CHAPTER 6

COMPARING THE SURFACE INFILTRATION RATES OF PERMEABLE PAVEMENT AND CONVENTIONAL ASPHALT PAVEMENT

6.1 INTRODUCTION
Permeable pavements have been known for allowing infiltration of water, which expedites the removal of surface runoff. Thus, the use of permeable pavements is increasingly becoming popular among road builders, as it alleviates the problem of water ponding on flat roads. Pavement surfaces with ineffective infiltration impedes the removal of surface runoff, which may lead to pavement cracking and deterioration due to water ponding on the pavement.

There are several types of permeable pavements available in the market, one being concrete grid pavers (CGP). CGP paving systems consist of concrete blocks with both voids inside and between the blocks. CGP generally has a maximum dimension of 60 mm x 60 mm, and a thickness of 90 mm. Voids range from 20 to 50 percent, while the minimum compressive strength is typically 35 MPa. The void spaces between blocks are commonly filled with top soil and grass, aggregate or sand. In contrast, conventional asphalt pavements consist of about 95 percent stone, gravel and sand by weight, and about 5 percent asphalt cement that acts as a glue to bind the pavement.

This study aims to investigate the difference between the surface infiltration rate of permeable pavement using CGP and asphalt pavement. Experiments were conducted at three car parks in Universiti Tun Hussein Onn Malaysia (UTHM), Batu Pahat. Two of the car parks consisted of parking bays with permeable pavement. One of it had void spaces filled with top soil and grass, while the other had void spaces filled with aggregate and sand. The third parking lot was completely paved with asphalt concrete.

6.2 LITERATURE REVIEW
Pavement surface courses not only carry horizontal and vertical wheel loads, but provide adequate skid resistance and also keep water from entering into the underlying pavement structure. Permeable concrete blocks such as CGP have voids within the blocks and void
spaces between blocks that can be filled with media such as soil, gravel or sand, which allow water to infiltrate through it.

The advantage of the installation of CGP is that it provides a landscaping alternative in car parks where the blocks that contain large vertical perforations are usually filled with soil and planted with grass. The purpose of permeable pavements is to allow storm water to permeate into the underground storage basin. Research has shown that permeable pavements were able to remove storm water runoff effectively. In addition, it is said that the exfiltration of permeable pavement contains lower concentrations of metal contaminants, such as lead, zinc and copper, compared to asphalt runoff. Apart from that, permeable pavements can act as a filter for some pollutants, by filtering chemicals such as automotive oil.

Water ponding on the pavement surface not only is detrimental to the pavement structure, but is also hazardous to traffic. It can decrease skid resistance, increase hydroplaning potential, limit driver visibility due to splash and spray, and cause difficulty in steering a vehicle over water puddles.

Surface runoff increases due to vast areas covered with impervious surfaces, which is closely related to urbanisation. Frequent heavy loading, lack of maintenance, and the formation level itself, which consists of clay soil, result in lower surface infiltration rate. It has been shown that regular maintenance of porous surfaces can significantly maintain high infiltration rates.

6.3 RESEARCH METHOD

Field testing on the infiltration rates of CGP permeable pavement and asphalt pavement was conducted in accordance with the ASTM C1701 method. The infiltration tests were conducted on CGP filled with soil and grass, on CGP filled with gravel, and on conventional asphalt pavement. The study locations are shown in Figures 6.1 and 6.2. The permeameter (cylindrical ring) used in the infiltration field test was developed using a polyvinyl chloride (PVC) pipe with an inner diameter of 300 mm, that was cut to a height of 50 mm as specified in ASTM C1701. The permeameter was secured to the pavement surface using plasticine that acted as a sealant to prevent water seeping out from the base. Surface temperature was measured around the field test area using an infrared thermometer in order to ensure that surface temperature at all test areas were constant to each other.
A pre-wetting test using water was carried out prior to actual tests by steadily pouring 3.6 kg of water into the permeameter to maintain a constant head between two marked lines (10 mm and 15 mm) from the bottom. A stopwatch was used to measure the time as soon as the water impacts the surface of the pavement until there is no longer free water present on the pavement surface. The infiltration time for the pre-wetting test was then recorded to the nearest 0.1 s.

