CHARACTERISTICS OF NEW TYPE PERMEABLE CONCRETE BLOCK PAVING SYSTEM

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Summary

This thesis deals with the characteristics and performance of a new type permeable concrete block paving system developed by the authors to solve problems inherent to permeable concrete block paving and permeable asphalt paving used within Japan.

1. Introduction

In recent years "harmonization with nature" has become a key phrase in Japanese urban planning and government and municipal offices have adopted this as their basic policy. Following this trend, there is a movement among local governments to enact regulations stating that permeable paving must be used for newly-constructed footpaths. (Regulations have already been enacted in Tokyo, Osaka and Nagano Prefecture.)

The permeable paving used in Japan up until now, however, has the following problems, preventing them from accommodating the needs of the market.

- The surface material is restricted to concrete or asphalt, with permeable paving using natural rock, tiles or bricks deemed impossible.
- The gaps in the paving material are easily blocked, which reduces the permeability of the paving.
- Once the permeability of the paving has been reduced, it is difficult to restore.

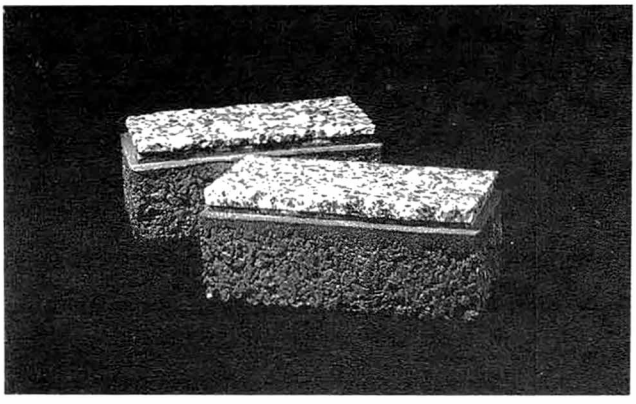
The authors developed a new type permeable concrete block paving system to resolve the problems inherent in conventional permeable paving.

2. Structure of New Type Permeable Concrete Block Paving System

2-1. Permeable Concrete Block Structure

As can be seen in Photograph 1, the blocks have a two layer structure comprising a porous concrete block above which is applied a special mortar bonded to a non-permeable material. Photograph 1 shows a block bonded to natural stone, but this could just as easily be ceramic tile or bricks, allowing the paving surface design to be changed almost at will. As can be seen in Fig. 1, which shows a cross sectional diagram of the block, the upper impermeable material is shaped to be smaller than the porous concrete, thereby creating a margin. This margin creates relatively large joints, which play the role of guiding the rainwater to the porous concrete layer and allowing it to return to the ground.

The method of manufacture and the manufacture facilities were described in detail at PAVE NEW ZEALAND '92, so are omitted here.



Photograph 1 Block Structure

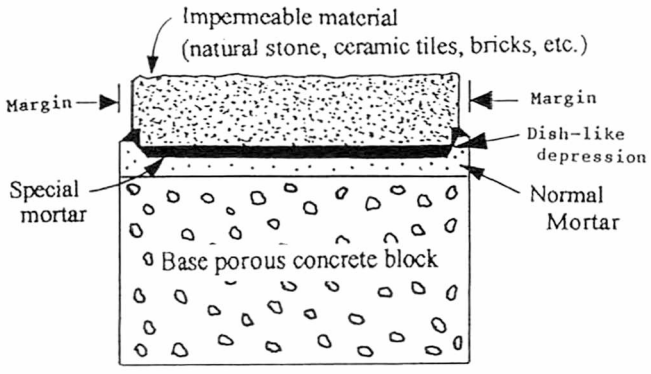


Fig. 1 Cross Sectional Drawing of Block

2-2, Paving System Structure

The structure of conventional permeable concrete block paving used in Japan is shown in Fig. 2. The joint material comprises sand filled in at every layer, and sand 0/2.5mm is used in the sandbed. In addition, the thickness of the base course is determined by the CBR of the subgrade.

