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REVISED MANUAL FOR INTERLOCKING BLOCK PAVEMENT DESIGN AND CONSTRUCTION (2007 VERSION)

NODA, Etsuro
Technical Reseach Institute,The Nippon Road Co., Ltd., 2-11-20 Tamagawa, Ota-ku, Tokyo JAPAN 146-0095. Tel.: +81-3-3795-4872, Fax.: +81-3-3795-2250. etsurou.noda@nipponroad.co.jp

KASAHARA, Atshushi
Hokkaido Institute of Tecnology

YAGINUMA, Hiroshi
Taiheiyo Recast Concrete Industry Co., Ltd.

Note: The following is the notation used in this paper: (.) for decimals and ( ) for thousands.

Summary

"Manual for Interlocking Block Pavement Design and Construction" was published by Japan Interlocking Block Pavement Engineering Association in July, 2000 and after that in 2001, "Technical Guideline for Pavement Design and Construction" which is the basic standard of the entire pavement by Japan Road Association was published inducing a new idea of pavement design based on performance-oriented specifications. In addition, nowadays such pavement as reduces road surface temperature and urban type of flooding is required viewing to reduce environmental load. Under these circumstances, the manual mentioned above was revised in 2007 in order to cope with such a movement for interlocking block (ILB) pavement.

In the revision, the design method and the construction standard were reviewed and at the same time, the evaluation criterion and the evaluation method of new functions were added to expand application possibilities as a paving material. The basic items revised are as follows:

- Clarification of the principle of ILB pavement
- Enhancement of descriptions for ILB like permeable block and vegetation block which are suitable for environmental preservation.
- Incorporation of slightly larger size of ILB which is gentle to the aged and the physically handicapped people into the Manual.
- Enhancement of descriptions of important points concerning design and maintenance and control to improve durability of ILB pavement.
- Reviewing of the contents subject to the revision of other technical standards.

The revision describes the application not only to roads (motorways and walkways) but also to airports, container yards and it even mentions about calculation examples of life cycle costs. It also mentions about the new testing and measuring methods caused by technical standardization for the block coping with environmental preservation. This paper emphasized to explain main revised points described in this manual.

1. INTRODUCTION

The first "Interlocking Block Pavement Design and Construction Manual"(MANUAL)"was published in July, 2000 by Japan Interlocking Block Pavement Engineering Association and after that, "Asphalt Pavement Manual" of Japan Road Association to which structural design was

referred was incorporated into "Technical Guideline for Pavement Design and Construction" [JRA (2005)] of the same Association following the issuance of "Technical Standard for Pavement Structure" by the Ministry of Land, Infrastructure, Transport and Tourism. Then, a new idea of pavement engineering emphasizing performance-oriented specifications in the road pavement was introduced. In addition, nowadays the lowering of road surface temperature for reducing environmental load and permeable pavement enforced by "Specific City River Inundation Damage Control Law" are also demanded.

Under the circumstances, MANUAL has been revised for the first time in 6 years [JIBPA (2007)]. Not only design method and construction standard are reviewed in this revision but also the evaluation standard and method for new functions are added to widen the application possibility as a pavement material.

2. BASIC POLICY OF THE REVISION AND STRUCTURE OF THE MANUAL

The basic policy of the revision is shown by the Table 1. And the structure of MANUAL is shown in Table 2, ILB pavement design of which consists of road surface design, structural design and plane design. As appendixes, descriptions of examples of calculating lifecycle costs, examples applied to airports and container yards were added to expand application possibilities in the future. Test and measuring methods were increased from old 12 to new 18 pursuant to technical standardization of block related to environmental preservation.

Table 1. The Basic Policy of the revision of MANUAL.

1. Distinction of interlocking block pavement policy.
2. Completion of description for ILB coping with environmental preservation.
3. Introduction to larger-size ILB coping with barrier free problem.
4. Completion of description for attending to design, maintenance and control to keep durability.
5. Review to performance oriented specification, which is stipulated by the revision of other technical standards.

Table 2. The Structure of revised MANUAL.

Chapter 1. Outline.
Chapter 2. Design.
Chapter 3. Material.
Chapter 4. Construction.
Chapter 5. Control of workmanship and quality.
Chapter 6. Inspection.
Chapter 7.
Chapter 8. Maintenance and repair.
Appendix
1. Section examples of pavement structure.
2. Applied sites and shapes and dimensions of ILB.
3. Examples of calculating lifecycle costs.
4. Examples applied to airports and container yards.
5. State of the arts of vegetation block.
6. Related test methods.
7. Equivalent layer coefficient and elastic modulus of ILB layer.
8. Load transfer efficiency of ILB layer needed on the applied sites and traffic volume.

