Government of the Peoples Republic of Bangladesh

Local Government Engineering Department (LGED)

Draft 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
ICPB	Interlocking Concrete Paving Block
IRC	Indian Road Congress
LGEB	Local Government Engineering Bureau
LGED	Local Government Engineering Department
LGI	Local Government Institution
MPa	Megapascal
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 liquification 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 (ICPB) in roadway construction is worldwide. The design comprises of a simple concept of ICPBs 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 ICPB roads is ancient. It started from the early Roman Empire and got refined after World War II. The only improvements ICPB has adopted over time are being manufactured with higher quality and accuracy in placement. Currently, Europe widely constructs ICPB 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 ICPB 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 ICPB roads.

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

As it is mentioned earlier, first merit ICPB 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 ICPBs, 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 ICPB road, then blocks at the point of interest are removed and necessary adjustments are made. Then the substituted blocks are replaced again, making ICPBs reusable.

Another distinguishable feature that ICPB 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, ICPB pavements do have a higher life-cycle with low maintenance, making them a suitable choice for developing countries such as Bangladesh.

ICPB 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 workplan 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 (ICPB) 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 ICPB 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 ICPB 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 ICPB and subsequently, efforts would be given in their successful inclusion into ICPB 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 Programme 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 Programme 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 programmes. In 1982 it was transformed into `Works Programme 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 Local Government Engineering Department (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 metalled 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	LGED/LGI

		with another Growth Center by a single main connection or connecting Growth Center to Higher Road System**, through shortest distance/route.	
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 Center on 13th January 1975 after the liberation of Bangladesh in order to mitigate the housing crisis for ever 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 housing schemes and enhancement in the quality of local construction practices for low income community. Aside from reseach, 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 traning 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 materials. 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 ICPB considering various dredged materials from rivers, khals, ponds, etc.
- To develop an implementation and maintenance manual including specification with costing for ICPB.
- 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 ICPB.
- 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 ICPB 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 ICPB 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 ICPB 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 ICPB 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 ICPB 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 ICPB Pavement Manuals:

To really understand the current practice regarding the inclusion of ICPB in roadway construction, two guidelines were referred to in order to understand the variation of different parameters of ICPBs 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 ICPB pavements in different scenarios such as footpaths, cycle tracks, car parks, etc. Then, they discussed about different advantages of utilizing ICPB 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 ICPB 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 ICPB 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 ICPB and stressed on using batch production plant with high pressure and controlled vibrations. The authors then briefly described the manufacturing process of ICPB.

As for the dimensional requirements, the authors proposed tolerances to the plan dimension and thickness of ICPB 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 ICPB 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 ICPB 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 ICPB 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 ICPB pavements and other types of pavements.

The authors prepared the guideline mainly for the structural design and construction of ICPB pavements under different scenarios (i.e. light, medium and heavy traffic). Then, the authors proceeded on to discuss about the principal components of ICPB 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 ICPB 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 ICPB pavement layers based on 07 (Seven) parameters.

The authors then moved straight to the installation process of ICPB paving, taking into consideration the subgrade condition, compaction and proofrolling, 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 ICPB 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 ICPB 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 ICPB 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 ICPB 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 ICPB 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 ICPB Pavement Guidelines which have been presented here clearly provide detailed information on construction of ICPB 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 ICPBs (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 were definitely shown into existing uniblock/ICPB 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
Singair Pourashava	2	21.18	0.25	0.00	4.37	9.92	25.80
Savar Pourashava	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	karnapara ghat to Nama ganda 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	Kadom rasul 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 ICPB 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 ICPB 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 ICPB:

Sand collected from the locations stated below were taken into the laboratory and sample ICPBs 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, Ishwardi Upazila, 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 ICPB 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 ICPB 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	Mirdha bari, Bottala, Board Bazar	Kabiler mor &Latif Hajir mor

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.	Kornapara ghat	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 ICPB blocks of required strength i.e. 30 and 35 Mpa by using different river sand. 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 turned 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 1**. Then dented sides were introduced to blocks for better interlocking effects with their surrounding units **Figure 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**) was introduced for better interlock. An improvement over A-Shape block was proposed (i.e. “X” shape, **Figure 7**) for additional interlocks and suitability for fully mechanized paving.

(Figure 5):

Figure 1: Plain Faced Rectangular Blocks

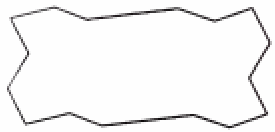


Figure 2: Dented Rectangular Blocks

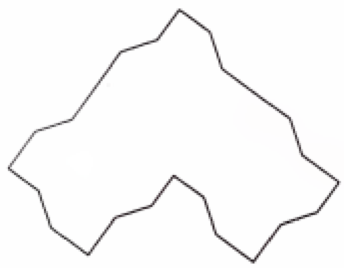


Figure 3: "A" Shaped Dented Block

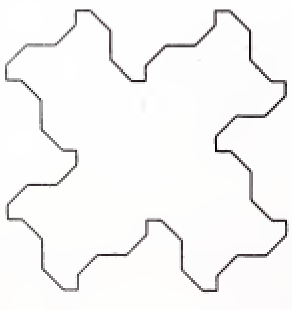


Figure 4: "X" Shaped Dented Block

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

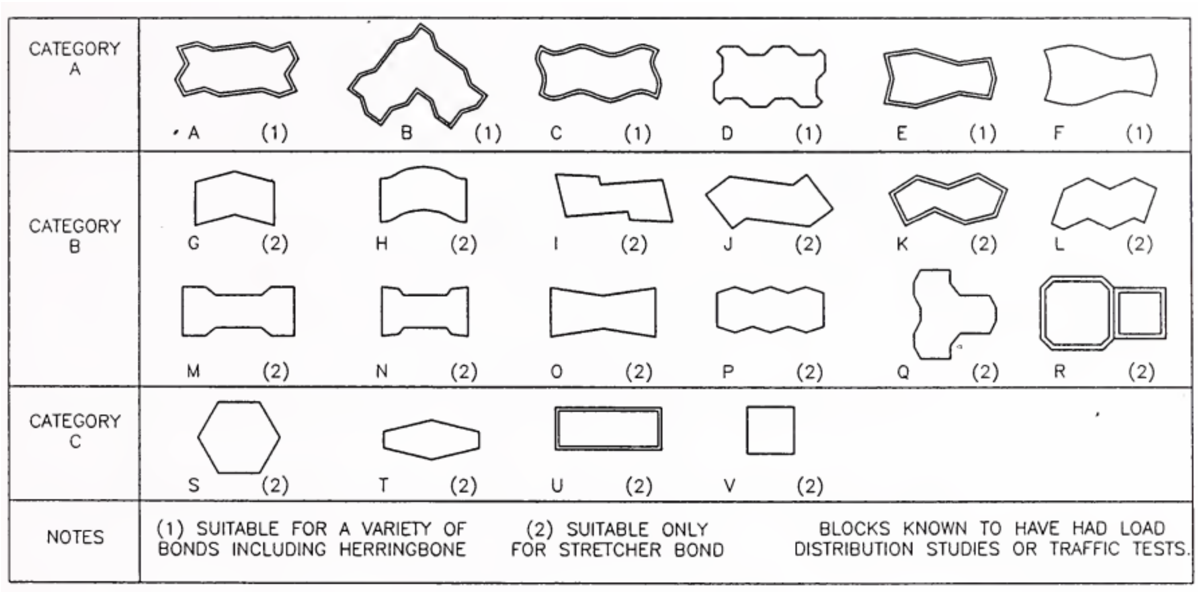


Figure 5: Different Categories of Blocks

To beautify the appearance of ICPB pavements, special grass blocks **(Figure 6)** are used which allow grass to grow in the hollow spaces in the blocks filled with soil.

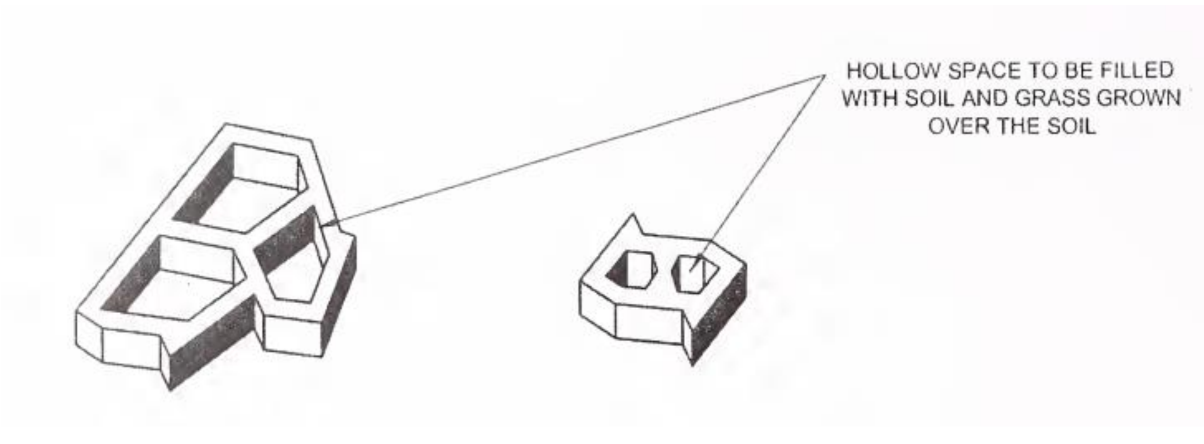


Figure 6: Typical Grass Blocks

3.6. Tests on ICPB (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 ICPB 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 ICPB as per ASTM C 67

d) Compressive Strength Test of ICPBs as per ASTM

e) Tensile Strength Test of ICPB*

*Currently, tensile strength test for ICPB 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 ICPB, 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 ICPB 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, medium and heavy traffic roads.

Design process flow chart **Figure 7** recommended to follow:

