Government of the Peoples Republic of Bangladesh

Local Government Engineering Department (LGED)

Final Report

on

Preparation and Incorporation of Alternative Pavement Section (Interlocking Concrete Block Pavement) into Road Design Manual

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Abbreviations and Acronyms

Abbreviation	Definition
ASTM	The American Society for Testing and Materials
BC	Brick-Cement
BRTC	Bureau of Research, Testing and Consultation
BUET	Bangladesh University of Engineering and Technology
CBR	California Bearing Ratio
CRDP	City Region Development Project
CVD	Commercial Vehicular Traffic
DCP	Dynamic Cone Penetration Test
DM	Dredged Materials
EDX	Energy Dispersive X-ray Spectroscopy
ESA	Equivalent Single Axle
FM	Fineness Modulus
FSPB	Factory Sediment-Amended Paving Blocks
HBB	Herring-Bone Bond
HBRI	Housing and Building Research Institute
HQ	Head Quarters
ICBP	Interlocking Concrete Paving Block
IRC	Indian Road Congress
LGEB	Local Government Engineering Bureau
LGED	Local Government Engineering Department
LGI	Local Government Institution
MPa	Mega Pascal
N/mm2	Newton per square millimeter
RCC	Reinforced Cement Concrete
RHD	Roads and Highways Department
RMC	Ready-Mix Concrete
SBP	Sea-Shell by Products
SEM	Scanning Electron Microscopy
SSWR	Small Scale Water Resources
XRD	X-ray Diffraction
XRF	X-ray Fluorescence

1. Background of the Project:

The project is conceived from the requirement for construction of huge road length of village road of low to medium volume commercial vehicles. The traditional way of building such kind of road initially by HBB and later reconstruction brick chips of the HBB bricks in lower layer and stone chips in upper layer (base course) with seal coating with pea gravel (small stone).

HBBs are made with clay burned bricks which give severe environmental impact. Government of Bangladesh is considering to stop burning of clay to manufacture bricks. Concrete blocks are in the way of construction of insignificant number of houses at present.

Asphalt road requires different types of machineries. For most required temperature controlled liquefaction of asphalt needs equipment which is very difficult in manual method. Thus, it is technically troublesome for constructing village road with semi-skilled men with only road roller. These kinds of roads could be paved for low and medium commercial vehicles very simply by using Concrete Blocks of appropriate strength and interlocking capacity.

Bangladesh has very little stone for use. Most of the asphalt road constructions are made with imported stones. But Bangladesh has river sand of different rivers of having different F.M. (Fineness Modulus) and to keep the rivers navigable, huge dredging works are made. Disposal of these dredged sands are making hazards to environment as well.

Prime Minister of Bangladesh gives directives to use these dredge sands in beneficial and be construction fitting way. Some of the dredged sands are used for manufacture of concrete block utilized in housing. But it is not up to significant level of construction of houses. Great shift from clay burn bricks to concrete blocks is required in the society. Some industries are making interlocking concrete blocks for industrial yard pavement. These huge dredged sands could be used in the manufacturing interlocking concrete blocks for pavement.

Also, LGED wants to be a pioneer in this field and wishes to pave its village roads for low to medium volume commercial roads with Interlocking Concrete Block of adequate strength i.e. 30 MPa& 35 MPa.

As these dredged sands are of different F.M. and contents, for getting concrete blocks of required strengths, it needs huge research work to establish mix design criteria for achieving these set strengths. HBRI is an experienced and capable institution for this purpose.

The use of Interlocking Concrete Paving Block (ICBP) in roadway construction is worldwide. The design comprises of a simple concept of ICBPs of preselected shape, size, color, etc. Seamlessly connected over sand base and thoroughly interlocked by using jointing sand. The choice and composition of base, sub-base and subgrade materials varies according to the physical, mechanical and environmental properties as per the geographic location at which the desired road would be established. The concept of ICBP roads is ancient. It started from the early Roman Empire and got refined after World War II. The only improvements ICBP has adopted over time are being manufactured with higher quality and accuracy in placement. Currently, Europe widely constructs ICBP roads and pavements, covering millions of square meters every year. North America is also quick to follow this trend and has started on broaden its reach.

A great advantage of ICBP roads is that it can distribute dynamic loads significantly due to its divided nature and interlocking properties and these parameters become substantial under traffic loads unlike conventional flexible pavements. However, due to the similarity in withstanding loads by these two types of pavements, the structural design and construction practice of flexible pavements could be translated into the preparation of ICBP roads.

In abroad (especially in North America), the primary use of ICBP is for residential and architectural purposes by taking aesthetics into consideration, replacing the use of asphalt and plain concrete. But soon, ICBP's load carrying property is soon recognized and it is then adopted in functional aspects as well.

As it is mentioned earlier, first merit ICBP has over traditional asphalt and concrete is its diversification in size, shape, color and layout pattern which make it an ideal choice for architectural application. Also, it can be incorporated in different types of roadways, considering all geometric possibilities with visual appearance in mind.

Also, due to the highest degree of quality assurance of ICBPs, they can withstand harsh chemicals, weather conditions and point loads as they are made with high strength and low absorption concrete. Once a road surface is properly prepared, they can be readily placed over it and traffic can be allowed immediately. If there is a need to carry out utility repair under ICBP road, then blocks at the point of interest are removed and necessary adjustments are made. Then the substituted blocks are replaced again, making ICBPs reusable.

Another distinguishable feature that ICBP imparts is that it can be applied over soils with poor condition since it can handle distress better and still remain in service unlike conventional flexible pavements. Overall, ICBP pavements do have a higher life-cycle with low maintenance, making them a suitable choice for developing countries such as Bangladesh.

ICBP pavements can be used in many scenarios such as:

- Footpaths and Side-walks
- Cycle Tracks
- Residential Streets
- Car Parks
- Fuel Stations
- Rural Roads through Villages
- Highway Rest Areas
- Toll Plaza
- Bus Depots
- Approaches to Railway Level Crossings
- Intersections
- City Streets
- Truck Parking Areas
- Industrial Floors
- Urban Sections of Highways
- Road Repairs during Monsoon
- Container Depots
- Port Wharf and Roads
- Roads in High Altitude Areas

(Source: IRC: SP: 63-2004)

After considering the aforementioned factors, as per the Terms of Reference (ToR), the use of clay bricks in the construction of rural roads are discouraged by the Government of Bangladesh (GoB). GoB provided a clear rule through a notification published on 24-11-2019 under serial no: 22.00.0000.075.32.002.14 (part -3)-410, urging all to reduce the use of traditional fire-burnt clay bricks and use blocks on a periodical basis in the construction, repair and maintenance of walls, boundary walls, HBB roads and Type-B village roads. Further details of the work plan and the goal for its implementation are provided as an attachment (Annexure I) at the end of this report. Therefore, the inclusion of various alternative technologies is essential in the construction of village roads with low traffic volume and subsequently low axel loads to make these more durable, environment friendly and economic. It is also found that the use of bituminous mixture or cement concrete technology is also impractical for rural pavement design due to their lack of proper drainage system and associated higher costs.

In the absence of definitive design principles, it has become difficult to incorporate Interlocking Concrete Paver Blocks (ICBP) in the context of Bangladesh, considering its numerous pavement characteristics along with social & environmental data, soil properties, etc. So, in order to mitigate the issues arising from not being able to widely use ICBP as a fundamental pavement construction method, an extensive study on existing LGED road design manuals would be carried out to get a clear understanding on road design procedures, construction practice and maintenance. Then, other national and international documents relevant to codes and standards for roadway design would be thoroughly reviewed for obtaining further knowledge regarding ICBP road design specifications. Some significant locations in Bangladesh would be visited to collect dredging sand samples to assess their potential as a raw material for the fabrication of quality ICBP and subsequently, efforts would be given in their successful inclusion into ICBP road design templates for different areas of Bangladesh. In accordance to the desire of the Client (i.e. LGED), implementation and maintenance manuals are to be prepared. Also, specification and costing would be furnished.

1.1. Background of LGED (Client)

Local Government Engineering Department (LGED) is one of the largest engineering agencies of the country. It began its journey in 60s as Rural Works Program under Cumilla Model and with the passage of time, its activities expanded from remotest corner of the country up to the cities.

The Rural Works Program included in the Cumilla model was basically aimed at developing rural infrastructures. Later in the 70s, an Engineering Cell was created under the Ministry of Local Government, Rural Development & Cooperatives for implementation of the program. In 1982 it was transformed into `Works Program Wing' under development budget. Works Programme Wing was reconstituted as Local Government Engineering Bureau (LGEB) in 1984 under revenue budget. LGEB was finally given the shape of a full-fledged department renaming it as LGED in 1992.

Role of LGED in strengthening of rural economy through development of rural transportation and improvement of rural markets and growth centers are visible across the country. Contribution of these infrastructures are enormous in achieving the ever-increasing national growth. People living in rural areas now have the access to metaled roads within two kilometers while the rural infrastructures play pivotal role in the improvement of lifestyle and reducing poverty.

LGED also maintains its presence in the infrastructure development in urban areas. The department is also involved in providing technical assistance, governance improvement and capacity building of Urban Local Bodies (Municipalities and City Corporations).

LGED's role in augmenting agricultural and fish production through small scale water resources (SSWR) development projects is remarkable. These initiatives have created short- and long-term employment opportunities for the low-income group of people. Local stakeholders are included while planning and implementing the schemes in the operation and maintenance.

Besides, the activities mentioned above, LGED extending technical assistance to Local Government Institutions. Required technical assistance is also provided to various ministries. LGED also develops infrastructure database, maps, technical specifications, manual etc. required for development projects. Regular training courses conducted by LGED for enhancing skill of its own employees, members of the Local Government Institutions and other stakeholders.

In short, Local Government Engineering Department is the prime engineering organization in pursuing rural development program. LGED's main functions are planning and implementation of infrastructure development projects in rural and urban areas to improve transportation network in order to facilitate employment generation vis-à-vis poverty reduction and to provide technical support to the Local Government Institutions.

Reflecting strong initiatives of Government for pursuing rural prosperity, the total volume of investment program on rural infrastructure has been continuously increasing. In addition, the better and reliable quality of developed rural infrastructure are requested to meet the social demand for efficient use of public investment. LGED has been playing a key role in this respect with high performance and flexibility on each project component.

The Government of the People's Republic of Bangladesh, through its Gazette Notification1 (November 2003), reclassified the National Road System into six categories, redefined them and re-delineated the ownership and responsibilities of the concerned organizations in conformity with its latest policy (Table 1.1). According to the road reclassification, LGED in collaboration with LGIs, is responsible for the construction, improvement and maintenance of three classes of roads, which have been named as Upazila Road, Union Road and Village Road in collaboration with LGIs.

Table 1: Road Classifications

Sl. No.	Types	Definition	Ownership and Responsibility
1	National Highway	Highways connecting National capital with Divisional HQ/s or seaports or land ports or Asian Highway.	RHD*
2	Regional Highway	Highways connecting District HQ/s or main river or land ports or with each other not connected by National Highways.	RHD
3	Zila Road	Roads connecting District HQ/s with Upazila HQ/s or connecting one Upazila HQ to another Upazila HQ by a single main connection with National/Regional Highway, through shortest distance/route.	RHD
4	Upazila Road	Roads connecting Upazila HQ/s with Growth Center/s or one Growth Center with another Growth Center by a single main connection or connecting Growth Center to Higher Road System**, through shortest distance/route.	LGED/LGI
5	Union Road	Roads connecting Union HQ/s with Upazila HQs, growth centers or local markets or with each other.	LGED/LGI
6	Village Road	(a) Roads connecting Villages with Union HQs, local markets, farms and ghats or with each other.	LGED/LGI
		(b) Roads within a Village.	

Source: Bangladesh Gazette 1st Part, 6 November 2003

* RHD – Roads and Highways Department, LGED – Local Government Engineering Department, LGI – Local Government Institutions.

** Higher Road System – National Highway, Regional Highway and Zila Road.

1.2. Background of HBRI (Consultant)

Father of the Nation Bangabandhu Sheikh Mujibur Rahman established Housing and Building Research Centre on 13th January 1975. After the liberation of Bangladesh in order to mitigate the housing crisis forever increasing population by fully utilizing local construction materials and other limited resources. Later, the center transformed into Housing and Building Research Institute and obtained its autonomous status. This institute conducts research regarding safe, durable and economic housings cement, sand enhancement in the quality of local construction practices for low income-community. Aside from research, the institute is also engaged in the marketing and expansion of its innovated products/ technologies, provide consultancy service to individuals or other entities on housing and construction & conduct training programs to increase the quality and skill of the present construction industry.

Housing & Building Research Institute (HBRI) is now running under the general direction and superintendence of the affairs and business of the institute are vested into the Governing Council. The Director is the ex-officio member–Secretary of the Council and the Chief Executive officer of the institute. Over the years, the institute has been able to build up necessary laboratory facilities for test/research works and recruit a good number of qualified engineers/architects/scientists with experience and training in home and abroad. Constant efforts are provided to impart higher education and training to research personnel in both local and foreign settings and this is the keystone of R & D (Research & Development) policies.

Divisions in the Institute:

a) Structural Engineering and Construction Division

This Division is entrusted with research and development of economic/durable structures so as to economize the use of building materials and enhance speed of construction and reduce the cost of that. Considering the socio-economic, environmental and climatic condition of Bangladesh, this division is engaged in finding out the less costly and more durable building components using the indigenous building materials with a view to improve the living condition of the people of urban, rural and disaster-prone areas.

Simultaneously to insure the quality of construction works this division has been playing the role with introducing prefabrication construction technique besides cast-in-situ system. Moreover, this division is engaged in dissemination of research findings through Extension and Dissemination Wing attached with it.

b) Soil Mechanics and Foundation Engineering Division

This division is concerned with the evaluation of properties of soils in the fields as well as in the laboratory to arrive at safe and economic foundation design for buildings. Improvement of soft soil for safe and economic design of foundation.

c) Housing Division

This division under Housing and Building Research Institute has been working relentlessly with a goal of timely innovation in the housing sector of Bangladesh. The main objectives of this department are to conduct innovative design of sustainable and affordable buildings, prepare guidelines for eco-friendly construction, plan the use of alternative building materials and conduct research related to green buildings in Bangladesh.

d) **Building Materials Division**

The aim of this department is to study for producing new or better construction materials from local raw materials and industrial and agricultural wastes with emphasis to augment the supply and use as substitute for commonly used building materials in our country. Also, evaluation of the properties and performance of different building materials and conducting the standard test for quality control of the materials are also included in the scope of activities under this division. There are two laboratories under this department namely (a) Chemical Testing and Research Laboratory and (b) Physical Testing and Research Laboratory.

1.3. Objective(s) of the Study

The objective of the assignment is to prepare and incorporate alternative pavement segment (Interlocking Concrete Block Pavement) into Road Design Manual of LGED. The objectives the consulting services of the assignment are:

- To develop design procedures and various design templates for the ICBP considering various dredged materials from rivers, khals, ponds, etc.
- To develop an implementation and maintenance manual including specification with costing for ICBP.
- To develop separate segment for other alternative sustainable pavement options.

1.4. Scope of Work

The scopes of the assignment typically include, but not be limited to, the following:

Conduct study and analysis on existing LGED road design manual.

Collect data and information through field visit of various districts, various national and international design manual, code, journals, research papers etc. for ICBP road.

Develop design procedures and various mix design templates for the ICBP

Develop an implementation and maintenance manual including specification with costing for using ICBP.

Develop a separate segment for other alternative pavement options

1.5. Expected Outputs

The outputs of the study that can be provided are as follows:

Design procedures and various mix design templates for the ICBP of 30 MPa and 35 MPa from dredged sands of rivers of different locations for low & medium volume commercial vehicles.

Implementation and Maintenance manual for using ICBP for various soil and environmental conditions.

Separated segment for other alternative sustainable pavement options.

Draft specification with costing.

2. Literature Review

As per the specific requirement in ToR regarding the review of existing LGED road design manuals and local standards along with other international codes, standards, journals and books, some reviews of LGED road related report(s), international ICBP pavement manuals and international journal papers are provided under this section.

2.1. National Report:

According to the final report (in approval stage) provided by BRTC, BUET regarding the Consultancy Services for Assessment of Road Design and Pavement Standards of LGED, the definitions of village road are as follows:

- Roads connecting Villages with Union HQs, local markets, farms and ghats or with each other. And
- Roads within a Village.

The aforementioned definitions were procured from Bangladesh Gazette 1st Part, 6 November 2003.

By considering the following definitions, total length of earthen road comprising of Upazila, Union, Village-A and Village-B is **2,56,051.35 km.** Therefore, it would be a commendable endeavor if these roads are reinforced with ICBP technology to allow the hassle-free movement of commuters and light traffic.

Under the Pavement Design Standards (Chapter-04, Page-50), 03 (three) types of traffic areas were mentioned based on the volume of daily commercial vehicular traffic (CVD). Those were, heavy medium and light traffic areas.

Since, this project is only concerned with the use of ICBP technology in rural roads, so it is expected that these roads would be categorized under “Light Traffic Area” and this area is described as “If the number of commercial vehicles per day (CVD) in an area is less than 200, then the road in that area will generally be considered a light traffic area.”

Based on the classification for of heavy, medium and light traffic, computation of design traffic was facilitated with the aid of a table containing Lane Factor for different roads, Growth Factor for different design periods and growth rates, flow chart for calculating cumulative ESA and flow chart for pavement design of light and medium traffic areas were given. Relevant examples demonstrating all the mathematical calculations along with the selection of thickness for different pavement layers were provided in the report.

As for the Road Materials and Construction Specifications (Chapter-6), preparation of subgrade material was discussed along with its conformation with the criteria such as: liquid limit, plasticity index and Dynamic Cone Penetration Test (DCP). Subgrade construction methods were also discussed. A section for improved subgrade was dedicated that covered its general description, materials complying the required limits for plasticity, CBR, DCP and FM value.

In the section containing materials specification for light and medium traffic areas regarding sub-base, the choice was "homogeneous mixture of crushed stone or brick aggregates and local sand, and/or natural or artificial mixture of sand, free from vegetable matter, soft particles, clay and excess silt". Just like the subgrade, the sub-base material should also govern the requirements such as Grading, CBR, Loss Angeles Abrasion Value/ Ten Percent Fines Value, Water Absorption and Plasticity.

Similarly, the composition of base material for light and medium traffic areas were focused on with its respective requirements.

Under the construction methods, preparation and spreading of Base, sprinkling, rolling and compacting & surface tolerance were explained in details.

Under the study on the **Technical Viability of the Block Road**, the researchers evaluated performance, socio-economic impact assessment, 3D finite element analysis of the road system and road safety to assess the viability of concrete block road constructed under SCBRMP of LGED. Under the endeavor, the study group collected information from both primary and secondary sources and conducted some tests (both in-situ non-destructive and destructive) tests. Their focuses were: pavement performance, riding quality and roadway safety, concrete mix design, socio-economic impact and detailed design of the pavement.

As a result, the team went to the study areas to observe road construction works and conducted a participatory socio-economic survey. In addition to that, they carried out extensive laboratory tests of sub-grade materials, block compositions and finished blocks.

As for the general observations of the research group, they found that the involvement of community in roadway construction was beneficial, use of rounded gravels enhanced workability of concrete mix and use of brick chips reduced concrete block making cost.

Also, semi-rigid block pavements were resilient to the harsh weather change and were easy for maintenance. Structure of the block pavement remained to be the same when submerged in water. Block pavement allowed unobstructed water flow and were more suitable for village roads. Strength of concrete blocks in the block pavement were not up to the mark due to the due to the inadequate role of cement in providing strength or and overall process failure in block manufacture.

Under the socio-economic impact, the use of block pavement improved access to service locations. Also, more women went out for accomplishing their daily objectives. There was a substantial growth in food consumption, income, household assets and business. Moreover, the active participation of women in the construction of block pavement road provided them with employment and a sense of ownership.

Under the geotechnical aspect, block pavement road could carry higher load than the design load so it was mostly under-utilized. Size of block determined its bearing capacity and settlement.

Under road-safety, block pavement had the quality to reduce vehicular speed over rigid pavement thereby considered to be safer and it was recommended by the research team to utilize block pavement in hazardous locations where accidents were prone to happen.

The research team recommended that quality control and supervision were required for concrete block manufacture for using these in pavement. They encouraged the use of mixture machine and compressed block manufacturing technique to improve quality of concrete blocks. They also emphasized on using quick-setting cement and admixture to maintain the quality and strength of concrete blocks and encouraged the use of various traffic control measures (e.g. road signs and marking) at accident prone areas.

In the end, the research team commented on using block pavement in coastal areas considering its performance and submersible attributes.

2.2. International ICBP Pavement Manuals:

To really understand the current practice regarding the inclusion of ICBP in roadway construction, two guidelines were referred to in order to understand the variation of different parameters of ICBPs according to the regional context. Firstly, "GUIDELINES

FOR THE USE OF INTERLOCKING CONCRETE BLOCK PAVEMENT" published by The Indian Roads Congress was studied. This manual was exclusively chosen due to India being the closest neighbor to Bangladesh and the similarities in socio-economic conditions, materials availability, environmental factors, etc. made it as a suitable choice for a thorough review.

This guideline was prepared, covering the design, construction and specifications into account. Firstly, the authors covered the applications of ICBP pavements in different scenarios such as footpaths, cycle tracks, car parks, etc. Then, they discussed about different advantages of utilizing ICBP into roadways, notably vehicular speed restriction, skid resistance, cheap labor cost, low maintenance, crack resistance and the ability of permeable blocks to restock underground water. Although, the authors presented some limitations of this technology as well such as its unsuitability in high speed roads, noise pollution due to the contact between ICBP blocks and speeding wheels and water seepage through joints.

The authors then proceeded to discuss the types and shapes of blocks, highly emphasizing the adjacent blocks' interlocking effects and shear strength. The authors then categorized the blocks according the **Category A, Category B and Category C** according to the presence of keys to the blocks' sides and their suitability in different types of bonding. **Category A** has keys in all four sides, **Category B** has interlocking features in two sides only and **Category C** has no locking features surrounding its sides. Then, the authors provided some benchmarks for the "overall dimensions" of the blocks.

Next, the authors proposed the compositions of block pavements according to the nature of loads they carried. Block thickness, sand bedding, base course thickness and sub-base course thickness were covered in both cases. Importance of providing bedding and jointing sand.

The writers then talked about edge restraints and how they resist the movement of concrete blocks sideways. They advised that the edge restrainers should be made with high strength concrete.

Under the structural design of interlocking concrete block pavement, the authors admitted that the design principle they adopted were based on institutions from abroad as the international agencies performed practical tests, taking into account different roads with varieties of traffic conditions. Bottom-line, there was no research conducted in India and they strongly advised to refer to the prescribed design catalogue.

In the design chart, the authors took traffic and road type along with subgrade CBR % to propose thickness to the different layers of ICBP road sections from blocks to granular sub-base. One thing is to be noted that, thicknesses were proposed for CBR % above 10 and within 5-10. If soil CBR fell below 5%, then appropriate stabilization scheme should be adopted to bring the CBR value at an acceptable range (i.e. ≥ 5).

The authors then talked about block manufacturing process by first going through the mix design aspects e.g. Water/cement ratio, water content, cement quantity, aggregate/cement ratio, aggregate composition, strength, pigment addition (i.e. coloration) and other additives.

In the manufacture of paving blocks, the authors discouraged the use of manual fabrication of ICBP and stressed on using batch production plant with high pressure and controlled vibrations. The authors then briefly described the manufacturing process of ICBP.

As for the dimensional requirements, the authors proposed tolerances to the plan dimension and thickness of ICBP and restricted their deviations to 2 and 3 mm respectively. Furthermore, the authors provided the suitable grading chart for both bedding and joint filling sand & material requirement of base and sub-base layers.

The authors emphasized on water-proofing block ICBP pavements by means of sub-surface drains with filter materials/geotextile. Also, the use of perforated pipe was also discussed under the drainage section.

Under the construction process, the authors provided detailed information on the preparation of subgrade, sub-base course, placement of bedding sand and block laying. Then, some examples of block patterns were provided such as stretcher or running bond, Herringbone bond and Basket weave or parquet bond. Detailed process on how the blocks were layer was provided. In the manual, two different types of block pavement construction were provided, one was manual and another was mechanized.

The authors provided a short maintenance manual and it was mentioned that ICBP pavements required minimal maintenance. The maintenance section was mainly grouped under three sections: Initial Maintenance, Storage of Blocks &Coating and Cleaning.

In the final section containing the technical specifications for laying concrete paving blocks, the authors again portrayed dimensional tolerances for base thickness, gradation of bedding sand layer and jointing sand layer and other requirements pertaining to concrete paving blocks.

Finally, the authors highlighted the necessities for conducting proper field/laboratory investigations when carrying out the design and construction of ICBP pavements. Also, they advised on seeking assistance from engineering institutions and their relevant engineers when conducting the tests.

Another design consideration for interlocking concrete pavements prepared by UNILOCK was studied as well. In the manual, the authors firstly discussed the general concept of interlocking concrete pavements with their advantageousness to distribute loads due to segmental nature, the use cases, advantages (e.g. resistance to high strength, low absorption concrete, high temperature, etc.). In this case also, the authors mentioned of the design of interlocking paver pavements to be the same as that of flexible (asphalt) pavements. The authors also mentioned about the life-cycle cost of interlocking pavement suggested to compare the difference between the cost of ICBP pavements and other types of pavements.

The authors prepared the guideline mainly for the structural design and construction of ICBP pavements under different scenarios (i.e. light and medium traffic). Then, the authors proceeded on to discuss about the principal components of ICBP systems. Just like IRC the authors addressed the fabrication of Concrete pavers, desiring the use of "zero-slump" concrete and used ASTM C 936 as a guideline for paver manufacture specification. The authors also went through the specifications of other components of ICBP pavements such as bedding sand, jointing sand, edge restraints, sealer, geotextile fabrics.

Under the installation, it was highly encouraged to employ 90-degree herringbone pattern to limit displacements of the paver units and "maximizing interlock"

In UNILOCK manual, the authors emphasized on the practical working knowledge of the materials for different ICBP pavement layers based on 07 (Seven) parameters.

The authors then moved straight to the installation process of ICBP paving, taking into consideration the subgrade condition, compaction and proof rolling, geotextile application, base construction, base stabilization, installation of pavers by both manual and mechanical methods, cutting of pavers for infill, application of jointing sand, compaction of pavers, sealing and final inspection.

The maintenance segment of this particular manual is elaborate, as the authors not only highlighted the types of distresses but also provided with a guideline on how to carry out pavement distress survey. Under each distress, description, measurement, severity level and remedial measure were concisely given. In addition to that, the methods for paver removal, paver cleaning, subgrade repair, base repair, etc. were also provided. A small section on drainage covering both subsurface and surface was focused on.

In the section containing structural design, the authors further elaborated on the various components of ICBP pavement and how each element helps in resisting the imposed wheel loads on the subgrade. For instance, horizontal interlock which is achieved by paving unit layout pattern, distributes braking, turning and accelerating forces of vehicles. Vertical interlock ensures shear load transmission through paving joints and sand. Authors also talked about the materials requirement for granular base and consideration for sub-base where traffic loads were substantial.

The authors considered four design factors for ICBP pavements. Those were: environmental, traffic, strength of existing subgrade soil and base and sub-base materials quality.

The authors then provided a design catalogue for quickly selecting suitable thicknesses of different components under ICBP pavements based on loading condition and subgrade soil type. Although, the authors strictly prohibited the use of it when designing a road section for heavy vehicular load. Nonetheless, the catalogue can be used primarily for estimating purposes.

Another unique aspect that the authors discussed in this manual was that ICBP could be used as a rehabilitation scheme for existing pavements

TECH SPEC GUIDE (2020) of Interlocking Concrete Pavement Institute of Rochester Concrete Product provides a wide range of information on construction and maintenance including Reinstatement of Interlocking Concrete Pavements.
There are 25 chapter of specific technical guidance of which most important and essential parts are as below.

* Construction
* Edge Restraining
* Structural Design
* Cleaning, Sealing and Joint Sand Stabilization
* Reinstatement of ICBP
* Repair of Utility Cut
* Guide Specification for the construction
* Application Guide for ICBP

There it is stated that the mixture of concrete should be "zero slump" and should be made factory - controlled conditions with that apply pressure and vibration. The result is a consistent, dense, high strength concrete molded into shape.

Physical Characteristics:

When manufactured in the US interlocking concrete pavers made by ICPI members typically meet the requirements in ASTM

C963, Standard Specifications for Solid Interlocking Concrete Paving Units. This standard defines concrete pavers as having a surface area no greater than 101sq in, (0.065 sqm) and their overall length divided by thickness, or aspect ratio, does not exceed 4. The minimum thickness is 2 3/8in (60mm)

Concrete pavers produced by Canadian ICPI members typically conform to Canadian Standard Association, CSA-A231.2, Precast Concrete Pavers. This standard defines a concrete paver as having a surface area less than or equal to 140 sq-in (0.09sqm), an aspect ratio less than or equal to 4:1 for pedestrian applications, less than or equal to 3:1 for vehicular applications. The minimum thickness is 2 3/8 (60mm)

Design and Application Standards:

For pedestrian applications and residential driveways, 2 3/8in (60mm) thick pavers are recommended. Pavements subject to vehicular traffic typically require 3 1/8in (80mm) thick pavers. Some heavy-duty commercial pavements use minimum 4 in. (100mm) thick units and sometimes 5 in. (120mm) thick for the heaviest load applications.

Units with an overall length to thickness (aspect) ratio of 4:1 or greater should not be used in vehicular applications. Those with aspect ratios between 4:1 and 3:1 may be used in areas with limited automobile use such as residential driveways. Units with aspect ratios of 3:1 or less are suitable for vehicular applications.

Interlocking concrete pavements are typically designed and constructed as flexible pavements on a compacted soil subgrade and compacted aggregate base.

Concrete pavers are than placed on a layer of bedding sand (1 in. or 25mm thick), compacted, sand swept into the joints, and the units compacted again. When compacted, the pavers interlock, transferring vertical loads from vehicles to surrounding pavers by shear forces through the joint sand. The sand in the joints enables applied loads to be spread in a manner similar to asphalt, reducing the stresses on the base and subgrade.

2.3. International Journal Papers:

(Said et al., 2015) proposed an approach to use dredging sand in the fabrication of paving units. The authors used "Rades harbor's non polluted sediments" and partially substituted quartz sand with it. The replacement ratio was only 19%. The researchers then carried out several experimental investigations on the modified concrete paving blocks like splitting tensile strength, water absorption, leaching test, etc. The results showed that the new blocks had similar tensile strength (i.e. 3.58 MPa) which was similar to the standard ones. Also the alternative pavers had lower absorption ratio (4.05%). In addition to that, the authors inferred that heavy metals arising out of leaching action from the crushed pavers were within acceptable range. In the end, the authors made a concluding remark by stating that manufacturing Factory Sediment-Amended Paving Blocks (FSPB) could be an excellent way to recycle dredged sediments.

(Beddaa et al., 2020) proposed that dredged river material could be a suitable option to be used as an aggregate to fabricate concrete. Under the research, the authors measured the variations of different parameters of dredged sediments by analyzing heavy metal concentrations, some pollutants, specific granular fractions and organic contents. The authors conducted these tests on different areas of Seine river over 02 (two) years. The authors found out that sediment characteristics does not alter with the progression of time. Moreover, the authors denoted that organic content of the sediments mainly occupied in the finest portion and was separated by sieving. The authors managed to utilize 30% of sediment volume as coarse aggregates, sands and fines and fabricated concrete. When the authors substituted normal aggregate for concrete with 30% of dredged sand, they noticed limited change in hydration, setting time extension and a negligible decrease in compressive strength (i.e. 10%) with 15% increase in shrinkage strain.

(Dauji, 2017) Stated that dredging at coastal areas and river-side areas were done for the operation of "navigable channel for port and harbor activities". The most economical way to dispose river-dredged sand was "Ocean Dumping" but due to the discard of that practice, the author explored into alternative means to utilize the excessive sediments buy using it in construction industries (e.g. cement production) and biodiesel production. The author believed this would also solve the increasing demand for the limited raw materials for structural constructions.

(Yang et al., 2020) put forward with an innovative way to use contaminated sediment in the production of environment-friendly foamed concrete by mixing cement, foam and silica fume to sediments as they felt that the deposition of contaminated dredged sediment in lands contributes to the undesired land occupancy alongside with soil and ground water pollution. The researchers found out that increase in foam % in the mixture resulted in the decrease of compressive strength and dry density in the resulting concrete. Also, the increase in foam also caused in the fall of thermal conductivity and water resistance coefficient. Also, the authors found that by replacing cement with a small percentage of silica fume (i.e. 10%) enhanced the properties of the resulting concrete such as hydration reaction and pore-filling effect. The researchers confirmed that with the help of X-ray fluorescence (XRF), X-ray diffraction (XRD) and scanning electron microscopy (SEM) in conjunction with energy dispersive X-ray spectroscopy (EDX). This innovative researched paved a new way for the utilization of heavy-metal contaminated river dredged sediments.

