DURABILITY EVALUATION OF GEOTEXTILES UNDER THE CUSHION SAND LAYER OF SEGMENTAL BLOCK PAVEMENTS

Katsuhiko Makiuchi[1], Kunio Minegishi[2] and Yukio Sugita[3]

[1]Professor of Geotechnical Engineering, College of Science & Technology, Nihon University, Funabashi City, Chiba, Japan, Tel: +81-47-474-5217, E-mail: makiuchi@trpt.cst.nihon-u.ac.jp
[2]Research Associate, College of Science & Technology, Nihon University, E-mail: kmine@trpt.cst.nihon-u.ac.jp
[3]Deputy General Manager, Specialty Business Unit, Nisseki Plasto Company Ltd, Tokyo, Japan, Tel: +81-3-3501-7643/38, E-mail: sugita-yukio@npcc.co.jp

SUMMARY

With segmental block pavements such as interlocking concrete block pavements, a cushioning layer of sand plays an important part in maintaining the evenness of the block surface and the interlocking action between the blocks under traffic loading. Since the surface block layer is permeable, rain water can easily cause the cushion sand to migrate to the base course. To prevent the depletion of this high-quality natural sand in Japan and to improve the durability of the pavements, a permeable fabric sheet (also known as a geotextile) is laid under the layer of cushion sand for the purposes of separation and reinforcement. This reduces the maintenance costs and promotes satisfactory long-term pavement performance.

This paper describes a laboratory simulation test apparatus and procedure developed for evaluating the performance of geotextiles under repetitive loading. Two types of geotextile were examined: a non-reinforced fabric sheet (needle-punched nonwoven geotextile) commonly used in actual block pavements in Japan, and a new type of reinforced fabric sheet (CLAF-reinforced nonwoven geotextile) which is classified as a 'geocomposite'. The evaluations were carried out with the geotextiles in both the air-dry state and when submerged under water in order to investigate the damage done to the geotextiles by repetitive loadings. It is clear from the results of the experiments that when subjected to repetitive loadings, the reinforced geotextile has superior durability to the non-reinforced one.

1. INTRODUCTION

Interlocking concrete block pavement was first introduced into Japan in 1976. Since then, interlocking concrete block pavements have been used for roadways, footpaths, walkways in parks and shopping malls, being constructed at a rate of about 8,000,000 m^2 per year (as of 1999). Recently interlocking concrete block pavements used for carriageways have accounted for about 10% of all the interlocking concrete block pavements in the country. At present there is considerable demand to expand the use of these pavements to heavily trafficked roads. Fabric sheets (also known as geotextiles) have been used as permeable layers for about ten years in this country. The Japanese Design and Construction Manual for Interlocking Block Pavement (JIPEA, 1987) recommends, depending on the situation, that a fabric sheet be used at the interface between the cushion sand layer and the base course for purposes of separation and for the drainage of any water that has penetrated the pavement. It is obvious that the combined use of fabric sheets and good-quality cushion sand will be advantageous for the long-term performance of block pavements.

The primary aim of this study was to investigate the durability of segmental pavements, using a simple laborarory apparatus. The secondary aim was to compare the newly developed reinforced geotextile with the nonreinforced one commonly used in our country. Placing a geotextile under the cushion sand layer helps to cut down on maintenance costs. From the point of view of long-term maintenance costs and considering the increasing costs of good-quality sand in Japan, it is less expensive to lay geotextiles than to use good-quality sand. Regarding the mechanism of damage to geotextiles, it is presumed that under repetitive loadings the settlement of blocks exerts a pulling force on the geotextile sheet, and the rough, hard stone aggregate in the granular base penetrates the sheet, punching holes into it.