3. OUTLINE

3.1 The Principle of ILB Pavement

It is specified that ILB pavement is such that executes load distribution functions by combination of interlocking effects, bedding sand, joint sand and edge restraints. The Figure 1 explains the principle that deflection of ILB right under the wheel load (Δx)→shear deformation of joint sand→(r_1)→generation of a horizontal compressive force between blocks due to volumetric expansion of joint sand by the shear deformation→(s_1)→Load transfer to adjacent ILBs. The Figure 2 shows the points to be noted for design and construction derived from this principle.

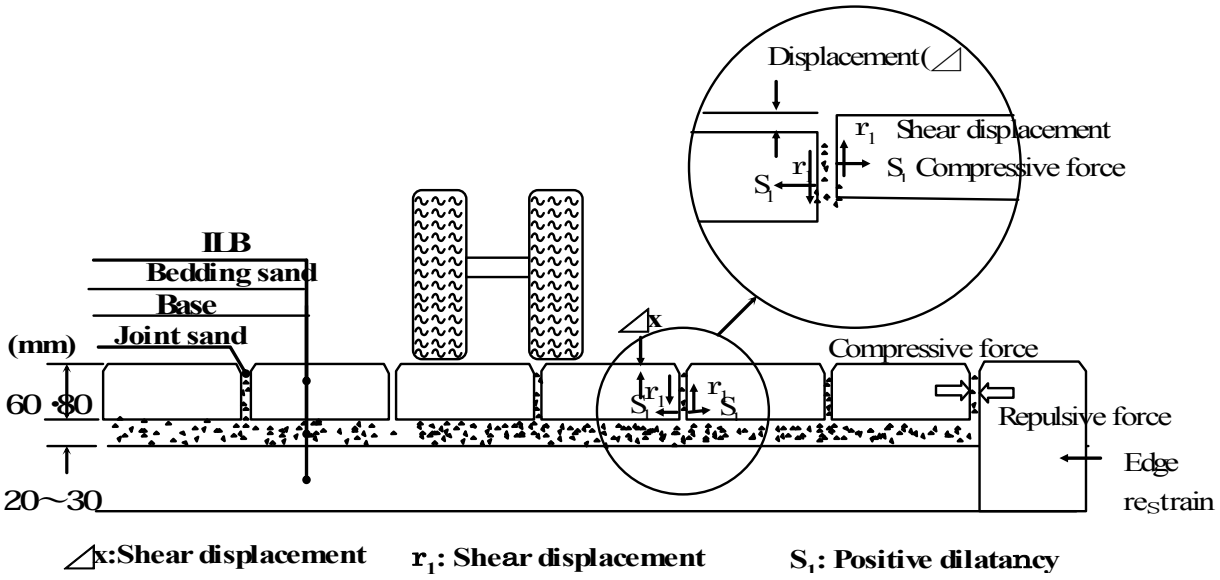


Figure 1. The Load Distribution Principle of ILB Pavement.