(Manap et al., 2016) felt that the wastes resulting from dredged materials cause broad scale environmental pollution. So, according to them, dredged sediments could be used in geotechnical and transportation related constructions such foundations, retaining wall and highways. For the experimental endeavor, they collected dredged sand and silt from two different rivers, produced concrete and compared their strengths with the conventional ones. The researchers used sand as a complete replacement of fine aggregate and silt as admixture in the modified concrete. At the end of their study, the authors found that concrete from dredged sand had maximum strength of 30.60 N/mm^2 at 28 days. Whereas, concrete made by incorporating silt as an admixture resulted in maximum strength of 48.8 N/mm^2 for 28 days curing period. When Silt content replaced as fine aggregate, the resulting strength of concrete decreased. Also, strength of modified concrete (i.e. inclusion of dredged sediments as fine aggregate) was found to be higher than standard concrete, confirming the authors' prediction on the suitability of dredged sand as fine aggregate in the production of concrete. The authors concluded the paper by stating that construction industries should search for dredged materials as a sustainable alternative for geotechnical applications.

(Ozer-Erdogan et al., 2016) emphasized on the use of both treated and untreated marine dredged materials (DM) in the production of ready mix concrete (RMC). For sampling, the researchers collected DMs from four different Turkish ports and made a synthesized DM by complying with their country's national regulation(s). The researchers then added silica sand at five (05) different ratios to both treated & untreated blended DMs and conducted laboratory experiments regarding "Mechanical, durability, leaching, mineralogical/micro-structural properties". After analyzing all the relevant characteristics, the authors came to the conclusion that DMs can be used in the production of high-strength RMC.

(Nguyen et al., 2013) found that SBP (Sea-Shell by Products) were wastes that could be used as a partial substitution of coarse aggregate in the production of pervious concrete pavers. Under the research, the authors initially fixed the energy and pressure of standard pervious pavers and replaced granular aggregate with SBPs. After that, the researchers conducted both mechanical and hydrological analysis of the resulting paving blocks and found those to be a viable option, comparable to control paving units.

(Darshita & Anoop, 2014) put forward that although dredged sand was one of the perfect choices in the production of concrete, but the natural reservoir of this resource started to deplete due to its excessive use in construction industries. Therefore, the researchers proposed two alternatives against the common fine aggregate. Those were crushed brick powder and crushed glass powder. After conducting compressive strength test of concrete prepared by replacing sand with brick powder and glass power, the authors found that 20% sand replacement by brick powder and 15% sand replacement by glass powder produced concrete that generated higher strength than standard concrete. Therefore, these two alternatives could be viable options as a partial replacement to sand in the production of concrete.

(Sojobi, 2016) introduced the use of sawdust and laterite in the production of environment-friendly and light concrete pavers as a potential substitute to both local sand and cement. He stated that both sawdust and laterite were readily available due to being by-products of industrial activities and also these were cost-effective. The researcher observed that "packing and filling effects" of sawdust along with the pozzolanic characteristics of the combined sawdust and laterite caused small increment in the compressive strength for Interlocking concrete pavers. The author also encouraged the collaboration of local government authority responsible for wastes with other entities responsible for the collection, storage and disposal of sawdust to work together and use this material for a sustainable environment.

2.4. Summary of the Studied Literatures:

After the study of some selected research articles along with ICBP road design manuals from both India and North America, it is concluded that numerous researches are concerned with the use of dredged sand as an alternative material to conventional fine aggregate in the production of concrete. Some researchers express their concern about the current disposal practices of river dredged sand that contribute to the deterioration of the environment. Therefore, almost all the literatures reviewed here direct towards the use of dredging materials in concrete production in such a manner that the performance of this concrete might rival that of the concrete made with standard constituents mainly in terms of compressive strength. Although, few researches reveal the use of alternative materials in concrete production against dredged sediments such as clay brick powder, glass powder, sawdust and laterite. But those investigations result due to the conservation of dredged soil as their excessive usage might deplete the natural reservoir at some point in the future. Other alternatives for the use of dredged sand include bio-diesel production. Some international ICBP Pavement Guidelines which have been presented here clearly provide detailed information on construction of ICBP pavement, its maintenance, structural design (in the form of catalogues) and associated costing.

So far, limited/no research has been conducted in the production of Interlocking Concrete Paving Blocks from dredged sediments from different locations of Bangladesh, that would certainly pose a challenge due to the expected inferior F.M., resulting in the implementation of numerous improvement protocols of the dredged materials in the production of viable concrete mixture to ultimately fabricate sustainable ICBPs (e.g. ratio adjustment, introduction of admixtures, Water: Cement ratio, etc.). This unique point of work would pave a way to utilize various river sands in the manufacture of durable, cost-effective and eco-friendly paving units with sufficient compressive strength and other appropriate properties in the application of rural roads with light-weight vehicular activities.

3. Research Methodology

3.1. Field Visit:

Roads at the locations stated below were assessed for their category, vehicle composition/presence of commercial vehicles, information regarding underlying layers, etc. In addition to that, other information regarding road characteristics were collected from concerned LGED authorities at those locations (e.g. road length, width, etc.). Special interest was definitely shown into existing uni-block /ICBP roads established by LGED. If permitted, some block samples could be collected from the sites for laboratory testing at HBRI. Locations to be Visited under City Region Development Project (CRDP), LGED are provided in the table below:

Table 2: List of Locations to be Visited under the Project:

Urban Center

District	Package (nos)	BC Road (km)	RCC Road (km)	CC Road (km)	Uni-Block (km)	Hard Shoulder (Uni-block) (km)	Total Road (km)
LGED Gazipur	2	6.48	0.58	1.29	0.54	5.66	8.89
LGED Dhaka	3	0.00	0.59	0.47	0.19	0.41	1.24
LGED Narayanganj	4	46.83	1.24	2.06	2.55	26.31	52.68
Sub-total	**9**	**53.31**	**2.41**	**6.23**	**3.28**	**26.72**	**62.81**

City Corporation and Pourashava

District	Package (nos)	BC Road (km)	RCC Road (km)	CC Road (km)	Uni-Block (km)	Hard Shoulder (Uni-block) (km)	Total Road (km)
Gazipur City Corporation (GCC)	5	5.00	4.39	0.00	0.00	6.38	6.39

Dhaka North City Corporation (DNCC)	1	8.10	0.00	0.00	0.00	0.00	8.10
Narayanganj City Corporation (NCC)	2	1.14	0.00	0.00	0.89	0.00	2.03
SingairPourashava	2	21.18	0.25	0.00	4.37	9.92	25.80
SavarPourashava	4	14.30	4.44	0.00	0.55	7.39	19.29
Sub-Total	**14**	**49.72**	**9.08**	**0.00**	**5.81**	**23.69**	**61.61**
Total	**23**	**103.03**	**11.49**	**6.23**	**9.09**	**50.41**	**124.42**

(Source: LGED)

A sample questionnaire chart is provided below for better accumulation of the existing field information:

Table 3: Sample Questionnaire for Field Visit of HBB and Cement Concrete Block Road

District: Dhaka

Sl. No	Road Name	Upzilla	Block Road Length Km	Block Road Width m	Road/Roads Category	Dimension of blocks used in the road	Traffic Composition	Underlying layers of CC Block and with their thickness	Remark on Performance of the road
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
01	Upazila H/Q to Sadapor Kongaon road	Savar	4.675 km	1.25 x 2	Union Road	220x110x100mm	Bus, Truck, Micro Bus, Auto rickshaw, etc.	Block:100 mm Sand Cushion: 40 mm One-layer BFS ISG:250 mm	Under construction
02	karnaparaghat to Namaganda road	Savar	2.77 km	1.00 x 2	Village Road (A)	220x110x100mm	Truck, Micro Bus, Auto rickshaw, etc.	Block:100 mm Sand Cushion: 40 mm One-layer BFS ISG:250 mm	Under construction

District: Khulna

Sl. No	Road Name	Upzilla	Block Road Length Km	Block Road Width m	Road/Roads Category	Dimension of blocks used in the road	Traffic Composition	Underlying layers of CC Block and with their thickness	Remark on Performance of the road
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
01	Poddargonj Bazar to Bajua UP office (Sluice Gate) via Chunkuri High School Road.	Dacope	5.962 Km	3 m	Village Road (A)	220x110x80mm	Truck, CNG, Auto rickshaw, Motor cycle, etc.	Block:80 mm Sand Cushion: 50 mm BFS: 75 mm ISG:150 mm Existing HBB Road	Good Condition
02	Loudobe UP Office (cattle market) to Burirdabur via Burirdabur satellite School road	Dacope	2.094 Km	3 m	Village Road (A)	220x110x80mm	Truck, CNG, Auto rickshaw, Motor cycle, etc.	Block:80 mm Sand Cushion: 50 mm BFS: 75 mm ISG:150 mm Existing HBB Road	Good Condition

District: Gazipur

Sl. No	Road Name	Upzilla	Block Road Length Km	Block Road Width m	Road/Roads Category	Dimension of blocks used in the road	Traffic Composition	Underlying layers of CC Block and with their thickness	Remark on Performance of the road
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
01	Bottala, Board Bazar to Jajor	City Corporation	4.00 km	1.00 x 2	City Corporation Road	220x110x80 mm	Truck, Micro Bus, Auto rickshaw, CNG, etc.	Block:80 mm Sand Cushion One-layer BFS ISG	Good Condition

District: Narayanganj

Sl. No	Road Name	Upzilla	Block Road Length Km	Block Road Width m	Road/Roads Category	Dimension of blocks used in the road	Traffic Composition	Underlying layers of CC Block and with their thickness	Remark on Performance of the road
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
01	Kadomrasul road (T Hosen road to Regional office of City Corporation)	Bondor	1.5 km	10.00 m	Upazila Road	220x110x80 mm	Bus, Truck, Micro Bus, Auto rickshaw, CNG, etc.	Block:80 mm Sand Cushion One-layer BFS ISG:1.50 m	Good Condition

3.1.1. Field Visit Observations:

Under the field visit, relevant information of ICBP roads comprising their lengths, widths, block dimensions, classifications based on location and vehicular composition, underlying layers thickness and overall condition were collected. Most of the roads assessed were village roads. The roads covered under Dhaka district are still under construction. Overall, all the roads exhibited satisfactory performance without any noticeable loss in joint sand, uneven joint widths, corner chipping, cracked paving units, settlements/depression, rutting, etc. However, road no. 2 under Khulna district developed larger joint width right at the middle of the roadway (i.e., > 3 mm-4mm) mainly due to the movement heavy traffic loads that were not covered under the design consideration and the presence of canal at the left side of the road might be responsible for the displacement of underlying layers, resulting in the unintended dislocations of the ICBP units.

In the end, it was observed that almost all the paving units used in the construction of roadways were free from cracks or other types of deformities, indicating their quality and ability to accommodate the intended traffic volumes.

3.2. Location(s) to Collect Dredging Sand for the Fabrication of ICBP:

Sand collected from the locations stated below were taken into the laboratory and sample ICBPs were prepared by conforming to the compressive strength and other factors stated in the national/international literatures which were thoroughly reviewed prior to the actual fabrication and testing of the specimens. The chosen sites for the collection of dredged sand are provided below:

- Pakshi Sand: Pakshi, IshwardiUpazila, Pabna District, Rajshahi Division
- Jamuna Sand: Tangail District, Dhaka Division.
- Tista Sand: Tista River, Rangpur Division, Rajshahi
- Brahmaputra Sand: Brahmaputra river, Muktagacha, Mymensingh, Mymensingh Division. (Sand from this location is selected instead of Paira river sand due to Paira river sand having low F.M. resulting in ICBP of lower than the required strength of 30-35 Mpa).
- Meghna River Sand: Chandpur District, Chattogram Division

As per the local experience of the engineering professionals, sands collected from each of the aforementioned location are expected to have Fineness Modulus (F.M.) of 1.0 or more.

So, it is anticipated that they could be suitable for the production of desired ICBP paving units after the adjustment of their composition in the concrete mixture along with the addition of some other additives (if applicable). But their actual characteristics could only be unveiled after through laboratory experiments conducted by HBRI.

For this particular venture, dredging sand from Shunamganj, Sylhet would be ignored as a primary constituent in the preparation and testing of paving blocks because it has considerably high F.M. and regarded as local sand. However, it is to be treated as one of the admixtures to enhance the features of the dredged materials under the study when required.

A sample questionnaire in tabular form was mailed to the respective LGED authority under each district to preliminarily assess the condition of sand and village road under each location.

Table 4: Sample Questionnaire for Sand Related Information from Technical Authority at Each District

Questionnaire	District Name			
	Khulna	Dhaka	Gazipur	Narayanganj
1. What type of sand is present at the particular district?	Fine sand	Fine sand	Fine sand	Fine sand
2. What is the sand's expected F.M.?	Garai& Padma River Sand FM:1.20 Chunkuri ,Vodra&Pasur River Sand FM:1.50	0.80	0.80	1.20
3. What is the length of the Earthen Work under the District?	2499 km	3590 km	3766 km	1473 km
4. How Many Villages are under the District?	1106	1999	1146	1374
5. What are the Names of the Villages	Chunkuri,Bajua, khotakhali	kornapara	Mirdhabari, Bottala, Board Bazar	Kabilermor & Latif Hajirmor

6. Name of the river(s) from which this sand is collected.	Garai, Padma, Chunkuri,Vodra,Pasur	Meghna River, Monshigonj	Meghna River, Monshigonj&Shitalakshya River	Jamuna River
7. Name of the sand selling market/center	Chalna, Dacope.	Kornaparaghat	Kaligonj, Ashulia	Voyapur

3.3. Existing Researches of HBRI:

A list of existing researches of HBRI regarding the fabrication and performance of varieties of brick alternatives are provided below chiefly to demonstrate HBRI's experience in this specific field. Most of the experimental investigations stated below are still ongoing and their data, information and interpretation would be revealed to the external bodies after the successful completion of the projects.

a) Verification survey with the private sector for disseminating Japan Technologies for non-fired solidification brick manufacturing process.
b) Effect of sand from different locations on the properties of sand cement solid block.
c) Development of Sustainable Non-Fired Geo Polymer Brick Using Local Geo-Resources.
d) Investigation of change in AAC block property with different parameter adjustments & influence of textile slug on sand cement block strength
e) Investigating the effect of chemical admixture on the quality of sand cement block in green building construction sector of Bangladesh.
f) Possibility of using alternative sustainable aggregate from sand cement solid block as a replacement of stone and brick aggregate.
g) Effect of Acidic Environment on Sand Cement Solid Block
h) Effect of coal tar on mechanical properties of non-fire block.
i) Effect of high range water reducing admixture along with early strength admixture on the compressive strength on sand cement solid block
j) High strength block using recycled coarse aggregates as alkali activator blast furnace slug.
k) The influence of hardening cogent on properties of AAC block.
l) Development of light weight concrete block with EPS.
m) Geo-polymer concrete block as a new type of sustainable green building materials.
n) Effective Replacement of Cement by Ceramic Waste and Blast Furnace Slag for Establishing Sustainable Concrete Block.

3.4. Block Manufacturing Process:

A concrete block is primarily used as a building material in the construction of walls and in upper layers of a road. A concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site. Most concrete blocks have one or more hollow cavities, and their sides may be cast smooth or with a design.

3.4.1. Raw Materials:

The Concrete commonly used to make Concrete Block is a mixture of Cement, Sand, Gravel or stone chips and Water. This produces a light gray block with a fine surface texture and a high compressive strength. In general, the concrete mixture used for blocks has a higher percentage of sand and a lower percentage of gravel and water than the concrete mixtures used for general construction purposes. This produces a very dry, stiff mixture that holds its shape when it is removed from the block mold.

In addition to the basic components, the concrete mixture used to make blocks may also contain various chemicals, called admixtures, to alter curing time, increase compressive strength, or improve workability. The mixture may have pigments added to give the blocks a uniform color throughout, or the surface of the blocks may be coated with a baked-on glaze to give a decorative effect or to provide protection against chemical attack. The glazes are usually made with a thermosetting resinous binder, silica sand, and color pigments.

Here we will make ICBP blocks of required strength i.e. 30 and 35 Mpa by using different river sands. As Bangladesh has very little stone to use, we will try to do it without mixing stone or gravel chips. So, our ingredients will be Cement, Dredging Sand from different rivers having F. M-1.0, Sylhet Sand of F. M-2.5, Super Plasticizer and Water. Here, we will use High Density Water Reducing Super plasticizer-234 @ 200 ml. and Accelerating and Early Strength gaining admixture X7 @ 400 ml per bag of cement. Water/Cement Ratio will be 0.26-0.30. Two Ratio of a) Cement: Dredged Sand (F. M-1.0): Sylhet Sand (F. M-2.5) = 1:1.5:1.5 and b) Cement: Dredged Sand (F. M-1.0): Sylhet Sand (F.M-2.5) = 1:1.25:1.25 by weight would be tested for different rivers sand.

3.4.2. Method:

The production of concrete blocks consists of four basic processes: mixing, molding and curing. Some manufacturing plants produce only concrete blocks, while others may produce a wide variety of precast concrete products including blocks, flat paver stones, and decorative landscaping pieces such as lawn edging. There are different types of plants; Automatic, Semi-Automatic etc. Some plants are capable of producing 2,000 or more blocks per hour depending on the size and shape of the block and also it depends on the mold size.

The following steps are commonly used to manufacture concrete blocks.

3.4.3. Mixing:

- The sand are stored outside in piles and are transferred into storage bins in the plant by a conveyor belt or mechanically as they are needed. The portland cement is stored outside in large vertical silos to protect it from moisture.
- As a production run starts, the required amounts of sand and cement are transferred by gravity or by mechanical means to a weigh batcher which measures the proper amounts of each material.
- The dry materials then flow into a stationary mixer where they are blended together for several minutes. There are two types of mixers commonly used. One type, called a planetary or pan mixer, resembles a shallow pan with a lid. Mixing blades are attached to a vertical rotating shaft inside the mixer. The other type is called a horizontal drum mixer. It resembles a coffee can turn on its side and has mixing blades attached to a horizontal rotating shaft inside the mixer.
- After the dry materials are blended, a small amount of water is added to the mixer. If the plant is located in a climate subject to temperature extremes, the water may first pass through a heater or chiller to regulate its temperature. Admixture chemicals and coloring pigments may also be added at this time. The concrete is then mixed for six to eight minutes.

3.4.4. Molding:

- Once the load of concrete is thoroughly mixed, it is dumped into an inclined bucket conveyor and transported to an elevated hopper. The mixing cycle begins again for the next load.
- From the hopper the concrete is conveyed to another hopper on top of the block machine at a measured flow rate. In the block machine, the concrete is forced downward into molds. The molds consist of an outer mold box containing several mold liners. The liners determine the outer shape of the block and the inner shape of the block cavities. As many as 15 blocks may be molded at one time.
- When the molds are full, the concrete is compacted by the weight of the upper mold head coming down on the mold cavities. This compaction may be supplemented by air or hydraulic pressure cylinders acting on the mold head. Most block machines also use a short burst of mechanical vibration to further aid compaction.
- The compacted blocks are pushed down and out of the molds onto a flat steel pallet. The pallet and blocks are pushed out of the machine and onto a chain conveyor. In some operations the blocks then pass under a rotating brush which removes loose material from the top of the blocks.

3.4.5. Curing:

- The pallets of blocks are conveyed to an automated stacker or loader which places them in a curing rack. Each rack holds several no. of blocks. When a rack is full, it is rolled onto a set of rails and moved into a curing kiln.
- The kiln is an enclosed room with the capacity to hold several racks of blocks at a time. There are two basic types of curing kilns. The most common type is a low-pressure steam kiln. In this type, the blocks are held in the kiln for one to three hours at room temperature to allow them to harden slightly. Steam is then gradually introduced to raise the temperature at a controlled rate of not more than 16°C per hour. Standard weight blocks are usually cured at a temperature of 66-74°C. When the curing temperature has been reached, the steam is shut off, and the blocks are allowed to soak in the hot, moist air for 12-18 hours. After soaking, the blocks are dried by exhausting the moist air and further raising the temperature in the kiln. The whole curing cycle takes about 24 hours or curing is done at least 14 days in open air at stockyard and keep 3 days for drying.

3.4.6. Quality Control:

The manufacture of concrete blocks requires constant monitoring to produce blocks that have the required properties. The raw materials are weighed electronically before they are placed in the mixer. The trapped water content in the sand and gravel may be measured with ultrasonic sensors, and the amount of water to be added to the mix is to be adjusted.

As the blocks emerge from the block machine, their height may be checked with laser beam sensors. In the curing kiln, the temperatures, pressures, and cycle times are all controlled and recorded.

3.4.7. Conclusion:

The simple concrete block will continue to evolve as architects and block manufacturers develop new shapes and sizes. These new blocks promise to make construction faster and less expensive, as well as result in structures that are more durable and energy efficient.

3.5. 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), **Figure** . Then dented sides were introduced to blocks for better interlocking effects with their surrounding units Figure 3.2, 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 3.3) was introduced for better interlock. An improvement over A-Shape block was proposed (i.e. “X” shape, Figure 3.4) for additional interlocks and suitability for fully mechanized paving.

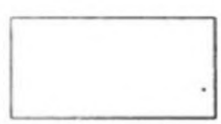


Figure 3.1: Plain Faced Rectangular Blocks

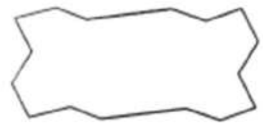


Figure 3.2: Dented Rectangular Blocks

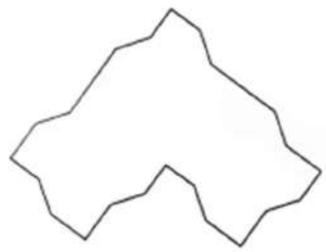


Figure 3.3: "A" Shaped Dented Block

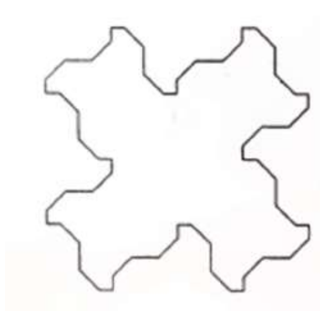


Figure 3.4: "X" Shaped Dented Block

Based on the above four shapes, blocks were further classified into three (03) Categories**(Figure 3.5)**:

- **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.

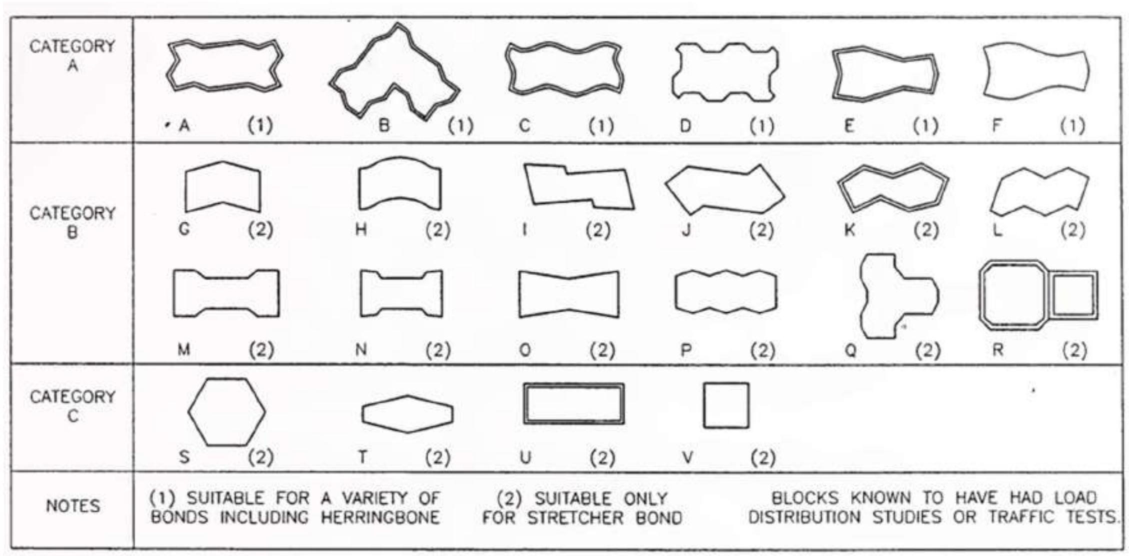


Figure 3.5: Different Categories of Blocks

To beautify the appearance of ICBP pavements, special grass blocks**(Figure 3.6)** are used which allow grass to grow in the hollow spaces in the blocks filled with soil.

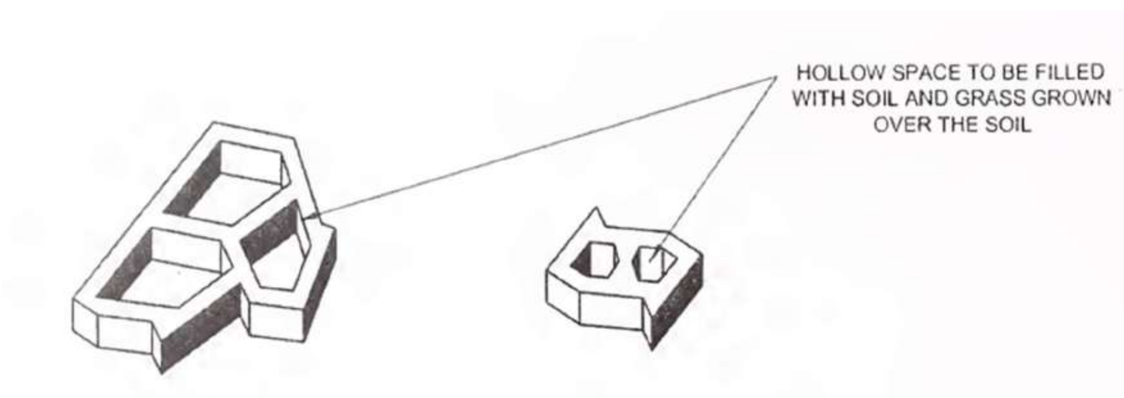


Figure 3.6: Typical Grass Blocks

3.6. 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.

3.7. 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 3.7** recommended to follow:

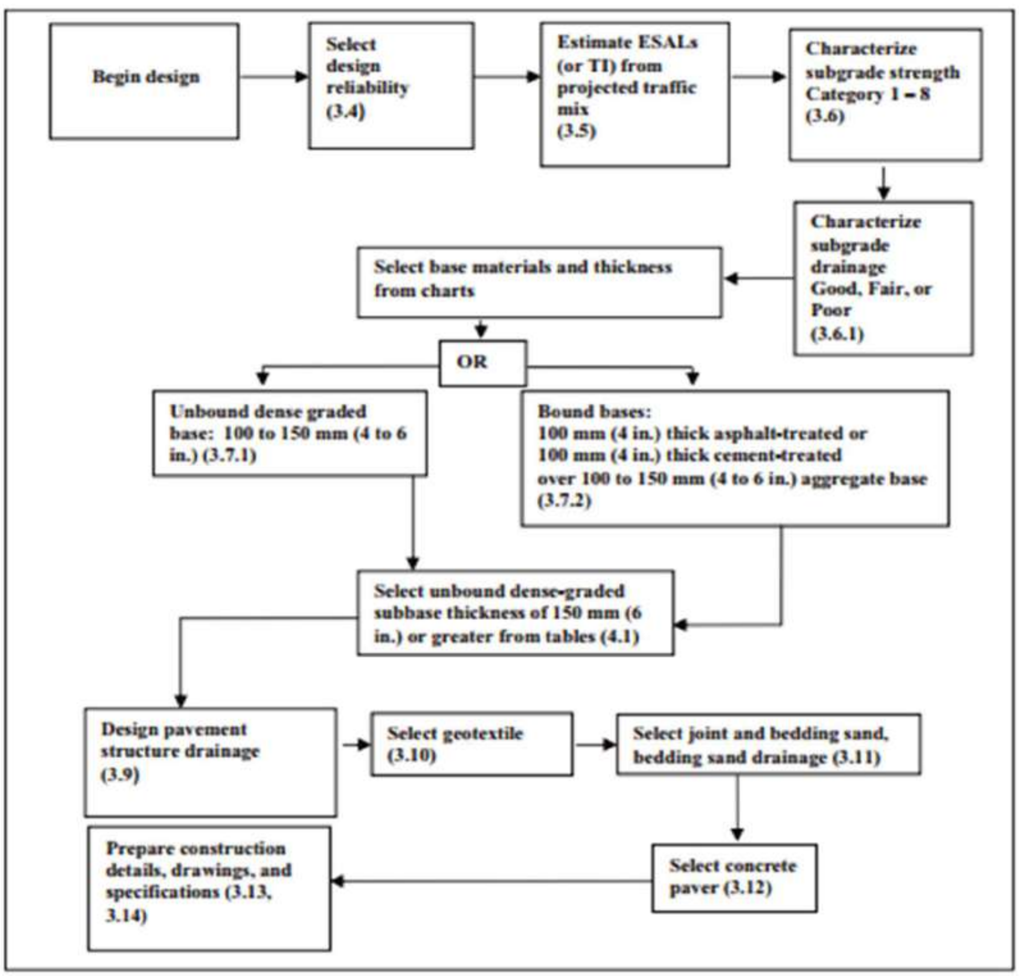


Figure 3.7: Design Process Flow Chart

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 5: 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	

<table>
<tr><th>Name of Institution/ Organization/ Manufacturer Provides Guidebook or Technical Bulletins</th><th>Dimension of Block and Strength Consideration</th><th>Structural Design on the Basis of Subgrade CBR and Drainage</th><th>Application Area, Street, Sidewalk, etc.</th><th>Traffic Load for Design of Pavement</th><th>Remark</th></tr>
<tr><td>UNILOCK Design Considerations for Interlocking Concrete Pavement</td><td>Three thickness considered
Light Traffic=60 mm</td><td>Poor subgrades needs to be modified to stabilized in bringing it to minimum CBR of 5.</td><td>• Streets
• Industrial Parking Areas
• Container and Multimodal facilities
• Airport Taxiway and aprons</td><td>Parking area</td><td></td></tr>
<tr><td>Cement and Concrete Association of New Zealand and New Zealand Concrete Masonry Association Inc.
Book: Interlocking Concrete Block Road Pavements</td><td>Maximum (horizontal) plan dimension=250 mm
Minimum thickness=60 mm
Manufactured thickness are 60 mm, 80 mm and 100 mm.</td><td>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
<table><tr><th>Classifications</th><th>CBR</th></tr><tr><td>Weak</td><td>4</td></tr><tr><td>Medium</td><td>7</td></tr><tr><td>Strong</td><td>15</td></tr></table></td><td>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</td><td>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.</td><td></td></tr>
</table>

3.7.1. 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.

3.8. 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.

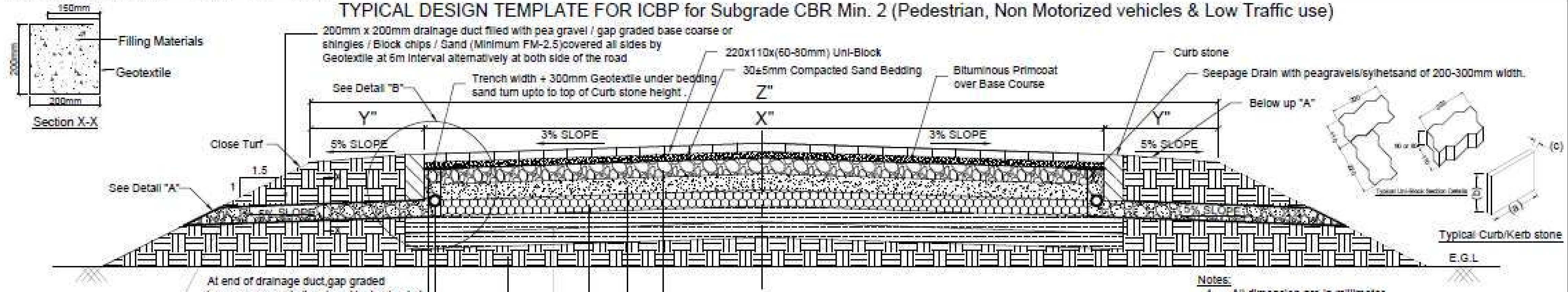
The consultant provided design template (s) for poor subgrade consisting of (1) silt (silted fine sand greater than 60%) and (2) clay after reviewing the booklet of UNIBLOCK design consideration for Interlocking concrete blocks pavements.

Table 6: 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)

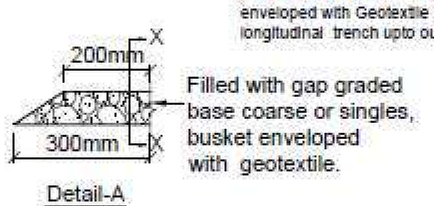
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

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.