Figure 1(a) Laying of fabric sheet on the base course



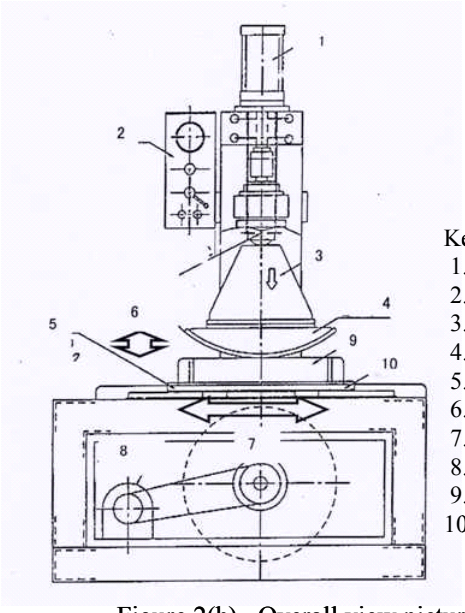
Figure 1(b) Placing surface blocks on the sand cushion layer

Figures 1(a) and (b) show how the fabric sheet is laid on a construction site. The selection of the

geotextile is done on the basis of experience of how easy it will be to lay and on the cost. The thinner a geotextile is, the more likely it is to be damaged, whereas the thicker a geotextile is, the more easily the cushion sand particles move, as a result of which the blocks gradually subside. For reasons of cost, a nonwoven geotextile with a mass of about 60 g/m^2 per unit area, which is the index of thickness for sheet materials, is commonly used in Japan. In recent years, the consumption of these geotextiles has amounted to about 1,000,000 m^2 per year. Furthermore, with the aims of building good-quality block pavements for heavily trafficked roads and of preventing the migration or loss of cushion sand, the use of geotextile (fabric sheets) has been increasing steadily in the country. There are a variety of geotextile products on the market and advanced types of geotextiles are gradually appearing. However, for various reasons, thin nonreinforced, nonwoven geotextiles are used in Japan. Given this situation, it became a matter of urgency to establish a standard testing method for material selection.



Figure 2(a) Overall view of the testing apparatus



Key
1. Pressurizing oil cylinder
2. Control panel
3. Pressurizing = Rolling
4. Roller
5. Left-and-right motion stroke
6. The maximum rolling height
7. The moving Length (stroke)
8. Motor
9. Mould
10. Sliding table

Figure 2(b) Overall view picture of the testing apparatus

A research committee on the standardization of a performance evaluation method for fabric sheets for block pavements, under the chairmanship of Prof. K. Makiuchi, at the Japanese Construction Material & Housing Equipment Industries Federation (known as KENSAN in Japan), under the auspices of NEDO (New Energy and Industrial Technology Development Organization, Japan), has developed a laboratory test method for evaluating the performance of a fabric sheet placed under the cushion sand layer of interlocking concrete block pavements, based on a large quantity of data from full-scale field trials on interlocking concrete block pavements conducted by the Research Institute of Public Works, Ministry of Construction, Japan, and on laboratory tests (KENSAN, 2001 and 2002). It is now proposed that this test method should become an international standard (ISO/DTS-19708).

2. TEST APPARATUS

In order to evaluate the performance of the fabric sheets (geotextiles) placed under the cushion sand of block pavements when subjected to repetitive loadings, a laboratory simulation test apparatus was developed at Nihon University. This apparatus was modified from a roller compactor used for making specimens of asphalt concrete mix. Figures 2(a) and (b) give an overall view of the test apparatus which is similar to that in ISO Technical Specification ISO/DTS-19708. This test method is classified as a damage acceleration test.

The square-shaped metal mould in which a pavement specimen is placed is 300 mm in length x 300 mm in width x 100 mm in height. The size of this mould is smaller than that of the test apparatus (width 450 mm x length 450 mm x height 100 mm) used in ISO/DTS-19708. Figure 3 shows the cross-section of the test specimen.

