Government of the Peoples Republic of Bangladesh

Local Government Engineering Department (LGED)

Design procedure, Template, Implementation and Maintenance Manual of Interlocking Concrete Block Pavement (ICBP)

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Housing and Building Research Institute
120/3, Darus-Salam, Mirpur Road, Dhaka-1216

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1.1. Types and Shapes of Blocks:

According to the guidelines for the use of interlocking concrete block pavement published by Indian Road Congress, blocks are now manufactured with improved shapes as per their practical applicability. Preliminarily, blocks were simply made rectangular with plain faces (like regular bricks). Then dented sides were introduced to blocks for better interlocking effects with their surrounding units Figure 1.2, resulting in higher shear strength of the block system, enhancing their load transmission capacity. Furthermore, an evolution over dented rectangular block (i.e., "A" shape, Figure 1.3) was introduced for better interlock. An improvement over A-Shape block was proposed (i.e. "X" shape, Figure 1.4) for additional interlocks and suitability for fully mechanized paving.

Figure 1.1: Plain Faced Rectangular Blocks

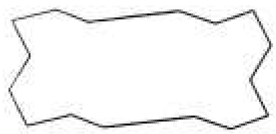


Figure 1.2: Dented Rectangular Blocks

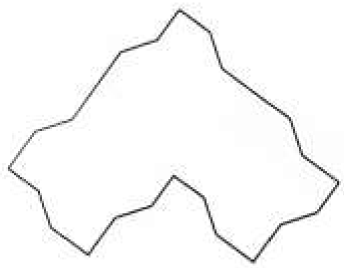


Figure 1.3: "A" Shaped Dented Block

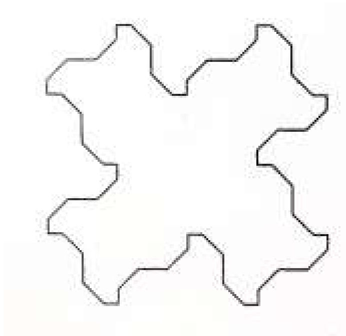


Figure 1.4: “X” Shaped Dented Block

Based on the above four shapes, blocks were further classified into three (03) Categories**(Figure 1.5)**:

- **Category A:** All four faces are suitable for interlock. These blocks can be laid in herringbone bond pattern.
- **Category B:** Only two faces are used for interlock. These blocks are laid in stretcher bond.
- **Category C:** These blocks are not dented in any face and laid in stretcher bond.

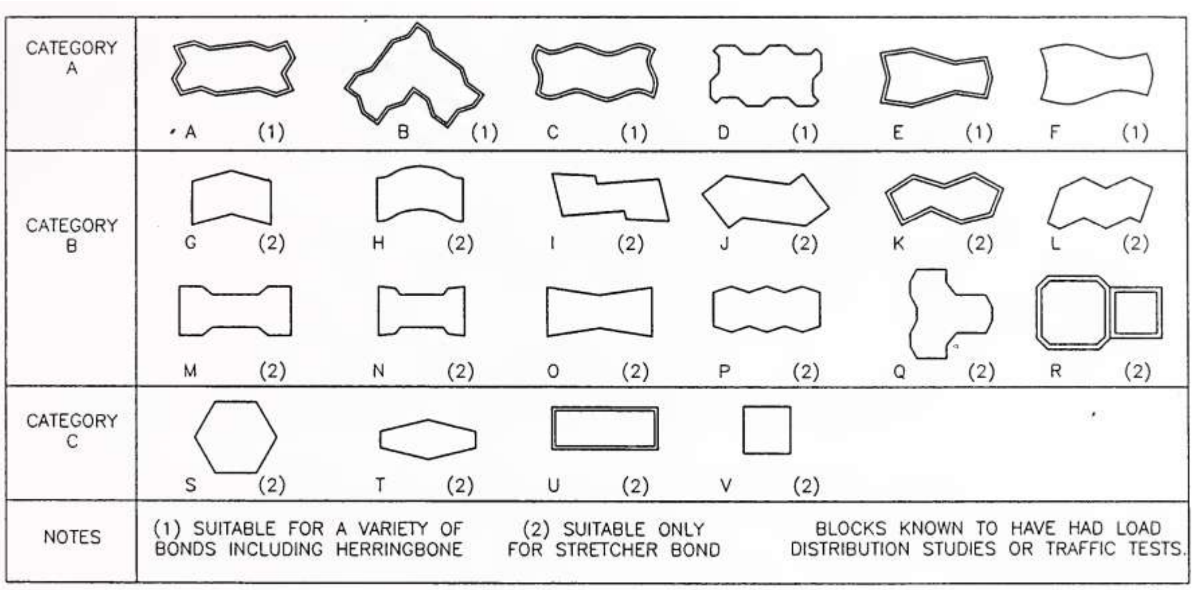


Figure 1.5: Different Categories of Blocks

To beautify the appearance of ICBP pavements, special grass blocks**(Figure 1.6)** are used which allow grass to grow in the hollow spaces in the blocks filled with soil.

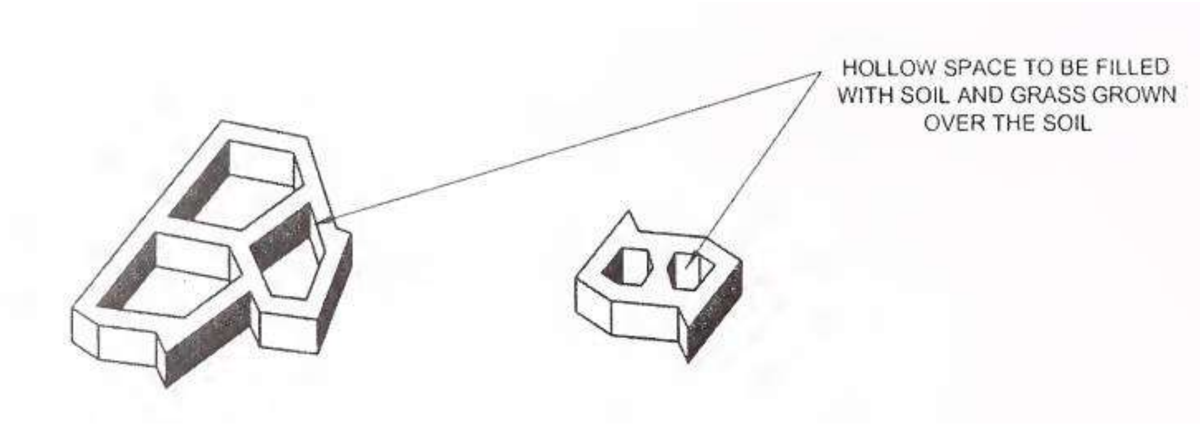


Figure 1.6: Typical Grass Blocks

1.2. Tests on ICBP (Materials + Final Product)

Some preliminary tests on the sample dredged materials collected from the desired locations would be conducted as per ASTM standards. Once, they are cleared for their suitability, then ICBP paving units would be prepared with them and their respective compressive strengths would be determined and commented upon. Since, all the experimental details could be found in ASTM standards, therefore, only title of each experiment is provided along with its respective source for reference.

a) Sieve Analysis and Hydrometer Analysis as per ASTM D 422
b) Water Absorption Test as per ASTM C 67
c) Efflorescence Test of ICBP as per ASTM C67
d) Compressive Strength Test of ICBPs as per ASTM
e) Tensile Strength Test of ICBP*

*Currently, tensile strength test for ICBP or bricks are not available at HBRI and HBRI already contacted BUET regarding this particular experimental investigation. Unfortunately, no clear confirmation from BUET is obtained as of yet regarding the institution's capacity to conduct this specific test. However, (Oskouei et al., 2017) proposed an indirect method of conducting this test on concrete cylindrical specimen(s) and it is called "Brazilian Test". Under this test, cylindrical test samples of 15 cm diameter and 30 cm height were prepared and they were subjected to the tensile strength testing machine which measured the compressive force and perpendicular displacement of the specimens. The formula used to calculate the tensile strength of concrete is shown in the next page:

$$\sigma_t = \frac{2p}{\pi D t}$$

Equation 1: Indirect Determination of Tensile Strength of Concrete (from Compressive Force)

where, σ_t=Tensile Strength of Concrete

p = Compressive force applied to the specimen till failure

D = Diameter of the specimen

t = Length of the specimen

Further information regarding sample collection, fabrication of ICBP, composition of materials used along with admixtures (i.e. chemicals), coarse sand, etc. and their resulting compressive strengths are provided in the final report.

1.3. Structural Design Considerations

According to the design considerations for interlocking concrete pavements prepared by UNILOCK, the design chart is based preliminarily on subgrade soil type including the contents of silt and sand represented in percentage against loading conditions measured in ESAL/day. Now, this design catalogue seems extensive at a first glance compared to IRC. But the values for the thicknesses of pavers, bedding sand, base and sub-base present in the table are pretty much the same provided in IRC manual since it is already discussed in IRC manual that the design methodologies for ICBP pavements are taken from other relevant codes and standards as independent research has not been conducted yet in India. Therefore, IRC recommends the use of its design catalogue for structural design considerations of light and medium traffic roads.

Design process flow chart **Figure 1.7** recommended to follow:

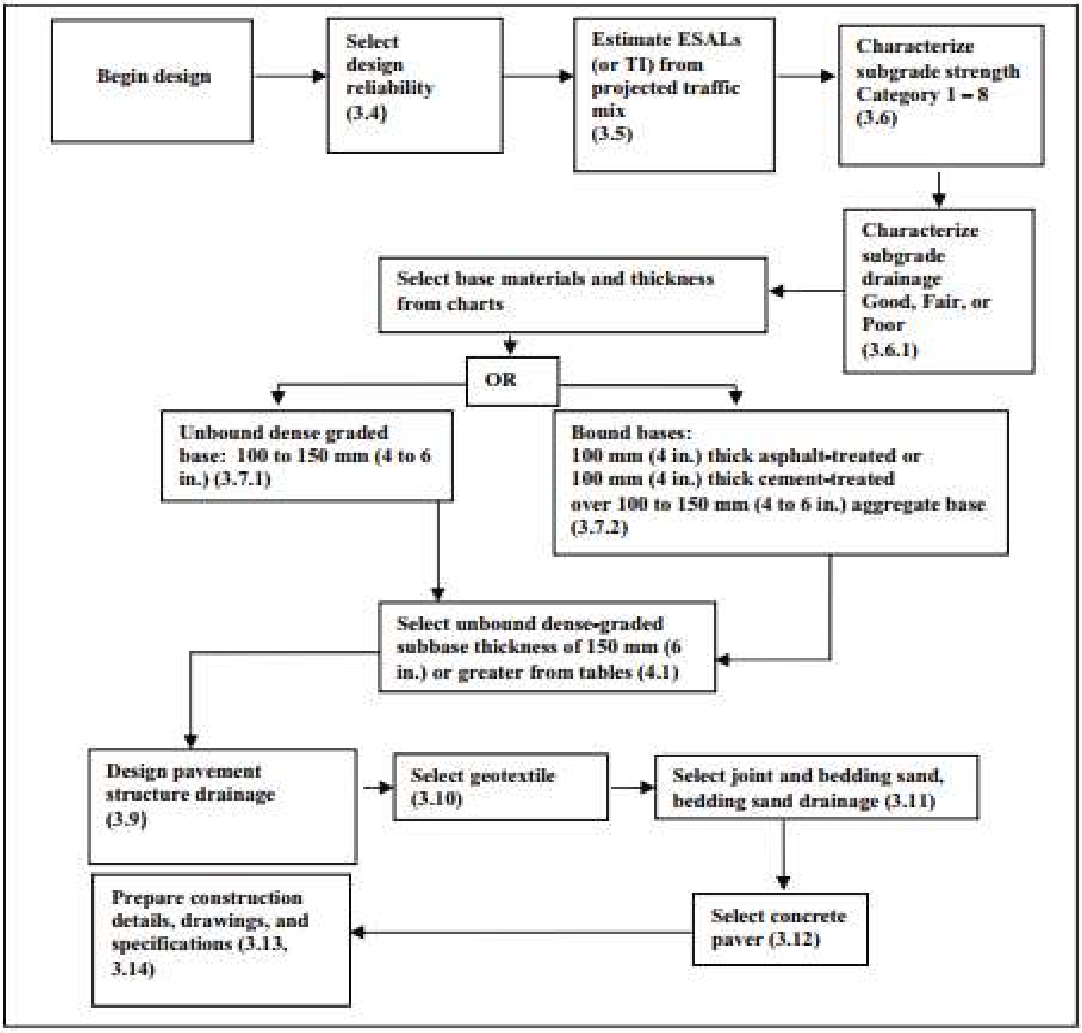


Figure 1.7: Design Process Flow Chart

Interlocking Concrete Pavement Institute (ICPI) provides technical information on ICBP pavement construction in the form of ICPI Tech Spec technical bulletins. Out of 25 bulletins, the following Tech Spec bulletins are more relevant in the present context of Bangladesh for design purpose.

Tech Spec 2: Construction of Interlocking Concrete Pavement.

Tech Spec 3: Edge Restrain for Interlocking Concrete Pavement.

Tech Spec 4: Pavement for Roads and Parking Lots.

Tech Spec 9: Guide Specification for the Construction of Interlocking Concrete Pavement.

Tech Spec 10: Application Guide for Interlocking Concrete Pavements.

Tech Spec 17: Bedding Sand Selection for Interlocking Concrete Pavements in Vehicular Applications.

Additionally, Technical Specification-4 of ICPI contains the structural design of interlocking concrete pavement for roads and parking lots. Design catalogues for this manual are so vast that thicknesses of different pavement layers are proposed on the basis of base treatment protocol, ESAL, Caltrans Traffic Index, pavement drainage conditions, etc. Furthermore, each design chart is further classified into 08 categories subsoil. Also, ICBP design procedures are explain for both flexible and rigid pavements.

The basis of designing pavement structure underneath the bedding sand and concrete block using AASHTO (1993) flexible pavement design method as per following equation:

$$log(w) = z_R \times s_0 + 9 \cdot 36 \times log(S_N + 1) - 0.20 + \frac{log\left[\frac{P_{i-P_t}}{P_i - 1 \cdot 5}\right]}{0 \cdot 40 + \frac{1094}{(s_N+1)^9}} + 2.32 \times log(M_R) - 8.07$$

Equation 2: Pavement Structure Design Equation below Concrete Block and Bedding Sand

Where

W= design traffic load in equivalent single axle load (ESALs)

Z_R= standard normal deviate for reliability, R

So = overall standard deviation

S_N = structural number of the pavement, calculated as $\sum a_i X d_i$

Where, a_i = structural layer coefficient per layer i

d_i = layer thickness per layer i

Pi = initial serviceability

Pt = terminal serviceability

M_R = subgrade resilient modulus (units must be US customary)

After analyzing the three design catalogues from IRC, UNILOCK and ICPI, it can be inferred that, IRC design template can be regarded as the simplest and most comprehensive one out of the three. Currently, this design catalogue can be readily implemented in field with some appropriate engineering judgements from professionals responsible for carrying out the actual planning and design of interlocking concrete block pavements.

Table 1: Salient Features of Interlocking Concrete Block Pavement Given in Guide Book Technical Bulletins of Different Institution and Organization and Paving Block Manufacturers

Name of Institution/ Organization/ Manufacturer Provides Guidebook or Technical Bulletins	Dimension of Block and Strength Consideration	Structural Design on the Basis of Subgrade CBR and Drainage	Application Area, Street, Sidewalk, etc.	Traffic Load for Design of Pavement	Remark
The International Road Congress, IRC: SP-63-2004	Block (Paving) different shapes 1. Top surface area: 5000 mm^2 -60000 mm^2. 2. Length not exceeding 28 cm 3. 1< mean length/mean width< 3 4. Thickness 60 mm to 140 mm. 5. Aspect i.e. Length/Width< 4 Block should be machine made under zero-slump mix. Block should be above 30 MPa Concrete Mix Coarse Aggregate = 40% Sand= 60%	Considered two types of CBR 1. Above 10 2. Between 5-10 3. If subsoil CBR is less than 5, subgrade should need to be improved and stabilized and bring to minimum CBR 5 or above.	Footpath, Sidewalk, Cycle Track, Residential Street, Light Vehicle Street and Commercial Vehicles	1. Cycle Track, Pedestrian footpath 2. Commercial traffic less than 10 MSA (Million Standard Axles) 3. 10-20 MSA 4. 20-50 MSA Paver Block Thickness and Underlying Flexible Road Structures are Provided.	

Name of Institution/ Organization/ Manufacturer Provides Guidebook or Technical Bulletins	Dimension of Block and Strength Consideration	Structural Design on the Basis of Subgrade CBR and Drainage	Application Area, Street, Sidewalk, etc.	Traffic Load for Design of Pavement	Remark
Interlocking Concrete Pavement Institute (ICPI) Ref: TECH SPEC GUIDE (Feb. 2017)	<u>Tech Spec 10</u> ASTM C936 standard surface area 101 in^2 (0.065 m^2). Aspect Ratio= length/thickness <4 As per Canadian Standard CSA-A231.2 Surface Area equal or less than 140 in^2 (0.09 M^2). Aspect ratio less than or equal to 4:1 for Pedestrian Application and less than or equal to 3:1 for vehicular application. <u>Tech Spec 21</u> Standard Strength as per ASCE C936 is 55 MPa and no individual unit below 50 MPa	Use Unified Soil Classification (USA) 8 Category considering materials and drainage characteristics with CBR value chart. As per AASHTO structural number layer coefficient (SN) of 0.44 for paver and bedding sand. ICPI provides 4 table of layer design for 8 categories of soil, considering 4 types of bases 1. Granular base 2. Asphalt treated base 3. Cement treated base 4. Asphalt concrete base.	ICP only for streets and parking lots on the basis of ESALs of traffic.	Use ESALs Trailer= 2 ESALS Trailer $(80/80)^4$= 1 (2 axles) Truck rear=1.2; (2 axles) $(70/80)^4$ =0.6*2 Truck front =0.15 ESAL $(50/80)^4$ =0.15 Car=0.0002 ESALs	

Name of Institution/ Organization/ Manufacturer Provides Guidebook or Technical Bulletins	Dimension of Block and Strength Consideration	Structural Design on the Basis of Subgrade CBR and Drainage	Application Area, Street, Sidewalk, etc.	Traffic Load for Design of Pavement	Remark
UNILOCK Design Considerations for Interlocking Concrete Pavement	Three thickness considered Light Traffic=60 mm	Poor subgrades needs to be modified to stabilized in bringing it to minimum CBR of 5.	• Streets • Industrial Parking Areas • Container and Multimodal facilities • Airport Taxiway and aprons	Parking area	
Cement and Concrete Association of New Zealand and New Zealand Concrete Masonry Association Inc. **Book: Interlocking Concrete Block Road Pavements**	Maximum (horizontal) plan dimension=250 mm Minimum thickness=60 mm Manufactured thickness are 60 mm, 80 mm and 100 mm.	Design CBR considered as C_d = C-1.28S where Cd = Design CBR, C is field samples CBR and S standard deviations. Subgrade classification on the basis of CBR (3 classifications Classifications – CBR Weak – 4 Medium – 7 Strong – 15	Type of street on the basis of illustrative EDA (Equivalent Design Axles) over 20 years 1. EDA upto $3*10^4$ Block thickness 60 mm 2. If> $3*10^4$ EDA thickness 80 mm Recommendation for Herringbone layering pattern	Using Equivalent Design Axles (EDA) instead of ESAL (Equivalent Single Axle Load of 80 KN) Considering vehicles equal or over gross weight of 3.5 Ton.	

1.3.1. Structural Design Remarks

From the above table of salient features of ICBP, it is seen that each organization/Institution has different preference for the use of ICBP. The guidebook of the Indian Road Congress, IRC: SP-63-2004, provides a minimum threshold strength of 30MPa with mix ratio of coarse aggregate 40% and sand 60%, manufactured through machine mold under appropriate pressure with zero slump mix.

IRC has considered two types of subgrade CBR: (I) above 10 & and (ii) between 5-10. If the CBR is less than 5, subgrade needs to be improved and brought to a minimum of 5 or above. In present case, the blocks are mainly for low traffic village roads. The thickness of block will be of 4 types.

The IRC guide book is suitable for Bangladesh village roads constructed manually.

All 3 institutions' guide/Specification books are related with mostly heavy commercial vehicles and therefore, not suitable for the given assignment of ICBP construction (strength 30-35 MPa) for Bangladesh with dredge sand of Rivers, Khals etc.

Also, IRC is exclusively chosen because India is neighboring county of Bangladesh and consideration of the similarities between climatic factors, socio-economic considerations and availability of materials are taken into consideration. The detailed structural design of ICBP roadways is resource-intensive and cannot be covered within the present budget, manpower and time limit. Thus, it requires extensive experiments and field constructions and performance evaluations.

It is worth mentioning that in IRC Structural Design, road types are provided on subgrade CBR (%) and ESAL of traffic volume of design lifetime which are useful for the purpose.

Since most of the efforts are given into the utilization of dredging sands from different locations, containing different gradations and FM to make ICBP of required strength (30-35 MPa) and incorporate these blocks with traffic loads and soil CBR values to propose suitable thickness of roads layers.

A consensus was reached which states that blocks are to be manufactured using dredged sands and for village roads construction, the strength of the blocks was considered between 30-35 MPa.

As discussed earlier, most international journals consider 55MPa (and single block minimum strength 50MPa) for ICBP roads for commercial vehicles.

Only IRC recommends a minimum strength of 30 MPa for low and light loader vehicular traffic.

The consultant has reviewed the LGED design template of ICBP where it cited the strength of 30-40MPa for cycle tracks, pedestrian footpath and non-motorized vehicles to low vehicles road (CVD 0-100) in 7 categories of traffics.

For cycle tracks, pedestrian footpaths, and non-motorized vehicles, 30MPa strength blocks of 60mm thickness, and for low traffic road, 35 MPa strength blocks of 80mm thickness were considered.

The consultant, therefore, agreed to use the LGED design template with slight modification to the thickness of bedding sand (IRC gives sand bedding range of 20-40mm) and deleting heavy traffic roads from the template as they correspond to higher strength of Paving blocks (40MPa) which are not considered for the blocks manufactured from dredged sands.

A modified version of typical cross-section(s) of ICBP road is provided in the following page consisting of cross-sectional layer thickness and material composition of base course, subbase course, improved subgrade, subgrade and original soil for proposed ICBP roadways for non-motorized vehicles (including footpaths) and light traffics. The design template also contains ICBP layout patterns, block dimensions, gradations of bedding sand, jointing sand, base and sub-base materials.

The consultant engages solely for experimenting to find appropriate mix design and add-mixture for machine manufacturing of Paving Concrete Block with dredge sand of Rivers in getting required strength of 30-35 MPa.

1.4. Design Template of Interlocking Concrete Block ICBP Pavement

Design Template of ICBP Pavement was discussed with concerned personnel of LGED.

The consultant reviewed the Bituminous Pavement Design Template of BRTC of BUET (October 2018). In producing design template, BRTC considered traffic volume of commercial vehicles per day (CVD) and sub-grade CBR.

It provides a good number of templates in combination of a range of sub-grade CBR and CVD range. CBR range is 2%-3%, 4%-6%, and >7% and CVD range is 0-100, 101-200, 201-300, 300-400, 500- 750 and 750- 1000. It did not provide design template for subgrade <2% and for cycle tracks, pedestrian footpaths and non-motorized vehicles.

The consultant also reviewed LGED design templates of typical cross-section details of UNIBLOCK roads and highly recommend the use as long as field constructions and performance could be observed, verified and evaluated.

As per present assignment, it is understood that interlocking concrete block pavements are to be used in village roars alongside with nil to low commercial vehicles and mostly use by non-motorized vehicles besides pedestrians for which design templates are required of subgrade CBR is less than 2% and improved subgrade sands FM minimum 0.8 and in the range of 0.5%-0.8 and of 0.3-0.5.

The subgrade CBR from 2%-3% to 7% are already provided in BRTC design templates which could easily be used for low to medium commercial vehicles traffic, leaving off Bituminous layer and instead using paving blocks of 80mm thick.

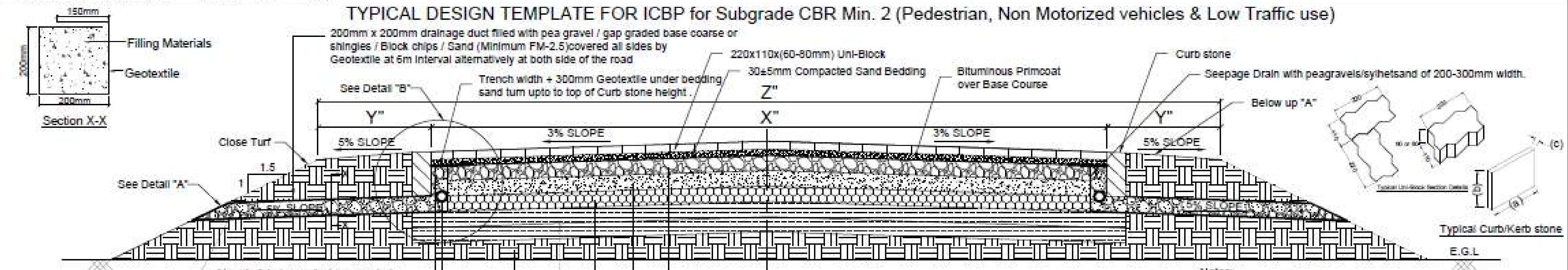
The consultant provided design template (s) for poor subgrade consisting of (1) silt (silted fine sand greater than 60%) and (2) clay after reviewing the booklet of UNIBLOCK design consideration for Interlocking concrete blocks pavements.

Table 2: Typical Pavement Structure by Subgrade Soil Type

Loading Conditions	Material	Subgrade Soil Type									
		Granular Suitable as Borrow		Silty Sand (Silt and Fine Sand less than 40%)		Silty Sand (Silt and Fine Sand 40 - 60%)		Silt (Silt and Fine Sand greater than 60%)		Clay	
		In.	mm	In.	mm	In.	mm	In.	mm	In.	mm
Pedestrian Use	Pavers	2 3/8 - 2 ¾	60 - 70	2 3/8 - 2 ¾	60 - 70	2 3/8 - 2 ¾	60 - 70	2 3/8 - 2 ¾	60 - 70	2 3/8 - 2 ¾	60 - 70
	Bedding Sand	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
	Base	6	150	6	150	6	150	6	150	6	150
	Subbase										
Light Duty (Driveways, Car Parking Areas)	Pavers	2 3/8 - 3 1/8	60 - 80	2 3/8 - 3 1/8	60 - 80	2 3/8 - 3 1/8	60 - 80	2 3/8 - 3 1/8	60 - 80	2 3/8 - 3 1/8	60 - 80
	Bedding Sand	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
	Base	6*	150	8	200	6	150	6	150	6	150
	Subbase					12	300	20	500	20	500
Minor Residential Roads	Pavers	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80
	Bedding Sand	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
	Base	6*	150	9	215	6	150	6	150	6	150
	Subbase					15	375	24	600	24	600
Residential and Collector Streets (25 to 500 ESAL/day)	Pavers	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80
	Bedding Sand	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
	Base	6*	150	6	150	6	150	6	150	6	150
	Subbase			11	275	17	425	26	660	26	660
Medium to Heavy Industrial Areas (500 to 1000 ESAL/day)	Pavers	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80
	Bedding Sand	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
	Base	6*	150	6	150	6	150	6	150	6	150
	Subbase			12	300	18	450	29	720	29	720
Heavy Industrial Areas (1000 to 1500 ESAL/day)	Pavers	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80
	Bedding Sand	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
	Base	6*	150	6	150	6	150	6	150	6	150
	Subbase			14	340	20	490	30	740	30	740

* Minimum recommended base course thickness.

TYPICAL DESIGN TEMPLATE FOR ICBP for Subgrade CBR Min. 2 (Pedestrian, Non Motorized vehicles & Low Traffic use)



At end of drainage duct,gap graded base coarse or similar size shingles busket enveloped with geotextile be placed. (Top 200mm Bottom 300mm)

200 mm-300 mm wide trench of appropriate slope upto outlet fill with gap graded base coarse material surrounded by Geotextile be constructed. Depth of the trench is to be upto,bottom of ISG or more to maintain slope according to length of outfall distance (In built up areas) as par note 12.Base coarse, Sub-base and ISG all are considered to act as Sub-surface drainage layers.

