PROPERTIES OF PERMEABLE CONCRETE BLOCKS WITH REVERSIBLE AND AESTHETIC SURFACES

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ABSTRACT

There is an increasing need for permeable pavement materials in Japan where precipitation is high, because such pavement materials allows rainwater to return to the underground, and so permeable concrete blocks are being developed by various organisations. The authors devised a new type of concrete block, which is permeable with reversible and aesthetically-pleasing surfaces. The main features of these blocks are that they have an innovative travertine-like texture, created by the combination of a smooth, polished-looking surface and pores of porous concrete on one surface, are easy to manufacture, and when deteriorated by clogging, their permeability can be restored by reversing the blocks. The blocks are produced by using crushed stone of 1.2 mm to 13 mm, setting the unit cement content at 550 kg/m^3.

1. INTRODUCTION

Permeable pavement materials enable rainwater to infiltrate into the ground and to return to the underground. This means that roads do not become flooded with rainwater, providing both pedestrians and drivers with a safer and more comfortable environment. For this reason, there has been an increasing need for permeable pavement materials in Japan, where the annual precipitation is high. Accordingly, the demand for pavement blocks is shifting to permeable paving materials, and as a result the development of concrete blocks is actively being carried out.

Through a series of studies designed to develop new features for permeable concrete blocks, the authors devised a new type of concrete block: a permeable concrete block with reversible and aesthetic surfaces (PCBRAS). This paper reports on the various properties of PCBRAS.

2. CHARACTERISTICS OF PCBRAS

Permeable pavement materials allow rainwater to infiltrate into the base course and subgrade and retain the water within the concrete, thereby offering various advantages such as the restraint of surface water runoff during rainfall and improvement of the vegetation, the underground ecosystem and temperature characteristics, as well as the reduction of vehicle noise.

However, in carriageways, a pavement system using permeable concrete interlocking blocks has not been popular, because such blocks are weaker than ordinary interlocking blocks due to their porous structure, and also because their performance deteriorates over time due to the clogging of pores. Today, despite such disadvantages, carriageway applications are increasing moving towards the introduction of high-strength permeable concrete blocks that incorporate a high-strength admixture specially designed for porous concrete.

Proceedings of the 7th International Conference on Concrete Block Paving (PAVE AFRICA 2003) 12th – 15th October 2003
ISBN Number: 0-958-46091-4 Sun City, South Africa
Proceedings produced by: Document Transformation Technologies Conference Organised by: Conference Planners

For pavements which are required to fit in well with the surrounding landscape or cityscape, there are permeable concrete blocks having as many shapes and colour tones as those of non-permeable ones. PCBRAS have the following main features:

- Unlike ordinary permeable concrete blocks, either surface (top or bottom) can be used as the road surface; an innovative travertine-like texture, created by a combination of the smooth, polished-looking surface and pores, characterize one surface.
- When deteriorated by clogging, their permeability can be regained by reversing the blocks upside down.
- Can be easily manufactured without additional capital investment.
- Can be used either for footways or carriageways.

Regarding the reversibility of PCBRAS, the two surfaces are interchangeable as a road surface: one surface offers a new aesthetic texture and the other has the ordinary texture. This new texture is created by a modified casting process and appropriately adjusting the rates and types of cement and aggregates.

The permeability of PCBRAS is restored by turning the blocks upside down when the pores become clogged, which is an inevitable drawback with a porous structure. Figure 1 shows changes with time in the permeability coefficient of PCBRAS, compared to ordinary permeable concrete blocks. This data was obtained by measuring the permeability of two types of blocks, each laid on a 50 cm x 50 cm area. To accelerate the clogging process, a clogging material was infiltrated into the blocks up to the equivalent of one, two, three and four years of service, respectively. It was found, that although the longer the blocks were used, the lesser their permeability became, reversing the PCBRAS when two years elapsed mitigated the clogging to a satisfactory degree, as is shown in the increase of the permeability coefficient level. On the contrary, the clogging of ordinary blocks was not mitigated sufficiently by the conventional common methods used for unclogging, such as jet-washing and vacuuming when two years had elapsed, as shown by the low coefficient level. When there was no infiltrated clogging, the two types of blocks showed more or less the same permeability. It is assumed that the smallness of pores near the surface of the PCBRAS helped prevent soil particles from entering, and thus they were able to regain permeability to a higher degree than ordinary blocks.