The structure of the permeable concrete block paving system developed by the authors is shown in Fig. 3. Joint material is sand 0.6/1.2mm filled into the lower levels of the joint, and split 1.2/5.0mm filled into the upper layers .of the joint. For the sandbed, instead of the usual sand 0/2.5mm splitt1.2/5.0mm is used.

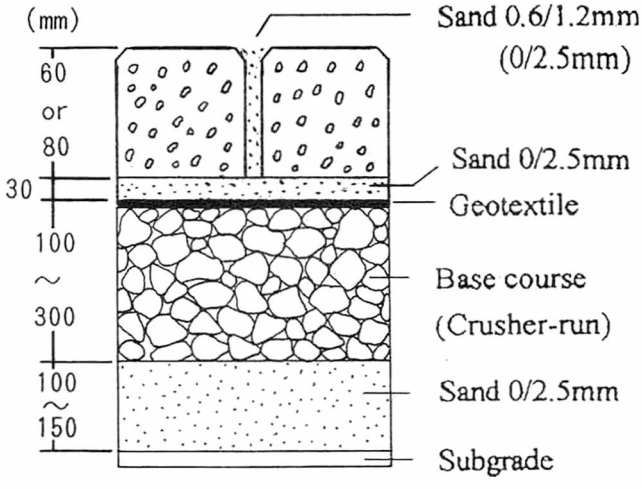


Fig. 2 Structure of Conventional Permeable Concrete Block Paving

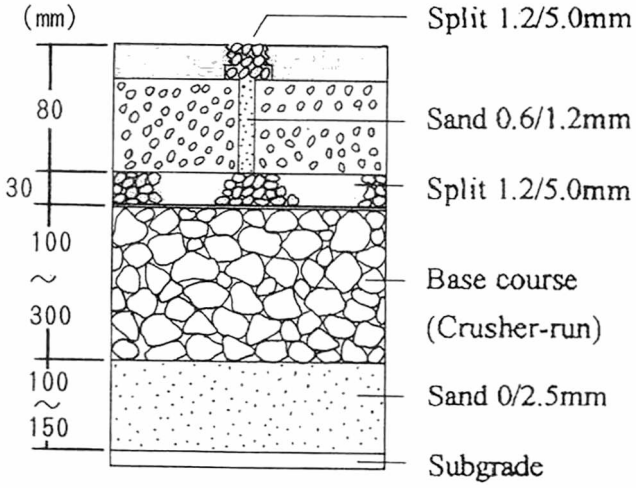


Fig. 3 Structure of New Type Permeable Concrete Block Paving System

2-3, Characteristics

Table 1 shows a comparison of the characteristics of the new type permeable concrete block paving system obtained by the structure above with the problems inherent in conventional permeable paving.

Table 1 Characteristics of New Type Permeable Concrete Block Paving System

Conventional Permeable Paving		New Type Permeable Concrete Block Paving System	
Problems		Improvements	Effect
	• The joint width of the joint-permeable type has narrow joint width and low permeability.	• Bonding of impermeable material on top of porous concrete block	• Surface material can be selected from natural stone, ceramic tile or bricks, etc., allowing design to be changed at will.
Permeable Concrete Block Paving (Joint-Permeable Type and Surface-Permeable Type	• Blockages occur easily in the sand surface section and in the sandbed surface, reducing permeability.	• By reducing the dimensions of the impermeable material a margin is created on the upper part of the block, and joint width is increased.	• Even the joint-permeable type is more permeable than both the conventional surface-permeable type of permeable concrete block paving and permeable asphalt paving.
	• In the event of a reduction in permeability, blockages cannot be removed from the sandbed surface, making it impossible to recover permeability.	• Lower layer of joint is filled with sand 0.6/1.2mmm and upper layer (margin) with split 1.2/5.0mm.	• Blockages occur mainly from split in the upper layer of the joints, and as blockage matter in the sandbed split is dispersed throughout the whole gap, reduction in permeability is minimal.
Aqueous Asphalt Paving	• Blockages occur easily in the base course surface, greatly reducing permeability.	• Split 1.2/5.0mm is used in sandbed.	• If a reduction in permeability occurs, permeability can be recovered simply by replacing the split in the upper layer of the joint.
	• In the event of a reduction in permeability, blockages cannot be removed from the base course surface, making it impossible to recover permeability.		• As the upper layer of the joint is composed of split it can be sucked up using a vacuum cleaner after spraying with water at low pressures of around 5kgf/cm^2.
Both Types of Paving	• Surface material is restricted to concrete or asphalt		

