PAVE 92

AN EVALUATION OF THE PERFORMANCE OF CONCRETE BLOCKS ON ROAD PAVEMENTS UNDER TRAFFIC LOADS

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SUMMARY

A performance of interlocking concrete block pavements subjected to motor vehicle traffic loadings was investigated for the period of one year. Eleven test sections having different types and patterns of block were put to light and medium traffic. Unicolock and uninormal blocks of 80 mm in thickness were tested on the same supporting condition. Block laying patterns were herringbone, swirl, linedecor and pallet-machine laying.
An edge-break of block was observed within a half year after construction and a few block of each section were cracked within one year. Results indicated that the edge-break and the crack of block were affected by the compressive strength of block, and an abration of surface block depended upon traffic volume. It was found that a unicolock-type block made less horizontal creep movements than others and its swirl pattern showed less movements than its herringbone pattern in the case of heavy traffic.

1. INTRODUCTION

In Japan, usage of interlocking concrete block pavements is extending steadily for light traffic such as footpaths, architechtural and park areas. On the other hand, only limited applications to heavy trafficked roads have been made up to the present day. In order to investigate a performance of interlocking concrete blocks on actual roads under different traffic conditions, a full-scale pavement test was conducted for the period of one year.

Eleven sections having different types of concrete block pavements were tested. A-area (75.84 m in length, 6.08 m in width) has A-class traffic volume (100 to 200 commercial vehicles per day, one direction), and B-area (58.0 m in length, 6.98 m in width) has L-class traffic volume (less than 100 commercial vehicles per day, one direction). Two types of concrete blocks of 80 mm in thickness (unicolock, and uninormal) were laid on the same condition of supporting layers; a sand cushion of 30 mm, a base-course of 80 mm and a subbase of 160 mm on a subgrade. Block laying patterns selected for the test were herringbone, swirl, linedecor and pallet-machine laying. A compressive strength test of concrete blocks sampled from the each section were carried out before the long-term tracing investigation.

The tracing investigations consist of breakage of blocks, abrasion of blocks, rutting of pavement surface, horizontal creep movement of blocks, deflection by Benkelman beam and plate bearing test. These measurements were carried out as of 1.5, 3, 6 and 12 months after construction.

2. DESIGN OF PAVEMENT STRUCTURE

2.1 TRAFFIC CONDITION

Table 1 and Fig.1 show traffic conditions on the routes of test pavement. According to Table 2 which is given in the manual for design of flexible pavement[1]. A and B-areas on the test routes can be classified as A- and L-traffic roads, respectively.

Table 1 Traffic flow volume (per day)

Route	Lane	Heavy vehicles	Ordinary trucks	Ordinary motor vehicles	Total
A ①	upwawd	140	28	314	482
	downward	157	31	225	413
B ②	upwawd	0	12	286	298
	downward	0	9	203	212
③	U-turn	53	9	0	62

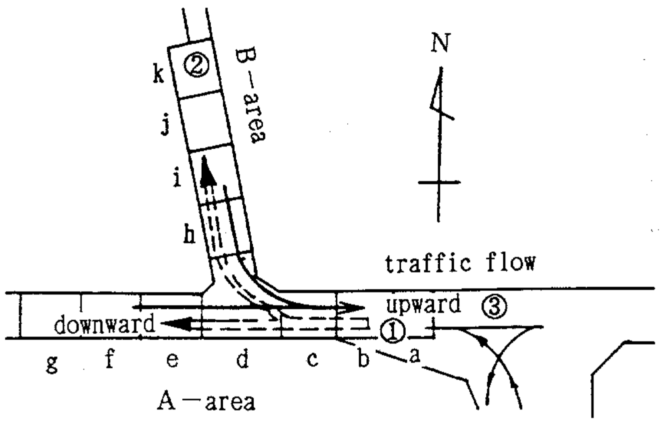


Fig.1 Traffic flow on test pavements

Table 2 Road classification by traffic (per day, per lane)

	Heavy vehicles
L-traffic	less than 100
A-traffic	100 to 250
B-traffic	250 to 1000
C-traffic	1000 to 3000
D-traffic	more than 3000

2.2 PAVEMENT STRUCTURE

2.2.1 DESIGN PROCEDURE

The design procedure is as follows:
1) Classification of the road by investigating a traffic volume
2) Determination of design CBR of subgrade[1]
3) Design of pavement thickness[2]

Pavement thickness is designed based on the design CBR and the road classification given in Table 2 such that each individual course does not fall below the target value of T_A shown in Table 3, and that the total pavement thickness does not become smaller than the target total thickness H in Table 3 by 1/5 or more.