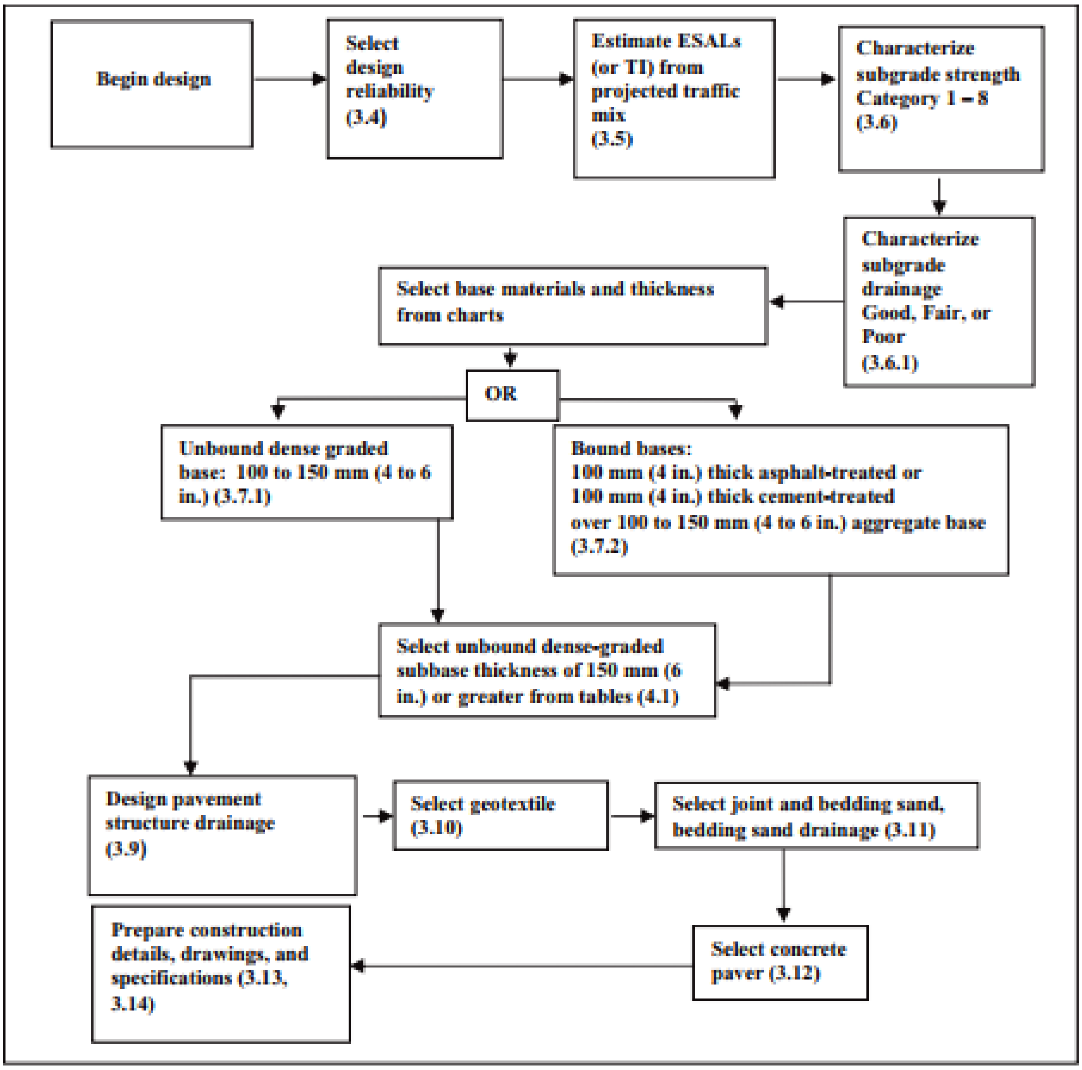


Figure 7: Design Process Flow Chart

Interlocking Concrete Pavement Institute (ICPI) provides technical information on ICPB 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, ICPB 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)	Tech Spec 10 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. Minimum thickness 60 mm; Recommended thickness of 100 mm for heavy vehicle 120 mm for heaviest vehicles Tech Spec 21 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
Heavy Traffic= 70mm
Most Heavy Traffic=80 mm
Standard Paver Strength 55 MPa
Minimum Single Block Unit= 50 MPa
Forced Plate minimum of 22 KN compacted to need to be used for heavily trafficked pavement</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>Road & parking area specially for heavy vehicles.</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><td>Classifications</td><td>CBR</td></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 of use of ICBP. In the guide book of the Indian Road Congress IRC: SP-63-2004, It provides threshold regarding dimensions of blocks and strength as minimum 30Mpa with mix ratio of coarse aggregate 40% and sand 60% manufactured through machine mold with pressure under Zero-slump mix. It considers two types of Subgrade CBR i.e (i) above 10 & (2) between 5-10. If the CBR is less than 5, subgrade needs to be improved and bring to minimum 5 or above the blocks are mainly for low traffic road thickness of block will be 4 types.

This guide book is suitable for Bangladesh Village road constructed by manually.

All others 3 institutions guide/specification books are related with mostly of heavy commercial vehicles, therefore not suitable for Bangladesh with making block (Strength of 30Mpa/35Mpa) with dredged sand of River khal etc.

Also, IRC is exclusively chosen because India is a neighboring country of Bangladesh and by considering the similarities of climatic factors, socio-economic considerations and materials availability. At this stage, detailed structural design of ICPB roadways is very resource intensive and cannot be covered within the fixed budget and time limit after completing the experimental portion dedicated for ICPB paving units only.

Road types based on traffic and Subgrade CBR (%) are provided in the design catalogue (Page-13) of the aforementioned manual. Since, the majority of the effort would be given into utilizing dredging sands from different locations, containing different gradations to make ICPBs of required strength (i.e. 35 mpa) and incorporate these blocks with traffic loads and soil CBR values to propose suitable thicknesses of road layers.

A consensus was reached that blocks are to be manufactured using dredged sands of rivers, khals to avoid clay burnt bricks, i.e best use of dredged sand. Therefore, the strength to be considered is between 30 and 35 MPa. As discussed earlier, most international journals consider 55 MPa (single block minimum strength 50 MPa) to be the standard strength for blocks in ICBP. IRC recommends a minimum strength of 30 MPa.

The consultant has reviewed the LGED design template of ICBP where it cited the strength of 30-40 MPa for cycle tracks, pedestrian footpath, and non-motorized vehicles to heavy traffic road (2.50 MESA < Traffic Volume 10.0 MESA) in 5 categories of traffics.

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

The consultant, therefore, adapted the LGED design template with a slight modification to the thickness of sand bedding (IRC giving sand bedding range of 20-40 mm) and deleting medium and heavy traffic road from the template as they need higher strength of paving blocks of 40 MPa which were not considered for the blocks manufactured from dredged sand.

A modified version of typical cross-section of ICPB road (**13)** is provided in the next page consisting of cross-sectional layer thickness and material composition of base-course, sub-base course, improved subgrade, subgrade and original soil for the proposed ICPB roadways for non-motorized vehicles (including footpaths) and light traffics. The design template also contains ICPB layout patterns, block dimensions, gradation of bedding sand, jointing sand, base and sub-base materials.

3.8. Design Template of Interlocking Concrete Block ICBP Pavement

Design template of ICPB pavement was discussed with LGED concerned personnel and consultant. The consultant reviewed the Bituminous Pavement Design Template (October 2018) by Bureau of Research Testing and Consultant (BRTC), BUET. BRTC considered traffic volume of commercial vehicles per day and sub-grade CBR. It provided number of templates on the basis of CBR range 2%-3%, 4%-6% and > 7% and CVD 0-100, 101-200, 201-300, 300-400, 400-500, 500-750 and 750-1000. It did not provide design template for CBR less than < 2 and for cycle track, pedestrian footpath and noon-motorized vehicles. The consultant also reviewed the LGED design templates of typical cross section details of uni-block road and highly recommend for use as long as field performance could be observed and verified. It is understood that interlocking concrete block pavement are to be used in village road also with nil or low commercial vehicles and mostly use by non-motorized vehicles also with pedestrians for which design templates are required.

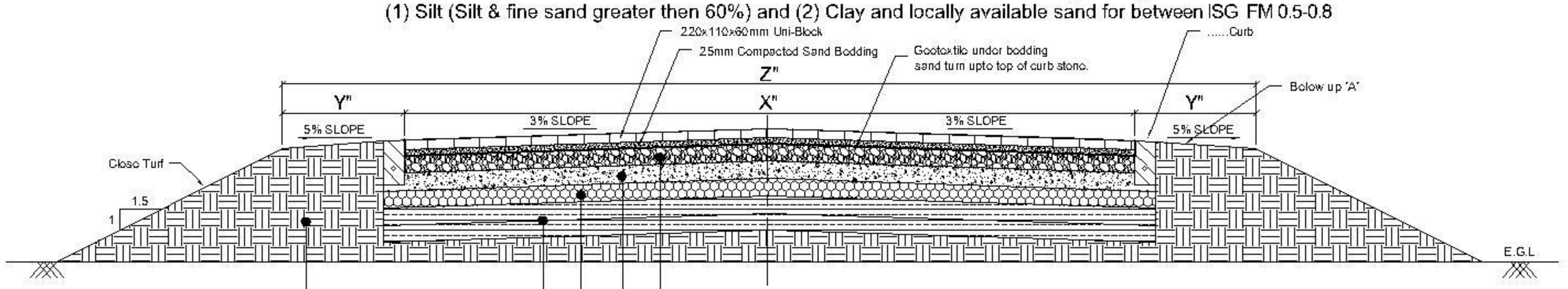
The sub grade CBR from 2-3 to 7 are already considered in BRTC design template which easily could be used for low to medium volume traffic, leaving off bituminous layer and instead using paving blocks (80 mm thick).

Consultant provided design template(s) for poor sub grade consisting (i) silt (silted fine sand greater than 60%) and (2) clay by reviewing the booklet of UNILOCK Design consideration for ICP interlocking concrete pavement. A table is given below for understanding.

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 60%)		Clay	
		in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
Pedestrian Use		2 3/8 - 2	60 - 70	2 3/8 - 2	60 - 70	2 3/8 - 2	60 - 70	2 3/8 - 2	60 - 70	2 3/8 - 2	60 - 70
	Bedding	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
		6	150	6	150	6	150	6	150	6	150
	Subbase										
Light Duty (Driveways, Car Parking Areas)		2 3/8 - 3	60 - 80	2 3/8 - 3	60 - 80	2 3/8 - 3	60 - 80	2 3/8 - 3	60 - 80	2 3/8 - 3	60 - 80
	Bedding	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
		6*	150	8	200	6	150	6	150	6	150
						12	300	20	500	20	500
Minor Residential Roads		3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80
	Bedding	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
		6*	150	9	215	6	150	6	150	6	150
						15	375	24	600	24	600
Residential and Collector Streets (25 to 500 ESAL/day)		3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80
	Bedding	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
		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)		3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80
	Bedding	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
		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		3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80	3 1/8	80
	Bedding	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30	1 ¼	30
		6*	150	6	150	6	150	6	150	6	150
				14	340	20	490	30	740	30	740

Design Template of Interlocking Concrete Block Pavement for 0-100 ESAL/Day on Subgrade of (1) Silt (Silt & fine sand greater then 60%) and (2) Clay and locally available sand for between ISG FM 0.5-0.8



Base Course: (150 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: (250 mm)* Sub-Base,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: (300 mm) Compacted Sand Improved Subgrade, Sand FM between 0.5-0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

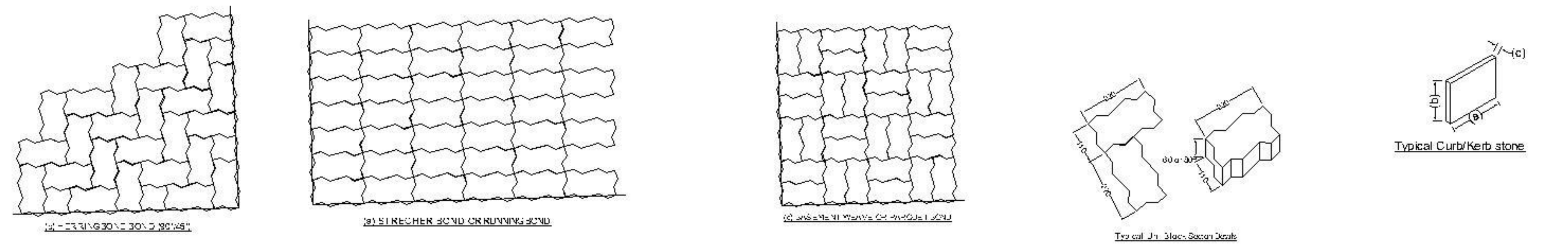
Subgrade: 300mm Subgrade Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 5%,PI value 8%~20%

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. 5% to achieve designed cross-section of side embankment.

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 uni-block (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after uni-block setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 15 years instead of 20 years of IRC
9. ESAL/Day instead of CVD (Commercial Vehicle Per day)
10. Locally available sand for ISG between FM 0.5-0.8
11. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi

TYPICAL X-Section



Road Type & Layers Specification

Sl No.	Road Type of Traffic	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c)*	Remarks
		ISG	Sub-Base	Base(/CC)	Sand Bedding	Concrete Block(CB)	Curb/Kerb Stone *		
01	Low Traffic Road (Traffic Volume<0.50MESA) ESAL/Day 0-100	300	250	150	25	80/35	150/35	500 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm									

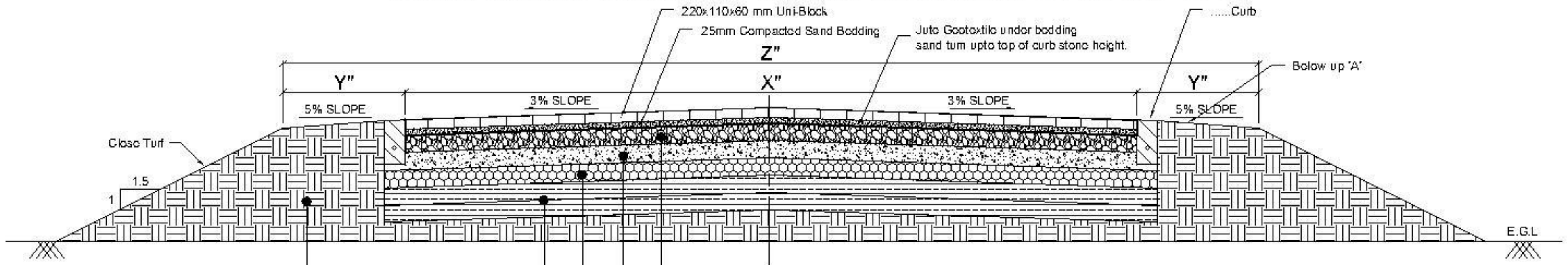
* Ref: UNILOCK: Design Considerations for Interlocking Concrete Pavement.

