Part—II

Requirements

Section VI

Employer's Requirements

Section 6 - Employer's Requirements

This Section contains the Specifications, the Drawings, and supplementary information that describe the Works to be procured, Personnel Requirements and Equipment Requirements.

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Preamble

Shillong, located in the East Khasi Hills district, is the capital of Meghalaya, popularly referred as "The Scotland of the East". Shillong functioned, during the British regime, as the administrative capital of the erstwhile Assam province apart from being the only major t ourist destination in the región. Situated at 25^0 31' 26" -- 25^0 39' 56" N Latitude and 91^0 47' 20" -- 92^0 0' 39" E Longitude, the altitude of the city varies between 1400 and 1800 M above mean sea level (MSL). The National Highway NH40 links Shillong with Guwahati and rest of the country. There is a minor airport at Umroi, 35 KM from Shillong. Guwahati, the largest urban centre of the región, located 100KM from Shillong, is the nearest railhead and National airport.

It is one of the few Hill stations with motorable roads all around the city. Shillong has its own charm, different from other Hill stations and presents a natural scenic beauty with wáterfalls, brooks, pine groves and gadens. The place, the people, the flora and fauna and the climate all combine to make Shillong an ideal resort throughout the year.

The Shillong city is located in seismic zone V. The slopes within the city are not very steep and ranges from 5% to 10%. Shillong experiences a humid subtropical climate and is characterized by moderate warm wet summers and cool dry winters. The growth trend in the city indicate a physical growth of the city towards the north-eastern direction, where the new Shillong township is proposed.

The existing Landfill site at Municipal Trenching Ground at Marten, Mawiong which has been operational and used for disposal purposes since 1938. The site already includes an operating compost facility.

The collected wastes throughout the city are disposed at Mawiong Disposal Site at a distance of about 8KM from the city. The proposed Landfill Area is about 6500 Sq.m. There are no sensitive receptors occuring within 500M of the site. Umiam Lake is approximately 3KM from the proposed disposal site. The existing and the proposed Solid Waste Disposal Site and the existing Compost Plant of 100 MTPD capacity is a part of Riatkhwan Reserve Forest.

Scope of Work

The said work was awarded in 2010 However the contractor could not complete the work hence the contract was terminated. The details of work completed so far are given below.

An indicative drawing showing the status of work executed and balance work is provided. However, the bidders are advised to visit the site and make their own assessment for the works to be done.

1. **Construction of Retaining Wall for Landfill**
   - RCC Counterfort Retaining Wall -12.5 meters height (Grid 19 to 34)
     Length of Retaining Wall - 52.50 meters,
     The status of the work completed is as follows
     Raft- Completed for a length 37.4 M

Concreting of Stem Wall and Counterforts- completed up to 3.4 M (Three Lifts) height for a length of 34.3 M

Balance work is to be executed.

- RCC Counterfort Retaining Wall -10.7 M height (On West Side ,Gird 16 to 18))
  Length of Retaining Wall - 7.4 meters,
  The status of the work completed is as follows
  Raft- Completed
  Concreting of Stem Wall and Counterforts- completed up to 6.5 M (Three Lifts) height for a length of 4.0 M , Completed up to 2.3 M Height for a length of 2.4 M
  Balance work is to be executed.
- RCC Counterfort Retaining Wall -10.7 M height (On East Side, Grid 34 to 36)
  Length of Retaining Wall – 12.6 meters,
  The status of the work completed is as follows
  Raft- Completed for length of 3.7 M
  Concreting of Stem Wall and Counterforts- completed up to 9.6 M (Eight Lifts) height for a length of 3.7 M.
  Balance work is to be executed.
- RCC Counterfort Retaining Wall -8.65 meters height (Grid 13 to 16)
  Length of Retaining Wall – 11.7 meters,
  The status of the work completed is as follows
  Raft- Completed
  Concreting of Stem Wall and Counterforts- completed up to 4.5 M (Four Lifts) height for a length of 11.7 M.
  Balance work is to be executed.
- Stone Masonry Retaining Wall (on West side, Grid 1 to 12) Length – 52.7 M Completed
- Stone Masonry Retaining Wall (on East side, Grid 387 to 40) Length – 15 M Completed

2. Landfill Life –

- Landfill area is about 6500 sq.m. (0.65 Ha.) Only.
- Design Life of Landfill : 3 years 3 months from the date of commissioning

3. Landfill Design – Standard design of landfill as per MSW Rules 2000 is provisioned:

- 90 cm thick of clay liner constructed using wet clay or soil amended with 10% bentonite, having coefficient of permeability not greater than 1 x 10-7cm/sec, compacted clay or amended soil (Bentonite amended soil),
- 1.5mm thick HDPE geo-membrane liner
- 30 cm thick Drainage layer of silty sand material
- 30 cm thick Drainage layer of coarse sand material

- Since the RCC wall is a vertical structure Geo-synthetic Clay Liner (GCL) of equivalent permeability requirement and HDPE sheet was proposed for the sides of landfill.