At build up area for both or one side. 80-100mm dia Perforated (upper half) PVC pipe enveloped with Geotextile be placed at bottom of longitudinal trench upto outlet.(Note 12 of Template)

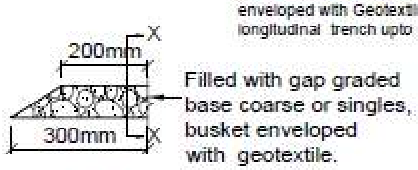
Base Coarse: (...........mm)"WMM / WBM,Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min. 80%, Compacted to 100% of MDD (Modified Proctor)

Sub-Base: (...........mm)" Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min.30%,Compacted to 98% of MDD (Modified Proctor)

ISG: (.............mm) Compacted Sand FM min. 0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

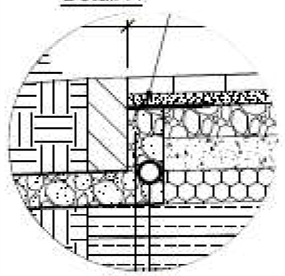
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

Original soil cut into designed shape, or fill with normal soil, PI Value 8%~20%, Compaction min. 95% of MDD (Modified Proctor),Soaked CBR min. 2% to achieve designed cross-section of side embankment.



Filled with gap graded base coarse or singles, busket enveloped with geotextile.

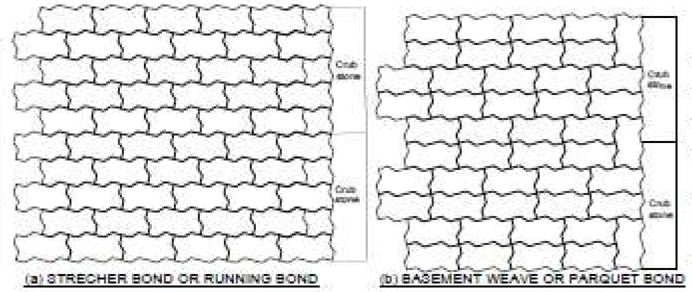
Detail-A



Sieve Size	Gap graded coarse material (Block/Brick chips) Drainage Materials for Trench Percent Passing(%)
50 mm	100
37.5 mm	90-100
19 mm	70-92
9.5 mm	50-70

Detail-B

TYPICAL X-Section



(a) STRECHER BOND OR RUNNING BOND

(b) BASEMENT WEAVE OR PARQUET BOND

Note for Geotextile

Sl.	Properties	Test Standard	Value
1	Minimum thickness	EN-ISO 9863	3.00mm
2	Opening size	EN-ISO 12956	0.075mm
3	Mass per unit area	BSEN 965	400 gm/m²
4	Tensile strength (md/cmd)	EN-ISO 10319	23kn/m
5	Elongation (md/cmd)	EN-ISO 10319	>=40% & <=100%

Note: See Annexure " VI "

Notes:

1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting ICBP (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after ICBP setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 20 years.
9. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi
10. If the road side situated beside pond or canal or unstable then size of kerb stone should be more and be consulted with the LGED design unit.
11. Drainage drain need to be placed at 6m interval in stagarred manner upto end of slope surrounded by Geotextile.
12. If road section runs through one or both side build up area a longitudinal drainage system is required with a gradient of 1:600 upto 1:1200 upto out fall.It may be open drain covered (for footpath) or uncovered or pipe drain or combination of both. 80-100mm dia Perforated (uper half) may required to be placed at bottom of the 200-300mm wide trenched filled with gapgraded base coarse. It may needs to be designed through design unit of LGED.
13. If sand is needed to be used in drainage duct then Fineness Modulus (FM) must grater then 2.5.
14. Compaction of material used in drainage duct must be 95% competed in proctor density test.
15. Note for Geotextile in Annexure "VI"

Typical Design template for ICPB

Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm) ISG	Sub-Base	Base	Sand Bedding (±5mm)	Thickness(mm)/Strength(Mpa) Concrete Block(CB)	Curb/Kerb Stone *	Probable Curb/Karb stone sizes (a x b x c) *	Remarks
01	Cycle Tracks,Pedestrian Footpaths Non-motorized Vehicles		250	–	150	30	60/30	150/30	550 x 200 x150	
02	Low Traffic Road for CVD 0-50	0.3 - 0.5	300	250	150	30	80/35	150/35	550 x 250 x150	
03		0.5 - 0.8	250	250	150	30	80/35	150/35	550 x 250 x150	
04		FM ≥ 0.8	200	200	150	30	80/35	150/30	550 x 250 x150	
05	Low Traffic Road for CVD 51-100	0.3 - 0.5	300	250	150	30	80/35	150/35	550 x 250 x150	
06		0.5 - 0.8	250	250	150	30	80/35	150/35	550 x 250 x150	
07		FM ≥ 0.8	250	200	150	30	80/35	150/35	550 x 250 x150	

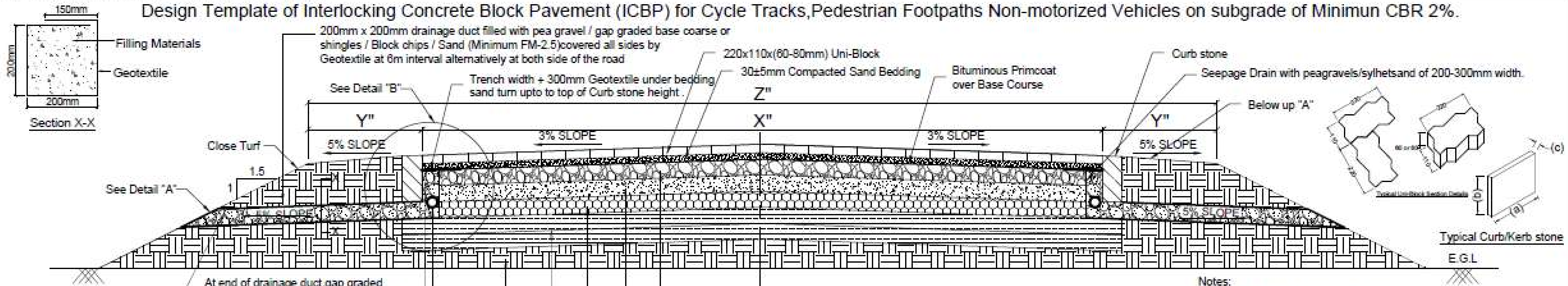
"*** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

Sieve Size	Base Material Gradation Percent Passing(%)	Sub-base material Gradation Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

Sieve Size	Bedding Sand Gradation Percent Passing(%)	Joint Filling Sand Gradation Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 1.1.1: Typical Design Template For ICBP for Subgrade CBR min.2(Pedestrian Non-Motorized Vehicles & Low Traffic use

Design Template of Interlocking Concrete Block Pavement (ICBP) for Cycle Tracks,Pedestrian Footpaths Non-motorized Vehicles on subgrade of Minimun CBR 2%.



At end of drainage duct,gap graded base coarse or similar size shingles busket enveloped with geotextile be placed. (Top 200mm Bottom 300mm)

200 mm-300 mm wide trench of appropriate slope upto outlet fill with gap graded base coarse material surrounded by Geotextile be constructed. Depth of the trench is to be upto,bottom of ISG or more to maintain slope according to length of outfall distance (in built up areas) as par note 12.Base coarse, Sub-base and ISG all are considered to act as Sub-surface drainage layers.

At build up area for both or one side. 80-100mm dia Perforated (upper half) PVC pipe enveloped with Geotextile be placed at bottom of longitudinal trench upto outlet.(Note 12 of Template)

Base Coarse: (..........mm)*WMM / WBM,Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min. 80%, Compacted to 100% of MDD (Modified Proctor)

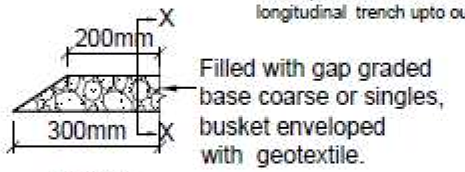
Sub-Base: (..........mm)* Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min.30%,Compacted to 98% of MDD (Modified Proctor)

ISG: (............mm) Compacted Sand FM min. 0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

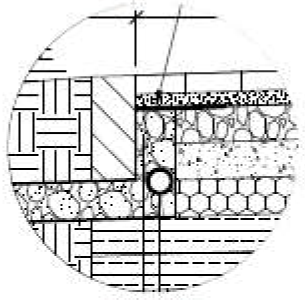
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

Original soil cut into designed shape, or fill with normal soil, PI Value 8%~20%, Compaction min. 95% of MDD (Modified Proctor),Soaked CBR min. 2% to achieve designed cross-section of side embankment.

TYPICAL X-Section

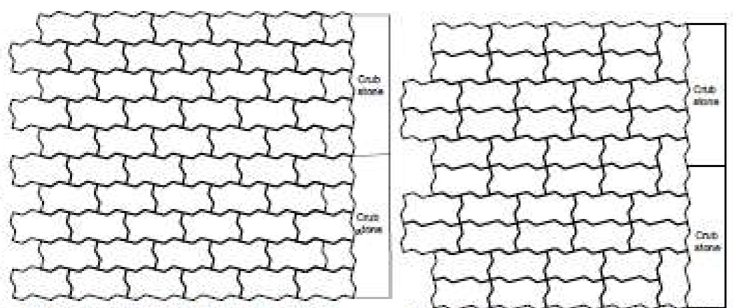


Detail-A



Detail-B

Gap graded coarse material (Block/Brick chips)	
Sieve Size	Drainage Materials for Trench Percent Passing(%)
50 mm	100
37.5 mm	90-100
19 mm	70-92
9.5 mm	50-70



(a) STRECHER BOND OR RUNNING BOND (b) BASEMENT WEAVE OR PARQUET BOND

Note for Geotextile

Sl.	Properties	Test Standard	Value
1	Minimum thickness	EN-ISO 9863	3.00mm
2	Opening size	EN-ISO 12956	0.075mm
3	Mass per unit area	BSEN 965	400 gm/m²
4	Tensile strength (md/cmd)	EN-ISO 10319	23kn/m
5	Elongation (md/cmd)	EN-ISO 10319	>=40% & <=100%

Note: See Annexure " VI "

Notes:

1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting ICBP (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after ICBP setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 20 years.
9. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi
10. If the road side situated beside pond or canal or unstable then size of kerb stone should be more and be consulted with the LGED design unit.
11. Drainage drain need to be placed at 6m interval in stagarred manner upto end of slope surrounded by Geotextile.
12. If road section runs through one or both side build up area a longitudinal drainage system is required with a gradient of 1:600 upto 1:1200 upto out fall.It may be open drain covered (for footpath) or uncovered or pipe drain or combination of both. 80-100mm dia Perforated (uper half) may required to be placed at bottom of the 200-300mm wide trenched filled with gapgraded base coarse. It may needs to be designed through design unit of LGED.
13. If sand is needed to be used in drainage duct then Fineness Modulus (FM) must grater then 2.5.
14. Compaction of material used in drainage duct must be 95% competed in proctor density test.
15. Note for Geotextile in Annexure "VI"

Design template for ICPB

Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c) *	Remarks
			ISG	Sub-Base	Base	Sand Bedding (±5mm)	Concrete Block(CB)	Curb/Kerb Stone *		
01	Cycle Tracks,Pedestrian Footpaths Non-motorized Vehicles		250	–	150	30	60/30	150/30	550 x 200 x150	

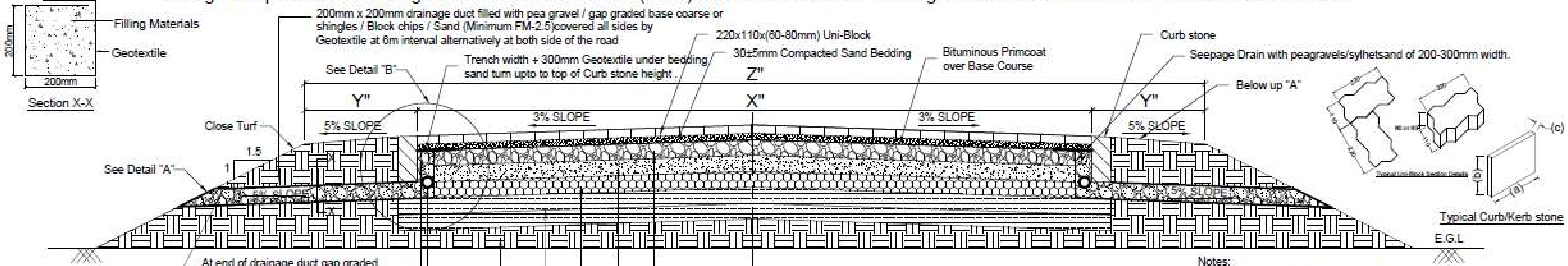
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

Sieve Size	Base Material Gradation	Sub-base material Gradation
	Percent Passing(%)	Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

Sieve Size	Bedding Sand Gradation	Joint Filling Sand Gradation
	Percent Passing(%)	Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 1.1.2: Design Template of Interlocking Concrete Block Pavement (ICBP) for Cycle Tracks, Pedestrian Footpaths Non-Motorized Vehicles on Subgrade of Minimum CBR 2%

Design Template of Interlocking Concrete Block Pavement (ICBP) for vehicles of 0-50 CVD subgrade CBR Min 2% ISG sand FM between 0.3 to 0.5



At end of drainage duct,gap graded base coarse or similar size shingles busket enveloped with geotextile be placed. (Top 200mm Bottom 300mm)

200 mm-300 mm wide trench of appropriate slope upto outlet fill with gap graded base coarse material surrounded by Geotextile be constructed. Depth of the trench is to be upto,bottom of ISG or more to maintain slope according to length of outfall distance (in built up areas) as par note 12.Base coarse, Sub-base and ISG all are considered to act as Sub-surface drainage layers.

At build up area for both or one side. 80-100mm dia Perforated (upper half) PVC pipe enveloped with Geotextile be placed at bottom of longitudinal trench upto outlet.(Note 12 of Template)

Base Coarse: (...........mm)*WMM / WBM,Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min. 80%, Compacted to 100% of MDD (Modified Proctor)

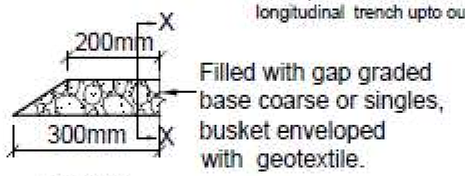
Sub-Base: (...........mm)* Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min.30%,Compacted to 98% of MDD (Modified Proctor)

ISG: (.............mm) Compacted Sand FM min. 0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

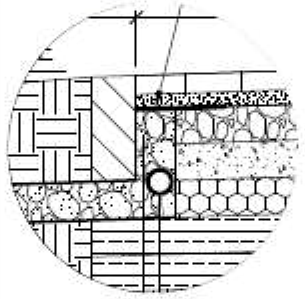
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

Original soil cut into designed shape, or fill with normal soil, PI Value 8%~20%, Compaction min. 95% of MDD (Modified Proctor),Soaked CBR min. 2% to achieve designed cross-section of side embankment.

TYPICAL X-Section

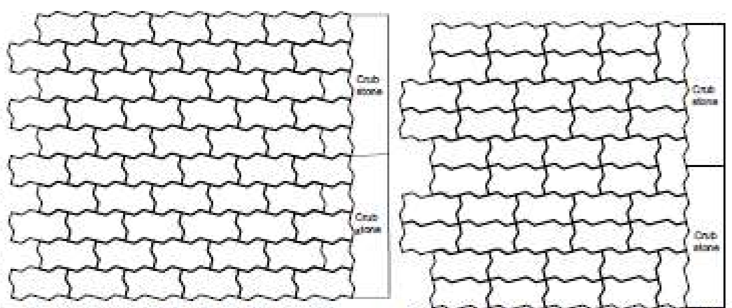


Detail-A



Detail-B

Gap graded coarse material (Block/Brick chips)	
	Drainage Materials for Trench
Sieve Size	Percent Passing(%)
50 mm	100
37.5 mm	90-100
19 mm	70-92
9.5 mm	50-70



(a) STRECHER BOND OR RUNNING BOND

(b) BASEMENT WEAVE OR PARQUET BOND

Note for Geotextile

Sl.	Properties	Test Standard	Value
1	Minimum thickness	EN-ISO 9863	3.00mm
2	Opening size	EN-ISO 12956	0.075mm
3	Mass per unit area	BSEN 965	400 gm/m²
4	Tensile strength (md/cmd)	EN-ISO 10319	23kn/m
5	Elongation (md/cmd)	EN-ISO 10319	>=40% & <=100%

Note: See Annexure " VI "

Notes:

1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting ICBP (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after ICBP setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 20 years.
9. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi
10. If the road side situated beside pond or canal or unstable then size of kerb stone should be more and be consulted with the LGED design unit.
11. Drainage drain need to be placed at 6m interval in stagarred manner upto end of slope surrounded by Geotextile.
12. If road section runs through one or both side build up area a longitudinal drainage system is required with a gradient of 1:600 upto 1:1200 upto out fall.It may be open drain covered (for footpath) or uncovered or pipe drain or combination of both. 80-100mm dia Perforated (uper half) may required to be placed at bottom of the 200-300mm wide trenched filled with gapgraded base coarse. It may needs to be designed through design unit of LGED.
13. If sand is needed to be used in drainage duct then Fineness Modulus (FM) must grater then 2.5.
14. Compaction of material used in drainage duct must be 95% competed in proctor density test.
15. Note for Geotextile in Annexure "VI"

Design template for ICPB

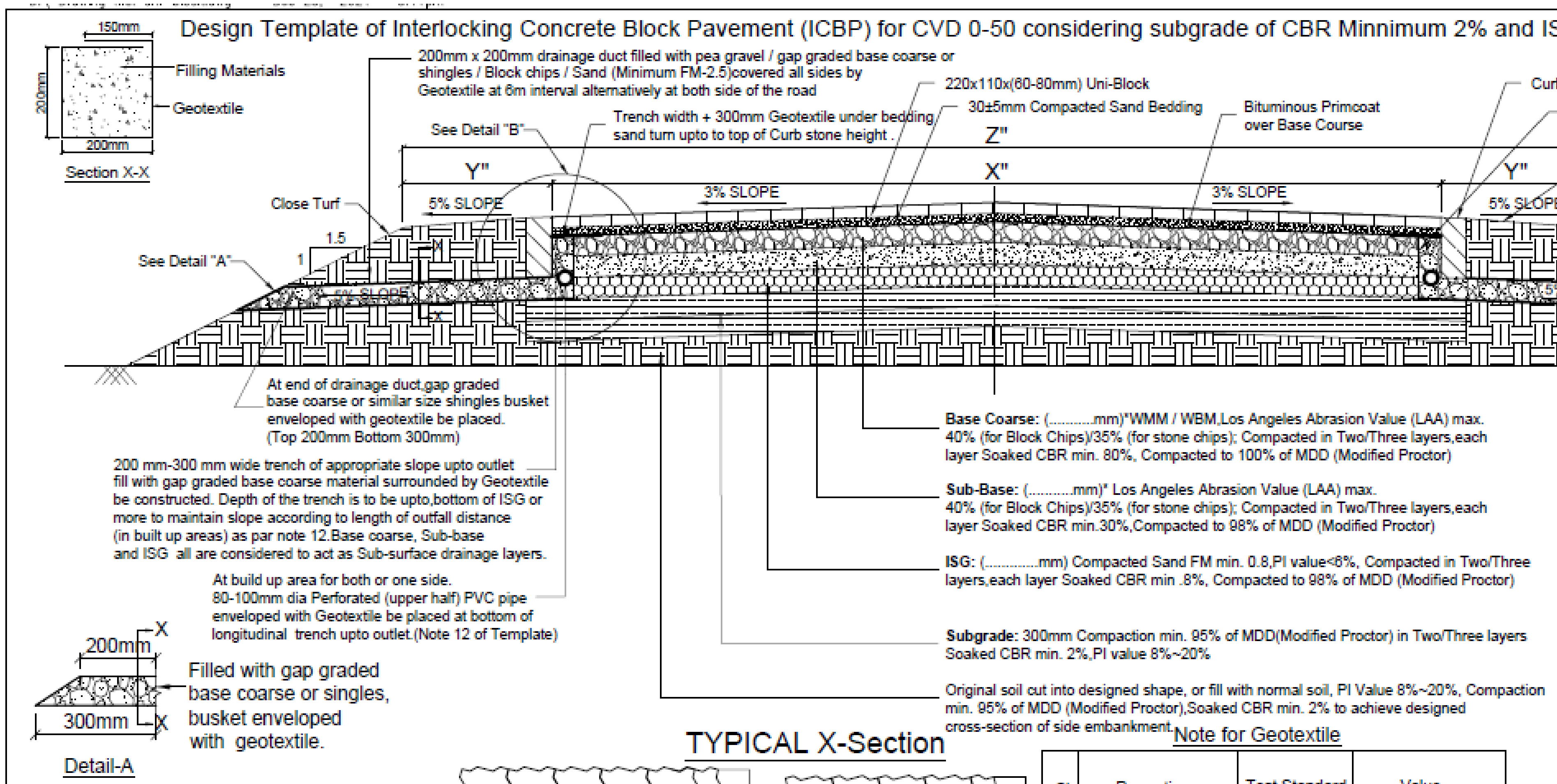
Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c) *	Remarks
			ISG	Sub-Base	Base	Sand Bedding (±5mm)	Concrete Block(CB)	Curb/Kerb Stone *		
01	Low Traffic Road for CVD 0-50	0.5 - 0.8	250	250	150	30	80/35	150/35	550 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm										

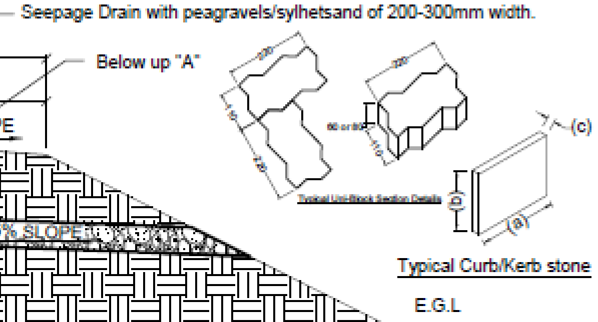
Sieve Size	Base Material Gradation	Sub-base material Gradation
	Percent Passing(%)	Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

Sieve Size	Bedding Sand Gradation	Joint Filling Sand Gradation
	Percent Passing(%)	Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 1.1.3: Design Template of Interlocking Concrete Block Pavement (ICBP) for vehicles of 0-50 CVD Subgrade CBR Minimum 2% ISG sand FM between 0.3-0.5

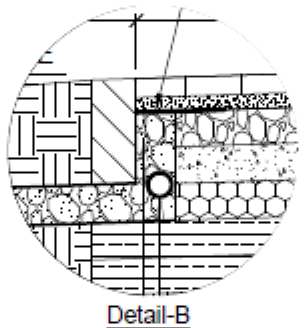
Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 0-50 considering subgrade of CBR Minnimum 2% and ISG sand FM 0.5 to 0.8



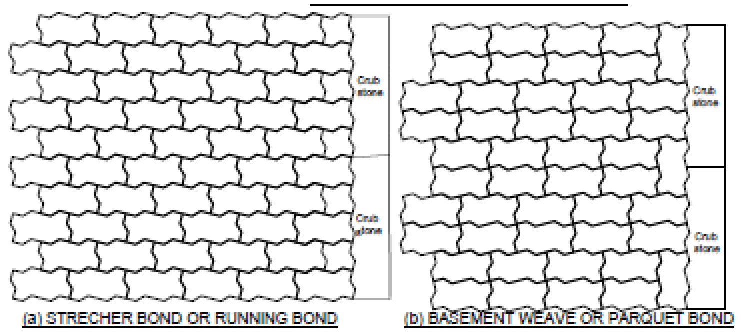


Notes:

1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting ICBP (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after ICBP setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 20 years.
9. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi
10. If the road side situated beside pond or canal or unstable then size of kerb stone should be more and be consulted with the LGED design unit.
11. Drainage drain need to be placed at 6m interval in stagarred manner upto end of slope surrounded by Geotextile.
12. If road section runs through one or both side build up area a longitudinal drainage system is required with a gradient of 1:600 upto 1:1200 upto out fall.It may be open drain covered (for footpath) or uncovered or pipe drain or combination of both. 80-100mm dia Perforated (uper half) may required to be placed at bottom of the 200-300mm wide trenched filled with gapgraded base coarse. It may needs to be designed through design unit of LGED.
13. If sand is needed to be used in drainage duct then Fineness Modulus (FM) must grater then 2.5.
14. Compaction of material used in drainage duct must be 95% competed in proctor density test.
15. Note for Geotextile in Annexure "VI"



Gap graded coarse material (Block/Brick chips)	
Sieve Size	Drainage Materials for Trench Percent Passing(%)
50 mm	100
37.5 mm	90-100
19 mm	70-92
9.5 mm	50-70



Note for Geotextile

Sl.	Properties	Test Standard	Value
1	Minimum thickness	EN-ISO 9863	3.00mm
2	Opening size	EN-ISO 12956	0.075mm
3	Mass per unit area	BSEN 965	400 gm/m²
4	Tensile strength (md/cmd)	EN-ISO 10319	23kn/m
5	Elongation (md/cmd)	EN-ISO 10319	>=40% & <=100%

Note: See Annexure " VI "

Design template for ICPB

Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c) *	Remarks
			ISG	Sub-Base	Base	Sand Bedding (±5mm)	Concrete Block(CB)	Curb/Kerb Stone *		
01	Low Traffic Road for CVD 0-50	0.5 - 0.8	250	250	150	30	80/35	150/35	550 x 250 x150	

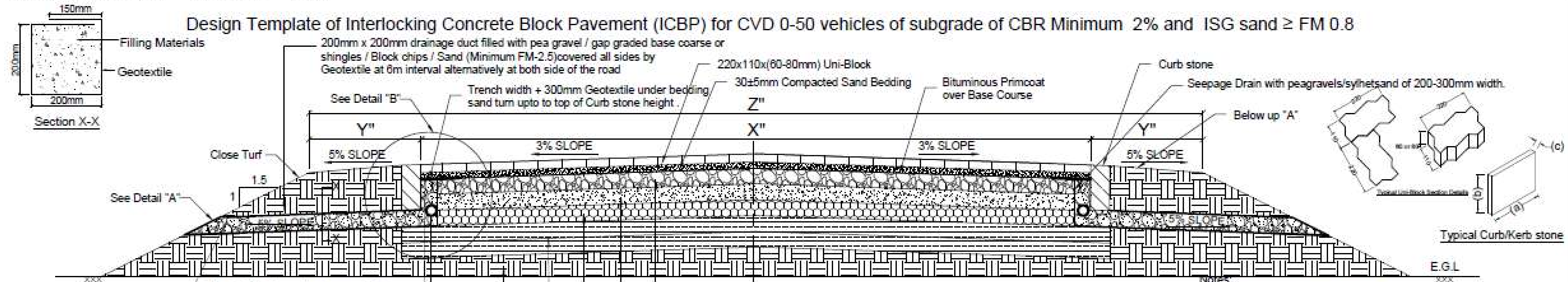
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

Sieve Size	Base Material Gradation	Sub-base material Gradation
	Percent Passing(%)	Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

Sieve Size	Bedding Sand Gradation	Joint Filling Sand Gradation
	Percent Passing(%)	Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 1.1.4: Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 0-50 considering subgrade of CBR minimum 2%and ISG sand FM between 0.5-0.8

Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 0-50 vehicles of subgrade of CBR Minimum 2% and ISG sand ≥ FM 0.8



At end of drainage duct,gap graded base coarse or similar size shingles busket enveloped with geotextile be placed. (Top 200mm Bottom 300mm)

200 mm-300 mm wide trench of appropriate slope upto outlet fill with gap graded base coarse material surrounded by Geotextile be constructed. Depth of the trench is to be upto,bottom of ISG or more to maintain slope according to length of outfall distance (in built up areas) as par note 12.Base coarse, Sub-base and ISG all are considered to act as Sub-surface drainage layers.

At build up area for both or one side. 80-100mm dia Perforated (upper half) PVC pipe enveloped with Geotextile be placed at bottom of longitudinal trench upto outlet.(Note 12 of Template)

Base Coarse: (..........mm)*WMM / WBM,Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min. 80%, Compacted to 100% of MDD (Modified Proctor)

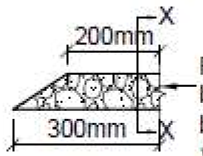
Sub-Base: (..........mm)* Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min.30%,Compacted to 98% of MDD (Modified Proctor)

ISG: (............mm) Compacted Sand FM min. 0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

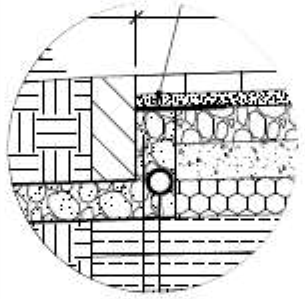
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

Original soil cut into designed shape, or fill with normal soil, PI Value 8%~20%, Compaction min. 95% of MDD (Modified Proctor),Soaked CBR min. 2% to achieve designed cross-section of side embankment.