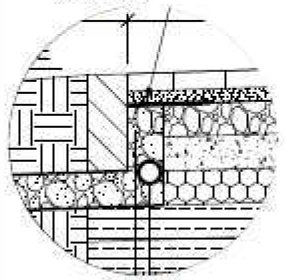
TYPICAL X-Section

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"

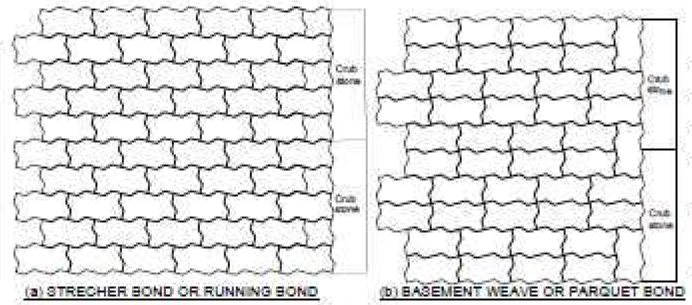


Detail-A



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 "

Typical Design template for ICPB

Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm) ISG	Layer Thickness(mm) Sub-Base	Layer Thickness(mm) Base	Layer Thickness(mm) Sand Bedding (±5mm)	Thickness(mm)/Strength(Mpa) Concrete Block(CB)	Thickness(mm)/Strength(Mpa) 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	

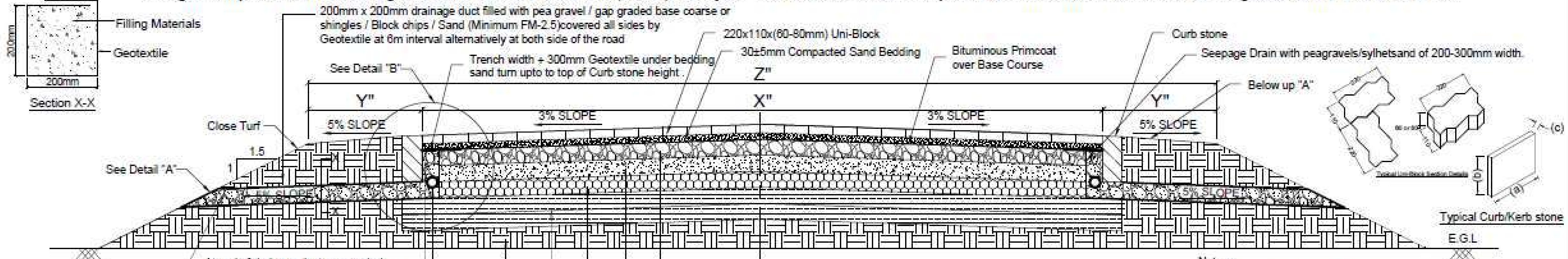
"*** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

Sieve Size	Base Material Gradation	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 3.1: 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)

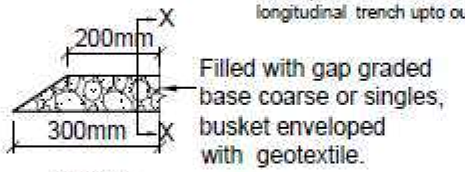
Sub-Base: (...........mm)* Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min.30%,Compacted to 98% of MDD (Modified Proctor)

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)

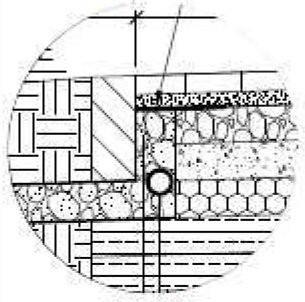
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

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

Sieve Size	Gap graded coarse material (Block/Brick chips) Drainage Materials for Trench Percent Passing(%)
50 mm	100
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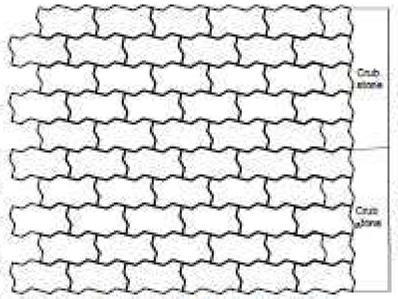
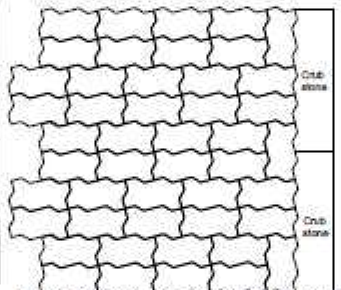


(a) STRECHER BOND OR RUNNING BOND



(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

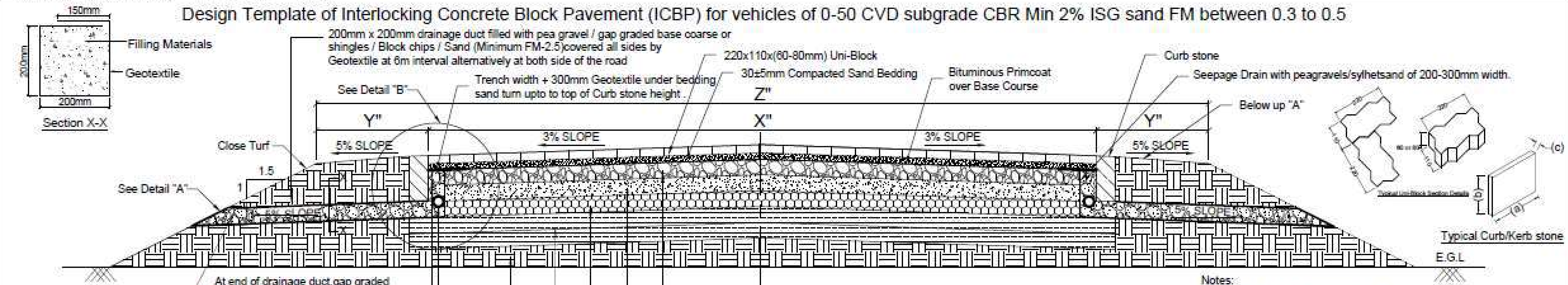
Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm) ISG	Layer Thickness(mm) Sub-Base	Layer Thickness(mm) Base	Layer Thickness(mm) Sand Bedding (±5mm)	Thickness(mm)/Strength(Mpa) Concrete Block(CB)	Thickness(mm)/Strength(Mpa) Curb/Kerb Stone *	Probable Curb/Karb stone sizes (a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

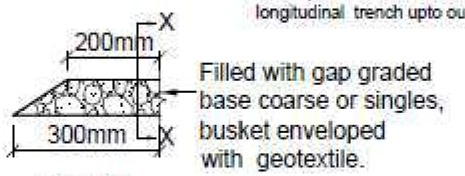
Sieve Size	Bedding Sand Gradation Percent Passing(%)	Joint Filling Sand Gradation Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 3.2: Design Template of Interlocking Concrete Block Pavement (ICBP) for Cycle Tracks, Pedestrian Footpaths Non-Motorized Vehicles on Subgrade of Minimum CBR 2%

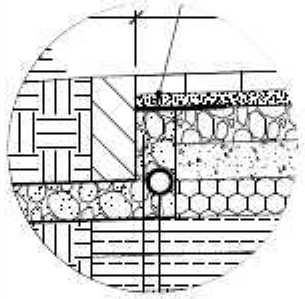
Design Template of Interlocking Concrete Block Pavement (ICBP) for vehicles of 0-50 CVD subgrade CBR Min 2% ISG sand FM between 0.3 to 0.5



TYPICAL X-Section

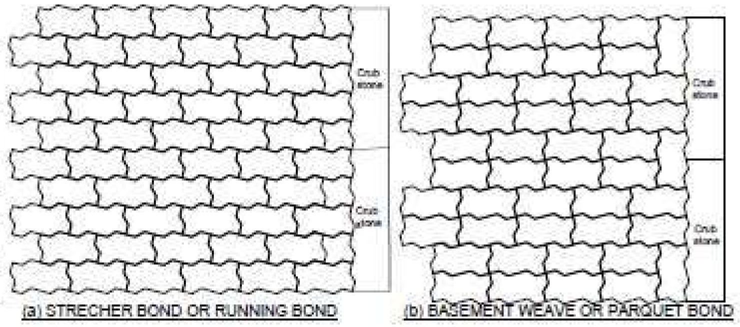


Detail-A



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)				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	

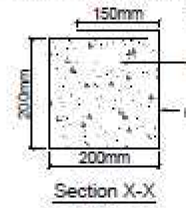
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

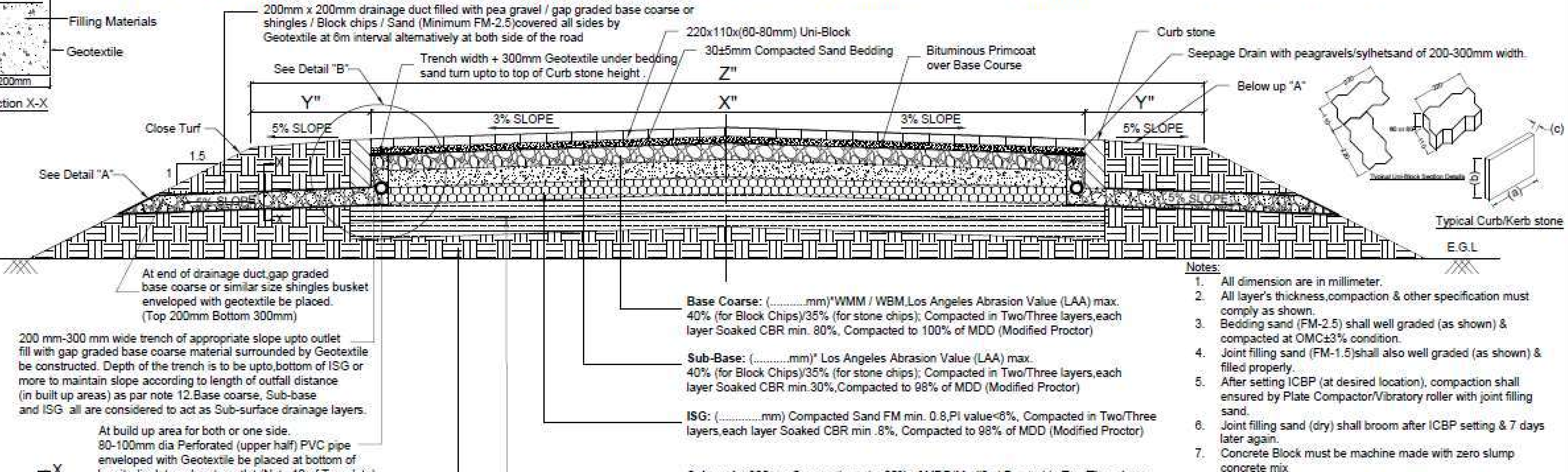
Sieve Size	Base Material Gradation	Sub-base material Gradation
	Percent Passing(%)	Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

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

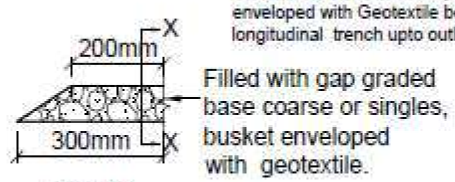
Figure 3.3: Design Template of Interlocking Concrete Block Pavement (ICBP) for vehicles of 0-50 CVD Subgrade CBR Minimum 2% ISG sand FM between 0.3-0.5

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

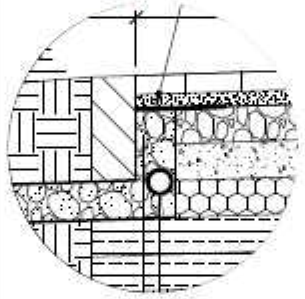




TYPICAL X-Section

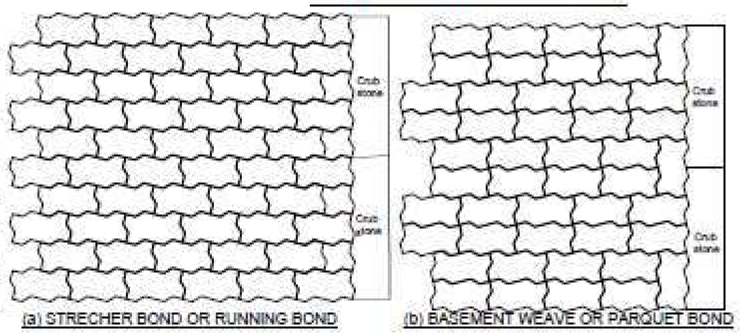


Detail-A



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



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	

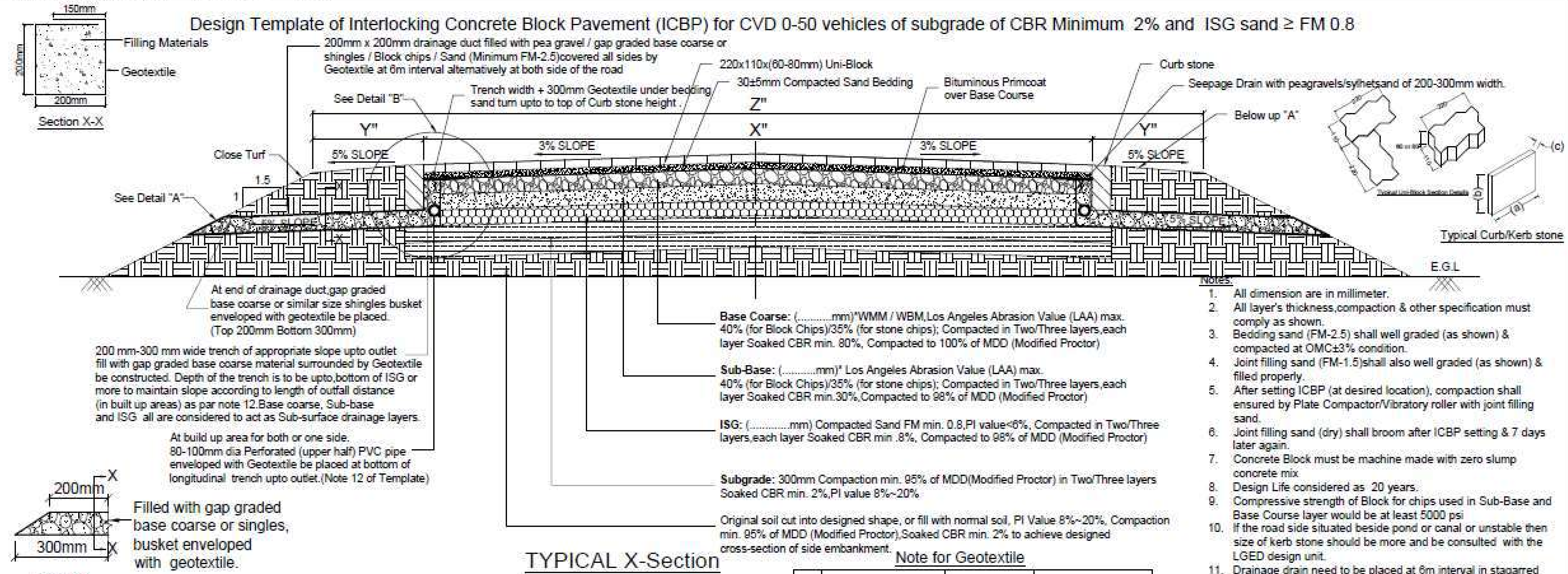
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

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

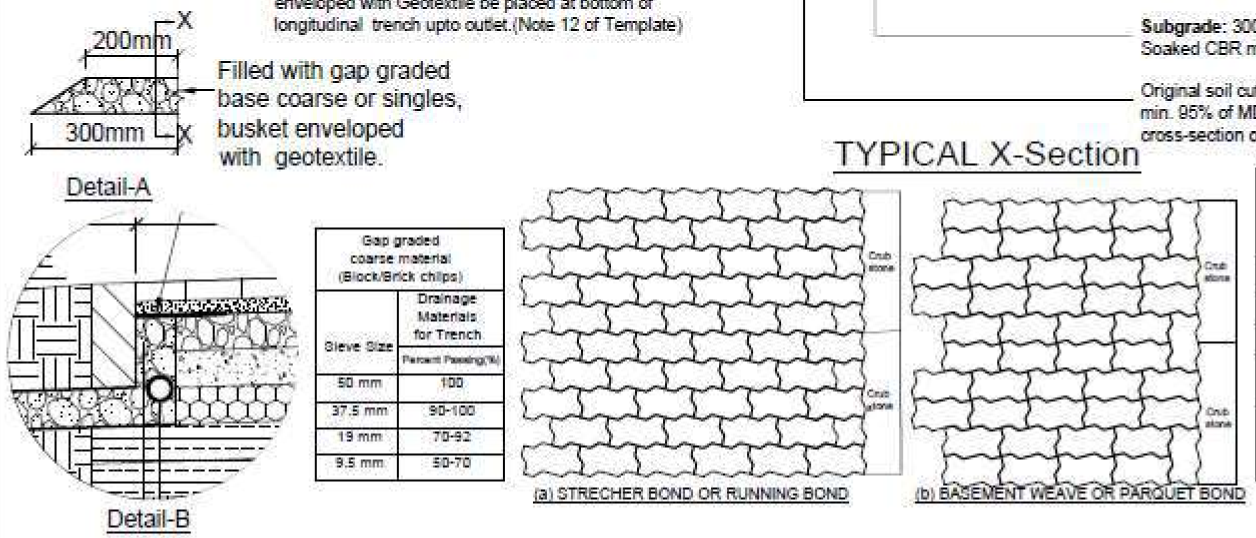
Figure 3.4: Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 0-50 considering subgrade of CBR minimum 2%and ISG sand FM between 0.5-0.8

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



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"



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

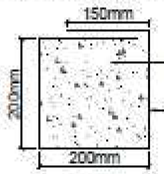
Sl No.	Road Type of Traffic	FM of Local sand used for ISG	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c) *	Remarks
			ISG	Sub-Base	Base	Sand Bedding (±5mm)	Concrete Block(CB)	Curb/Kerb Stone *		
01	Low Traffic Road for CVD 0-50	FM ≥ 0.8	200	200	150	30	80/35	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	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

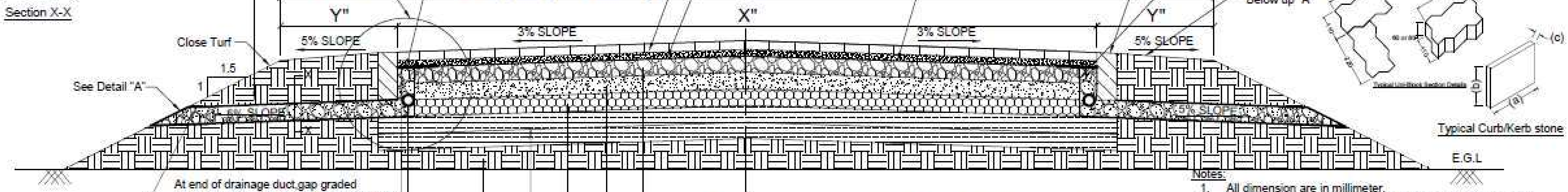
Sieve Size	Bedding Sand Gradation	Joint Filling Sand Gradation
	Percent Passing(%)	Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

Figure 3.5: 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



Section X-X



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)

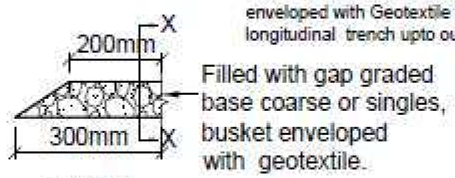
Base Coarse: (..........mm)*WMM / WBM,Los Angeles Abrasion Value (LAA) max. 40% (for Block Chips)/35% (for stone chips); Compacted in Two/Three layers,each layer Soaked CBR min. 80%, Compacted to 100% of MDD (Modified Proctor)

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)

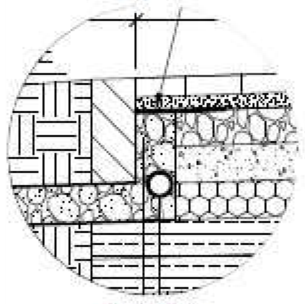
Subgrade: 300mm Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 2%,PI value 8%~20%

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

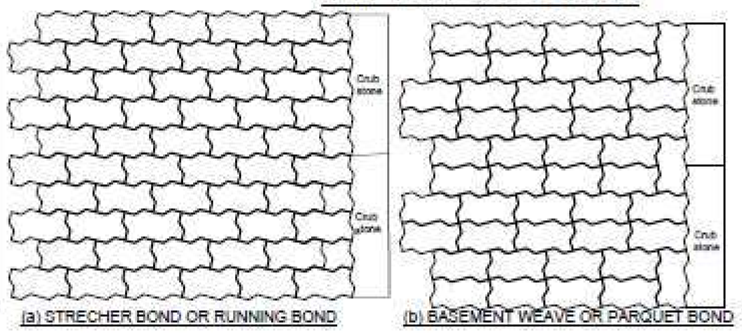


Detail-A

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	0.3 - 0.5	300	250	150	30	80/35	150/35	550 x 250 x150	

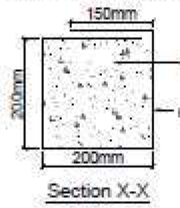
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

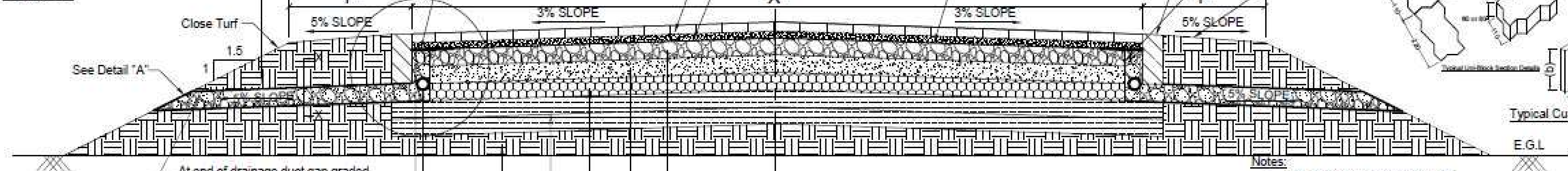
Sieve Size	Base Material Gradation	Sub-base material Gradation
	Percent Passing(%)	Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

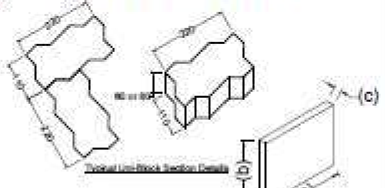
Sieve Size	Bedding Sand Gradation	Joint Filling Sand Gradation
	Percent Passing(%)	Percent Passing(%)
9.52 mm	100	-
4.75 mm	90-100	-
2.36 mm	80-100	100
1.18 mm	50-95	90-100
600 micron	25-60	60-90
300 micron	10-30	30-60
150 micron	0-15	15-30
75 micron	0-10	0-10

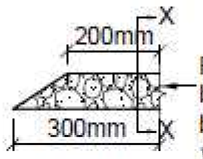
Figure 3.6: Design Template of Interlocking Concrete Block Pavement (ICBP) for vehicles of 51-100 CVD subgrade CBR minimum 2% ISG sand FM between 0.3 to 0.5

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







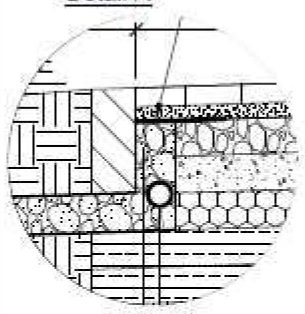


Detail-A

TYPICAL X-Section

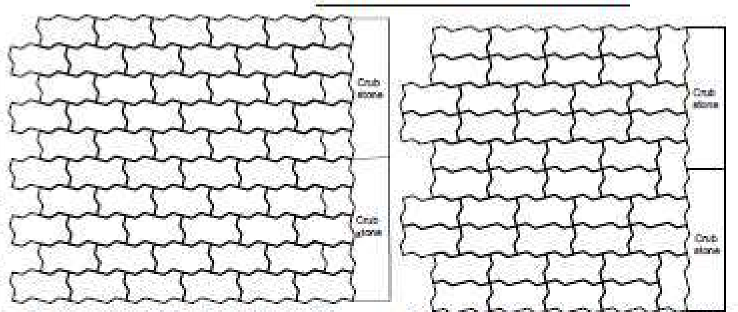
Notes:

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"



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 "

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 x 150	

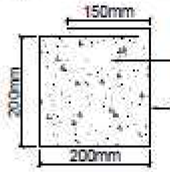
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm

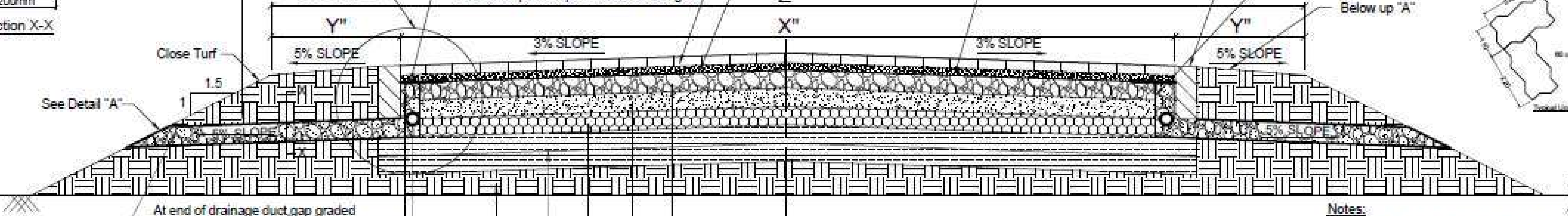
Sieve Size	Base Material Gradation	Sub-base material Gradation
	Percent Passing(%)	Percent Passing(%)
50 mm	100	100
37.5 mm	95-100	90-100
19.0 mm	70-92	-
9.5 mm	50-70	-
4.75 mm	35-55	30-60
600 micron	12-25	-
75 micron	0-8	0-12

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

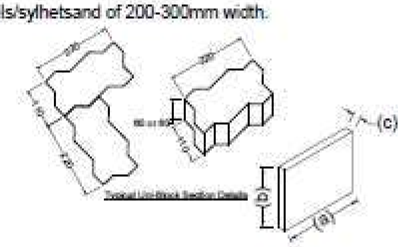
Figure 3.7:Design Template of Interlocking Concrete Block Pavement (ICBP) for CVD 51-100 on subgrade of minimum CBR 2% sand for between ISG FM 0.5 to 0.8

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

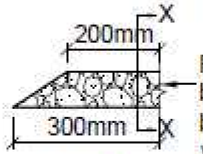




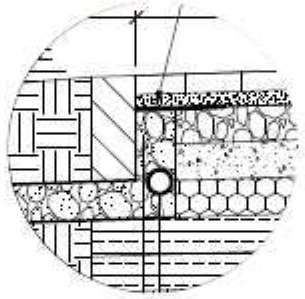
TYPICAL X-Section



Typical Curb/Kerb stone

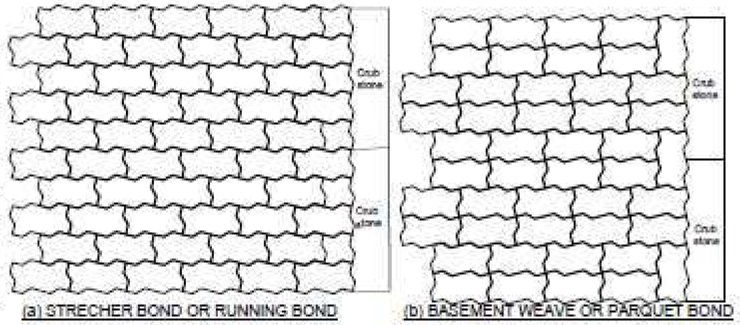


Detail-A



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)				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 3.8: 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.

3.9. 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.

4. Materials

4.1. General

ICB Pavements are considered for 3 categories of use (1) Cycle Tracks, Pedestrian Footpaths, non-motorized vehicles (2) Low traffic Road for CVD 0-50 and (3) Low Traffic Road for CVD 51-100. Accordingly, Pavement Structures materials are considered.

Improved sub-grade: For road structure the sand should be of FM minimum 0.8 PI value <6% and free of organize and dust. It should be perfect for compaction up to 98% of MOD (Modified Proctor) and soaked CBR minimum 8%.

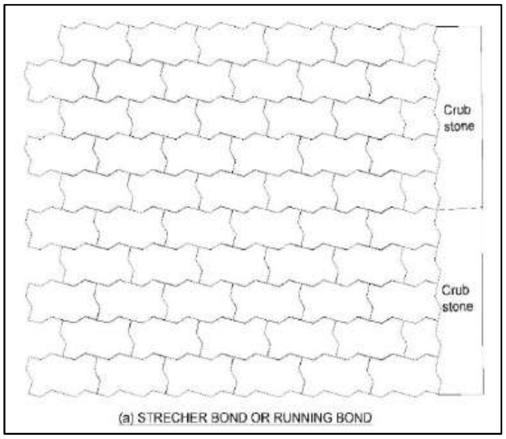
Sub- Base: Sub-Base material should have maximums Loss Angeles Abrasion value (LAA) 40% for Block or Bricks chips and 35% stone chips and minimum soaked CBR of Compacted to 98% of MDD (Modified Proctor) layer should be 30%.

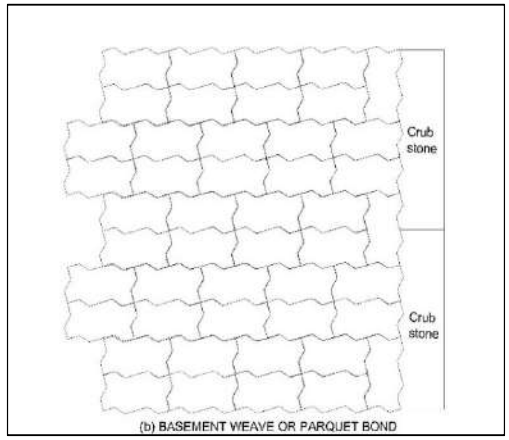
Base course: Base material or WMM or WBM should be preferably of stone chips. In lieu of stone chips Blocks or Bricks chips may be used. Maximum LOS Angeles Abrasion value (LAA) for stone chips is 35% and for Block and bricks 40% Socked CBR of Compacted 100% of MDD (Modified Proctor) layer minimum 80%

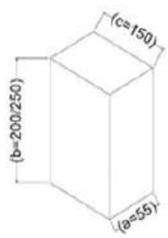
Gradation of Base and Sub-Base of Materials:

Sieve Size	Base Percent Passaging	Sub-Base Percent Passaging
50mm	100	100
37.5mm	95-100	90-100
19.0mm	70-92	-
9.5mm	50-70	-
4.75mm	35-55	30-60
600 micron	12-35	-
75 micron	0-8	0-12

Interlocking Paving Concrete Block and Edge curb stone:







Tvpical Curb/Kerb stone

Sand for Bedding and Joint Fillings:

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

4.2. Technical Specification of Admixture

To achieve required strength, manufacturers are using different brands of admixtures in Bangladesh. Technical specifications of some admixtures are shown below;

Brand	Technical Specification
MasterGlenium 51	1.Polycarboxylic ether based material. 2. Improves early and final compressive and flexural strength. 3. Improves mechanic properties like carbonation, resistance to chlorine ion attack, shrinkage & creeping. 4. Enables the production of low water/cement ratio, low segregation and leaching risk
MasterPolyheed 8650	1.Light brown free flowing fluid 2. Achieve high early strength 3. Optimize curing cycles by reducing curing time and curing temperature.
Conplast SP337	1. It is supplies as dark brown liquid, instantly dispersible in water. 2. Provides higher strength without increase in cement content or reduction in workability. 3. Improves durability and impermeability 4. Chloride free.
Conplast SP430	1.SulphonatedNapthalene Polymers and supplied as brown liquid, dispersible in water. 2. Provides high early strength and improved workability. 3. Risk of segregation and bleeding is less 4. Cohesion is improved due to dispersion of cement particles.

5. Implementation Manual

5.1. 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.

5.2. ICB Pavement Composition

Cross Section of pavement Composition is shown in Figures

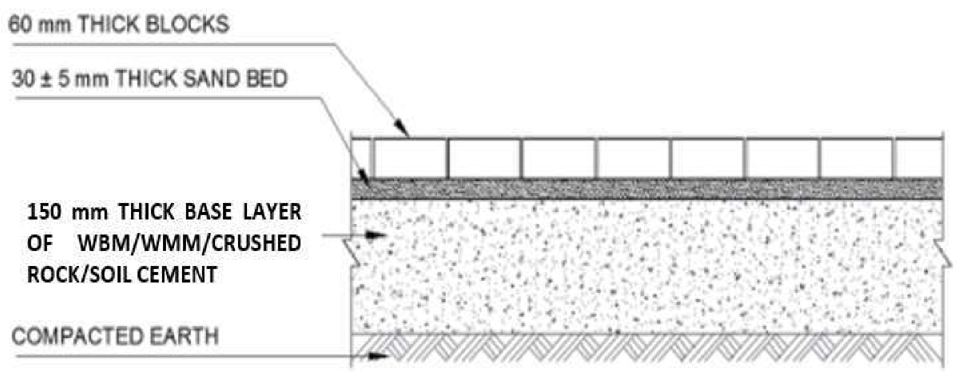


Figure 5.1: Typical Cross Section of Block Pavement used in Sidewalks /Footpaths/Car-parks /Cycle Tracks

5.3. 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)

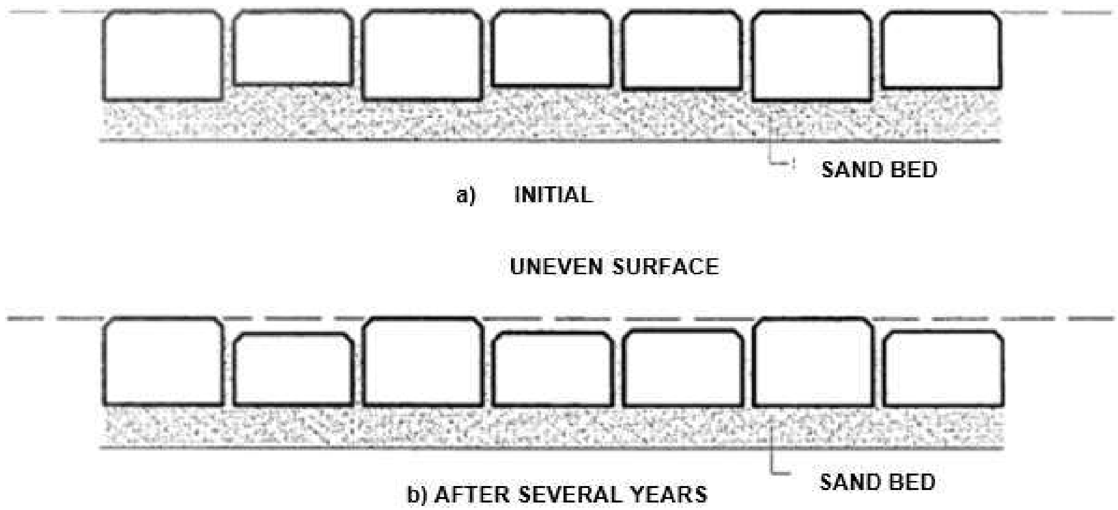


Figure 5.2: Effect of Thickness Variations in Paving Blocks

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.