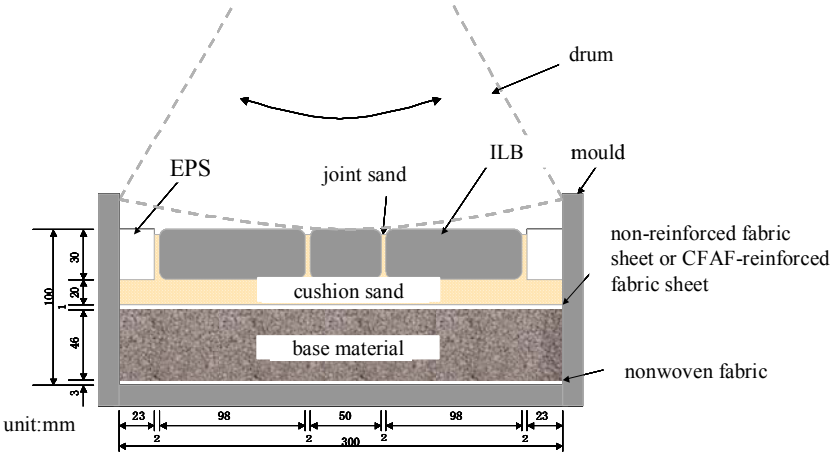


Figure 3 Cross section of test specimen

After a nonwoven fabric sheet has been laid as a drainage material on the bottom porous plate of the mould (which has several holes), a base course of crushed stone (grain size: 13 – 5 mm), 46 mm in thickness, is compacted. A geotextile specimen is placed on top of the base course, and cushion sand (grain size: 2 – 0.2 mm) is then are spread on top of the geotextile specimen. Finally, blocks are placed on the cushion sand layer, and their joints are filled with the same sand. The blocks used in the test are rectangular-shaped interlocking concrete blocks (nominal size: 200 mm in length x 100 mm in width

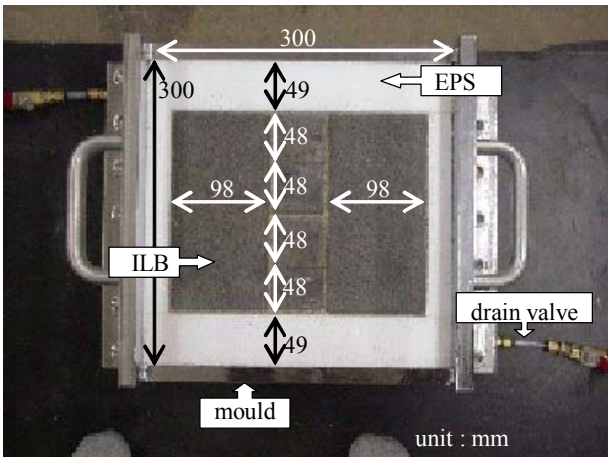


Figure 4 Plan of test specimen

x 80 mm in thickness). All those used in the test are cut to a thickness of 30 mm. Square-shaped blocks (48 mm x 48 mm x 30 mm) are placed in the central part of the pavement specimen. The space at the edges between the blocks and the walls of the mould are filled using EPS (expanded polystyrene foam) blocks. An arrangement of these blocks is shown in Figure 4.

Table-1 Testing condition

item	factor	testing level
Roller compactor apparatus	roller total load	50 kN
	number of load repetions	10, 500, 700
Specimen	geotextile	nonreiforced nonwoven geotextile, CLAF-reinforced nonwoven geotextike
	pavement structure	as shown in Fig. 3
	edge filling	EPS foam block
	moisture condition	air-dry state, submerged state

The pavement specimen constructed in the mould is placed on a sliding table. A semicircular steel roller is positioned on the top surface of the pavement specimen and then pressure is applied to the specimen with an oil cylinder. Repeated loads are applied to it by left and right movements of the table. The maximum number of cyclical loadings applied is 700 repetitions so that each test is completed within a day.

3. TEST CONDITIONS AND PROCEDURE

3. 1 Test Conditions

The experiments in this study were carried out under the test conditions listed in Table 1. A constant roller wheel load (total load of 50 kN) was applied.