The thickness for flexible pavements is derived from the following formulae:

$$T_A = A_1 T_1 + A_2 T_2 + \cdots + A_n T_n, \qquad H = T_1 + T_2 + \cdots + T_n$$

where T_A: the required thickness of a full depth hot mix asphalt pavement having an equivalent strength

$T_1, T_2, \cdots T_n$: thickness of individual layers of pavement (cm)

$A_1, A_2, \cdots A_n$: coefficients of relative strength given in Table 4

H: total pavement thickness (cm)

Table 3 Targrt values for T_A and total pavement thickness, H , cm

Design CBR (%)	Road classification L-traffic T_A	H	A-traffic T_A	H
2	17	52	21	61
3	15	41	19	48
4	14	35	18	41
6	12	27	16	32
8	11	23	14	27
12	—	—	13	21
20 or more	—	—	—	—

Table 4 Coefficients of relative strength for calculating T_A

Pavement course	Method and material of construction used	Condition	Coefficient A_n
Surface	Interlocking block	—	1.00
Base	Crushed stone for mechanical stabilization	Modified CBR = 88%	0.35
	Cement stabilization	q_u = 30 kgf/cm^2	0.55
Subbase	Crusher-run	Modified CBR = 30%	0.25
	Cement stabilization	q_u = 10 kgf/cm^2	0.25

2.2.2 DETERMINATION OF CROSS SECTIONS

In A-area, the design CBR was 6 % and the road was classified as A-traffic road. Therefore, the target values of T_A and H are 16 cm and 26 cm (= 32× 4/5), respectively.

	H		A_n		T_A
surface c.	8	×	1.00	=	8.0
base	8	×	0.35	=	2.8
subbase	26	×	0.25	=	6.5

T_A = 8 + 2.8 + 6.5 = 17.3 cm > 16 cm
H = 8 + 8 + 26 = 42 cm > 26 cm

In B-area, the design CBR was 3 % and the road was classified as L-traffic road. Therefore, the target values of T_A and H are 15 cm and 33 cm (= 41× 4/5), respectively.

	H		A_n		T_A
surface c.	8	×	1.00	=	8.0
base	8	×	0.35	=	2.8
subbase	26	×	0.25	=	6.5

T_A = 8 + 2.8 + 6.5 = 17.3 cm > 15 cm
H = 8 + 8 + 26 = 42 cm > 33 cm

Based on the above calculation, the total thickness of both pavements are determined as 45 cm. As shown in Fig.2, the pavement is composed of a surface block of 8 cm, a sand cushion of 3 cm, a mechanically stabilized crushed stone (max.grain size d_{max}=30 mm) base of 8 cm and a stabilized subbase of 26 cm.

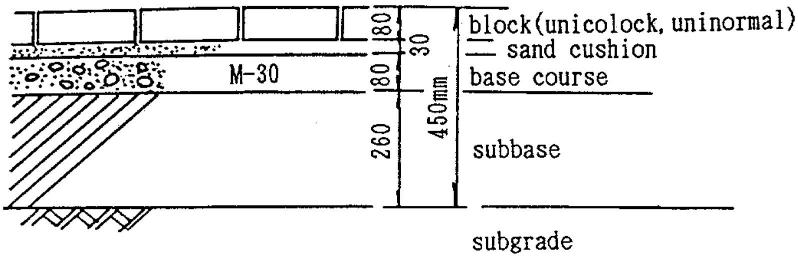


Fig.2 Cross section of pavement

3. TEST PAVEMENT SECTIONS

The test pavement has 6.89 m in width and 123 m in total length. As shown in Fig.1, the A-area is devided into 7 sections; i.e. from a-to g-sections and the B-area is devided into 5 sections; from h-to l-sections. Types of block used for the tests are uninormal (UN) and unicolock (UC) of 80 mm in thickness.