5.4. 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.

5.5. 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.

5.6. 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.

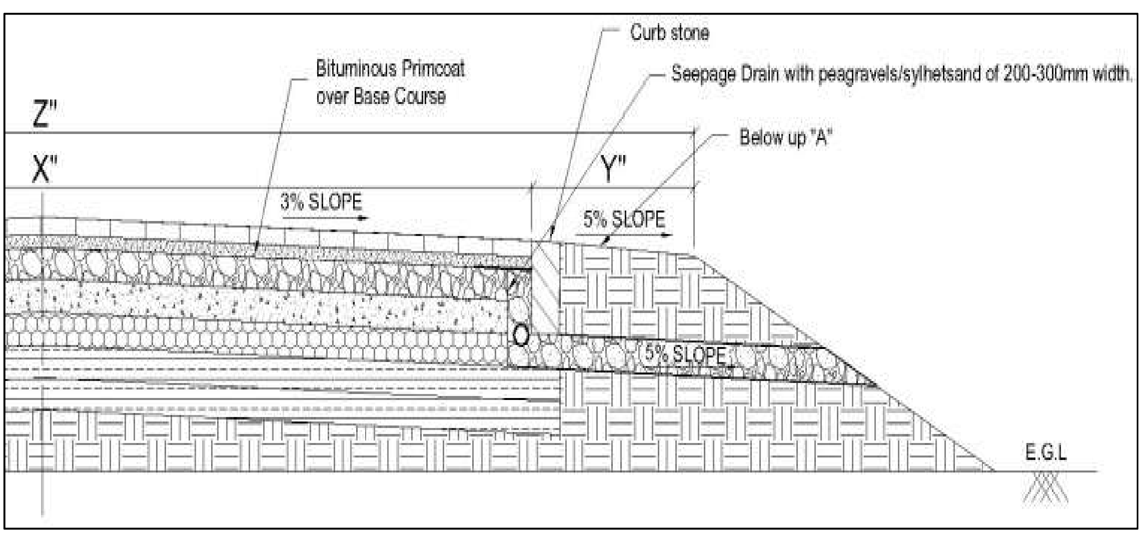


Figure 5.3: Edge Restraints

6. 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.

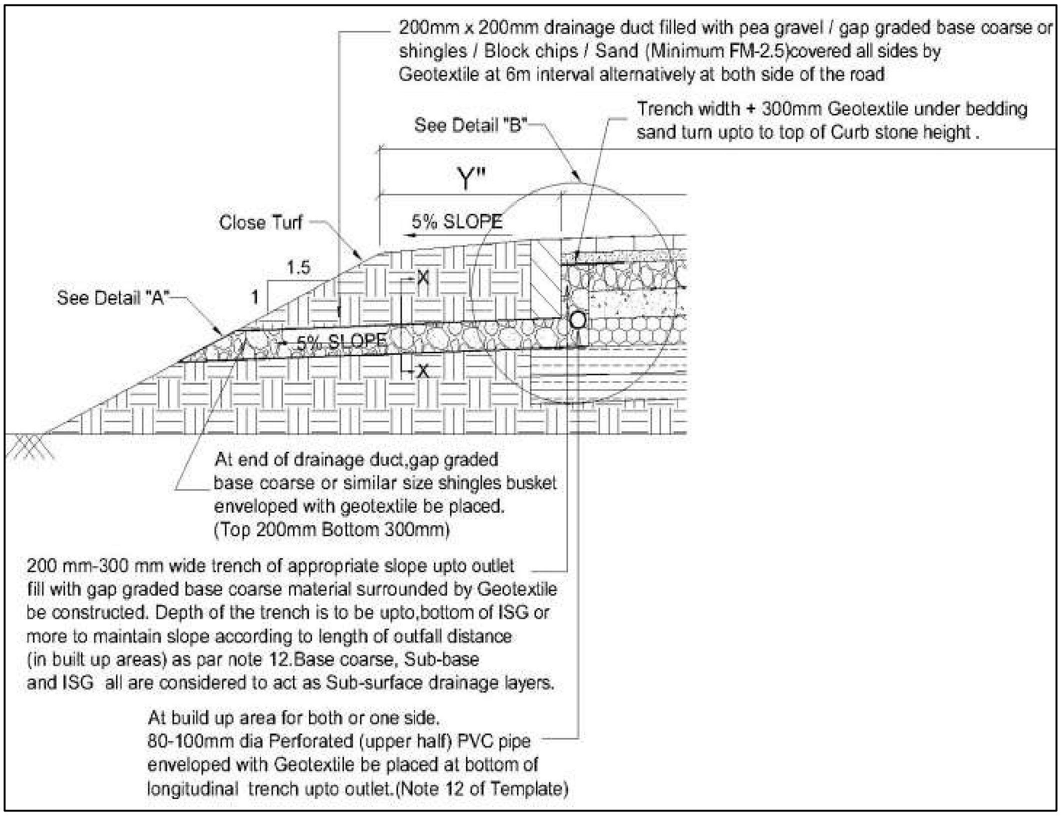


Figure 6.1: Sub Surface Drainage in a Block Pavement

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.

7. Construction

7.1. 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.

7.2. 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.

7.3. 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.

7.4. 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.

7.5. 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:

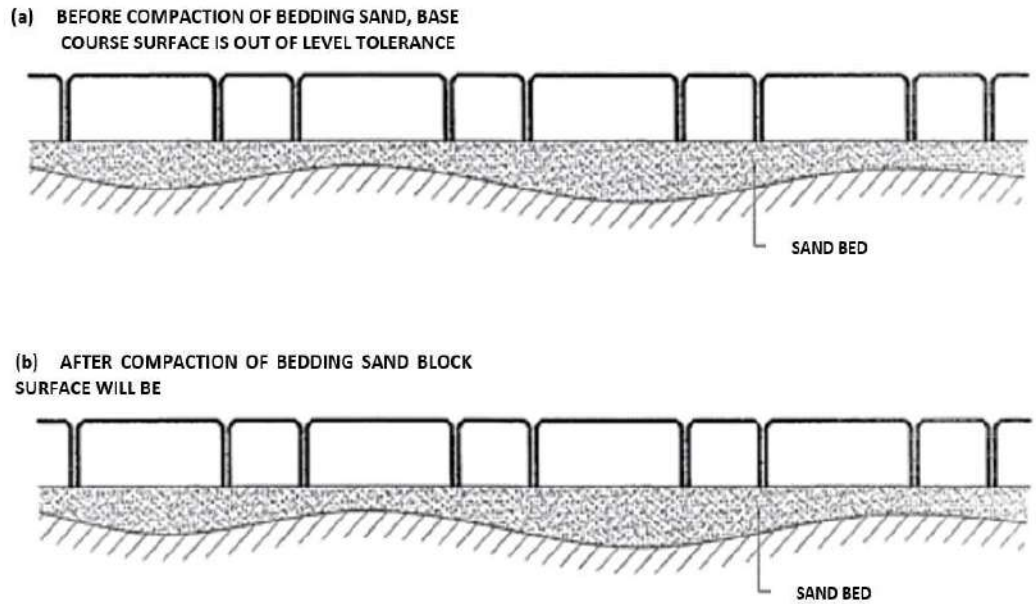


Figure 7.1: Effect of Base-Course Surface Shape on Bedding Sand and Block Surface Shape

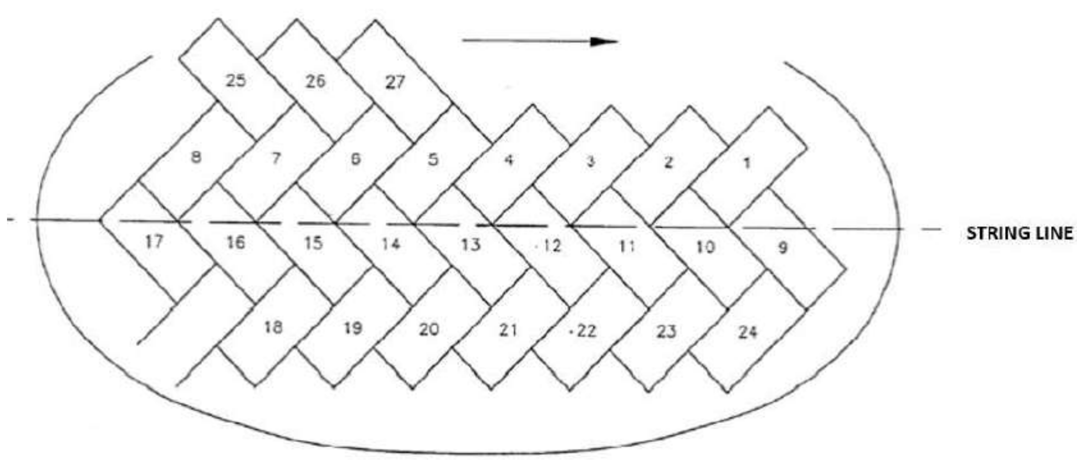


Figure 7.2: Starting at Irregular Shaped Edge Restraint

7.6. 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.

7.7. 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.

7.8. Methods of Construction of Block Pavement

7.8.1. 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.

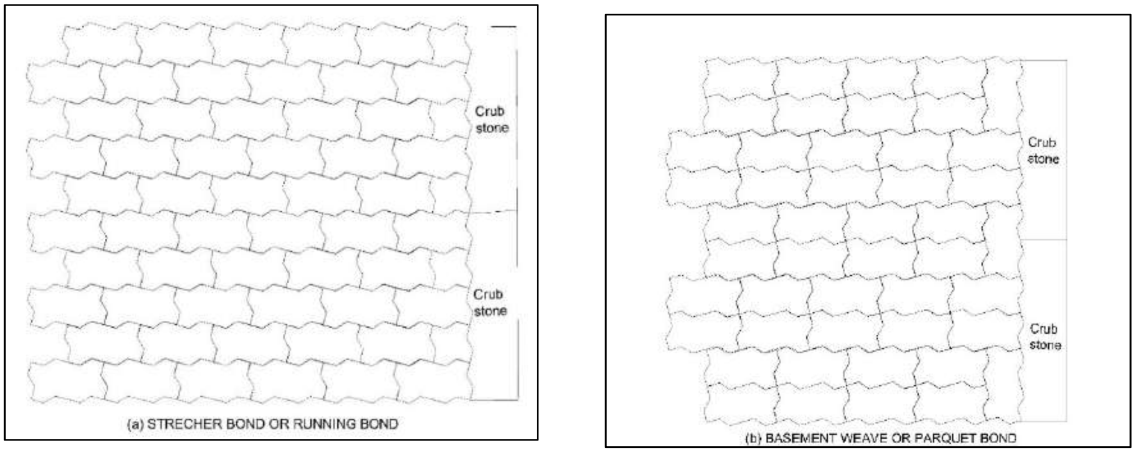


Figure 7.3: Typical Bond or Laying Pattern of Bond

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.

7.8.2. Mechanized Method:

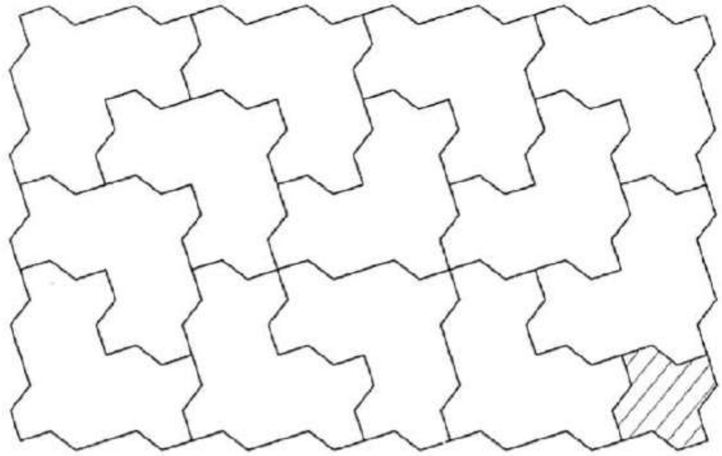
Mechanized laying requires the use of specialized equipment for transporting and placing clusters of paving blocks. The size of paving block cluster suitable for paving, is usually 0.3 to 0.5 m2 in area for hand-operated equipment. For fully mechanized equipment, the cluster surface area can be up to 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.

7.8.3. 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.



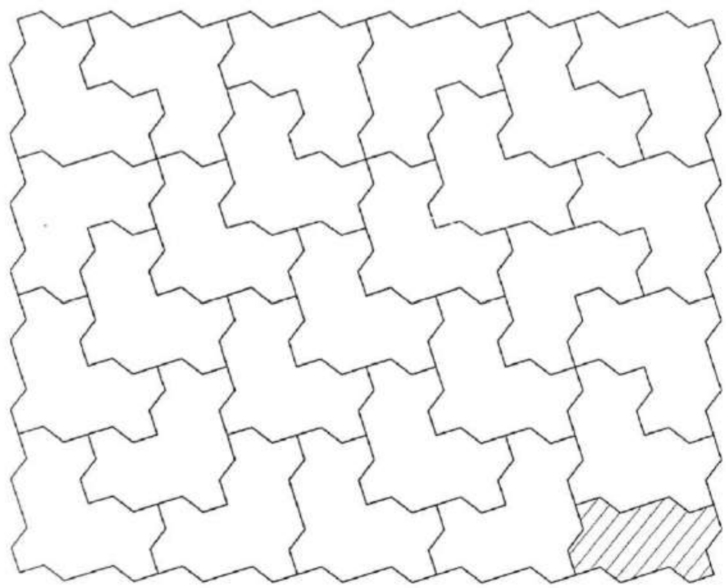


Figure 7.4: Typical Block Cluster in merchandised Laying

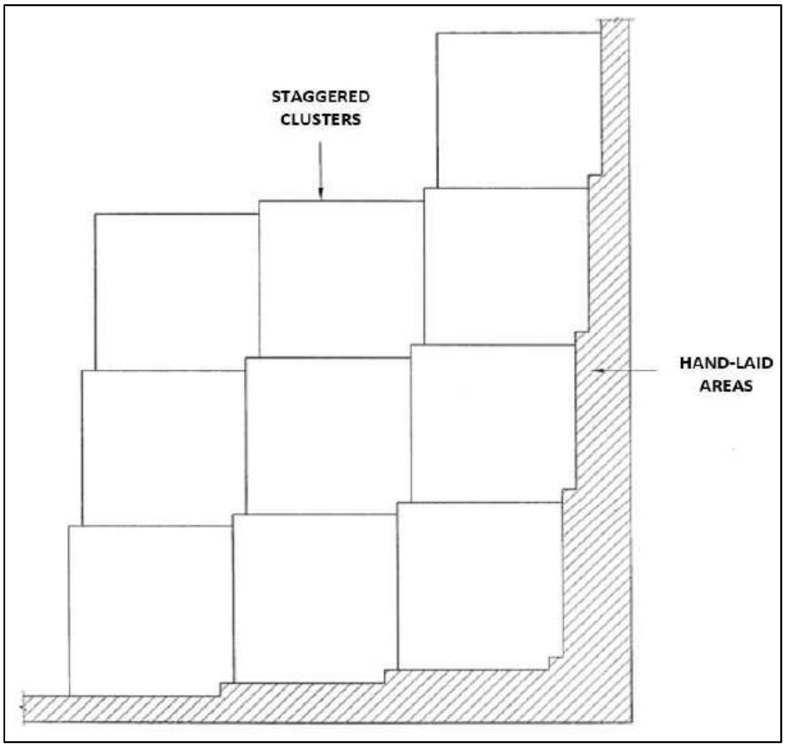


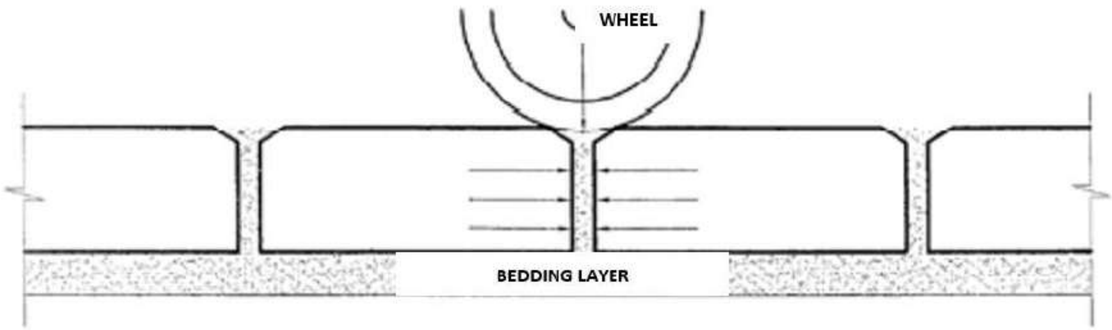
Figure 7.5: Staggered Installation of Block Clusters

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.

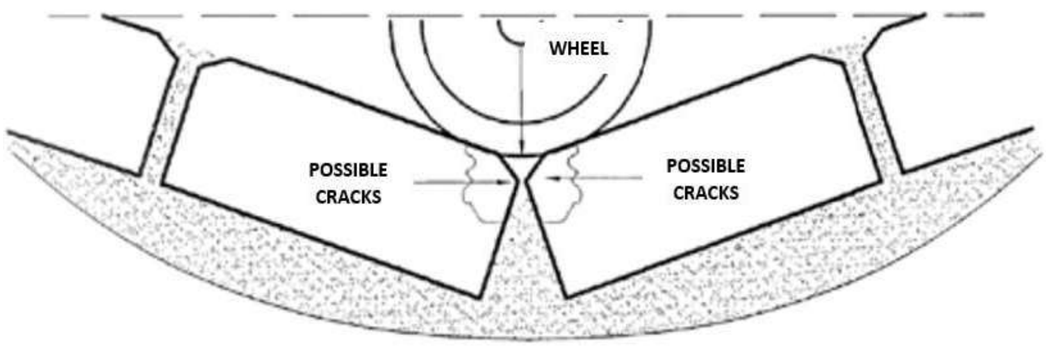
7.8.4. Joint filling

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 7.6: 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.

7.8.5. 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.

7.8.6. 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

7.8.7. 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.

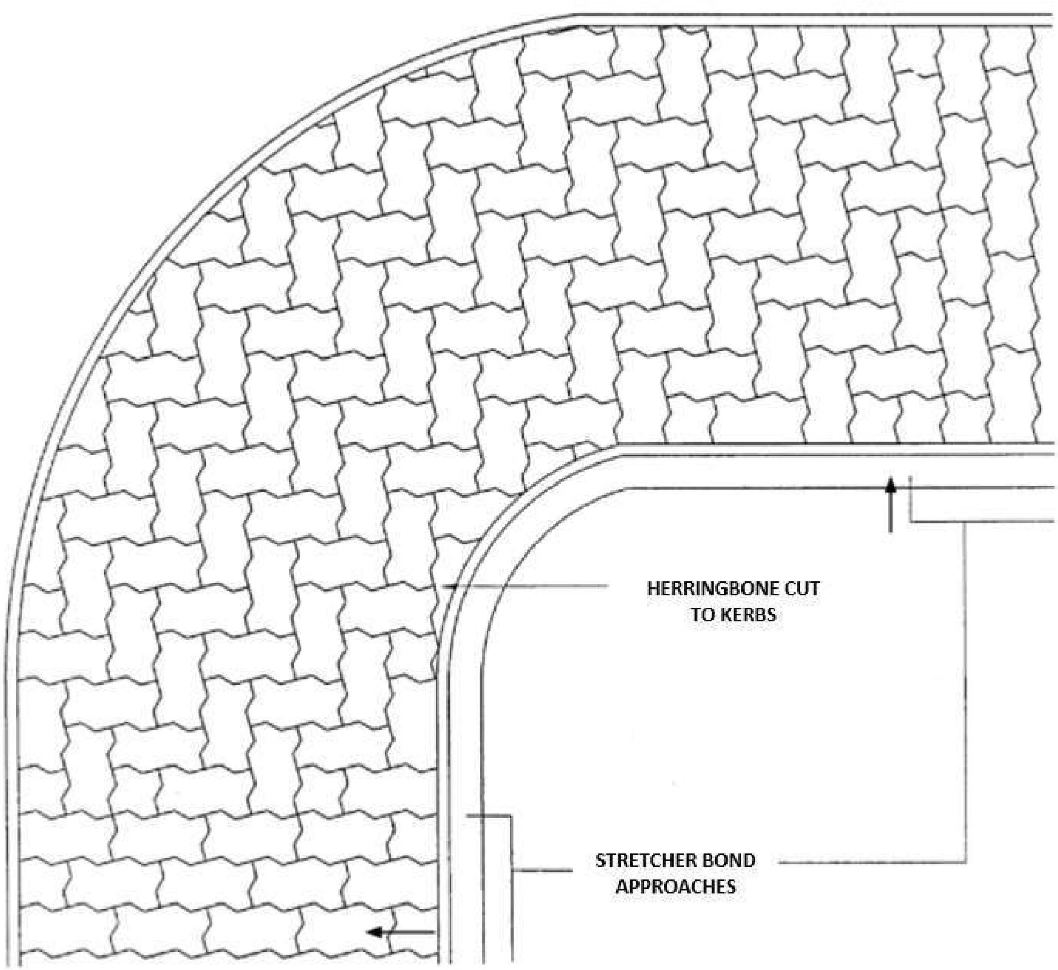


Figure 7.7: Curve in Herringbone Bond and Approaches in Stretcher Bond

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.

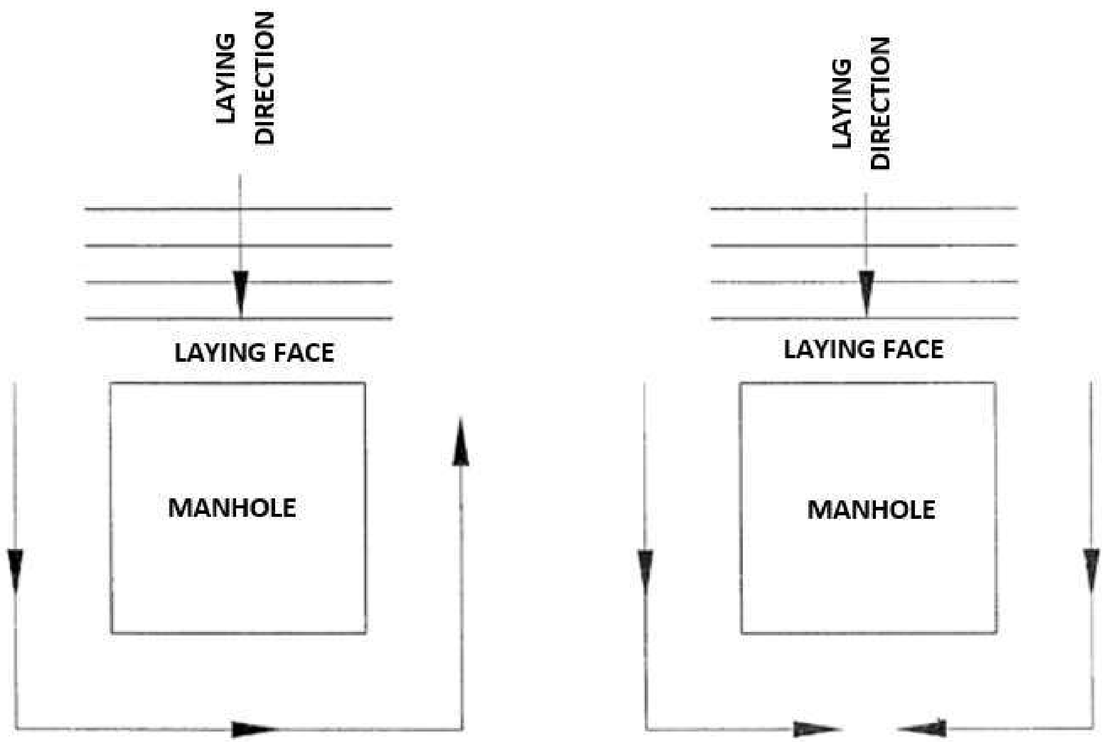


Figure 7.8: Laying Block Paving Around a Manhole

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.

7.9. Specifications

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

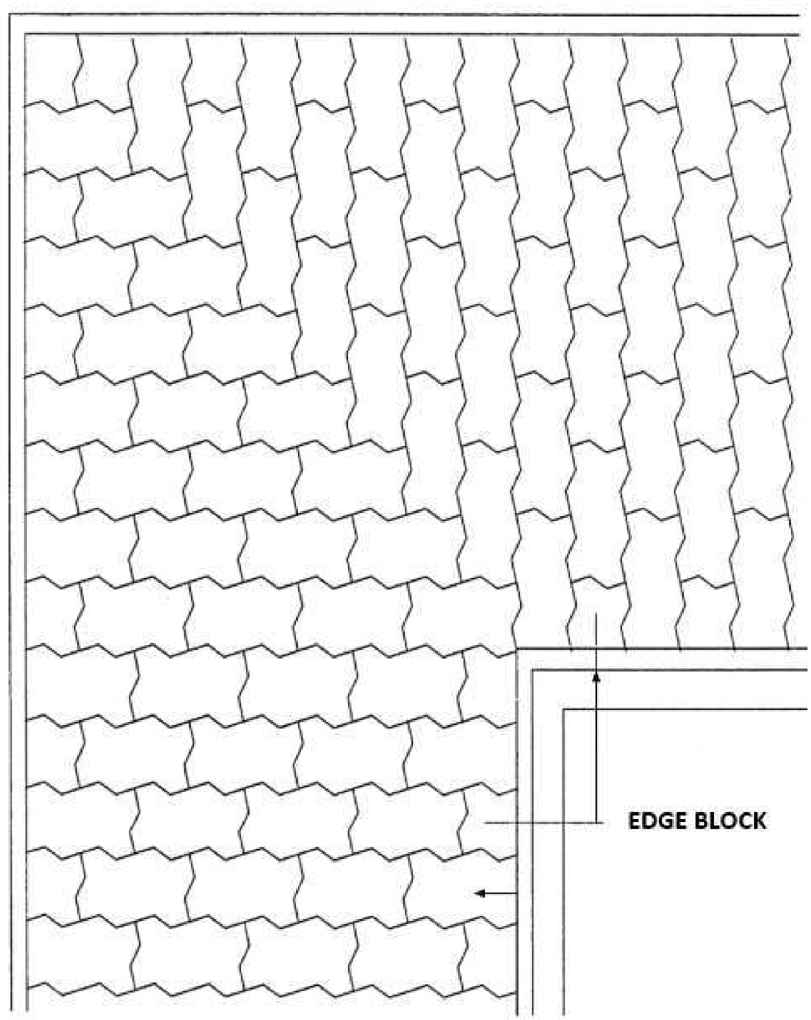


Figure 7.9: 90° Change in Alignment using Stretcher Bond

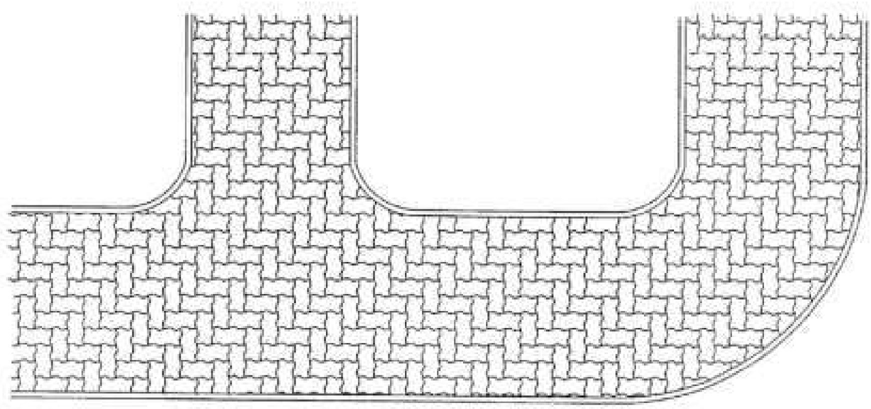


Figure 7.10: Adaptation of Herringbone Bond to Changes in Alignment

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

8. Maintenance

8.1. 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.

8.2. 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.

8.2.1. 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.

8.2.2. 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.

8.2.3. 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.

8.2.4. 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.

8.2.5. Shoulder & slope repair

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

8.3. 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.

8.4. 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.

9. Technical Specification

9.1.1. Base

The Finished surface of the concrete base shall match the design profile of the concrete blocks within ±10 mm.

Compaction shall be done with vibratory roller. In restricted areas where normal rollers cannot operate, hand-held or plate vibrators should be employed.

9.1.2. Bending Sand Layer

The bedding sand layer shall be from either a single source or blended to achieve the following grading.

Table 7: Grading of Bedding Sand Layer

IS Sieve Size	Percent Passing
9.52mm	100
4.75 mm	95-100
2.36mm	80-100
1.18mm	50-95
600 micron	25-60
300 micron	10-30
150 micron	0-15
75 micron	0-10

- Single sized, gap-graded sands or those containing an excessive amount of fines will not be used.
- The sand particles should preferably be angular type.
- The joint-filling sand should pass a 2.35 mm sieve and be well graded. The following grading is recommended:

Table 8: Grading of Joint-Filling Sand

Sieve Size	Percent Passing
2.36 mm	100
1.18mm	90-100

600 micron	60-90
300 micron	30-60
150 micron	15-30
75 micron	0-10

- The use of cement in the joint-filling sand is not recommended as a general practice as the cemented sand is likely to crack into segments which are easily dislodged.
- Average thickness of this laying course shall be 20 to40 mm.
- The sand should be slightly moist, and the moisture content shall be about 4 per cent by weight.
- It should contain no more than 3 per cent by weight of clay and silt and the materials shall be free from deleterious salts or contaminates.
- The finished surface of the bedding layer shall match exactly the design profile as indicated on the drawings
- Before placing the bedding layers, the surface of concrete should be cleared by sweeping.
- Walking or driving on the finished surface of the bedding layer shall not be permitted.

9.1.3. Concrete Paving Block

Laying of the blocks shall be done, precisely at the indicated level and profile and in a way that a good surface draining to the gulley chambers is assured.

Around gulley chambers and inspection pits the pavement shall have a level of 5 mm higher than the above mentioned elements.

The blocks shall be laid to the pattern directed by the Engineer or the pattern recommended by the designer. The blocks shall be laid as tight as possible to each other. The maximum joint width shall be limited to 4 mm.

Laying of broken blocks is not allowed except along connections or edges. The maximum length of a purpose broken block is 100 mm. Breaking of the blocks shall be done with a "block splitter" or a mechanical saw.

Fine angular sand as per specification shall be brushed into the joints, and thereafter compaction shall be done with a vibrating plate compactor on a clean surface. After compaction, again fine angular sand shall be brushed into the joints.

9.1.4. Surface Tolerance

Surface tolerance for finished surface shall be ±10 mm from the design level.

The surface tolerance for base course shall be in the range of O to +10 mm from nominated level and 10 mm deviation from a 3 m straight edge.

The surface tolerance for sub-base shall be within Oto -20 mm of nominated level.