The actual test was conducted using 3.6 kg of water that was poured into the permeameter (see Figure 6.3), similar to the aforementioned procedure. If the infiltration time for the pre-wetting test is less than 30 s, 18.0 kg of water is used instead. The mass of water ($M$) and the infiltration time ($t$) were recorded. The tests were repeated to obtain five
readings each (different points) at four randomly selected parking bays from the three car parks. The infiltration rate was then determined using the following formula:

\[ I = \frac{KM}{D^2t} \]  

(6.1)

where,
- \( I \) = infiltration rate (mm/hour)
- \( M \) = mass of infiltrated water (kg)
- \( D \) = inner diameter of permeameter (mm)
- \( t \) = time required for water to infiltrate through the pavement (s)
- \( K \) = permeability constant

**Figure 6.3:** Infiltration test using single ring permeameter

To compare infiltration rates of the pavement types, two hypotheses were set and tested for significance using the t-test for means of two populations with variances assumed to be unequal. This was to confirm the claim that infiltration rate obtained from field tests of CGP filled with media \((I_i)\) is expected to be higher than that of asphalt pavement \((I_j)\) is true or not. The hypotheses are as follows:

- **Null hypothesis**, \( H_0 \): The infiltration rates are equal, \( I_i = I_j \)
- **Alternate hypothesis**, \( H_a \): The infiltration rate for CGP is higher, \( I_i > I_j \)
The decision to reject the null hypothesis is made when the two-tailed P-value is equal to or less than (0.05), where $\alpha$ is the significance level corresponding to a 95% confidence level. Rejection of the null hypothesis ultimately means that the infiltration rate of CGP filled with media is significantly higher than that of asphalt pavement.

### 6.4 RESULTS AND CONTRIBUTIONS OF THE RESEARCH

Figure 6.4 clearly shows that permeable pavements using CGP filled with media such as soil, grass and gravel have a considerably higher infiltration rate than asphalt pavements. This study found that CGP filled with gravel has an infiltration rate 42 times higher than asphalt pavements, while CGP filled with soil and grass has an infiltration rate 15 times higher than asphalt pavements. It was also found that using gravel as fill media for CGP can result in infiltration rates 3 times higher than using soil and grass as fill media.

![Figure 6.4: Infiltration rates (mm/hour) measured randomly at four points on parking bay surfaces consisting of CGP filled with gravel, CGP filled with soil and grass, and asphalt](image-url)

The t-tests revealed that the infiltration rate of CGP filled with media is significantly higher than that of asphalt pavement. This was evident when infiltration rates of CGP filled with gravel, and filled with soil and grass were tested against those of asphalt pavement. The P-values obtained were both close to zero (refer to Table 6.1).
Table 6.1: Two-sample t-test results

<table>
<thead>
<tr>
<th>Pavement type</th>
<th>Mean</th>
<th>t_{statistic}</th>
<th>t_{critical}</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGP filled with gravel</td>
<td>453.46</td>
<td>19.73</td>
<td>2.09</td>
<td>4.08E-14</td>
</tr>
<tr>
<td>Asphalt</td>
<td>10.67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CGP filled with soil and grass</td>
<td>161.87</td>
<td>28.34</td>
<td>2.09</td>
<td>5.23E-17</td>
</tr>
<tr>
<td>Asphalt</td>
<td>10.67</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The findings imply that the permeability of CGP has a great capacity to allow surface runoff through its own voids and the void spaces between blocks that is filled with pervious media. CGP generally consists of a mixture with low sand or fines content, which results in void ratios between 15% and 30%. This significantly provides high infiltration rates, as the time taken by water to infiltrate increases with the increase of voids. In addition, capillary effect also influences the filtration of water through the pavement surface into the ground.

Nevertheless, traffic loading and age of pavement may exert some influence on the surface infiltration rate performance. Pavements that have been in service for a longer time and are subjected to greater repeated loading over time, eventually affects pavement structure and soil structure, thus influencing the infiltration of water. It should also be noted that lower infiltration rates may also be partly due to clogging from fines and sediments on the pavement surface.

6.5 CONCLUSIONS

From the field tests conducted in accordance with ASTM C1701 to compare the infiltration rates on pavement surfaces of car parks comprising of CGP filled with media and conventional asphalt, it can be concluded that permeable pavements using CGP have a far better infiltration rate than conventional asphalt pavements. CGP fill media type also influences the infiltration rate, as follows:

1. Permeable pavements consisting of CGP filled with gravel has an infiltration rate 42 times greater than that of asphalt pavement.
2. Permeable pavements consisting of CGP filled with soil and grass has an infiltration rate 15 times greater than that of asphalt pavement.
REFERENCES


