A Study on the Application of Permeable Interlocking Block Pavements in Roadway

Eui-Seok Han[1], Dae-Geun Park[2] , Won-Kyong Jung[3] and Jongeun Baek[4]

[1]Institute of Construction Technology, DONGIL Engineering Consultants, co. ltd, 7 Songi-ro 30-gil, Songpa-gu, Seoul,05800, Republic of Korea

[2]Seoul Institute of Technology, Research Project Team, Ph. D.,37, Maebongsan-ro, Mapo-gu, Seoul, 03909, Republic of Korea

[3]Korea Construction Quality Testing Institute, Ph. D., 990-30 Manse-ro, Wongok-myeon, Anseong-si, Gyeonggi-do, Republic of Korea

[4]Pavement ResearchCenter,Quality Inspection Office Division, Seoul Metropolitan Government, Ph. D., 131 Taebong-ro, Seocho-gu, Seoul, Republic of Korea

Correspondence e-mail address: dgpark@sit.re.kr

Abstract :

Recently, in many cities including Seoul, permeable concrete block pavements have been applied to roadway for the improvement of urban landscape, recovery of hydrologic cycle, and mitigation of heat island. In this study, permeable interlocking block pavements were constructed in a test section in urban area. An in-situ performance tests were conducted to evaluate the effect of base course materials on the permeability of the roads.

Key Words : interlocking block pavement base course material permeablity test; rainfall runoff

1. Introdouction

With rapid urbanization, lots of permeable surfaces such as forests and parks have been substituded by buildings and roads. The increase of imperable area are vulunerable to urban flood as well as drought because of abnormal hydrologic cycle that rains cannot infiliate into the ground sufficiently. Therefore, the city of Seoul enacted regulations to improve the hydrologic cycle. As a part of its action plan, permeable pavements were encouraged to be built on small roads less than 8 meters wide in order to allow much more rains to infiltrate into soil. The permeable pavements, however, have not been widely applied due to insufficient structural performance and high cost compared to conventional asphalt pavements. The purpose of this study is to evaluate the structural and functional performance of permeable interlocking block pavements using various in-situ performance tests. In particular, the sustainability and long-term performance were evaluated according to different types of base course materials of the permeable pavements.

2. Test road construction

For the study, a test road was constructed in a small road with thewidth of 6.8 meters nearby residential area and a small park. As shown in Figure 1, the total length of the test road was 180.35 m and a total of eight sections were applied. There are two groups of sections: The first group, sections of A,

B, C, and D, has the same permeable interlocking block in the wearing course but different types of base course materials; and the second group, sections of E, F, G, and H, has different permeable wearing surface but the same base course. In this study, only the first group was used to evaluate the effect of the base course materials on the performance of the permeable pavement.

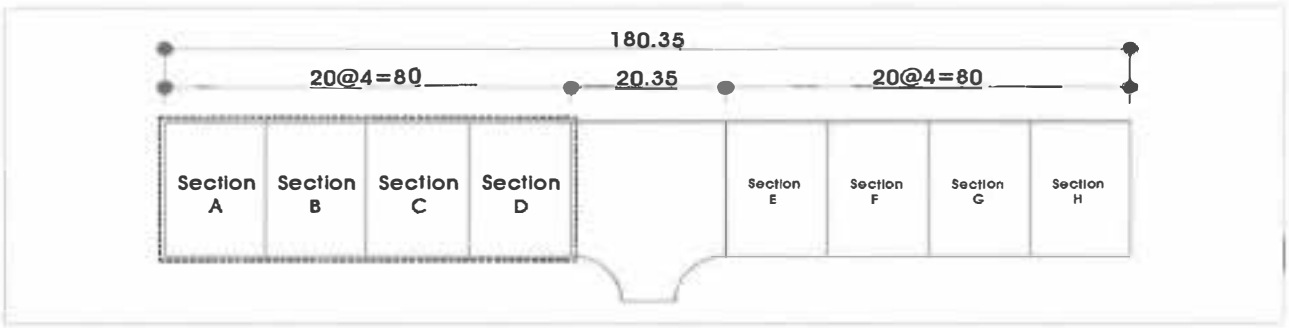


Figure 1. (a) Plane of Test Road

2.1 Test sections

The test sections mainly consisted of three layers: 80 mm of permeable block layer, 20 mm of bedding sand layer, and 400 mm of base and subbase course layer. In addition, a permeable sheet was placed between the bedding sand and base course and drain pipes were installed at the bottom of the subbase course. In the base course, different materials were used: Only aggregates in the section A, aggregates with bi-grid stiffener in the section B, aggregates with mesh type stiffener in the section C, and soil cement with aggregate holes in the section D. Detailed cross section and material information is referred to Figure 2 and Table 1.