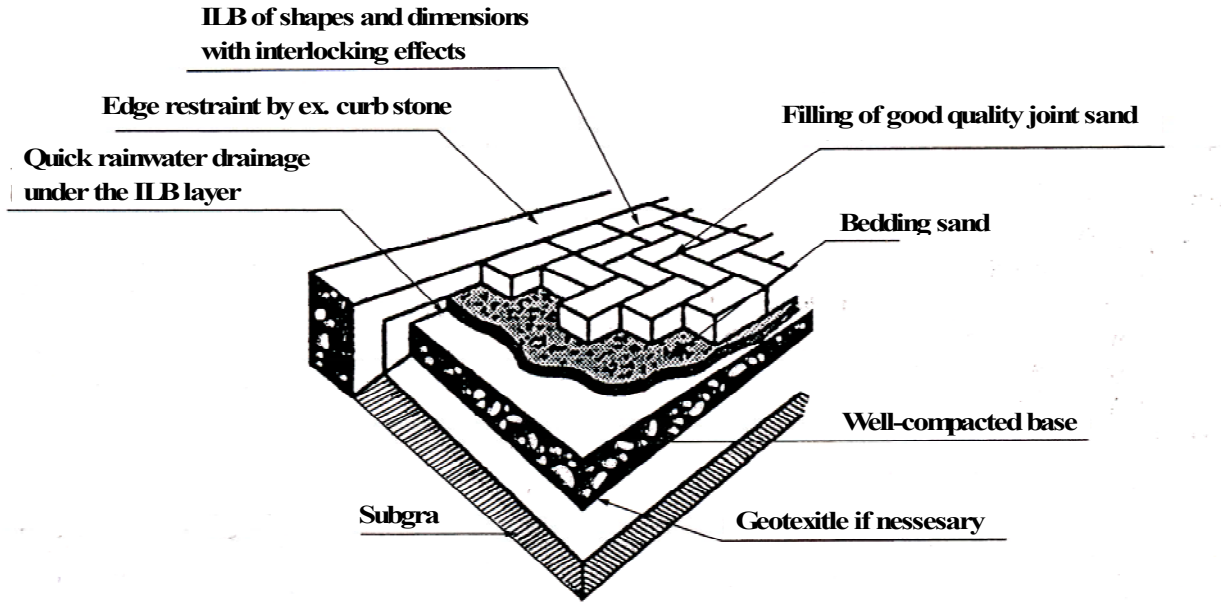


Figure 2. Key-points for Design, Construction and Maintenance of ILB Pavement.

3.2 The Definition of ILB

ILB is defined as concrete block for pavement which can executes interlocking effects and the interlocking effects are quantitatively expressed by load transfer efficiency (Elt, see Figure 3) which is the deflection ratio between the adjacent blocks. Fig-4 shows the larger the side area /upper surface area is, the lager Elt becomes. The shapes and dimensions which can secure the required Elt are classified into the two types shown in Table 3. The newly defined blocks are the ones called "Flag type" whose surface area is bigger than the conventional shapes and dimensions which are designated as "Segmental type".

Load Transfer Efficiency(E_{lt}) = D_1'/D_1

D_1 :Deflection at the edge of loaded ILB

D_1' :Deflection at the edge of unloaded ILB

D_0 :Deflection at the loading point

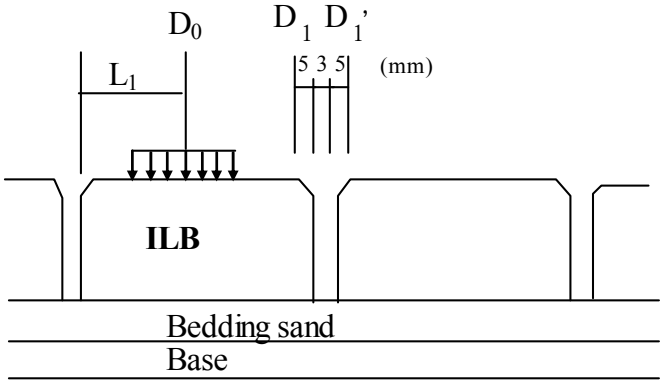


Figure 3. Measurement of Elt of ILB layers.

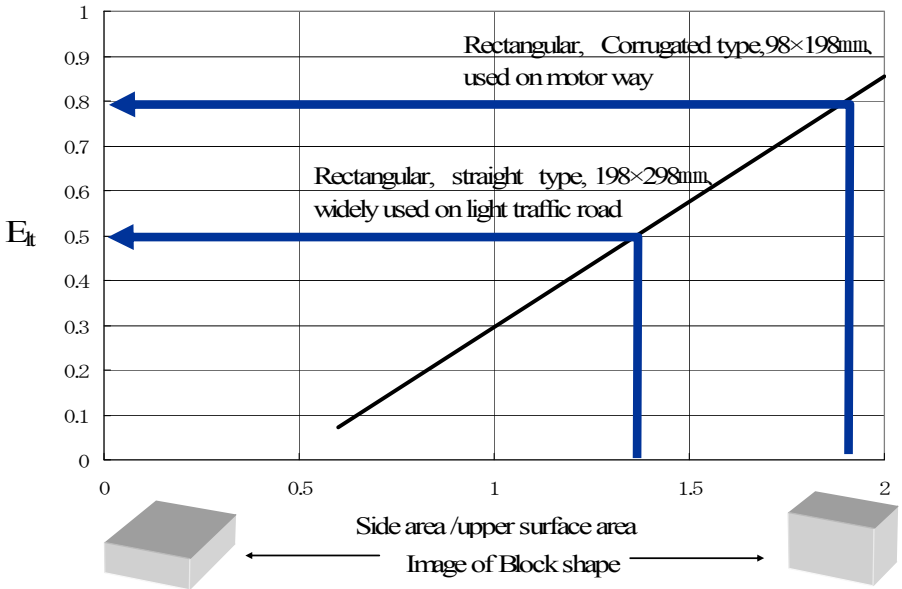
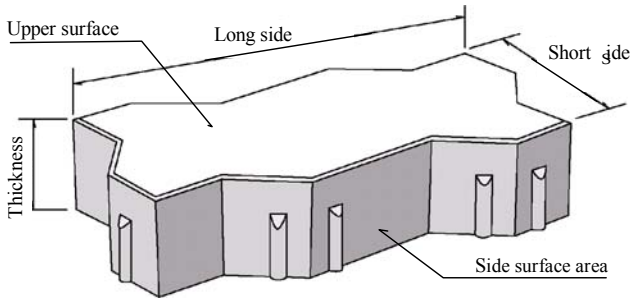