3. Performance of New Type Permeable Concrete Block Paving System

3-1. Permeability

(1) Measurement of Permeability Using a Constant Water Level Permeability Tester

Permeability of the new type permeable concrete block paving system was measured using the constant water level permeability tester shown in Fig. 4. For comparison purposes the measurements shown in Table 2 were also taken for conventional permeable block paving system and permeable asphalt paving.

Table 2-1 **Types of Paving Tested**

Test No.	Type of Surface Material	Structure of Sandbed and Joint Material	
1	New type permeable concrete block developed by the authors	● Upper layer of joint: split 1.2/5.0mm ● Lower layer of joint: sand 0.6/1.2mm ● Sandbed: split 1.2/5.0mm	→ Structure of Paving A
2	Conventional paving structure using the new type permeable concrete blocks developed by the authors	● Upper layer of joint: split 1.2/5.0mm ● Lower layer of joint: sand 0.6/1.2mm ● Sandbed: sand 0/2.5mm	→ Structure of Paving B
3	Conventional joint-permeable type permeable concrete blocks (integrated structure means no margin on upper section)	● All layers of joint: sand 0.6/1.2mm ● Sandbed: sand 0/2.5mm	
4	Conventional surface-permeable type permeable concrete blocks (1-layer finish: type which stresses function)	● All layers of join: sand 0.6/1.2mm ● Sandbed: sand 0/2.5mm	
5	Conventional surface-permeable type permeable concrete blocks (2-layer finish: type which stresses design, with fine aggregate on surface)	● All layers of join: sand 0.6/1.2mm ● Sandbed: sand 0/2.5mm	
6	Conventional permeable asphalt	No joints	→ Structure of Paving C