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 8: Design Template of ICPB Pavement for 0-100 ESAL/Day on Subgrade of (1) Silt (Silt and Fine Sand Greater than 60%) and (2) Clay and Locally Available Sand for between ISG F.M. 0.5-0.8

Design Template of Interlocking Concrete Block Pavement for Cycle track,Pedestrian Footpath, non-Motorized vehicles of Subgrade of (1) Silt (Silt & fine sand greater then 60%) and (2) Clay (ISG sand ≥ FM 0.8)



Base Course: (150mm)*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: (150mm)* Sub-Base, 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)

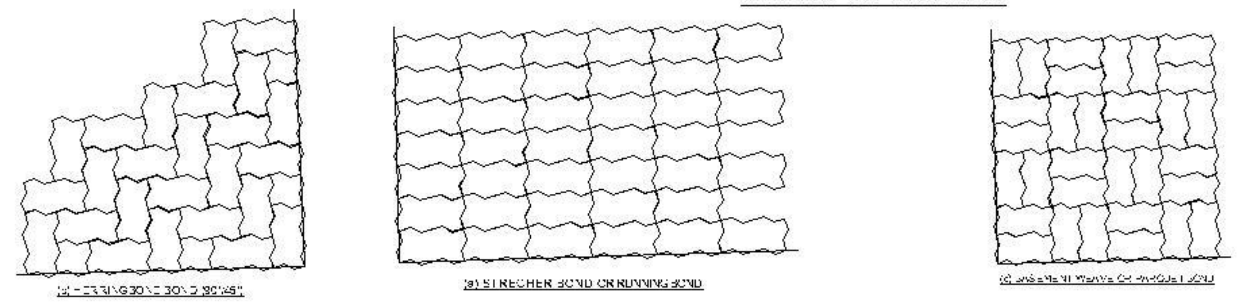
ISG: (250mm) Compacted Sand Improved Subgrade, Sand FM min. 0.8,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

Subgrade: 300mm Subgrade Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 5%,PI value 8%~20%

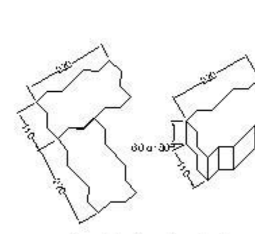
Original soil cut into designed shape, or fill with normal soil, PI Value 8%~20%, Compaction min. 95% of MDD (Modified Proctor),Soaked CBR min. 5% to achieve designed cross-section of side embankment.

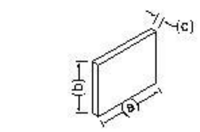
Notes:
1. All dimension are in millimeter.
2. All layer's thickness,compaction & other specification must comply as shown.
3. Bedding sand (FM-2.5) shall well graded (as shown) & compacted at OMC±3% condition.
4. Joint filling sand (FM-1.5)shall also well graded (as shown) & filled properly.
5. After setting uni-block (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after uni-block setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 15 years instead of 20 years of IRC
9. ESAL/Day instead of CVD (Commercial Vehicle Per day)
10. Consider locally available sand is FM 0.8 or more.
11. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi

TYPICAL X-Section



(b) STRECHER BOND OR RUNNING BOND





Typical Curb/Kerb stone

*Table-1: Different Road Type & Layers Specification

Sl No.	Road Type of Traffic	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c)*	Remarks
		ISG	Sub-Base	Base(/CC)	Sand Bedding	Concrete Block(CB)	Curb/Kerb Stone*		
01	Cycle Tracks, Pedestrian Footpaths Non-motorized Vehicles	250	150	150	25	60/30	150/30	500 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm									

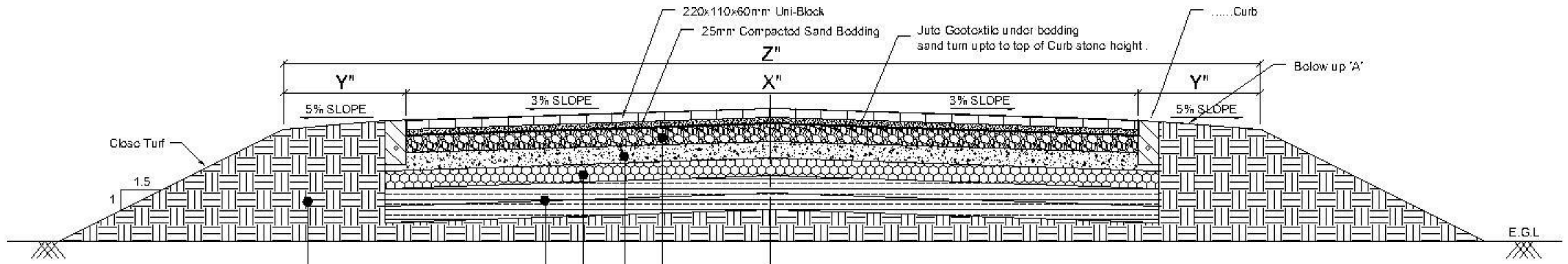
* Ref: UNILOCK: Design Considerations for Interlocking Concrete Pavement.

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	95-100	-
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 9: Design Template of ICPB Pavement for Cycle Track, Pedestrian Footpath, Non-Motorized Vehicles of Subgrade of (1) Silt (Silt and Fine Sand Greater than 60%) and (2) Clay (ISG Sand ≥ F.M. 0.8)

Design Template of Interlocking Concrete Block Pavement for Cycle track,Pedestrian Footpath, non-Motorized vehicles considering Subgrade of (1) Silt (Silt and fine sand greater then 60%) and (2) Clay (Locally Available ISG sand min FM 0.5)



Base Course: (150mm)*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: (150mm)* Sub-Base, 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: (300mm) Compacted Sand Improved Subgrade, Sand FM min. 0.5,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min .8%, Compacted to 98% of MDD (Modified Proctor)

Subgrade: 300mm Subgrade Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 5%,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. 5% 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 uni-block (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after uni-block setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 15 years instead of 20 years of IRC
9. ESAL/Day instead of CVD (Commercial Vehicle Per day)
10. Locally available sand for ISG >FM 0.5
11. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi

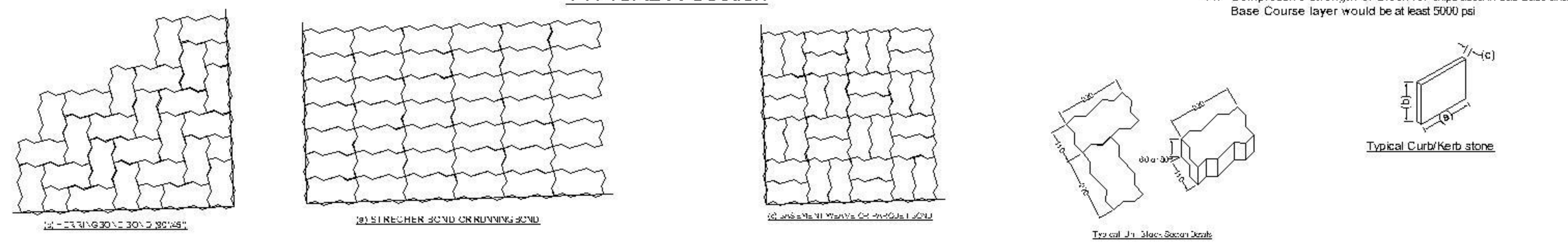


*Table-1: Different Road Type & Layers Specification

Sl No.	Road Type of Traffic	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c)*	Remarks
		ISG	Sub-Base	Base(/CC)	Sand Bedding	Concrete Block(CB)	Curb/Kerb Stone *		
01	Cycle Tracks, Pedestrian Footpaths Non-motorized Vehicles	300	150	150	25	60/30	150/30	500 x 250 x150	
**** X,Y,Z shall as per Approved geometry. Y must not less then 1000mm									

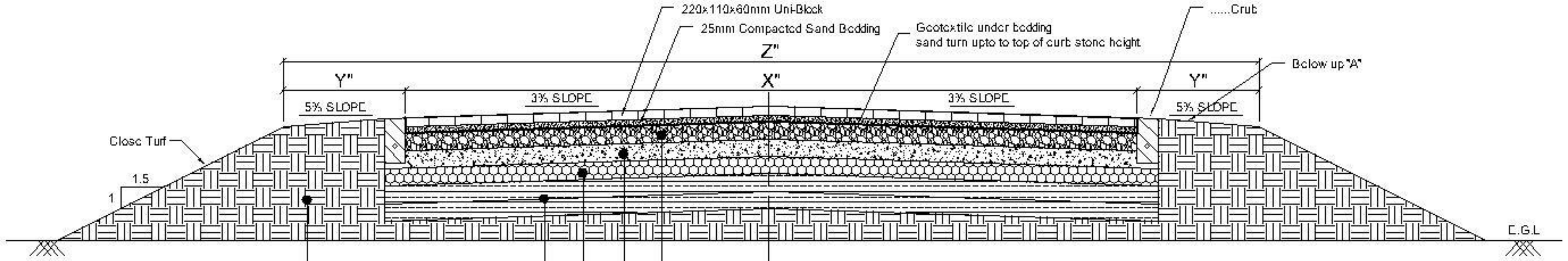
* Ref: UNILOCK: Design Considerations for Interlocking Concrete Pavement.

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	95-100	-
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 10: Design Template of ICPB Pavement for Cycle Track, Pedestrian Footpath, Non-Motorized Vehicles Considering Subgrade of (1) Silt (Silt and Fine Sand Greater than 60%) and (2) Clay (Locally Available ISG Sand min. F.M. 0.8)

Design Template of Interlocking Concrete Block Pavement for Cycle track,Pedestrian Footpath, non-Motorized vehicles of Subgrade of (1).Silt (Silt & fine sand greater then 60%) (2) Clay (ISG sand FM between 0.3 to 0.5)



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 uni-block (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after uni-block setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix.
8. Design Life considered as 15 years instead of 20 years on IRC
9. ESAL/Day instead of CVD (Commercial Vehicle Per day)
10. Locally available sand for ISG is FM between 0.3-0.5
11. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi

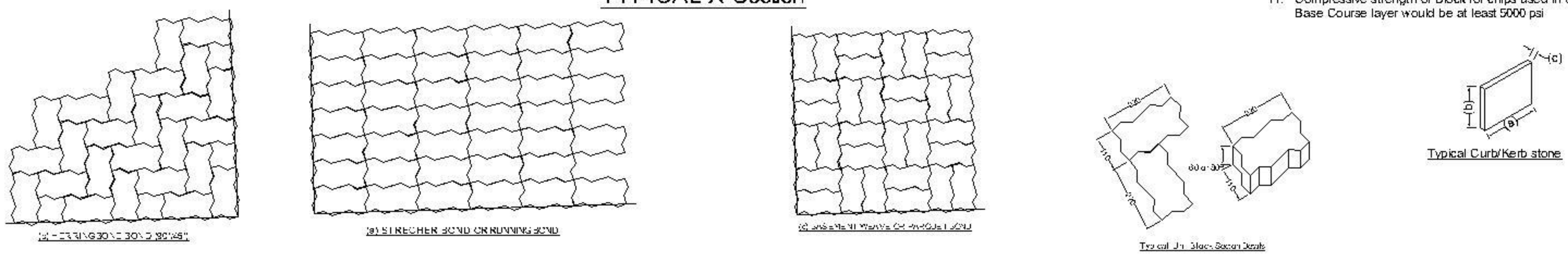


*Table-1: Different Road Type & Layers Specification

Sl No.	Road Type of Traffic	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c)*	Remarks
		ISG	Sub-Base	Base(/CC)	Sand Bedding	Concrete Block(CB)	Curb/Kerb Stone*		
01	Cycle Tracks, Pedestrian Footpaths Non-motorized Vehicles	450	150	150	25	60/30	150/30	500 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm									

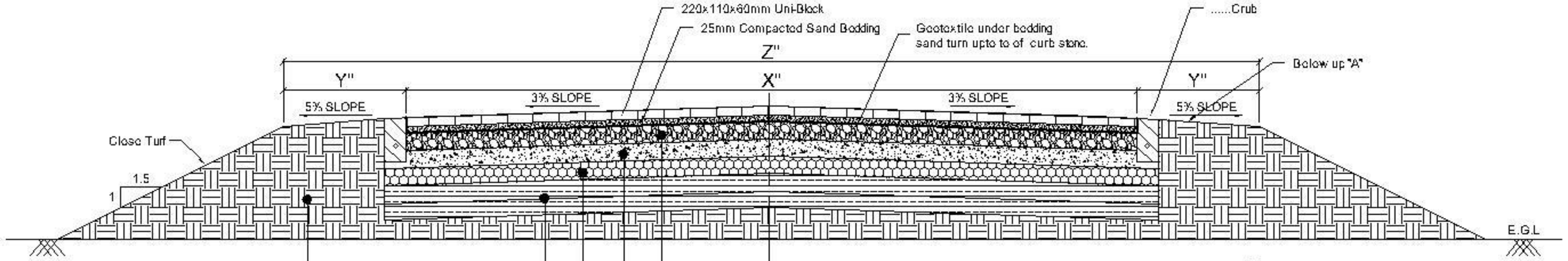
* Ref: UNILOCK: Design Considerations for Interlocking Concrete Pavement.

