SEASONAL CHANGE CHARACTERISTIC OF INTERLOCKING BLOCK PAVEMENT USED FOR THE ROADWAY

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SUMMARY

We have investigated of the values of fundamental data of interlocking block pavement only winter and summer seasons from 1993 to 1998, for the purpose of establishment of the reliability of interlocking block pavement. It was earned out about 7,000,000 wheels/one-way that is a number of equivalent 5-ton wheel load for 10 years. This number is estimated load of a roadway where the classification of traffic flow volume is equivalent to C traffic.
In this trace investigation, the amount of deflection was measured by FWD against interlocking block pavement and adjoining asphalt pavement. The characteristic of pavement according to the seasonal conditions analyzed that structure form differs, to multi layered elastic theory was performed, and the elastic modulus of pavement layer. Moreover, the maintenance control index (MCI) for every term was computed from the investigation result about the surface shape of pavement, and the performance of interlocking block pavement.

1. INTRODUCTION

The interlocking block pavement in Japan has spread focusing on the pavement for pedestrians, such as a sidewalk, a park, and an open space. For this reason, the application example to roadway pavement was few, and moreover, many of actual results applied to the roadway were the things for light traffic pavement. Since the dynamic characteristic of interlocking block pavement under the condition heavy vehicle traffic load mainly runs a condition repeatedly is not frilly solved, this is considered to be based on tire reliability of interlocking block pavement in the country fully not being obtained.
Authors did pursuit investigation of the collection of fundamental data of interlocking block pavement of the winter and summer from 1993 to 1998, for the purpose of establishment of the reliability of interlocking block pavement. It was carried out by about 7,000,000 wheels/one-way which is a number of equivalent 5-ton wheel load of the totals for 10 years. This is a roadway where the classification of traffic flow volume is equivalent to C traffic. The contents of this pursuit investigation are related the shape of the measurement of amount of deflection, and pavement surface nature by FWD. Among these measurement of the amount of deflection by FWD was similarly carried out in interlocking block pavement and asphalt pavement which adjoins this. From this result, the seasonal change characteristic of the amount of deflection of interlocking block pavement from which the structure form of pavement differs, and asphalt pavement was verified. The amount of deflection obtained by this was analyzed by multi layered elastic theory, and the elastic modulus of pavement each class was presumed. Moreover, the maintenance control index (MCI) for every term was computed from the investigation result about the shape of pavement surface characteristic, and the performance of interlocking block pavement.

2. OUTLINE AND PAVEMENT STRUCTURE OF PURSUIT INVESTIGATION

The interlocking block pavement made into the object of this pursuit investigation is a pedestrian crossing which connects the shopping mall in the central area in Sendai City of the Miyagi prefecture. This pedestrian crossing is shown in Figure 1. This is crossing the roadway whose width member which has a medial strip is about 30 m, with single sided 3 lane, the vertical section direction of a pedestrian crossing is about 20 m, and the pavement area is about 600 m. Therefore, the scale is fairly large scale

compared with a general pedestrian crossing. Measurement of the amount of deflection by FWD was carried out about several points in the position in which the interval which exists in the vertical section direction of each lane and the same lane. Namely, the amount of deflection of a total of 15 points of 2 points was measured for every lane of single sided 3 lane of interlocking block pavement by 3 points and asphalt pavement which adjoins this.

The enforcement time of pursuit investigation which will reach in 5 years made it fundamentally the time zone after 21:00 night, in order that winter and summer might secure the safety of the pedestrian crossing. It means measuring at the time zone by which the temperature state of pavement is stabilized as a result by this, and some points of becoming a problem by measurement in the daytime are cleared.

The pavement structure of interlocking block pavement and asphalt pavement is as being shown in Figure 2. Except that surface material (10 cm depth) is different, structure conditions, such as base course and subgrade, are completely the same. The form (with joint keep) and the laying pattern of a block which were used for this interlocking block pavement are shown in Figure 3.