Two types of geotextile specimen were tested: one was a nonreinforced nonwoven fabric sheet (needle-punched polyester fabric sheet) with a mass of 60 g/m^2 per unit area, which is commonly used as a separating material in interlocking concrete block pavements in Japan; the other was a new type of geotextile, which is reinforced on one side of a nonwoven fabric sheet of 60 g/m^2 with a net of thin polyethylene strips, designated as CLAF-reinforced fabric sheet (also known as WARIFU in Japanese).

Two moisture conditions were used for the pavement specimens – air-dry and water-submerged. The latter condition simulates rainfall having permeated into the pavement substructure. For testing in the submerged condition, water is poured into the pavement specimen constructed in the mould, using a plastic hose, until it drains out of the bottom plate and overflows the mould.

Repetitive stresses (10, 500 or 700 load repetitions) are applied to the specimens. The settlement of each block is measured between loadings. The geotextile specimens are removed carefully after the loading test is finished and damage to the geotextile is carefully observed. However, damage observations are done only on the specimens in the air-dry state because those in the water-submerged state are so weak that they cannot be removed without further damage.

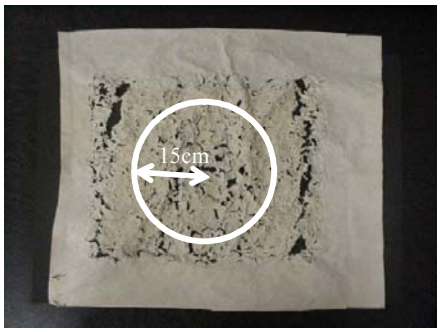


Figure 5 Measuring method of damaged holes of specimen

3. 2 Measurement Items

Measurements of the following three items are done to evaluate performance: (i) settlement of blocks under repetitive loadings, (ii) visual inspection of the surface of the geotextile subjected to repetitive loadings (damage is assessed after the test is finished), (iii) holes in the geotextile. The damage (the rough average diameter of the holes and their numbers) is recorded carefully in a circular area of radius 15 cm at the center of the geotextile specimen, as shown in Figure 5, after the test is complete.

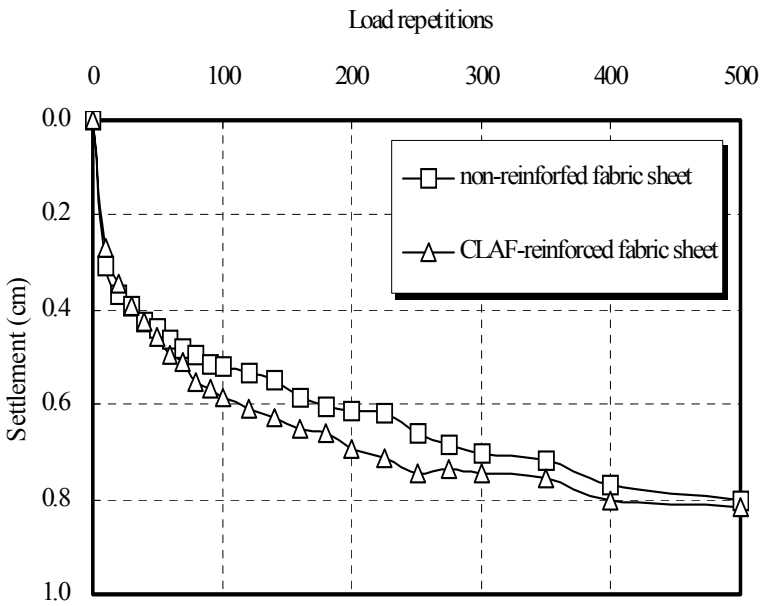


Figure 6 Settlement subjected to repeated loadings in air-dry test condition

4. TEST RESULTS AND DISCUSSION

4. 1 Settlement of blocks under repetitive loadings

Figures 6 and 7 show the relationships between the load repetitions and the settlement of blocks in the air-dry and submerged test conditions respectively.