TYPICAL X-Section

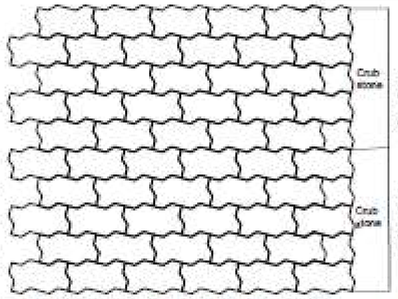


Detail-A

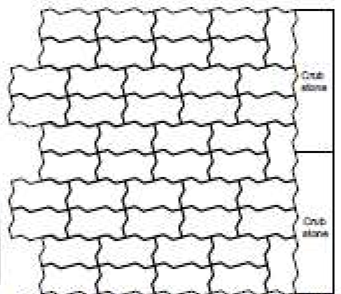


Detail-B

Gap graded coarse material (Block/Brick chips)	
Sieve Size	Drainage Materials for Trench Percent Passing(%)
50 mm	100
37.5 mm	90-100
19 mm	70-92
9.5 mm	50-70



(a) STRECHER BOND OR RUNNING BOND



(b) BASEMENT WEAVE OR PARQUET BOND

Note for Geotextile

Sl.	Properties	Test Standard	Value
1	Minimum thickness	EN-ISO 9863	3.00mm
2	Opening size	EN-ISO 12956	0.075mm
3	Mass per unit area	BSEN 965	400 gm/m²
4	Tensile strength (md/cmd)	EN-ISO 10319	23kn/m
5	Elongation (md/cmd)	EN-ISO 10319	>=40% & <=100%

Note: See Annexure " VI "

Notes:

1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting ICBP (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after ICBP setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 20 years.
9. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi
10. If the road side situated beside pond or canal or unstable then size of kerb stone should be more and be consulted with the LGED design unit.
11. Drainage drain need to be placed at 6m interval in stagarred manner upto end of slope surrounded by Geotextile.
12. If road section runs through one or both side build up area a longitudinal drainage system is required with a gradient of 1:600 upto 1:1200 upto out fall.It may be open drain covered (for footpath) or uncovered or pipe drain or combination of both. 80-100mm dia Perforated (uper half) may required to be placed at bottom of the 200-300mm wide trenched filled with gapgraded base coarse. It may needs to be designed through design unit of LGED.
13. If sand is needed to be used in drainage duct then Fineness Modulus (FM) must grater then 2.5.
14. Compaction of material used in drainage duct must be 95% competed in proctor density test.
15. Note for Geotextile in Annexure "VI"

Design template for ICPB

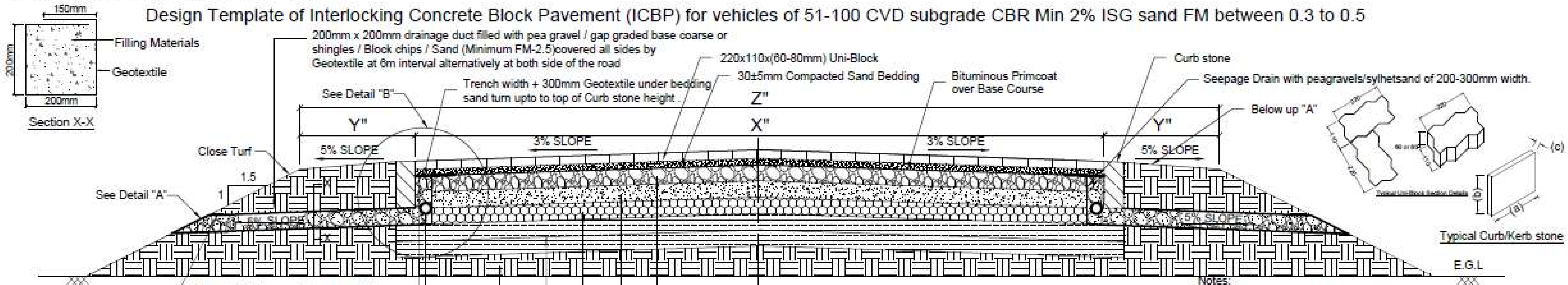
Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm) ISG	Sub-Base	Base	Sand Bedding (±5mm)	Thickness(mm)/Strength(Mpa) Concrete Block(CB)	Curb/Kerb Stone *	Probable Curb/Karb stone sizes (a x b x c) *	Remarks
01	Low Traffic Road for CVD 0-50	FM ≥ 0.8	200	200	150	30	80/35	150/30	550 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm										

Sieve Size	Base Material Gradation Percent Passing(%)	Sub-base material Gradation Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

Sieve Size	Bedding Sand Gradation Percent Passing(%)	Joint Filling Sand Gradation Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 1.1.5: Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 0-50 vehicles of subgrade of CBR minimum 2%and ISG sand ≥FM 0.8

Design Template of Interlocking Concrete Block Pavement (ICBP) for vehicles of 51-100 CVD subgrade CBR Min 2% ISG sand FM between 0.3 to 0.5



At end of drainage duct,gap graded base coarse or similar size shingles busket enveloped with geotextile be placed. (Top 200mm Bottom 300mm)

200 mm-300 mm wide trench of appropriate slope upto outlet fill with gap graded base coarse material surrounded by Geotextile be constructed. Depth of the trench is to be upto,bottom of ISG or more to maintain slope according to length of outfall distance (in built up areas) as par note 12.Base coarse, Sub-base and ISG all are considered to act as Sub-surface drainage layers.

At build up area for both or one side. 80-100mm dia Perforated (upper half) PVC pipe enveloped with Geotextile be placed at bottom of longitudinal trench upto outlet.(Note 12 of Template)

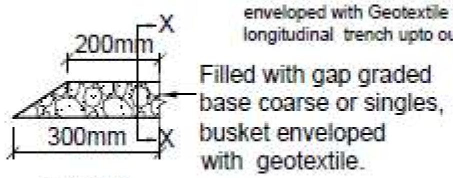
Base Coarse: (...........mm)*WMM / WBM,Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min. 80%, Compacted to 100% of MDD (Modified Proctor)

Sub-Base: (...........mm)* Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min.30%,Compacted to 98% of MDD (Modified Proctor)

ISG: (............mm) Compacted Sand FM min. 0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

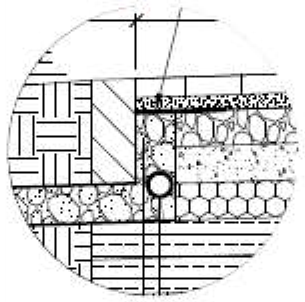
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

Original soil cut into designed shape, or fill with normal soil, PI Value 8%~20%, Compaction min. 95% of MDD (Modified Proctor),Soaked CBR min. 2% to achieve designed cross-section of side embankment



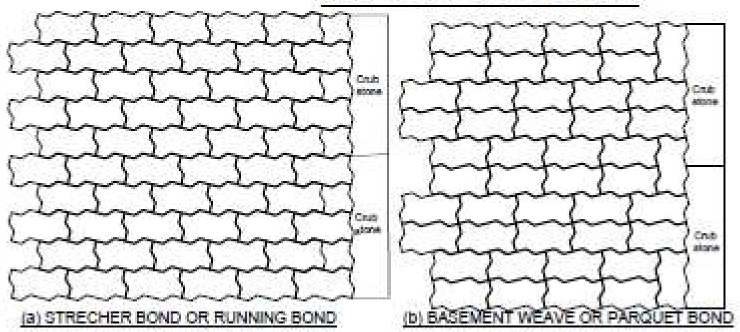
Detail-A

TYPICAL X-Section



Detail-B

Sieve Size	Gap graded coarse material (Block/Brick chips) Drainage Materials for Trench Percent Passing(%)
50 mm	100
37.5 mm	90-100
19 mm	70-92
9.5 mm	50-70



(a) STRECHER BOND OR RUNNING BOND

(b) BASEMENT WEAVE OR PARQUET BOND

Note for Geotextile

Sl.	Properties	Test Standard	Value
1	Minimum thickness	EN-ISO 9863	3.00mm
2	Opening size	EN-ISO 12956	0.075mm
3	Mass per unit area	BSEN 965	400 gm/m²
4	Tensile strength (md/cmd)	EN-ISO 10319	23kn/m
5	Elongation (md/cmd)	EN-ISO 10319	>=40% & <=100%

Note: See Annexure " VI "

Notes:

1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting ICBP (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after ICBP setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 20 years.
9. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi
10. If the road side situated beside pond or canal or unstable then size of kerb stone should be more and be consulted with the LGED design unit.
11. Drainage drain need to be placed at 6m interval in stagarred manner upto end of slope surrounded by Geotextile.
12. If road section runs through one or both side build up area a longitudinal drainage system is required with a gradient of 1:600 upto 1:1200 upto out fall.It may be open drain covered (for footpath) or uncovered or pipe drain or combination of both. 80-100mm dia Perforated (uper half) may required to be placed at bottom of the 200-300mm wide trenched filled with gapgraded base coarse. It may needs to be designed through design unit of LGED.
13. If sand is needed to be used in drainage duct then Fineness Modulus (FM) must grater then 2.5.
14. Compaction of material used in drainage duct must be 95% competed in proctor density test.
15. Note for Geotextile in Annexure "VI"

Design template for ICPB

Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm) ISG	Sub-Base	Base	Sand Bedding (±5mm)	Thickness(mm)/Strength(Mpa) Concrete Block(CB)	Curb/Kerb Stone *	Probable Curb/Karb stone sizes (a x b x c) *	Remarks
01	Low Traffic Road for CVD 51-100	0.3 - 0.5	300	250	150	30	80/35	150/35	550 x 250 x150	

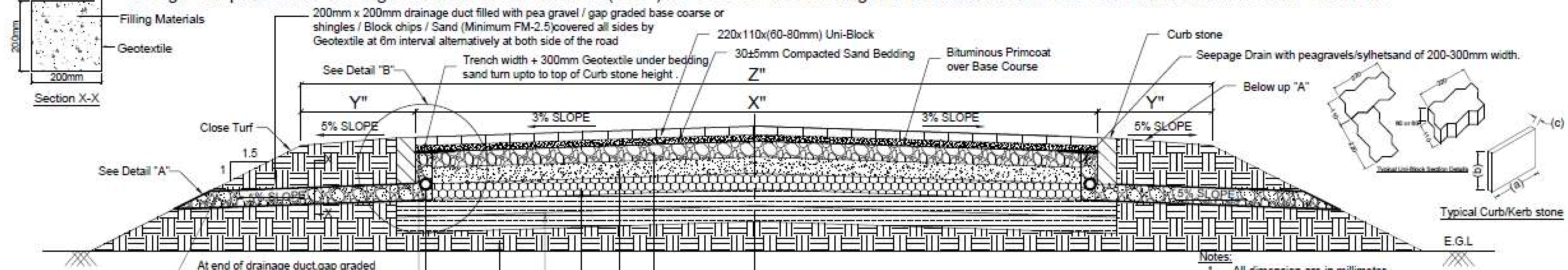
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

Sieve Size	Base Material Gradation Percent Passing(%)	Sub-base material Gradation Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

Sieve Size	Bedding Sand Gradation Percent Passing(%)	Joint Filling Sand Gradation Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 1.1.6: Design Template of Interlocking Concrete Block Pavement (ICBP) for vehicles of 51-100 CVD subgrade CBR minimum 2% ISG sand FM between 0.3 to 0.5

Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 51-100 on subgrade of minimum CBR 2% sand for between ISG FM 0.5 to 0.8



At end of drainage duct,gap graded base coarse or similar size shingles busket enveloped with geotextile be placed. (Top 200mm Bottom 300mm)

200 mm-300 mm wide trench of appropriate slope upto outlet fill with gap graded base coarse material surrounded by Geotextile be constructed. Depth of the trench is to be upto,bottom of ISG or more to maintain slope according to length of outfall distance (in built up areas) as par note 12.Base coarse, Sub-base and ISG all are considered to act as Sub-surface drainage layers.

At build up area for both or one side. 80-100mm dia Perforated (upper half) PVC pipe enveloped with Geotextile be placed at bottom of longitudinal trench upto outlet.(Note 12 of Template)

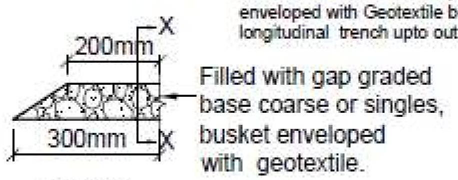
Base Coarse: (...........mm)*WMM / WBM,Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min. 80%, Compacted to 100% of MDD (Modified Proctor)

Sub-Base: (...........mm)* Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min.30%,Compacted to 98% of MDD (Modified Proctor)

ISG: (............mm) Compacted Sand FM min. 0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

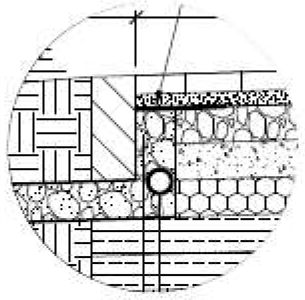
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

Original soil cut into designed shape, or fill with normal soil, PI Value 8%~20%, Compaction min. 95% of MDD (Modified Proctor),Soaked CBR min. 2% to achieve designed cross-section of side embankment.



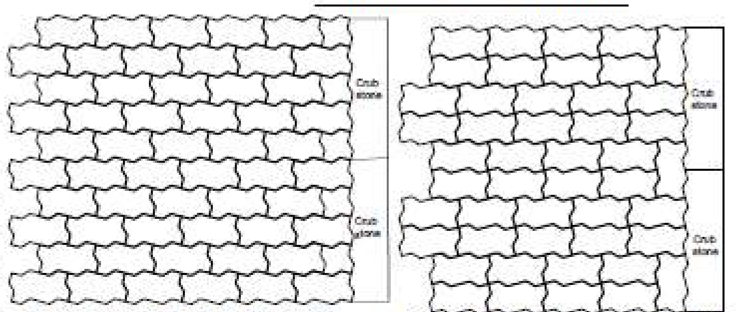
Detail-A

TYPICAL X-Section



Detail-B

Gap graded coarse material (Block/Brick chips)	
Sieve Size	Drainage Materials for Trench Percent Passing(%)
50 mm	100
37.5 mm	90-100
19 mm	70-92
9.5 mm	50-70



(a) STRECHER BOND OR RUNNING BOND

(b) BASEMENT WEAVE OR PARQUET BOND

Note for Geotextile

Sl.	Properties	Test Standard	Value
1	Minimum thickness	EN-ISO 9863	3.00mm
2	Opening size	EN-ISO 12956	0.075mm
3	Mass per unit area	BSEN 965	400 gm/m²
4	Tensile strength (md/cmd)	EN-ISO 10319	23kn/m
5	Elongation (md/cmd)	EN-ISO 10319	>=40% & <=100%

Note: See Annexure " VI "

Notes:

1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting ICBP (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after ICBP setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 20 years.
9. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi
10. If the road side situated beside pond or canal or unstable then size of kerb stone should be more and be consulted with the LGED design unit.
11. Drainage drain need to be placed at 6m interval in stagarred manner upto end of slope surrounded by Geotextile.
12. If road section runs through one or both side build up area a longitudinal drainage system is required with a gradient of 1:600 upto 1:1200 upto out fall.It may be open drain covered (for footpath) or uncovered or pipe drain or combination of both. 80-100mm dia Perforated (uper half) may required to be placed at bottom of the 200-300mm wide trenched filled with gapgraded base coarse. It may needs to be designed through design unit of LGED.
13. If sand is needed to be used in drainage duct then Fineness Modulus (FM) must grater then 2.5.
14. Compaction of material used in drainage duct must be 95% competed in proctor density test.
15. Note for Geotextile in Annexure "VI"

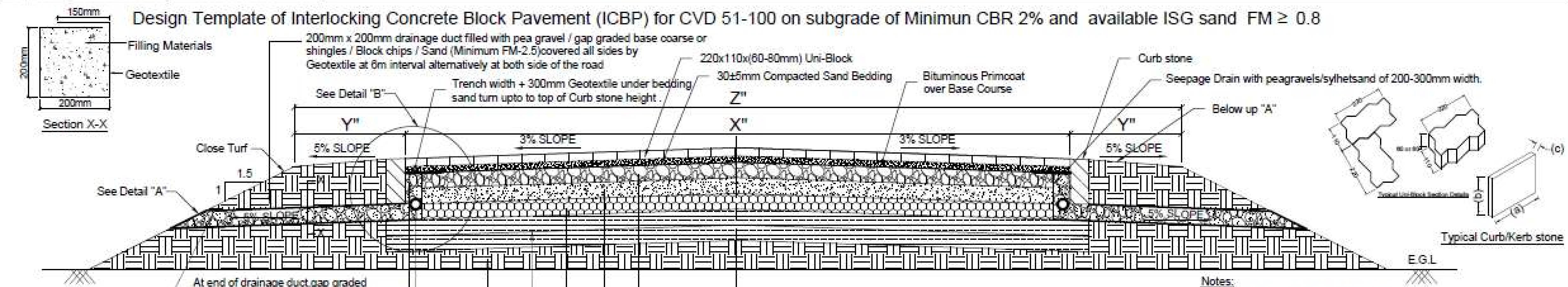
Design template for ICPB

Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c) *	Remarks
			ISG	Sub-Base	Base	Sand Bedding (±5mm)	Concrete Block(CB)	Curb/Kerb Stone *		
01	Low Traffic Road for CVD 51-100	0.5 - 0.8	250	250	150	30	80/35	150/35	550 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm										

Sieve Size	Base Material Gradation	Sub-base material Gradation
	Percent Passing(%)	Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

Sieve Size	Bedding Sand Gradation	Joint Filling Sand Gradation
	Percent Passing(%)	Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 1.1.7: Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 51-100 on subgrade of minimum CBR 2% sand for between ISG FM 0.5 to 0.8



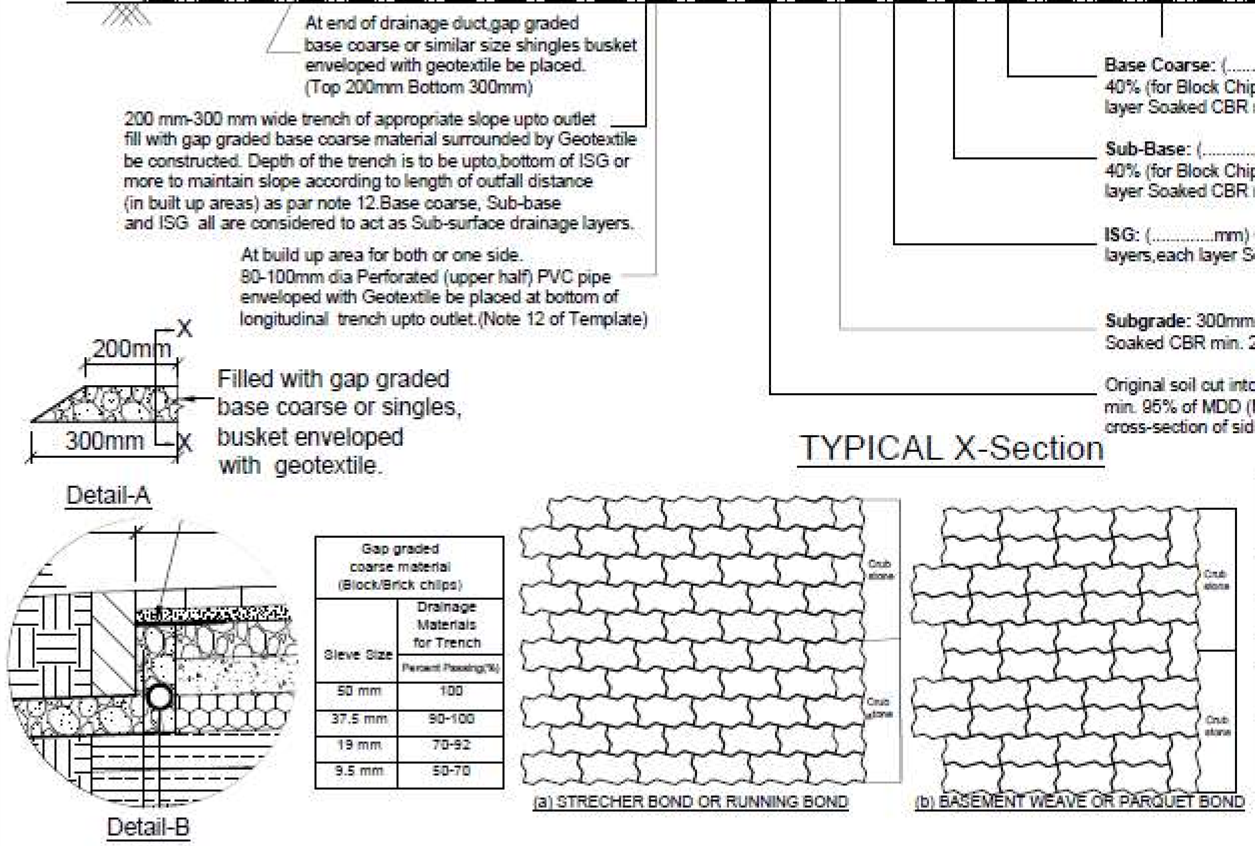
Base Coarse: (...........mm)*WMM / WBM,Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min. 80%, Compacted to 100% of MDD (Modified Proctor)

Sub-Base: (...........mm)* Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min.30%,Compacted to 98% of MDD (Modified Proctor)

ISG: (.............mm) Compacted Sand FM min. 0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

Original soil cut into designed shape, or fill with normal soil, PI Value 8%~20%, Compaction min. 95% of MDD (Modified Proctor),Soaked CBR min. 2% to achieve designed cross-section of side embankment.



Note for Geotextile

Sl.	Properties	Test Standard	Value
1	Minimum thickness	EN-ISO 9863	3.00mm
2	Opening size	EN-ISO 12956	0.075mm
3	Mass per unit area	BSEN 965	400 gm/m²
4	Tensile strength (md/cmd)	EN-ISO 10319	23kn/m
5	Elongation (md/cmd)	EN-ISO 10319	>=40% & <=100%

Note: See Annexure " VI "

Notes:

1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting ICBP (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after ICBP setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 20 years.
9. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi
10. If the road side situated beside pond or canal or unstable then size of kerb stone should be more and be consulted with the LGED design unit.
11. Drainage drain need to be placed at 6m interval in stagarred manner upto end of slope surrounded by Geotextile.
12. If road section runs through one or both side build up area a longitudinal drainage system is required with a gradient of 1:600 upto 1:1200 upto out fall.It may be open drain covered (for footpath) or uncovered or pipe drain or combination of both. 80-100mm dia Perforated (uper half) may required to be placed at bottom of the 200-300mm wide trenched filled with gapgraded base coarse. It may needs to be designed through design unit of LGED.
13. If sand is needed to be used in drainage duct then Fineness Modulus (FM) must grater then 2.5.
14. Compaction of material used in drainage duct must be 95% competed in proctor density test.
15. Note for Geotextile in Annexure "VI"

Design template for ICPB

Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c) *	Remarks
			ISG	Sub-Base	Base	Sand Bedding (±5mm)	Concrete Block(CB)	Curb/Kerb Stone *		
01	Low Traffic Road for CVD 51-100	FM ≥ 0.8	250	200	150	30	80/35	150/35	550 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm										

Sieve Size	Base Material Gradation	Sub-base material Gradation
	Percent Passing(%)	Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

Sieve Size	Bedding Sand Gradation	Joint Filling Sand Gradation
	Percent Passing(%)	Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 1.1.8: Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 51-100 on subgrade of minimum CBR 2% and available ISG sand FM ≥ 0.8

Sub-surface drainage is a very important area as it is shown in the design template. There are some sand sections run through one or both sides build up area (houses) etc. In these sections, longitudinal drainage system is required.

The design templates are provided for use in the fields on ad hoc basis as long as performance evaluations are done for further modification if required fit to the purpose as desired for final approval.

To finalize the template from the consultant side, it requires adequate time for research and ICBP experiential construction, review of the cost and material source and evaluations along with evaluations of field constructions using the provided templates.

1.5. Preparation of ICBP Mix Design Charts:

As it has been stated before, after thoroughly reviewing some recognized international design guidelines (e.g. IRC and Uni-block) regarding the use of Interlocking Concrete Paving Block (ICBP) in roadway construction, there is a need to develop some mix design charts based on ICBPs with desired strength fabricated with dredged sands from different locations of Bangladesh where it would be easier to adopt this sustainable alternative technology in the construction of rural (village) roads. Therefore, in a typical chart, the variable parameters would be the location of dredged soil/sand, its gradation, desired composition for ICBP construction, water/cement ratio, coarse sand, admixtures, etc. But compressive strength, CBR values and traffic load compositions would be preselected and they would be based on the existing ICBP paving guidelines. By doing this, several design templates could be developed in the form of detailed diagrams and charts from where technical personnel would gain readily available insight into the condition of local dredged sand for his chosen location to design and construct an ICBP road along with the manufacturing protocol he needs to adopt in order to gain the desired specifications of the ICBP roadways. Subsequently, he can then select the accurate thickness for the layers (i.e. subgrade, sub-base, base-course, bedding sand and ICBPs with jointing sand) required to successfully make reasonable judgment in the final construction. To summarize the template, 02 (two) thicknesses (i.e. 60 mm and 80 mm) of interlocking blocks would be prepared with 02 (two) different strengths (30 MPa and 35 MPa). Also, sands from 05 (four) locations would be taken. So, after permutations, around 20 ICBP mixing criteria are thought of at the initial stage. It might be debated that the existing block manufacturers in Bangladesh have already made enough efforts to fabricate durable paving units for roadway construction. But, most of the manufacturers import aggregates, having suitable gradation and F.M. to easily mass-produce pavers as per consumers' requirement without finding means to adopt different types of dredged sands. Therefore, it is imperative that, a unique design chart is innovated from the collaborative efforts of both the client (LGED) and the Consultant (HBRI) that mainly focuses on the best use of dredged sands from different locations of Bangladesh with compliance to the mechanical and chemical characteristics that are to be found from the laboratory experiments already discussed. Detailed information about the admixture used in the fabrication of ICBP units for experimental purpose is provided. For each mix design chart, firstly, compressive strength of the respective sample would be assessed at 7 days. If it attains at least 60% of the targeted strength, then further samples under that mix design type would be prepared and detailed tests would be conducted.

Tabular form for typical Mix-Design Charts (ICBP portion) are provided in annexure I.

2. Implementation Manual

2.1. General

Except for the top wearing of the pavement (Bituminous layers) the base and sub-base layers are similar to the conventional flexible pavement as preload design (Predicted or Considered) coming on them and sub-grade CBR, the composition and thickness of layers differs.

2.2. ICB Pavement Composition

Cross Section of pavement Composition is shown in Figures

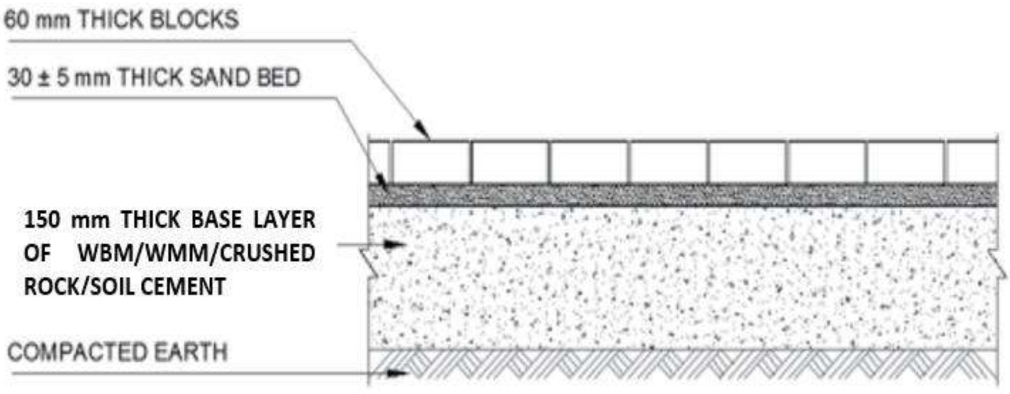


Figure 2.1: Typical Cross Section of Block Pavement used in Sidewalks /Footpaths/Car-parks /Cycle Tracks

2.3. Block Thickness

ICB is manufactured in different thickness (60mm-120mm or more) considering predicted design loads. These blocks serve as wearing surface (as bituminous wearing surface in case flexible pavement) but at the same time act in reducing stress imposed on subgrade and also act in resisting deformation and elastic deflections similar to the base course of a flexible pavement.

In case of light traffic, such as pedestrians, non-motorized vehicles, cycles, etc. 60 mm thick ICB in considered to be reasonable.

Block of 80mm thick in generally used for low traffic road CVD 0-50 and 51-100

Thick blocks are appropriate where high volume of turning movements are involved.