Figure 4. Shape of ILB and Elt.

Table 3. The type of ILB.

SEGMENTAL	FLAG
Widely applied for motorways to walkways. ILB wich an secure mjore than 0.3 Elt due to its shape and dimensions	**Maily applied to walkways. ILB wich an secure mjore than 0.1 Elt due to its shape and dimensions**
(Side surface area/Upper surface area) ≥ 1.0 (Long side / Thickness Lo) < 4 Short side ≥ 50 mm. Thickness ≤ 120 mm	**(Side surface area/Upper surface area) ≥ 0.65 Short side ≥ 50 mm. Thickness ≤ 80 mm**
	

3.3 Characteristics of ILB Pavement

ILB pavement can be widely applied to heavy traffic and light traffic roads, walkways and plazas but it is important to apply to such places as it can make the most of its characteristics. MANUAL clarified the following characteristics and points to be noted which ILB pavement possesses.

Characteristics:

1. Formation of Landscape and Enhancement.
2. Reservation and improvement of environment.
3. High durability like oil resistance and wear resistance.
4. Securing of traffic safety.
5. Easiness of repairing.
6. Quick opening to traffic.
7. Possibility to reduce lifecycle costs.

Points to be noted:

1. To pay attention to noise and vibration when it is applied to places of heavy traffic due to a number of joints.
2. To pay attention to quick loss of evenness and increase of joint faults in difficult cases of design and construction and maintenance.

4. DESIGN

4.1 Flow of Design

ILB pavement design is carried out for road surface design, structural design and plane design respectively. The outline of these designs are shown in Table 4. The structural design here contains not only the design for thickness and materials but also the ILB special own design items like edge restraint.

4.2 Road Surface Design

The type of ILB to be determined by road surface design shown in Table-4 is normal, permeable, water retaining and tactile block functionally classified. Examples of expected road surface

function and ILB type shown in Table-5 should be referred to when choosing the type of ILB which satisfies the set road surface function. The road surface design for pedestrians also includes choosing the Flag type which is easy for pedestrians and wheelchairs to walk on due to fewer joints.

Table 4. The Outline of the Three Design Items.

Road Surface Design	To determine the type, shape and dimension of ILB which constitute the appropriate road surface so that the road surface functions are satisfied.
Structural Design	To determine the material, thickness and structure of the edge restraint constituting each layer of the pavement according to the set structural design conditions so that the fixed functions are satisfied.
Plane Design	The road surface design to determine how to arrange as the laying pattern the geometric pattern of ILB pavement surface constituted by the color shade and surface texture of ILB.

Table 5. An Example of Expected Property and Kind of ILB.

EXPEDITED PROPERTY	KIND OF ILB	APPLIED SITE	
		MOTORWAY	WALKWAY
Resistance against Plastic Deformation	**Normal, Permeable, Water Retentive**	O	O
Permeability	**Permeable**	O	O
Drainability	**Permeable**	O	O
Noise Reduction	**Permeable**	O	---
Skid Resistance	**Normal, Permeable, Water Retentive**	O	O
Reduction of Road Surface Temperature	**Water Retentive**	O	O
Brightness	**Normal, Permeable, Water Retentive**	O	O
Visibility	**Permeable**	O	---
Design	**Normal, Permeable, Water Retentive**	O	O
Abrasion Resistance	**Normal (Single Layer)**	O	---

4.3 Structural Design

4.3.1 Traffic Conditions

The actually applied sites and traffic load are shown in Table 6 as ILB is often used widely not only for motorways but also for parking lots and pedestrian roads etc. Application examples for container yards and airports are shown in the appendix of MANUAL.