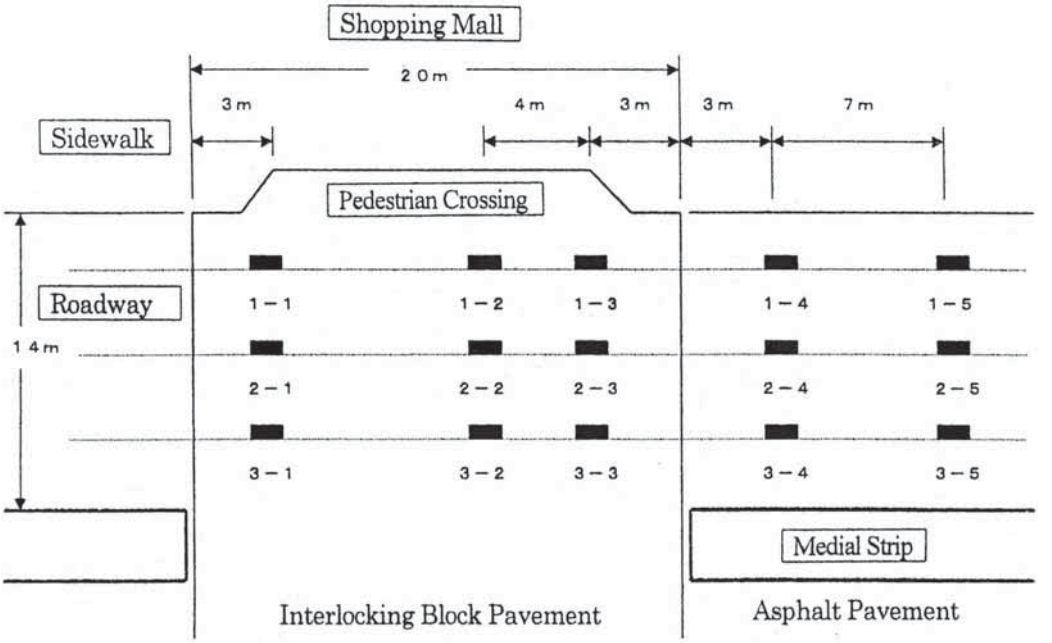

Figure 1 Outline of the pursuit investigation spot

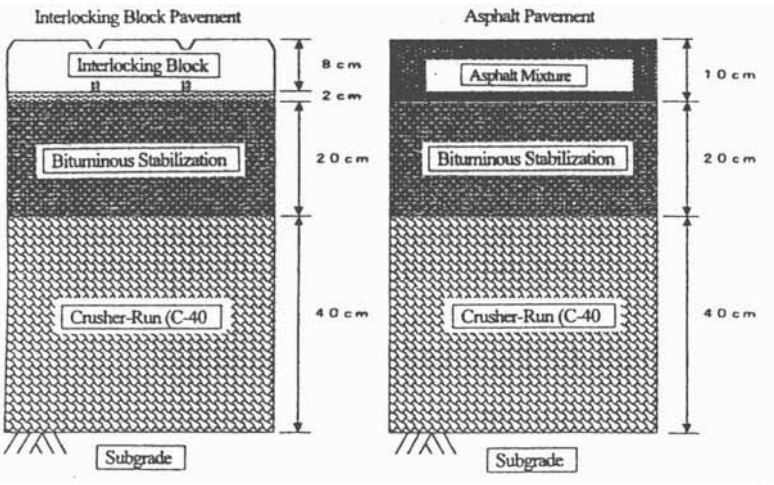

Figure 2 Pavement structure

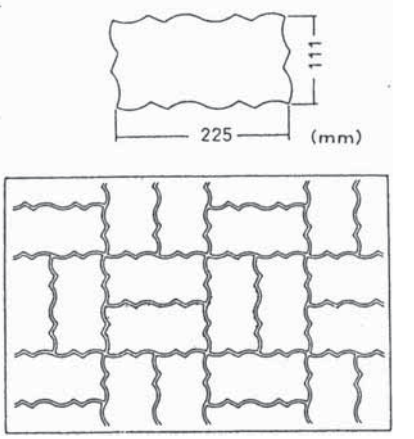

Figure 3 Block form and laying pattern

3. INVESTIGATION ITEM

The investigation item about the shape of the measurement of amount of deflection and pavement surface nature by FWD is as being shown in Table 1. The time and the temperature which carried out this pursuit investigation were shown in Table 2. Among these, the investigation about the shape of pavement surface nature of interlocking block pavement carried out flat nature of the pavement surface by longitudinal profilometer, rut depth read in the measurement result of the amount of cross section profile by crossing profilometer and visual observation of the breakage form of a block, and its quantity. The maintenance control index (MCI) was computed from these investigation results. Moreover, it checked also about the quality of sand used for the skid resistance and the sand cushion of interlocking block pavement.