For ICB pavement thickness of blocks must be uniforms otherwise block affects the evenness of the surface. A block pavement which is initially paved to a levelled surface will settle unevenly with the movement of vehicles (as shown in figure 5.2)

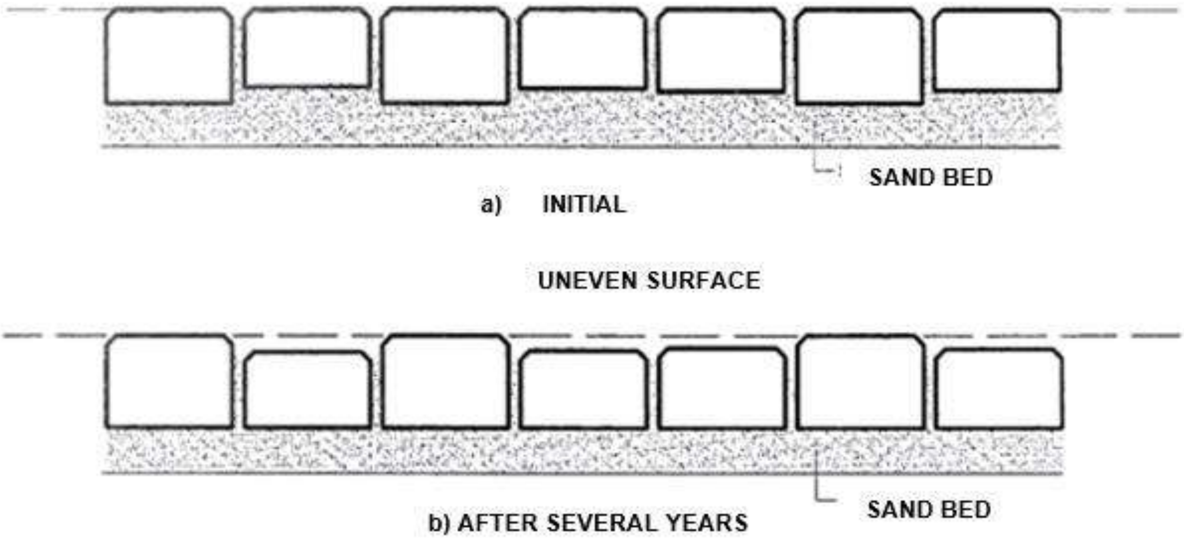


Figure 2.2: Effect of Thickness Variations in Paving Blocks

To avoid this problem all blocks should be of same thickness. The maximum allowable trance limits of ± 2 mm similarly, variations in length and width of blocks should be lines to ± 2 to ± 3mm for ensuring uniform joint width and avoiding staggering effect.

2.4. Sand bedding and Jointing

A layer of sand bedding is provided on top of base or sub-base for the following structural reason.

(a) To provide a cushion between the hard base (or sub-base) and the paving block.

(b) The base or sub-base will have some permitted surface unevenness by providing a layer of sand bed, the paved block can be levelled perfectly.

(c) Sand bed prevent propagation of cracks formed in base or sub-base.

(d) Sand bed, provides added interlocking effect by keeping lower part of the joint filled with sand.

The sand bed should not be much thick as it is becoming very difficult to keep and control the pavement surface level in design shape. Sand bedding of 30+5 is experienced to be satisfactory. Thickness of bedding sand should be uniform Varying thickness of bedding sand ultimately results in uneven surface of the pavement. Bedding sand should be of appropriate standard.

2.5. Base and Sub-base layers

Base and sub-base layers is (are) structural layers. The materials should be of as per standard specification of LGED to fit to purpose of base and sub base construction. It may be either bound material like lean concrete or soil-cement or bituminous layers or unbound materials like wet mix macadam or WBM. The sub-base is generally of granular materials. In many cases, the sub-base is with material with appropriate gradation (if required gap graded) to act as sub-surface drainage layer. Considering the intensity of loading; the type of soil and CBR would be the guiding factor in determining the type and thickness of base and sub-base. For weak sub-grade soil like clays and where ground water table is shallow bound (Bituminous or cement treated) base are preferred.

2.6. Edge Restrained Blocks and Curbs

During Trafficked movement, concrete blocks are getting experience of horizontal force thus tent to move sideways and comings forward due to braking of vehicles and in negotiating curves and maneuvering of vehicles. The tendency to move sideways has to be restricted at the edges by special edge blocks and curbs. The edge block should be such that the rotation or displacement of blocks is resistant. Figures shown below are some typical edge restrain block

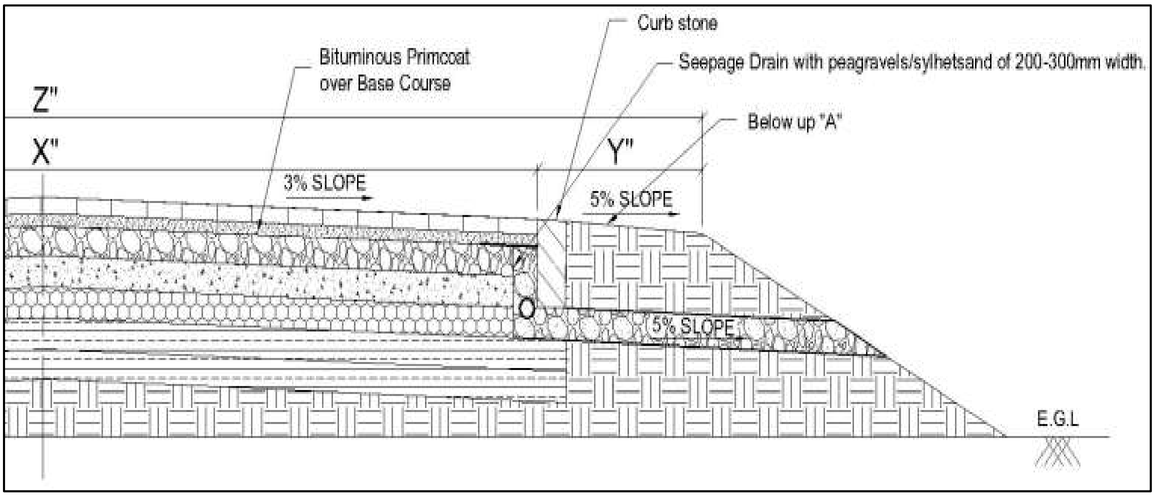


Figure 2.3: Edge Restraints

3. Drainage

Interlocking Concrete Block Pavement (ICBP) with joints filled with sand does not provide a waterproof road surface until joints filled up sand well compacted with time (few months after construction). The initial stage seeping of rain is water much more. After few months of construction surface run-off would be considerable with appropriate cross fall slope as filling sand considered properly to be set between the gaps of blocks.

As the ICBP surface would never be water proof appropriate care has to be taken to drain out the surface water seeping downward through the joints (particularly in initial stage of few months if happen to be rainy months of the construction) to sand bed below, base, sub-base and sub grade layers to avoid any possibility of load bearing capacity of road structure especially sub-grade.

The drainage provided generally consists of subsurface draining layer with subsurface edges longitudinal drains surrounded by filter materials as geotextiles / geo composite through which water could pass towards outfall and at the same time prevent the escape of bedding sand.

Typical Subsurface drainage arrangement in ICBP is shown in figures below. It is to be mention that pervious concrete below the sand bed in to be one of the arrangement. Arrangement could be provided so that the water collected be carried through perforated PVC Pipe preferably of 80-100 mm dia.

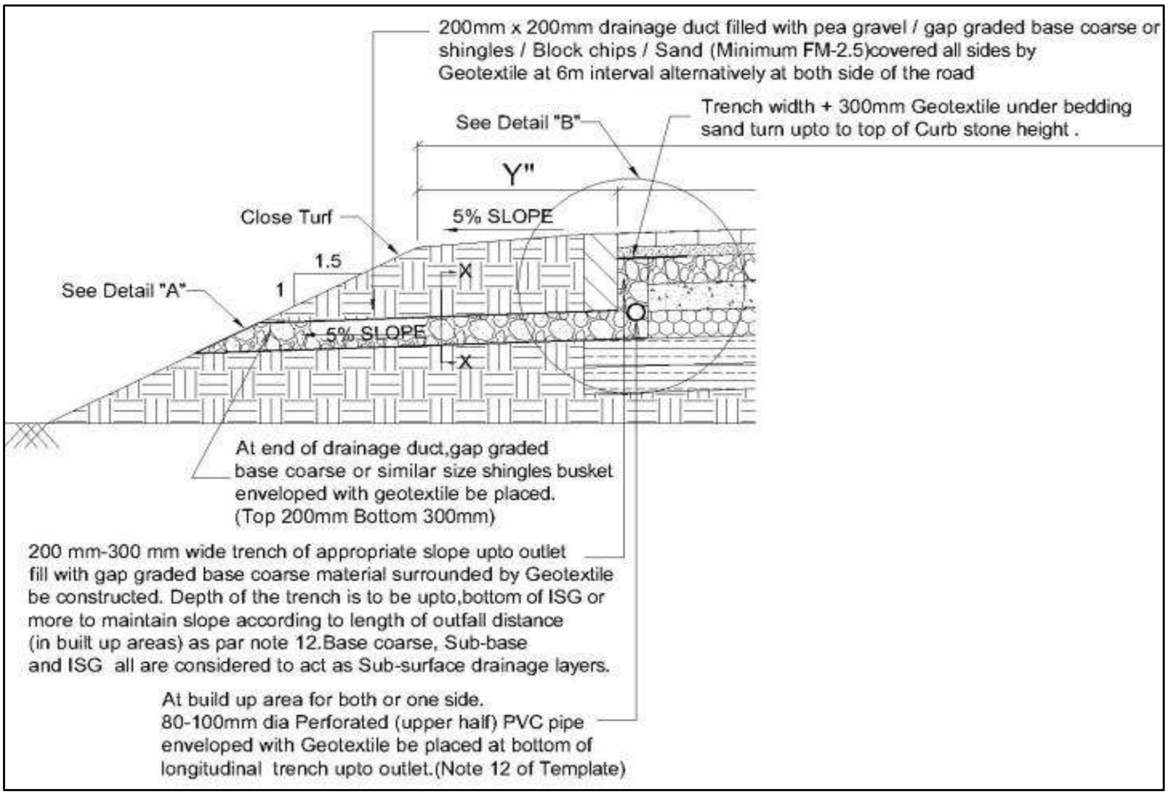


Figure 3.1: Sub Surface Drainage in a Block Pavement

Inside curbstone 200-300mm wide trench of appropriate slope up to bottom level of ISG and outlet fill with gap-graded base coarse material surrounded by Geotextile of having 4 appropriate qualifications (Separation, Reinforcement, filtration and Drainage). And ducts of 200mm ×200mm filled with pea-gravel/ gap-graded base coarse or singles covered all sides by geotextile at 6 m interval alternatively at both sides of the road need to be placed. In case of built up area of one side or both, long trench needs to be constructed up to outfall with a slope of 1:600 to 1:1200 thus the bottom level of trench would be more than the level of ISG.

A cross fall of 3 percent slope is considered to be acceptable to drain the surface run-off.

The ICBP Pavement should be at least 5mm above the manholes and EDGE STRIP Block.

4. Construction

4.1. General

The construction of block pavement involves preparation of subgrade, sub-base and base course layers, bedding sand and finally the laying of blocks. The block paving can be done entirely by manual labor. However, for efficient construction work, the work force has to be properly trained for this specialized job. Paving can also be done by mechanical means.

4.2. Preparation of Subgrade

This is the foundation layer on which the block pavement is constructed. Like in conventional pavements the water table should be at a minimum depth of 600 mm below the subgrade. Subgrade should be compacted in layers of 150 or 100 mm thickness as per LGED Specifications.

4.3. Base and Sub-Base Course

Base and sub-base courses are constructed in accordance with standard procedures as per LGED Specifications. Constructing the layers to proper level and grade is very essential to maintain the level and surface regularity of the block pavement. In small widths where compaction of GSB, WBM, and WMM may not be done adequately it is recommended that field officials would consult with LGED design unit for those special area.

4.4. Placing and Screeding of Bedding Sand

The thickness of the sand bed after compaction should be in the range of 30 ± 5 mm, whereas, in the loose form it can be 30 to 50 mm. It is preferable to restrict the 'compacted thickness to 30 ± 5 mm to reduce the risk of any localized pre-compaction, which would affect the final block surface level. Bedding sand should not be used to fill-up local depressions on the surface of a base or sub-base. The depressions should be repaired in advance before placing sand.

Sand to be used should be uniformly in loose condition and should have a uniform moisture content. Best moisture content is that when sand is neither too wet nor too dry and have a value of 6 to 8 per cent. Requirement of sand for a day's work should be prepared and stored in advance and covered with tarpaulin or polythene sheets.

The processed sand is spread with the help of screed boards to the required thickness. The screed boards are provided with nails at 2-3 m apart which when dragged gives the desired thickness. The length of nail should take into account the surcharge to be provided in the compacted thickness. Alternatively, the screed can be dragged on edge strips kept on both sides as guide. Asphalt paver can be employed in large projects. The sand is subsequently compacted with plate vibrators weighing 0.6 tons or more. Level checks shall be carried out on a grid pattern to establish that the desired level is achieved. Local correction can be done either by removing or adding extra sand followed by levelling and compacting the layer. There will be some settlement of sand after the blocks are placed and compacted, which must be allowed for, while fixing the level of sand bed.
The effect of undulating surface of base or sub-base on the profile of block pavement is explained in Figure7.1. The blocks will settle after trafficking in such a manner that the surface profile becomes parallel to base/sub-base profile. Sand bed assumes uniform thickness under moving loads.

4.5. Laying of Blocks

Blocks can be laid generally by manual labor but mechanical aids like hand-pushed trolleys can expedite the work. Normally, laying should commence from the edge strip and proceed towards the inner side. When dentate blocks are used, the laying done at two fronts will create problem for matching joints in the middle. Hence, as far as possible, laying should proceed in one direction only, along the entire width of the area to be paved.
While locating the starting line, the following should be considered:

- On a sloping site, start from the lowest point and proceed uphill on a continuous basis, to avoid downhill creep in incomplete areas.
- In case of irregular shaped edge restraints or strip, it is better to start from straight string line as shown in Figure 7.2.
- Influence of alignment of edge restraints on achieving and maintaining laying bond.

While locating the starting line, the following should be considered:

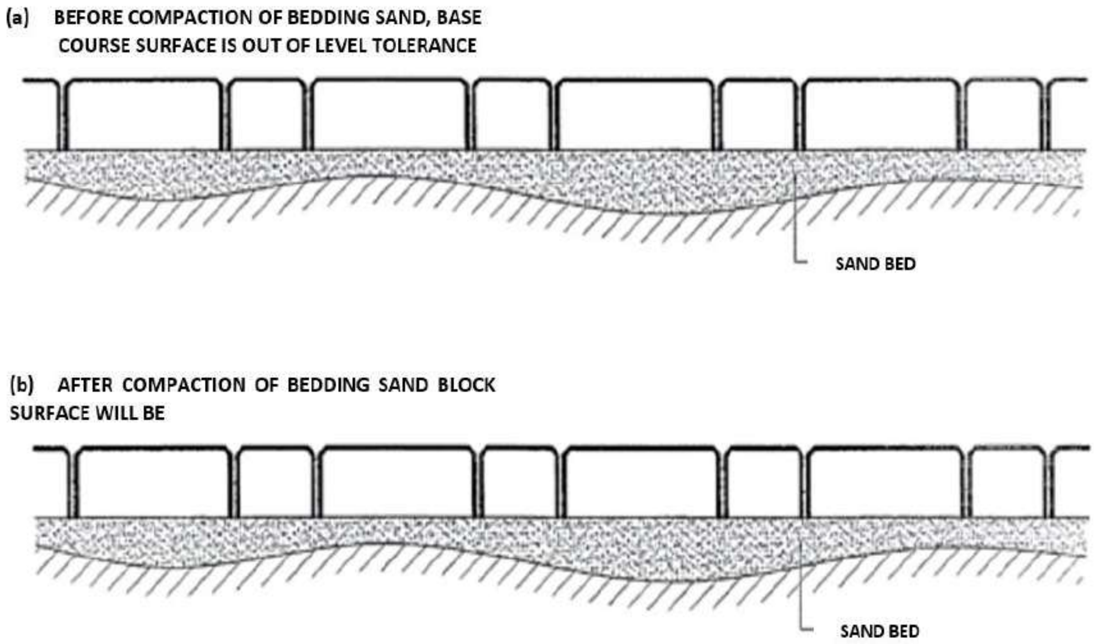


Figure 4.1: Effect of Base-Course Surface Shape on Bedding Sand and Block Surface Shape

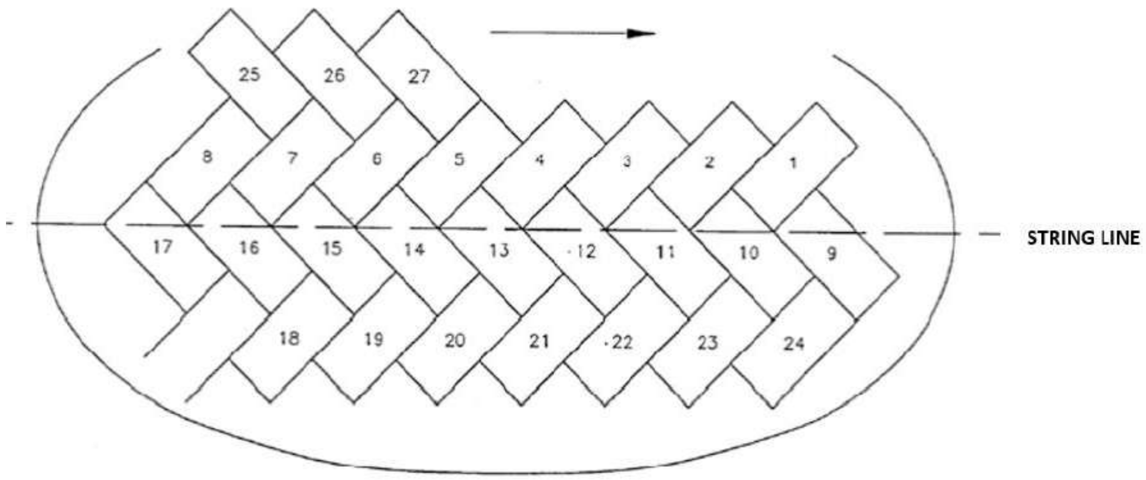


Figure 4.2: Starting at Irregular Shaped Edge Restraint

4.6. Bonds or Patterns of Laying Bricks

The blocks can be placed to different bonds or patterns depending upon choice. Some popular bonds commonly adopted for block paving are:

(i) Stretcher or running bond

(ii) Basket weave or parquet bond

The typical layout of these bonds are given in Figure 7.3.

4.7. Establishing the Laying Pattern

In relation to the starting line, the blocks should be placed at the correct angle to achieve the final orientation as required by the laying pattern. If the edge restraint is straight and suitably oriented, the first row of blocks can about it. For irregular-shaped and unfavorably oriented edge restraints, a string line should be established a few rows away to position the first row. With the help of gauges, the joint width specification (2 to 3 mm) should be checked in the first few square meters, where it should be ensured that the block alignment is correct. To start with, full blocks should be used; only subsequently, cutting and in-filling at edges be permitted. Under no circumstances should the blocks be forced or hammered into the bedding sand at this stage of laying. For cutting paving blocks, hydraulic or mechanical block cutters, or power saws are used. Cut units less than 50 mm minimum dimension should not be used, as these are difficult to cut accurately and can be dislodged under traffic. Where space does not permit use of a larger segment, use premixed concrete or a sand-cement mortar instead.

The control over alignment, laying pattern and joint widths can be maintained by the use of chalked string lines, at about 5 m intervals.

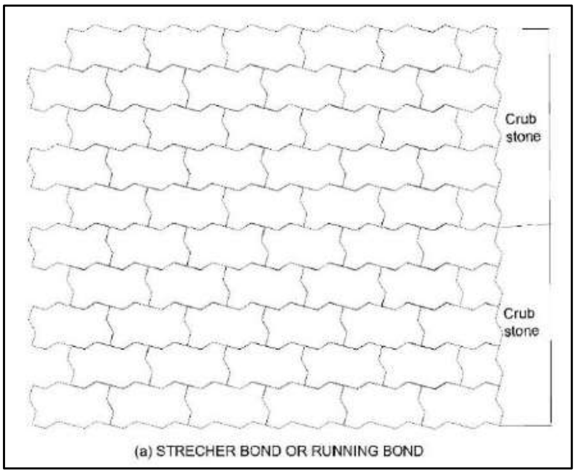
4.8. Methods of Construction of Block Pavement

4.8.1. Manual Method:

In the traditional manual method, the sand is roughly screened and a skilled worker (called a pavior) levels the sand and then embeds the block using a hammer; he works backwards so as to have a continuous view of the completed pavement in order to obtain a good finish. A pavior, along with an assistant, can lay 50 to 75 sqm of paving per day.

An alternative to the above method, the block layers (generally unskilled laborers) work on the completed surface, moving forward.

For optimum output, it is advantageous to select an easy fitting block shape, with the desirable size being that which can be easily accommodated in the worker's hand; in addition, the blocks should be chamfered for easy handling and their weight should preferably be less than 4 kg.



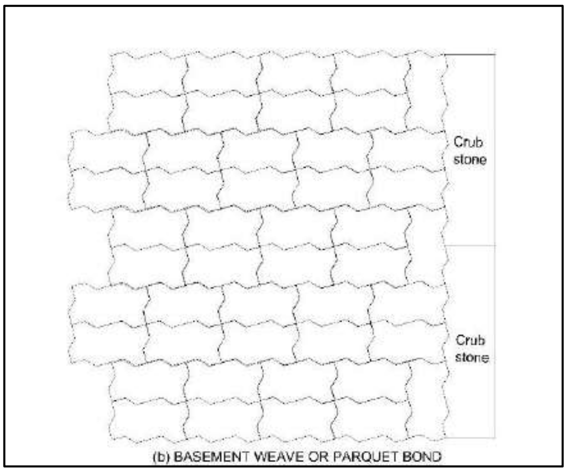


Figure 4.3: Typical Bond or Laying Pattern of Bond

The output of finished pavement varies widely with training of workmen, over a wide range from a low of 20 to a high of 120 sqm /man-day. The higher outputs being for industrial hard standings where intrusion like manholes, etc. are minimal. To keep up the speed of work, it is important to maintain an adequate supply of paving blocks to the laying site for manual paving. Ordinarily, hand pushed trolleys are adequate for the purpose, but for large projects employing a number of laying teams, use of powered trolleys is preferable.

Care must be taken to see that paving blocks are not tightly butted against each other, otherwise there could be non-uniformity in the laying patterns and the blocks may spall or even crack. Joint widths of 2 to 3 mm can be maintained if, when laying a paving unit, it is held lightly against the face of an adjacent laid unit and allowed to vertically slide into position. Since each workman may produce slightly different joint widths, it is desirable to rotate workmen along the workface, and also periodically interchange the personnel laying and transporting blocks.

The average joint width can be measured and checked, by determining statistically the representative values of average length and breadth of blocks at the project site and then obtaining average distance between joints, say 40 blocks apart; or it can be done by measuring joint widths directly, using a calibrated, hardened steel mandrel which is forced into joints at a series of randomly selected location, to obtain a statistically representative figure.

4.8.2. Mechanized Method:

Mechanized laying requires the use of specialized equipment for transporting and placing clusters of paving blocks. The size of paving block cluster suitable for paving, is usually 0.3 to 0.5 m2 in area for hand-operated equipment. For fully mechanized equipment, the cluster surface area can be up to about 1.2 sqm. These clusters are designed to maintain a joint space of about 3 mm between blocks, when clamped together (Figure 7.4).

Since the blocks are placed in separate clusters, there exists the possibility of damage if joints between adjacent clusters run uninterrupted throughout the pavement. To overcome this problem, clusters may be arranged so that the joints are periodically staggered both along and across the cluster axis or link blocks are installed by hand across these joints (Figure 7.5).

Mechanized laying must be coordinated with the manufacturer, so that the blocks are delivered stacked on pallets in the required pattern; in some cases, spacing ribs may be cast on the sides of blocks to preserve the required joint spacing.

4.8.3. Compaction

For compaction of the bedding sand and the blocks laid over it, vibratory plate compactors are used over the laid paving units; at least two passes of the vibratory plate compactor are needed. Such vibratory compaction should be continued till the top of each paving block is level with its adjacent blocks. It is not good practice to leave compaction till end of the day, as some blocks may move under construction traffic, resulting in the widening of joints and corner contact of blocks, which may cause spalling or cracking of blocks. There should be minimal delay in compaction after laying of the paving blocks to achieve uniformity of compaction and retention of the pattern of laying; however, compaction should not proceed closer than 1 m from the laying face, except after completion of the pavement.

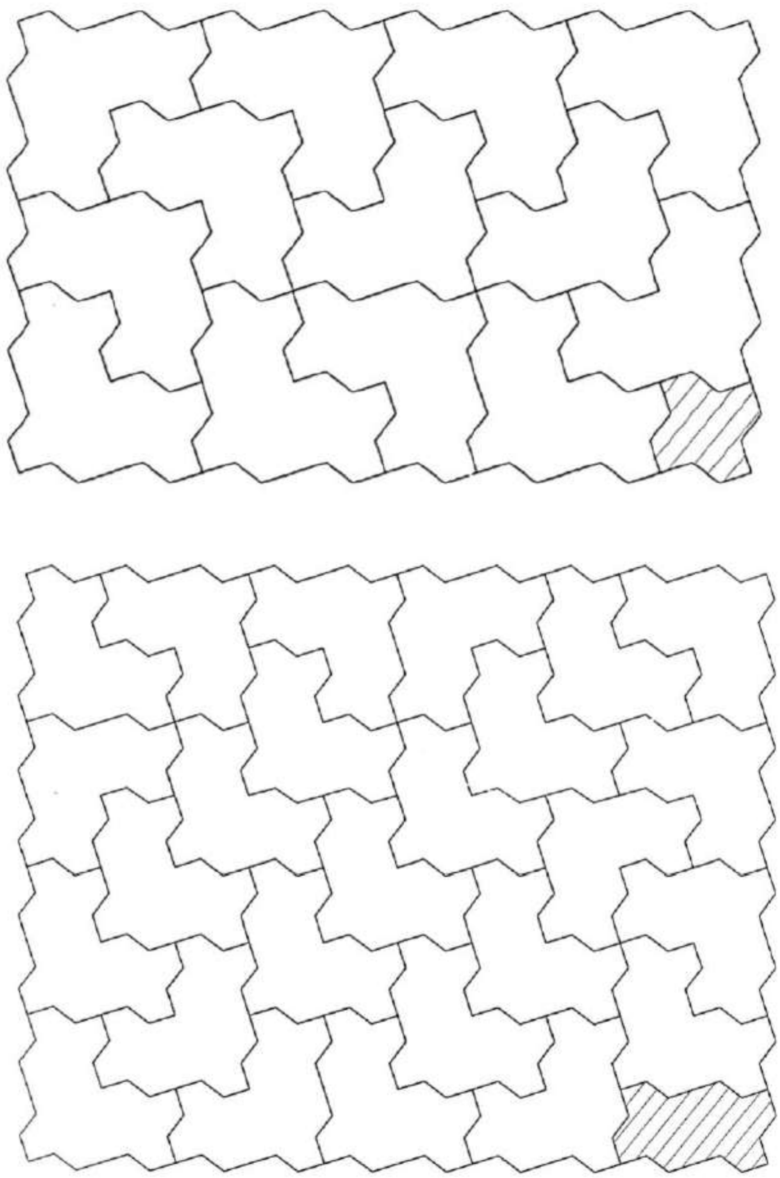


Figure 4.4: Typical Block Cluster in merchandised Laying

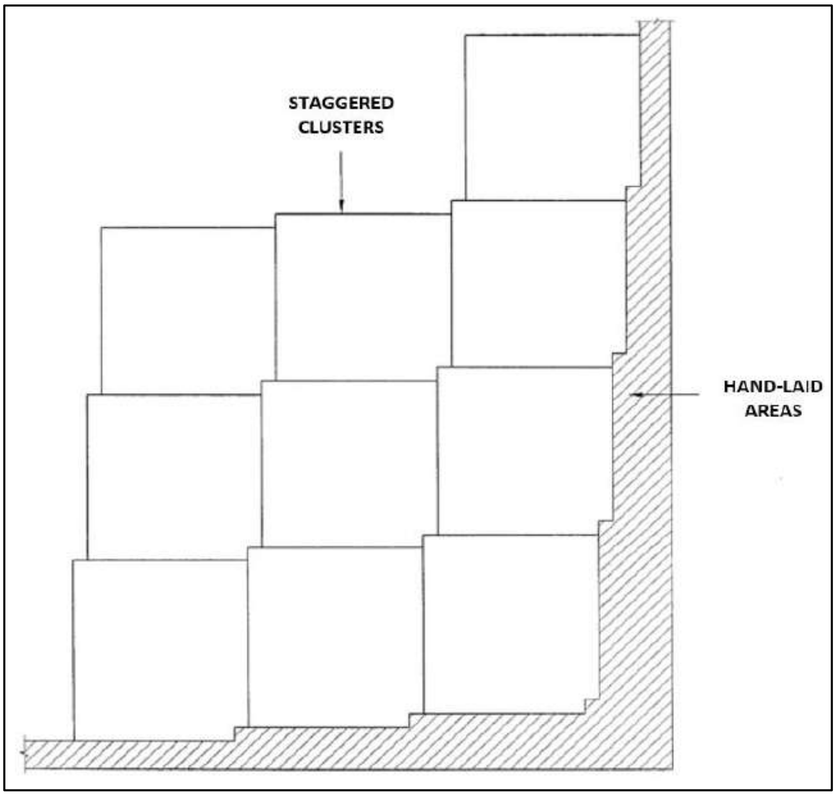


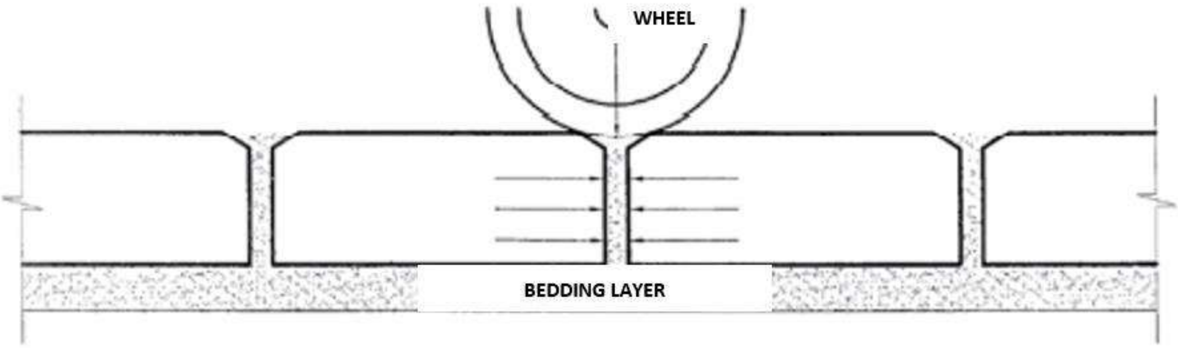
Figure 4.5: Staggered Installation of Block Clusters

During vibratory compaction of the laid blocks, some amount of bedding sand will work its way into the joints between them. The extent of sand getting worked up into the joints will depend on the degree of pre-compaction of sand and the force applied by the block compactor. Standard compactors may have a weight of about 90 kg, plate area of about 0.3 sqm and apply a centrifugal force of about 15 kN. After compaction by vibratory plate compactors, some 2 to 6 passes of a vibratory roller (with rubber coated drums or those of static weight less than 4 tonnes and nominal amplitude of not more than 0.4 mm) will further help in compaction of bedding sand and joint filling.