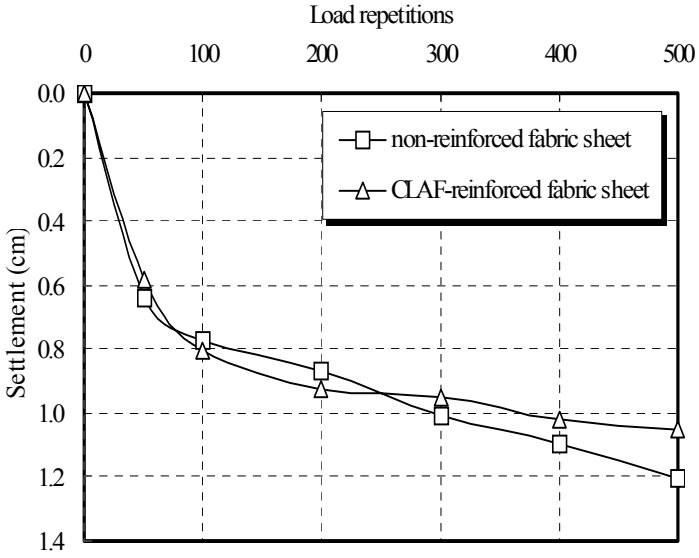


Figure 7 Settlement subjected to repetitive loadings in submerged test condition

The results show that settlement is greater in the case of the submerged condition than in the air-dry condition. Therefore it can be assumed that in the submerged condition hydraulic compaction is induced or the cushion sand layer becomes unstable due to the pumping action (usually of traffic). In the latter case, the sand particles rearrange themselves and the sand migrates into the base course through the damage holes in the geotextile caused by the load repetitions. Moreover, it is believed that a few particles of joint and cushion sand are carried away together with the water when it overflows from the top of mould. All these factors cause the settlement of blocks to increase in the submerged condition.

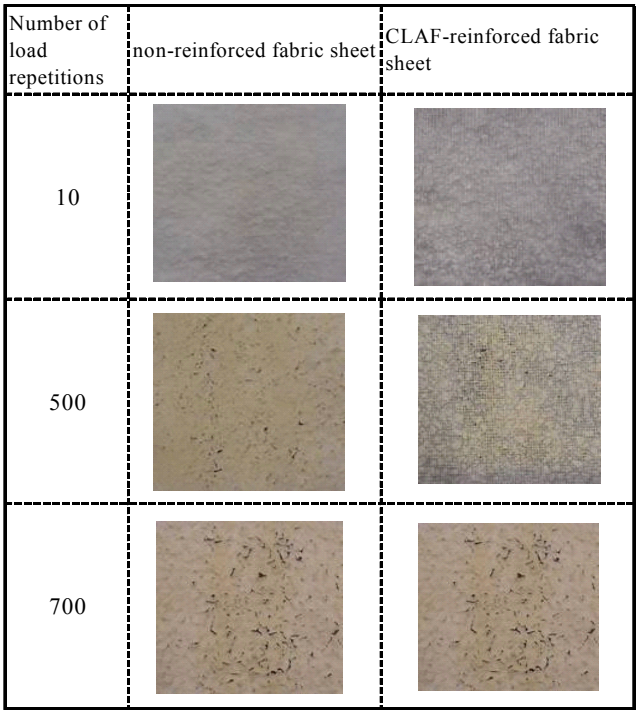


Figure 8 Surface damage of specimens after repetitive loadings in air-dry test condition

4. 2 Visual inspection of damage to the surface of the geotextile

Figures 8 and 9 are photographs showing the state of the surface of the fabric sheets (geotextiles) subjected to the specified numbers of load repetitions in the air-dry and submerged test conditions respectively. It can be seen from these photos that damage to the geotextile is greater under the submerged condition than under the air-dry condition when the same number of load repetitions is applied. It is thought that the cushion sand moves readily in the submerged condition and that it presses the flexible geotextile onto the aggregate, eventually causing holes in the geotextile.