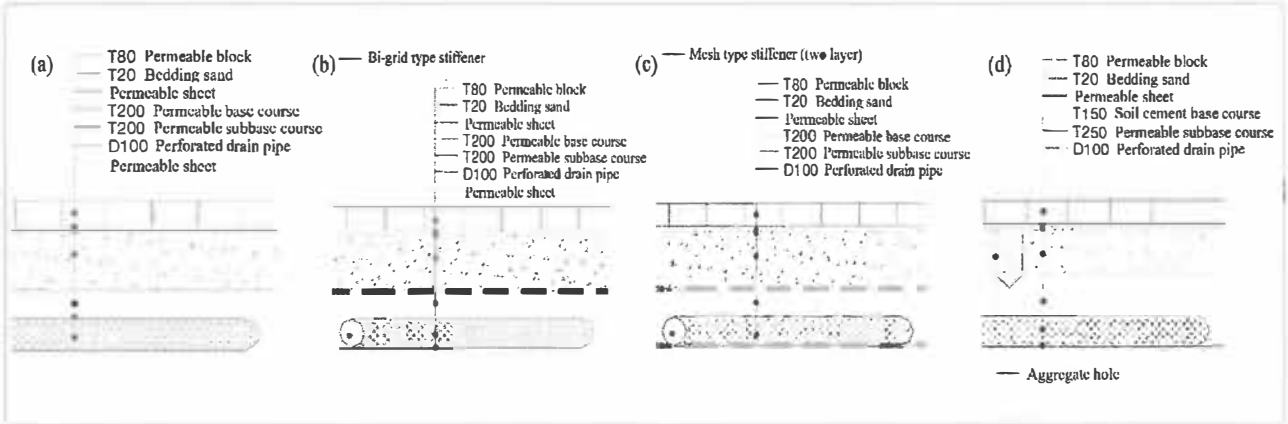


Figure 2. Cross Sections of Test road ((a) Section A : aggregates (b) Section B : aggregates + Bi-grid stiffener; (c) Section C : aggregates + mesh type stiffener(2 layer) (d) Section D + soil cement with holes)

Table 1. Variables of Test road

Items	Section A	Section B	Section C	Section D
Surface	T = 80 mm Permeable concrete block			
Base course	Aggregates	Aggregates + bi-grid stiffener	Aggregates + mesh type stiffener	Soil cement (+aggregate hole)

The design of the permeable block pavements was based on traffic volume, rainfall intensity, permeability coefficient, and duration of rainfall to consider the temporary rainwater detention, Q(m^3/m^2), of the permeable block pavements. In particular, to analyze the permeability coefficient of the test sections, a test bed excavation was conducted as shown in Figure 3(a). The type of subgrade of the pavement was determined as silty-gravel(GM) and clay-gravel(GC) according to the unified soil classification. The permeability of the soil was measured to 0.36×10-3(cm/sec) which is at the boundary between permeable and impermeable soil. Therefore, a perforated pipe was additionally installed to complement somewhat poor permeability of the subgrade as shown in Figure 3(b). Thus, rainwater could easily be drained to the lateral side of the road.



Figure 3. Test section construction: (a) permeability test in the subgrade and (b) perforated pipe installation

2.2 Base course construction

As shown in Figure 4, only aggregates were used for the base and subbase course in the section A. The section B had a specially-prepared stiffener, so called bi-grid stiffener which was inserted to the top side of the subbase course. In the section C, two mesh-type stiffeners were inserted on top and at the bottom of the subbase course. In the section D, impermeable soil cement was used as the base courseto increase bearing capacity of the road as the way of reducing permanent deformation. To secure sufficient permeability, several holes were drilled through the whole base course layer and aggregates were filled into the holes. The maximum particle size of aggregates was 75 mm for the subbase course and 25 mm for the base course. Also, the base coursehad only single-size aggregates to secure a sufficient permeability.

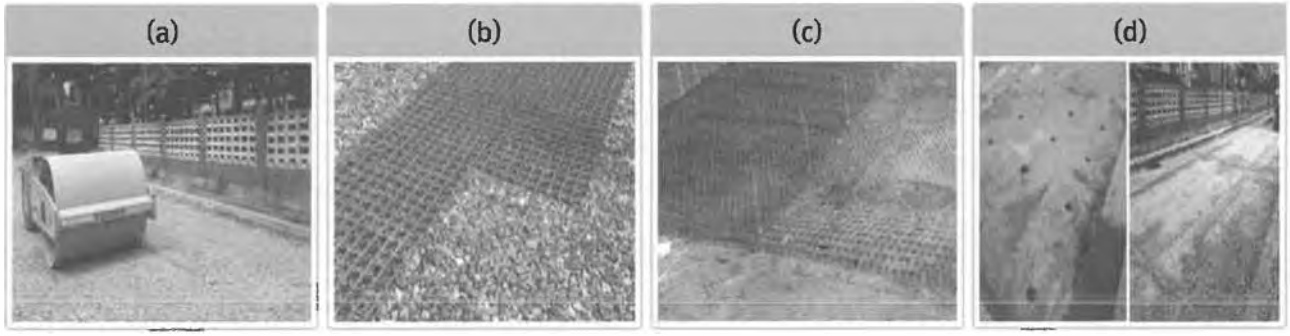


Figure 4. Types of base course: (a) Aggregates (b) aggregates + bi-grid stiffener (c) aggregates + mesh type stiffener (b) soil cement + aggregate holes