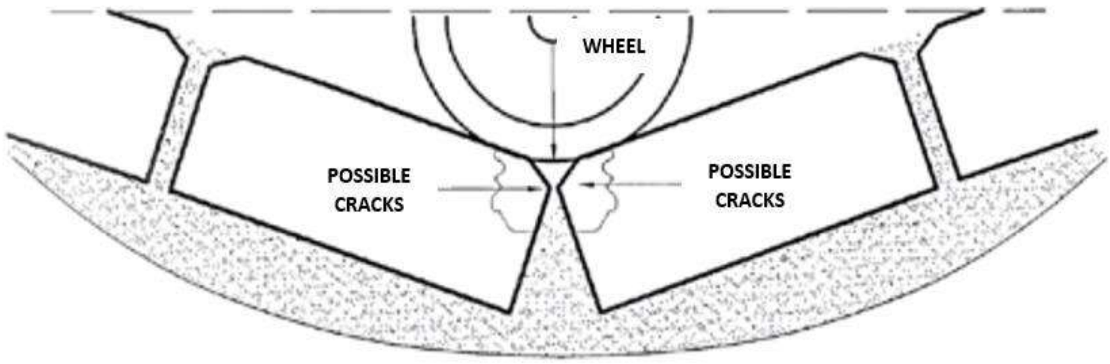
4.8.4. Joint filling

The importance of complete joint filling cannot be over-emphasized. Unfilled or partially filled joints allow blocks to deflect, leading to loose blocks, possibly spalling the edges and a locally disturbing bedding sand layer, as shown in Figure 7.6.

After the compaction of the bedding sand has been completed and some bedding sand has been forced up in the joints between blocks, the joints should be completely filled with sand meeting the desired specifications of materials as given in Section 4. The joint filing sand should be stockpiled at suitable locations for convenience. There should be minimum delay in joint filling; the process should in any case, be completed by the end of the day's work.



(A) Sand Filled Joint Spreads Wheel Load



(B) Unfilled Joint allows Blocks to Deflect Leading to Lose Blocks with Possible Creaks

Figure 4.6: Need for Complete Filling of Joints

The operation of joint filling comprises of spreading a thin layer of the joint filling sand on the block surface and working the sand into each joint by brooming. Following this, a few passes of heavy plate compactor are applied to facilitate fine sand to fill the joints. The sand should be broomed or spread over the surface with a small surcharge.

Dry sand and dry blocks are best for the filling of joint, as damp sand tends to stick at the very top of the joints; also, if the block is wet and the sand dry, the sand will again stick at the joint top. Hence, if either the blocks or sand are wet, one may get a false impression of the joints being full, but the next rain will reveal that they are actually hollow. If the weather does not allow sand and blocks to be dry, the joint filling sand should be washed in by light sprinkling of water. In this case, several cycles of application of sand, water-sprinkling and plate compaction will be necessary to completely fill the joints.

4.8.5. Opening to Traffic

Until all the joints are completely filled, no traffic should be permitted over the block pavement. In case of lime or cement treated layers in the pavement, it must be ensured that these are given at least 14 and 7 days respectively to cure, before traffic is permitted. The block pavement should be inspected frequently, to ensure that any incompletely filled joints, exposed by traffic and/or weather are promptly filled. Such frequent inspection should be continued till dust and detritus from the roadway tightens the surface of the joints.

4.8.6. Layering and Surface Tolerance

While laying the surface tolerances, given below may be observed:

Layer/Item	Tolerance
Subgrade	+0, -25 mm of nominated level
Select subgrade/Sub-base	-0, -20 mm of nominated level
Base Course	-0, +10 mm of nominated level 10 mm deviation from a 3 m straight edge
Plan deviation From any 3 m line From any 10 m line	10 mm (maximum) 20 mm (maximum)
Vertical deviation from 3 m line at curbs Intrusions, channels, edge restraints elsewhere	+3 mm, -0 mm
Maximum difference in surface level Between adjacent paving units	+5 mm, -5 mm
Deviation of finished surface level Designated level	+10 mm, -15 mm
Joint width range	2 mm to 3 mm
Percentage of joints outside rage	10% max. along 10 m line
Nominal joint width	3 mm
Final finished surface with 3m straight edge	± 3 mm

4.8.7. Detailing block Pavements

Essentially, there are three important aspects in detailing. These are

(i) Curves

(ii) Treatment of intrusions

(iii) Changes in alignment

Curves:

It is necessary to cut the paving units to fit the edge restraints. Rectangular blocks of a similar or contrasting color as an edging have been used to minimize the visual effects of small errors in block cutting. To avoid unsightly and potentially weak construction joints, it is often preferable to change the laying pattern at the curve. For example, as shown in Figure 7.7, the curve itself can be installed in herringbone bond and yet the pavement can revert to stretcher bond on the approaches.

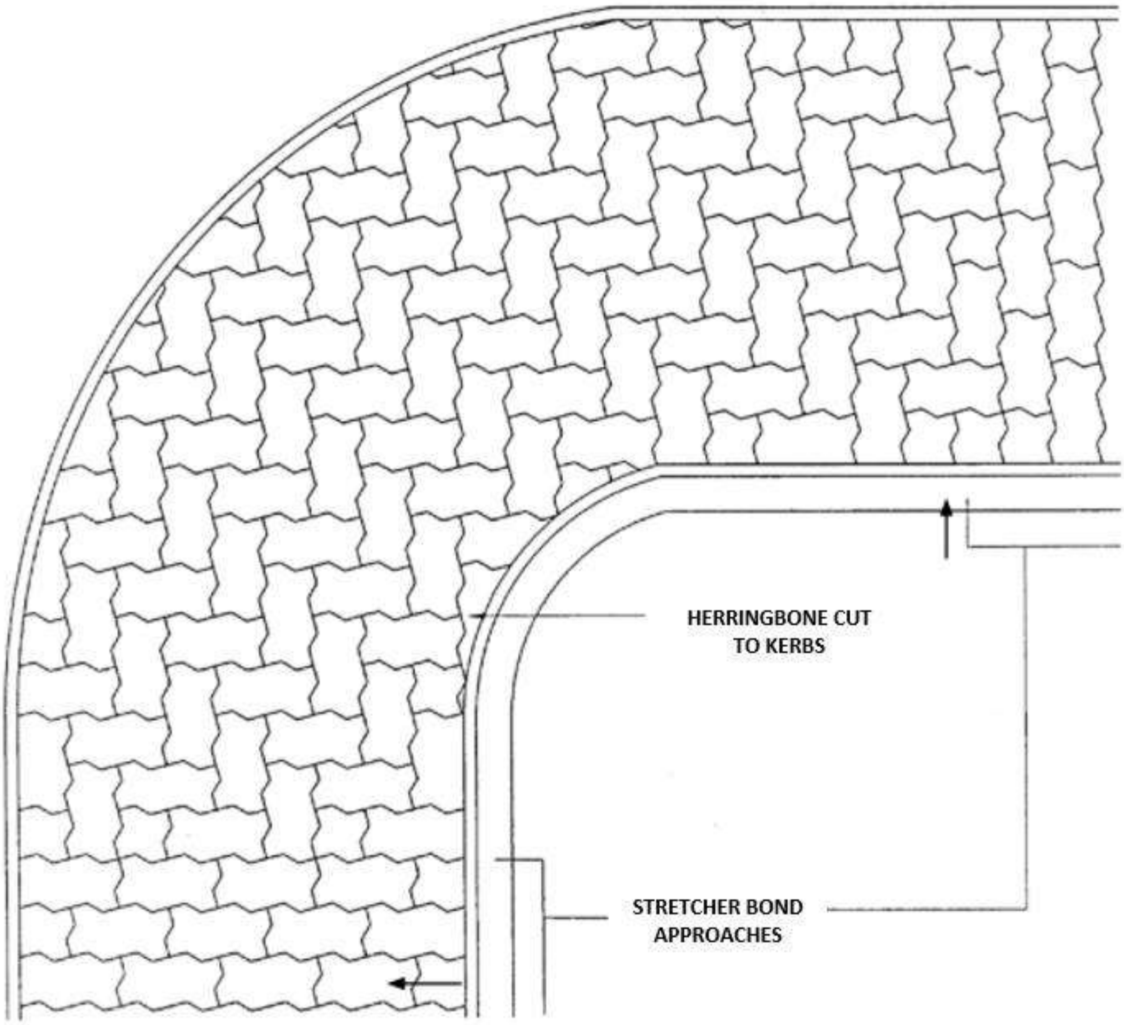


Figure 4.7: Curve in Herringbone Bond and Approaches in Stretcher Bond

Pavement Intrusions:

On some pavements, like in city streets, there could be several intrusions, like, manholes, drainage gulleys, etc. Where meeting these intrusions with the pavement is desirable. Figure 7.9 shows how this should be done around a manhole.

Around intrusions, it is good practice to lay along both sides of the intrusion simultaneously so that closure is made away from the starting workface, rather than carrying the pavement around the intrusion to return to the original laying face (Figure 7.8) to avoid accumulation of closing error.

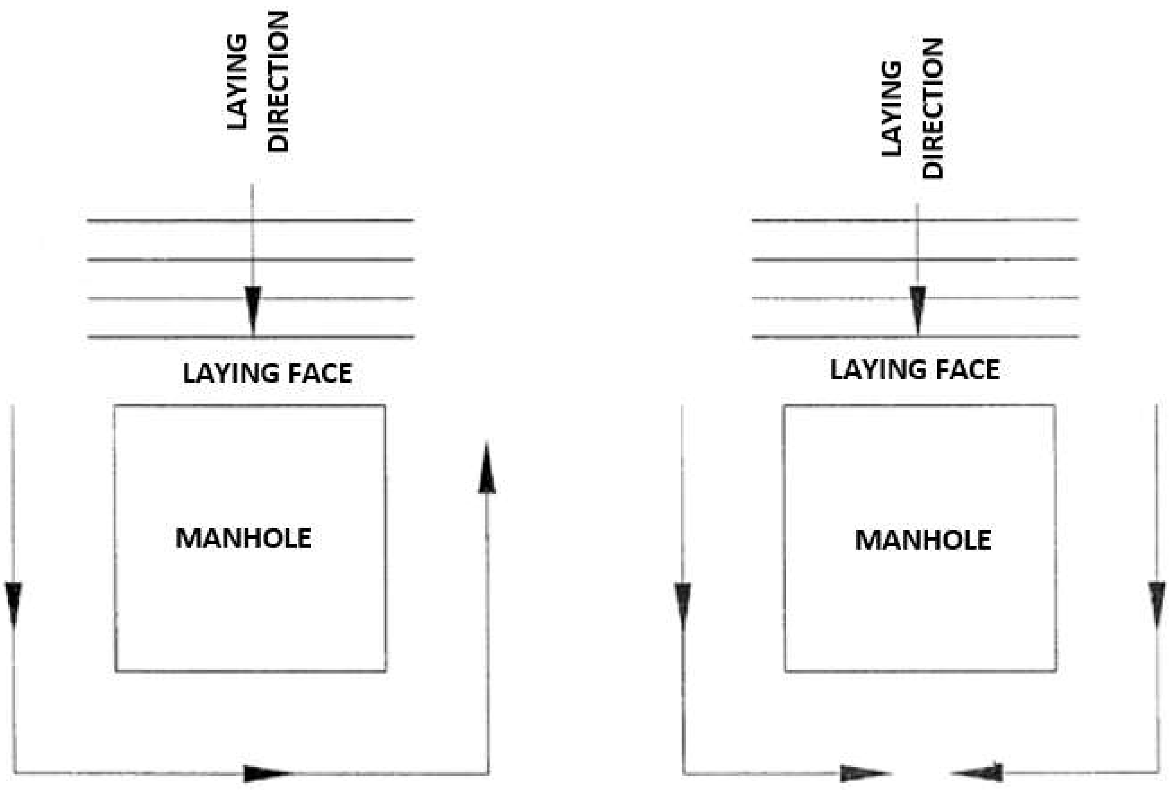


Figure 4.8: Laying Block Paving Around a Manhole

Change in alignment:

Changes in alignment of a road pavement can sometimes be achieved by the use of special blocks. However, it is generally easier to choose a block that can be installed in herringbone bond and simply cut the blocks to fit the edge restraints. Where aesthetic requirements or shape of the paving unit dictate the use of stretcher bond, then only a 90° shape change in alignment can be achieved without cutting the blocks (Figure 7.9). At intersections, if a herringbone bond laying pattern is adopted, the paving can proceed without the need for construction joints (Figure 7.10). An alternative to this is to install a shoulder (support) course of rectangular paving units between the main roadway and the side streets; this permits different laying patterns to be used in the two roadways.

4.9. Specifications

Approved Specification of LGED for precast Concrete Blocks for Paving need to be followed for the manufacture and testing of blocks.

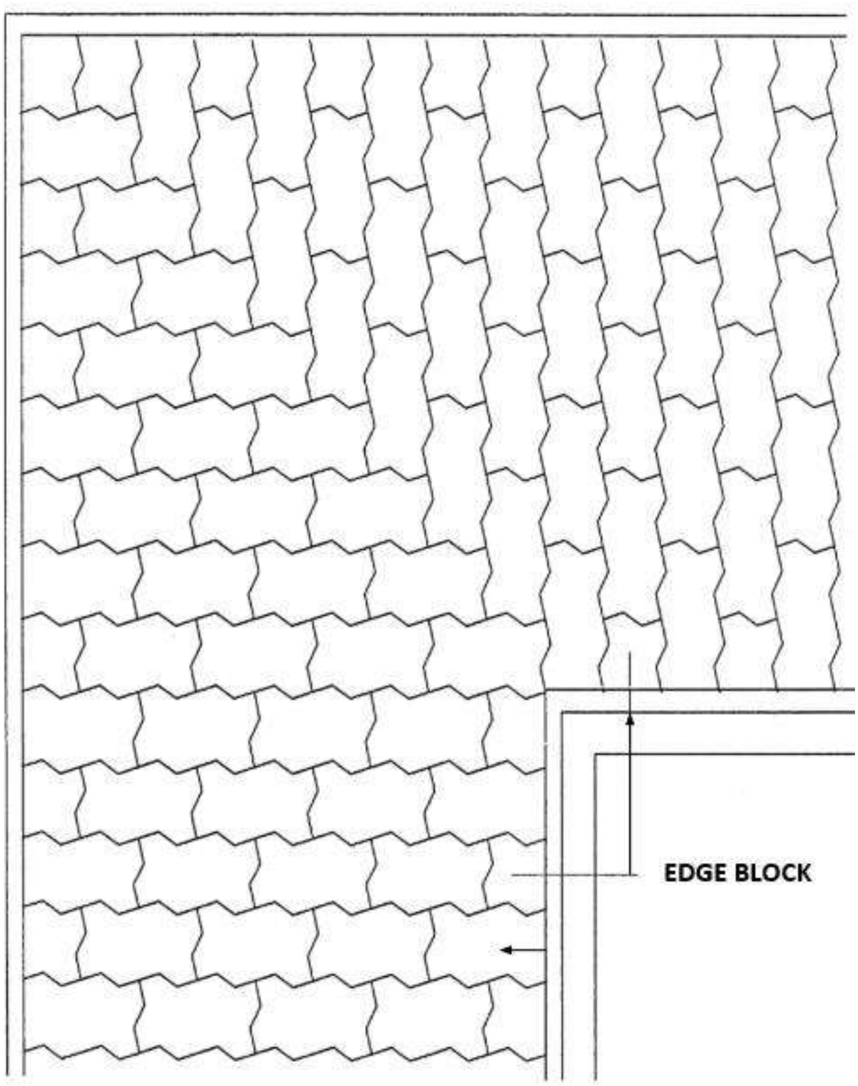


Figure 4.9: 90° Change in Alignment using Stretcher Bond

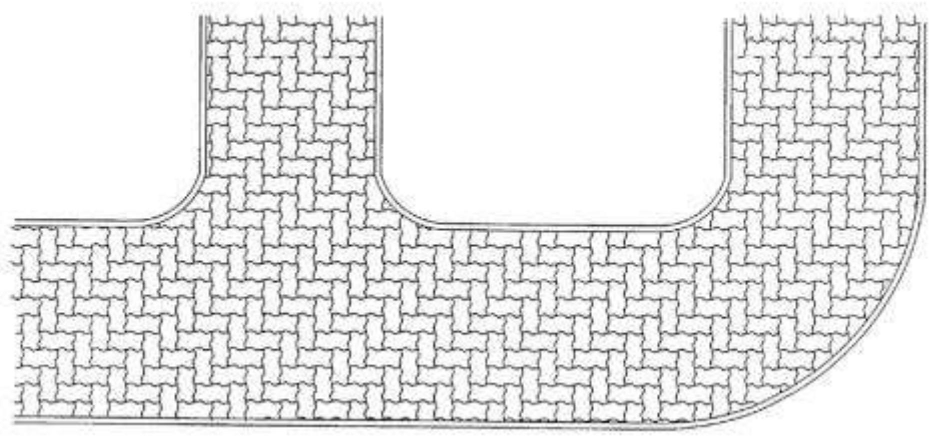


Figure 4.10: Adaptation of Herringbone Bond to Changes in Alignment

SOME REAL PICTURES DURING CONSTRUCTION

Figure: Measuring and Checking the level of Base

Figure: Measuring and Checking the level of Base

Figure: Compaction of Base

Figure: Compaction of Base

Figure: Block Laying in Stretcher Bond

Figure: Cutting and Laying in Stretcher Bond for adjustment with curb stone

Figure: Ongoing Block Laying

Figure: Ongoing Designed Block Laying

Figure: Completed Roadway

Figure: Completed Roadway

5. Maintenance

5.1. General

Like any other road work, block pavement also required to be maintained to get long service. The maintenance requirement of block pavement is minimal. The block pavement requires initial maintenance soon after its laying, say after a week or two for checking sand in the joints. Subsequently, the maintenance is in the form of replacing any damaged block/blocks or raising the settled section, if any. Repair especially after laying a cable duct is much simpler in the case of block pavements. The cut area can be reinstated without any blemish.

5.2. Initial maintenance

After about a week of laying the blocks there is a need to inspect the surface to check for any loss of sand at joints. Wherever sand level has dropped down it should be reinstated. This type of inspection should continue for two to three months till the sand level is stabilized and topping up is no more required. With time the joints receive fine dust and detritus thus making them waterproof. During rains these joints may allow weeds to grow but these normally should get eliminated with the traffic. In case it does not get eliminated these may have to be controlled by spraying herbicide or by manual removal. Annual inspection, however, will be required.

5.2.1. Removing Stains

Specifically designed cleaning products for ICBP is be procured for cleaning. Initially, through clean through water afterward remove stains with specific cleansing chemicals according typing of stains, stains of following types

(i) Asphalt and roofing far (ii) blood, candy, and ketchup grease dripping from food. (iii) Caulking (iv) Chewing gum (v) Clay soil (vi) Creosote (vii) leaf, woods rot or tobacco stain (viii) Mortar (ix) smoke (x) Penetrated or grease (xi) Paint (xii) dried paint (xiii) tire skied marks.

In case of small stained areas, removal and replacement with new pavers may be an option. Otherwise for wide area Professional clearing methods are required to be engaged.

5.2.2. Efflorescence and its Removal

Efflorescence is a whitish powder like deposit which can be appear on concrete products. It does not affect the structural performance or durability or concrete pavers. Efflorescence is normally remove by rain water.

5.2.3. Joint sand Stabilizers and Sealers

Joint sand stabilizer come in liquid and dry applied form, Primary function is to provide additional protection to concrete paver surface.

5.2.4. Clearing of grass, small herbs

Clearing of grass, small herbs etc. on the pavement surface is done by hand picks or by using small tools. Regular inspection is very important. It is very informant activity. 3 monthly inspections of ICBP by responsible engineer is required.

5.2.5. Shoulder & slope repair

Blocks of ICB paver become loose and damage due to shoulder and slope damage thus needs timely repair.

5.3. Storage of Blocks

For the purpose of reinstating damaged blocks, it is necessary to stockpile a small percentage of blocks from the lots used in the construction. The size and color of the blocks may be difficult to obtain at a later date matching with the original blocks. For important projects, it is normal to stockpile blocks from 1 per cent to 3 per cent of initial supply for subsequent use.

5.4. Coating and cleaning

As part of preventive maintenance, blocks can be sealed using compounds, like, silicone, acrylics and silica fluorides for enhancing the color, reducing absorptive nature of the blocks and for improving surface toughness. These coating have life of 1 to 3 years and hence they have to be repeated as per the requirement. The most durable of these chemicals is solvent borne acrylics which are abrasion resistant and also minimize chemical effects of spillage even at 60°C.

Cleaning of block pavement can be done by mechanical brooms, compressors or even by manual means. For removing certain stains, chemicals, like, oxalic, acetic and phosphoric acids etc. are used. Sometimes it may be expedient to replace the blocks where stains have penetrated to a greater depth.

Maintenance guidelines for all ICBP (Interlocking Concrete Block Pavements) distresses are as follows;

Distress	Activity	Frequency
Clogged/ Damaged Secondary Features	Clean out or secondary drainage features.	Annually, after major rain event
Depressions	Repair all paver surface depressions, exceeding 10 mm.	Annually, repair as needed
Rutting	Repair all paver surface rutting, exceeding 10 mm.	Annually, repair as needed
Faulting	Repair all paver surface faulting, exceeding 5 mm.	Annually, repair as needed
Damage Paver Unit	Repair medium to high severity cracked, spalled or chipped paver unit.	Annually, repair as needed
Edge Restraint Damage	Repair pavers offset by more than 5 mm from adjacent units or curbs, inlets, etc.	Annually, repair as needed
Excessive Joint Width	Repair pavers exhibiting joint widths exceeding 10 mm.	Annually, repair as needed
Joint Filler Loss	Replenish aggregate in joints	As needed
Horizontal Creep	Repair areas exhibiting horizontal creep exceeding 10 mm.	Annually, repair as needed
Excessive settlement	For settlement greater than 1 in, consult a pavement engineer versed in OGA design and construction to determine cause and correction.	As needed
Additional Distress	Missing pavers shall be replaced. A geotechnical investigation is recommended for pavement heaves.	Annually, repair as needed

For detail information regarding maintenance and repair of Interlocking Concrete Pavement (ICBP) is referred by the following heading in **Annexure-V.**

A. Cleaning, Sealing and Joint Sand Stabilization
B. Reinstatement
C. Repair of Utility Cuts Within Interlocking Concrete Pavements.