As shown in Table 5 and Figs.3 and 4, the laying patterns of uninormal blocks are herringbone and linedecor and the patterns of unicolock are herringbone, swirl and palette. The blocks are laid down for the angle of 90° in the direction of traffic. Pallet type by machine laying arranged in g-section.

Table 5 Types and patterns of paving blocks

type \ pattern		swirl	herringbone	linedecor	pallet
unicolock	good	①	②		⑧
	poor		③		
uninormal	good		④	⑥	
	poor		⑤	⑦	

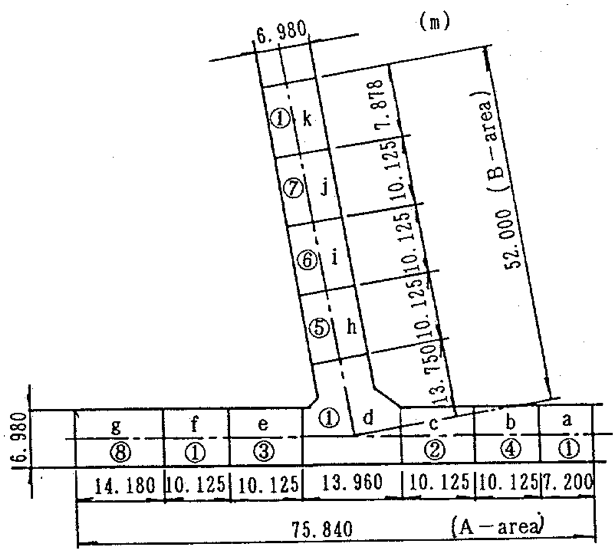
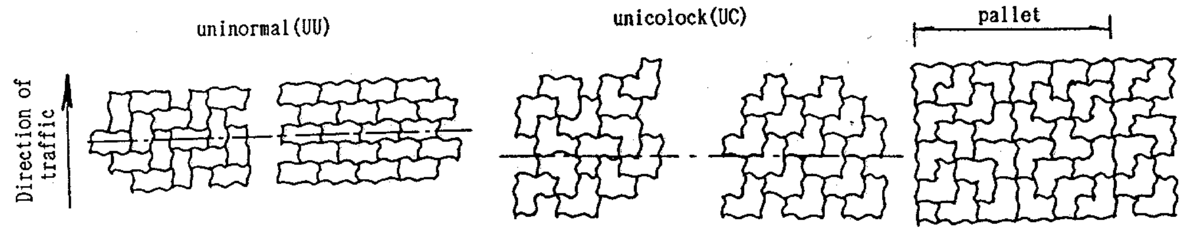


Fig.3 Arrangement of test pavement section



Laying pattern	(herringbone)	(linedecor)	(swirl)	(herringbone)	(pallet)
No.	④ ⑤	⑥ ⑦	①	② ③	⑧
Section	b h	i j	a, d, f, k	c e	g

Fig.4 Laying patterns of paving blocks

4. PROPERTIES OF BEARING LAYERS AND PAVEMENT BLOCKS

4.1 IN-SITU CBR AND PLATE BEARING CAPACITY

In-situ CBR of subgrade are given in Table 6. Table 7 shows the results of plate bearing test, K_{30}, on each layer. The sections in a and b shows high values because of a lime stabilization adopted in the former pavement in this area.

Table 6 Results of in-situ CBR of subgrade

section	a	b	c	d	e	f	g	h	i	j	k	mean
in-situ CBR (%)	67.9	98.6	53.4	35.7	38.4	19.8	19.4	19.3	18.4	6.4	10.2	35.1

A−area (a–g) B−area (h–mean)

Table 7 Results of plate bearing test

section	a	b	c	d	e	f	g	h	i	j	k	mean
surface	168.0	172.6	105.7	70.3	92.1	77.5	58.2	56.2	38.2	46.2	33.4	83.5
base-course	42.3	90.9	65.2	40.8	34.9	37.4	31.7	24.1	20.6	23.3	15.7	33.4
subbase	105.4	130.1	88.6	49.5	25.9	20.3	23.4	17.1	13.8	17.2	13.5	45.9
subgrade	140.9	171.2	72.3	29.7	52.9	17.7	26.9	15.7	11.8	10.9	7.9	50.7

4.2 COMPRESSIVE STRENGTH OF BLOCKS

Five concrete blocks were sampled randomly from the each test section ten days after construction, The test results of a compression test are shown in Table 8. Test sections were classified into two groups based on the strength. Good means more than 500 kgf/cm² in the average strength and poor is less than it.