Table 2-2 Types of Paving Tested

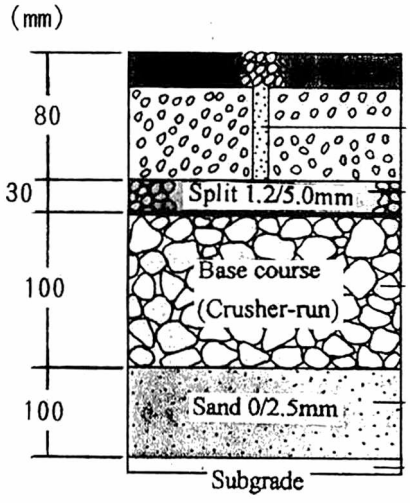
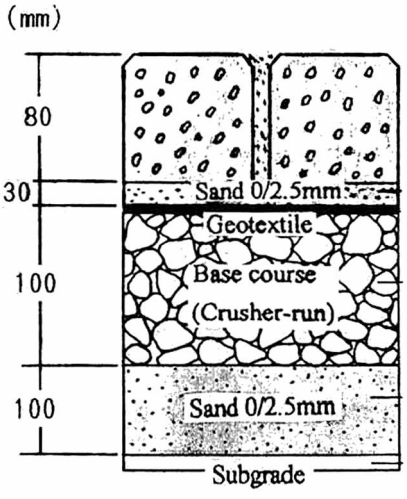
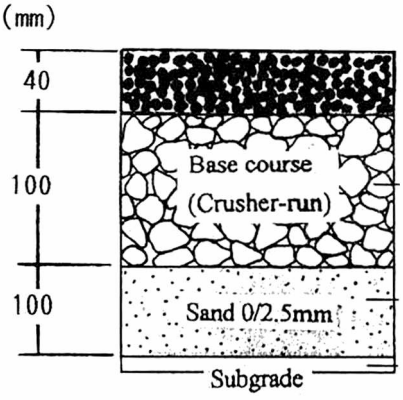
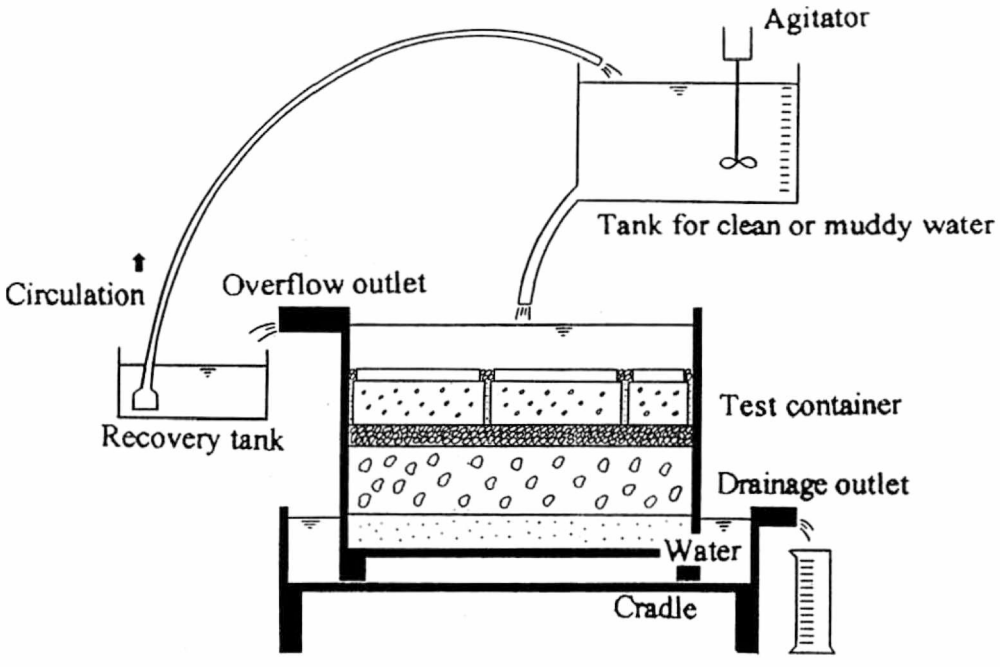
Structure of Paving A	Structure of Paving B	Structure of Paving C
New type permeable concrete block paving system developed by the authors	Conventional permeable concrete block paving	Conventional permeable asphalt paving
		

Table 3 Permeability Test Results

Coefficient of Permeability (cm/sec)	Surface Material Only (Including Joint Material)		Including Sandbed		Including Roadbed and Lower Sand Level	
Test No.	Observed Value	Theoretical Value	Observed Value	Theoretical Value	Observed Value	Theoretical Value
No. 1	0.088	0.066	0.127	0.188	0.044	0.044
No. 2	0.088	0.066	0.044	0.040	0.036	0.033
No. 3	0.013	0.015	0.010	0.014	0.024	0.020
No. 4	1.200	1.200	0.051	0.058	0.038	0.037
No. 5	0.021	0.021	0.025	0.019	0.027	0.024
No. 6	0.200	0.200	-	-	0.039	0.036
	0.010 or above	Specifications for surface materials of permeable asphalt and permeable concrete blocks within Japan				



(Permeable Area 50cm x 50cm)

Fig. 4 Constant Water Level Type Permeability Tester

The coefficients of permeability for each type of paving are shown in Table 3. The following observations about the permeability of the new type permeable concrete block paving system can be made from these results.

■ Coefficients of permeability for the surface material are inferior to those of conventional surface-permeable type blocks (1-layer finish) and permeable asphalt, but were approximately seven times better than conventional joint-permeable type blocks and approximately four times better than conventional surface-permeable type blocks (2-layer finish). These values mean that the new paving adequately satisfies the specifications for surface materials of permeable asphalt and permeable concrete blocks within Japan.

■ Coefficients of permeability that included the sandbed were more than double those recorded for conventional surface-permeable type concrete block paving.

■ Coefficients of permeability including the base course and filter layer are determined largely by the coefficients of permeability for the base course, so there was virtually no difference in coefficients of permeability between surface materials.