9.2. Market rate of Some Recognized Manufacturers

Table 9: Cost of Fabricating ICBP by Some Recognized Manufacturers

Sl	Name & Address	Size	Materials	Strength In(psi)	Price
01	Mir Concrete Products Ltd. Basha No. B-147, Road 22, Mohakhali DOHS, Dhaka - 1206.	222x110x80mm	Cement, Sylhet Sand, Stone chips, Admixture	5000	22tk In Dhaka
02	Concord Ready Mix & Concrete Products Ltd. Concord Center, 43 North C/A, Gulshan 2, Dhaka - 1212	222x110x60mm	Cement, local Sand, Stone dust, stone chips, Admixture	2175-2900	20tk In Dhaka
		222x110x80mm	Cement, local Sand, Stone dust, Stone chips, Admixture	4500-5075	25tk In Dhaka
		222x110x100mm	Cement, local Sand, Stone dust, Stone chips, admixture	6500+	30tk In Dhaka
03	Block Tech Baraboo, Kanchan, Rup Ganj, Narayanganj.	222x110x80mm	Cement, Sylhet Sand, stone chips, Admixture	5000+	18tk In Dhaka
04	Master Concrete Block Manufacturing Company Corporate Office: Master Group, 50 Purana Paltan Lane (2nd Floor), Dhaka - 1000. Factory:Narayanpur, Belabo, Narshingdi.	222x110x80mm	Cement, Sylhet Sand, Stone chips, Admixture	5075	17tk In Dhaka
05	Sky View Concrete Products Ltd. Corporate Office: Sky View Trade Center 27, ShilpachariyaJoynulAbedin Road, (old 118/2), Shanti Nagar, Dhaka - 1217. Factory: Dorikandi, Murapara, Rupganj, Narayanganj. (beside Gazi Bridge)	222x110x80mm	Cement, Sylhet Sand, Stone chips, Admixture	5000	22tk In Dhaka

06	Ecoiit (ইকোইট) Corporate Office: Rasas 47, 2nd Floor, West Shibganj (Opposite of BakhtiarBibiGovt Primary School), Tamabil Road, Sylhet.	222x110x80mm	Cement, Sylhet Sand, Stone chips, Admixture	5800	17tk in Sylhet.
07	MS Ava Concrete Bricks & Blocks Wazirpur,barishal	222x110x80mm	Cement, Sylhet Sand, Stone chips, Admixture	5000+	20tk In Barisal
08	EcoCrete BD Ltd. Jamila Complex (2nd Floor), Dhaka Road, Shirajganj Road, Hatikumrul, Salanga, Sirajganj. Factory: Hatikumrul Bazar, Salanga, Sirajganj.	222x110x80mm	Cement, Sylhet Sand, Stone chips, Stone dust, Admixture	3500-5000	28 tk in Sirajganj

9.3 Rate Analysis of Sand-Cement ICBP Road (Paver Portion)

Table 10: Rate Analysis of Sand Cement ICBP Road (Paver Portion)

District: Tangail ,Dhaka ,Gazipur, Manikganj

SL No.	Brief Description of Item	Unit	Detailed Analysis				
			Sub-Item	Quantity	Unit	Rate	Amount
1	2	3	4	5	6	7	8
1.0	Sand Cement ICBP with 60mm Thick (size 220mmX110mm) ,Colour: Gray, Minimum Compressive Strength : 30 Mpa	sqm	Sand Cement ICBP with 60mm thick Uni-Block ,30Mpa ,Colour-Gray	40.00	each	13.00	520.00
			Sand (FM-2.5)	0.0300	m3	1660.00	49.80
			Sand (FM-0.8)	0.0100	m3	575.00	5.75
			Mason	0.0500	day	640.00	32.00
			Skilled Labour	0.0500	day	550.00	27.50
			Ordinary Labour	0.1500	day	470.00	70.50
			Subtotal-A:				705.55
			Subtotal-B: Lab test Fees, Incidental charges &Overhead (Add 2% on subtotal-A/A1):				719.66
			Subtotal-C: 10% profit (Add 10% on subtotal-B):				791.63
			VAT : 7.5% of Total				67.85
			IT : 5% of Total				45.24
						Total:	**904.72**

SL No.	Brief Description of Item	Unit	Detailed Analysis				
			Sub-Item	Quantity	Unit	Rate	Amount
1	2	3	4	5	6	7	8
2.0	Sand Cement ICBP with 60mm Thick(size 220mmX110mm) ,Colour: Red/black/any other suitable colour, Minimum Compressive Strength : 30 Mpa	sqm	Sand Cement ICBP with 60mm thick Uni-Block ,30Mpa ,Colour- Red/Black/any other suitable colour	40.00	each	15.00	600.00
			Sand (FM-2.5)	0.0300	m3	1660.00	49.80
			Sand (FM-0.8)	0.0100	m3	575.00	5.75
			Mason	0.0500	day	640.00	32.00
			Skilled Labour	0.0500	day	550.00	27.50
			Ordinary Labour	0.1500	day	470.00	70.50
			Subtotal-A:				785.55
			Subtotal-B: Lab test Fees, Incidental charges & Overhead (Add 2% on subtotal-A/A1):				801.26
			Subtotal-C: 10% profit (Add 10% on subtotal-B):				881.39
			VAT : 7.5% of Total				75.55
			IT : 5% of Total				50.36
						Total:	**1007.30**

District:Tangail ,Dhaka ,Gazipur, Manikganj

SL No.	Brief Description of Item	Unit	Detailed Analysis				
			Sub-Item	Quantity	Unit	Rate	Amount
1	2	3	4	5	6	7	8

SL No.	Brief Description of Item	Unit	Detailed Analysis				
			Sub-Item	Quantity	Unit	Rate	Amount
1	2	3	4	5	6	7	8
3.0	Sand Cement ICBP with 60mm Thick(size 220mmX110mm) ,Colour: Gray, Minimum Compressive Strength : 35 Mpa	sqm	Sand Cement ICBP with 60mm thick Uni-Block ,35Mpa ,Colour-Gray	40.00	each	14.00	560.00
			Sand (FM-2.5)	0.0300	m3	1660.00	49.80
			Sand (FM-0.8)	0.0100	m3	575.00	5.75
			Mason	0.0500	day	640.00	32.00
			Skilled Labour	0.0500	day	550.00	27.50
			Ordinary Labour	0.1500	day	470.00	70.50
			Subtotal-A:				745.55
			Subtotal-B: Lab test Fees, Incidental charges & Overhead (Add 2% on subtotal-A/A1):				760.46
			Subtotal-C: 10% profit (Add 10% on subtotal-B):				836.51
			VAT : 7.5% of Total				71.70
			IT : 5% of Total				47.80
						Total:	**956.01**
			Sand Cement ICBP with 60mm thick Uni-Block ,35Mpa ,Colour-Red/Black/any other suitable colour	40.00	each	16.00	640.00
			Sand (FM-2.5)	0.0300	m3	1660.00	49.80
			Sand (FM-0.8)	0.0100	m3	575.00	5.75

4.0	Sand Cement ICBP with 60mm Thick(size 220mmX110mm) ,Colour: Red/black/any other suitable colour, Minimum Compressive Strength : 35 Mpa	sqm	Mason	0.0500	day	640.00	32.00
			Skilled Labour	0.0500	day	550.00	27.50
			Ordinary Labour	0.1500	day	470.00	70.50
			Subtotal-A:				825.55
			Subtotal-B: Lab test Fees, Incidental charges & Overhead (Add 2% on subtotal-A/A1):				842.06
			Subtotal-C: 10% profit (Add 10% on subtotal-B):				926.27
			VAT: 7.5% of Total				79.39
			IT : 5% of Total				52.93
						Total:	**1058.59**

District:Tangail ,Dhaka ,Gazipur, Manikganj							
SL No.	Brief Description of Item	Unit	Detailed Analysis				
			Sub-Item	Quantity	Unit	Rate	Amount
1	2	3	4	5	6	7	8
			Sand Cement ICBP with 80mm thick Uni-Block ,30Mpa ,Colour-Gray	40.00	each	17.00	680.00
			Sand (FM-2.5)	0.0300	m3	1660.00	49.80
			Sand (FM-0.8)	0.0100	m3	575.00	5.75
			Mason	0.0500	day	640.00	32.00
			Skilled Labour	0.0500	day	550.00	27.50

5.0	Sand Cement ICBP with 80mm Thick(size 220mmX110mm) ,Colour: Gray, Minimum Compressive Strength : 30 Mpa	sqm	Ordinary Labour	0.1500	day	470.00	70.50
			Subtotal-A:				865.55
			Subtotal-B: Lab test Fees, Incidental charges & Overhead (Add 2% on subtotal-A/A1):				882.86
			Subtotal-C: 10% profit (Add 10% on subtotal-B):				971.15
			VAT : 7.5% of Total				83.24
			IT : 5% of Total				55.49
			Total:				**1109.88**

District:Tangail ,Dhaka ,Gazipur, Manikganj

SL No.	Brief Description of Item	Unit	Detailed Analysis				
			Sub-Item	Quantity	Unit	Rate	Amount
1	2	3	4	5	6	7	8
	Sand Cement ICBP with 80mm Thick(size 220mmX110mm) ,Colour:		Sand Cement ICBP with 80mm thick Uni-Block ,35Mpa ,Colour-Red/Black/any other suitable colour	40.00	each	19.00	760.00
			Sand (FM-2.5)	0.0300	m3	1660.00	49.80
			Sand (FM-0.8)	0.0100	m3	575.00	5.75
			Mason	0.0500	day	640.00	32.00
			Skilled Labour	0.0500	day	550.00	27.50

6.0	Red/black/any other suitable colour, Minimum Compressive Strength : 30 Mpa	sqm	Ordinary Labour	0.1500	day	470.00	70.50
			Subtotal-A:				945.55
			Subtotal-B: Lab test Fees, Incidental charges & Overhead (Add 2% on subtotal-A/A1):				964.46
			Subtotal-C: 10% profit (Add 10% on subtotal-B):				1060.91
			VAT : 7.5% of Total				90.93
			IT : 5% of Total				60.62
						Total:	**1212.47**

District:Tangail ,Dhaka ,Gazipur, Manikganj							
SL No.	Brief Description of Item	Unit	Detailed Analysis				
			Sub-Item	Quantity	Unit	Rate	Amount
1	2	3	4	5	6	7	8
			Sand Cement ICBP with 80mm thick Uni-Block ,35Mpa ,Colour-Gray	40.00	each	18.50	740.00
			Sand (FM-2.5)	0.0300	m3	1660.00	49.80
			Sand (FM-0.8)	0.0100	m3	575.00	5.75
			Mason	0.0500	day	640.00	32.00
			Skilled Labour	0.0500	day	550.00	27.50

7.0	Sand Cement ICBP with 80mm Thick(size 220mmX110mm) ,Colour: Gray, Minimum Compressive Strength : 35 Mpa	sqm	Ordinary Labour	0.1500	day	470.00	70.50
			Subtotal-A:				925.55
			Subtotal-B: Lab test Fees, Incidental charges & Overhead (Add 2% on subtotal-A/A1):				944.06
			Subtotal-C: 10% profit (Add 10% on subtotal-B):				1038.47
			VAT : 7.5% of Total				89.01
			IT : 5% of Total				59.34
						Total:	**1186.82**

District:Tangail ,Dhaka ,Gazipur, Manikganj

SL No.	Brief Description of Item	Unit	Detailed Analysis				
			Sub-Item	Quantity	Unit	Rate	Amount
1	2	3	4	5	6	7	8
			Sand Cement ICBP with 80mm thick Uni-Block ,35Mpa ,Colour-Red/Black/any other suitable colour	40.00	each	21.00	840.00
			Sand (FM-2.5)	0.0300	m3	1660.00	49.80
			Sand (FM-0.8)	0.0100	m3	575.00	5.75
			Mason	0.0500	day	640.00	32.00

8.0	Sand Cement ICBP with 80mm Thick(size 220mmX110mm) ,Colour: Red/black/any other suitable colour, Minimum Compressive Strength : 35Mpa	sqm	Skilled Labour	0.0500	day	550.00	27.50
			Ordinary Labour	0.1500	day	470.00	70.50
			Subtotal-A:				1025.55
			Subtotal-B: Lab test Fees, Incidental charges & Overhead (Add 2% on subtotal-A/A1):				1046.06
			Subtotal-C: 10% profit (Add 10% on subtotal-B):				1150.67
			VAT : 7.5% of Total				98.63
			IT : 5% of Total				65.75
						Total:	**1315.05**

9.4 Alternative Pavement option

As a part of future research, other substitutes to dredged sand such as blast furnace slag, fly ash, jute fiber, glass dust, ceramic waste, wood dust, etc. along with the combination of other materials in the manufacture of ICBPs would be explored.

Some of the alternative options in the preparation of ICBP are as follows:

- Ceramic waste: A large amount of ceramic waste is produced in the form of deformed or broken ceramic products. A suitable waste recycling outlet for ceramic waste is to replace natural fine aggregates in concrete. One of the concerns with using alternative building materials is the durability performance under adverse environmental conditions. Ceramic waste powder as supplementary cementing material the ceramic powder used can be categorized as class F pozzolans as the total SiO2 + Al2O3 + Fe2O3 content is higher than 70%. The waste products from the ceramic industries are durable and highly resistant to chemical and physical degradation forces.
- Ground Granulated Blast Furnace slag: GGBS is a by-product from blast furnaces used to make iron. The effect of GGBS as a cement replacement was examined on concrete interlocking paving blocks and other sand cement Blocks. Ground Granulated blast-furnace Slag is the granular material formed when

  molten iron blast furnace slag is rapidly chilled by immersion in water. It is a granular product with very limited crystal formation, is highly cementations in nature. GGBS is derived from pig iron manufacturing process. When the molten slag cools; it changes into a fine, granular, almost fully non crystalline, glassy form known as granulated slag. It has latent hydraulic properties. The finely ground slag, when mixed with Portland cement, gives very good binding properties. It has same chemical properties as that of cement, but less reactive than Portland cement (PC).

- Geo-polymer concrete: Green paver blocks is an eco-friendly method of making concrete paver block using geo-polymer concrete, ie, geo-polymer concrete production technology can also applicable in pavers production. Therefore, they do not easily crack, low cost, cement free, curing free pavers can be produced. Geo-polymer concrete can be synthesized by fly ash and recycled asphalt pavement aggregates for making of paver blocks. Geo-polymer, a novel binder, was initially studied by Davidovits (1982), and historically started as alkali-activated cements. The process of geo-polymerization involves alkaline activation of materials rich in silica and alumina and therefore giving a three-dimensional silico-aluminate structure by poly condensation. Fly ash is an excellent material to produce geo-polymer concrete. Most with low-calcium (CaO< 10%) and combined (Si + Al) ranging from 68 to 80%. It was found that most low-calcium fly ash are susceptible of being alkali-activated, providing good cementitious properties.

- CRT glass: Recycled glass derived from discarded cathode ray tube (CRT) glass as an alternate fine aggregate for the production of dry-mixed concrete paving blocks. The recycled CRT funnel glass used had been acid treated and regarded as a non-hazardous material based on the regulatory thresholds of the Toxicity Characteristic Leaching Procedure (TCLP). The use of up to 100% CRT funnel glass as fine aggregate in concrete paving blocks not only have satisfactory levels in compressive strength (>45 MPa) and ASR expansion (<0.1%), but improved the resistance to water absorption, drying shrinkage and photocatalytic performance for reducing air pollutants.
- Low grade recycled aggregates: Low grade recycled aggregates obtained from a construction waste sorting facility were tested to assess the feasibility of using these in the production of concrete block. The characteristics of the sorted construction waste are significantly different from that of crushed concrete rubbles that are mostly derived from demolition waste streams.
- Coal waste: coal waste can be used to replace conventional sand as a fine aggregate for concrete paving blocks. This work can be used to replace conventional sand as a fine aggregate for concrete paving blocks.

10. Summary of the Project

This project entails the preparation and incorporation of ICBP (Interlocking Concrete Paving Block) into Road Design Manual. Under this research endeavor, numerous literatures were studied which involved national reports, international ICBP pavement manuals and international journal papers. These secondary sources revealed that dredged sand could be considered as a suitable alternative to conventional fine aggregate in the production of concrete and it could also be a sought-after way to best recycle dredged sand to promote infrastructural and socio-economic development of Bangladesh. Therefore, this study project mainly focused on the use of utilizing dredged sediments from different locations of Bangladesh in the production of ICBPs of desired strength despite having non-compliant F.M. (in some cases) by incorporating suitable concrete mix ratio, water: cement ratio and admixture. Also, this project shed lights on the use of ICBPs in rural roads by considering light traffic.

Under the field visit, a total of 04 districts (Dhaka, Khulna, Gazipur and Narayanganj) were covered. Information related to ICBP roads comprising their lengths, widths, block dimensions, classifications based on location and vehicular composition, underlying layers thickness and overall condition were collected. Most of the existing ICBP roads observed were free from any significant deformity and almost all the paving units were intact. This further confirmed the suitability of using ICBP as a choice for roadway material. Furthermore, sand related information, mainly F.M. (Fineness Modulus), river source and sand selling marketplace were gathered from these four districts.

Method to fabricate ICBP was clearly described along with its various shapes and the corresponding performance to distribute vehicular loads with diagrammatic representations. As for the structural design considerations, IRC was selected out of 04 technical guidelines as it seemed to cover road design for light weight vehicles and complied with other factors such as climatic factors, socio-economic factors and materials availability.

Next, ICBP mix design charts were prepared, taking into account, sand F.M., location, thickness, concrete mix ratio, water: cement ratio, admixture quantity and strengths obtained at 7, 14 and 28 days. Almost all the samples achieved the desired strength of 35 MPa after 14 days of curing. Graphs of strength vs F.M. of the samples were drawn to better establish the relationship between the two parameters. It was found that ICBPs with high thickness had higher strength, there was a proportional relationship between Sand F.M. and compressive strength and early recommended strength of ICBP could be achieved by adding early strength gaining admixture with high density water reducing super plasticizer.

Under the additional aspects of ICBP, construction process, maintenance manual and technical specification were provided and they were adopted directly from IRC guidelines for the use of ICBP in roadway construction.

11. Market Strategy of Sand Cement Uni-Block in Bangladesh

Bangladesh, a severely land-scarce country loses one percent of agricultural land annually mainly because of unplanned settlement and production of clay burnt bricks using fertile top soil. Again, this clay burnt brick kilns are one of the major sources of air pollution in this country. To secure the fertile top soil and to reduce the air pollution, the government of Bangladesh has decided to phase out the bricks by 2025 in all its government construction works. According to the plan, sand cement concrete blocks will be used in 20 percentage of the government's construction projects from 2020-21, 30 percent from 2021-22, 60 percent from 2022-23, 80 percentages from 2023-24 and 100 percent by 2024-25. To achieve this target to ensure the safety of our agricultural production along with our environment, the use of Dredged sand in the production of concrete block is very important. Approximately 60 concrete block manufacturers in Bangladesh are currently in production of Dredged Sand Cement Uni Block. Although being a new product in this market, gradually Sand Cement Uni Block is getting recognition among the professionals. According to the 7 Stages of New Product Development (NPD) Process, Sand Cement Uni Block is currently at the final stage of 'Commercialization'. In this commercialization stage of NPD, a few strategies will have to be implemented to ensure the wide spread use of this environment friendly product to achieve the goal of the government.

1. Advertisement & Promotion: Wide Spread Advertisement on social awareness and benefits of using sand cement uni-block will have to be ensured so that not only the concerned authority, but also the community get involved in the process of transition from clay burnt brick to sand cement block.
2. Direct Marketing Campaign: Direct Marketing Methods such as direct mail, social media campaign, online and in person seminar for professionals and concerned officials will help to achieve the goal to inform people about sand cement uni-block.
3. Database of Manufacturers: A complete database of Sand Cement Block Manufacturers will have to be maintained. Housing and Building Research Institute (HBRI) has developed a database of Sand Cement Block Manufacturers in Bangladesh, which is available online on the website of HBRI, so that people from all walks of life can easily get the information of Sand Cement Blocks and their availability throughout the Country.

4. Training: To achieve the target of 100 percent use of Sand Cement Block by 2025, our professionals and construction workers will have to be properly trained on the efficient use and construction method using sand cement uni-block.
5. Incentives for Entrepreneurs: As a comparatively new product in the construction industry, the number of quality manufacturer is still very low in respect to the production of conventional bricks. To motivate the brick kiln owners to shift from clay brick to concrete blocks and to inspire entrepreneurs to invest in this filed, some incentives should be introduced from the government like soft loan and technical supports etc. Because of these incentives many entrepreneurs will be convinced to invest in this business.

12. LIMITATION OF THE PROJECT

- As for the review of the existing literatures, focus was mainly put on journal papers concerning the utilization of dredging sand for the manufacture of ICBP but further studies could not be conducted on the actual design of ICBP road section due to budget and time constraints.

- Not all the districts of Bangladesh were possible to be covered in order to assess existing road conditions due to the ongoing COVID-19 pandemic and imposed lockdown by the government.

- Water Absorption Test and Efflorescence Test of ICBPs could not be done to comply with the client's wish to finish the project within the time frame.

- Tensile strength of ICBP could not be carried out as this test is currently not available at HBRI.

- Under structural design consideration, only four international design guidelines were referred to and the most suitable one was chosen.

- Implementation manual (i.e., construction process), maintenance manual and technical specification of ICBP were mostly taken from IRC and these sections could not be adjusted further in the context of Bangladesh by referring to additional journal papers/guidelines for construction and maintenance of ICBP, etc.

- Other manufacturers of ICBP were only willing to share information regarding the dimension of ICBPs they produced along with their expected strength. But they did not supply HBRI with other vital information related to admixture type and amount, concrete mix ratio, etc. chiefly due to their confidential nature and privacy concern. Therefore, technical specification of admixtures and other aspects in the fabrication of ICBPs could not be provided to draw a comparative analysis.

- COVID-19 situation in Bangladesh put a hindrance for HBRI to conduct social survey with the stakeholders and road users of existing ICBP roads, covering the discussion and comments.

13. RECOMMENDATION

- By using dredged sands, ICBP could be prepared with desired strength of 30-35 MPa. So, these blocks could be used in the design and construction of ICBP pavements.
- Block manufacturers of Bangladesh should be notified of the research project by taking initiative from both government and non-government levels and encourage them to chiefly adopt dredging sand in the fabrication of ICBP.
- Design templates (for silt and clay) in the project are made on ad hoc basis. So, further research and evaluation by field testing should be done to assess their suitability.
- The road design templates provided by BRTC, BUET contain bituminous layers. But those templates could also be used by using ICBP section instead of bituminous layer.

14. Selected Photographs depicting Project Related Activities

HBRI Laboratory visited by LGED Representatives


Dredging Sand Collected by HBRI from Different Locations of Bangladesh


Block Manufacturing Process Carried out at HBRI Plant


Compressive Strength Test of ICBP at HBRI Workshop

Field Visits

15. Activities Chart

Sl. No.	Activity	Months							
		1		2		3		4	
	Monthly Segments[1]	1	2	1	2	1	2	1	2
1	Introductory meeting								
2	Literature review								
3	Preparation and submission of inception report								
4	Field visit								
5	Compilation of information								
6	Sample sand collection from various locations of Bangladesh								
7	Experimental and laboratory investigations: 1. Laboratory tests of sand. 2. Fabrication of sample ICBPs 3. Laboratory investigations on prepared ICBPs								
8	Preparation of a draft Design Procedure, Template, Implementation and Maintenance manual along with specification and costing								
9	Preparation and Submission of Draft Final Report (Design Procedure, Template, Implementation and Maintenance manual along with specification and costing)								
10	Review Meeting for Draft Final Report								
11	Preparation of Final Report with Design Procedure, Template, Implementation and Maintenance manual along with specification and costing								
12	Conducting seminar to present research findings and the final products of the project and receive feedback for future development.								

[1]. Monthly segment means that a month is divided into 02 (two) parts (i.e. 1 and 2) and each part comprises of roughly 15 day

16. References

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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

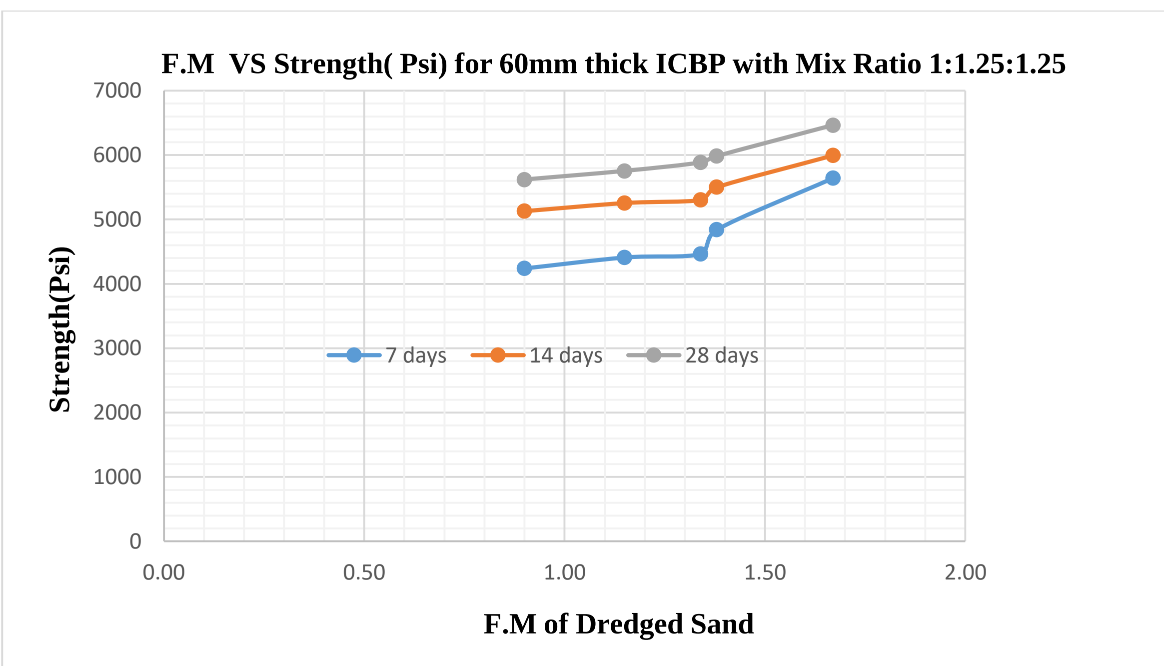


Figure 1: F.M. Vs Strength (Psi) for 60 mm thick ICBP*w*ith Mix Ratio 1: 1.25:1.25

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

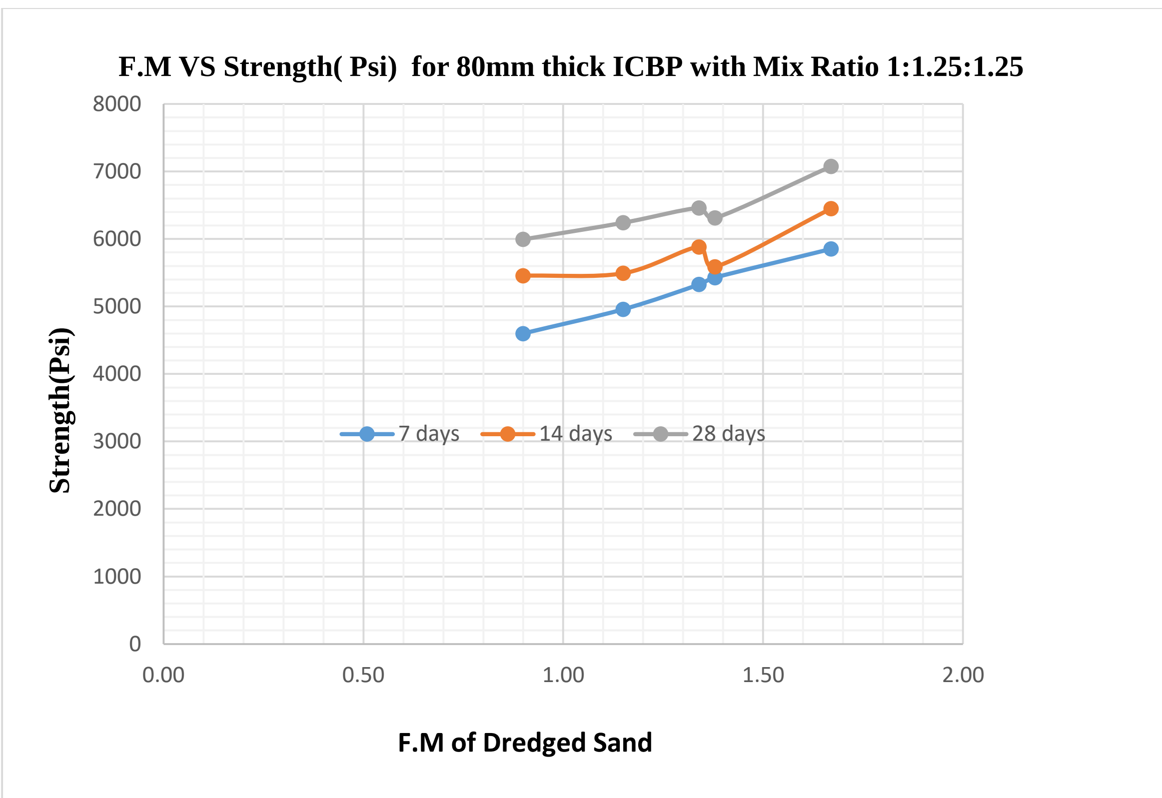


Figure 2: F.M. Vs Strength (Psi) for 80 mm thick ICBP with Mix Ratio 1: 1.25:1.25

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

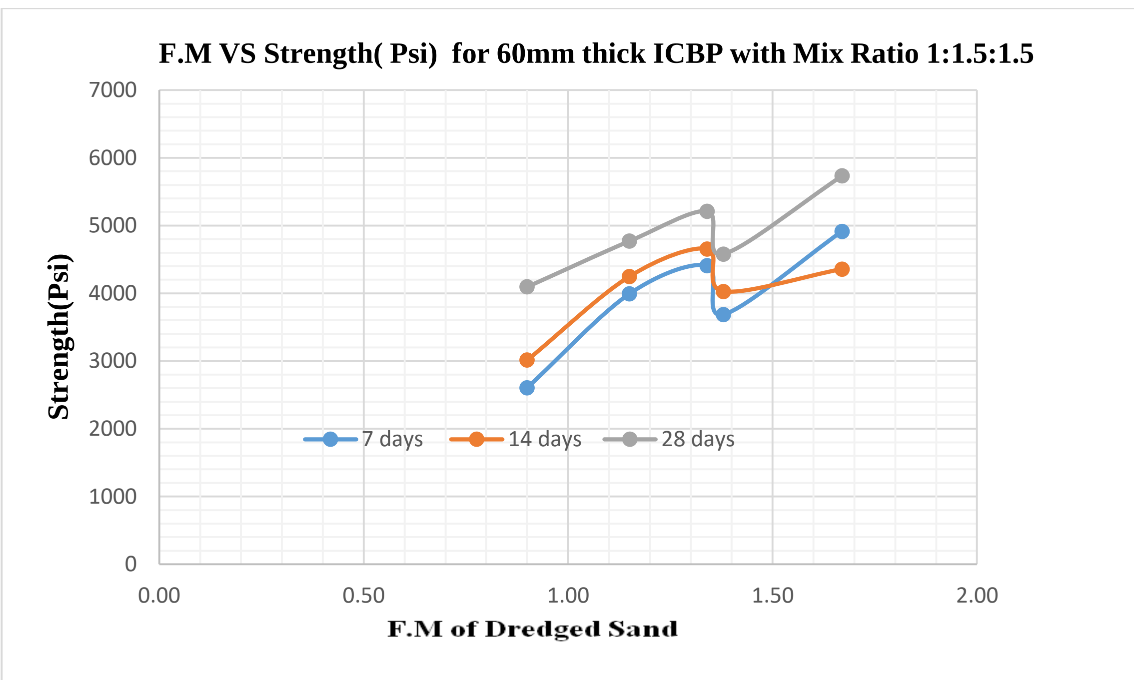


Figure 3: **F.M. Vs Strength (Psi) for 60 mm thick ICBP with Mix Ratio 1:1.5:1.5**

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

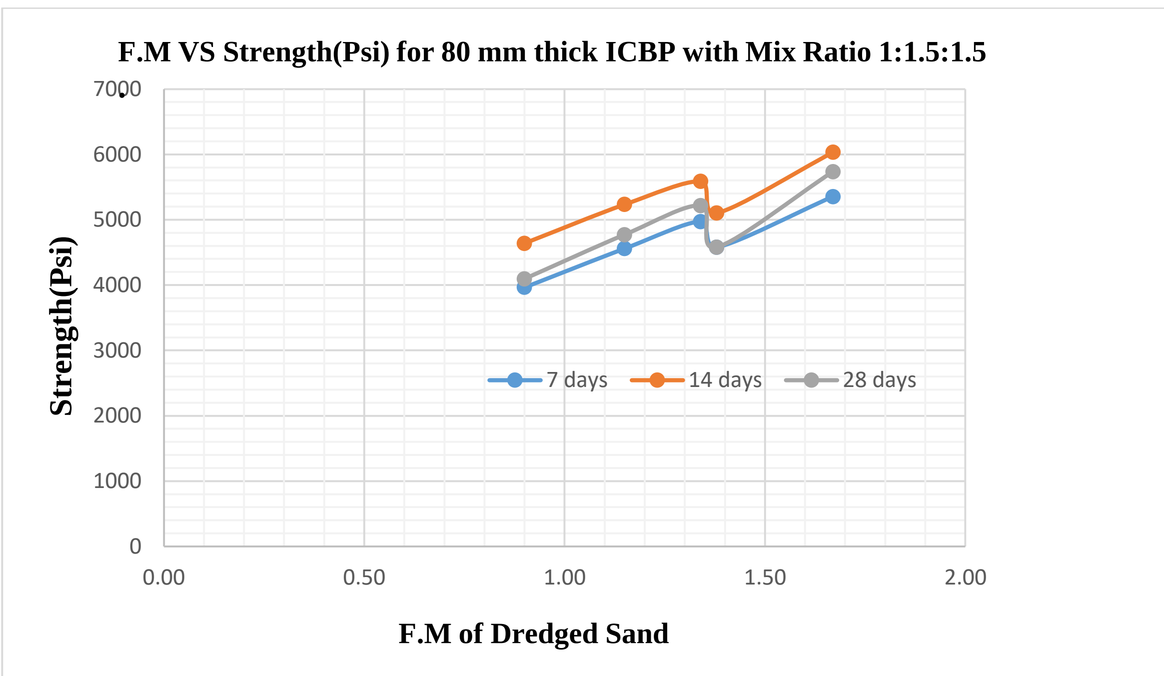


Figure 4: F.M. Vs Strength (Psi) for 80 mm thick ICBP with Mix Ratio 1:1.5:1.5

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

GoB Notification Regarding the use of Blocks

গণপ্রজাতন্ত্রী বাংলাদেশ সরকার
পরিবেশ, বন ও জলবায়ু পরিবর্তন মন্ত্রণালয়
পরিবেশ দূষণ নিয়ন্ত্রণ শাখা-১
www.moef.gov.bd