Table 8 Compressive strength of blocks

	a	b	c	d	e	f	g	h	i	j	k
type	UC	UN	UC	UC	UC	UC	UC	UN	UN	UN	UC
color	brown	red	black	brown	red	natural	brown	natural	red	natural	brown
thickness (mm)	79.5	79.4	79.8	80.2	80.2	80.2	80.0	80.2	80.6	79.5	81.1
density (g/cm^3)	2.253	2.257	2.259	2.229	2.224	2.214	2.234	2.123	2.230	2.151	2.215
compressive strength (kgf/cm^2)	506.3	455.3	539.8	530.8	389.2	520.6	526.6	394.5	512.5	421.9	532.1

5. PAVEMENT PERFORMANCE

5.1 BREAKAGE OF BLOCKS

Degree of breakage of blocks are classified into three levels; A: edge-breakage, B: single crack, C: heavy crack. A breakage rate D (%) is defined as follows;

D = Number of broken blocks / Total number of blocks in the section × 100

Figure 5 shows the results of investigation on breakage of blocks. Only A-level breakage occured until 6 months after construction. The breakage rates increased during 6 to 12 months. Most of breakage were A-level; however, C-level breakage of some blocks were also found. It can be seen that the occurrence of breakage of block is slightly affected by its compressive strength.

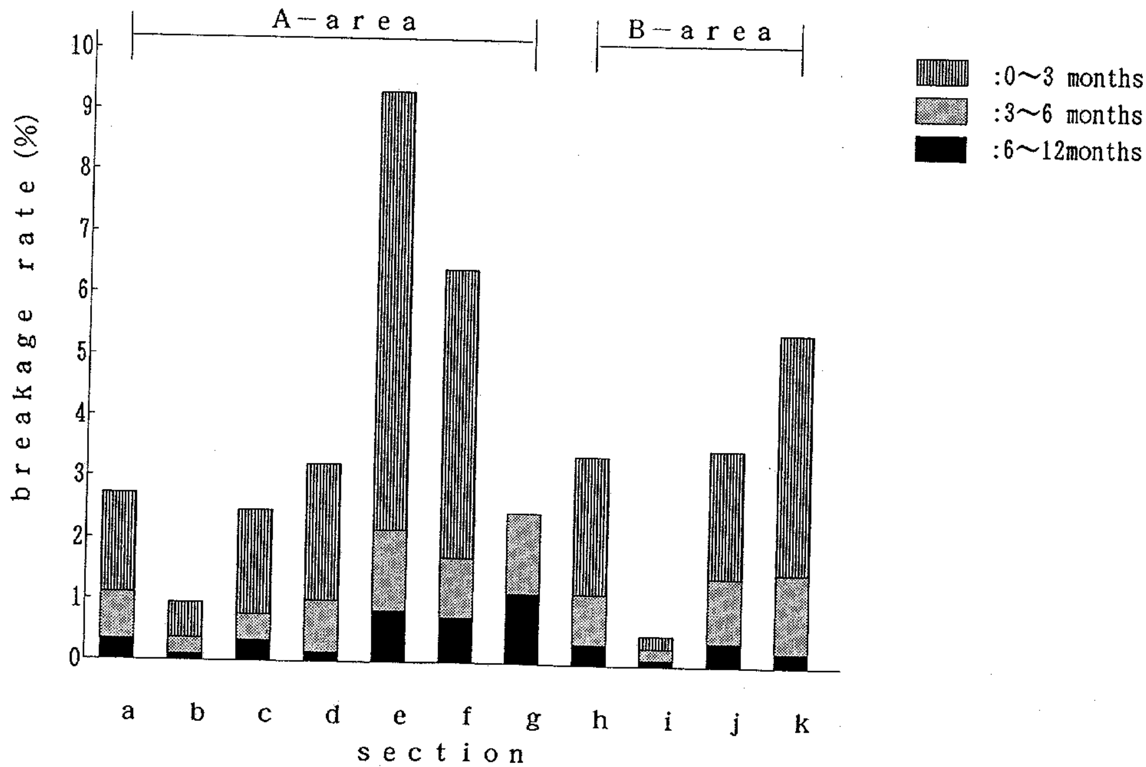


Fig.5 Breakage of paving blocks

5.2 ABRASION OF BLOCKS

Figure 6 shows the change of abrasion of blocks under traffic loadings. It can be found that the amount of abrasion was affected by traffic volume but not types and patterns of blocks. High abrasion in g-section is due to the drag of sands and stones from the adjacent unpaved road.