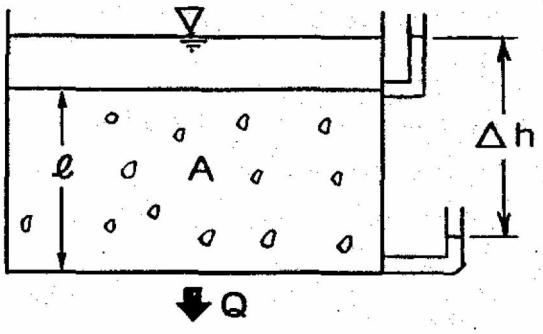
■ The theoretical values for coefficients of permeability calculated based on the principles shown in Fig. 5 correspond almost perfectly to the observed values. This means that if the individual coefficients of permeability can be established for the materials that constitute the paving (surface material, sandbed, base course, filter layer, etc.), an estimation can be made of the coefficients of permeability when these materials are combined.

(1) In the case of a single material

Darcy's Law

$$k = \frac{\ell}{\Delta h} \cdot \frac{Q}{A} \quad (cm/sec)$$

Head differential : Δh
Thickness : ℓ
Area : A
Capacity : Q
Coefficients of permeability : k

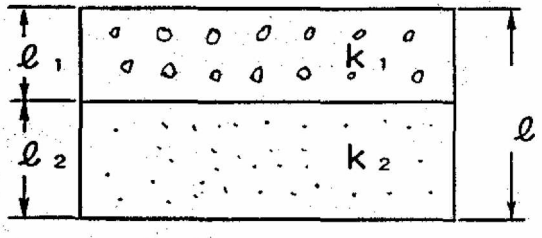


(2) When materials with differing coefficients of permeability are layered

Taking k as the average coefficients of permeability

$$\frac{1}{k} = \frac{\ell_1}{\ell} \cdot \frac{1}{k_1} + \frac{\ell_2}{\ell} \cdot \frac{1}{k_2} + \cdots\cdots$$

Thickness : ℓ_1
Thickness : ℓ_2
Total thickness : ℓ
Coefficients of permeability : k_1
Coefficients of permeability : k_2



(3) When materials with differing coefficients of permeability are adjoining

Taking k as the average coefficients of permeability

$$k = \frac{A_1}{A} \cdot k_1 + \frac{A_2}{A} \cdot k_2 + \cdots\cdots$$

Area : A_1
Area : A_2
Total area : A
Coefficients of permeability : k_1
Coefficients of permeability : k_2