2.3 In-situ tests

In this study, a variety of in-situ tests were conducted to evaluate the performance of the permeable pavements in terms of skid resistance, longitudinal roughness, settlement, permeability, and infiltration. The field performance was done immediately, 5, 9, and 18 months after the construction. The British pendulum test was used to measure the skid resistance of the block pavement in terms of British pendulum number (BPN). A working profiler was used to measure International Roughness Index (IRI). Vertical settlement was measured to monitor structural capacity of the pavements. A single ring falling head infiltrometer test was used to measure field permeability and infiltration capacity of the pavement. Rainfall runoff analysis was carried out 20 months after construction for the section C, considering the duration of rainfall.

3. Test Results

3.1 Skid resistnace and longitudinal roughness

The BPN of the block pavements ranged from 51 to 54 right after the construction. After 5 months, the BPN of the block pavement decreased to 44~47 and was similar after 9 months and 18 months. The BPN of 32 to 47 was successful to satisfy the skid resistance criterion for small roads with low traffic volume. The IRI of the block pavement measured 5, 9, and 18 months after construction ranged from 4.27 to 6.18 m/km which is less than its requirement of 7.0 m/km for the small roads. Thus, the block pavement could be acceptable in terms of skid resistance and roughness for the use of small roads even 18 months after the construction.

3.2 Settlement

A vertical settlement of the each test section was measured from immediately to 5 months after construction. The vertical settlement was minimal from 3 to 5 mm in the sections. The settlement could result from initial consolidation of sand and deformation by repeated vehicular loads.
The settlement gradually increased by time because of the continuous loss of the joint and support sand. After 20 months later, the settlement increased to about 10 to 15 mm especially at the wheel-path without the supplement of joint and bedding sand. The section A was largely settled to the nearest 15 mm. And section B and C was settled in the range of 10 ~ 13mm. In case of section D, it was settled in the range of 7 ~ 10mm including initial consolidation.

3.3 Permeability

To evaluate the permeability of the permeable pavements, the amount of permeation and the infiltration capacity at the site were measured immediately after construction and after 5, 9 and 18 months. The in-situ permeability test according to KS F 2394 is a measurement of time for 400 ml rainwater to penetrate the road. As shown in Figure 5(a), the test sections A and B satisfied the quality requirement immediately after the construction and after 5 and 9 months. However, the test sections A and B showed poor permeability after 18 months and the section C showed poor permeability after 9 and 18 months. The test section D showed poor permeability immediately after the construction and 18 months after. The result of infiltration capacity test according to ASTM C 1701 as shown in Figure 5(b) was generally higher than 0.1 mm/sec, the requirement of Seoul. Since the rainwater is induced from larger areas, which is different from the permeability test results.

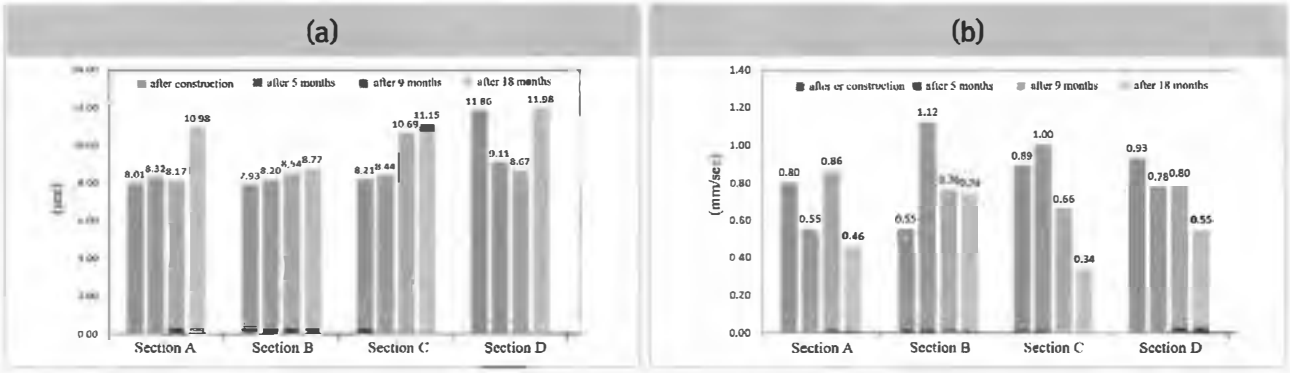


Figure 5. Permeability test results: (a) in-situ permeability test and (b) infiltration capacity test

3.4 Rainfall Runoff

At 20 months after the construction, as shown in Figure 6, the inflow and outflow during rainfall duration were measured.