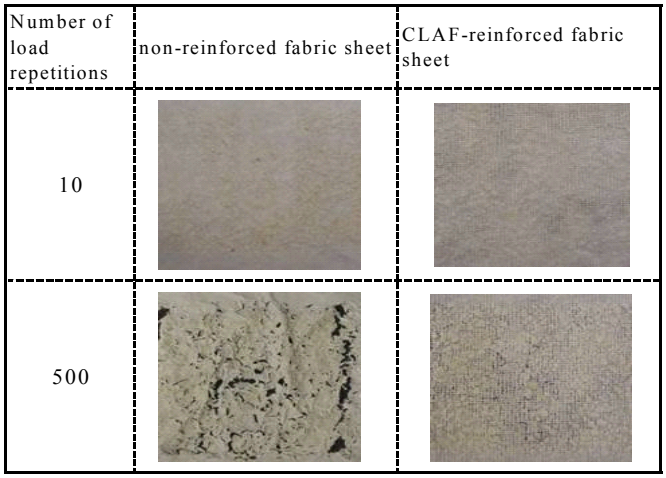


Figure 9 Surface damage of specimens after repetitive loadings in submerged test condition

The nonreinforced, nonwoven geotextile is heavily damaged after 500 load repetitions in the submerged condition, so that it appears like a piece of thin paper. On the other hand, the reinforced geotextile has only a few holes punched in it and the surface appears ‘fuzzy’. It is concluded that the CLAF-reinforced geotextile has a high durability in this separation function in comparison with the nonreinforced geotextile.

more

4. 3 Size and numbers of damage holes

Figures 10(a) and (b) show the size (diameter) and numbers of the damage holes in the nonreinforced geotextile and the reinforced geotextile respectively, after 500 load repetitions have been applied in the air-dry condition.

Figures 11(a) and (b) show the size and numbers of damage holes in the nonreinforced geotextile and the reinforced geotextile respectively, after 700 load repetitions have been applied in the air-dry condition.

It is obvious from these figures that the size of the damage (punched) holes is small and that there are fewer holes in the reinforced geotextile than in the non-reinforced one. The durability is also excellent.

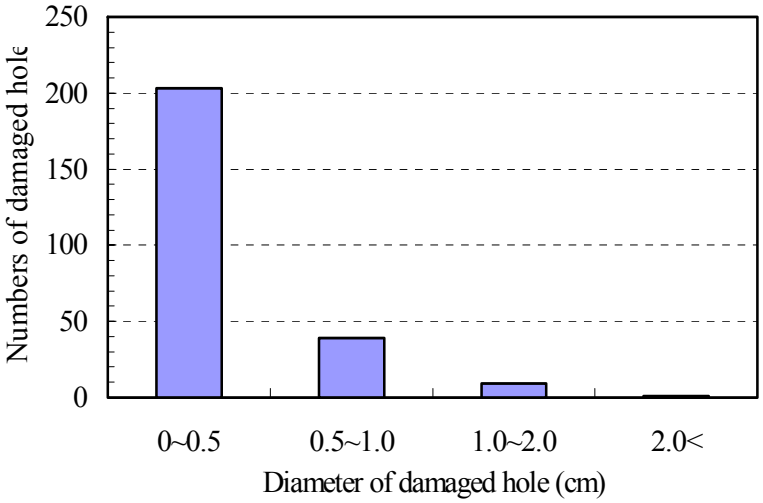


Figure 10(a) Size and numbers of damaged hole of non-reinforced fabric sheets subjected to 500 load repetition