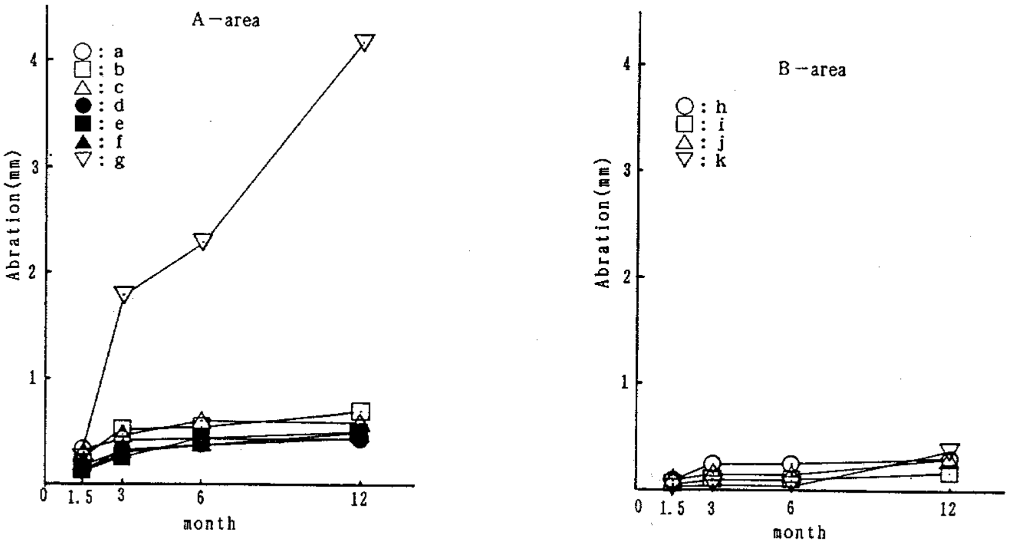


Fig.6 Abrasion of paving blocks

5.3 RUTTING OF BLOCKS

Figure 7 shows the vertical rutting deformation of blocks. The rutting increased with traffic volume. Larger settlements in e and f sections are supposed to be due to an insufficient compaction and a shortage of sand in joints.

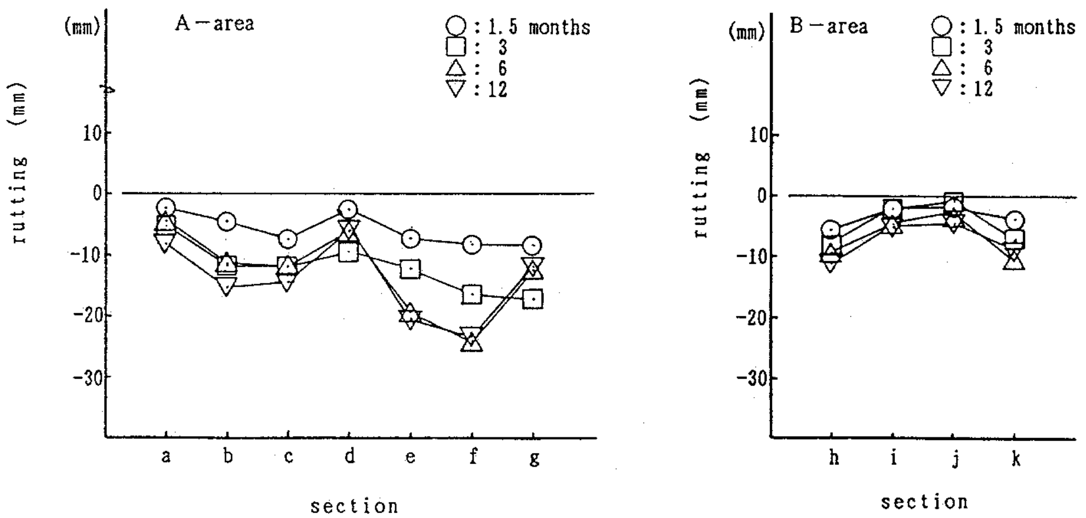


Fig.7 Rutting of paving blocks

5.4 MOVEMENT OF BLOCKS

A direction and an amount of horizontal creep movement of blocks are illustrated in Fig.8. Large movement of blocks were observed in the period from 1.5 to 3 months after construction. The blocks were moved almost in the same direction to traffic flow, and the movements in A-area are larger than that in B-area. Therefore, block movements are influenced by traffic volume and it is supposed to be caused by the brake of tyre.