Table 1 Investigation item

Investigation item		Contents of evaluation	Evaluation object
Amount of FWD deflection (mm)		Seasonal change characteristic of the amount of bending Presumption of the elastic modulus of pavement each class	Interlocking block pavement Asphalt pavement
Pavement surface nature	Roughness (mm)	Maintenance control index (MCI)	Interlocking block pavement
	Rut depth (mm)		
	Rate of block breakage (%)		
	Skid resistance (BPN)		
	Quality of sand used for the sand cushion		

Table 2 Time which carried out pursuit investigation, and temperature

Year	Days and months	Time	Temperature	Season
1993	February 4th	21:00		Winter
	July 27th	21:00	21^{U}C	Summer
1994	February 17th	21:00	3^{U}C	Winter
	September 19th	21:00	25^{U}C	Summer
1996	February 8th	21:00	2"C	Winter
1998	February 26th	23:00		Winter

4. AMOUNT MEASUREMENT RESULT OF FWD BENDING

4-1. Seasonal change characteristic of the amount of deflection

The measuring point of the amount of deflection selected the boundary of interlocking block pavement and asphalt pavement, the boundary with a sidewalk and a medial strip central, and the position left from both pavement boundary with the central lane which the influence of a measurement position does not produce as much as possible. The 15 points measuring of deflection were shown in Figure 1. Among those, the position of 2-2 and the asphalt pavement of interlocking block pavement are the positions of 2-5. The measurement result of the amount of deflection by FWD shows asphalt pavement to Figure 4, and shows interlocking block pavement to Figure 5.

The amount directly under load of asphalt pavement of deflection is changed by 0.2 mm in winter and by 0.3-0.4 mm in summer. It is considered that this is based on the influence of temperature since about 20 °C of the temperature at the time of measurement in winter and summer are different. Moreover, although a difference is seen also about the amount of deflection in summer, change of a time temperature in pavement deflection with the influence of the temperature at the time in this case, and

having influence quantity hears. Although a possibility of having been based on causes, such as secular change, on the structure of pavement was also considered, since there was almost no influence on the amount of deflection in winter, change on structure was analyzed as that which is not.
The amount directly under load of interlocking block pavement of deflection is 0.5-0.6 mm. Compared with asphalt pavement, it is a little big value. Moreover, since it bent and quantity became small when separated 150 cm or more from the center of loading point, it has checked that interlocking block pavement was pavement which is easy to bend near directly under load point from asphalt pavement considered as the deflection nature pavement[1]. By one of these, it was found by there almost being no difference in winter and summer that the deflection form of interlocking block pavement is pavement in which the influence of temperature to deflection has the small characteristic compared with asphalt pavement.