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 11: Design Template of ICPB Pavement for Cycle Track, Pedestrian Footpath, Non-Motorized Vehicles of Subgrade of (1) Silt (Silt and Fine Sand Greater than 60%) and (2) Clay (ISG Sand F.M. between 0.3 to 0.5)

Design Template of Interlocking Concrete Block Pavement for 0-100 ESAL/Day on Subgrade of (1).Silt (Silt & fine sand greater then 60%) and (2) Clay Locally available sand for ISG FM between 03.-0.5



Base Course: (1500mm)*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: (250mm)* Sub-Base,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: (450mm) Compacted Sand Improved Subgrade, Sand FM between 0.3-0.5,PI value<6%, Compacted in Two/Three layers,each layer Soaked CBR min.8%, Compacted to 98% of MDD (Modified Proctor)

Subgrade: 300mm Subgrade Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 5%,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. 5% 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 uni-block (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after uni-block setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix.
8. Design Life considered as 15 years instead of 20 years of IRC
9. ESAL/Day instead of CVD (Commercial Vehicle Per day)
10. If locally available sand for ISG between FM 0.3-0.5
11. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi

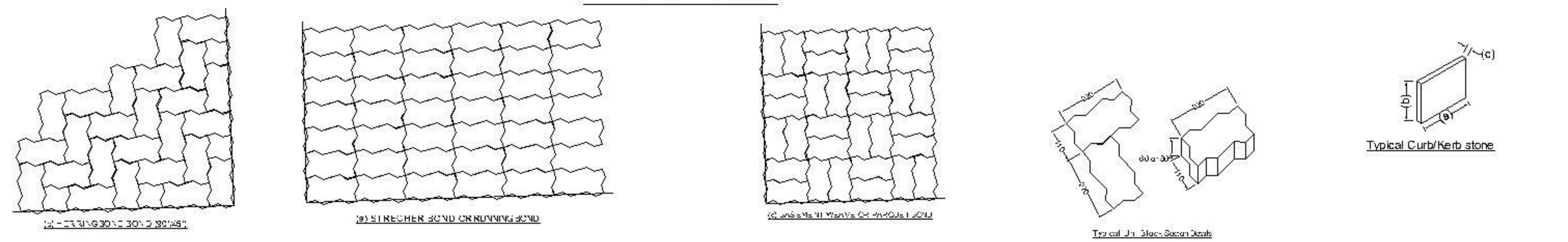


*Table-1: Different Road Type & Layers Specification

Sl No.	Road Type of Traffic	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c)*	Remarks
		ISG	Sub-Base	Base(/CC)	Sand Bedding	Concrete Block(CB)	Curb/Kerb Stone*		
01	Low Traffic Road (Traffic Volume<0.50MESA) ESAL/Day 0-100	450	250	150	25	80/35	150/35	500 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm									

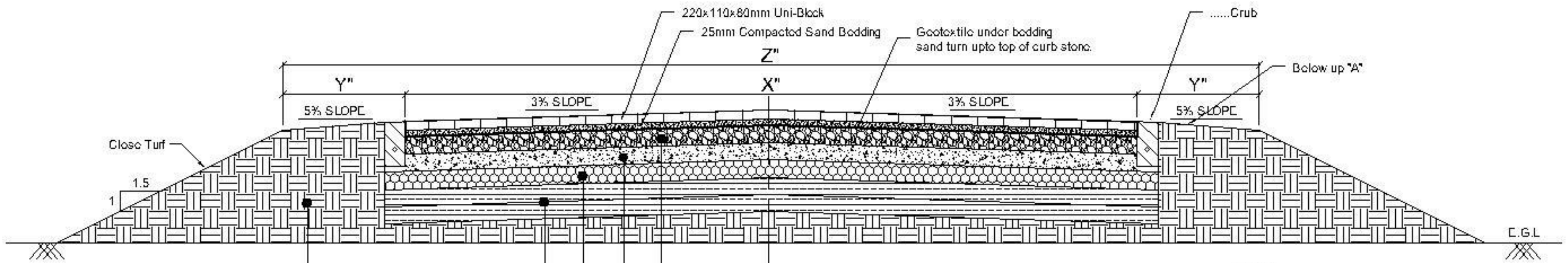
* Ref: UNILOCK: Design Considerations for Interlocking Concrete Pavement.

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 12: Design Template of ICPB Pavement for 0-100 ESAL/Day on Subgrade of (1) Silt (Silt and Fine Sand Greater than 60%) and (2) Clay and Locally Available Sand for between ISG F.M. 0.3-0.5

Design Template of Interlocking Concrete Block Pavement for 0-100 ESAL/Day on Subgrade of (1).Silt (Silt & fine sand greater then 60%) and (2) Clay (Locally available ISG sand FM ≥ 0.8)



Base Course: (150mm)*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: (200mm)* Sub-Base,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: (250mm) Compacted Sand Improved Subgrade, 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 Subgrade Compaction min. 95% of MDD(Modified Proctor) in Two/Three layers Soaked CBR min. 5%,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. 5% 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 uni-block (at desired location), compaction shall ensured by Plate Compactor/Vibratory roller with joint filling sand.
6. Joint filling sand (dry) shall broom after uni-block setting & 7 days later again.
7. Concrete Block must be machine made with zero slump concrete mix
8. Design Life considered as 15 years instead of 20 years of IRC
9. ESAL/Day instead of CVD (Commercial Vehicle Per day)
10. If locally available sand for ISG FM≥0.8
11. Compressive strength of Block for chips used in Sub-Base and Base Course layer would be at least 5000 psi

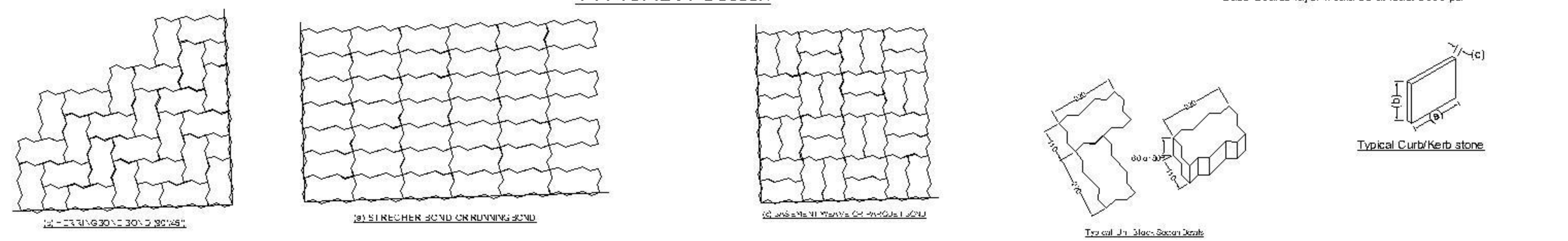


*Table-1: Different Road Type & Layers Specification

Sl No.	Road Type of Traffic	Layer Thickness(mm)				Thickness(mm)/Strength(Mpa)		Probable Curb/Karb stone sizes (a x b x c)*	Remarks
		ISG	Sub-Base	Base(/CC)	Sand Bedding	Concrete Block(CB)	Curb/Kerb Stone *		
01	Low Traffic Road (Traffic Volume<0.50MESA) ESAL/Day 0-100	250	200	150	25	80/35	150/35	500 x 250 x150	
**** X,Y,Z shall as per Approved geometry.Y must not less then 1000mm									

* Ref: UNILOCK: Design Considerations for Interlocking Concrete Pavement.

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 13: Design Template of ICPB Pavement for 0-100 ESAL/Day on Subgrade of (1) Silt (Silt and Fine Sand Greater than 60%) and (2) Clay (Locally Available ISG Sand F.M. ≥ 0.8)

The design templates are provided for use in the field and these will be finalized after review of filed construction and performance. As it is understood that no construction and experiment could be possible for shortage of logistic and time and mostly due to COVID-19 pandemic, the template are given very much on ad-hor basis. To finalize the template for consultant side it requires adequate time for research and evaluation of field performance.

3.9. Preparation of ICPB Mix Design Charts:

As it has been stated before, after thoroughly reviewing some recognized international design guidelines (e.g. IRC and Unilock) regarding the use of Interlocking Concrete Paving Block (ICPB) in roadway construction, there is a need to develop some mix design charts based on ICPBs 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 ICPB 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 ICPB 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 ICPB road along with the manufacturing protocol he needs to adopt in order to gain the desired specifications of the ICPB roadways. Subsequently, he can then select the accurate thickness for the layers (i.e. subgrade, sub-base, base-course, bedding sand and ICPBs 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 ICPB 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 in section 6.2.2. 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 (ICPB portion) are provided on the next pages.

Table 7: 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 8: 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 9: 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 10: 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 11: 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 12: 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 13: 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 14: 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 15: 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 16: 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 17: 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 18: 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 19: 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 20: 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 21: 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 22: 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 23: 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 24: 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 25: 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 26: 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 27: Comparative Study of ICPB Test Result

River Sand	Location	Fineness Modulus(F. M)of Local Dredged Sand	Admixture	Mixing Ratio	Average Strength (Psi)					
					60mm thick ICPB			80mm thick ICPB		
					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

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

Table 28: F.M. and Average Strength of ICPB (60 mm) with Mix Ratio (1:1.25:1.25)

	Specimen=	Sand Cement ICPB (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

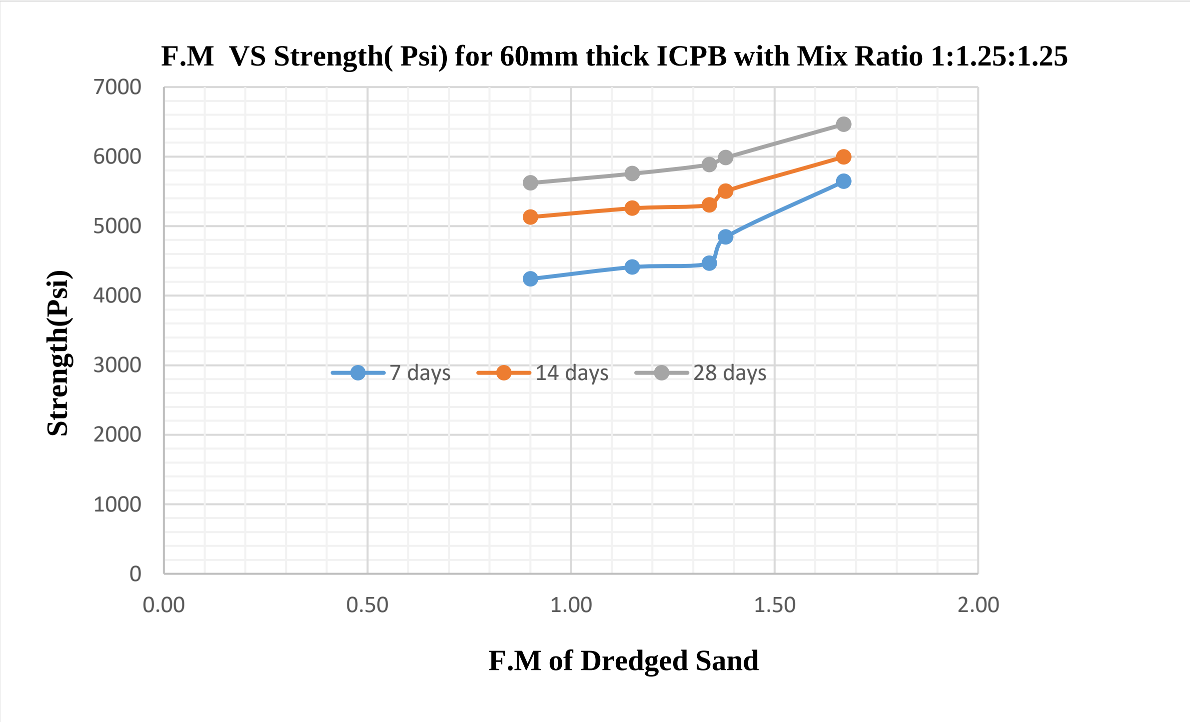


Figure 14: F.M. Vs Strength (Psi) for 60 mm thick ICPB *w*ith Mix Ratio 1: 1.25:1.25