স্মারক নং- ২২.০০.০০০০.০৭৫.৩২. ০০২.১৪ (অংশ-৩)- ৪১০ তারিখঃ ০৯ অগ্রহায়ন , ১৪২৬ বঙ্গাব্দ। / ২৪ নভেম্বর, ২০১৯ খ্রি:।

প্রজ্ঞাপন

ইট প্রস্তুত ও ভাটা স্থাপন (নিয়ন্ত্রণ) আইন, ২০১৩ (সংশোধিত ২০১৯) এর ধারা ৫(৩ক) এ প্রদত্ত ক্ষমতাবলে মাটির ব্যবহার পর্যায়ক্রমে হ্রাস করিবার উদ্দেশ্যে সকল সরকারি নির্মাণ, মেরামত ও সংস্কার কাজে ভবনের দেয়াল ও সীমানা প্রাচীর, হেরিং বোন বন্ড রাস্তা এবং গ্রাম সড়ক টাইপ- 'বি' এর ক্ষেত্রে ইটের বিকল্প হিসাবে উক্ত আইনের ২(নন) উপধারায় সংজ্ঞায়িত ব্লক ব্যবহারে নিম্নরূপ সময়াবদ্ধ কর্মপরিকল্পনা ও লক্ষ্যমাত্রা অনুযায়ী ব্লক ব্যবহার বাধ্যতামূলক করা হইলঃ

অর্থবছর	ব্লক ব্যবহারের লক্ষ্যমাত্রা
২০১৯ - ২০২০	১০%
২০২০ - ২০২১	২০%
২০২১ - ২০২২	৩০%
২০২২ - ২০২৩	৬০%
২০২৩ - ২০২৪	৮০%
২০২৪ - ২০২৫	১০০%

তবে সড়ক ও মহাসড়কের বেইজ ও সাব-বেইজ নির্মাণ, মেরামত ও সংস্কারে এ নির্দেশনা প্রযোজ্য হইবে না।

০২। উল্লিখিত সময়াবদ্ধ কর্মপরিকল্পনা বাস্তবায়নের কোনরুপ ব্যত্যয় বা ব্যর্থতার ক্ষেত্রে আইনানুগ ব্যবস্থা গ্রহণ করা হইবে।

রাষ্ট্রপতির আদেশক্রমে

স্বাক্ষরিত/-
(আবদুল্লাহ আল মোহসীন চৌধুরী)
সচিব

স্মারক নং- ২২.০০.০০০০.০৭৫.৩২. ০০২.১৪ (অংশ-৩)- ৪১০ তারিখঃ ০৯ অগ্রহায়ন , ১৪২৬ বঙ্গাব্দ / ২৪ নভেম্বর, ২০১৯ খ্রি:

বিতরণঃ (জ্যেষ্ঠতার ক্রমানুসারে নয়)

১। মন্ত্রিপরিষদ সচিব, মন্ত্রিপরিষদ বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
২। প্রধানমন্ত্রীর মুখ্য সচিব, প্রধানমন্ত্রীর কার্যালয়, তেজগাঁও, ঢাকা।
৩। সিনিয়র সচিব, বাংলাদেশ জাতীয় সংসদ সচিবালয়, ঢাকা।
৪। সিনিয়র সচিব, অভ্যন্তরীণ সম্পদ বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৫। সিনিয়র সচিব, মাধ্যমিক ও উচ্চ শিক্ষা বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৬। সিনিয়র সচিব, দুর্যোগ ব্যবস্থাপনা ও ত্রাণ মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৭। সিনিয়র সচিব, সমাজকল্যাণ মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৮। সিনিয়র সচিব, বিদ্যুৎ বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৯। সিনিয়র সচিব, আর্থিক প্রতিষ্ঠান বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
১০। সিনিয়র সচিব, তথ্য ও যোগাযোগ প্রযুক্তি বিভাগ, আইসিটি টাওয়ার, আগারগাঁও, ঢাকা।
১১। সিনিয়র সচিব, জ্বালানী ও খনিজ সম্পদ বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
১২। সিনিয়র সচিব, জননিরাপত্তা বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।

১৩। সিনিয়র সচিব, পররাষ্ট্র মন্ত্রণালয়, সেগুন বাগিচা, ঢাকা।
১৪। সচিব, গৃহায়ন ও গণপূর্ত মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
১৫। সচিব, জন বিভাগ, রাষ্ট্রপতির কার্যালয়, বঙ্গভবন, ঢাকা।
১৬। সচিব, তথ্য মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
১৭। সচিব, প্রতিরক্ষা মন্ত্রণালয়, গণভবন কমপ্লেক্স, শেরে বাংলা নগর, ঢাকা।
১৮। সচিব, সড়ক পরিবহন ও মহাসড়ক বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
১৯। সচিব, বিজ্ঞান ও প্রযুক্তি মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
২০। সচিব, রেলপথ মন্ত্রণালয়, আব্দুল গণি রোড, ঢাকা।
২১। সচিব, স্থানীয় সরকার বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
২৩। সচিব, নৌপরিবহন মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
২৪। সচিব, ধর্ম বিষয়ক মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
২৫। সচিব, জনপ্রশাসন মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
২৬। সচিব, স্বাস্থ্য সেবা বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
২৭। সচিব, খাদ্য মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
২৮। সচিব, মৎস্য ও প্রাণি সম্পদ মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
২৯। সচিব, পরিসংখ্যান ও তথ্য ব্যবস্থাপনা বিভাগ , শেরে বাংলা নগর, ঢাকা।
৩০। সচিব, পরিকল্পনা বিভাগ, শেরে-ই-বাংলা নগর, ঢাকা।
৩১। সচিব, পানি সম্পদ মন্ত্রণালয় , বাংলাদেশ সচিবালয়, ঢাকা।
৩২। সচিব, বেসামরিক বিমান পরিবহন ও পর্যটন মন্ত্রণালয় , বাংলাদেশ সচিবালয়, ঢাকা।
৩৩। সচিব, প্রাথমিক ও গণশিক্ষা মন্ত্রণালয় , বাংলাদেশ সচিবালয়, ঢাকা।
৩৪। সচিব, অর্থ বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৩৫। সচিব, শিল্প মন্ত্রণালয়, মতিঝিল, ঢাকা।
৩৬। সচিব, কৃষি মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৩৭। সচিব, অর্থনৈতিক সম্পর্ক বিভাগ, শেরে-ই-বাংলা নগর, ঢাকা।
৩৮। সচিব, ভূমি মন্ত্রণালয় বাংলাদেশ সচিবালয়, ঢাকা।
৩৯। সচিব, মুক্তিযুদ্ধ বিষয়ক মন্ত্রণালয়, পরিবহনপুল ভবন, সচিবালয় লিংক রোড, ঢাকা।
৪০। সচিব, কারিগরি ও মাদ্রাসা শিক্ষা বিভাগ, সচিবালয় লিংক রোড, বাংলাদেশ সচিবালয়, ঢাকা।
৪১। সচিব, বাস্তবায়ন পরিবীক্ষণ ও মূল্যায়ন বিভাগ, শেরে-ই-বাংলা নগার, ঢাকা।
৪২। সচিব, সংস্কৃতি বিষয়ক মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৪৩। সচিব, ডাক ও টেলিযোগাযোগ বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৪৪। সচিব, পার্বত্য চট্টগ্রাম বিষয়ক মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৪৫। সচিব, সুরক্ষা সেবা বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৪৬। সচিব, বাণিজ্য মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৪৭। সচিব, শ্রম ও কর্মসংস্থান মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৪৮। সচিব, সেতু বিভাগ, নিউ এয়ারপোর্ট রোড বনানী, ঢাকা।
৪৯। সচিব, স্বাস্থ্য শিক্ষা ও পরিবার কল্যাণ বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৫০। সচিব, যুব ও ক্রীড়া মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৫১। সচিব, প্রবাসী কল্যাণ ও বৈদেশিক কর্মসংস্থান মন্ত্রণালয়, প্রবাসী কল্যাণ ভবন, ৭১-৭২ পুরাতন এলিফ্যান্ট রোড, ইস্কাটন গার্ডেন, রমনা, ঢাকা।
৫২। সচিব, বস্ত্র ও পাট মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৫৩। সচিব, পল্লী উন্নয়ন ও সমবায় বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৫৪। সচিব, মহিলা ও শিশু বিষয়ক মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৫৫। সচিব, আইন ও বিচার বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৫৬। সচিব, লেজিসলেটিভ ও সংসদ বিষয়ক বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।
৫৭। অতিরিক্ত সচিব (সকল), পরিবেশ, বন ও জলবায়ু পরিবর্তন মন্ত্রণালয়।
৫৮। মহাপরিচালক, পরিবেশ অধিদপ্তর, আগারগাঁও, ঢাকা।
৫৯। প্রধান বন সংরক্ষক, বন অধিদপ্তর, আগারগাও, ঢাকা।
৬০। চেয়ারম্যান, বাংলাদেশ বন শিল্প উন্নয়ন কর্পোরেশন, ৭৩, মতিঝিল বা/এ, ঢাকা।
৬১। ব্যবস্থাপনা পরিচালক, বাংলাদেশ জলবায়ু পরিবর্তন ট্রাস্ট, মহাখালী, ঢাকা।
৬২। চেয়ারম্যান, বাংলাদেশ রাবার বোর্ড, প্রধান কার্যালয়, ই ১০-১৩, এম এ কে খলিল সড়ক, পশ্চিম পাহাড়, বিএফআরআই ক্যাম্পাস, চট্টগ্রাম

৬৩। পরিচালক, বাংলাদেশ বন গবেষণা ইনস্টিটিউট, চট্টগ্রাম।
৬৪। পরিচালক, বাংলাদেশ ন্যাশনাল হারবেরিয়াম, মিরপুর, ঢাকা।

অনুলিপি: (সদয় অবগতি ও প্রয়োজনীয় ব্যবস্থা গ্রহণের জন্য প্রেরণ করা হলো)

১। উপ-নিয়ন্ত্রক, বাংলাদেশ সরকারি মুদ্রণালয়, বিজি প্রেস, তেজগাঁও, ঢাকা (বাংলাদেশ গেজেটে পরবর্তী সংখ্যায় প্রকাশের অনুরোধসহ)।
২। মাননীয় মন্ত্রীর একান্ত সচিব, পরিবেশ, বন ও জলবায়ু পরিবর্তন মন্ত্রণালয়।
৩। মাননীয় উপমন্ত্রীর একান্ত সচিব, পরিবেশ, বন ও জলবায়ু পরিবর্তন মন্ত্রণালয়।
৪। সচিবের একান্ত সচিব, পরিবেশ ও বন মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
৫। সিস্টেম এনালিস্ট, পরিবেশ, বন ও জলবায়ু পরিবর্তন মন্ত্রণালয়।
৬। অতিরিক্ত সচিবগণের ব্যক্তিগত কর্মকর্তাগণ, পরিবেশ, বন ও জলবায়ু পরিবর্তন মন্ত্রণালয়।

২৪.১১.২০১৭
(আফরোজা বেগম)
সিনিয়র সহকারী সচিব
ফোন নং-৯৫৪৬৪১০

ANNEXURE III

Geological Map of Bangladesh

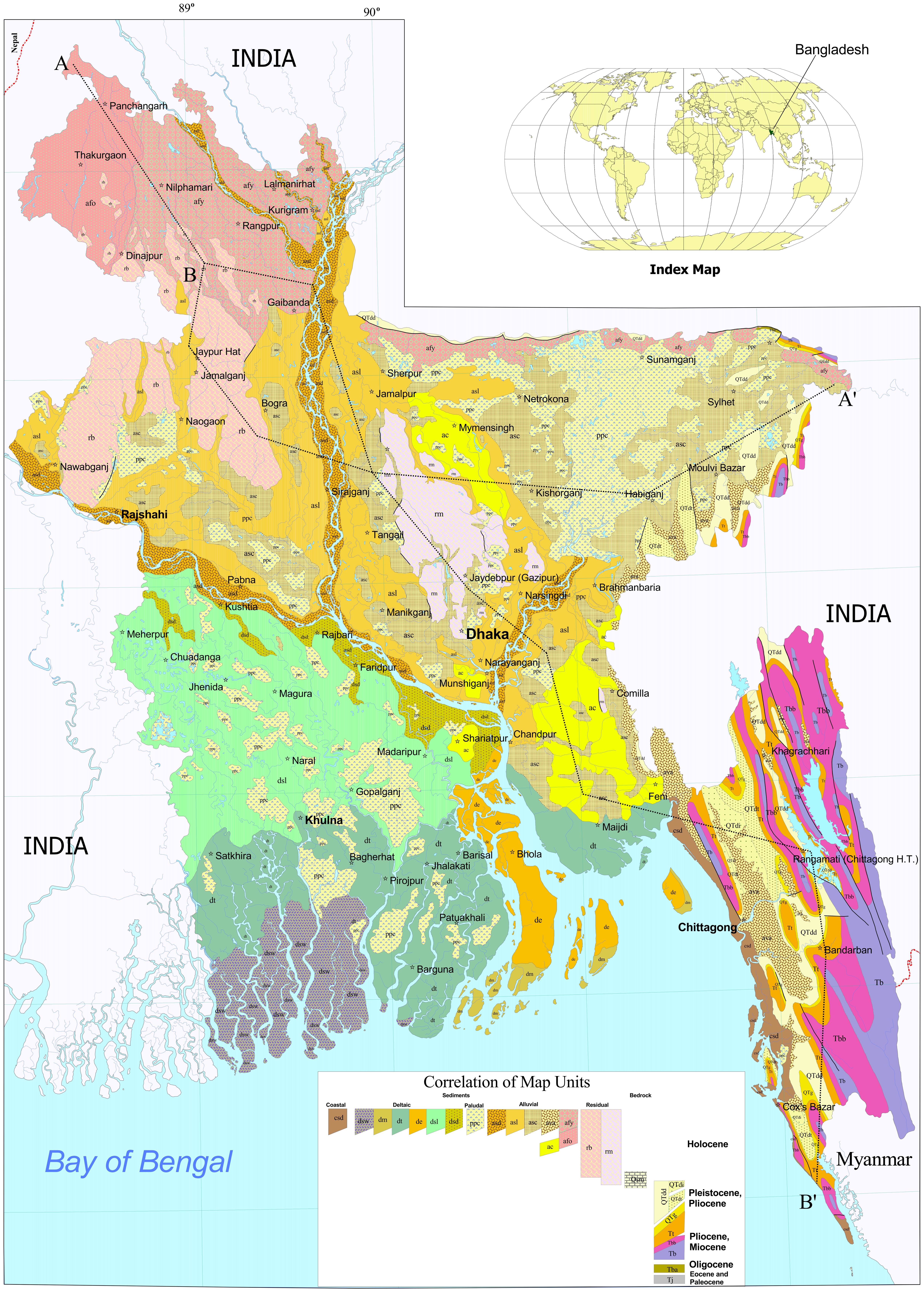
OPEN FILE REPORT 97- 470H

ABOUT THIS MAP

This map was compiled as part of the Bangladesh gas resources assessment conducted under the Participating Agency Service Agreement (PASA) signed between U.S. Agency of International Development (USAID) and the U.S. Department of Energy (DOE) - PASA No: 388-P-00-99-00026. The PASA provides for assistance to the natural gas sector pursuant to which the resources assessment was jointly carried out. PASA also encourages transfer of new technology, modelling practices and geoscience theory from existing and established programs in the Government of Bangladesh, Petrobangla, and Bangladesh academia.

This map has been compiled from the Geological Map of Bangladesh, by Md. Khurshid Alam, A.K.M.Shahidul Hasan, and Mujibur Rahman Khan (Geological Survey of Bangladesh), and John W. Whitney (United States Geological Survey), scale 1:1,000,000, published by Geological Survey of Bangladesh in 1990.

1. Original map was scanned on large format Ideal scanner in color mode with resolution 200 dpi.
2. The scanned image was transformed to Lambert Conformal projection by ArcInfo REGISTER and RECTIFY utilities.
3. Reference points for transformation were latitude-longitude crosses taken from paper map compared with the same crosses projected to Lambert in ArcInfo PROJECT utility. Overall RMS error of transformation was 250 m (0.25 mm on original paper map).
4. On-screen digitization was performed using a rectified image as a backdrop in ArcInfo ARCEDIT.
5. Geologic attributes were assigned to GLG item of Feature Attribute Table (FAT) of geology coverage.
6. Base map data layers - rivers, lakes, cities - were digitized as separate coverages.
7. All the ArcInfo coverages were converted into .E00 files, then imported to ArcView by IMPORT 71 utility and saved as shape files.



Projection - Lambert Conformal Conic
Spheroid - Everest 1969
Central Meridian - 87 E
1-st standard parallel - 22 N
2-nd standard parallel - 25 N

Index Map

Description of Map Units

Surface Geology

Holocene Sediments:

Coastal Deposits:
- csd Beach and dune sand

Deltaic Deposits:
- dsw Mangrove swamp deposit
- dm Tidal mud
- dt Tidal deltaic deposits
- de Estuarine deposits
- dsl Deltaic silt
- dsd Deltaic sand

Paludal Deposits:
- ppc Marsh clay and peat

Alluvial Deposits:
- asd Alluvial sand
- asl Alluvial silt
- asc Alluvial silt and clay
- ac Chandina alluvium
- ava Valley alluvium and colluvium

Alluvial Fan Deposits:
- afy Young gravelly sand
- afo Old gravelly sand

Residual Deposits:
- rb Barind clay residuum
- rm Madhupur clay residuum

Bedrocks:
- Qsm St. Marin limestone (Pleistocene)
- QTdd Dihing and Dupi Tila Formation Undivided
- QTdi Dihing Formation (Pleistocene and Pliocene)
- QTdt Dupi Tila Formation (Pleistocene and Pliocene)

Tipam Group:
- QTg Girujan Clay (Pleistocene and Neogene)
- Tt Tipam Sandstone (Neogene)

Surma Group:
- Tbb Boka Bil Formation (Neogene)
- Tb Bhuban Formation (Miocene)
- Tba Barail Formation (Oligocene)

Jaintia Group:
- Tj Jaintia Group includes:
  Kopili Formation (Late Eocene)
  Sylhet Limestone (Middle to Early? Eocene)
  Tura Formation (Eocene and Paleocene)

- Lake
- Ocean and wide river
- Areas outside of Bangladesh
- Major City
- Faults - Approximately located
- River
- Contact
- Political Boundary
- Section Line

Scale 1:1,000,000

30 0 30 60 Miles

40 0 40 80 Kilometers

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GEOLOGICAL MAP OF BANGLADESH

Original Geological Map by Md. Khurshid Alam, A.K.M.Shahidul Hasan, and Mujibur Rahman Khan, (Geological Survey of Bangladesh), and John W. Whitney, (United States Geological Survey)
1990
Digitally compiled by F.M.Persits, C.J.Wandrey, R.C. Milici, (USGS), and Abdullah Manwar, (Director General, Geological Survey of Bangladesh)
2001

ANNEXURE IV

List of Rivers in Bangladesh

Annexure IV: List of Major Rivers in Bangladesh

Name of River	District Covered by a River in Miles	Total length in Miles
Surma-Meghna	Sylhet (180), Comilla (146), Barisal (90)	359 miles (578 km)
Karatoya-Atrai-Gurgumari-Hursagar	Dinajpur (161), Rajshahi (160) & Pabna (50)	382 miles (615 km)
Donai-Charalkata-Jamuneswari-Karatoya	Rangpur (120) Bogra (98) & Pabna (62)	227 miles (365 km)
Padma (Ganges)	Rajshahi (90) Pabna (60) Dhaka (60) & Faridpur (80)	222 miles (357 km)
Garai-Madhumati-Baleswar	Kushtia (36) Faridpur (70) Jessore (91) Khulna (104) and Barisal (65)	233 miles (375 km)
Old Brahmaputra	Mymensingh (172)	150 miles (240 km)
Brahmaputra-Jamu	Rangpur (75) Pabna (75)	94 miles (151 km)
Kobadak	Jessore (49) Khulna (112)	113 miles (182 km)
Banshi	Mymensingh (123) Dhaka (25)	115 miles (185 km)
Ghagat	Rangpur (247)	148 miles (238 km)
Dhanu-Boulai-Ghor	Sylhet (68), Mymensingh (78)	136 miles (219 km)
Nabaganga	Kushtia (16) Jessore (128)	144 miles (232 km)
Kushiyara	Sylhet (142)	143 miles (230 km)

Annexure IV: List of Major Rivers in Bangladesh

Bhogai-Kangsa	Mymensingh (140)	141 miles (227 km)
Jamuna	Dinajpur (100) Bogra (29) Tangail (205)	56 miles (90 km)
Dakatia	Comilla (112) Noakhali (17)	69 miles (111 km)
Little Feni	Noakhali (59) Comilla (62)	50 miles (80 km)
Bhadra	Jessore (36) Khulna (84)	119 miles (192 km)
Betna-Kholpotua	Jessore (64) Khulna (55)	80 miles (130 km)
Sangu	Chittagong (50) and Chittagong Hill Tracts (58)	113 miles (182 km)
Chitra	Kushtia (12) Jessore (94)	97 miles (156 km)
Banar	Faridpur (96) Barisal (5)	101 miles (163 km)
Kumar (Faridpur Di)	Faridpur (101)	81 miles (130 km)
Punarbhaba	Dinajpur (50) Rajshahi (50)	100 miles (160 km)
Arial Khan	Faridpur (64) Barisal (36)	102 miles (164 km)
Dhaleswari	Mymensingh (100)	105 miles (169 km)
Bhairab	Jessore (81) Khulna (18)	136 miles (219 km)

Annexure IV: List of Major Rivers in Bangladesh

Mathabhanga	Rajshahi (10), Kushtia (87)	81 miles (130 km)
Rupsa-Pasur	Khulna (88)	41 miles (66 km)
Karnaphuli	Chittagong H.T. (40) Chittagong (37)	100 miles (160 km)
Teesta	Rangpur (70)	71 miles (114 km)

Source: Wikipedia

Annexure V

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/ Commercial 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 V

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.

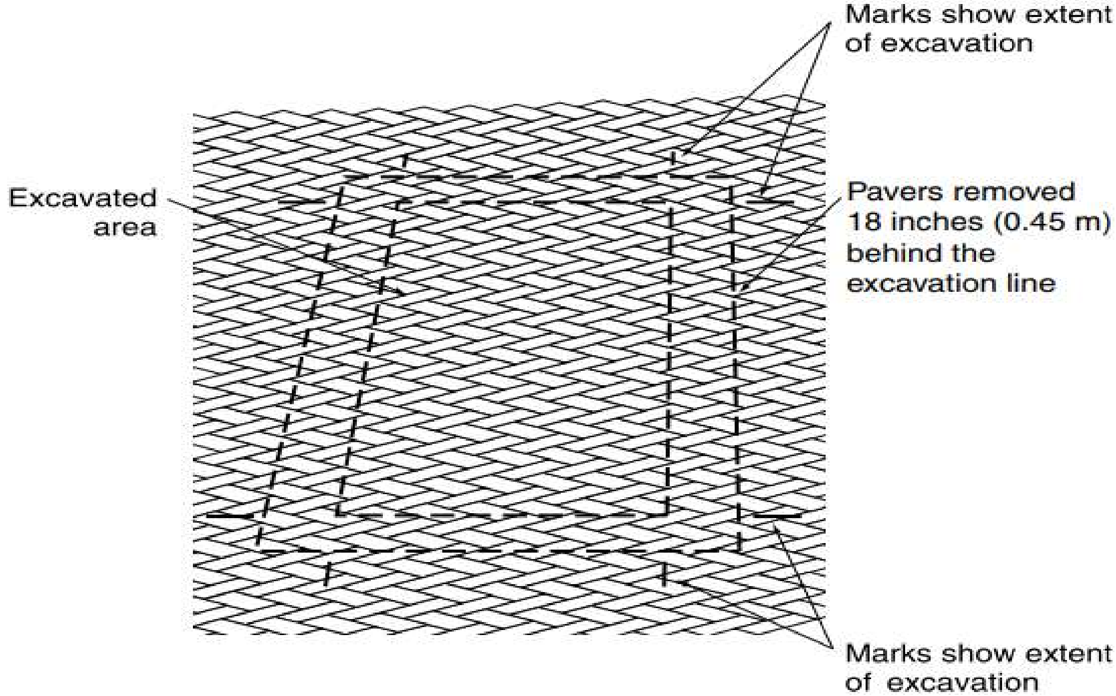

Figure 1. Pavement markings show the extent of paver removal and trench area.

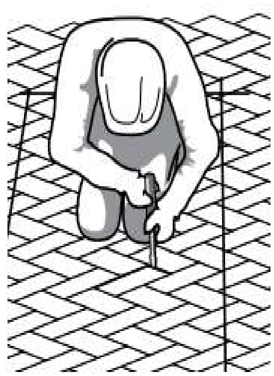

Figure 2. Removing joint sand surrounding the first paver to be removed.

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.

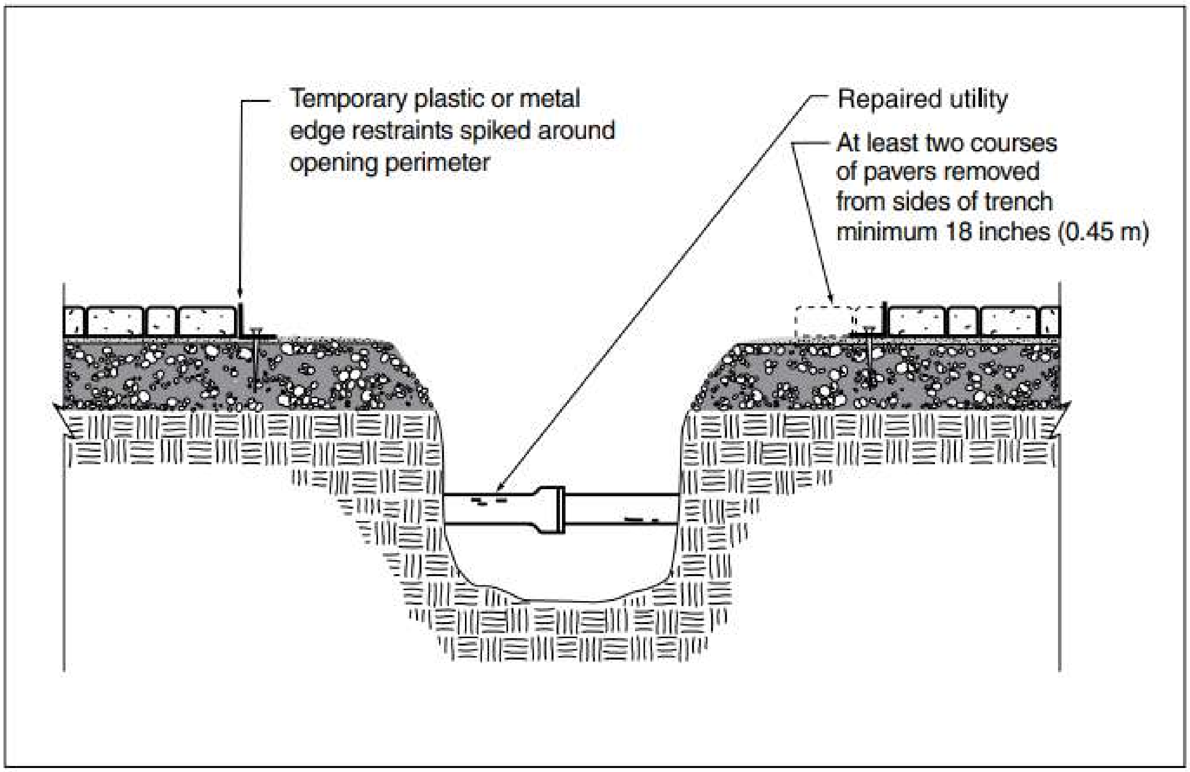

Figure 8. T-shaped cross section of the excavated opening

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.

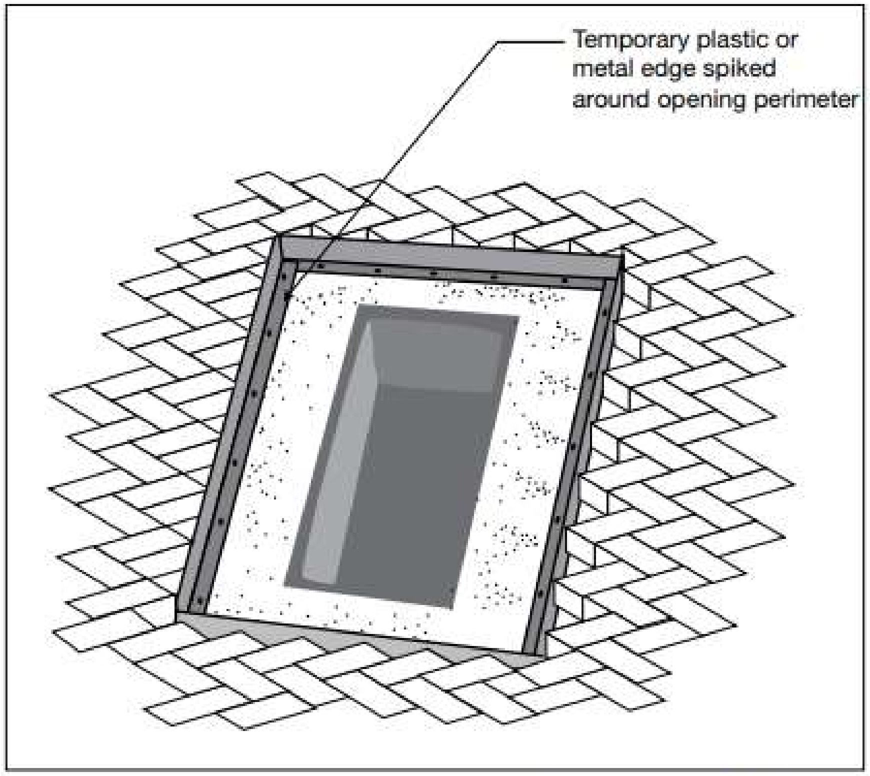

Figure 9. Temporary bracing at the pavement opening will help keep units in place during excavation, repairs and reinstatement.

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 V

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.

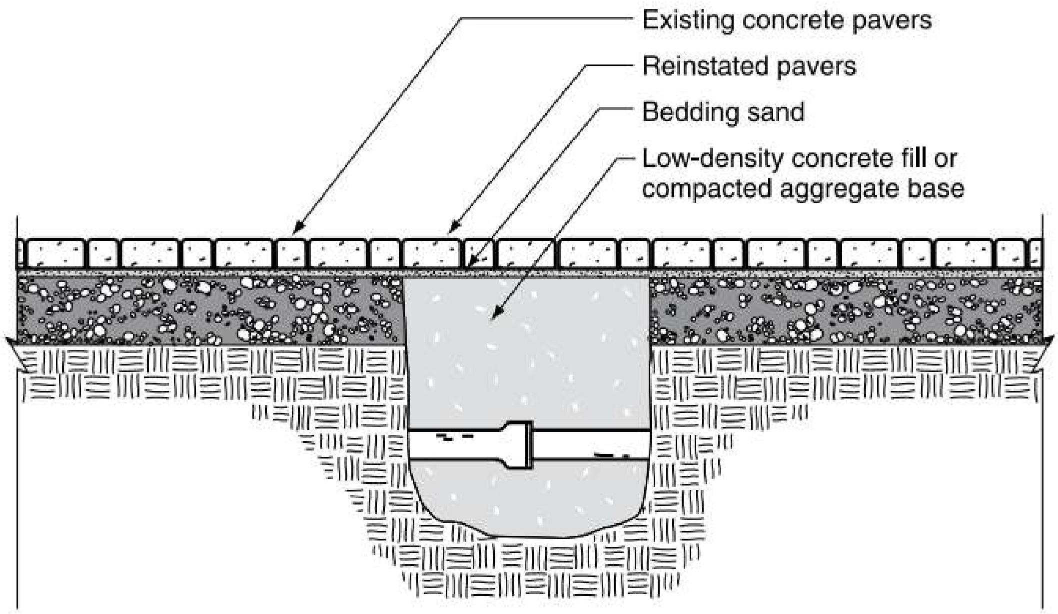

Figure 6. Cross section of reinstated utility cut into interlocking concrete pavement.

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.