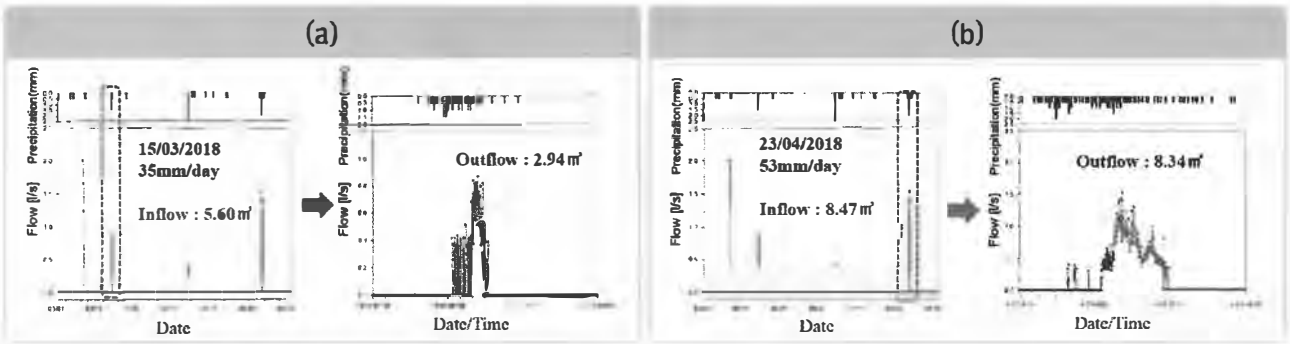


Figure 6. Results of rainfall runoff: (a) 8-hour-long rainfall and (b) 26-hour-long rainfall

To design the cross section of the permeable pavement, the duration of rainfall was considered as 1 hour while actual duration of rainfall was measured 8 hours and 26 hours at the site. In the case of after the 8-hour-long rainfall, there had been no rain for 6 days prior to the rainfall. Thus, the reduction of rainfall efflux was high about 47.6%. On the other hand, both the base and subbase course of the pavement had already been saturated with rainwater after the 26-hour-long rainfall. Therefore, the reduction was as low as 1.6%. This indicated that most rainfall was drained throughout the perforated pipe as the rate of inflow rainwater is higher than the permeability of the subgrade.

3.5 Noise and surface temperature

As a supplemental function of the permeable pavements, the reduction of noise and surface temperature in the test sections was evaluated. Compared to the asphalt pavement next to the test sections, the noise level of the test sections slightly increased at a speed of 60 km/h or higher. However, in the case of 30-40 km/h, the noise level was acceptable, ranging from 60-66 dB which is lower than 68 dB of noise level requirement for residential area. For the surface temperature reduction, it was found that the surface temperature of the test sections was basically 1 to 3°C lower than the asphalt pavement due to higher albedo of the block. After rainfall, the temperature was about 5°C lower immediately after rainfall which indicates the permeable pavement can provide more pleasant environment to pedestrians.



4. Conclusion

Hydrologic cycle of urban area is very difficult since most of urban are surfaced with impermeable materials including asphalt pavements. As a result, urban floods occur frequently due to localized torrential rainfalls. Therefore, permeable block pavements instead of conventional asphalt pavements can be a good option to improve the hydrologic cycle in urban roads. In this study, the applicability of permeable interlocking pavements was investigated in field. From the in-situ tests, it was concluded that the permeable block pavements could be applicable to small roads with the width of 8 meters or less.

The vertical settlement was larger in the order of section A, section B, section C, section D. However, the permeability was similar to that of A to C, while that of D was slightly small. Therefore, it is hoped that it will be reasonably applied to small-scale roads considering future vehicle traffic and permeability.

Acknowledgements

This study was carried out as a part of the 'Development of Material and Construction Technology for Reflective Coating Based Cool pavement and Permeable pavement (2017)' supported by Seoul Metropolitan Government.

References

[1] Baek, J. E., Park, D. G., and Han, E. S. Development of Material and Construction Technology for Reflective Coating Based Cool pavement and Permeable pavement, Project report No. 2017-21-2, Seoul Metropolitan Government, 2017.

[2] Cho, Y. H. Technological Development for Improved Performance of Permeable Pavement, Project report, Seoul Metropolitan Government, (2013)