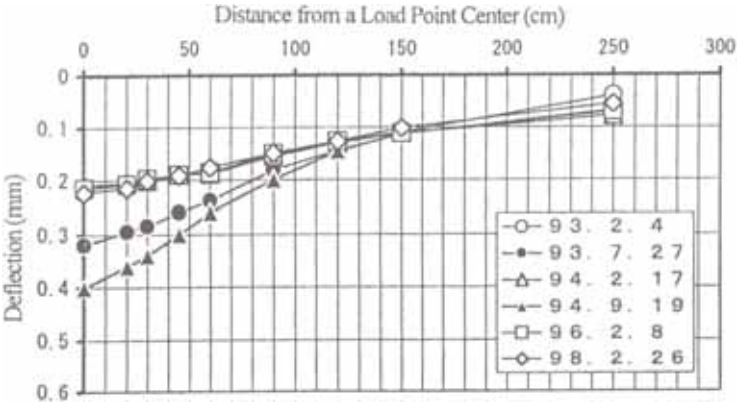

Figure 4 Amount of deflection of asphalt pavement

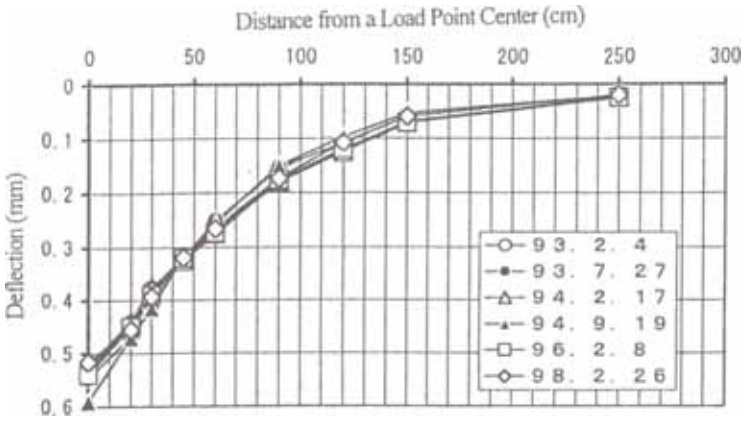

Figure 5 Amount of deflection of interlocking block pavement

4-2. Elastic modulus of pavement layer (the analysis method and analysis result based on FWD deflection)

On the basis of the amount of deflection obtained by FWD, the elastic modulus of pavement layer was presumed according to multi layered elastic theory. ELSA (elastic layer system analysis) was used for the analysis by this multi layered elastic theory, and the pavement parameter was presumed. The procedure of the analysis is shown below.

(1) The interlocking block pavement is modeled in 5 layers, and asphalt pavement is modeled in the structure of 4 layers and layer depth of layer is given.
(2) The elastic modulus of layer and Poisson's ratio are assumed.
(3) The amount of deflection of multi layered elastic theory and the amount of deflection obtained by FWD are measured.
(4) When both are not in agreement, the elastic modulus of layer is corrected and calculation is repeated from (3).
(5) If both value is in agreement, let the elastic modulus at that time be a presumed elastic

modulus.

The restrictions conditions in this analysis have feature in the conditions of pavement layer being equal, except that a surface differs in interlocking block pavement and asphalt pavement. Although the elastic modulus of layer obtained as a result of analysis was as being shown in Table 3, since the structure below base course was equal here, the elastic modulus below base course presumed, the elastic modulus of interlocking block pavement using the value presumed by asphalt pavement. In addition, as shown also in Table 3, in order [which was presumed from the survey value and the multi layered elastic theory of the amount of deflection by FWD] to bend and to make a curve (theoretical value) in agr eement, there was a layer which cannot but loosen a part of restrictions conditions.

Table 3 Elastic modulus of pavement layer

Interlocking block pavement				Asphalt pavement			
Layer	Summer (kN/nrm^2)	Winter (kN/nrm^2)	Layer depth(cm)	Layer	Summer (kN/mnr^2)	Winter (kN/inm^2)	Layer depth(cm)
1	20	2.0	8	1	6.0	12.0	10
2	0.03	0.03	2				
3	3.5	3.5	20	2	3.5	10.0	20
4	0.04	0.04	40	3	0.04	0.05	40
5	0.1	0.1	CO	4	0.1	0.1	oo

From the amount measurement result of deflection of FWD in asphalt pavement, the amount of deflection on February 4th, 1993 (winter) and July 27th, 1993 (summer) was analyzed and the amount of deflection presumed the elastic modulus of pavement layer which gives the value near survey value. Tirus tire obtained deflection curve (theoretical value) was indicated to be Figure 6 (summer) to Figure 7 (winter). In any case, it bends and a curve (theoretical value) and survey value are well in agreement.