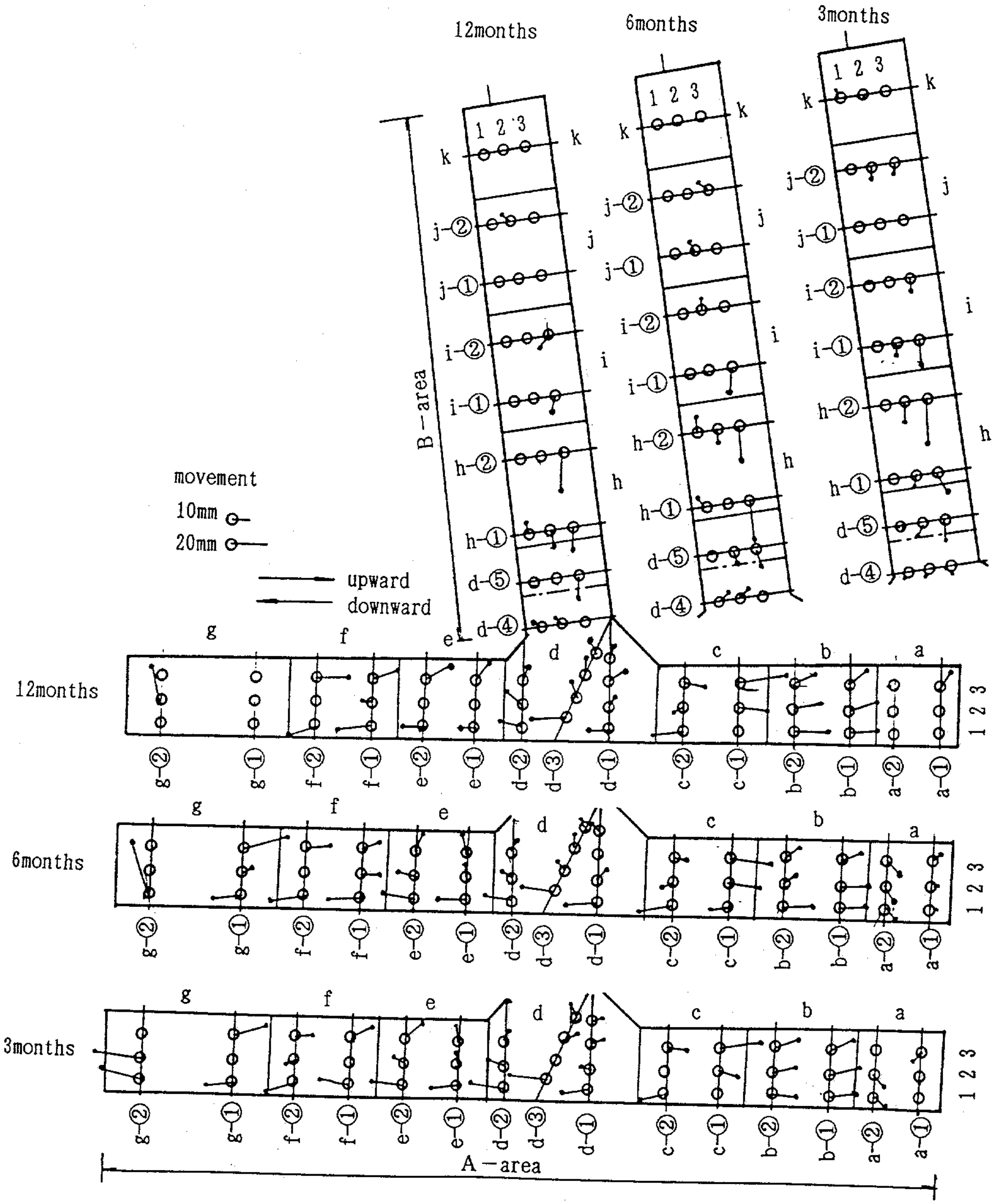


Fig.8 Horizontal movement of paving blocks

5.5 PLATE BEARING CAPACITY OF PAVEMENTS

Coefficients of pavement surface reaction, K_{30}, by a plate bearing test with 30 cm in diameter are shown in Fig.9. It can be found that the coefficients increased gradually with the passage of time and the coefficients after one year indicated nearly twice in value than that just after construction. This increase in bearing capacity may be interpreted to be