Table 29: F.M. and Average Strength of ICPB (80 mm) with Mix Ratio (1:1.25:1.25)

	Specimen=	Sand Cement ICPB (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

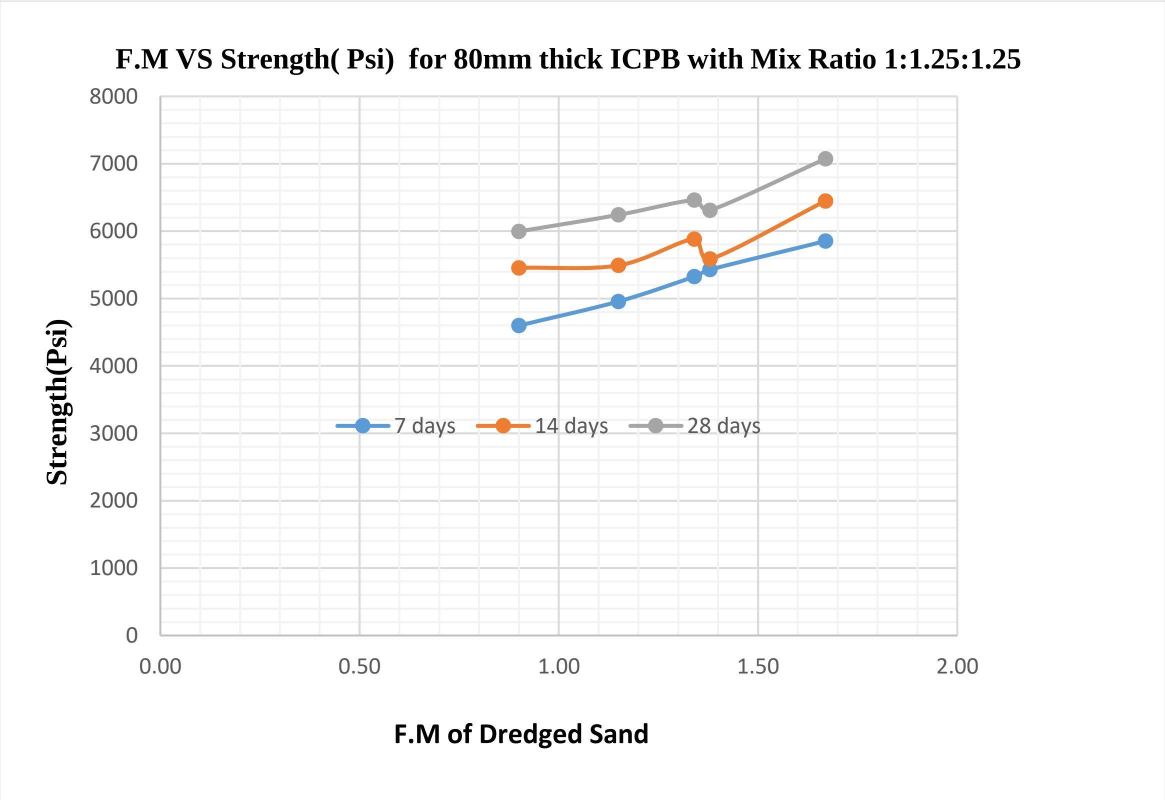


Figure 15: F.M. Vs Strength (Psi) for 80 mm thick ICPB with Mix Ratio 1: 1.25:1.25

Table 30: F.M. and Average Strength of ICPB (60 mm) with Mix Ratio (1:1.5:1.5)

	Specimen=	Sand Cement ICPB (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

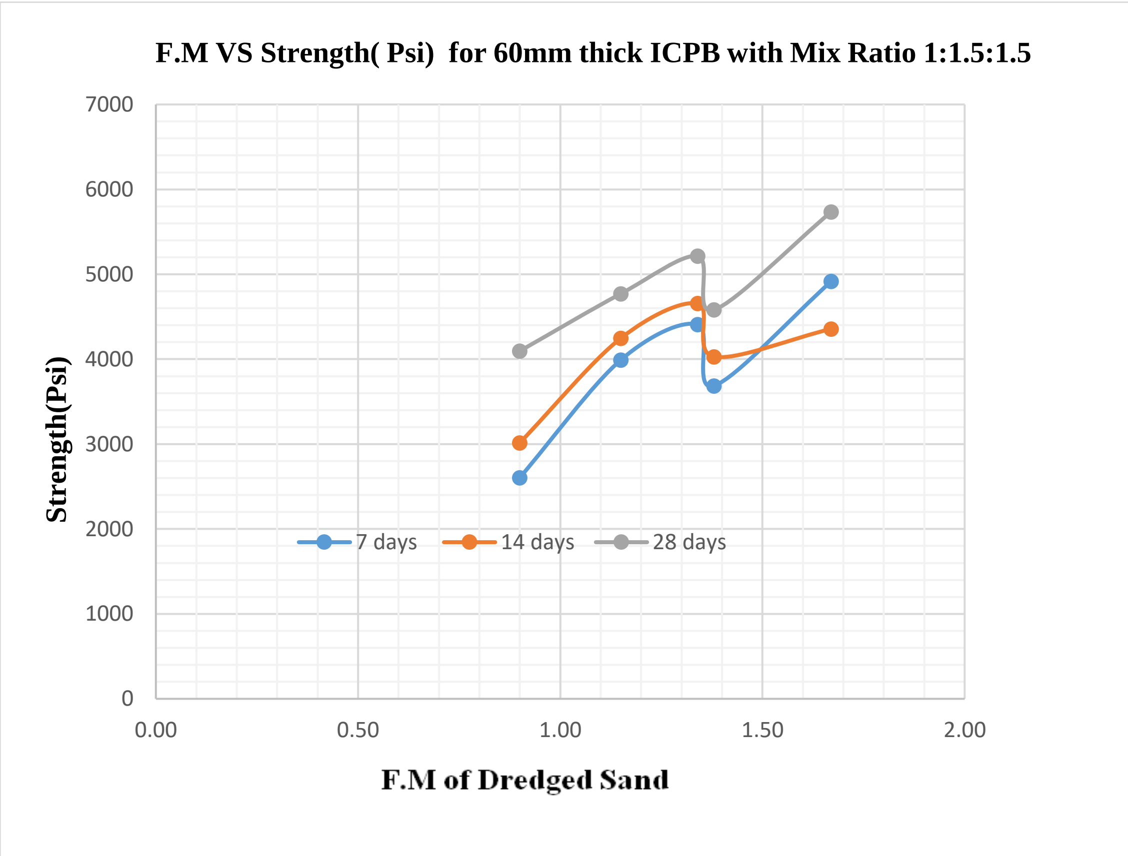


Figure 16*:* **F.M. Vs Strength (Psi) for 60 mm thick ICPB with Mix Ratio 1:1.5:1.5**

Table 31: F.M. and Average Strength of ICPB (80 mm) with Mix Ratio (1:1.5:1.5)

	Specimen=	Sand Cement ICPB (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

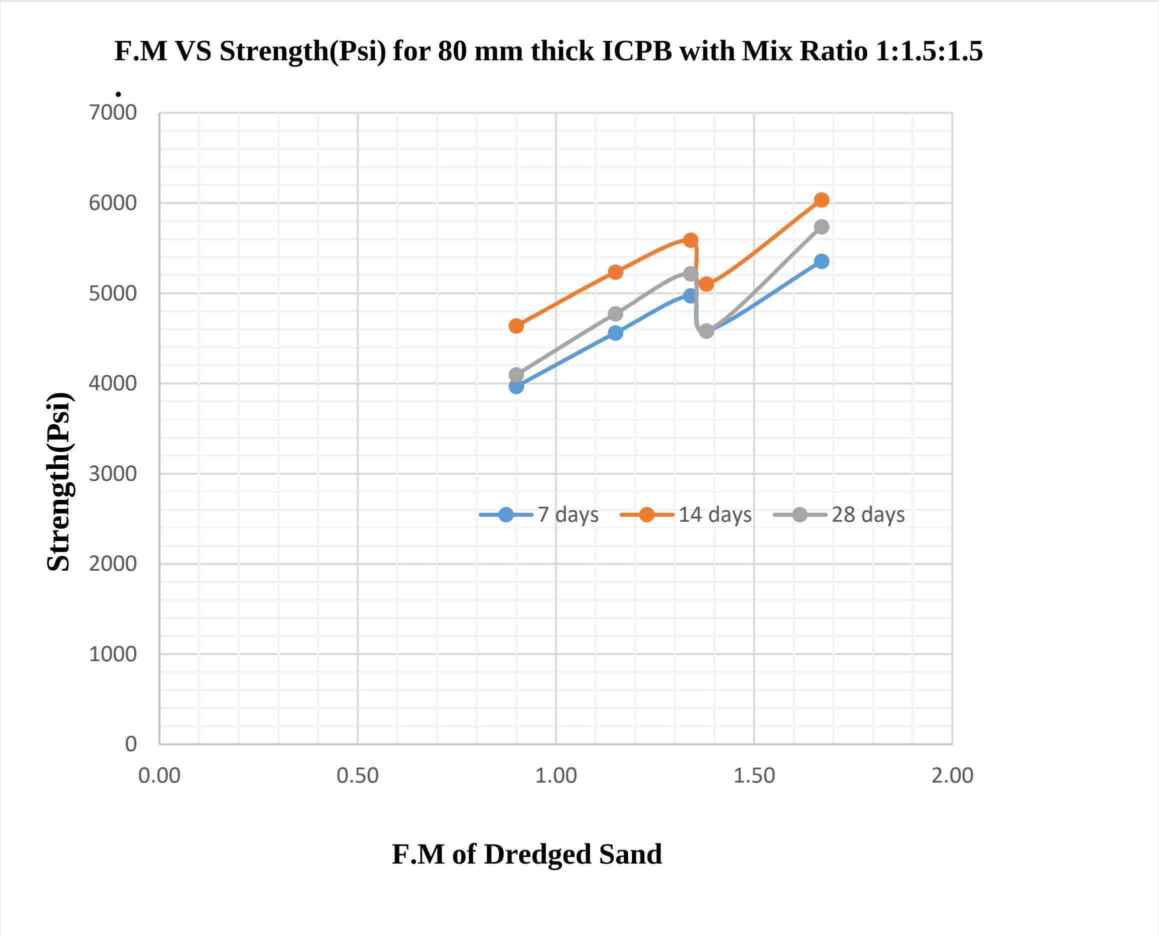


Figure 17: F.M. Vs Strength (Psi) for 80 mm thick ICPB with Mix Ratio 1:1.5:1.5

Observations:

1. Strength of higher thickness ICPB 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.

5. Other Aspects of ICPB Pavements

5.1. Implementation Manual (Construction Process):

5.1.1. 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 labour. 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.