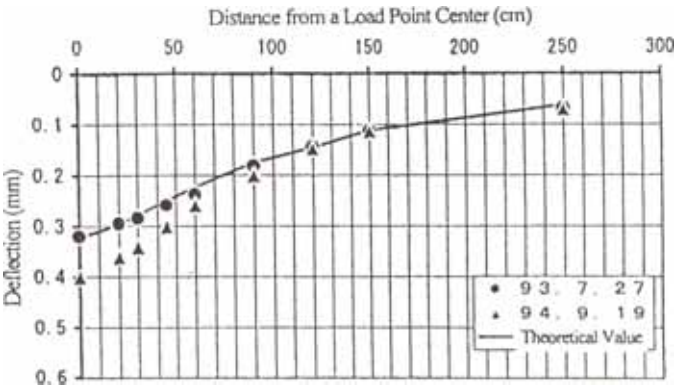

Figure 6 Amount of deflection of the summer in asphalt pavement

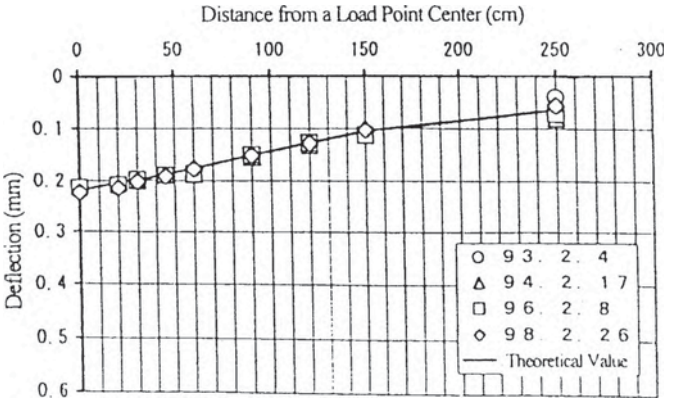

Figure 7 Amount of deflection of the winter in asphalt pavement

Next, it asked for the elastic modulus of the block layer and the sand cushion layer of interlocking block pavement using the elastic modulus obtained by asphalt pavement. The interlocking block pavement assumed that it was 5 layers which fill the amount of deflection of FWD. Moreover, the elastic modulus of the 1st layer (block layer) and the 2nd layer (sand cushion layer) of interlocking block pavement gave the restrictions conditions that neither winter, nor summer changed. Consequently, the deflection curve (theoretical value) of obtained interlocking block pavement is shown in Figure 8(summer) and Figure 9 (winter). Tire deflection curve (theoretical value) of interlocking block pavement is mostly in agreement with survey value near directly under load point. However, the tendency that bend from survey value and curved (theoretical value) one becomes large was seen as it separated from load point.

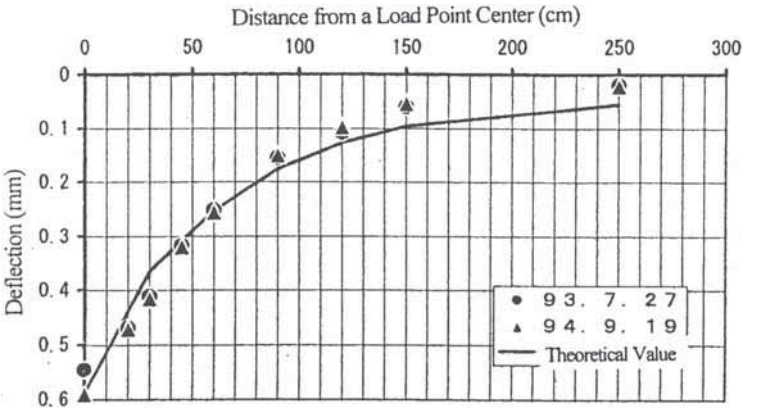

Figure 8 Amount of deflection of the summer of interlocking block pavement

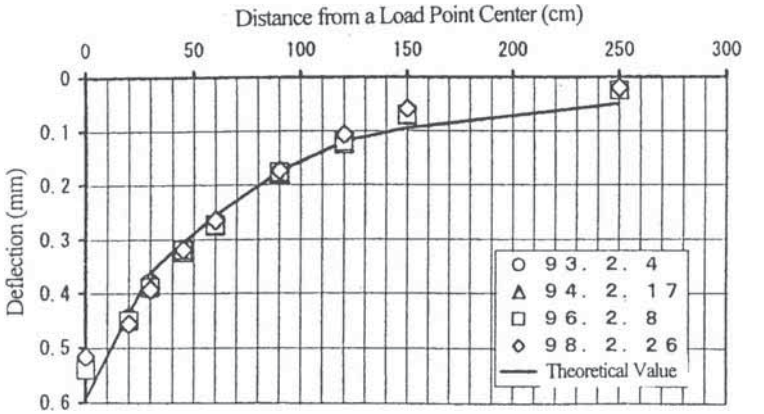

Figure 9 Amount of deflection of the winter of interlocking block pavement

In presumption of tire elastic modulus of asphalt pavement, deflection form was able to be expressed, fulfilling restrictions conditions mostly so that tire above result might show. On the other hand, when the surface of interlocking block pavement was presumed as if it consisted of a continuous material like an asphalt mixture, the satisfactory result expressing form was obtained near directly under load pint using tire elastic modulus by which the shape of deflection nature in summer was obtained from tire analysis of asphalt pavement. Moreover, tire satisfactory result which expresses deflection form mostly was obtained by loosening a part of restrictions conditions also in winter. However, as for quantity if it separates directly under load point, it will bend, and direction of theoretical value becomes large from survey value generally. The tiring with it assuming interlocking block layer to be a continuation object been has been checked.