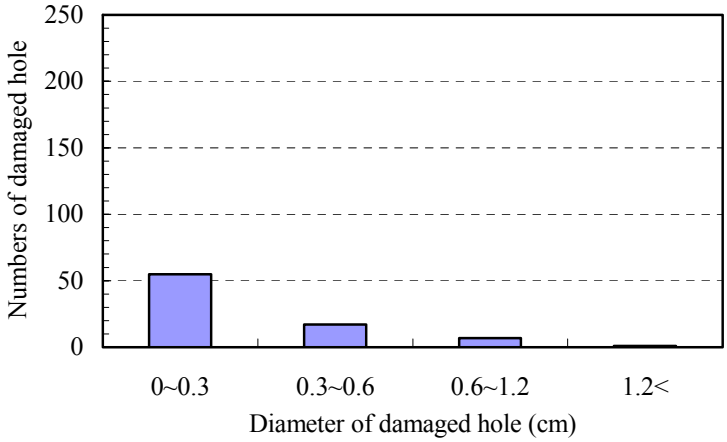


Figure 10(b) Size and numbers of damaged hole of CLAF-reinforced fabric sheet subjected to 500 load repetitions

5. CONCLUDING REMARKS

The main results obtained from these experiments are as follows:

1) The durability of the CLAF-reinforced geotextile was superior to that of the ordinary nonreinforced geotextile commonly used.

2) Heavier damage was caused to the geotextiles and there was more severe rutting of the surface blocks in the submerged condition than in the air-dry condition.

Moreover, it was found that the test apparatus developed can also be applied for relative evaluations of geotextiles to be used under the

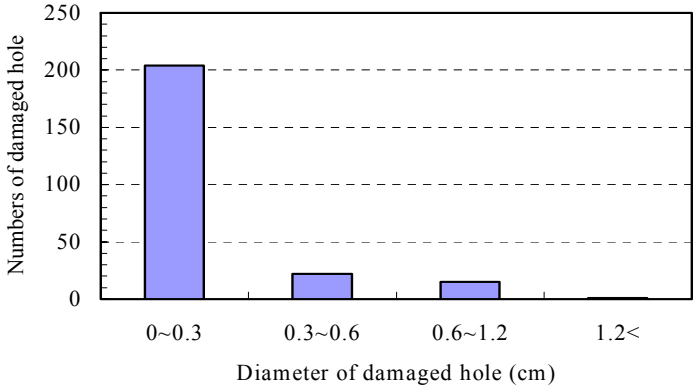


Figure 11(a) Size and numbers of damaged hole of non-reinforced fabric sheet subjected to 700 load repetitions

cushion sand layer of block pavements. However, more objective and quantitative inspection methods are needed to evaluate damage to geotextiles. Finally, in order to elucidate the mechanism of damage to geotextiles in pavements, it will be necessary to accumulate experimental data and to establish the precise correlation between the performance of geotextiles in actual pavements and that in the laboratory simulation test.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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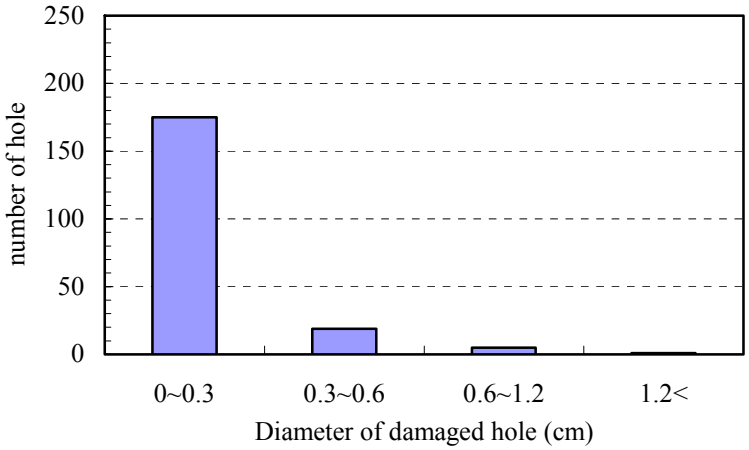


Figure 11(b) Size and numbers of damaged hole of CLAF-reinforced fabric sheet subjected to 700 load repetitions

KENSAN, 2001 and 2002. Study reports on the standardization of performance evaluations of geotextiles for pavements (in Japanese). Note: Unfortunately, only limited references written in English referring to this study are available at present.