Table 32: Design Catalogue for Pavement Thickness (As shown in IRC SP: 63-2004)

Traffic and Road Type	Subgrade-CBR (%)		
		Above 10	5-10
Cycle, Tracks, Pedestrian, Footpath	Blocks Sand Bed Base	60 20-30 200	60 20-30 200
Commercial Traffic Axle load Repetitions less than 10 ME/SA	Blocks Sand Bed WBM/WMM Base Granular Sub-base	60-80 20-40 250 200	60-80 20-40 250 200
Commercial Traffic Axle load Repetition 10-12 ME/SA Collector Streets, Industrial Street, Bus and Truck Parking Area	Blocks Sand Bad WBM/WMM Base Granular Sub-Base	80-100 20-40 250 200	80-100 20-40 250 250
Commercial Traffic Axle Load Repetition 20-50 ME/SA Arterial Streets	Blocks Sand Bed WBM/WMM Base or WBM/WMM Base and DLC over it Granular Sub-Base	80-100 20-40 250 150 75 200	80-100 20-40 250 150 75 250

* In case of Road having inadequate drainage or heavy rainfall areas (above 1500 mm per annum)

Notes: 1. Thickness of Layers given above are in mm

2. Granular sub-base should have at least 150 mm layer at eh bottom which is drainable.

3. A typical cross -section is given.

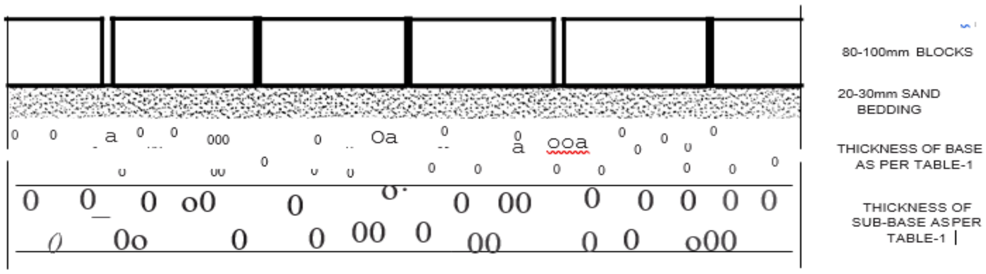


Figure 18: A typical cross section of block pavement for heavily trafficked roads

4. If the Sub-grade soil has a CBR of less than 5 it should be improved by suitable Stabilization technique to bring the CBR value to 5.
5. MSA dents repetitions in Million Standard axles.

5.1.2. 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 1RC:36-1970. The prepared subgrade should be graded and trimmed to a tolerance of ± 20 mm of the design levels, and its surface evenness should have a tolerance of within 15 mm under a 3 m straight edge.

5.1.3. Base and Sub-base Course

Base and sub-base courses are constructed in accordance with standard procedures contained in the relevant IRC Specifications, like, IRC:37-2001, IRC:50-1973, IRC:51-1993, IRC:63-1976, IRC: 19-1977. When cement bound base are proposed it may be constructed using rolled lean concrete as per IRC: SP-49. The quality control specified in IRC: SP-1 1 shall apply. Constructing the layers to proper level and grade is very essential to maintain the level and surface regularity of the block pavement.

5.1.4. Placing and Screeding of Bedding Sand

The thickness of the sand bed after compaction should be in the range of 20-40 mm, whereas, in the loose form it can be 25 to 50 mm. It is preferable to restrict the compacted thickness to 20-25 mm to reduce the risk of any localized precompaction, 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 subbase. 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 uncompacted 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 tonnes 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 be

The effect of undulating surface of base or sub-base on the profile of block pavement is explained in **Figure** 19. 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.

5.1.5. Laying of Blocks

Blocks can be laid generally by manual labour 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 dentated 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 poiht 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 **Figure** 20.

- Influence of alignment of edge restraints on achieving and maintaining laying bond.

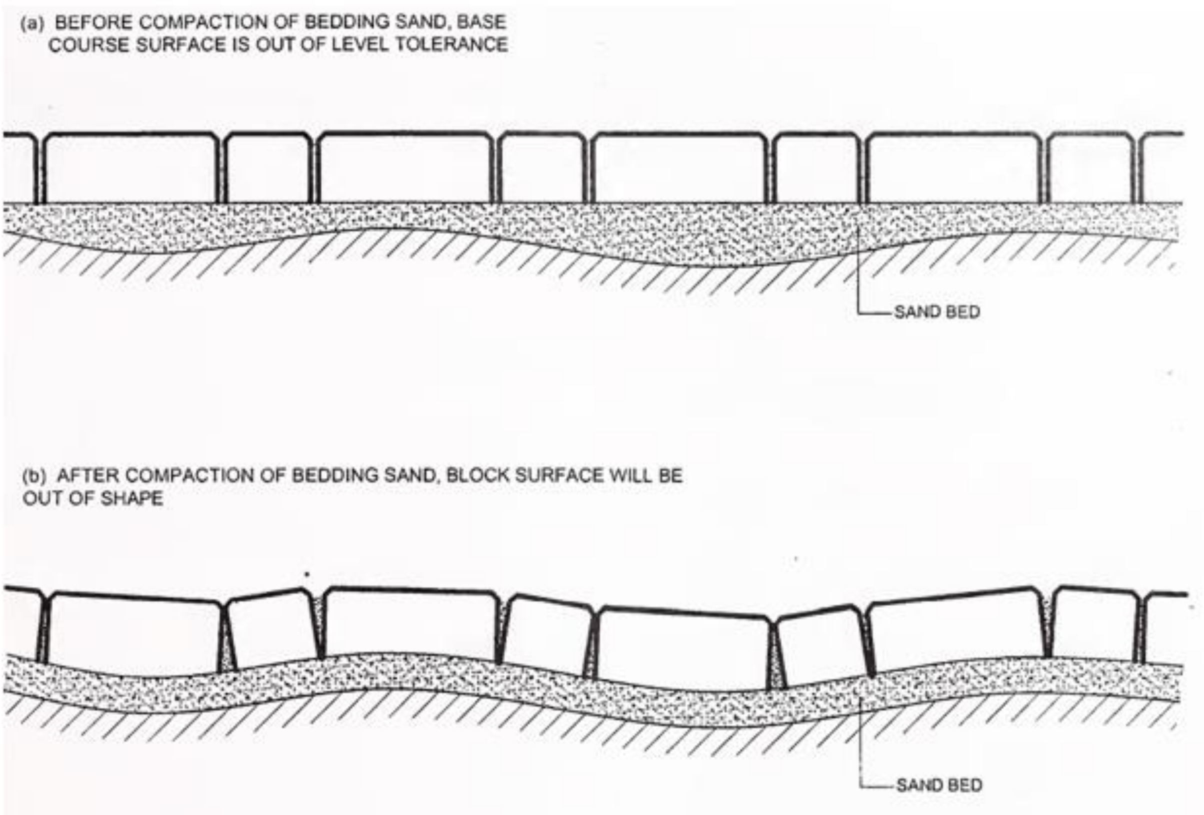


Figure 19: Effect of base-course surface shape on bending sand and block surface shape

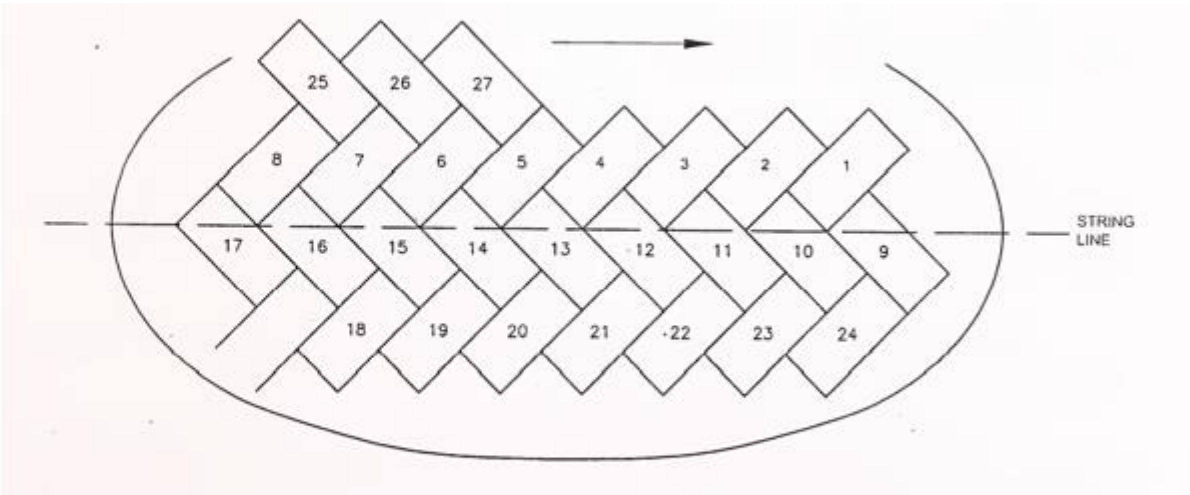


Figure 20: Starting at irregular shaped edge restraint

5.1.6. Bonds or Patterns of Laying Blocks

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

a) Stretcher or running bond
b) Herringbone bond
c) Basket weave or parquet bond

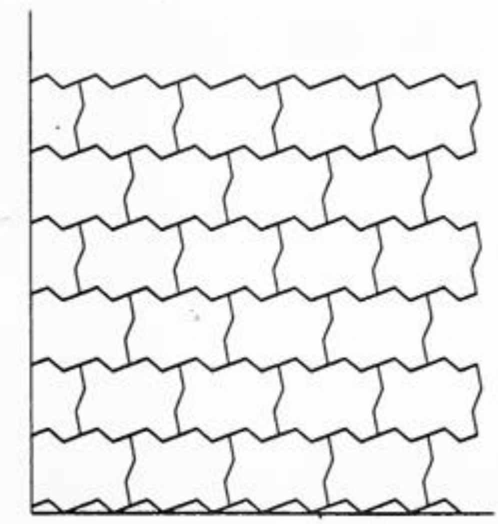
The typical layout of these bonds is given in Fig.

5.1.7 Establishing the Laying Pattern

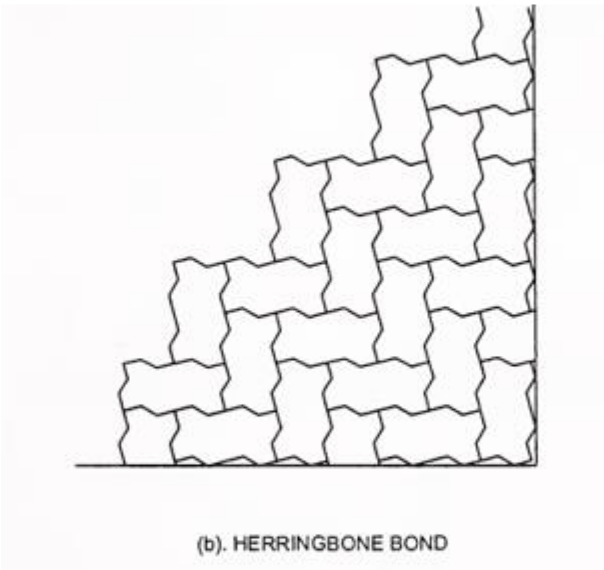
In relation to the starting line, the blocks should be placed at the correct angle to achieve the final orientation as required by the laying pattern. If the edge restraint is straight and suitably oriented, the first row of blocks can abut it. For irregular-shaped and unfavorably oriented edge restraints, a stringline should be established a few' rows away to position the first row.

With the help of gauges, the joint width specification (2 to 4 mm) should be checked in the first few square metres, where it should be ensured that the block alignment is correct. The laying patterns and face should be established **Figure** 21 to permit fast and easy laying without the necessity of forcing a block between previously positioned blocks. 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.