5. INVESTIGATION RESULT ABOUT THE SHAPE OF PAVEMENT SURFACE CHARACTERISTIC

5-1. Maintenance control index of interlocking block pavement (MCI)

The evaluation formula (formula — 1 ~4) of MCI created in order that the Ministry of Construction might use for the management[2] of a direct control national highway (asphalt pavement) was used for calculation of the maintenance control index (Maintenance Control Index) of interlocking block pavement in this pursuit investigation. According to the evaluation classification of MCI which shows tire result to Table 4, the shape of pavement surface nature of interlocking block pavement was evaluated.

$$MC\ I = 10 - 1.48\ C^{0.3} - 0.29\ D^{0.7} - 0.47\ \sigma \quad \text{(Formula - 1)}$$

$$MC\ I = 10 - 0.51\ C^{0.3} - 0.30 D^{0.7} \quad \text{(Formula - 2)}$$

$$MC\ I = 10 - 2.23\ C^{0.3} \quad \text{(Formula - 3)}$$

$$MC\ I = 10 - 0.54 D^{0.7} \quad \text{(Formula - 4)}$$

Here, it is C : The rate (%) of breakage of interlocking block
D : An average of rut depth (mm)
σ : Flat nature of a pavement surface (mm)

Table 4 Evaluation classification of MCI

Rank	Contents	Score
A	A defect does not accept at all (good).	10
B	Although there is a defect a little, it is considered that it is good.	8
C	Although there are many defects, they do not require repair.	6
D	Easy maintenance repair is required. (Patting, Partial seal coat, etc.)	4
E	Large-scale repair is required. (Overlay, Construction, etc.)	2

It can set to 5 ton of the accumulation for 5 years by about 3,500,000 wheels/one-way. The measurement result about the shape of pavement surface nature until a number of equivalent 5-ton wheel load is presumed is shown in Table 5 and the maintenance control index (MCI) is shown in Figure 10. Tire minimum value[3] of the maintenance control index (MCI) of interlocking block pavement computed from three factors of the roughness of a pavement surface, mt depth, and the number of block breakage was 7.2 for 5 years.
This result corresponds to rank B (although there is a defect a little, it is considered that it is good) from the evaluation classification of MCI shown in Table 4. It is judged that this is almost good as a state of interlocking block pavement.

Table 5 Measurement result and the maintenance control index (MCI) about the shape of pavement surface nature

Tenn (Year)	Rate of block breakage(%)	Rut depth (mm)	Roughness ct (mm)	MCI	MCIo	MCE	MCI2
0	0	0	3.2	9.4	10.0	10.0	10.0
0. 5	0	2.7	3.3	8.8	9.4	10.0	8.9
1.0	0	5.1	3.6	8.5	9.1	10.0	8.3
1.5	0	5.4	4.0	8.4	9.0	10.0	8.2
3.0	0	9.2	3.9	8.0	8.6	10.0	7.4
5.0	0	10.5	4.3	7.9	8.4	10.0	7.2

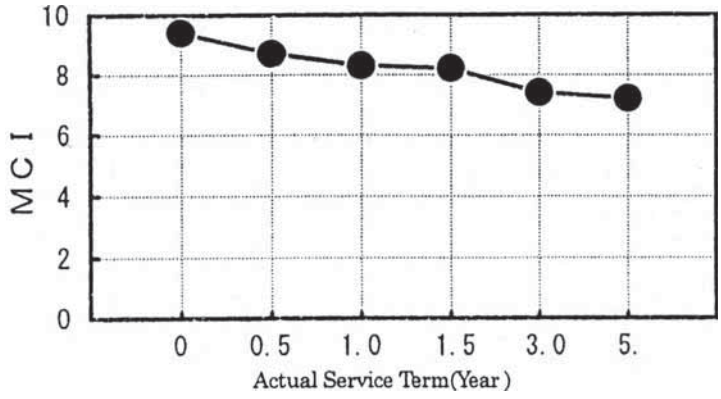

Figure 10 Change of MCI with the passage of time

5-2. Skid resistance

This interlocking block pavement is the large-scale crossing sidewalk applied to the main trunk road in a big city. And, since there are not only many amounts of traffic of a vehicle very, but they adjoins a station and a shopping mall, many and unspecified pedestrians also use.