caused by the lock-up effect of interlocking blocks. Larger value of K_{30} in a-and b-sections were due to their high subbase strength as shown in Tables 6 and 7.

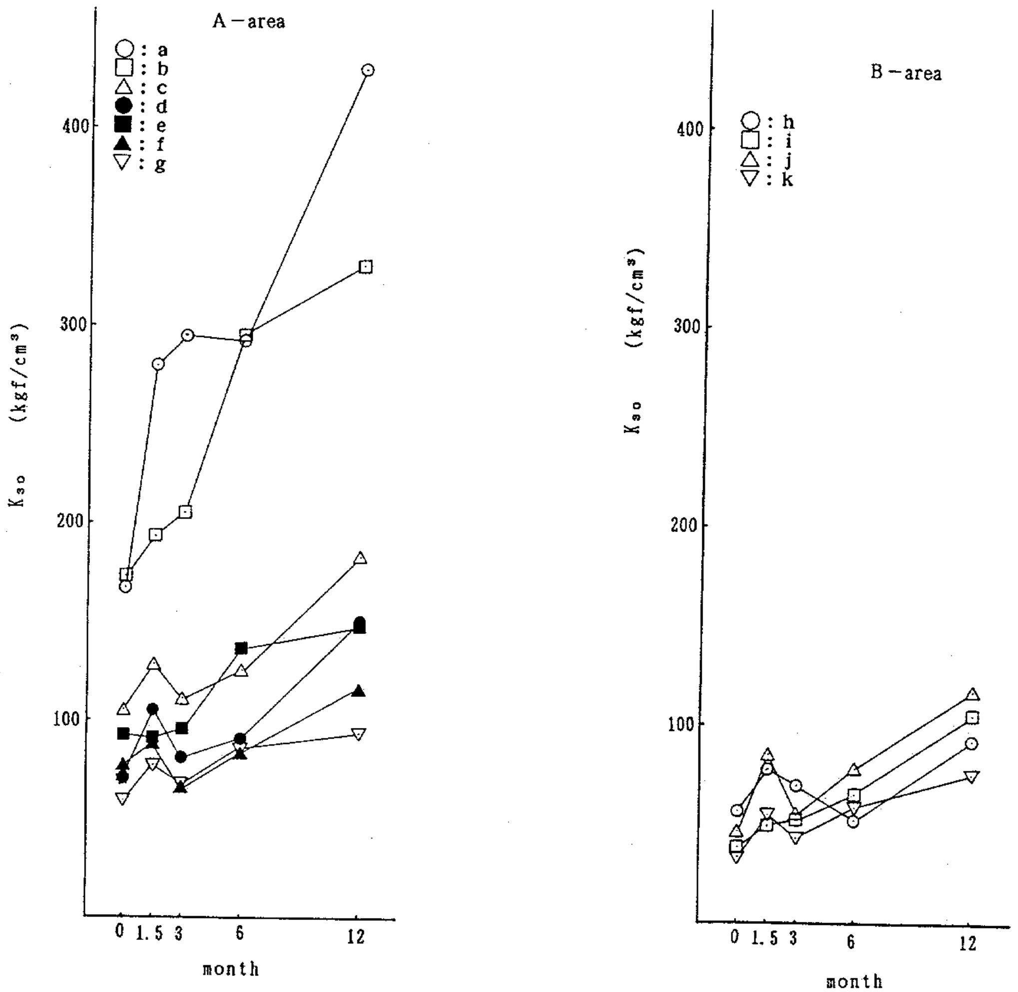


Fig.9 Plate bearing capacity of pavement

5.6 PAVEMENT DEFLECTION BY BENKELMAN BEAM TEST

Figure 10 shows surface block deflections by Benlelman beam test using 5 t wheel load. The deflections were decreased with the lapse of time. This is due to the same reason as mentioned above.