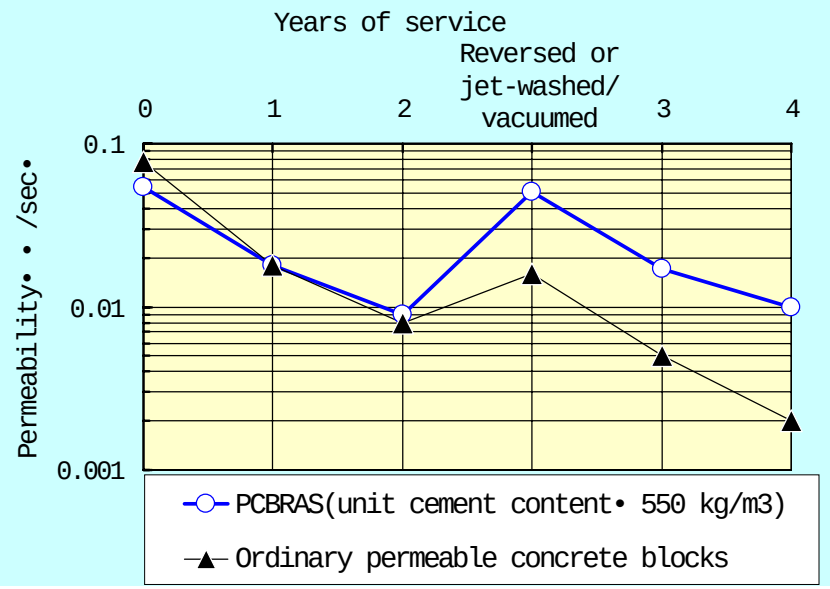

Figure 1. Changes with time in the permeability coefficient of the blocks.



Photo 1. Surface of PCBRAS using ordinary Portland cement (right) and surface of an ordinary permeable concrete block (left).



Photo 2. Surface of PCBRAS coloured with pigment (right) and surface of an ordinary permeable concrete block (left)

Photos 1 and 2 show examples of the blocks. Photo 1 compares the surface of PCBRAS that contains ordinary Portland cement and that of an ordinary permeable concrete block.
Photo 2 shows PCBRAS that contains ordinary Portland cement mixed with pigment, which gives a calm, tasteful shade to the surface, unlike with ordinary concrete.
Photo 3 shows a layout example. The surface appearance looks like a stone-pavement, adding a historical touch to the tasteful texture.



Photo 3. Block layout example.

3. PRODUCTION OF PCBRAS

3.1 Materials

Table 1 shows an example of the materials used for producing PCBRAS, which include ordinary Portland cement and the JIS A5001 #7 crushed stone, ranging from 1.2 mm to 5 mm (JIS: Japanese Industrial Standard).

Table 1. Example of material used.

Material	Description
Cement	Ordinary Portland cement
Coarse aggregates	Crushed stone: #7 (1.2 mm to 5 mm)
Admixture	Super plasticizer

3.2 Target properties of PCBRAS

Table 2 shows the target properties of PCBRAS in the production process. The permeability performance of each concrete block must be verified as 1 x 10^{-2} cm/sec or greater, by conducting a constant head permeability test. The permeability performance of a permeable concrete block pavement must be verified as 300 ml per 15 seconds or greater, by conducting an on-site permeability test. If one of the blocks in a pavement proves to have a permeability coefficient of 1 x 10^{-2} cm/sec or greater, the pavement is considered to satisfy the requirement for permeability. Therefore, the target permeability coefficient of PCBRAS was set as the target for a unit block. Note that the target values adopted here are those set by the Japan Interlocking Block Pavement Engineering Association.

Table 2. Target properties.

Property	Target value
Permeability coefficient	1 x 10^{-2} cm/sec or greater
Flexural strength	3 MPa or greater

3.3 Determination of mixture proportions

One of the characteristics of permeable concrete blocks is that the percentage of pores, i.e. the permeability coefficient, varies inversely with the flexural strength. Therefore, an optimal range of percentage pores that provides a good compromise between permeability and flexural strength must be found by examining various percentages of pores. To achieve this objective, various levels of cement contents in mixture proportions must be tested. In order to produce a block with the target properties shown in Table 2, block specimens having a variety of unit cement contents were made, and the permeability and flexural strength were measured to determine the optimum mixture proportions. Note that concrete was placed in one lift for each block specimen.

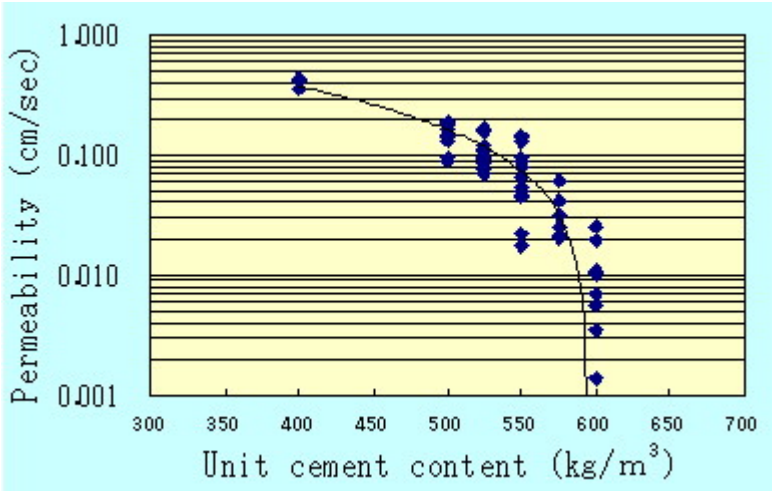

Figure 2. Relationship between unit cement content and permeability coefficient.

