. When the surface of the walkway is dry after the rain, users would feel more comfortable and safer.

3. Method

3.1. Observation
To compare the whole conditions, the observations on five pedestrian walkways were carried out at two different times, before and after the rain. With the help of camera for the documentation, the observation was held from 15 April 2019 to 10 May 2019.

3.2. Questionnaire Survey
In addition to observations, surveys were also conducted in the form of questionnaires. This questionnaire survey is aimed to gather pedestrians’ opinions regarding their comfort. The questionnaire survey forms were distributed to 20 users at each observation point with the minimum requirement of passing pedestrian walkways 3 times a week, and a total of 15 questions.

3.3. Study Area
Figure 1 shows the study area located in campus University of Indonesia, Depok, Indonesia. In this area five pedestrian walkways that used permeable pavement selected. The pedestrian walkway is St.UI - FIB (A), St.UI - Fpsi (B), St.Pondok Cina-Balairung (C), Gerbang Kukusan (D), and Vokasi
These pedestrian ways were chosen after the author made an initial observation by making a list about the type of material used in the entire campus area and counting the number of people doing activities in the morning and evening. And these five locations were chosen because they used different materials and had high activity rates.

Figure 1. Observation point location.

### 4. Result and Discussion

Point A is the main pedestrian walkway since it has the largest width and sidetracks in the middle area. The total width of the walkway is 470 cm with a total distance of 200 m. Point B has a distance of 135 meters with a width of 190 cm. Just like point A, the walkway is flanked by forests with large and high trees. The path at point C is divided into 3 parts with different widths from the smallest to the largest are 100 cm, 200 cm and 280 cm respectively. Point D has a width of 160 cm and 220 cm with a total distance of 90 m. Point E is side by side with the vehicle's walkway and forests on the other side. It has a total distance of 200 m and the width of the walkway is 90 cm. In the end, the contour of the walkway increases.

**Table 1.** The list of paving material, plan and section of five observation points.

| Observation Point | Pavement Material | Plan and Section |
|-------------------|-------------------|------------------|
| A                 | Image             |                  |
| Material Type     | Square conblock   | Constone         |
| Size              | 20 x 20 cm        | 40 x 40 cm       |
| Ingredients       | Cement, mineral materials and color pigment. | Cement and mineral materials. |
Table 1 shows the site condition and kind of material used at the five observation points. Overall the five observation points used 3 types of paving blocks. Rectangular Conblock brick, square Conblock and Constone. Constone is a product manufactured by PT Conbloc Internusa in a square shape and has 2 shades of grey, namely light grey and darker grey. The difference between Conblock and Constone is the surface layer. The constone’s surface is coated with shot blast and it can be
smooth or rough [11]. Based on the observation, the observation point that used Constone type is newer than the one that used rectangular conblock brick or square conblock.

Figure 2, 3, and 4 shows the result of two questions in the questionnaire regarding the walkway condition after the rain. The questionnaire was answered by 20 respondents at each point with a total of 100 respondents.

**Figure 2.** Respondent’s evaluation about pavement material.

Figure 2 shows that score 4 has the highest value at point A (45%), C (65%) and E (40%). This indicates that the condition of the pavement material in the area is good although at the point C and E, based on the field observation, the age of the material is quite old and even damaged some areas. For point B, despite its more recent installation, the highest value is tied between score 2 and 3 (35%). This indicates that some of the correspondents considered the pavement material as not good and quite good. For point D, the highest value is score 3 (50%) which indicates that the respondent considers the pavement material as quite good.

**Table 2.** The condition on five observation points before and after the rain.

| Observation Point | Before Rain | After Rain | Condition After Rain | Possible Reason |
|-------------------|-------------|------------|----------------------|-----------------|
| A                 | ![Image](image1.png) | ![Image](image2.png) | There is a lot of puddle in several areas, especially in the middle part of the walkway. | The contour of the site, flat surface, and poor drainage system. |
| B                 | ![Image](image3.png) | ![Image](image4.png) | The puddle is only visible in one point on the edge of the walkway. | Imperfect installation of the pavement. |
Table 2 shows the condition after the rain on the five observation points. There are puddles caused by several factors. Some of those conditions included bumpy material or uneven surface, poor material installation or damage. Another factor is the condition of the site especially the state and slope of the soil contour. However, point B showed no visible and disturbing large puddle after the rain because of the contours that are slightly tilted so the water flow is not accumulated in the walkway area. A puddle is only visible at 1 point due to the improper installation of the material.

After the rain, the flow of pedestrian movement slightly changed because of the puddle in the walkway. Some pedestrians will change their direction or slightly jump to avoid the puddle. The speed of the movement becomes slower also as they are more cautious now.

Figure 3. Result of the questionnaire about seeing a puddle.
Figure 3 shows that most respondents stated to have seen puddle at all five observation points. In accordance with the field observation, puddle is well visible in all pedestrian walkways after the rain. For point A, 55% respondents have seen the puddle at least once and 35% respondents often seen the puddle after the rain. Point B, 50% respondents have seen the puddle at least once and 30% respondents often seen the puddle after the rain. Point C, 70% respondents have seen the puddle at least once and 15% respondents often seen the puddle after the rain. Point D 45% respondents have seen the puddle at least once and 55% respondents often seen the puddle after the rain. For point E, 90% respondents have seen the puddle at least once.

![Graph showing the percentage of respondents feeling disturbed by the puddle at different points.](image)

**Figure 4.** Result of the questionnaire about how they feel about the puddle.

Figure 4 shows that for point A, the most respondents give very disturbed response (75 %) and think that the only thing they can do is to avoid them. This is probably due to big size and loads of puddles seen on the walkway. Points B, C shows that the respondents are feeling disturbed (45% and 60% respectively) rather than very disturbed, while they feel very disturbed at point D (45%), and they think the only thing to do is to avoid the puddles. For point B, there is just one puddle seen on the edge of the walkway. The condition at point C and D is similar with the condition at point A. Lots of puddles spread along the walkway. For point E most people feel disturbed (60%) and think that what they can do is keep passing on the walkway. This is probably because the puddle is at the side of the walkway, so the pedestrians can keep walking at the other side of the walkway.

5. **Conclusion**

The purpose of this study is to examine how the relationship between the selection of permeable pavement material in the pedestrian walkway and the comfort of the human movement space on pedestrian walkway in campus of University of Indonesia. From the results of data analysis obtained from the observations that have been done directly and from the respondent's response from the distribution of questionnaires, it can be concluded that the use of permeable material on pedestrian walkways at the five observation points at the University of Indonesia does not play a role in increasing user comfort after the rain. More than 45% of respondents felt disturbed by the presence of puddle at the five observation points. This situation also caused a direction change of human’s movement on the pedestrian walkway. Additionally, the puddle could also harm the pedestrians because it is slippery and its dirty water could stain their clothes.

Thus, the material selection is not the only one factor. The other factors such as imperfect and poor installation of the material, second rate maintenance of the material caused damages to many areas , apart from the aging of old material. In turn, the optimum performance cannot be reached and the drainage system is not well functioned and does not support the work of the permeable material system. These eventually create puddles of water on the pedestrian walkway and interfered with the comfort of pedestrians. The construction factors of the pedestrian walkway can be studied further.
Acknowledgments
This research is funded by the Directorate of Research and Community Engagement of University of Indonesia under the grant of Hibah Publikasi Internasional Terindeks Untuk Tugas Akhir Mahasiswa (PITTA-B UI) 2019 [grant number NKB-0714/UN2.R3.1/HKP.05.00/2019].

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