4.3.2 Edge Restraints

Figure 5 shows the examples of edge restraints for which in-situ concrete or precast concrete products should be used in order to secure interlocking effects and to prevent movement of blocks by traffic load.

4.3.3 Structural Design for Motorways

The design is to be carried out by TA method as so far adopted regarding the coefficient of relative strength of the ILB layer is equivalent to that of the base layer in the asphalt mix index (1.0). Design Traffic Volume for Pavement for the structural design (see Table 7) is set to be average vehicle traffic volume traveling one direction per day during the design period and it is classified

into ordinary road and light vehicle road. The performance of ILB pavements under N7 traffic category must be monitored as the actual cases under such heavy traffic are few. The design period is set for 10 or 20 years.

Table 6. Applied Sites and Traffic Load.

APPLIED SITES		TRAFFIC LOAD AND USERS
Motorway	**Ordinary road**	Heavy vehicles, Light vehicles
	Light vehicle road	Light vehicles, Passenger cars
Parking lots		Heavy vehicles, Light vehicles, Passenger cars
Pedestrian Roads	**Walkway**	Pedestrians, Bicycles, Wheelchairs
	Road exclusively for pedestrians	
	Cycling road	
	Road for pedestrians and bicycles	
	Road in the park	
	Plaza	
Container yards		Forklifts, Containers
Airport Aprons		Aircrafts, Toeing tractors

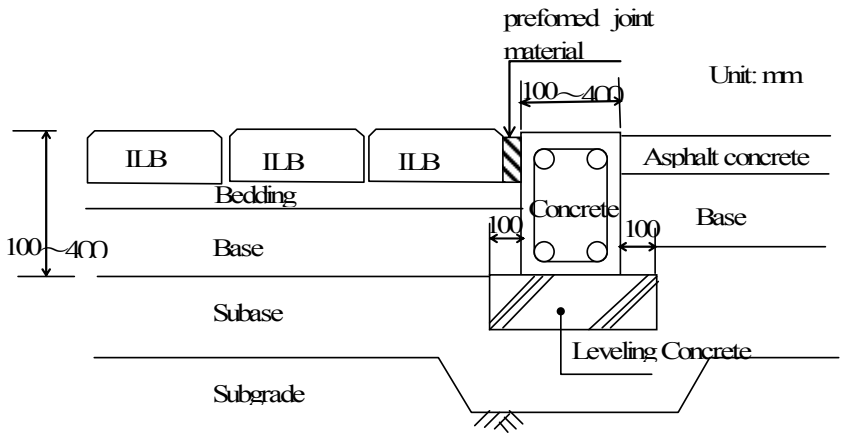


Figure 5. Example of Edge Restraint (in-situ concrete).

Table 7. Design Daily Traffic Volume of motorway for pavement.

	DESIGN TRAFFIC LOAD	TRAFFIC CATEGORY	DESIGN DAILY TRAFFIC VOLUME X DAY/DIRECTION
Ordinary road	**Heavy vehicle (49 kN Wheel load)**	N7	$X \geq 3\,000$
		N6	$3\,000 > X \geq 1\,000$
		N5	$1\,000 > X \geq 250$
		N4	$250 > X \geq 100$
		N3	$100 > X \geq 40$
		N2	$40 > X \geq 15$
		N1	$15 > X$
Light vehicle road	**Light vehicle (17 kN Wheel load)**	S4	$X \geq 3\,000$
		S3	$3\,000 > X \geq 650$
		S2	$650 > X \geq 300$
		S1	$300 > X$

4.3.4 Structural Design for Parking Lots

Parking lots are consisted of parking spaces mainly for static load, roads connecting to the parking space which are used for slow driving, entrances and exits to general roads whose traffic volume is most in the parking yards etc. Since the respective usage of these areas is different, the structural design should be carefully done considering such usage. So, important points for designing parking spaces, driving ways and entrances and exits respectively are shown in MANUAL.