3.4 Results of mixture proportion examination

The relationship between the unit cement content and permeability coefficient and the relationship between the unit cement content and flexural strength are shown in Figs. 2 and 3, respectively. As shown in Fig. 2, the permeability coefficient requirement of 1 x 10^{-2} cm/sec or greater was satisfied when the unit cement content was 575 kg/m^3 or smaller.

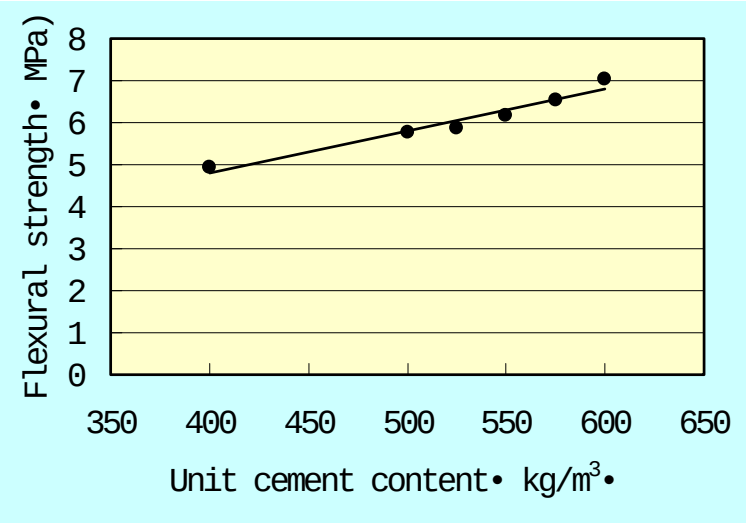

Figure 3. Relationship between unit cement content and flexural strength.

Considering production variance, it would be safe to set the unit cement content at 550 kg/m^3 or smaller. As shown in Fig. 3, the flexural strength requirement of 3 MPa or greater was satisfied when the unit cement content was 400 kg/m^3 or greater. Photo 4 shows smooth, polished-looking surfaces obtained by adopting various unit cement contents in the production process. Starting from the left, the unit cement content was set at 400, 500, 550 and 600 kg/m^3. As shown here, the unit cement content of 550 kg/m^3 produced a texture with a balanced mixture of smooth, polished-looking surface and pores. In addition, if the unit cement content is set at 550 kg/m^3 or greater, the flexural strength will be 5 MPa, which would be sufficient for carriageway applications.

Based on the above results, the value of 550 kg/m^3 was designated as the appropriate unit cement content; a mixture proportion example is shown in Table 3.

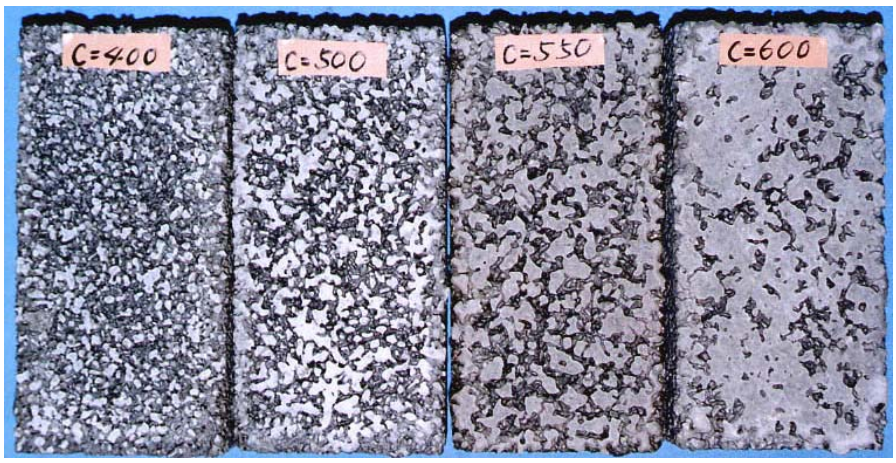

Photo 4. Smooth, polished-looking surface obtained for various unit cement contents. (Starting from the left, the unit cement content is set at 400, 500, 550 and 600 kg/m^3.)

Table 3. Example of mixture proportion.

W/C ratio (%)	Unit content (kg/m^3)			
	Water	Cement	Coarse aggregates	Admixture
23	126	550	2058	8.25

4. CONCLUSIONS

The main features and mixture proportions of the reversible permeable concrete blocks with a new aesthetic quality developed are summarized as follows:

- Unlike the ordinary permeable concrete blocks, either surface (top or bottom) can be used as the road surface; an innovative travertine-like texture, created by a combination of the smooth, polished-looking surface and pores, characterize one surface.
- When deteriorated by clogging, the permeability can be restored by reversing the blocks upside down.
- Can be easily manufactured without additional capital investment.
- Can be used for either footways or carriageways.
- Can be properly manufactured by using crushed stone of 1.2 mm to 13 mm, setting the unit cement content at 550 kg/m^3.

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A BRIEF RESUME OF MINORU HATA

Engaged in research and development of interlocking block for 20 years since he entered Taiheiyo Cement Corporation.

Engaged mainly in evaluation of interlocking block applied to motorways, development of composite interlocking block using tile and natural stone, development of high strength permeable interlocking block for motorways and development of water retentive interlocking block..