ANNEXURE I

Tabular form for Typical Mix Design Chart

Table 1: Type A1

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Padma River Sand: Pakshi, Ishwardi Upazila, Pabna Rajshahi Division	1.67	A	60	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.30	5239	6176	6195
		B			1:1.25:1.25		0.30	5898	5817	6415
		C			1:1.25:1.25		0.30	5792	5997	6753

Table 2: Type A2

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Padma River Sand: Pakshi, Ishwardi Upazila, Pabna Rajshahi Division	1.67	A	60	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.30	4991	5057	5140
		B			1:1.5:1.5		0.30	4986	5557	5810
		C			1:1.5:1.5		0.30	4771	5457	6257

Table 3: Type A3

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Padma River Sand: Pakshi, Ishwardi Upazila, Pabna Rajshahi Division	1.67	A	80	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.30	6078	6487	7113
		B			1:1.25:1.25		0.30	5575	6153	6889
		C			1:1.25:1.25		0.30	5910	6711	7224

Table 4: Type A4

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Padma River Sand: Pakshi, Ishwardi Upazila, Pabna Rajshahi Division	1.67	A	80	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.30	5093	6145	6927
		B			1:1.5:1.5		0.30	5428	5698	6145
		C			1:1.5:1.5		0.30	5541	6257	6592

Table 5: Type B1

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Jamuna Sand: Tangail District, Dhaka Division	1.34	A	60	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.30	4910	5598	5699
		B			1:1.25:1.25		0.30	4246	4916	6257
		C			1:1.25:1.25		0.30	4246	5398	5699

Table 6: Type B2

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Jamuna Sand: Tangail District, Dhaka Division	1.34	A	60	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.30	4022	4433	5084
		B			1:1.5:1.5		0.30	4357	5102	5419
		C			1:1.5:1.5		0.30	4850	4433	5140

Table 7: Type B3

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Jamuna Sand: Tangail District, Dhaka Division	1.34	A	80	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.26	5363	6169	6927
		B			1:1.25:1.25		0.26	5140	5922	6257
		C			1:1.25:1.25		0.26	5475	5563	6201

Table 8: Type B4

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Jamuna Sand: Tangail District, Dhaka Division	1.34	A	80	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.30	4804	5810	5922
		B			1:1.5:1.5		0.30	4972	5699	6257
		C			1:1.5:1.5		0.30	5140	5251	6592

Table 9: Type C1

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Teesta Sand: Teesta River, Dalia, Nilfamari, Rangpur Division	1.38	A	60	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.27	4526	5579	5871
		B			1:1.25:1.25		0.27	5084	5167	6012
		C			1:1.25:1.25		0.27	4917	5761	6071

Table 10: Type C2

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Teesta Sand: Teesta River, Dalia, Nilfamari, Rangpur Division	1.38	A	60	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.27	3352	4081	5140
		B			1:1.5:1.5		0.27	3910	3975	4581
		C			1:1.5:1.5		0.27	3799	4031	4022

Table 11: Type C3

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Teesta Sand: Teesta River, Dalia, Nilfamari, Rangpur Division	1.38	A	80	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.27	5472	5559	6238
		B			1:1.25:1.25		0.27	5449	5577	6573
		C			1:1.25:1.25		0.27	5370	5625	6127

Table 12: Type C4

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Teesta Sand: Teesta River, Dalia, Nilfamari, Rangpur Division	1.38	A	80	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.27	4805	5028	5586
		B			1:1.5:1.5		0.27	4581	5140	5642
		C			1:1.5:1.5		0.27	4358	5140	6033

Table 13: Type D1

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Brahmaputra Sand: Brahmaputra river, Muktagacha , Mymensingh, Mymensingh Division	1.15	A	60	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.27	4640	4941	5439
		B			1:1.25:1.25		0.27	4030	5371	5954
		C			1:1.25:1.25		0.27	4560	5456	5869

Table 14: Type D2

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Brahmaputra Sand: Brahmaputra river, Muktagacha , Mymensingh, Mymensingh Division	1.15	A	60	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.28	4200	4458	4875
		B			1:1.5:1.5		0.28	3574	3942	4890
		C			1:1.5:1.5		0.28	4202	4374	4551

Table 15: Type D3

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	**14 days**	**28 days**
Brahmaputra Sand: Brahmaputra river, Muktagacha , Mymensingh, Mymensingh Division	1.15	A	80	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.27	5007	5057	6399
		B			1:1.25:1.25		0.27	4800	5695	5810
		C			1:1.25:1.25		0.27	5064	5724	6517

Table 16: Type D4

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	**14 days**	**28 days**
Brahmaputra Sand: Brahmaputra river, Muktagacha , Mymensingh, Mymensingh Division	1.15	A	80	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.28	4807	5334	5450
		B			1:1.5:1.5		0.28	4011	5160	5431
		C			1:1.5:1.5		0.28	4862	5208	5406

Table 17: Type E1

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Meghna River Sand: Chandpur District, Chattogram Division	0.90	A	60	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.27	4053	4682	5411
		B			1:1.25:1.25		0.27	3886	5354	5546
		C			1:1.25:1.25		0.27	4781	5354	5905

Table 18: Type E2

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Meghna River Sand: Chandpur District, Chattogram Division	0.90	A	60	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.30	2569	3463	4246
		B			1:1.5:1.5		0.30	2681	2681	4022
		C			1:1.5:1.5		0.30	2570	2905	4022

Table 19: Type E3

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Meghna River Sand: Chandpur District, Chattogram Division	0.90	A	80	35	1:1.25:1.25	**X-234:** 200ml/per bag cement	0.27	4693	5419	5810
		B			1:1.25:1.25		0.27	4469	5587	6145
		C			1:1.25:1.25		0.27	4637	5363	6033

Table 20: Type E4

Sand Name and Location	Sand F.M	Specimens	Thickness (mm)	Desired Strength (mpa	Mix Ratio Cement: Dredged Sand: Sylhet Sand (when applicable)	Quantity of Admixture (s) used	Water/ Cement Ratio	Average compressive strength (psi)		
								7 days	14 days	28 days
Meghna River Sand: Chandpur District, Chattogram Division	0.90	A	80	35	1:1.5:1.5	**X-234:** 200ml/per bag cement	0.30	3576	4469	4804
		B			1:1.5:1.5		0.30	3911	4865	4916
		C			1:1.5:1.5		0.30	4413	4581	5140

Table 21: Comparative Study of ICBP Test Result

River Sand	Location	Fineness Modulus(F. M)of Local Dredged Sand	Admixture	Mixing Ratio	Average Strength (Psi)					
					60mm thick ICBP			80mm thick ICBP		
					7 days	14 days	28 days	7 days	14 days	28 days
Meghna River Sand	Chandpur, Chattogram Division	0.90	**X-234:**200ml/per bag cement	1:1.25:1.25	4240	5130	5620	4599	5456	5996
				1:1.5:1.5	2606	3016	4096	3966	4638	4953
Brahmaputra Sand	Muktagacha, Mymensingh, Mymensingh Division	1.15	**X-234:**200ml/per bag cement	1:1.25:1.25	4410	5256	5754	4957	5492	6242
				1:1.5:1.5	3992	4258	4772	4560	5234	5429
Jamuna Sand	Tangail , Dhaka Division	1.34	**X-234:**200ml/per bag cement	1:1.25:1.25	4467	5304	5885	5326	5884	6461
				1:1.5:1.5	4409	4656	5214	4972	5586	6257
Teesta River Sand	Dalia, Nilfamari, Rangpur Division	1.38	**X-234:**200ml/per bag cement	1:1.25:1.25	4842	5502	5984	5430	5587	6312
				1:1.5:1.5	3687	4029	4581	4581	5102	5753
Padma River Sand	Pakshi, IshwardiUpazila, Pabna Rajshahi Division	1.67	**X-234:**200ml/per bag cement	1:1.25:1.25	5643	5996	6454	5854	6450	7075
				1:1.5:1.5	4916	5357	5735	5354	6033	6554

Graphical Representations of F.M. (Fineness Modulus) Vs Strength for ICBP under Different Rivers, Mix Ratios& Paver Thickness

Table 22: F.M. and Average Strength of ICBP (60 mm) with Mix Ratio (1:1.25:1.25)

	Specimen=	Sand Cement ICBP (60 mm thick)		
	Ratio=	1:1.25:1.25		
	Admixture =	200ml/bag cement		
Sand Location	F.M (Sand)	Average Strength (Psi)		
		7 days	14 days	28 days
Meghna River	0.90	4240	5130	5620
Brahmaputra	1.15	4410	5256	5754
Jamuna River	1.34	4467	5304	5885
Tista River	1.38	4842	5502	5984
Padma River	1.67	5643	5996	6465

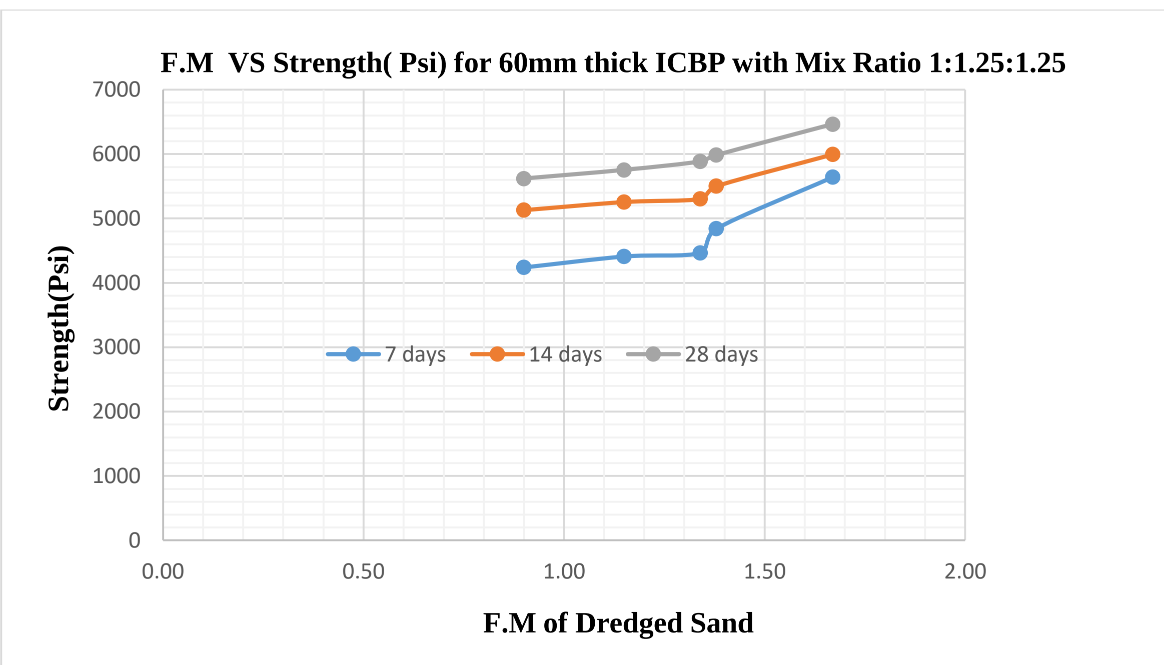


Figure 1: F.M. Vs Strength (Psi) for 60 mm thick ICBP*w*ith Mix Ratio 1: 1.25:1.25

Table 23: F.M. and Average Strength of ICBP (80 mm) with Mix Ratio (1:1.25:1.25)

	Specimen=	Sand Cement ICBP (80 mm thick)		
	Ratio=	1:1.25:1.25		
	Admixture =	200ml/bag cement		
Sand Location	F.M(Sand)	Average Strength (Psi)		
		7 days	14 days	28 days
Meghna River	0.90	4599	5456	5996
Brahmaputra	1.15	4957	5492	6242
Jamuna River	1.34	5326	5884	6461
Tista River	1.38	5430	5587	6312
Padma River	1.67	5854	6450	7075

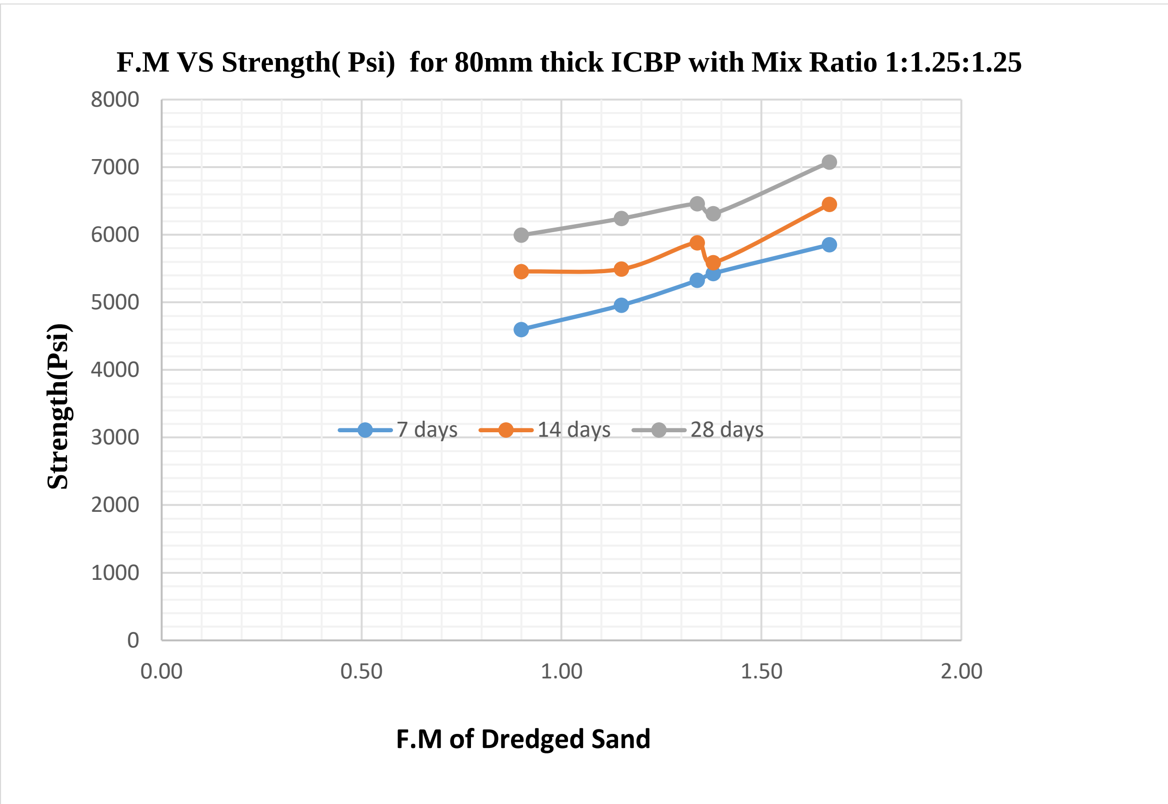


Figure 2: F.M. Vs Strength (Psi) for 80 mm thick ICBP with Mix Ratio 1: 1.25:1.25

Table 24: F.M. and Average Strength of ICBP (60 mm) with Mix Ratio (1:1.5:1.5)

	Specimen=	Sand Cement ICBP (60 mm thick)		
	Ratio=	1:1.5:1.5		
	Admixture =	200ml/bag cement		
Sand Location	F.M(Sand)	Average Strength (Psi)		
		7 days	14 days	28 days
Meghna River	0.90	2606	3016	4096
Brahmaputra	1.15	3992	4248	4772
Jamuna River	1.34	4409	4656	5214
Tista River	1.38	3687	4029	4581
Padma River	1.67	4916	4357	5735

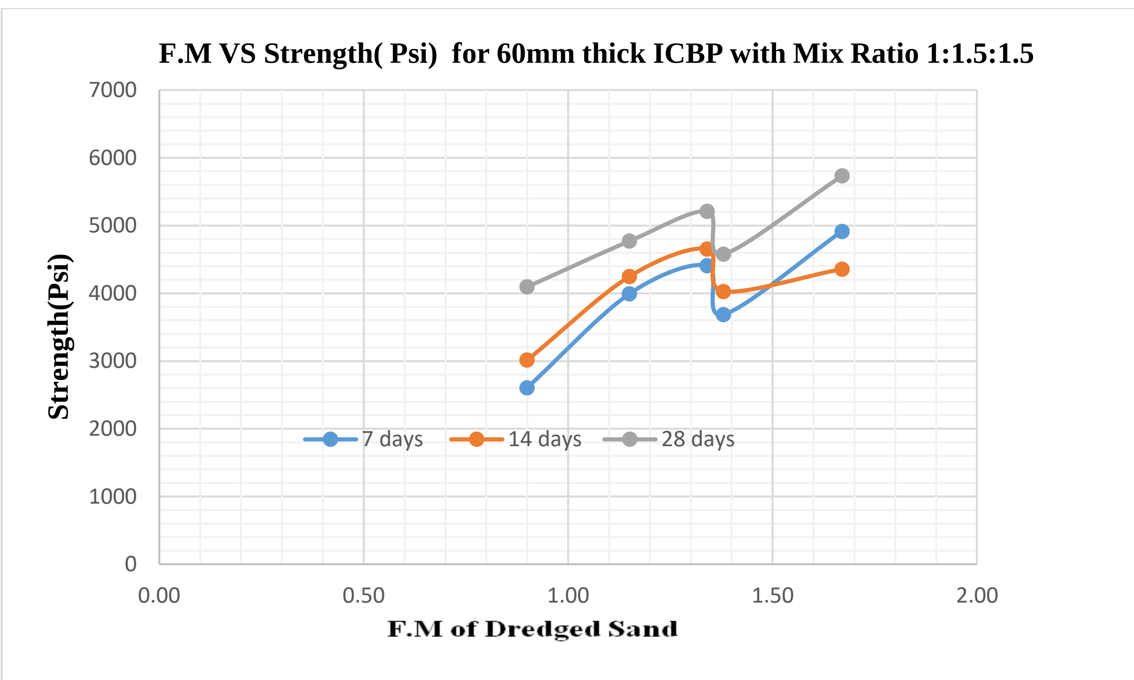


Figure 3*:* **F.M. Vs Strength (Psi) for 60 mm thick ICBP with Mix Ratio 1:1.5:1.5**

Table 25: F.M. and Average Strength of ICBP (80 mm) with Mix Ratio (1:1.5:1.5)

	Specimen=	Sand Cement ICBP (80 mm thick)		
	Ratio=	1:1.5:1.5		
	Admixture =	200ml/bag cement		
Sand Location	F.M(Sand)	Average Strength (Psi)		
		7 days	14 days	28 days
Meghna River	0.90	3966	4638	4953
Brahmaputra	1.15	4560	5234	5429
Jamuna River	1.34	4972	5586	6257
Tista River	1.38	4581	5102	5753
Padma River	1.67	5354	6033	6554

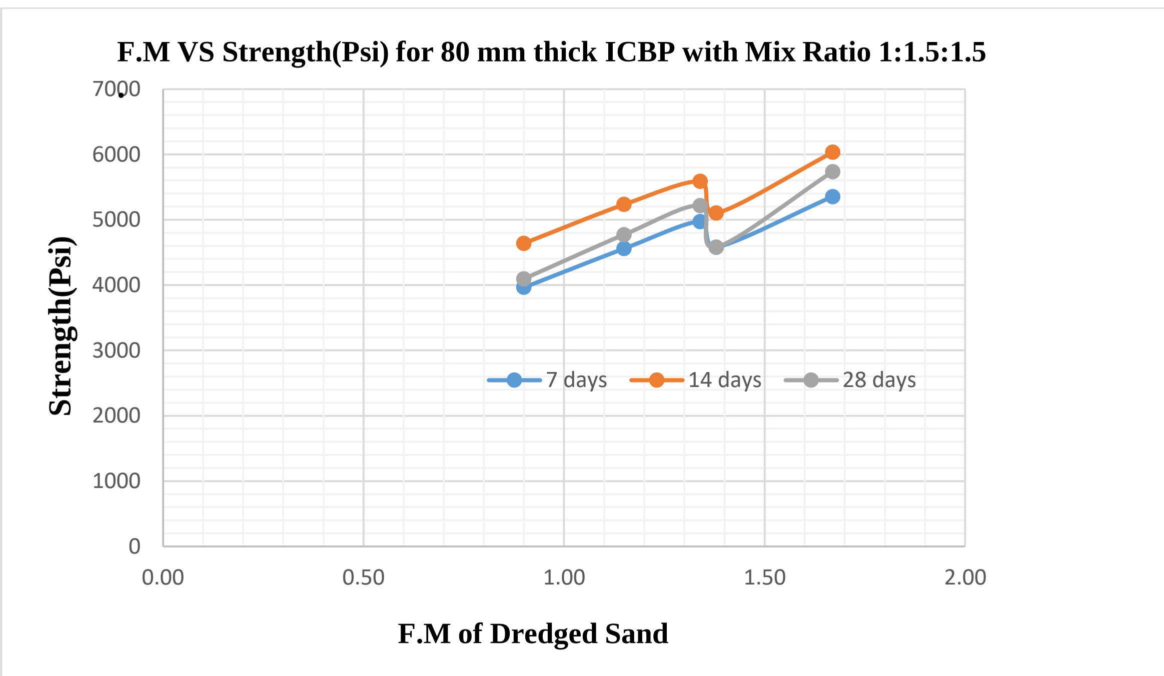


Figure 4*:* F.M. Vs Strength (Psi) for 80 mm thick ICBP with Mix Ratio 1:1.5:1.5

Observations:

1. Strength of higher thickness ICBP is higher.
2. If Fineness Modulus of Local dredged sand is higher, we will get higher strength.
3. To have higher strength within short time we need to use early strength gaining admixture with High density water Reducing super Plasticizer.

Annexure II

A) Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavement

When properly installed, interlocking concrete pavements have very low maintenance and provide an attractive surface for decades. Under foot and vehicular traffic, they can become exposed to dirt, stains and wear. This is common to all pavements. This technical bulletin addresses various steps to ensure the durability of interlocking concrete pavements and to help restore their original appearance. These steps include removing stains and cleaning, plus joint stabilization or sealing if required.

Stains on specific areas should be removed first. A cleaner should be used next to remove any efflorescence and dirt from the entire pavement. A newly cleaned pavement can be an opportune time to apply joint sand stabilizers or seal it. In order to achieve maximum results, use stain removers, cleaners, joint sand stabilizers, and sealers specifically for concrete pavers.

Removing Stains

Commercial stain removers available specifically for concrete pavers provide a high degree of certainty in removing stains. Many kinds of stains can be removed while minimizing the risk of discoloring or damaging the pavers. The container label often provides a list of stains that can be removed.

Figure 1: Many sealers enhance the appearance of concrete pavers and protect against staining

Start removal of stains at the bottom of the pavement and work up the slope in manageable sections. By working up the slope, cleaning fluids will drain down the pavement. This technique assists in uniform removal while allowing the used cleaner to be rinsed away consistently. The surface remains dry ahead of the cleaner-soaked wet areas, allowing better visibility of the stains to be removed.

Take care in selecting and applying cleaning products, as acidic ones may harm vegetation and grass. These cleaners should not run onto vegetation. When using strong acidic stain removers or cleaners that might drain onto vegetation, saturate the vegetation with water prior to using acidic cleaners. This will minimize absorption of cleaner rinse water and reduce risk of damage to vegetation.

Removal of Common Stains

There are proprietary cleaning products specifically designed for concrete pavers. Many have been developed through extensive laboratory and field testing to ensure cleaning effectiveness. These chemicals should be used whenever possible. Using manufactured cleaning chemicals for specific stains relieves the user from the uncertainty of attaining the proper mixture of chemicals.

If no proprietary stain removal products are available, a comprehensive source of information on stain removal is found in Removing Stains from Concrete by William H. Kuenning. It describes chemicals, detergents or poultice (scrubbing) materials recommended for removing particular stains, and the steps to be followed in removal. This publication recognizes that some of the treatments involve hazardous chemicals and it advises specific precautions.

Removal of several common stains from Removing Stains from Concrete are listed below

(1). Most involve typical household chemicals. Searching the internet using the key phrases mentioned below can provide additional information. The ICPI disclaims any and all responsibility for the application of the information. The user is advised to use cleaners specifically made to remove stains that commonly occur on concrete pavers. They will likely be more effective.

Asphalt and emulsified asphalt—Chill with ice (if warm outside), scrape away and scrub the surface with scouring or abrasive powder. Rinse thoroughly with water.

Cutback asphalt and roofing tar—Use a poultice made with talc or diatomaceous earth. Mix with kerosene, scrub, let dry and brush off. Repeat as needed.

Blood, candy, ketchup, mustard, grease drippings from food—For stubborn stains, apply liquid detergent full strength and allow it to penetrate for 20 to 30 minutes. Scrub and rinse with hot water. Removal is easier if these stains are treated immediately.

Caulking—Scrape off excess and scrub with a poultice of denatured alcohol. Rinse with hot water and detergent. Acrylic latex caulk—follow guidelines for removal of latex paint.

Chewing gum—same as caulking, or scrub with naphtha.

Clay soil—Scrape off dry material, scrub and rinse with hot water and strong detergent.
Creosote—apply a poultice with paint thinner and talc. Scrub and allow to dry. Scrape off, scrub with scouring powder and rinse with water.

Leaf, wood rot, or tobacco stains—apply household bleach and scrub with a stiff bristled brush.

Mortar—Let harden and carefully remove hardened spots with a trowel, putty knife or chisel.

Smoke—Scrub with a poultice of talc with bleach diluted 1:5 with water. Rinse with water.

Oil or grease that has penetrated—Mop up any excess oil with rags. Cover the area with oil absorbent (kitty litter). Talc, fuller's earth, diatomaceous earth can be used. Leave it on the stain for a day then sweep up.

Paint—Fresh paint should be mopped up immediately with rags or paper towels by blotting. Do not wipe as this will spread the paint and extend the job of removal. If the paint is latex and water based, soak and then scrub the area with hot water, scouring powder and a stiff brush until no more improvement is seen. Let the remaining paint dry and remove as described below.

Dried paint—Scrape any excess oil based paint, varnish or water based latex paint off the surface. Apply a commercial paint remover and let it sit for 20 to 30 minutes. Loosen with gentle scrubbing. Do not rub the loosened paint into the surface of the paver. Instead, blot up the loosened paint and thinner. Repeat as necessary.

Tire skid marks—Scrub black area with water, detergent and scouring powder.

In the case of small stained areas, removal and replacement with new pavers may be an option.

Overall Cleaning

Overall cleaning of the pavement can start after stains are removed. In preparation for cleaning, low tree branches, shrubs and vegetation adjacent to the pavement should be tied back or covered to protect from overspray of cleaning solutions or sealers. The area should be inspected for any cracked or broken units. These should be replaced. Badly stained units can be replaced, but it is usually easier to clean stains and less costly than replacing the pavers.

When pavers have stains too difficult to remove, replace them with the same type of units. Refer to ICPI Tech Spec 6, Reinstatement of Interlocking Concrete Pavements, for a full description on replacing pavers. If pavers must be replaced, there may be a difference in color from the surrounding pavers. This variation should eventually disappear. If color variation is unacceptable, controlled use of proprietary cleaners designed to improve the color of concrete pavers can minimize variation.

Removal of accumulated dirt and efflorescence is the objective of cleaning. It is essential in preparing the pavers for sealing as well. Many cleaners effective in removing dirt and efflorescence are a mix of detergent and acid. Cleaners with strong acids will change the color of the pavers slightly. The degree of change can be controlled by the type of acid in the cleaner, its concentration and the length of time on the pavers. Proprietary cleaners will give specific instructions on their application. These directions should be followed. In order to achieve proper results, cleaners should be tried on a small area to test results and any color changes. The concentration and time on the pavement can be adjusted accordingly. Protective clothing and goggles should always be worn when using acidic solutions.

Anticipate where the cleaning fluids will drain, i.e, across the pavement and not onto grass or vegetation. Sediment or cleaners allowed to pond in low spots may stain the pavers. If unsure of the runoff direction, test drainage with ordinary water first to identify any trouble spots. Be sure to rinse these areas thoroughly. Turn off all automatic sprinkler systems during cleaning, sealing and drying.

Professional Cleaning Methods

For most jobs, cleaning should be handled by a professional company experienced in the use of cleaners and spray equipment. Professionals typically use a pressure washer and an applicator to apply efflorescence cleaner (when needed). The various methods for applying joint sand stabilizers and sealers are covered later.

A high pressure sprayer applies cleaner and water between 1,000 and 4,000 psi (6.9 and 27.6 MPa), and at a rate between 2 and 6 gallons/minute (7.6 and 22.7 liters/minute). See Figure 2. The rate of flow is adjusted to ensure sufficient rinsing. The pressure loosens dirt and pushes water from the surface without the need for scrub brushes. The nozzle type and its distance from the paver surface influences the effectiveness of the cleaning as well. A nozzle that creates a wide spray enables a large area to be covered efficiently and prevents sand from being washed from the joints. A low angle of attack from a wide nozzle spray will also reduce the risk of dislodging joint sand.

Cleaners to remove efflorescence are applied with a low pressure pump spray 30 to 100 psi (0.2 to 0.7 MPa). A shower type spray nozzle will help ensure even distribution of the cleaner. Cleaning chemicals are applied, allowed to sit an appropriate time, and then rinsed away with a high pressure sprayer. The final rinse should be water only. A large amount of water is more important to rinsing than high pressure.

For small areas, an adequate cleaning job can be achieved without this equipment. Such areas include residential patios, walks, or small driveways. Cleaners can be applied by hand, the pavers scrubbed to remove dirt and efflorescence, then thoroughly rinsed with water from a garden hose. Scrub brushes with steel bristles are not recommended. They will loosen from the brush, rust, and leave stains. Brass or plastic bristles are acceptable. This method of cleaning is for do-it-yourselfers who wish to refurbish a small area of pavers.

Efflorescence and Its Removal

Efflorescence is a whitish powder-like deposit which can appear on concrete products. When cement hydrates (hardens after adding water), a significant amount of calcium hydroxide is formed. The calcium hydroxide is soluble in water and migrates by capillary action to the surface of the concrete. A reaction occurs between the calcium hydroxide and carbon dioxide (from the air) to form calcium carbonate, then called efflorescence.

Efflorescence does not affect the structural performance or durability of concrete pavers. The reaction that takes place is the formation of water soluble calcium bicarbonate from calcium carbonate, carbon dioxide and water. It may appear immediately or within months following installation. Efflorescence may reach its peak in as short as 60 days after installation. It may remain for months and some of it may wear away. If installation takes place during dry period of the year, the next cycle of wet weather may sometimes be necessary for efflorescence to materialize.

If there is a need to remove deposits before they wear away, best results can be obtained by using a proprietary efflorescence remover. The acid in proprietary cleaning chemicals is buffered and blended with other chemicals to provide effective cleaning without damage to the paver surface. Always refer to the paver supplier or chemical company supplying the chemicals for recommendations on proper dilution and application of chemicals for removal of efflorescence. They are generally applied in sections beginning at the top of slope of the pavement. If the area is large, a sprayer is an efficient means to apply the cleaner.

Figure 2: Pressurized cleaning equipment used by professional cleaning and sealing companies can bring out the best appearance from pavers

The chemicals are scrubbed on the surface, then rinsed away. Results can be verified after letting the area dry for at least 24 hours. In most instances one application is sufficient. However, in severe instances of efflorescence, a second application may be necessary. Contact the manufacturer of the cleaning product to determine if a second application will not discolor the pavers or expose some aggregates. Note: Protective clothing, chemical resistant rubber boots and gloves, and eye goggles should be worn when applying acid or alkalies.

Joint Sand Stabilizers and Sealers

Stabilizer and sealers are two distinct products sometimes with overlapping functions. Joint sand stabilizers help secure sand in the joint after it has been installed. Their primary function reduces the risk of removal of joint sand from flowing water, wind, aggressive cleaning, tire action and intrusion of organic matter, seeds and insects.

Joint sand stabilizers come in liquid and dry applied forms. Some liquid stabilizers are made of the same materials as sealers, but with a higher solids content with additional wetting agents. When applied to the paver surface and joints, stabilizers can make the surface easier to clean and prevent staining in a manner similar to sealers. Depending on the chemical contents, liquid stabilizers may or may not change the appearance of the paver surface.

All surface sealers are applied as liquids. Their primary function is providing additional protection to concrete paver surfaces. Such chemicals can be similar to products used to seal cast-inplace concrete slabs. Sealers are applied to the entire surface of an installation to add further protection from stains, oils, dirt, or water. Occasionally, sealers are applied to pavers during manufacturing. Whether applied in a factory or on a site, most sealers change the appearance of the paver surface by darkening it and enhancing the surface color. Since liquid sealers penetrate the joint sand to some extent during application, they secondarily provide some stabilization.

Joint Sand Stabilizers

Liquid and dry applied stabilizers provide initial protection against joint sand loss. They accelerate joint sealing that can normally occur from a combination of atmospheric dust deposits, dirt and sediment that finds its way to the pavement, and contributions from passing tires. Stain removal, efflorescence removal, and overall surface cleaning should precede application of liquid stabilizers in new construction. None of these preparatory treatments are needed prior to the application of a dry applied stabilizer. It is applied first with the joint sand to complete the paver surface and begin interlock. Stain and efflorescence removal, cleaning and sealing can be done subsequently.