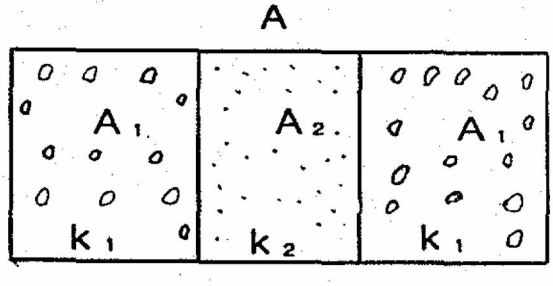


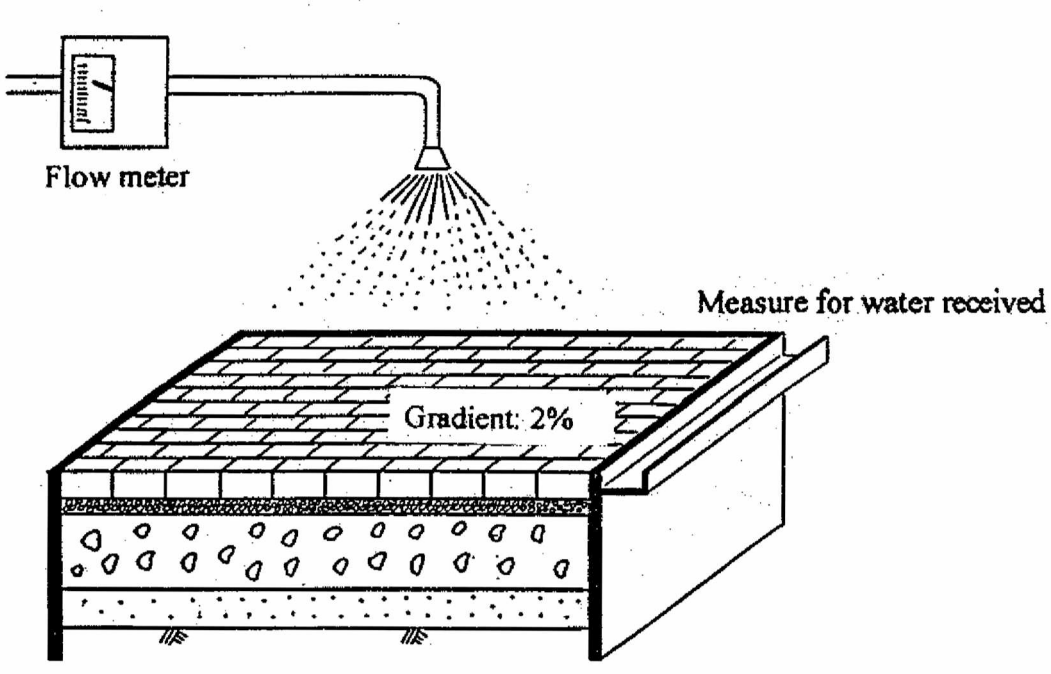
Fig. 5 Principles of Coefficient of Permeability

(2) Measurement of Permeability Using Artificial Rain Generator

The permeability of the new type permeable concrete block paving system was tested using the artificial rain generator shown in Fig. 6. Paving structure was the same as that used in Test No. 1. The following observations were made.

■ Under 100mm/hr, the maximum amount of rainfall able to be generated by this apparatus, surface run-off did not occur until the gaps in the paving were completely filled with water. The time taken for surface run-off to occur was determined largely by the permeability of the subgrade and base course thickness.

■ Taking into account the rainfall conditions in Japan, there is no problem with the permeability of the new type permeable concrete block paving system.



(Permeable Area 2m x 2m)

Fig. 6 Artificial Rain Generator

3-2. Recovery Performance in the Event of a Fall in Permeability

The ratio of decrease in permeability caused by blockage and recover performance in the event of such a drop in permeability for the new type permeable concrete block paving system were measured by injecting waste using the constant water level permeability tester shown in Fig. 4. The structure of the paving was the same as that used in measuring permeability (Test No. 1 in Table 1). For comparison purposes measurements were also taken for when sand is used as the sandbed (Test No. 2 in Table 1) and permeable asphalt paving (Test. No. 6 in Table 1). The results are shown in Table 7, and the following observations were made.

■ The reduction in permeability can be minimized by replacing the usual sand 0/2.5mm in the sandbed with split 1.2/5.0mm.

■ By using split 1.2/5.0mm in the sandbed, should a drop in permeability occur due to blockage of gaps in the paving, by spraying out the upper layer of split and cleaning up with a vacuum cleaner before filling with new split, permeability can be recovered to more than 70% of its original level.

■ These observations are confirmed by the significant accumulation of soil and waste that occurs in the surface layer when sand 0/2.5mm is used, compared to the dispersion of these materials in the gaps of the split and subseuqent accumulatiuon when split 1.2/5.0mm is used.