ANNEXURE VI

Geo-synthetics for Segmental Concrete Pavement

Tech Spec 22

Geosynthetics for Segmental Concrete Pavements

This Tech Spec provides fundamental information on geosynthetics including a brief history, uses, and basic applications for interlocking concrete pavements (ICP) and permeable interlocking concrete pavements (PICP). While this Tech Spec provides some general guidelines on engineered applications, it is not intended to provide geosynthetic engineering design advice. While many of the general principles and applications of geosynthetics are easily understood, the field of geosynthetics and the technical information available is too voluminous for a single technical bulletin. This Tech Spec is presented as an introduction to the wide range of geosynthetic materials available, as shown in Figure 1, for readers interested in this subject and its application to segmental concrete pavements.

The term geosynthetics derives its meaning from Greek word "geo" meaning of the earth or ground, and the synthetic referring to materials formed through a chemical process by human action rather than by nature. The term geosynthetic is defined in ASTM D4439 *Standard Terminology for Geosynthetics* (ASTM 2015) as "a planar product manufactured from polymeric material used with soil, rock and earth or other geotechnical engineering related material as an integral part of a man-made project, structure, or system." Geosynthetics are predominantly manufactured from polymers and may also include fiberglass, rubber, or other natural materials.

History

Various materials have been placed on or in soils under pavements for thousands of years. Compacted stones were used in roadway construction in Roman days to stabilize roadway soils and their edges. Natural fibers and fabrics were later mixed with soil to improve road quality, particularly when built on unstable soil. Such materials were also used to stabilize steep slopes and walls such as ancient ziggurats. While many of the earliest attempts to improve or reinforce soil were not recorded, there is some evidence. Some of the oldest roads in Britain utilized split logs, or a 'corduroy' road, laid over peat bogs to provide a stable platform. There is also evidence that in some cases a stabilized soil mixed with paving stones or paving blocks were placed over the corduroy road.

Obviously, natural materials in soils led to biodegradation from microorganisms. The advent of polymers in the mid-twentieth century provided longer lasting and more stable materials for pavements.

Even before the term geosynthetics existed, synthetic materials were being used in the field. In the early 1960s, the Dutch used geotextiles in the design of the Delta

Figure 1. Different types of geosynthetics

Figure 2. Different types of geotextiles

Figure 3. Geogrid examples

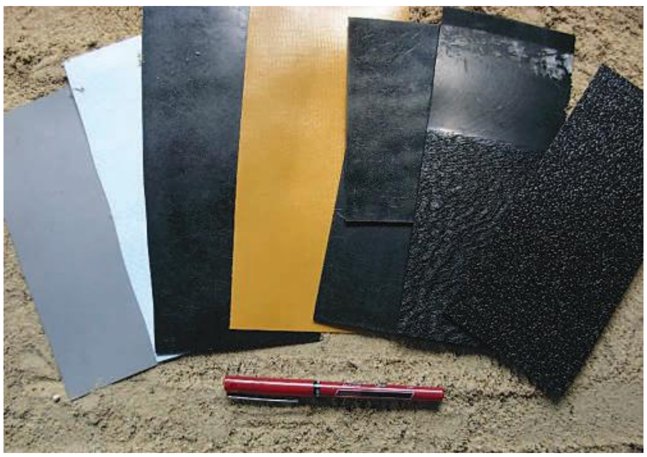


Figure 4. Geomembrane examples

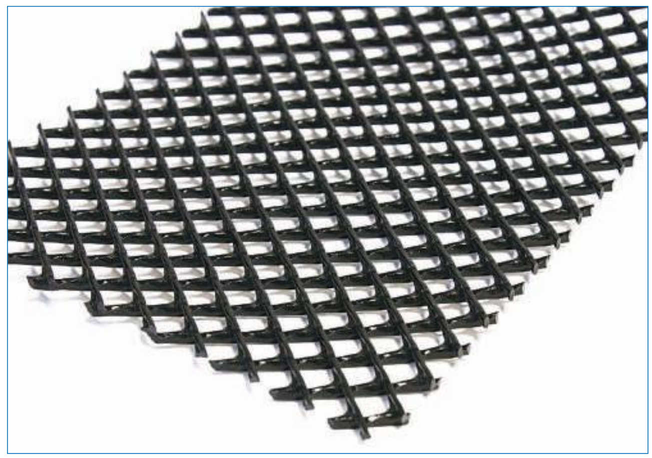


Figure 5. Geonet example

Works flood protection project as a response to deadly North Sea flooding there in 1953. The terms "geotextile" and "geosynthetics" were introduced by Dr. J.P. Giroud in a Paris engineering conference in 1977 (Kelsey 2014). Compared to other paving materials, geosynthetics have a short history of about 50 years, even though improving the load bearing capacity and strength of soil has been occurring for thousands of years.

Types of Geosynthetics

Geosynthetics can be grouped in several product categories, i.e. geotextiles, geogrids, geomembranes, geonets, geosynthetic clay liners, geopipes, geofoam, geocells and geocomposites. Polymer materials make them suitable for use in applications where high durability is required. They can also be used in exposed, above ground applications. With their range of materials and products, this enables geosynthetics to have a wide range of applications in many civil, geotechnical, transportation, geo-environmental, hydraulic, and private development applications. These include roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, dams, erosion control, sediment control, landfill liners, landfill covers, mining, aquaculture and agriculture.

Geotextiles

Geotextiles form one of the two largest groups of geosynthetics. They are fabrics consisting of synthetic fibers predominantly made of polypropylene (PP) rather than natural fibers making them less susceptible to biodegradation. Synthetic fibers are made into flexible, porous sheets, made by standard weaving machinery, are called slit film, monofilament or multifilament. Another subset of gerotextiles are matted together randomly and not woven. These nonwoven materials are made with processes called needle punched or heat bonded. There is also a very small subset of geotextiles that are knitted. Examples are shown in Figure 2.

Geotextiles are permeable to liquids and gases, but vary to a wide degree. These variations produce materials with a wide range of mechanical and hydraulic properties. As a result, there are at least 100 specific application areas for geotextiles. However, these can be simplified to four discrete functions: separation, reinforcement, filtration, and/or drainage.

Geogrids

Rather than being a continuous fabric, geogrids are polymers formed into an open, small grid-like configurations with apertures between individual ribs as illustrated in Figure 3. Geogrids typically consist of polyethylene (PE), polypropylene (PP), or polyester (PET). They are typically classified as being bidirectional, with equal strength in both directions, or unidirectional, with a greater strength in one direction. Geogrids are made by one of three methods; (1) stretching a polymer sheet in one, two or three directions for improved physical properties; (2) woven or knit using standard textile manufacturing methods; or (3) laser or ultrasonically bonded rods or straps. While there are many applications, geogrids function almost exclusively as reinforcement.

Geomembranes

Geomembranes represent the largest group of geosynthetics, and see higher sales than geotextiles. Geomembranes grew rapidly in the United States and Germany when government regulations in the early 1980s required lining of solid waste landfills. Uses expanded to all types of landfills, surface impoundments, canals, and containment of vapors, liquid or solid materials. Geomembranes are typically made from polyvinyl chloride (PVC), ethylene propylene diene monomer (EPDM), high-density polyethylene (HDPE) and linear lower density polyethylene (LLDPE) as shown in Figure 4. The range of applications extend beyond environmental management to geotechnical and transportation uses, including roles in hydraulic designs.

Geonets

Geonets, also called geospacers by some, are formed by a continuous extrusion of parallel sets of polymeric ribs at acute angles to one another. See Figure 5. When the ribs are opened, relatively large apertures are formed into a netlike configuration. Two types are most common, either bi-planar or tri-planar designs. Many different types of drainage cores are available consisting of nubbed, dimpled or cuspated polymer sheets, three-dimensional networks of stiff polymer fibers in different configurations and small drainage pipes or spacers within geotextiles. In most cases their surfaces are covered with a geotextile as a component in a geocomposite. The typical polymer is polypropylene (PP). They function by providing planar or lateral movement of liquids (or gasses) and are also called drainage mats. I*CPI Tech Spec 14 Concrete Paving Units for Roof Decks* covers the use of drainage mats in detail.

Geosynthetic clay liners

Geosynthetic clay liners (GCLs) sandwich a thin layer of bentonite clay between two geotextiles or bonded to a geomembrane as shown in Figure 6. Structural integrity of the composite is obtained by needle-punching, stitching or adhesive bonding. GCLs are used as a component beneath a geomembrane or alone in containment, hydraulic, transportation and geotechnical applications. GCLs are a competitive alternative to compacted clay liners.

Geopipe

Geopipe is another name for drainage pipe and is manufactured from high-density polyethylene (HDPE) and polyvinylchloride (PVC) as shown in Figure 7. Versions are available with rigid, smooth walls or flexible corrugated pipe. The geopipes may be perforated to allow liquids or gases to

Figure 6. Geosynthetic clay liners

Figure 7. Various geopipes

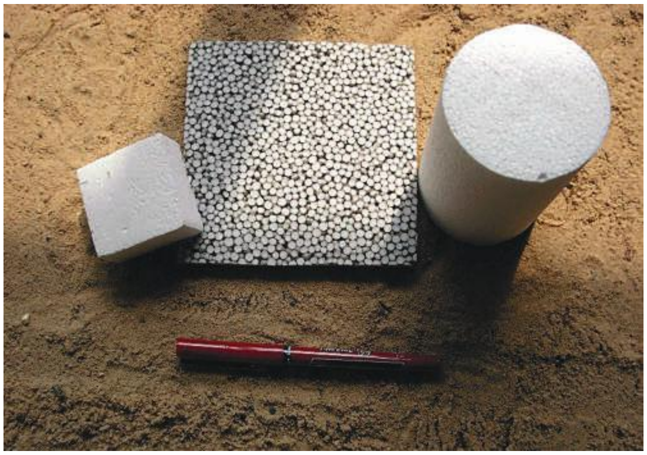


Figure 8. Geofoam examples

Figure 9. Geocells partly filled with aggregate

enter or exit the pipe as well as non-perforated to transfer them. There has been enormous growth in the use of corrugated HDPE and large diameter pipe in recent years.

Geofoam

Geofoam is created by a polymer expansion of polystyrene (EPS) resulting in a "foam" consisting of many closed, gas-filled, cells as shown in Figure 8. The skeletal nature of the cell walls is the unexpanded polymer material. The resulting product is generally in the form of large, but extremely light, blocks which are stacked side-by-side providing lightweight fill in numerous applications. Geofoam is also used for insulation of frost-sensitive soil applications. Geofoams are being used as a substitute for compacted dense-graded aggregate base in mostly residential, pedestrian-only applications. This is a new application and requires evaluation of field performance on various soils and climates.

Geocells

Geocells (also known as cellular confinement systems) are three-dimensional honeycombed structures that confine compacted soil or base materials within them as shown in Figure 9. Extruded polymer strips ultrasonically welded together in series are expanded on site form stiff walls (typically textured and perforated) that create a three-dimensional cellular mattress. Infilled with soil or base materials, a more stable structure is created. The cellular confinement reduces the lateral movement of materials, thereby maintaining compaction and stiffness capable of distributing loads over a wide area. Traditionally used in slope protection and earth retention applications, geocells are increasingly used for long-term road and railroad support. Much larger geocells are also made from stiff geotextiles sewn into similar, but larger, unit cells that are used for protection bunkers and walls.

Geocomposites

A geocomposite combines geotextiles, geogrids, geonets and/or geomembranes in a factory fabricated unit as shown in Figure 10. GCLs are an example of a geocomposite as are geonets covered with geotextile. Applications are numerous and constantly growing and cover the range of functions for geosynthetics.

Handling Geosynthetics

Many geosynthetics are supplied in rolls with unique serial numbers for manufacturer quality control. Installation contractors should remove these labels from delivered materials and keep them with other project records.

Geosynthetics will degrade when exposed to ultra-violet rays in sunlight over long time periods so they should

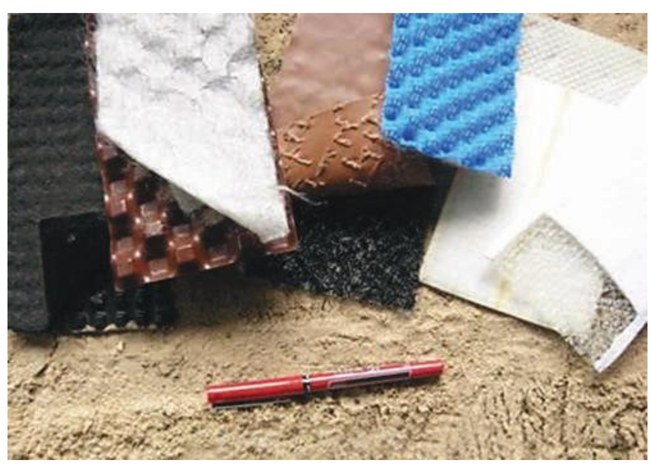
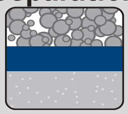
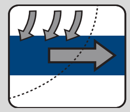
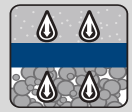
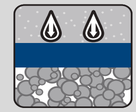


Figure 10. Geocomposite examples

Table 1. Geosynthetic functions

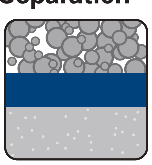
Geosynthetic	Separation 	Reinforcement 	Filtration 	Drainage 	Containment 
Geotextile	✓	✓	✓	✓	
Geogrid	✓	✓			
Geomembrane					✓
Geonet				✓	
Geosynthetic clay liner					✓
Geopipe				✓	
Geofoam	✓				
Geocell		✓		✓	
Geopipe				✓	
Geocomposite	✓	✓	✓	✓	✓

remain in their packaging, covered, or stored inside until use. While additives are in the polymers that provide some resistance, continued exposure weakens them and they may not perform as expected. Excessive heat can also damage geosynthetics which provides another reason to store geotextiles away from sunlight in places with air circulation. On a hot sunny day, placing a heavy tarp over geosynthetics rolls can heat it and reduce strength and performance. To maintain their performance, geotextiles are best stored elevated above the ground in their original packaging out of direct sunlight, protected from precipitation and excessive heat. Further information is available in ASTM D4873 *Standard Guide for Identification Storage & Handling of Geotextiles*.

Geosynthetic Functions

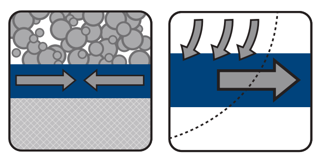
Geosynthetics are generally selected and designed for a particular application by considering their primary function or functions. Table 1 illustrates functions of various geosynthetics. The functions are defined below.

Separation



Separation places a flexible geosynthetic material such as a permeable geotextile between dissimilar materials so the integrity and function of both materials remain intact or even be improved. Paved roads, unpaved roads, and railroad bases are common applications. Also, the use of thick nonwoven geotextiles for cushioning and protection of geomembranes is in this function category. In addition, for most applications of geofoam and geocells, separation is the major function.

Reinforcement



Reinforcement synergistically improves a system's strength when introduced to a geotextile, geogrid or geocell all of which function well in tension. These can strengthen a soil that is otherwise weak in tension. Applications include mechanically stabilized and retained earth walls and steep soil slopes. Such walls can be connected to concrete units to create vertical retaining walls. Other applications are reinforcement of weak soils and over deep foundations for embankments with heavy surface loads. Unlike geotextiles, stiff polymer geogrids and geocells do not have to be in tension to provide soil reinforcement. Stiff two-dimensional geogrids and three-dimensional geocells interlock with the aggregate particles, providing reinforcement through confinement of the aggregate. The resulting mechanically stabilized aggregate layer provides improved loadbearing performance. Stiff polymer geogrids with very open apertures in addition to three-dimensional geocells made from various polymers are increasingly specified in unpaved and paved roadways, within dense and open-graded aggregate bases, and especially in railroad ballast where the improved loadbearing characteristics can significantly reduce the need for high-quality, expensive imported aggregate.

Filtration

Filtration allows water or gases to move through the plane of the material without the undesired movement or loss of soil. Filtration applications are highway underdrain systems, retaining wall drainage, landfill leachate collection systems, silt fences and curtains, and flexible forms for bags, tubes and containers.

Drainage

Drainage allows water or gases to move within the plane of the material without the undesired movement or soil loss. Geopipe highlights this function, and also geonets, geocomposites, and very thick geotextiles. Drainage applications for these different geosynthetics are retaining walls, sport fields, dams, canals, reservoirs, and capillary breaks. Sheet, edge and wick drains are geocomposites for various soil and rock drainage applications.

Containment

Containment is achieved with geomembranes, geosynthetic clay liners, or some geocomposites which function as liquid or gas barriers. Landfill liners and covers rely on their continued containment. All hydraulic applications (tunnels, dams, canals, surface impoundments, and floating covers) use these geosynthetics as well.

Use of Geotextiles

Typical pavement applications achieve separation, filtration and possibly reinforcement. Geotextiles can help provide a longer service life and reduce pavement material use. Understanding geotextile properties is fundamental to selecting them for pavement applications. Properties are listed below and each are associated with an ASTM test method.

- Grab tensile strength
- Wide width tensile strength
- Trapezoidal tear strength
- CBR puncture
- UV resistance
- Apparent opening size
- Permittivity
- Flow Rate
- Transmissivity

While there is a broad range of geotextiles properties, some are more appropriately applied for a given application. In general, the grab tensile strength and wide width tensile strength tests provide the ultimate strength and strain values at specified elongation rates. Trapezoidal tear and CBR puncture characterize resistance to installation damage. The CBR puncture test measures the force required to push a 2 in. (50 mm) piston through a geotextile similar to a 2 in. (50 mm) rock interaction with a geotextile in the field. Permittivity, flow rate, and transmissivity are hydraulic properties on how readily water moves through or within a given geotextile.

Geotextile Properties

Geotextiles are classified into two main categories based on their method of manufacture: woven and non-woven.

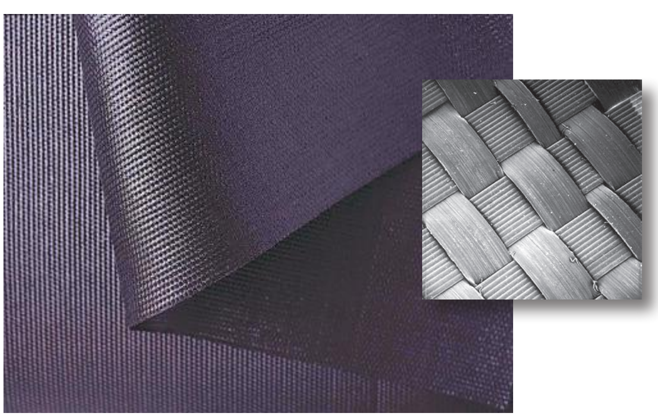


Figure 11. Woven slit-film geotextile with close-up

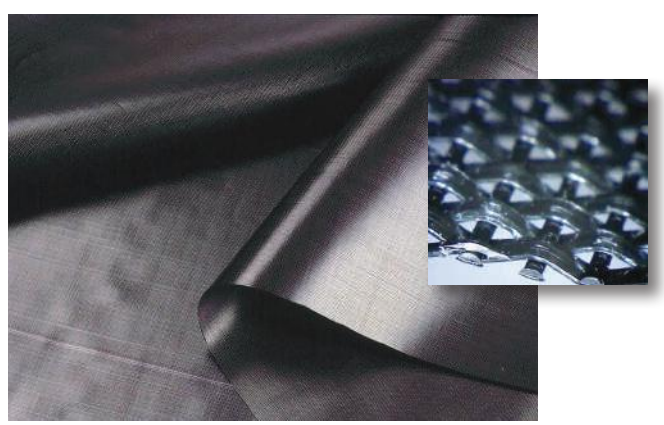


Figure 12. Woven mono-filament geotextile with close-up

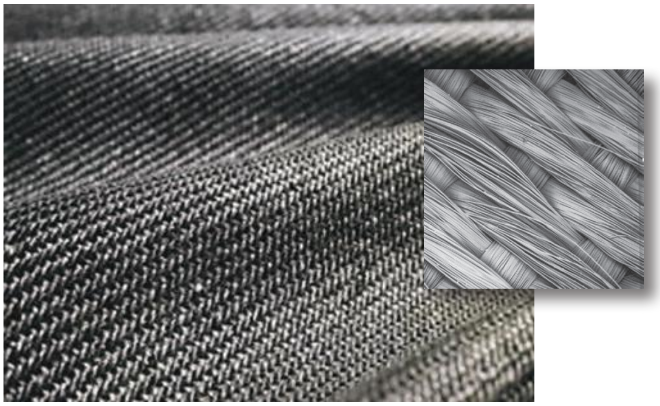


Figure 13. Woven multi-filament geotextile with close-up

Figure 14. Non-woven needle punched geotextile with close-up

Woven geotextiles

Woven geotextiles are manufactured from various polymers with increasing strengths typically increasing their cost. Woven geotextiles typically provide good resistance to abrasion from bedding materials and bases. They also provide strength with minimal elongation (stretching) because of the orientation of the individual fibers. This allows woven geotextiles to function as a good reinforcement. Woven geotextiles are classified into subcategories based on the shape of the fibers used to construct them.

Woven Slit-film—Also known as woven slit-tape geotextile, this fabric is made from long, continuous wide fiber relative to their thickness. See Figure 11. When woven together the fibers create very small openings that impede water movement to a slow rate while preventing the passage of fine soil particles. The weave creates lower filtration and greater separation, as well as being a relatively economical material. The fabric is for applications where separation with some reinforcement and lower water filtration volumes are required.

Woven mono-filament—This weave is constructed using similar techniques to slit-film geotextiles but with round or oval individual fibers resulting in a tight, stable geotextile. See Figure 12. This creates larger holes and a higher water flow through it. Because of the higher fiber cost and specialized machinery used to weave it, mono-filament geotextiles are typically the most expensive woven geotextiles.

Woven multi-filament—These are manufactured using bundles of fibers that opens up the weave so more water can pass compared to a slit-film geotextile. See Figure 13. The multi-filament fiber material cost is also lower than a monofilament fiber. When compared to a slit-film or mono-filament geotextiles, multi-filament geotextiles provide filtration at a rate and cost between them.

Nonwoven Geotextiles

The other main category of geotextiles is nonwoven where the fibers are laid out randomly and run through one of two secondary processes called needle-punching or heat bonding to give the material its structure.

Nonwoven needle-punched is created by pushing needles with barbs at their tips through the mass of random fibers. See Figure 14. This process forces some of the fibers through the matrix which binds the fibers together. This creates a material with many small openings through the mass of fibers that allow water to flow a high rate while filtering the water. The mass also creates loft or thickness that allows water to travel laterally within the plane of the geotextile which provides drainage. Some nonwoven needle-punched geotextiles are thicker which increases their drainage capacity. Unfortunately, the random fiber mat gives needle-punched geotextile a relatively low strength. When a heavy load is applied, the fabric can stretch significantly before it tears. For some applications its ability to stretch or elongate is a desirable feature.

The thickness of a nonwoven needle punched geotextile is identified by the weight per unit area. For example, a 4 ounce per square yard is considered a typical, lightweight material approximately 2 mm thick. Whereas a 20 oz/sy would be a very thick material probably over 10 mm. Thick needle-punched geotextiles are used for demanding applications like landfill sites and the material can be expensive. Nonwoven needle-punched geotextiles are sometimes used to

Table 2. Geotextile types and function ratings

Type	Separation	Reinforce	Filtration	Drainage	Cost
Woven Slit-film	Excellent	Good	Poor	Poor	Low
Woven Mono-filament	Good	Good	Good	Poor	Medium
Woven Multi-filament	Excellent	Excellent	Good	Acceptable	High
Non-woven Needle-punched	Good	Poor	Excellent	Good to Excellent	Low
Non-woven Heat-bonded	Good	Acceptable	Acceptable	Acceptable	Low

provide a separation layer for a geomembrane to prevent punctures from aggregates during compaction or from other objects.

Nonwoven heat bonded geotextiles are created using polymer fibers with a high melt temperature in their core encapsulated by a second polymer with a lower melt temperature. See Figure 15. The fibers are laid out in a random layer and then run through heated rollers, called calendaring, that melts the outer layer of the fibers and press them together. Heat bonded geotextiles have higher strength compared to nonwoven needle-punched fabrics because the individual fibers are welded together. However compressing the fibers together reduces the openings in the matrix and this restricts water flow and its filtration function. The compressed matrix minimizes its ability for water to flow within the layer and provide drainage. Table 2 summarizes functions and relative cost for the different types of geotextiles presented.

Figure 15. Non-woven heat bonded geotextile with close-up

Basic Design Concepts for Geotextiles

The American Association of State Highway and Transportation Officials (AASHTO) M-288 Standard Specification for Geotextile Specification for Highway Applications is a widely accepted geotextile specification by provincial and state departments of transportation as well as municipalities. M-288 covers six geotextile applications: subsurface drainage, separation, stabilization, permanent erosion control, sediment control, and fabrics used within paving materials. M-288 is not a design guideline and places design and selection decisions on the engineer who considers site-specific soil and water conditions.

M-288 includes three survivability classes for geotextiles, i.e. Class 1, 2 and 3. Class 1 is the most severe and Class 3 represents least severe site conditions. Potential damage during construction and use is considered in selecting a class. Each class subdivides geotextiles according to elongation, greater or less than 50%, and the designer can select nonwoven or woven geotextiles for each class based on various characteristics listed in Table 2. For stabilization and separation applications, a woven fabric is typically less expensive than nonwoven options. For subsurface drainage and erosion control, woven fabrics are more expensive than non-woven.

When selecting a geotextile primarily for its separation function, it is important to make sure that it exceeds these minimum criteria specified in M-288 as shown in Table 3, also provided in *ICPI Tech Spec 2 Construction of Interlocking Concrete Pavements*.

AASHTO M-288 also provides guidance on the overlapping of geotextile pieces necessary to achieve con-

Table 3. Selection criteria for geotextiles in separation functions per AASHTO M-288

Geotextile Class	ASTM Test Method	Class I [a]		Class II [a]		Class III [a]	
Elongation	ASTM D4632	< 50%	> 50%	< 50%	> 50%	< 50%	> 50%
Grab Strength [b]	ASTM D4632	315 lb [1400 N]	202 lb [900 N]	247 lb [1100 N]	157 lb [700 N]	180 lb [800 N]	112 lb [500 N]
Sewn Seam Strength [b,c]	ASTM D4632	283 lb [1260 N]	182 lb [810 N]	223 lb [990 N]	142 lb [630 N]	162 lb [720 N]	101 lb [450 N]
Tear Strength [b]	ASTM D4533	112 lb [500 N]	79 lb [350 N]	90 lb [400 N] [d]	56 lb [250 N]	67 lb [300 N]	40 lb [180 N]
Puncture Strength [b]	ASTM D6241	618 lb [2750 N]	433 lb [1925 N]	495 lb [2200 N]	309 lb [1375 N]	371 lb [1650 N]	223 lb [990 N]
Permitivity [b,e]	ASTM D4491	0.02 sec^{-1}					
Apparent Opening Size	ASTM D4751	0.024 in [0.60 mm] maximum average roll value					
Ultraviolet Stability	ASTM D4355	> 50% after 500 h exposure					

[a] The severity of the installation conditions generally dictates the required geotextile class. Class 1 is the most severe and Class III is the least severe.
[b] All numeric values represent MARV in the weaker principal direction.
[c] When sewn seams are required.
[d] The required tear strength for woven monofiliment geotextiles if 250 N.
[e] Default Value. Permittivity of the geotextile should be greater than the soil.

tinuous coverage as shown in Table 4, also provided in *ICPI Tech Spec 2*.

In March 2012, the AASHTO National Transportation Product Evaluation Program (NTPEP) approved the adoption of a work plan for the evaluation of geotextile materials in highway applications. NTPEP is an AASHTO program that evaluates materials and products of common interest for use in highway and bridge construction. The program provides cost-effective evaluations for state DOTs by eliminating duplication of testing and auditing by the states, and duplication of effort by the manufacturers that provide products for evaluation. The NTPEP work plan establishes a list of manufacturing facilities, private label companies, geotextile converters and their associated geotextile products that conform to the quality control and product testing requirements of the work plan and AASHTO M-288. This provides a resource on companies that can provide geotextiles that conform to AASHTO M-288. Visit www.ntpep.org for additional information.

Table 4. Geotextile overlap recommendations in AASHTO M-288

Soil CBR, %	Overlap
> 3.0	1.0 ft [0.3 m] to 1.5 ft [0.45 m]
1.0 to 3.0	2.0 ft [0.6 m] to 3.0 ft [1.0 m]
0.5 to 1.0	3.0 ft [1.0 m] or sewn
< 0.5	Sewn
All roll ends	30 ft [1.0m]

Geotextile Applications for Segmental Concrete Pavements

The following provides examples of where geotextiles might be used in segmental concrete pavements. Recommendations are provided on the type of geotex-

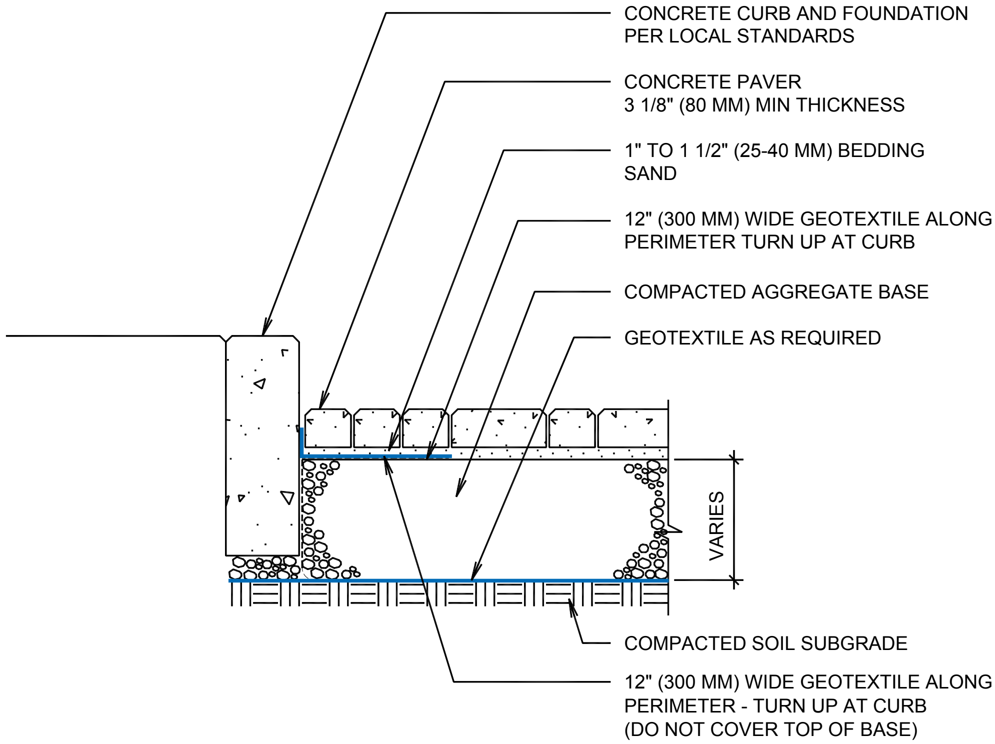


Figure 16. Geotextile in an interlocking concrete pavement over a flexible base

Table 5. Geotextile application guidelines for applications illustrated in Figure 16.

Site conditions and requirements	Recommended geosynthetics
Separate base from subgrade • Soil is a fine-grained silt or clay with little potential to infiltrate water and alternate drainage provided	Woven slit-film geotextile • Filtration not as important • Reinforcement is beneficial • Separation is important
Separate base from subgrade • Soil is sandy or gravelly with good potential to infiltrate water	Woven multi-filament geotextile or woven mono-filament geotextile • Filtration important • Reinforcement is beneficial • Separation is important
Prevent Bedding Sand Loss • Structures adjacent to bedding sand could crack, gaps and/or drain holes	12 in. (300 mm) strip of non-woven needle-punched geotextile • Filtration important

tiles best suited to site conditions. While these are general guidelines, contractors should follow the recommendations and use materials specified in the construction documents.

When placing geotextile avoid wrinkles in the fabric. Follow the overlap recommendations specified in ASSHTO M-288 as noted in Table 4 above and avoid excessive overlapping of edges. Make sure the geotextile is placed in full contact with the surrounding soils or aggregates. Voids, hollows or cavities from wrinkles created under or beside the geotextile compromises its intended function.

Figure 16 illustrates geotextiles separating the compacted aggregate base from the soil subgrade. This can help maintain consolidation of the base materials over time by preventing intrusion of fines in the bottom and sides. This slows the rate of rutting in the base and on the soil subgrade.