Given the wide range of joint sand stabilizers and proprietary formulations, it is best to consult with the manufacture to determine expected lifespan and/or reapplication rates.

Joint sand stabilization is generally optional and not required for many interlocking concrete pavements. Sand in joints will likely stabilize over time without additional treatment as a result of silts or other fines working their way into spaces between the sand particles.

Figure 3. This liquid joint sand stabilizer is applied with a low-pressure sprayer and squeegeed across the surface after allowing some time for soaking into the joints. This helps maintain slip and skid resistance of the paver surface.

Figure 4. Liquid joint sand stabilizers can deepen the surface color slightly and they provide some surface sealing as well. Tumbled pavers shown here have wider joints than other shapes. These type of pavers can require stabilization of the joint sand.

Figure 5. Joint sand can be pre-mixed and delivered to the site (typically in bags), or mixed with stabilizer at the site, then swept into the joints, compacted for consolidation in them to create interlock, and wetted to activate the stabilizer.

The rate of stabilization depends on the amount and sources of traffic, plus sources of fines that work their way into the joints from traffic over time.

There are some applications where early stabilization of the joints is important to maintaining functional performance of the paver surface. For example, stabilization is recommended on high slope applications over 7% and on applications where the slope is less than 1.5%. Applications on high slopes will help prevent washout of joint sand. Stabilizers in very low slope or flat areas can help reduce infiltration of standing water.

Stabilization benefits pavements subject to aggressive, regular cleaning. Examples might include amusement parks and restaurant exteriors. Pavements that see regular, heavy rainfall can benefit from stabilization of the joint sand. Surfaces that experience concentrated water flow such as gutters receiving sheet flow from large areas or at the drip lines under the eaves of buildings will better resist erosion of joint sand if stabilized.

Stabilizers have been effective in securing joint sand in places subject to high winds such as in desert climates. They can prevent joint sand displacement from high-speed tire traffic. Like sealers, joint and stabilization materials reduce the potential for weeds and insects in the joints.

Figure 6. Whether using liquid or dry joint stabilization materials, the surface of the pavers should be cleaned with a blower or broom after the joint sand is compacted into the joints.

Figure 7. Dry-applied joint sand with a stabilizer is wetted in order to activate it and stiffen the sand. Once the joints dry, they are stabilized.

In residential applications stabilization at downspouts and under eaves helps keep joint sand in place. Tumbled pavers (cobble stone-like units) and circular patterns have wider joints than other paver shapes. Tumbled pavers may require stabilized joint sand between them if they have slightly irregular sides and wide joints.

Studies on the permeability of the surface of interlocking concrete pavements have indicated ranges between 10% and 20% perviousness (2). The rate of permeability depends on several factors. They include the fineness of the joint sand (percent of material passing the No. 200 or 0.075 mm sieve), the joint widths, slope, and consolidation of the sand plus the age of the installation. Newly placed pavers have higher permeability (as much as 25%) than installations trafficked for several years. Sealers and joint sand stabilizers can contribute to long-term performance by reducing infiltration of water to the bedding sand and base.

Liquid Penetrating Stabilizers

These are water or solvent-based with the primary resin or bonding agent being an acrylic, epoxy, modified acrylic, or other polymers as solids (by volume) typically 18% to 28%. Solvent or water carries the solids into the joint sand. They will evaporate and leave the solids behind as the binding agent. Modifiers such as epoxy resins may also add to the ability of the product to create a solid matrix in the joint sand. When initially applied, liquid stabilization materials should be allowed to penetrate at least 3/4 inch (20 mm) into the joint sand. A mock-up is beneficial in determining application rates for specific products, joint sands, and for specific job site conditions.

Joint sand gradation can affect the depth of penetration of the liquid stabilizer. The amount of fines or material passing the No. 200 (0.075 mm sieve) can influence the depth of penetration. A joint sand gradation with less than 5% passing the No. 200 (0.075 mm) sieve can allow better penetration of liquid stabilizers. A job site mock-up should be tried to determine the penetration rate. The mock-up also will determine the appropriate application rate.

Prior to applying liquid materials, the surface should be clean and dry and any efflorescence removed from the pavers. Either a broom or leaf blower can efficiently remove excess sand. Some successful methods of application involve applying liquid joint stabilizers with low pressure, high volume spray, followed immediately by a squeegee to move the material into the joints. See Figure 3. Other methods use rollers, watering cans, or hand pumped, garden-type sprayers. Some equipment has multiple spray nozzles and mechanized rollers and/or squeegees. All application methods must provide uniform dispersion and effective penetration.

Liquid stabilizers bind the sand in the joint and secondarily provide sealing of the concrete paver surface. All liquid based stabilizers create some change in the appearance of the pavers. This ranges from a slight color enhancement, a modest sheen, to a high gloss. Like sealers, cured liquid stabilizers that remain on the surface of the pavers enhance their color, inhibit fading, and protect against staining. It also makes the paver surface easier to clean and maintain (Figure 4). However, joint sand stabilization will last significantly longer than the enhancement of the surface appearance.

Dry Joint Sand Stabilizers

These are dry additives mixed with joint sand. The additives are organic, inorganic, or polymer compounds that stiffen and stabilize the joints when activated by water applied to the joint sand. Additives come either pre-mixed with bagged joint sand, or are sold separately as an additive mixed with the joint sand on the job site per the supplier’s instructions. The additive is often mechanically mixed for consistency. Dry stabilizers are appropriate for residential settings, parking lots, bike lanes, plazas, and other areas with low velocity wheel loads or areas without concentrated water flow. They are convenient for application by homeowners. Some dry stabilizers have been successfully used in high traffic streets.

The pavers are initially compacted into the bedding sand. Joint sand is applied to the surface with a stabilizer additive mixed in it. See Figure 5. It is then compacted into the joints with a plate compactor like all interlocking concrete pavement installations. After compaction and removal of all sand from the paver surface, the joints are wetted. When dry, the material in the sand stabilizes the full depth of the joint and it helps maintain interlock among the pavers. For either pre-mixed or job site mixed additives, a job site mock-up is beneficial for determining the depth of stabilization. The mock-up will determine the rate and application method of water to ensure full activation of the stabilizer.

Figure 8. Before and after application of an acrylic sealer shows how it deepens the appearance of concrete pavers.

A mock-up will confirm a consistent method for uniform distribution of the additive in the sand for job site mixed additives in particular.

Prior to application, blowing or sweeping the surface clean is recommended. Use of a respirator and restricting access to the area must be addressed to comply with OSHA regulations. See Figure 6. Since water activates these products, no moisture should be present on the surface or in the joints until they are ready to be placed in the joints. Once the pavers and joint sand are compacted, the joints are full of sand, and all excess sand is removed from the surface, water is added to activate the bonding agent. The water is applied as a light, wide spray, and allowed to collect and soak into the joints (Figure 7). A narrow spray should not be used because it can dislodge sand from the joints. It is imperative to immediately remove any excess moist joint sand that inadvertently gets on the surface of the pavers. Otherwise, once it is moistened and allowed to cure on the surface, the sand will need to be removed with hot water. Some stabilizers may require removal with a wire brush or a pressure washer. Dry products will not leave a surface sheen like liquid stabilization products. This can be beneficial for a contractor or owner who needs to stabilize isolated areas through selected application of the product.

Installation, Functional and Structural Considerations

Liquid and dry applied joint stabilizers are not a substitute for recommended installation practices. Prior to their application, all liquid stabilization products require that the joint sand be compacted and consolidated in the joints until full. Some dry stabilizers require mixing with joint sand then spreading, filling, and compacting the sand and pavers until the joints are full. Other stabilizers are premixed in bags and are ready for filling the joints. Stabilizers resist many of environmental conditions that lead to functional deterioration of the paver surface. However, stabilizers do not add to the structural (load bearing) capacity of the pavement. Therefore, structural calculations for base thickness design should not consider a joint sand stabilizer.

Sealers:

Uses

Sealers reduce the intrusion of water, stains, oils and dirt into the paver surfaces. Like stabilizers, application of a sealer follows stain removal, efflorescence removal and overall surface cleaning. Sealers are used for visual and functional reasons.

Figure 9. Sealers resist stains which makes them ideal for high use areas where they might occur.

They offer visual Improvement by intensifying the paver colors. Some will add a glossy sheen or “wet” look to the pavement (see Figure 8). Other sealers offer some color enhancement and produce a low sheen, or a flat finish.

Sealers offer many functional advantages. They can protect pavers from stain penetration. They are useful around trash receptacles, fast food restaurants, driveways, other areas subject to stains, and where oil drippings are not wanted (see Figure 9).

Like stabilizers, sealers are also useful in stopping unwanted insects and weeds. Sealers can stabilize joint sand between pavers cleaned by vacuum equipment. They can help maintain the sand in the joints under high velocity water flows. Where solvents may be spilled onto pavers, elastomeric urethanes and certain water based sealers have been successfully used to prevent their penetration. Likewise, special urethane sealers have been used to seal and stabilize joint sand subject to propeller wash, jet engine fuels and exhaust in commercial and military airports (2).

Types of Sealers for Concrete Pavers

Table 1 lists the various types of sealer for concrete pavers. The table suggests applications and compares important properties (3). The sealer manufacturer or supplier should be consulted prior to using any sealer to verify that their product will perform in the environment planned for its use. Sealers not recommended for use with pavers are alkyds, esters, and polyvinyl acetates. Epoxies and silicones are generally not used on concrete pavers.

Solvent and Water Based Sealers

Like stabilizers, sealers can be either solvent or water based. Solvent based sealers consist of solids dissolved in a liquid. Solvent based products carry the dissolved solids as deep as the solvent will penetrate into the concrete paver. After the solvent evaporates, the sealer remains.

Water based sealers are emulsions, or very small particles of the sealer dispersed in water. Water based sealers penetrate concrete as far as the size of the particles will permit. After the water evaporates, typically at a slower rate than solvents, the remaining particles bond with the concrete and to each other. These particles cannot penetrate as deeply as those carried by solvents. Water based sealer curing time will vary with the temperature, wind conditions and humidity.

Silanes/Siloxanes

Silanes and siloxanes penetrate concrete well. Silanes are the simpler form that, when exposed to moisture, begin to link up to other silanes. Siloxanes do the same linking together. Both chemicals become a polymer, curing as a film in the capillaries of the concrete. A hydrophobic barrier to moisture is created, preventing moisture from entering but allowing the concrete to “breathe” or release water vapor.

Because silanes and siloxanes reduce moisture from entering the concrete, they can deter efflorescence from appearing on the surface of concrete pavers. They initially enhance colors and produce a flat, no-gloss finish on the paver surface. This makes silanes and siloxanes very suitable on exterior areas for resisting efflorescence when a glossy surface is not desired.

Silanes and siloxanes do not resist penetration of petroleum stains unless they have additives specifically for that purpose. When required, proprietary mixtures with additives can increase petroleum stain resistance. Other additives can ensure greater consistency in the color of pavers and avoid a blotchy appearance.

Silanes have smaller molecules, so they penetrate farther into the concrete than larger siloxane molecules. However, they are more volatile (tend to evaporate) until they bond to the concrete paver. Silane sealers generally require a higher percent of solids to counteract their rate of evaporation. Therefore, silanes tend to be more expensive than siloxanes.

Silanes and siloxanes are typically used as water repellents for concrete bridge decks, parking garages, and masonry walls. Their primary use for reinforced concrete structures is to prevent the ingress of chloride ions from deicing salts (4). This intrusion causes reinforcing steel corrosion in the concrete, and a weakened structure. Their ability to decrease intrusion of chloride materials provides additional protection of pavers subject to deicing salts or salt air, such as walks, streets, parking lots, plaza roof and parking decks. They are also useful around pool decks to minimize degradation from chlorine.

Most silane and siloxane sealers are solvent based. Certain manufacturers offer water based products as well. These products may have a very short shelf life after the silane or siloxane has been diluted with water. The user should check with the manufacturer on the useful life of the product.

Acrylics

Acrylic sealers can be solvent or water based. They enhance paver colors well and create a gloss on the surface. Acrylic sealers provide good stain resistance. Their durability depends on traffic, the quality of the acrylic and the percentage of solids content. They provide longer protection from surface wear than silanes or siloxanes.

Acrylic sealants are widely used in residential and commercial paver applications. They generally last for a few years in these applications before re-coating is required. Acrylics specifically developed for concrete pavers do not yellow over time. When they become soiled or worn, pavers with acrylics can be easily cleaned and resealed without the use of extremely hazardous materials.

Acrylics should not be used on high abrasion areas such as industrial pavements or floors. Water based acrylics perform well for interior applications. They may be allowed by municipalities that regulate the release of volatile organic contents (VOCs) in the atmosphere.

Urethanes

As either solvent or water based, polyurethanes produce a high gloss and enhance the color of pavers. Aromatic urethanes should contain an ultra-violet (UV) inhibitor to reduce yellowing over time. The product label should state that the sealer is UV stable. Urethanes themselves are more resistant to chemicals than acrylics.

While aliphatic urethanes can be used for coating the surface of pavers, elastomeric (aromatic or aliphatic) urethanes should be used where the primary need is to stabilize joint sand. For airfield and gas station applications, the urethane should have a minimum elongation of 100% per ASTM D 2370, Standard Test Method for Tensile Properties of Organic Coatings. Urethanes resist degradation from petroleum based products and de-icing chemicals. This makes them suitable for heavy industrial areas, as well as airfield and gas station pavements.

Table 1—Properties of Sealers for Concrete Pavers—Confirm application and properties with supplier

	Patios, walks, pool decks	Residential/ Comlercial drives	Gas Stations Airports	Areas subject to chlorine & heavy de-icing salts	Finish	Enhances color	Joint sand stabilizer	UV resistant	Can be re-coated	Ease of removal	Price
Silane	Yes	Yes		Yes	Flat	*		Yes	Yes	Mod.	++
Siloxane	Yes	Yes		Yes	Flat	*		Yes	Yes	Diff.	++
Acrylic	Yes	Yes			Gloss	Yes	Yes	Varies	Yes	Diff.	+
Urethane	Yes	Yes	Yes	Yes	Gloss	Yes	Yes	Varies	No	V. Diff.	++
Water-based Epoxy	Yes	Yes	Yes	Yes	Semi-Gloss	Yes	Yes	Yes	Yes	Mod.	++

*Initially, then diminishes. Diff.=Difficult V. Diff.=Very Difficult +=Moderate Price ++=Higher price

Urethanes cannot be rejuvenated simply by re-coating. If urethane sealers must be removed, methylene chloride or sand blasting is often necessary. Methylene chloride is a hazardous chemical, and is not acceptable for flushing into storm drains. It should not be allowed to soak into the soil. Therefore, urethane removal is best handled by professionals.

Water Based Epoxy Sealers

Water based epoxy sealers combine other types of sealers with epoxy. They cure by chemical reaction as well as by evaporation. They have very fine solids allowing them to penetrate deep into concrete while still leaving a slight sheen to enhance the color of the pavers. They generally do not change the skid resistance of the surface. When applied, water based epoxy sealers create an open surface matrix that allows the paver surface to breathe thereby reducing the risk of trapping efflorescence under the sealer should it rise to the surface. They resist most chemicals and degradation from UV radiation. These characteristics make these types of sealers suitable for high use areas such as theme parks and shopping malls. The elasticity and adhesion of these sealers make them appropriate for heavily trafficked street projects and areas subject to aggressive cleaning practices.

Sealing Procedures All dirt, oil stains and efflorescence must be removed prior to sealing. The cleaned surface must be completely dry prior to applying most sealers. Allow at least 24 hours without moisture or surface dampness before application. The pavers may draw efflorescence to the surface, or the sealer or liquid stabilizer may whiten under any one of these conditions:

• The surface and joints are not dry

• The pavers have not had an adequate period of exposure to moisture

• There is a source of efflorescence under the pavers (i.e, in the sand, base, or soil) moving through the joint sand and/or pavers

• The sealer is not breathable, i.e., does not allow moisture to move through to the surface of the paver and evaporate. If the base under the pavers drains poorly, the sealer is applied.

to saturated sand in the joints, or is applied too thick, the sealer can become cloudy and diminish the appearance of the pavers. In this situation, the sealer must be removed or re-dissolved. Consult your sealer supplier for advice on treating this situation.

Cover and protect all surfaces and vegetation around the area to be sealed. For exterior (low-pressure) sprayed applications, the wind should be calm so that it does not cause an uneven application, or blow the sealer onto other surfaces. For many sealers, especially those with high VOC's, wear protective clothing and mask recommended by the sealer manufacturer to protect the lungs and eyes.

Sealers can be applied with a hand roller if the area is small (under 1000 ft2 or 100 m2). For larger areas, more efficient application methods include a powered roller, or a low pressure sprayer. Sealers are often applied with a foam roller to dry pavers having clean surfaces and chamfers. However, the use of a squeegee to spread the sealer will avoid pulling joint sand out of the joints. See Figure 10.

Sealer should be spread and allowed to stand in the chamfers, soaking into the joints. Penetration into the joint sand should be at least 3/4 inch (20 mm). The excess sealer on the surface is pushed to an unsealed area with a rubber squeegee. The action of a squeegee wipes most of the sealer from the surface of the pavers while leaving some remaining in the chamfers to eventually soak into the joints. Generally only one coat is required. For other applications, follow the sealer manufacturer's recommendation for application and for the protective gear to be worn during the job. With some sealers that recommend two coats, the first coat is usually applied to saturation. A light second coat, if needed, can be applied for a glossy finish. Be careful not to over apply the sealers such that the surface becomes slippery when cured. For water based sealers requiring two coats, always apply the second coat while the first coat is still very tacky. Prevent all traffic from entering the area until the sealer is completely dry, typically 24 hours

Figure 10. Urethane is applied with squeegees to stabilize joint sand between pavers on aircraft pavement.

If spraying sealer on the pavers, care should be taken to prevent the spray nozzle from clogging and causing large droplets to be unevenly distributed on them. This is most important for water based sealers. This can cause a poor appearance and performance.

Sealers normally require reapplication after a period of wear and weather. The period of reapplication will depend on the use, climate, and quality of the sealer.

Safety Considerations

Adequate slip (foot) and skid (tire) resistance of concrete pavers should be maintained with properly applied joint sand stabilizer or surface sealers. See ICPI Tech Spec 13 – Slip and Skid Resistance of Interlocking Concrete Pavements for test methods and guidelines. See www.icpi.org to obtain this and all ICPI Tech Spec technical bulletins. The manufacturers of stabilization and sealers should be consulted concerning slip and skid resistance performance characteristics under wet and dry conditions.

Some commercial or industrial pavement use painted pavement markings. Consult with the stabilizer and sealer manufacturers for compatibility of their materials with pavement markings. Where there are pavement markings, applications using high gloss materials should be avoided as they can increase the difficulty of reading pavement markings under certain light conditions.

Federal, state/provincial, and some municipal governments regulate building materials with high volatile organic contents (VOCs). The restrictions usually apply to solvent based sealers. The VOC level of a sealer refers to the pounds per gallon (or grams per liter) of solvent which evaporates from the sealer, excluding the water. VOCs have been regulated since they can contribute to smog. Most water based sealers comply with VOC restrictions and some solvent based products may comply as well. The user should check with the sealer supplier to verify VOC compliance in those areas that have restrictions.

Many solvents based products are combustible and emit hazardous fumes. Therefore, flame and sparks should be prevented in the area to be sealed. Never use solvent based sealers in poorly ventilated or confined areas.

Persons applying joint sand stabilizers and sealers should wear breathing and eye protection as recommended by the manufacturer, as well as protective equipment mandated by local, state/provincial, or federal safety agencies. Follow all label precautions and warnings concerning handling, storage, application, disposal of unused materials, and those required by all government agencies.

The U.S. Federal Government and Canadian Government require that all shipments of hazardous materials by common carrier must be accompanied by a Material Safety Data Sheet (MSDS). All chemical manufacturers must supply sheets to shippers, distributors and dealers of cleaners, joint sand stabilizers, and sealers if the materials are hazardous. The MSDS must accompany all shipments and be available to the purchaser on request. The MSDS lists the active ingredients, compatibility and incompatibility with other materials, safety precautions and an emergency telephone number if there is a problem in shipping, handling or use. The user should refer to the MSDS for this information.

Annexure II

B. Reinstatement of Interlocking Concrete Pavements

Concrete pavers can act as a zipper in the pavement. When the need arises to make underground repairs, interlocking concrete pavements can be removed and replaced using the same material. Unlike asphalt or poured-in-place concrete, segmental pavement can be opened and closed without using jack hammers on the surface and with less construction equipment. This results in no ugly patches and no reduction in pavement service life. In addition, no curing means fast repairs with reduced user delays and related costs.

The process of reusing the same paving units is called reinstatement. This Tech Spec covers how to reinstate or "unzip and zip" interlocking concrete pavement. The following step-by-step procedure applies to any interlocking concrete pavement, including pedestrian areas, parking lots, driveways, streets, industrial, port and airport pavements.

The methods described here will work for permeable interlocking concrete pavements with a few exceptions. The excavation through the open graded base and subbase aggregates will require shallower side slopes. This will require a larger area of pavers to be removed before excavation. It may be possible to stockpile excavated aggregates near the opening for reuse. If the different aggregate layers are mixed during removal, they should not be reused, and it should be replaced with new aggregates. Additionally, aggregates placed back into the excavation and compacted should be new materials meeting the specifications of the original project.

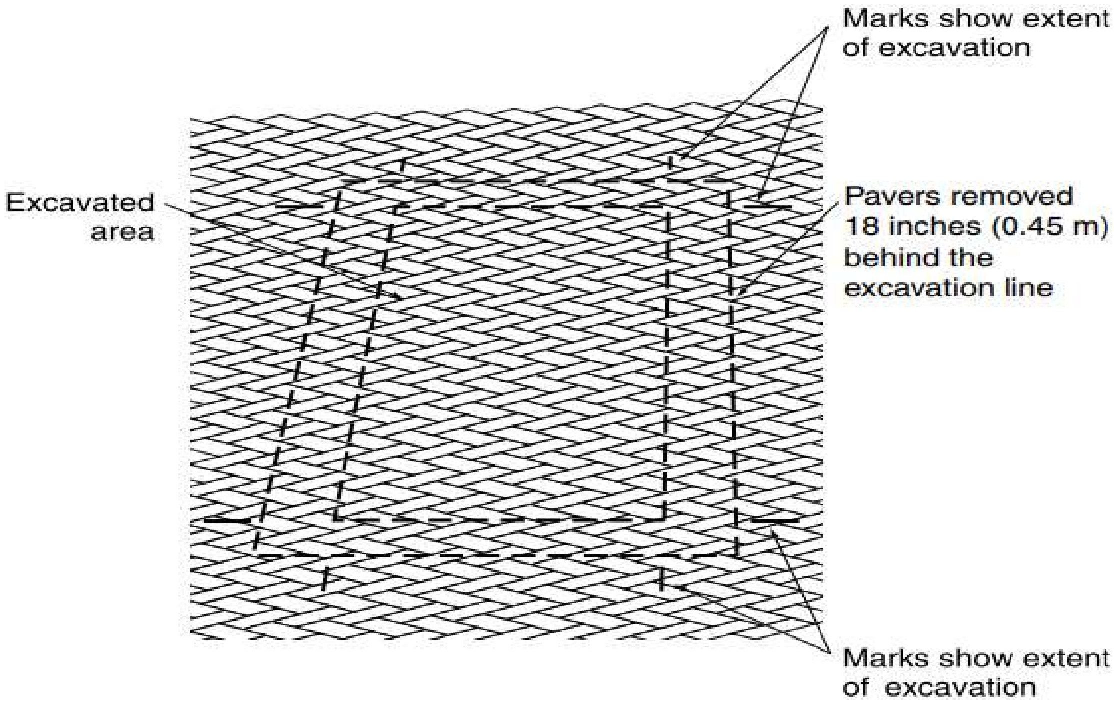


Figure 1. Pavement markings show the extent of paver removal and trench area.

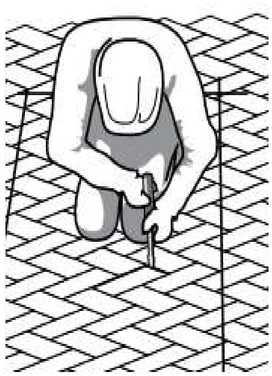


Figure 2. Removing joint sand surrounding the first paver to be removed.

Figure 3. Prying the paver upwards with two large screwdrivers.

Figure 4. Prying with a screwdriver and pulling the paver out.

Step 1—Locate Underground Utilities in the Area to be Excavated

The location and depth of existing utilities should be established prior to excavating. Many localities have one telephone number to call for obtaining marked utility locations. Set cones, traffic signs, or barricades around the area to be excavated according to local and state or provincial standards.

Determine and mark the area of pavers to be removed. Remove pavers 18 inches (0.45 m) wider on each side of the trench opening. This shoulder around the opening should consist of undisturbed bedding sand. It will be used as a guide for reinstating the sand and pavers later (Figure 1).

Paint or crayon should be used to mark the area of pavers for removal. The trench area can be marked on the pavers as well. Paint may be necessary to establish a more permanent marking than crayon, especially if there is vehicular traffic, or if there will be an extended period of time between marking and excavation. The same paving units will be reused, so in some instances paint on them may not be desirable, especially if there is little traffic to wear it away over time.

Figure 5. Using a paver extractor to remove a paver

Step 2—Remove the First Paver

Locate the first paver to be removed. This is typically at one end of the marked area. Scrape the sand from the joints around the first paver using a putty knife or small trowel (Figure 2). If stabilize joint sand has been used, it will take more effort to remove the paver. Carefully pry each side upward with one or two large screwdrivers. Begin prying on the short ends of the paver. The paver will rise a small distance with each prying (Figure 3). When the paver is high enough to grasp, wiggle it loose, pulling upward. If necessary, pry with a screwdriver using one hand while pulling upward with the other (Figure 4). Sometimes, one end of the paver can be pulled above the others so a pry bar can be inserted under it. The paver can then be pried out.

Paver extractors can also be used to remove the first paver and subsequent ones (Figure 5). They are designed to clamp the paver tightly. These work most efficiently in removing the first paver if some of the joint sand is removed before clamping and pulling. Water can be applied to lubricate the joint sand to facilitate extraction.

If the pavement has been subject to vehicular traffic for a length of time, the first paver may be need to be broken in order to be removed. A small sledge hammer (3 lb. maul) applied to an appropriate chisel will break a paver into small pieces. Protective eye goggles should be worn during this procedure. Remove all broken pieces from the space until the bedding sand is completely exposed. Pneumatic hammers or cutting saws are generally not required to remove the first unit.

Step 3—Remove the Remaining Pavers

After the first one is removed, surrounding pavers can be loosened and pried out (Figure 6). Grab the pavers by the short end, as it offers less resistance than the long side (Figure 7). Remove pavers to the marks on the pavement for the opening.

Sand sticking to the sides and bottoms of pavers can interfere with their reinstatement and compaction into the bedding sand. Scrape off sand from each unit as it is being removed. A small trowel, wide putty knife, wire brush, or another paver works well. Again, if stabilize joint sand has been used, it will take more effort to remove the sand sticking to the paver.

The direction of removal should consider where pavers are going to be stacked. Stack the pavers neatly near the opening, out of the way of excavation equipment such as backhoes or dump trucks. If the pavers need to be removed from the site, stack them on wooden pallets and secure them tightly so there is no loss during transit.

Equipment used to move pallets with pavers should be capable of lifting in excess of 3,000 lbs. (1,365 kg). If the pavers need to be moved only a short distance, then stack them directly on a paver cart at the opening and set them nearby. They will then be ready for pick up by the paver cart when reinstated.

For every project, a small stockpile of spare pavers should be stored and used for repairs during the life of the pavement. Weathering, wear and stains may change the appearance of removed pavers compared to spares kept in storage for repairs. When pavers are removed for base or utility repairs, all undamaged units should be retained for future reinstatement.

Figure 6. Prying out the remaining pavers

Figure 7. Pulling out a paver by the short end provides greater leverage and makes extraction easier.

Pavers from the stockpile that replace damaged or broken units should be scattered among the pattern of the existing reinstated pavers. This will reduce the visual impact of color variations.

Step 4—Remove the Bedding Sand

The removed pavers will reveal compacted bedding sand. It may be removed and reused, or removed during excavation of the base. For some projects with time constraints, the sand will probably be removed during excavation and not reused.