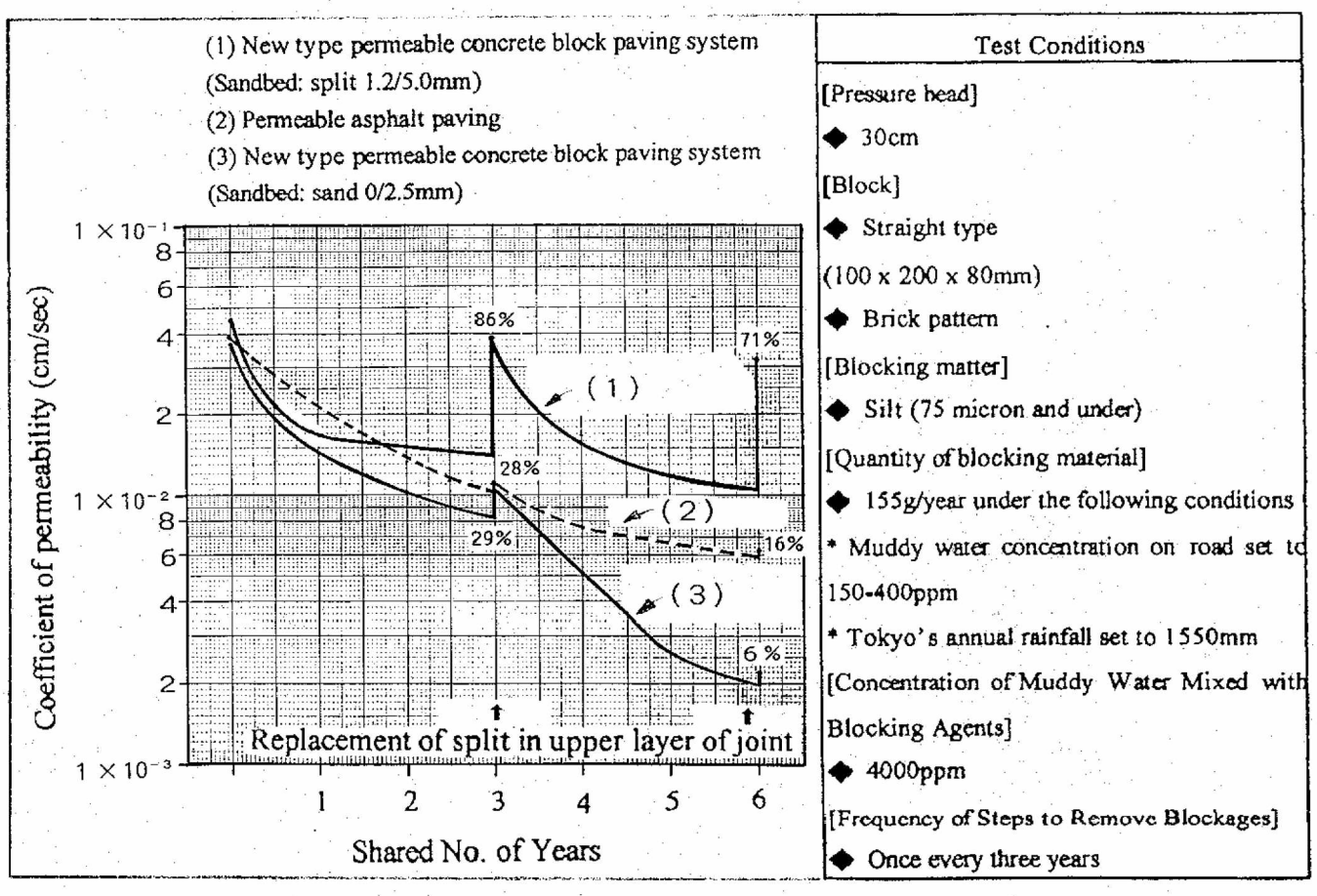


Fig. 7 Recovery Performance After Drop in Permeability

3-3. Field Test

The following observations were made from the results of the field test of the new type permeable concrete block paving system.

■ Even when split 1.2/5.0mm is used as the sandbed, the flatness and distortion of the paving surface was equivalent to the sand 0/2.5mm used previously.
■ A section of PVC pipe was implanted into the paving and a constant water level test carried out, the results of which indicated the recovery performance from a drop in permeability was similar to that indicated in the indoor tests.

3-4. Solid State Properties of Blocks

The strength, slip resistance and other solid state properties of the new type permeable concrete blocks vary according to the material bonded onto the surface, and when tried and tested materials such as natural stone, ceramic tiles and bricks are used, the blocks adequately satisfy the Japanese concrete paving block solid state property standards.

4. Conclusion

The superior performance possessed by the new type permeable concrete block paving system compared to conventional permeable paving types in use in Japan was verified in indoor and field tests.
Further long term field tests will be carried out in the future, and their results verified in terms of conformity with those of indoor tests.



Photograph 3 Tokyo University
(Working square : 1840m²)