4.3.5 Structural Design for Pedestrian Walkways

The pavement structure for pedestrians, bicycles, and wheelchairs is shown in Table 8. A revision characteristic is seen in the point that a section using flag type of blocks is also shown.

Table 8. The pavement structure for pedestrians, bicycles and wheelchairs.

KIND AND TYPE OF ILB		INTERLOCKING BLOCK LAYER (mm)		BASE (mm)	TOTAL THICKNESS (mm)
		ILB	BEDDING SAND	CRUSHER RUN (C30 OR RC30)	
Normal	Segmental	60	30	100	190
	Flag	60 (80) Note 1	30	100	190 (210)
Note 1: The 80 mm thickness applies to flag type of block with dimensions of 298 x 598, 398 x 598, 398 x 398, 448 x 448, 498 x 498 (mm).					

4.3.6 Structural Design for Drain, Permeable and Water Retaining Block Pavement

As infiltration and disposal of rainwater have to be considered, the structure of drainage pavement using permeable block, permeable pavement using permeable block, and water retaining pavement using water retaining block is shown. An example of structure for drainage pavement for walkways the application to which is most is shown in Table 9.

Table 9. Permeable Pavement Structure for Pedestrian Walkways.

KIND AND TYPE OF ILB		INTERLOCKING BLOCK LAYER (mm)			BASE (mm)	FILTER LAYER	TOTAL THICKNESS (mm)
		ILB	BEDDING SAND	PERMEABLE SHEET	CRUSHER RUN (C30 OR RC30)		
Permeable	Segmental	60	30	Geotextile	10	50	24
	Flag	60 (80) Note 1	30	Geotextile	10	50	240 (260)
Note: The 80 mm thickness applies to flag type of block with dimensions of 298 x 598, 398 x 598, 398 x 398, 448 x 448, 498 x 498 (mm).							

4.3.7 Structural Design for Special Place

The examples of Structural Design for Special Places (See Table 10) are shown in this MANUAL.

Table 10. Structural Design for Special Places.

1. Bus bay and Bus terminal.
2. Vehicle-into-OK area on pedestrian walkways.
3. Area for fire engines.
4. Intersections and pedestrian crossings.
5. Sharp slopes.
6. Bridges.
7. Tunnels.
8. Airports and Port container yards.

4.4 Plane Design

Main revisions are as follows:

1. Points for plane designing when large size, Flags, are used are increased.
2. Descriptions when tactile blocks are used are more thorough and as especially in "Movement Facilitation Maintenance Guideline for Road" [JICE, 2002] it is considered to be appropriate to secure 0.2 luminosity contrast ratio between tactile blocks and the peripheral road surface so that the blocks can be recognized by amblyopic people and compatible for people having healthy eyesight, the recommendable method to measure and calculate luminosity contrast ratio is shown in the appendix. Color combination examples between tactile blocks and the peripheral ILBs are shown in color.
3. Since classifications of application and traffic volume categories increased, the places to be applied and laying patterns are rearranged as shown in Table 11.

5. MATERIALS

5.1 ILB

1. The definition from the production aspect is shown as "Interlocking block is concrete block produced on the highly vibrated and pressurized instant demolding system."
2. The shape and dimension of mainly produced ILB is shown in Table 12. The size of the flag type is known from this Table.
3. The quality standard of ILB is shown in Table 13. From the structural design point of view, more than 5.0 MPa bending strength for the place where large vehicles travel regardless of the kind of ILB is required. There are various kinds of vegetation (greening) blocks developed and not all of them match satisfies the definition in Table 3 but since the recommended specifications are already in JIS A 5371, the standard is shown in the table.
4. From the hearing survey results from manufacturers concerning freeze/thaw damage of ILB, it was judged to have practically sufficient freeze/thaw resistance if normal ILB has more than 5.0 MPa bending strength and if permeable ILB has more than 3.0 MPa.

5.2 Others

Since bedding sand greatly influences serviceability of ILB pavement, the quality standard of sand for each traffic volume classification was set up. It is important to use bedding sand having the maximum particle size of 4.75 mm and sieve passing less than 5% on 75 μm sieve. And since a lot of examples of unevenness are observed when dry mix mortar is used for the bedding layer, it is provided that dry mix mortar must not be used.

6. CONSTRUCTION

As far as construction is concerned, basically there was not a big change except for revision of some words but the points when Flag type is used are added in each construction procedure.