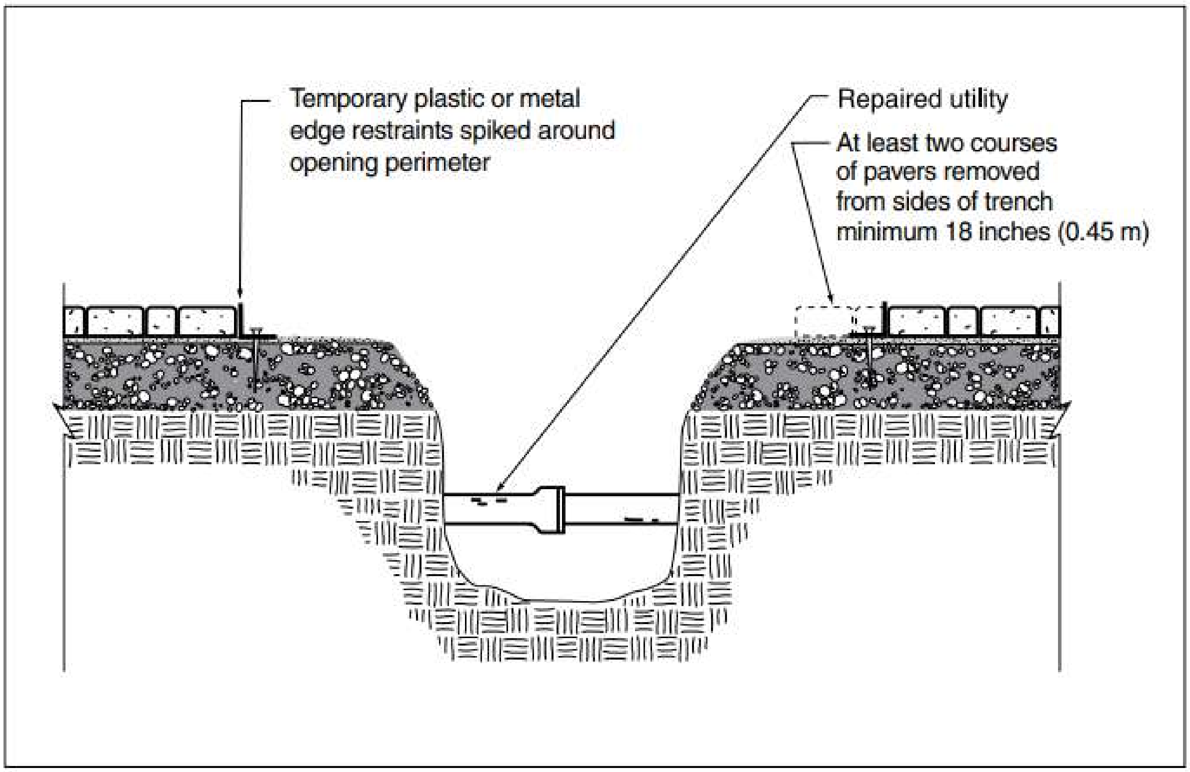


Figure 8. T-shaped cross section of the excavated opening

If the sand is reused, it may need to be loosened with rakes before removal by shoveling. The sand should be neatly stockpiled and kept free from soil, aggregate base, or foreign material. If the sand is mixed with these materials, it should not be reused, and it should be replaced with clean sand.

Whether or not it is reused, always leave an undisturbed area of sand 6 to 12 in. (15 to 30 cm) wide next to the undisturbed pavers. This area will provide a stable support for temporary edge restraints and for screeding the bedding sand after the base is reinstated.

Step 5—Excavate the Base Material and Soil

If aggregate base material is removed, it may be possible to stockpile it near the opening for reuse. Keep the aggregate base material separate from excavated subgrade soil. Any soil removed should be replaced with base material unless local regulations require reinstatement of the native soil. The final shape of the excavated opening should be T-shaped in cross section. (Figure 8). This helps prevent undermining and weakening of the adjacent pavement. Follow local codes on the use of shoring, as it may need to be inserted to prevent collapse of the trench sides.

Figure 9 illustrates temporary bracing with plastic or metal edge restraints around the perimeter of the opening. This is recommended practice. The restraints are pinned to the base using metal spikes. Bracing helps keep the undisturbed pavers in place during excavation and fill activities, and will enable reinstatement of units into the existing laying pattern without cutting them to fit.

Step 6—Replace the Base Material

After the repairs are complete, soil at the bottom of the trench should be compacted prior to placing and compacting the base material. Repairs typically use the same base material that was removed. A crushed stone aggregate base should be placed and compacted in 2 to 4 in. (50 to 100 mm) lifts (Figures 10 and 11). If the excavated base material was stabilized with asphalt or cement, it should be replaced with similar materials.

Monitoring density of the compacted soil subgrade and base is essential to reinstating any pavement, including interlocking concrete pavements. It will help prevent rutting and premature failure.

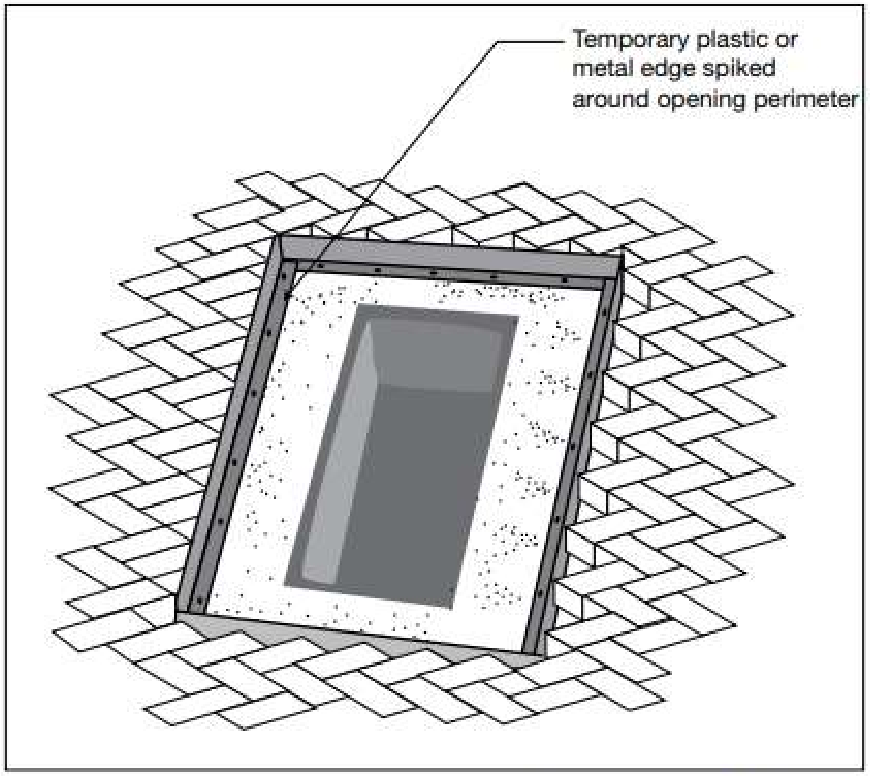


Figure 9. Temporary bracing at the pavement opening will help keep units in place during excavation, repairs and reinstatement.

A dynamic cone penetrometer is an effective means for monitoring the density of each lift while working in the opening. If the soil or base material is too dry during compaction, a small amount of water can be sprayed over each lift prior to compacting. This will help achieve maximum density. A nuclear density gauge is recommended for checking the density of the completed compaction of the soil and base layers. A qualified civil engineer should monitor compaction for conformance to local standards.

If there are no local standards for compaction, a minimum of 98% standard Proctor density is recommended for the soil subgrade, and a minimum of 98% modified Proctor density for the base. Compaction equipment companies can provide guidelines on equipment selection and use on the soil and the base. For further guidance on compaction see ICPI Tech Spec 2—Construction of Interlocking Concrete Pavements.

The final elevation of the compacted base at the opening perimeter should match the bottom of the existing undisturbed sand layer that surrounds the opening. The elevation of the middle of the base fill placed in the opening should be slightly higher than its perimeter to compensate for minor settlement.

Controlled low-strength materials (CLSM) (sometimes called slurry mix, flowable fill, or unshrinkable fill) can be used in some applications as a replacement for unsterilized base materials (1). The fill can be made from aggregate bound with fly ash, pozzolans, or cement. Because it is poured from a truck, the fill will form around pipes and underground structures where soil or base backfill and compaction are difficult. Low-strength fill can be poured into undercuts and under pipes where it is impossible to fill and compact aggregate base. The material is also self-leveling.

Low-strength flowable fill requires a short curing time and can be used in freezing weather. It requires no compaction and with some mix designs, can be opened to traffic in 24 hours. Low-strength fill is stiffer than aggregate base and offers higher resistance to settling and rutting. This reduces deterioration of the pavement surface over time. In order to facilitate re-excavation, flowable fill should be made with a small amount of cement. Check with suppliers on the strength of in-place fill that is at least two years old, and on ease of excavation of these sites. The strength of the fill should not exceed 300 psi (2 MPa) after two years of service. Low-strength fill has been used successfully in Toronto and London, Ontario; Colorado Springs, Colorado; Cincinnati, Ohio, Kansas City, Missouri; Peoria, Illinois; and many other municipalities. It is generally more cost-effective than using aggregate base by reducing job time and future pavement repairs. Local ready-mix suppliers can be contacted for available mixes, strengths, installation methods and prices. See ICPI Tech Spec 7—Repair of Utility Cuts with Interlocking Concrete Pavements for further information on low-strength fill.

Figure 10. Compaction of the base in 2 to 4 in. (50 to 100 mm) lifts and monitoring density with a dynamic cone penetrometer or a nuclear density gauge are essential to minimizing settlement.

Step 7—Replace the Bedding Sand Layer

During the foregoing procedures, it is likely that the pavers and bedding sand around the opening were disturbed especially if no temporary edge restraints were placed to secure the pavers. If so, then remove an additional two rows of pavers, or back to an undisturbed course. Clean sand from these pavers and set them aside with the others. Be sure there is at least 6 to 8 in. (150 to 200 mm) of undisturbed bedding sand exposed after removal of the course(s) of pavers. This area of undisturbed sand can be used to guide screeding of fresh bedding sand over the compacted and leveled base. Prior to screeding, carefully remove any temporary edge restraints so that adjacent pavers remain undisturbed.

Place a straight edge or string line across the paver surface on either side of the opening. Measure down at several points along the string line to confirm the base follows the grade of the surrounding paver surface, with a slight crown near the center to account for future consolidation of the newly compacted base. It may be necessary to remove a few courses of pavers to straighten the edge of the pavers (Figure 12). Low areas should be filled with base material and compacted. Do not use the bedding sand to compensate for low places in the surface of the base.

Use the string line to determine the undisturbed bedding sand thickness by measuring from the string line to the base surface then subtract the paver thickness. This should be approximately 5/8 in. [16 mm]. Set screed rails below the string line the thickness of the pavers minus 50% of the undisturbed bedding sand thickness. The additional thickness of the bedding sand will account for compaction and sand moving into the joints. Screed sand to ensure uniform thickness is placed over entire base surface.

It may be necessary to confirm this is the correct bedding thickness by placing pavers and compacting. The paver surface should be 1/16 to 1/8 in. [2 to 3 mm] above the adjacent paver surface to account for further consolidation.

Step 8—Reinstate the Pavers

Pull and secure string lines across the opening along the pavement joints every 6 to 10 ft. (2 to 3 m). By following the string lines, joints of reinstated pavers will remain aligned with undisturbed ones. Lay the remaining pavers from the smaller end of the opening, generally working “uphill,” i.e., from a lower elevation of the pavement to the higher one. Minor adjustments to the alignment and spacing of joints can be made with pry bars or large screw drivers. Make adjustments prior to compacting the pavers (Figure 13).

Place the pavers in the original laying pattern and compact them with at least two passes of a minimum 5,000 lbf. (22 kN) plate compactor. The path of the plate compactor should overlap onto the undisturbed pavers. Spread joint sand and compact again until the joints can no longer accept sand (Figure 14). Sweep away excess sand. The elevation of the reinstated pavers after compaction should be no higher than 1/8 in. (2 mm) at the edges and 3/16 in. (5 mm) at the center. Traffic and minor settlement will compact the pavers to a level surface. After a short period of time, the repaired area will be undetectable (Figure 15).

Applications such as airports or gas stations require joint sand stabilizers. If an area is reinstated in such uses, then a stabilizer will need to be re-applied to the joints. See ICPI Tech Spec 5—

Cleaning and Sealing Interlocking Concrete Pavements for advice on sealers and joint sand stabilizers.

Production rates are highly variable and are dependent on several factors which include original installation methods, crew experience, weather, traffic, site access, a steady flow of materials around the repair site, and the number of pavers to be cut. An experienced crew will reinstate pavers with little or no cutting, aligning reinstated pavers with existing joint lines, pattern, and spacing between the units.

Figure 11. Trench filled with compacted aggregate base. Temporary edge restraints should be used around the opening perimeter.

Figure 12. Screeded bedding sand. Note that a few courses of pavers are removed to create even sides for screeding. Installing temporary edge restraints prior to excavating is preferred practice.

Although existing pavers can be used in reinstatement, there may be projects where it is more cost-effective to remove and replace the area with new pavers. Stabilized joint sand may be difficult to remove and it will probably be more cost effective to discard the old pavers. An experienced paver installation contractor can provide guidance on cost-effective approaches for each reinstatement project.

Figure 13. Adjusting joint spacing and alignment.

Figure 14. Second and final compaction of the pavers. The first compaction occurs after the pavers are placed (no sand in the joints). The second compaction works the sand on pavers into the joints. This process causes the pavers to interlock.

Municipalities, utility companies and other users should use experienced ICPI Certified Installer to reinstate interlocking concrete pavers. Others may use in-house labor which should be trained in the procedures described above. Contact a local Interlocking Concrete Pavement Institute paver installation contractor member to assist with training. Successful reinstatement using experienced contractors will result in successful reinstatement jobs that leave no ugly patches nor do they weaken the pavement. See Figures 15 and 16.

Figure 15 and 16. Reinstated pavers leave no ugly patches nor do they weaken the pavement.

Annexure II

C. Repair of Utility Cuts Within Interlocking Concrete Pavements

The Costs of Utility Cuts

The annual cost of utility cuts to cities is in millions BDT. These costs can be placed into three categories. First, there are the initial pavement cut and repair costs. These include labor, materials, equipment, and overhead for cutting, removing, replacing, and inspecting the pavement, plus repairs to the utility itself. Costs vary depending on the size and location of the cut, the materials used, waste disposal, hauling distances, and local labor rates.

Second, there are user costs incurred as a result of the repair. They include traffic delays, detours and denied access to streets by users, city service and emergency vehicles.

User costs depend on the location of the cut. A repair blocking traffic in a busy center city will impose higher costs and inconvenience from delays than a cut made in a suburban residential street. There are downstream costs to users from utility repairs such as lost productivity due to delays, and damage to vehicles from poor pavement riding quality. While these losses are difficult to quantify, they are very present.

The third cost is subtle and long term. It is the cost of pavement damage after the repair is made. Cuts damage the pavement.

Damage can range from negligible to substantial, depending on the quality of the reinstated area and the condition of the surrounding pavement. The damage reduces pavement life and shortens the time to the next rehabilitation. The need to rehabilitate damaged pavements earlier rather than when normally required has costs associated with it.

Several studies have demonstrated a relationship between utility cuts and pavement damage. For example, streets in San Francisco, California, typically last 26 years prior to resurfacing. A study by the City of San Francisco Department of Public Works demonstrated that asphalt streets with three to nine utility cuts were expected to require resurfacing every 18 years (1). This represented a 30% reduction in service life compared to streets with less than three cuts. Streets with more than nine cuts were expected to be resurfaced every 13 years. This represents a 50% reduction in service compared to streets with less than three cuts. The report concludes that while San Francisco has some of the highest standards for trench restoration, utility cuts produce damage that extends beyond the immediate trench. "...even the highest restoration standards do not remedy all the damage. Utility cuts cause the soil around the cut to be disturbed, cause the backfilled soil to be compacted to a different degree than the soil around the cut, and produce discontinuities in the soil and wearing surface. Therefore, the reduction in pavement service life due to utility cuts is an inherent consequence of the trenching process."

Figure 1. Repairs to utilities are a common sight in cities, incurring costs to cities and taxpayers.

A 1985 study in Burlington, Vermont, demonstrated that pavements with patches from utility cuts required resurfacing more often than streets without patches. Pavement life was shortened by factors ranging between 1.70 and 2.53, or 41% to 60% (2). Research in Santa Monica, California, showed that streets with utility cuts saw an average decrease in life by a factor of 2.75, or 64% (3). A 1994 study by the City of Kansas City, Missouri, notes that "street cuts, no matter how well they are restored, weaken the pavement and shorten the life of the street." It further stated that permit fee revenue does not compensate the city for the lost value resulting from street cuts (4). A 1995 study by the city of Cincinnati, Ohio, showed that damage to the pavement extends up to three feet (1 m) from the edge of properly restored cuts (5).

The cost of pavement damage includes street resurfacing and rehabilitation to remedy damage from cuts. Permit fees charged by cities to those making cuts often do not fully account for pavement damage after the cut pavement is replaced. Some cities, however, are mitigating the long-term costs of pavement cuts by increasing fees or by charging a damage fee. They seek compensation for future resurfacing costs to remedy pavement damage. The rationale for fees to compensate for early resurfacing can be based on the following formula in Table 1.

$$\text{Annual cost of pavement damage from utility cuts to one category of streets (local, collector thoroughfare, etc.)} = \text{Annual cost of resurfacing streets damaged by utility cuts} - \left[\text{Annual cost of resurfacing streets damaged by utility cuts} \times \left(\frac{\text{Number of years of life remaining before resurfacing streets with utility cuts}}{\text{Expected years of life before resurfacing if there are no utility cuts}} \right) \right]$$

Where the:

$$\text{Annual cost of resurfacing streets damaged by utility cuts} = \left(\text{percent of all resurfaced streets that are damaged by cuts} \right) \times \left[\text{Total annual cost of resurfacing all streets} \times \left(\frac{\text{Total miles (km) of streets resurfaced that year of one category (local, collector thoughfare, etc.)}}{\text{total miles (km) of all streets resurfaced in that year}} \right) \right]$$

A damage fee would be derived by dividing the annual cost of resurfacing a particular category of street damaged by utility cuts by the number of years of life expected from those streets. The fee would be higher if a street to be cut had been recently resurfaced, and lower for a street that is about ready for resurfacing.

Table 1—Annual cost of pavement damage from utility cuts (4).

Pavement damage fees may be necessary for conventional, monolithic pavements (asphalt and cast-in-place concrete) because they rely on the continuity of these materials for structural performance and durability. Cuts reduce performance because the continuity of the pavement surface, base, and subgrade has been broken. Traffic, weather, deicers, and discontinuities in the surface, in the compacted base, and in the soil shorten the life of the repaired cut. When pavement life is shortened, rehabilitative overlays are needed sooner than normal, thereby incurring maintenance costs sooner than normal.

Figure 2. After compaction of the base, bedding material is screeded.

Figure 3. Once smoothed and joined with undisturbed materials at the opening perimeter, the bedding receives concrete pavers.

Figure 4. Reinstatment using the same pavers continues following the existing herringbone paving pattern.

Figure 5. The final paver is inserted, the reinstated area compacted, joints filled, and compacted again. There are not cuts or damage to the pavement surface.

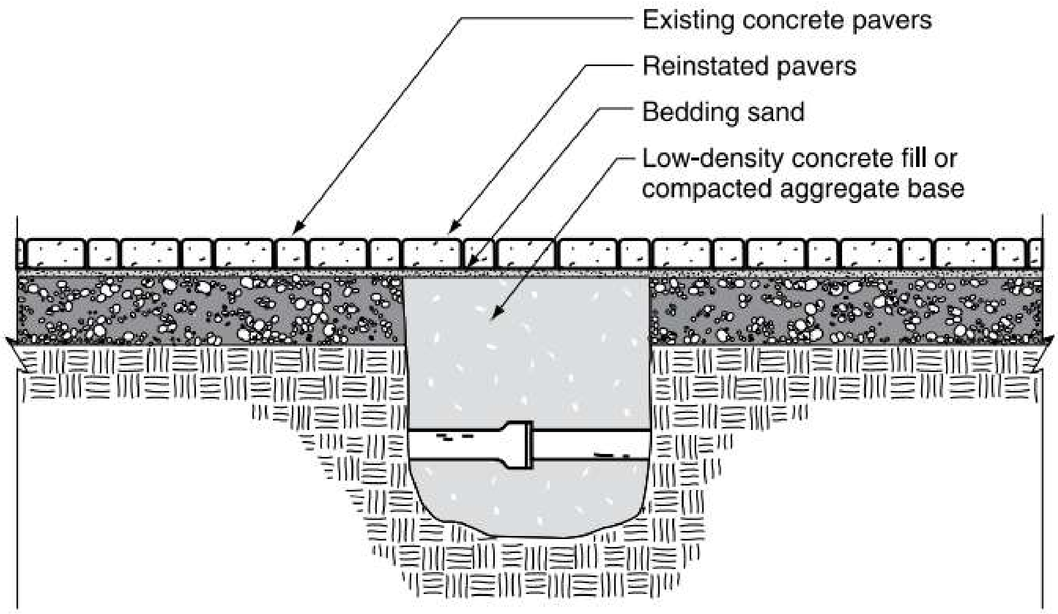


Figure 6. Cross section of reinstated utility cut into interlocking concrete pavement.

Reducing Costs with Interlocking Concrete Pavements

Interlocking concrete pavements can reduce pavement cut and repair costs, and user costs. They can also reduce costs from long term pavement damage, and the fees to rehabilitate them.

Reducing Pavement Cut and Repair Costs

Costs to open interlocking concrete pavements can be competitive with monolithic pavements such as asphalt or poured concrete. Cost savings occur because saw-cutting equipment and pneumatic jack hammers are not required for removal. Since the same paver units are reinstated, additional savings can result from reducing waste and hauling. Minimizing waste material is important in urban street repairs because of compact working conditions and increasing landfill costs.

Reducing User Costs—User costs due to traffic interruptions and delays are reduced because concrete pavers require no curing. They can handle traffic immediately after reinstatement, reducing user delays. Furthermore, reinstated concrete pavers preserve the aesthetics of the street or sidewalk surface. There are no patches to detract from the character of the neighborhood, business district, or center city area. With many projects, concrete pavers help define the character of these areas. Character influences property values and taxes. Attractive paver streets and walks without ugly patches can positively affect this character.

Reducing Costs of Pavement Damage

Since interlocking concrete pavements are not monolithic, they do not suffer damage from cuts. The modular pavers and joints are superior to the cracks from cuts that typically result in accelerated wear to monolithic pavements. The role of joints in interlocking concrete pavement is the opposite from those in monolithic pavements. Any break in monolithic pavement, e.g., joints, cuts or cracks, normally shortens pavement life because the continuity of the material is broken as shown in Figure 7. In contrast, the joints of the modular units in interlocking concrete pavements maintain structural continuity.

Figures 2, 3, 4, 5 and 6 show the process of repair and illustrate the continuity of the paver surface after it is completed.

Figure 7. Pavement damage from settlement and shrinkage of cold patch asphalt.

Figure 8. Low density concrete fill (unshrinkable fill) poured into a utility trench from a

The reinstated units are knitted into existing ones through the interlocking paving pattern and sand filled joints. Besides providing a pavement surface without cuts, the joints distribute loads by shear transfer. The joints allow minor settlement in the pavers caused by discontinuities in the base or soil without cracking.

When pavers are reinstated on a properly compacted base, there is no damage to adjacent, undisturbed units. Unlike asphalt, concrete pavers do not deform, because they are made of high strength concrete. The need for street resurfacing caused by repeated utility cuts is eliminated because concrete pavers are not damaged in the reinstatement process. In addition, the use of low-density concrete fill can help reestablish the broken continuity of the base and subgrade. This reduces the likelihood of settlement and helps eliminate damage to the pavement.

Therefore, long term costs of pavement damage from utility cuts to interlocking concrete pavement can be substantially lower when compared to monolithic pavements. This makes interlocking concrete pavement cost effective for streets that will experience a number of utility repairs over their life. Furthermore, lower costs from less damage can mean lower fees for cuts when compared to those for cutting into monolithic pavements.

Excavation of the base and soil must be within the limits of the removed pavers, and care must be taken to not undermine the adjacent pavement. Trench excavation, bracing, shoring, and/or sheeting should be done in accordance with the local authority. Equipment should be kept from the edges of the opening as loads may dislodge pavers around the opening. Excavated soil and base materials should be removed from the site. The trench should be kept free from standing water. ICPI Tech Spec 6 – Reinstatement of Interlocking Concrete Pavements provides additional guidance on repairs to utility cuts.

Unshrinkable fill poured into a trench is shown in Figure 8. The fills flows into undercuts providing additional support, and in places where the soil or base has fallen from the sides of the trench. These places are normally impossible to completely fill and compact with aggregate base or backfill material.

There are many mixes used for low-density concrete fill (7)(8). Proprietary mixtures include those made with fly-ash that harden rapidly. Others are made with cement. A recommended mix can be made with ASTM C150 (9) Type I Portland cement (or Type 3 for winter repairs), or CAN3-A23.5-M type 10 (or type 30 Portland cement) (10). The slump of the concrete should be between 8 and 12 in. (200 and 300 mm) as specified in ASTM C143 (11) or CAN3-A23.2.5C (10). When air entrainment is required to increase flowability, the total air content should be between 4 and 6% as measured in ASTM D6023 Standard Test Method for Density (Unit Weight), Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low-Strength Material (CLSM) or CAN3-A23.2-4C (10). Air content greater than 6% is not recommended as it may increase segregation of the mix.

A strength of 10 psi (0.07 Mpa) should be achieved within 24 hours. The maximum 28 day compressive strength should not exceed 50 psi (0.4 Mpa) as measured by ASTM C39 (11) or CAN3-A23.2-9C (10). Cement content should be no greater than 42 lbs/cy (25 kg/m3). The low maximum cement content and strength enables the material to be excavated in the future. Mixes containing supplementary cementing materials should be evaluated for excessive strength after 28 days.

Repaired utility lines are typically wrapped in plastic prior to pouring the low density fill. This keeps the concrete from bonding to the lines and enables them to move independently. When the fill is poured, it is self-leveling. It should be poured to within 4 in. (100 mm) of the riding surface to accommodate 3.125 in. (80 mm) thick concrete pavers and 1 in. (25 mm) of bedding sand.

Bedding sand can be installed when the concrete is firm enough to walk on, generally within a few hours after placement. The bedding sand should be as hard as available and should conform to the grading requirements of ASTM C33 (11) or CSA A23.1 (10). Mason sand, limestone screenings or stone dust should not be used. The sand should be moist, but not saturated or frozen. Screed the bedding with 1 in. (25 mm) diameter screed pipe. Remove excess sand from the opening.

Since the low-density concrete fill is self-leveling, it will create a flat surface for the bedding sand. In most cases, there will be a slope on the surface of the street. The flowable fill can be screeded to slopes while stiffening. Drain holes at lowest elevations can be cut into the curing material using a metal can. This can be done when the material supports walking but has not yet completely cured. The approx 2 in. (50 mm) diameter holes are filled with washed pea gravel and covered with geotextile to prevent ingress of bedding sand. Adjustments to the thickness of the bedding sand may be necessary for the finished elevation of the pavers to follow the slope on the surface of the street. This can be accomplished by adjusting the height of the screed pipes.

Concrete pavers should be at least 3.125 in. (80 mm) thick and meet ASTM C936 (12) or CSA A231.2 (13). They should be delivered in strapped bundles and placed around the opening in locations that don’t interfere with excavation equipment or ready-mix trucks. The bundles should be covered with plastic to prevent water from freezing them together. The bundles need to be placed in locations close to the edge of the opening. Most bundles have several rows or bands of pavers strapped together. These are typically removed with a paver cart. The paver bundles should be oriented so that transport with carts is done away from the edge of the pavement opening.

Rectangular concrete pavers [nominally 4 in. by 8 in. (100 mm x 200 mm)] should be placed against the cut asphalt sides as a border course. No cut paver should be smaller than one third of a unit if subject to tire traffic.

Place pavers between the border course in a 90 degree herringbone pattern (Figure 12). Joints between pavers should be between 1/16 and 3/16 in. (2 to 5 mm). Compact the pavers with a minimum 5,000 lbf (22 kN) plate compactor. Make at least four passes with the plate compactor. A small test area of pavers may need to be compacted to check the amount of settlement. The bedding sand thickness should be adjusted in thickness to yield pavers no higher than 1/8 in. (3 mm) above the edge of the undisturbed pavers.

Spread and compact sand into the joints. The joint sand is typically finer than the bedding sand, and should conform to the grading requirements of ASTM C144 (11) or CSA A179 (10). The joints must be completely full of sand after compaction. Remove excess sand and other debris. The pavers may be painted with the same lane, traffic, or crosswalk markings as any other concrete pavements. Plastic markings are not recommended. Light colored pavers can be used for pavement markings. This can save re-painting costs.

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Figure 1 is from iStock.com and Figure 8 is courtesy of Gavigan Contracting Ltd., London, Ontario.