The measurement result (wet state) of the skid resistance value (BPN) of interlocking block pavement by the portable skid resistance tester of pendulum type is shown Figure 11. Here, since it should be based on the actual walk or the run of a vehicle, it measured by including joint of interlocking block pavement. Although the composite slide resistance value by the surface texture and joint of a block was evaluated, the result with which it is 60 BPN mostly satisfied was obtained.

5-3. Quality of sand used for the sand cushion

In recent years, the quality[4)] of sand used for the sand cushion attracts attention as one of the factors which affect tire performance of interlocking block pavement. The particle-size curve of sand used for the sand cushion of this interlocking block pavement is as being shown in Figure 12. Breakage peculiar to interlocking block pavement with which the quality of sand used for the sand cushion in 5 years is considered to be a cause is not generated at all.

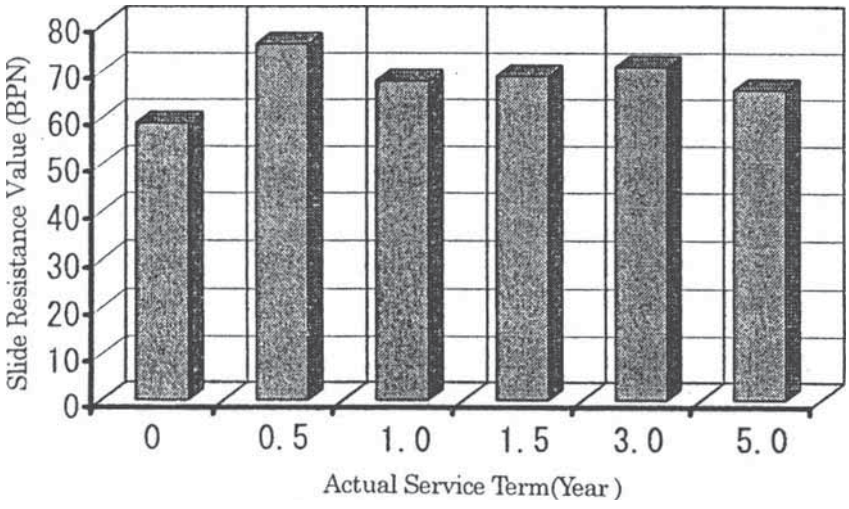

Figure 11 Skid resistance measurement result (wet state)

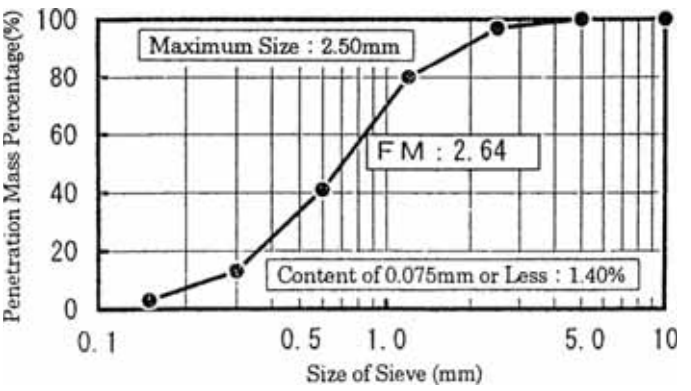

Figure 12 Particle size curve of sand used for the sand cushion

6. CONCLUSION

The difference in the deflection characteristic of interlocking block pavement and asphalt pavement was verifiable with this pursuit investigation. Moreover, the good state of interlocking block pavement applied to the heavy traffic pavement with the high rate of commercial vehicles ratio has checked over for 5 years. While accumulating such investigation and research further, he utilizes a past result effectively and he wants to establish reliability of interlocking block pavement from now on. Domestic roadway spread must be made to realize with it.

In addition, although not described to the result of this pursuit investigation, generating of local subsidence is accepted in tine boundary portion of interlocking block pavement and asphalt pavement, lliis local subsidence is not restricted to interlocking block pavement, but asphalt pavement adjoins similarly and it has generated it. In order to aim at roadway spread of interlocking block pavement, the subject on the design construction in the boundary portion with pavement from which structure differs in tliis way is also left be pending.

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