7. CONTROL OF WORKMANSHIP, QUALITY CONTROL AND INSPECTION

The control standard and inspection standard are revised due to fractionation of applied places and traffic load as follows:

1. The kind of damage was reviewed, for instance, clogging of permeable block was considered as a damage.

2. Important points when ILBs are removed and reused and at the same time, the importance of sufficient construction control are shown.
3. More thorough descriptions on maintenance and repair are given.

Table 11. Places to be Applied and Laying Patterns.

PLACES TO BE APPLIED		DESIGN TRAFFIC VOLUME CLASS OR DESGING TRAFFIC	LAYING PATTERNS
No.1	**Ordinary road**	N1-N4	Herringbone bond 90°
	Light vehicle road	S4	Herringbone bond 45°
No.2	**Ordinary road**	N3	Herringbone bond 90°
	Light vehicle road	S3	Herringbone bond 45°
	Parking lot	Heavy Vehicle	Stretcher bond
	Vehicle-into-OK area on walkway		
No.3	**Ordinary road**	N2, N3	Herringbone bond 90°
	Light vehicle road	S2, S1	Herringbone bond 45°
	Parking lot	Light vehicle	Stretcher bond
	Vehicle-into-OK area on walkway	Passenger car	Basket weave
	Part for fire engine	N1	Irregular type
	Pedestrian Walkway	---	Combination of big and small blocks
			Etc.

Table 12. Places to be Applied and Laying Patterns.

TYPE	THICKNESS (mm)	SHAPE		DIMENSION (mm)
Segmental	60 or 80	Rectangular	Corrugated type	109.5 x 222, 111 x 225, 117 x 237
			Straight type	98 x 198, 148 x 198, 148 x 248, 148 x 298, 198 x ¿?
		Square	Corrugated type	222 x 222, 225 x 225, 237 x 237
			Straight type	98 x 98, 148 x 148, 198 x 198, 298 x 298
Flag	60	Rectangular	Straight type	298 x 448, 298 x 498
	80	Rectangular	Straight type	298 x 598, 398 x 598
		Square	Straight type	398 x 398, 448 x 448, 498 x 498

Japan Interlocking Block Pavement Engineering Association (JIBPEA) [2007]. Manual for Interlocking Block Pavement Design and Construction (2007 Version). (In Japanese).

8. CONCLUSIONS

The revision this time precisely described the design method and the construction standard widened its application possibility as a paving material by adding evaluation standard and method of new functions. More figures and photos are increased for an easier guideline.

It is necessary to utilize this MANUAL recognizing that ILB pavement is pavement which exerts its function if only material efficiency, pavement design and construction method come to a harmony

9. REFERENCES

Japan Road Association (JRA), (2005). Technical Guideline for Pavement Design and Construction, 2005, Dec. (in Japanese).

Japan Institute of Construction Engineering (JICE), (2002). Movement Facilitation Maintenance Guideline for Road-For the aged and physical handicapped person. 2002, Jan. (In Japanese).

Table 13. Quality Standard of Interlocking Block.

KIND	ITEM	MOTORWAY	PEDESTRIAN ROADS
		Parking lot (mainly heavy vehicle or light vehicle)	Parking lot (mainly passenger car)
		Vehicle-into-OK area on walkway (mainly heavy vehicle)	Vehicle-into-OK area on walkway (mainly or passenger car)
		Part for fire engines	---
Normal	Dimension (width, length)	Within ± 2.5 mm	
	Thickness	Within ± 2.5 mm	
	Bending strength	More than 5.0 MPa	More than 3.0 MPa
Permeable	Dimension (width, length)	Within ± 2.5 mm	
	Thickness	-1.0 to +4.0 mm	
	Bending strength	More than 5.0 MPa	More than 3.0 MPa
	Coefficient of permeability	1.0 x 10-2 cm/s	
Water retaining	Dimension (width, length)	Within ± 2.5 mm	
	Thickness	Within ± 2.5 mm	Within -1.0 to +4.0 mm
	Bending strength	More than 5.0 MPa	More than 3.0 MPa
	Water retentivity	Water retention more tan 0.15 g/mc3	
	Water absorption	Absorbing height more tan 70%	
Vegetation block	Dimension (width, length)	Within ± 2.5 mm	
	Thickness	Within ± 2.5 mm	
	Bending strength	More tan 4.0 MPa	