(a). STRETCHER BOND OR RUNNING BOND



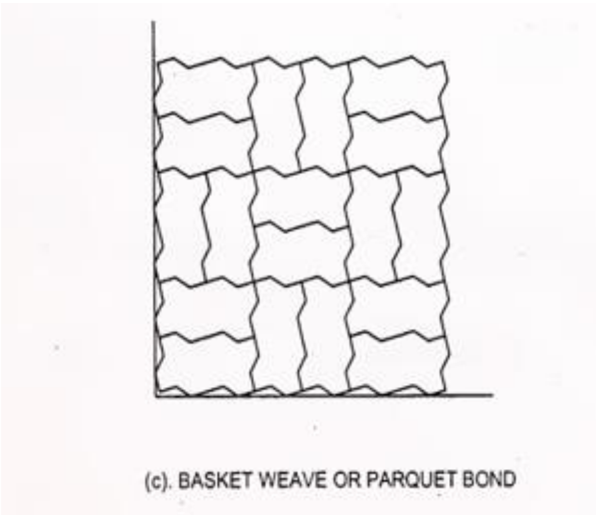


Figure 21: Typical bond or laying pattern of bond

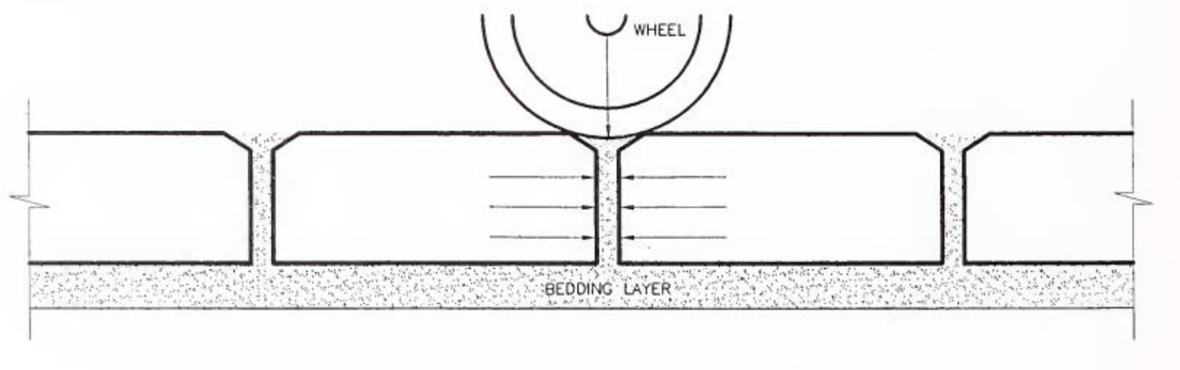
5.1.8 Compaction

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 comer 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.

5.1.9 Joint filling

The importance of complete joint filling cannot be over-emphasised. Unfilled or pm1ially 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 22

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, as given in Section 6. 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

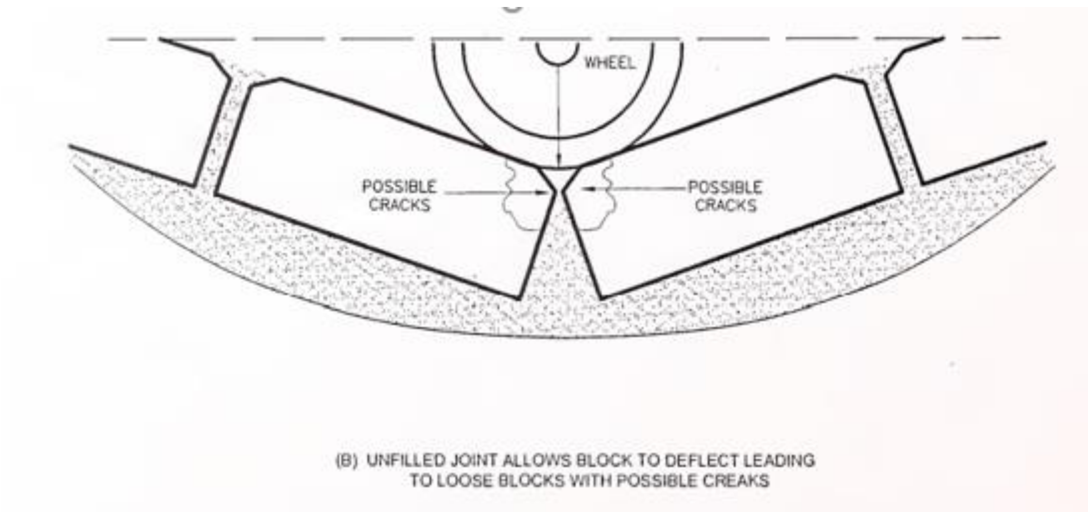


Figure 22: Need for complete filling of joints

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 far 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 tap of the joints; also, if the blocks 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 t 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.

5.1.10 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.

5.1.11 Laying and Surface Tolerances

While the laying, the surface tolerances, given in the next page may be observed:

Table 33: Layer/Item and the Corresponding Surface Tolerance

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	10 mm (maximum)
from any 10 m line	20 mm (maximum)
Vertical deviation from 3 m line at kerbs intrusions, channels, edge restraints elsewhere	
Maximum difference in surface level between adjacent paving units	+10 mm, -15 mm
Deviation of finished surface level from designated level	+10 mm, -15 mm
Joint width range	2 mm to 4mm
Percentage of joints outside range	10% max. along 10 m line
Nominal joint width	3mm

5.1.12 Pavement intrusions

On some pavements, like in city street s, there could be several intrusions, like, manholes, drainage gulleys, etc. where mating these intrusions with the pavement is desirable. Figure 23 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 work face, rather than carrying the pavement around the intrusion to return to the original -laying face Figure

23 to avoid accumulation of closing error.

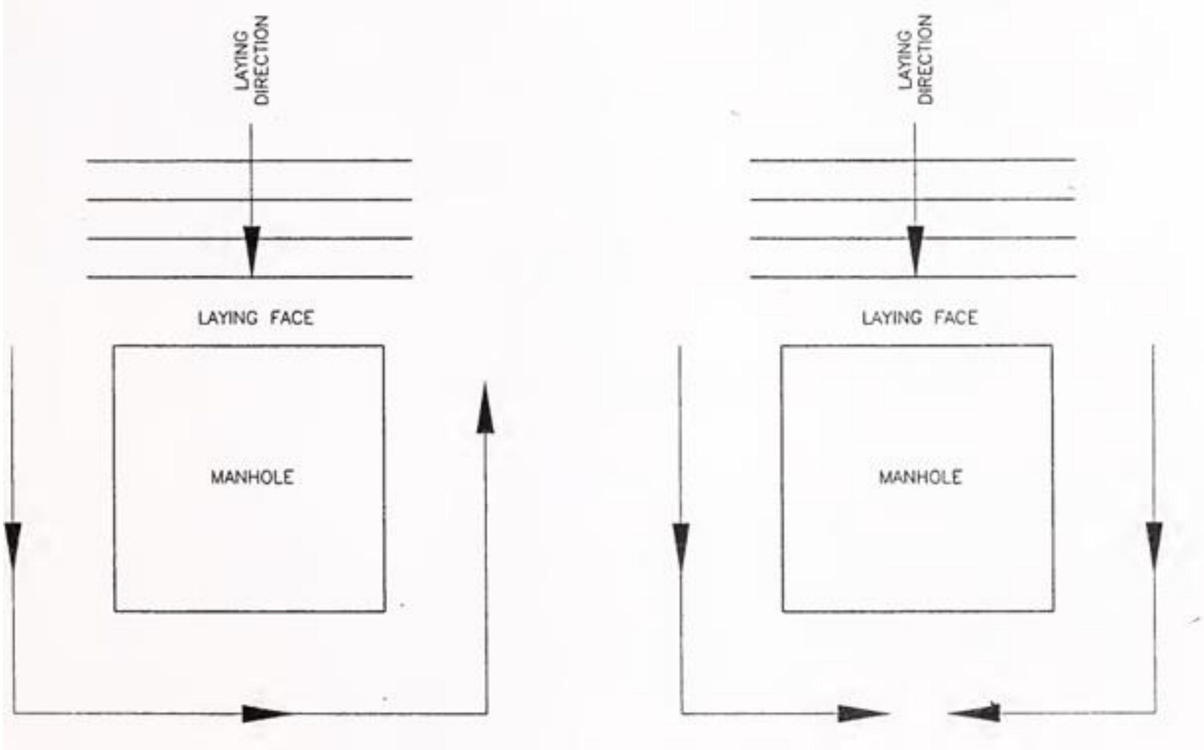


Figure 23: Laying block paving around a manhole

5.1.13 Changes 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 (Fig. 21). At intersections, if a herringbone bond laying pattern is adopted, the paving can proceed without the need for construction joints. 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.

5.1.14 Design Strength

It is considered that blocks are to be manufactured using dredged sands of rivers, khals to avoid clay burnt bricks i.e., to best use of dredged sand and thus strength considered is 30-35 MPa. It is discussed earlier that most of the international journals consider 55 MPa (Single block minimum thickness 50 MPa) block in ICPB. Only IRC has minimum strength of 30 MPa.

Consultant reviewed LGED design template of ICPB where it considers 30-40 MPa for cycle track, pedestrian footpath, non-motorized vehicles to heavy traffic road 2.50 MESA traffic volume <10.00 MESA> in 5 categories of traffics.

For cycle tracks, pedestrian footpaths, non-motorized vehicles, 30 MPa strength blocks with 60 mm thickness are considered. Whereas, for low traffic roads, 35 MPa strength of 80 mm thickness blocks are taken into account.

The consultant therefore adopted LGED design template with slight modification of the thickness of the sand bedding (IRC giving sand bedding range of 20-40 mm) and deleting medium and heavy traffic road from the template as they need higher strength of paving blocks of 40 MPa which is not considered for the blocks manufactured for dredged sand.

5.2. Pavement Maintenance Manual

5.2.1. General

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

5.2.2. Initial Maintenance

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

5.2.3. 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 colour of the blocks may be difficult to obtain at a later date matching with the original blocks. For important projects, it is normal to stockpiL blocks from 1 per cent to 3 per cent initial supply for subsequent use.

5.2.4. Coating and Cleaning

As part of preventive maintenance, b1ocks can be sealed using compounds, like, silicone, acrylics and silica flomides for enhancing the colour, reducing absorptive nature of the blocks and for improving surface tough ness. 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 a1so 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.

5.3. Technical specifications:

5.3.1. 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.

5.3.2. Bedding Sand Layer

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

Table 34: 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 35: 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 not 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.

5.3.3. Concrete Paving Blocks

- 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 recommendedby the designer. The blocks shall be laid as tight as possible to each other.1The 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.

5.3.4. Surface Tolerances

- 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 nominat ed 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.

5.4. Cost Analysis

Table 36: Cost of Fabricating ICPB 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, ShilpachariyaJoynul Abedin 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 Bakhtiar Bibi Govt 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 inSirajganj

5.5. Rate Analysis of Sand-Cement ICPB Road (Paver Portion)

Table 37: Rate Analysis of Sand Cement ICPB 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 ICPB with 60mm Thick (size 220mmX110mm) ,Colour: Gray, Minimum Compressive Strength : 30 Mpa	sqm	Sand Cement ICPB 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 & Overhesd (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 ICPB with 60mm Thick(size 220mmX110mm) ,Colour: Red/black/any other suitable colour, Minimum Compressive Strength : 30 Mpa	sqm	Sand Cement ICPB 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**

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 ICPB with 60mm Thick(size 220mmX110mm) ,Colour: Gray, Minimum Compressive Strength : 35 Mpa	sqm	Sand Cement ICPB 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**

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
4.0	Sand Cement ICPB with 60mm Thick(size 220mmX110mm) ,Colour: Red/black/any other suitable colour, Minimum Compressive Strength : 35 Mpa	sqm	Sand Cement ICPB 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
			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
5.0	Sand Cement ICPB with 80mm Thick(size 220mmX110mm) ,Colour: Gray, Minimum Compressive Strength : 30 Mpa	sqm	Sand Cement ICPB 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
			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
6.0	Sand Cement ICPB with 80mm Thick(size 220mmX110mm) ,Colour: Red/black/any other suitable colour, Minimum Compressive Strength : 30 Mpa	sqm	Sand Cement ICPB 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
			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
7.0	Sand Cement ICPB with 80mm Thick(size 220mmX110mm) ,Colour: Gray, Minimum Compressive Strength : 35 Mpa	sqm	Sand Cement ICPB 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
			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
8.0	Sand Cement ICPB with 80mm Thick(size 220mmX110mm) ,Colour: Red/black/any other suitable colour, Minimum Compressive Strength : 35Mpa	sqm	Sand Cement ICPB 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
			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**

5.6. Alternative Pavement Options

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 ICPBs would be explored.

Some of the alternative options in the preparation of ICPB 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 $SiO_2 + Al_2O_3 + Fe_2O_3$ 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 noncrystalline, 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, geopolymer 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. Geopolymer concrete can be synthesized by fly ash and recycled asphalt pavement aggregates for making of paver blocks. Geopolymer, a novel binder, was initially studied by Davidovits (1982), and historically started as alkali-activated cements. The process of geopolymerisation involves alkaline activation of materials rich in silica and alumina and therefore giving a three-dimensional silico-aluminate structure by polycondensation. Fly ash is an excellent material to produce geopolymer 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.