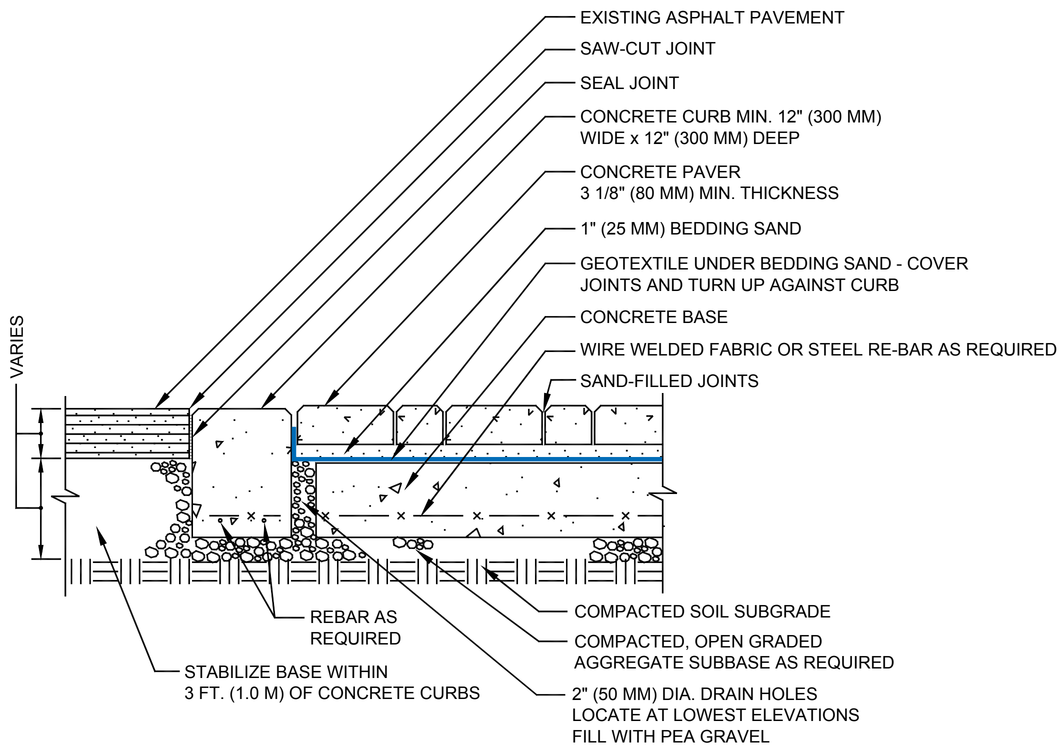


Figure 17. Interlocking concrete pavement overlay on a rigid concrete base

Table 6. Geotextile options for Figure 17.

Site conditions and requirements	Recommended geosynthetics
Prevent Bedding Sand Loss • Concrete base with potential to crack • Lower load applications	Non-woven needle-punched geotextile • Filtration important
Prevent Bedding Sand Loss • Concrete base with potential to crack • High traffic (truck) load applications	Woven multi-filament geotextile or woven mono-filament geotextile • Filtration important • Abrasion resistance * Include engineer familiar with geosynthetics in design process

Geotextile placed under the bedding sand next to the curb provides a 'flashing' function. This separates the sand from the base and prevents sand loss into joints between the concrete curb and the compacted aggregate base, as they are two structures that can move independently of each other. Table 5 provides guidelines for geotextile selection depending on conditions and requirements.

Figure 17 illustrates geotextile on a concrete base in a crosswalk applications. For new sidewalks, crosswalks, and streets, 12 in. (300 mm) wide strips of geotextile are recommended over all joints in new concrete bases to prevent loss of bedding sand, as well as over weep holes. New asphalt generally should not require geotextile on it except at curbs, structures and pavement junctions where bedding sand might enter. For existing asphalt and concrete bases, the surface of each should be inspected for cracks, and their severity and extent determined for repairs. If cracks are few and minor (suggesting substantial remaining life in these bases), geotextile should be placed over the cracks to prevent potential future loss of bedding sand. Table 6 provides guidelines for geotextile selection for overlay applications depending on the conditions and requirements.

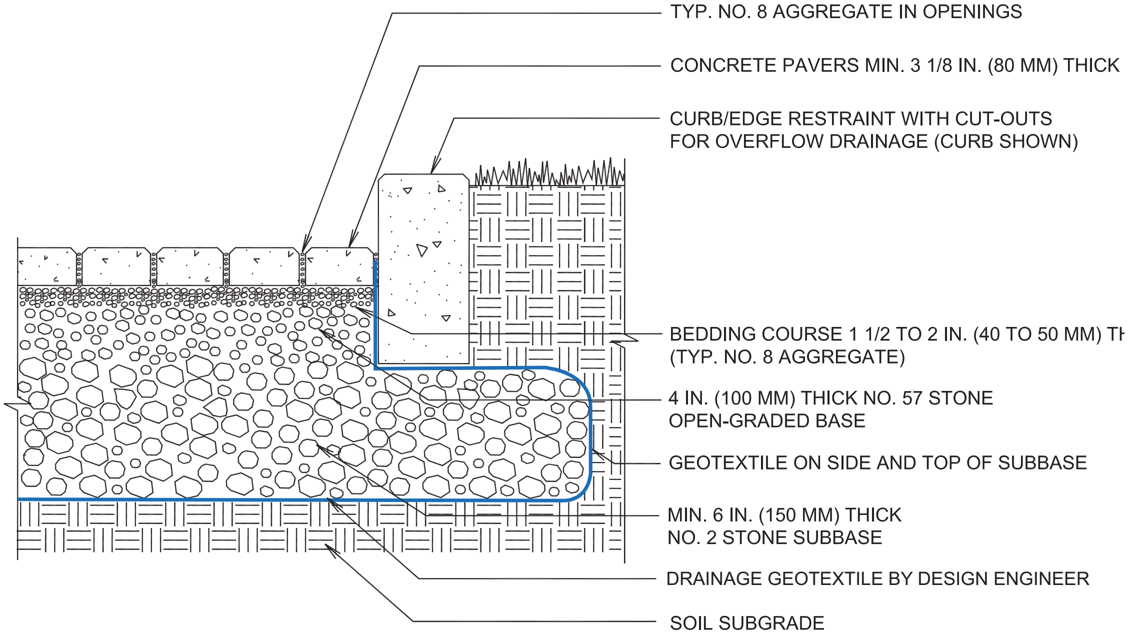


Figure 18: Permeable Interlocking Concrete Pavement geotextile locations

Table 7. Geotextile options for PICP in Figure 18

Site conditions and requirements	Recommended geosynthetics
Prevent migration of site soil into PICP base • Open graded aggregate base	Non-woven needle-punched geotextile • Filtration important
Separate base from subgrade • Open graded aggregate base • Infiltration of water from base into subgrade	Non-woven needle-punched geotextile, Woven multi-filament geotextile or Woven mono-filament geotextile • Filtration important • Separation important * Include engineer familiar with geosynthetics in design process

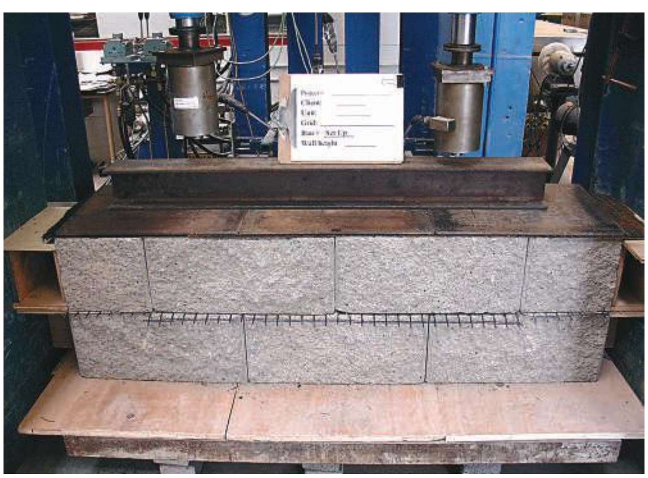



Figure 19. Geogrid connection testing with SRW units

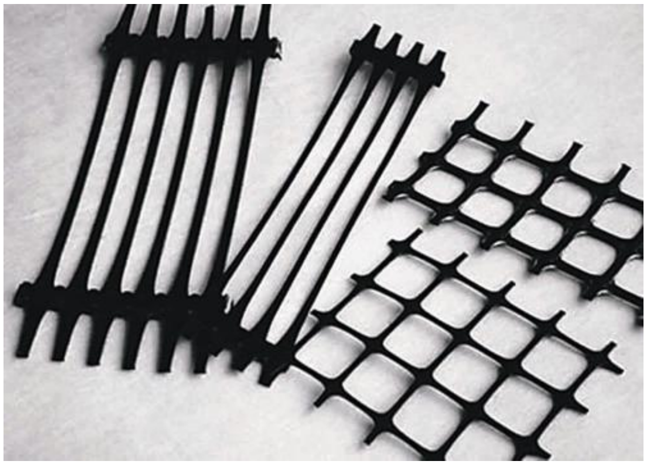


Figure 20. Uniaxial and biaxial, punched and drawn geogrids

Figure 18 illustrates a typical application of geotextile in PICP. Its application against the sides of the subbase against the excavated soil is essential in all PICP projects that do not use full-depth concrete curbs that completely confine open-graded aggregates at the pavement perimeter. The design and selection of geotextiles for PICP is covered in detail in the ICPI manual, *Permeable Interlocking Concrete Pavements—Design, Specification, Construction, and Maintenance*. Table 7 provides recommendation for the selection of a geosynthetic in PICP applications based on the conditions and requirements

Use of Geogrids

Geogrids typically reinforce applications such as mechanically stabilized earth (MSE) and weak soil subgrade improvement for roadway applications. Geogrid properties include the following:

- Wide width tensile strength
- Strain
- UV resistance
- Aperture size
- Coefficient of interaction

For MSE applications, long term design strength (LTDS) in pounds per foot or kilonewtons per meter is determined in the design process to represent the effective strength of the geogrid over the design life of the structure. Additional properties are evaluated and applied to determine the LTDS. These include creep, i.e. the amount of deformation under sustained load; durability, the resistance to degradation; and installation damage, or strength reduction that occurs during installation. Creep, durability, and installation damage factors are applied to the ultimate strength of the geogrid as reduction factors to determine the LTDS.

If the geogrids is to be used with a segmental retaining wall (SRW) system additional tests related to the connection strength and shear strength are performed as shown in Figure 19. The connection strength test determines the maximum load that can be applied to the connection between the SRW units and the geogrid. The shear strength test considers the reduction in shear strength between SRW courses with the geogrids inclusion.

Geogrid Properties

Geogrids are divided in to three categories: 1) punched and drawn, 2) woven or knitted and 3) bonded. These

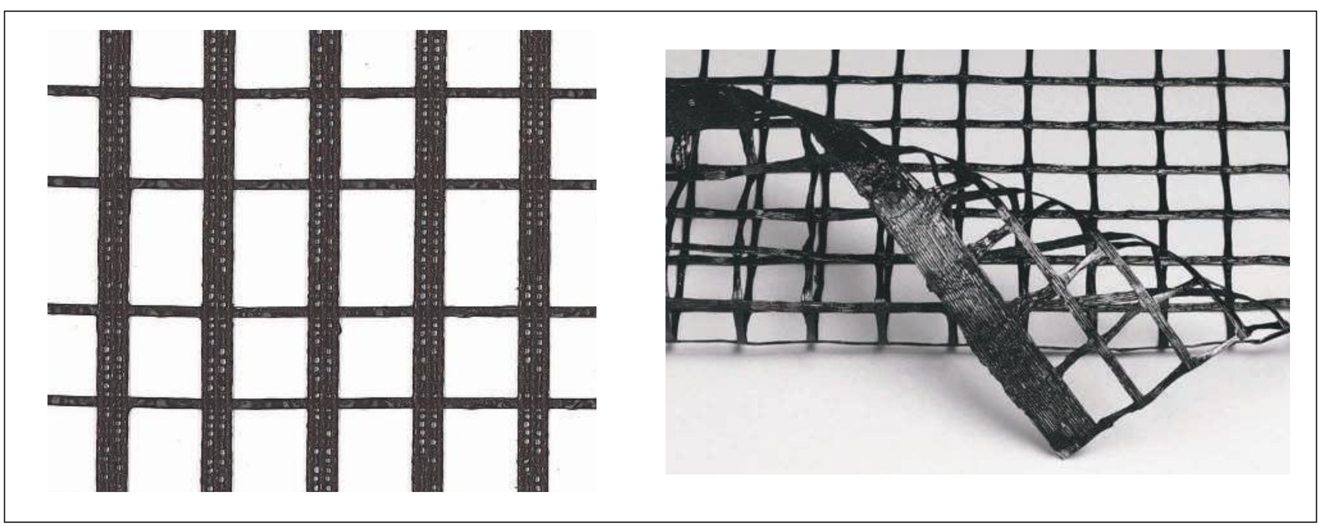


Figure 21. Uniaxial and biaxial, knitted and woven geogrids

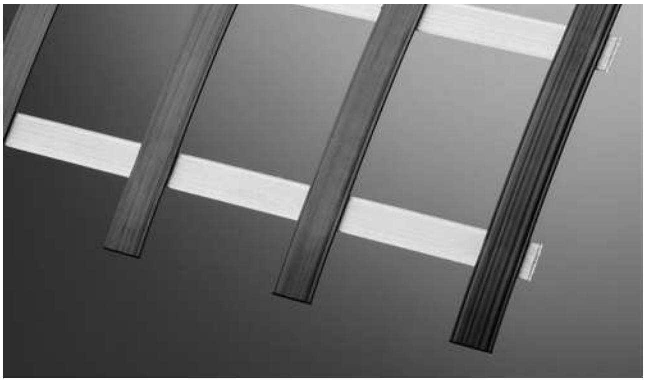


Figure 22. Uniaxial bonded geogrid

groupings are based on their manufacturing method. As mentioned above geogrids are also classified on their load carrying ability. If the geogrid is designed to carry load in one principal direction, typically along its length, it is referred to as a uniaxial geogrid. If the geogrid is designed to carry load along its length and width it is called biaxial.

Punched and Drawn Geogrids

The first category of geogrid, punched and drawn, is a sheet of plastic with punched holes, heated and stretched in one or more directions. Uniaxial geogrids are stretched in one direction as shown in the two samples on the left of Figure 20. Biaxial geogrids are stretched in two or more directions as shown in the two samples on the right of Figure 20. Polymers typically are polypropylene (PP) or high density polyethylene (HDPE). This type of geogrid is stiff, allowing it to anchor in the soil to carry large loads with minimal movement.

Woven or Knitted Geogrids

The second category of geogrid is woven or knitted. The fibers are typically made from polyester with variations made from polyvinyl alcohol and fiberglass. Once the fibers are woven or knitted, they are coated with polyvinyl chloride (PVC) or similar materials to bind them together and increase durability. Uniaxial (shown on the left in Figure 21) and biaxial woven or knitted geogrids (right in Figure 21) are possible. The more fibers in one direction, the higher the strength. Woven and knitted geogrids tends to be more flexible which making them easier to manipulate on the jobsite.

Bonded Geogrids

The third category of geogrid is bonded which represents a small portion of geogrids. Figure 22 show a geogrid made from polyester ribbons welded together ultrasonically to form a very stiff mat. Uniaxial and biaxial varieties are available.

Biaxial geogrids are best suited to aggregate base reinforcement in pavement applications whereas uniaxial geogrid are optimized for MSE (soil subgrade) applications. However, biaxial geogrids may have some installation advantages when used in MSE applications. Table 8 compares geogrid types and applications. The cost of each geogrid depends on the strength required from the grid material.

Basic Design Concepts with Geogrids

When designing with a geogrid, the manufacturer can provide and ultimate strength of the material. However site conditions degrade the geogrid over its life due to loads within the pavement or wall structure. The designer must consider the effects of creep (i.e., slow elongation), installation damage and durability to determine a maximum allowable long term design strength (LTDS).

$$LTDS = \frac{T_{ult}}{(RF_{CR} \times RF_{ID} \times RF_{D})}$$

Where;

T_{ult} = ultimate tensile strength, pounds per foot or kilonewtons per meter

RF_{CR} = Reduction factor due to creep

RF_{ID} = Reduction factor due to installation damage

RF_{D} = Reduction factor due to durability

Creep occurs in polymer materials when subject to a sustained load over a long period of time. If the load is too great, the polymer will continually stretch and even-

Table 8. Geogrid comparisons

Type	Aggregate Base Reinforcement	Soil Slope/Wall Reinforcement
Punched & Drawn Uniaxial	Poor	Excellent
Punched & Drawn Biaxial	Excellent	Poor
Woven/Knitted Uniaxial	Poor	Excellent
Woven/Knitted Biaxial	Excellent	Poor
Bonded Uniaxial	Poor	Excellent
Bonded Biaxial	Excellent	Poor

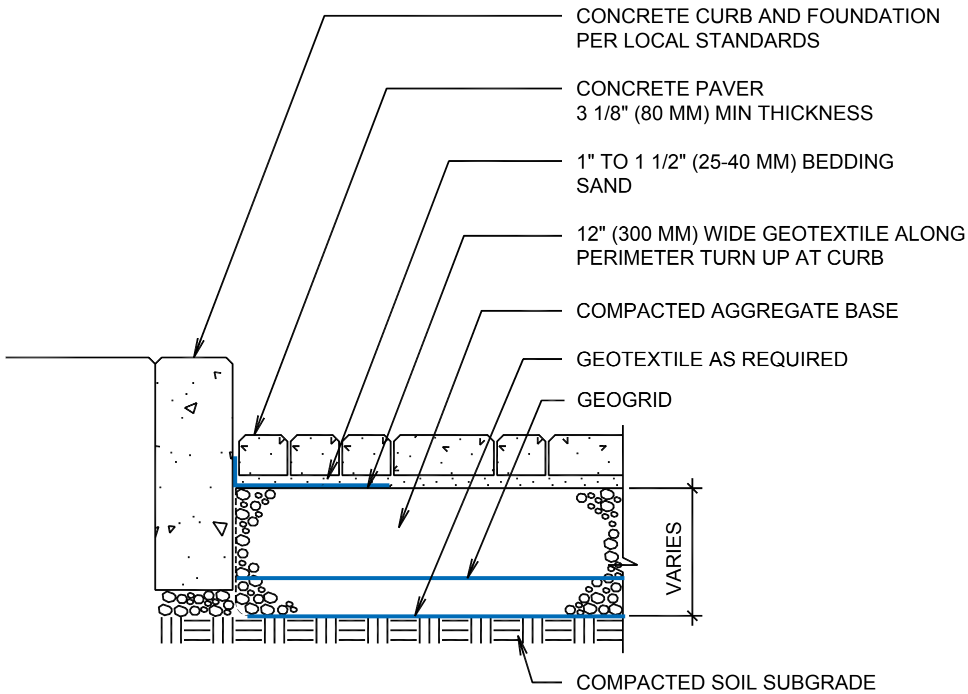


Figure 23. Interlocking concrete pavement with geogrid in the base for reinforcement

Table 9. Geogrid applications for Figure 23

Site conditions and requirements	Recommended geosynthetics
Reinforce aggregate base • Weak subgrade • Higher load applications	Biaxial geogrid • Reinforcement in length and width important

tually break. The load must be limited to prevent this unrestricted creep. This is considered in the design as the RF_{CR} factor. When aggregate is compacted on the geogrid it is damaged and the strength reduced. Different types of aggregates will create different amount of damage. This affect is considered in the strength calculation as the RF_{ID} factor. Lastly, chemical and biological agents may affect the geogrid over the life of the geogrid causing it to lose strength. These affects are considered in the strength equation by including the RF_D factor. An experienced design engineer can apply appropriate reduction factors in estimating the LTDS.

Geogrid Applications with Segmental Concrete Pavements

Geogrids are designed to provide reinforcement, and can enhance the strength and longevity of interlocking concrete pavements. Some examples are presented below. Recommendations are also provided for the type of geogrid best suited to the site conditions. Nonetheless, contractors should always follow recommendations for materials specified in the construction documents.

When placing geogrids they should be installed with a small amount of tension. Wrinkles in the geotextile should be removed. When placing aggregate on top of a geogrid, spread it out so it will keep the tension the geogrid instead of releasing the tension, i.e. place the aggregate and spread it towards the free ends of the geogrid. For SRWs, do not overlap geogrid between block courses. This will push the units above the overlap out of horizontal alignment.

Figure 23 illustrates using a geogrid layer to improve the strength and load distribution characteristics of a compacted aggregate base. This method of construction would be appropriate for low strength soils. It is important

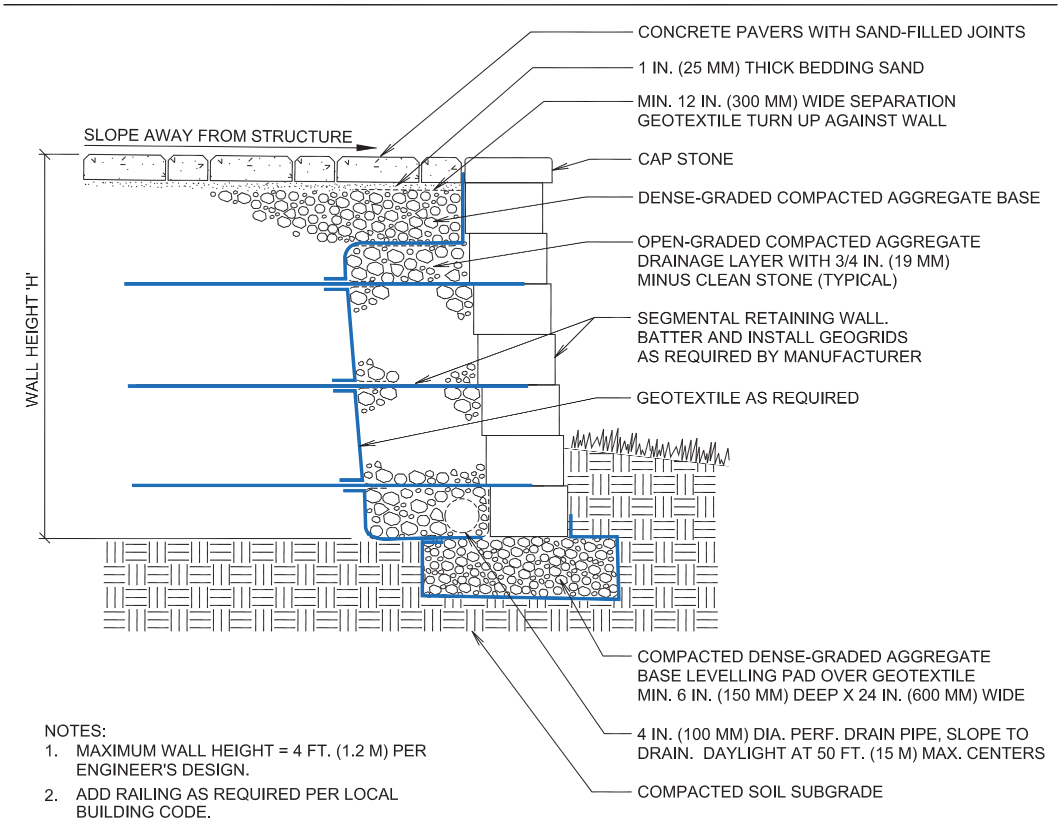


Figure 24. Raised patio with geogrid reinforced segmental retaining wall

Table 10. Geogrid applications for Figure 24 with segmental retaining walls and concrete pavers

Site conditions and requirements	Recommended geosynthetics
Reinforced segmental retaining wall • Total SRW height exceeds 2 x depth of SRW units	Non-woven needle punched geotextile • Separation and Filtration are important Uniaxial geogrid • Reinforcement perpendicular to wall face important and length as specified in engineered drawings Biaxial Geogrid • Only if roll width exceeds minimum specified length and cross roll strength exceeds deign requirements

to note that the geogrid will typically be placed within the aggregate base and not at the base – subgrade interface. This will optimize the reinforcement function of the geogrid. If a minimal level of containment is desirable, and a less than optimized reinforcement function is allowable the geogrid may be placed at the subgrade – base interface. Table 9 provides recommendations for geogrids used in base reinforcement applications depending on the conditions and requirements.

Figure 24 is a cross section detail of a raised patio. This application can benefit from reinforcement by using a geogrid to create a mechanically stabilized earth retaining wall. Additionally filtration is necessary to prevent fine soil particles from being washed out of the backfill and pavement base, which can lead to settlement over an extended period. Confinement of the aggregate used to construct the retaining wall base can also be advantageous when building over weaker fine grained soils like silts and

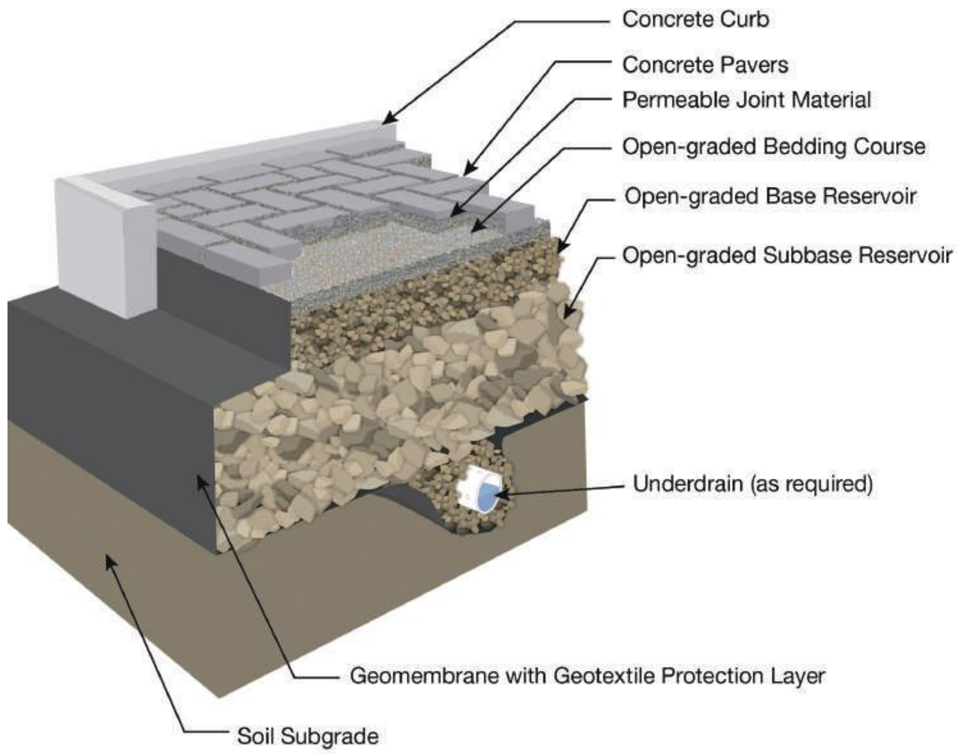


Figure 25. Typical geomembrane application in a no infiltration PICP design

clays. Table 10 provides recommendations for geotextiles and geogrids used in SRW applications depending on the conditions and requirements.

Use of Geomembranes

Geomembranes create an impermeable barrier that prevents the flow of liquid or gas. Geomembranes are manufactured from polyvinyl chloride (PVC), ethylene propylene diene monomer (EPDM), high-density polyethylene (HDPE) and linear lower density polyethylene (LLDPE). Other polymers that may be used for special applications include chlorosulfonated polyethylene (CSPE), chlorinated polyethylene (CPE), polypropylene (PP), and very flexible polyethylene (VFPE). Each of these polymers is unique and provides varying levels of resistance to acids, alkalis or petrochemicals. Some polymers can also function in extreme heat or cold. Normally, the surface of a geomembrane is smooth, but some sloped applications can benefit from a textured surface that provides greater friction with the adjacent geotextiles or soil.

PICP systems can be designed and constructed to accommodate three drainage conditions:

- Full infiltration of water into to a high infiltration rate soil subgrade with no underdrains;
- Partial infiltration of water into a low infiltration rate soil subgrade with some outflow through underdrains; and
- No infiltration into a soil subgrade with all outflow exiting through underdrains.

All conditions have similar surfacing, and base/subbase reservoir construction. In some PICP designs, a geomembrane is used next to building foundations or adjacent pavements with dense graded bases to prevent them from saturation and damage. Geomembranes may be used within a PICP subbase on sloped applications as check dams to slow the flow of water and encourage infiltration between each vertical liner. Additionally, no infiltration systems make use of a geomembrane on the sides and bottom of the base/subbase reservoir to contain

Figure 26. Geomembrane protected with a nonwoven geotextile for a PICP alley.

stormwater and prevent it from infiltrating into the soil subgrade as shown in Figure 25.

A no-infiltration PICP design with a geomembrane is typically used in the following conditions:

- The soil has very low permeability, low strength, or is expansive;
- High depth to a water table or bedrock;
- To protect adjacent structures and foundations from water; or
- When pollutant loads are expected to exceed the capacity of the soil subgrade to treat them.

By storing water in the base/subbase and then slowly draining it through pipes, the design behaves like an underground detention pond with the added benefit of filtering some pollutants. A no infiltration design may be used for water harvesting. The water may be piped to an underground cistern for re-use on site. Harvested rainwater can be used to reduce landscaping water requirements and in some cases it can be used for gray water within buildings.

Geomembrane Properties

Geomembrane thicknesses depend on the polymers and the manufacturing process. For example, HDPE geomembrane is typically available in 40, 60 and 80 mil (1.0, 1.5 and 2.0 mm) thicknesses and in a range of roll widths. Geomembranes have different engineering properties depending on polymer type, thickness and manufacturing process. Properties typically provided by the manufacturers' literature and referenced in project specifications include,

- nominal thickness,
- density,
- tensile strength,
- tear resistance,
- dimensional stability and puncture resistance

Geomembrane Applications for Permeable Interlocking Concrete Pavements

Geomembranes for PICP are typically fabricated on the job site and this requires cutting, fitting and seaming to create waterproof joints. Different seaming techniques are used depending on the material, environmental conditions and project requirements. Materials like EPDM and PVC are routinely seamed using an adhesive or double sided tape. Before two panels are joined, the areas to be joined are usually cleaned and primed. HDPE and other polymers are typically welded together with extrusion welders or hot wedge welders. Seams for all materials should be field tested to ensure they are waterproof especially around underdrains penetrating the geomembrane. For smaller projects, it might be possible to have the supplier prefabricate the geomembrane to meet site requirements. Prefabricated geomembranes are typically delivered to the site folded on a pallet.

When preparing a site for a geomembrane application, rocks, roots, and other sharp objects are removed that can damage the geomembrane during installation (especially from aggregate compaction) or use. Such protrusions should be removed and voids filled with dense-graded aggregate base and compacted before placing

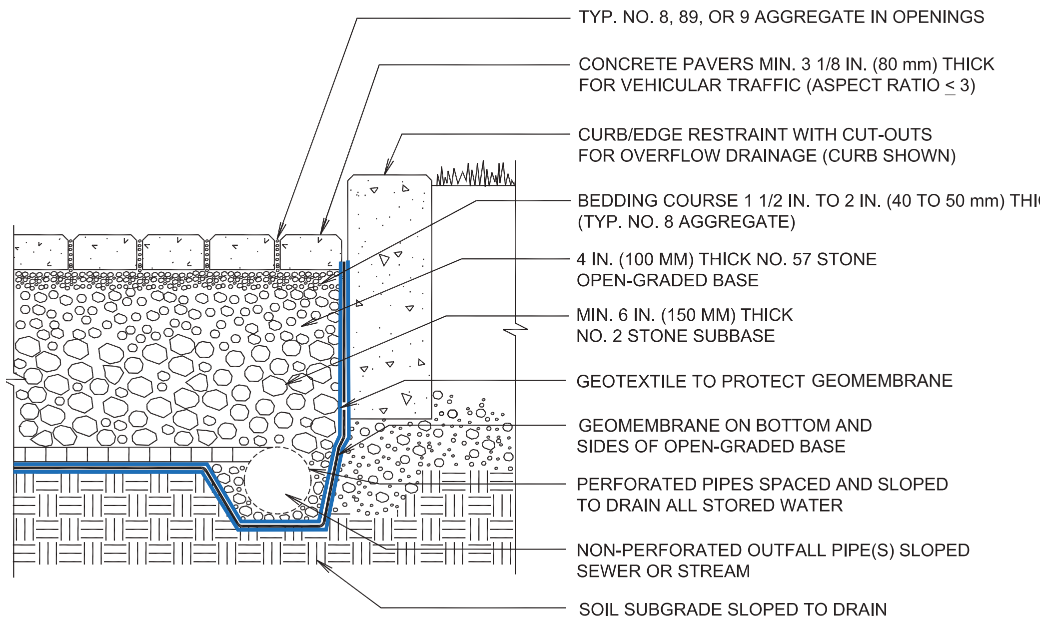


Figure 27: No infiltration Permeable Interlocking Concrete Pavement

Table 11. Geosynthetics used in No Infiltration PICP shown in Figure 27

Site conditions and requirements	Recommended geosynthetic
No Infiltration PICP system • Open graded aggregate base	Geomembrane with a non-woven needle-punched geotextile • Protection important • Containment important

the geomembrane over them. A layer of non-woven geotextile is commonly used to protect one or both sides of the geomembrane. The thickness of the geotextile is typically selected based on the materials placed next to the geomembrane and the degree of risk for punctures. Figure 26 illustrates a green alley in Richmond, Virginia with a geomembrane protected by a nonwoven geotextile. Both are placed before placing and compacting the open-graded aggregate subbase. Figure 27 shows the typical cross section for a No-exfiltration PICP system.

When designing a no infiltration PICP system there are many factors that must be considered in selecting the geomembrane and protection materials. In addition, geomembranes may be wrapped around utility lines to protect them from exposure to water within PICP bases/subbases. For most projects, consultation with an engineer familiar with the design of geomembranes is recommended. Table 11 provides recommendations for geomembrane and geotextile selections based on conditions and requirements.

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