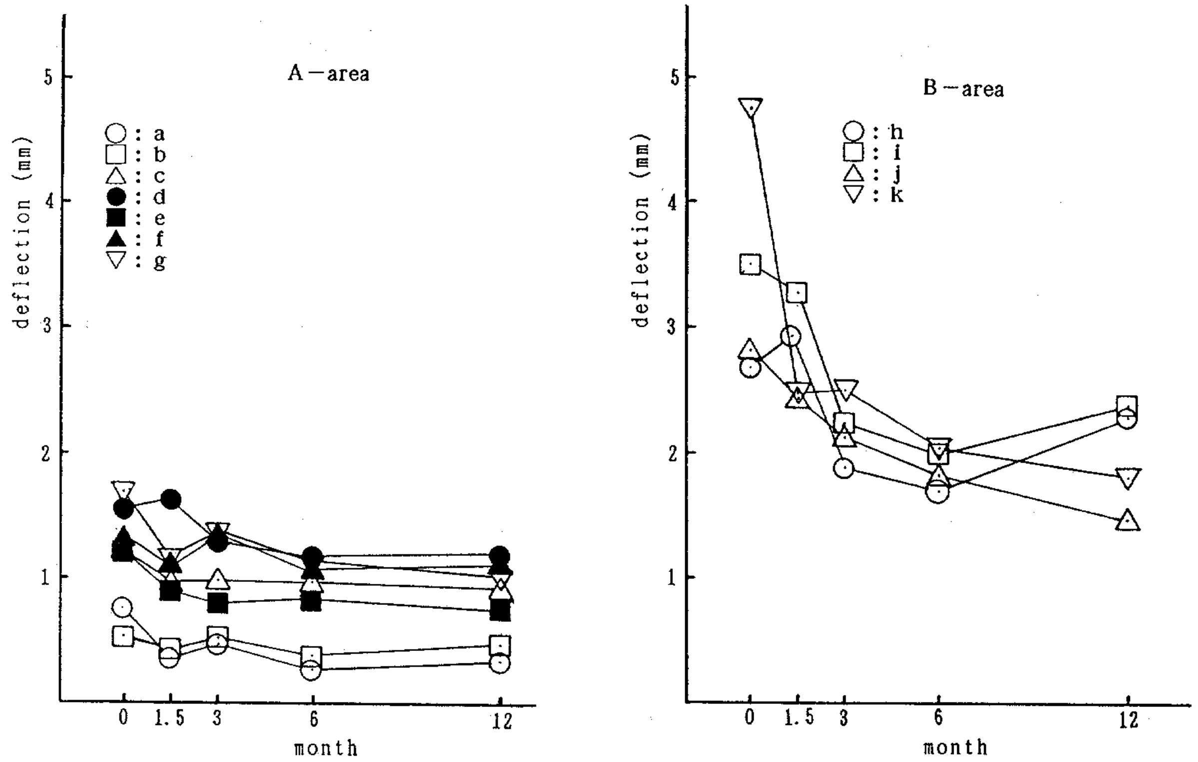


Fig.10 Pavement deflection by Benlelman beam test

6. CONCLUSIONS

1) An edge-break of block was observed for a half year and a few block in each section were cracked within one year. It was found that the edge-break and the crack of blocks were affected by the compressive strength of block.

2) The breakage rate during 6 months after construction was 0.8 % in the average. Block breakages were observed near the junction of road, and were supposed to be caused by the stong contact between their corners resulting from the lock-up effect.

3) An abrasion of surface block depended upon traffic volume and ranged from 0.43 to 0.70 mm for a year in A-area under heavy traffic.

4) A direction and an amount of horizontal creep movement of block were influenced by traffic volume and it was found that both vertical and horizontal permanent movements were accelerated for the period of a half year.

5) A unicolock-type block made less horizontal movements than others and its swirl pattern showed less movements than those of its herringbone pattern under heavy traffic.

REFERENCES

1) Japan Road Association: Manual for design and construction of asphalt pavement, 1980

2) Japanese Society of Architecture: Masonry construction - Chapter 3 Interlocking block construction, 1988