6. Summary of the Project

This project entails the preparation and incorporation of ICPB (Interlocking Concrete Paving Block) into Road Design Manual. Under this research endeavor, numerous literatures were studied which involved national reports, international ICPB 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 ICPBs 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 ICPBs 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 ICPB 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 ICPB roads observed were free from any significant deformity and almost all the paving units were intact. This further confirmed the suitability of using ICPB 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 ICPB 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, ICPB 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 ICPBs with high thickness had higher strength, there was a proportional relationship between Sand F.M. and compressive strength and early recommended strength of ICPB could be achieved by adding early strength gaining admixture with high density water reducing super plasticizer.

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

7. Limitations 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 ICPB but further studies could not be conducted on the actual design of ICPB 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 ICPBs could not be done to comply with the client's wish to finish the project within the time frame.

• Tensile strength of ICPB 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 ICPB 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 ICPB were only willing to share information regarding the dimension of ICPBs 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 ICPBs could not be provided to draw a comparative analysis.

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

8. Recommendations

- By using dredged sands, ICPB could be prepared with desired strength of 30-35 MPa. So, these blocks could be used in the design and construction of ICPB 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 ICPB.
- 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 ICPB section instead of bituminous layer.

9. Selected Photographs Depicting Project Related Activities

9.1. HBRI Laboratory Visited by LGED Representatives


9.2. Dredging Sand Collected by HBRI from Different Locations of Bangladesh


9.3. Block Manufacturing Process Carried out at HBRI Plant


9.4. Compressive Strength Test of ICPB at HBRI Workshop

9.5. Field Visits

10. 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 ICPBs 3. Laboratory investigations on prepared ICPBs								
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 days.

11. References:

11.1. National Report:

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Final Report on Technical Viability Study of Block Road under SCBRMP (Shunamganj Community Based Resource Management Project), prepared by Bureaus of Research, Testing and Consultation (BTRC), Bangladesh University of Engineering and Technology (BUET)

11.2. International ICPB Road Design Guidelines:

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11.3. International Journal Papers:

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12. Annexures:

12.1. Annexure I: GoB Notification Regarding the use of Blocks.

12.2. Annexure II: Geological Map of Bangladesh

12.3. Annexure III: List of Rivers in Bangladesh

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

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

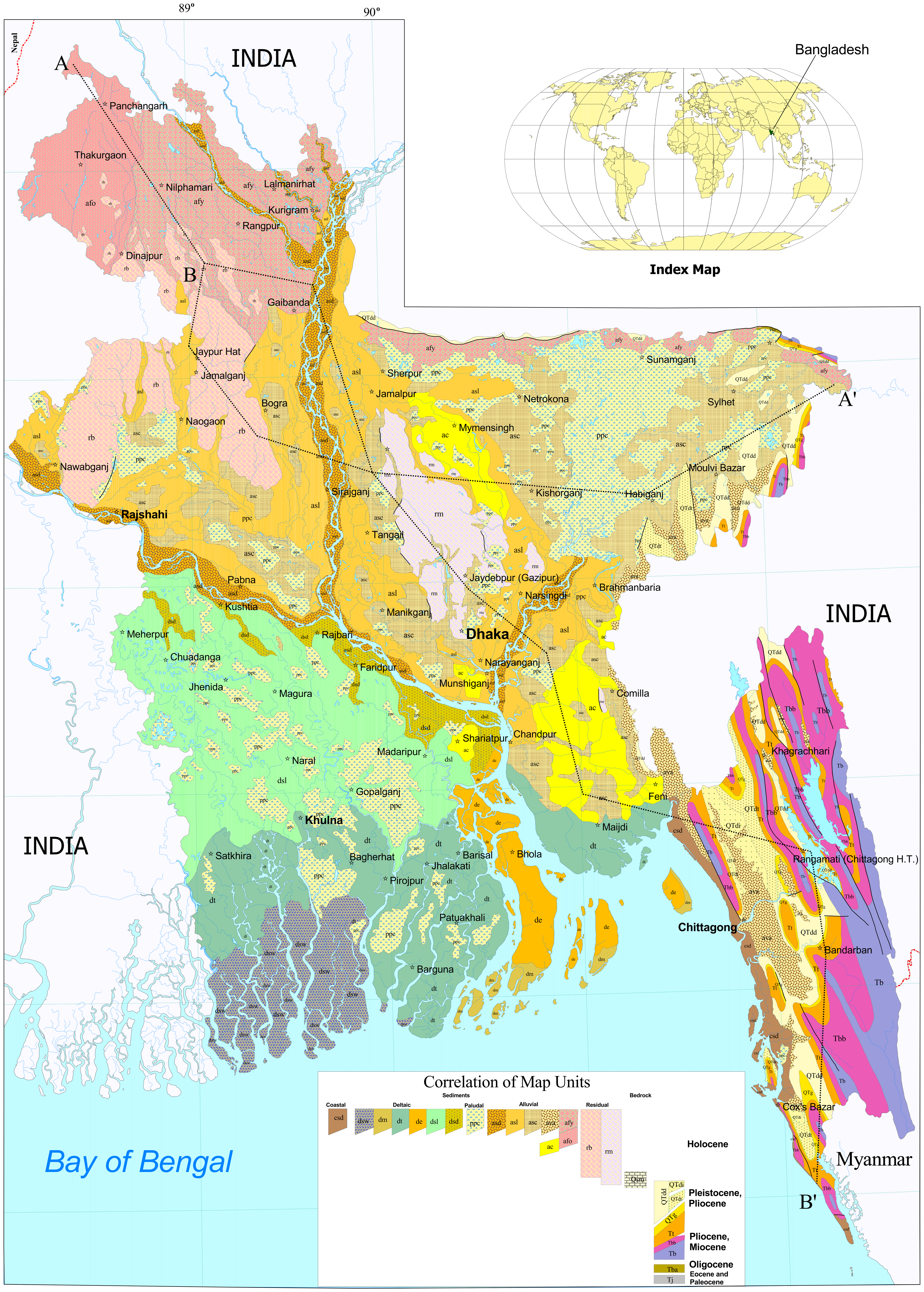
OPEN FILE REPORT 97- 470H

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 United States to 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

Scale 1:1,000,000

30 0 30 60 Miles
40 0 40 80 Kilometers

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

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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 III: 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 II: 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 II: 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

Decisions and Implementations of the First Workshop
on
Preparation and Incorporation of Alternative Pavement Section (Interlocking Concrete Block Pavement) into Road Design Manual

SL.	Requirements of the Client (LGED)	Responses from the Consultant (HBRI)
1.	গবেষণা কাজের উদ্দেশ্য এবং কার্যপরিধি চুক্তিপত্রের Terms of Reference এ উল্লেখিত উদ্দেশ্য এবং কার্যপরিধির অনুযায়ী হতে হবে।	Submission of the final report would be done as per objectives and scope of the research works stipulated under the Terms of Reference. Also, objectives, scope of works and expected outputs are reverted back to the terms and conditions mentioned under the contract document.
2.	Inception Report এ Background অংশটিতে বাংলাদেশ সরকার কর্তৃক গৃহীত আইন এবং লক্ষ্যমাত্রা সম্পর্কে বিস্তারিত বর্ণনা দিতে হবে।	Government's directives regarding the use of blocks in the construction of buildings and roadways are discussed under the Background section. Details are attached as an annexure (Annexure I) at the end of the report.
3.	Inception Report এ Organization অংশটির বর্ণনা সংক্ষিপ্ত করতে হবে।	Some contents from the Organization portion of the inception report are omitted. These mostly consist of specific activities of each division under HBRI.
4.	Inception Report এর মধ্যে Methodology and Scope এর ব্যাপারে বিস্তারিত বর্ণনা দিতে হবে।	Methodology regarding the manufacturing process of concrete blocks is provided under section 3.4 of the inception report.
5.	Inception Report এর মধ্যে Other Alternative Pavement Options এর ব্যাপারে সুস্পষ্টভাবে বর্ণনা দিতে হবে।	Some other alternative pavement options are focused under a separate section (i.e. 4.5) of the inception report.
6.	এলজিইডির কর্তৃক নির্মিত Interlocking Concrete Block Pavement সমূহ পরিদর্শনের জন্য ঢাকা বিভাগ বাদে অন্য বিভাগের কিছু জেলা (কমপক্ষে ৫ টি) পরিদর্শন করতে হবে।	Due to the broad scope of the existing research, it might not be possible to visit the 05 other districts requested by the client. The consultant would like to fulfill this requirement depending on the time available at hand. Also, Covid-19 situation and the ongoing lockdown arising from this phenomenon prevent the consultant from physically visiting the sites requested by the client. However, photographs containing full width of the road section (i.e. concrete block road), damaged section and depressed road section, picking out several blocks from the road to

		visualize the condition of the underlying sub-base and subgrade of the road could be provided to the consultant by Upazila Engineers from Client's side)
7.	Inception Report এ Sunamganj Community Based Resource Management Project (SCBRMP) প্রকল্পে বুয়েট কর্তৃক প্রস্তুতকৃত "The Viability of Concrete Block Road" শীর্ষক রিপোর্ট এবং Interlocking Concrete Pavement Institute (ICPI) এর রিপোর্টগুলোর Literature Review করতে হবে।	Literature review of the report containing "Viability of Concrete Block Road" is done and incorporated in section 2.1: National Report. Literature review of ICPI report is incorporated in section 2.2: International ICPB Pavement Manuals.
8.	চূড়ান্ত রিপোর্টে ড্রেজড বালি দিয়ে তৈরিকৃত ব্লকের Flexural Strength, Technical & Physical Properties এর বিষয়সমূহ অন্তর্ভুক্ত করতে হবে।	The parameters regarding Flexural Strength, Technical and Physical Properties requested by the client would be included in the final report.
9.	Inception Report এ Implementation Manual সেকশনে Subgrade Preparation, Improved Subgrade Preparation, Shoulder Compaction এর বিষয়সমূহ অন্তর্ভুক্ত করতে হবে।	Under implementation manual section (i.e. Section 4.1), separate points on subgrade preparation, improved subgrade preparation and shoulder compaction are written. Detail information related to the aforementioned criteria would be provided in the final report.
10.	Inception Report এ Maintenance Manual সেকশনে Routine Maintenance সহ অন্যান্য বিষয়সমূহ অন্তর্ভুক্ত করতে হবে।	A separate paragraph on routine maintenance is added under section 4.2: Pavement Maintenance Manual.
11.	Inception Report এ উল্লেখিত রাস্তার তথ্য সংগ্রহ ছক/ প্রশ্নাবলী পুনর্গঠন করতে হবে।	Tables regarding roadway information collection and questionnaire are slightly updated (i.e. Table 3 and Table 4)
12.	রাস্তা ব্যবহারকারী সকল স্টেকহোল্ডারদের জন্য একটি আলাদা তথ্য সংগ্রহ ছক/প্রশ্নাবলী অন্তর্ভুক্ত করতে হবে।	This Template along with its content would be provided in the final report. This particular aspect should be highlighted based on the information to be collected from **Table -3, column 10** and it would be produced in the final report. The collected content under Table 3 column 10 would be summarized to portray the qualitative assessment of the existing roads in the final report.
13.	চূড়ান্ত রিপোর্টে ড্রেজড বালি দিয়ে তৈরি ব্লক এবং বাজারে প্রচলিত ব্লকের একটি তুলনামূলক বিশ্লেষণ অন্তর্ভুক্ত করতে হবে।	The comparative study between blocks made with dredged sand and existing blocks at the markets would be provided in the final report.
14.	চূড়ান্ত রিপোর্টে ড্রেজড বালির Source (Name of Place), Availability এবং Specifications ছক আকারে অন্তর্ভুক্ত করতে হবে।	It would be covered in the final report.

15.	এলজিইডির পরিকল্পনা ইউনিটের গবেষণা, ইনোভেশন ও জ্ঞান ব্যবস্থাপনা সেল এবং মাননিয়ন্ত্রণ ইউনিটের প্রকৌশলীদের গবেষণার অগ্রগতি ও কার্যক্রম প্রতিমাসে অবহিত করতে হবে।	Monthly research progress would be notified to the client as per their wishes.