4. Leachate Collection & Removal System:

- Leachate generated from the Landfill shall be collected and discharged outside by the Leachate collection and removal system (HDPE perforated pipes of 160 mm of feeder pipe and 315mm dia header pipe).
- 30 cm thick Drainage layer of silty sand material and 30 cm thick Drainage layer of coarse sand material
- Leachate collection & treatment system to collect leachate from landfill area

5. Construction of Leachate Holding Tank -1 Nos

- Leachate holding tank size – 14.4 m x 5.5 m
- 22 Cu.m per day of leachate shall be treated by conventional leachate treatment plant

6. Construction of Storm Water Drain

- Open Concrete Drain 250 x 250 (Length= 150m)

7. Approach Road

- Construction of internal roads 5 m wide, 502 m length, 3.75 m black top,
- Excavation – Completed for 380 m
- Soling – Completed for 380 m
- Balance works to be executed.

8. Construction of Tube Well

- Boring of Tube Well is completed
- Balance works to be executed.

9. Ground Water Reservoir

- RCC structure for the raft, vertical walls and dome of the water reservoir is completed.
- The balance works are plumbing, ventilation, pipe connections, steps etc and other finishing items.

Specification Document (Vol III)

Issued separately as Volume III

Particular Specifications

- The works would be quoted for all lead and lift unless otherwise specified particularly in the document.
- The Employer does not undertake to construct or make available any approach road to the proposed worksite if not mentioned in the Bill of Quantities and the bidder shall get acquainted with available means of approaches to the proposed site and quote for various items. The Employer shall not be liable for any claim raised later on the plea of non availability or non access to the site.
- The Contractor is advised to visit the site and acquaint himself of the prevailing local conditions at site, labour, water and other material requirements etc; required for the successful completion of the works

1.1. General

All the materials incorporated in the works shall be the most suitable for the duty concerned and shall be new and of first class commercial quality, free from imperfections and selected for long life and minimum maintenance. It shall be tested according to relevant IS Specifications in qualified labs and certificates produced to the satisfaction of the Project Manager.

If the specification for a particular item is not given, relevant IS Specifications ,the Standard Specifications of Meghalaya PWD or MSPHED or CPWD shall be followed.

The objective of the specifications given in this section is to specify the details pertaining to the design, drawing, and selection of equipment or product. The equipment or product supplied shall be of high standard of quality and best engineering practices and shall comply with all currently applicable standards, regulations and codes.

Except as otherwise specified in this technical specification, the Indian/International Standards and Codes of Practice in their latest version shall be adhered to for the design, manufacturing, inspection, calibration, installation, field testing, packing, handling and transportation of product.

Should any product be offered conforming to other standards, the equipment or products shall be equal to or superior to those specified and the documentary confirmation shall be submitted for the prior approval of the Employer. In case of any discrepancy in interpretation of the code/ clause the decision of the Project Manager shall be final and binding on the Contractor.

The successful contractor shall construct a Landfill facility at Marten as per the MSW Rules 2000 and requirements furnished below.

1.2. Topographical Survey & Geotechnical investigations

The indicative layout plan for proposed works is enclosed along with Tender Drawings for reference. The Contractor shall provide the Total station along with the surveyor for total project period. The report on geotechnical investigations are also appended herewith for reference. The Contractor shall carryout the confirmatory topographical survey and geotechnical investigations of his own and get satisfied before proceeding with the works. No extra cost shall be allowed by the Employer for such survey and investigations to the Contractor. The Contractor shall submit two hard and soft copies of the details of confirmatory topographical and Geotechnical surveys conducted for approval of client.

1.3. Site grading

Before taking up the site grading works the Contractor shall fix the base grid and lines along with bench mark stones and proceed with the grading works without disturbing the grid markings and bench marks fixed for the purpose. The Contractor shall clear the site of all the shrubs and muck if any before starting the excavation.

The excavation shall be done using hydraulic excavators & tippers with disposal upto 5 km for site grading. For road work grading, hydraulic excavator of required power and capacity shall be used along with tippers and earth shall be conveyed to the place shown by the Project Manager and disposed as per the direction of the direction of Project Manager. The bidder shall ascertain the soil quantity and nature of work for grading required through site visit before quoting for the tender. The Contractor shall submit the excavation plan and shall carry out accordingly duly as per the approved drawing and maintain the required slopes of the bund. The bunds shall be trimmed manually to the required grade as shown in the drawings. The required site grading vehicles and equipments shall be organized by the successful bidder before starting of the works.

1.4. RCC Counterfort Retaining wall

The Retaining wall, shall be constructed on the Northern side of the landfill site. The total length of the wall is considered as 150m (**Annexure -1** – Geo-technical Investigation Report attached). The wall comprises of Stone Masonry and RCC Counterfort Retaining Wall. This wall shall be constructed on a priority basis prior to the construction of landfill liner system. Considering a massive concrete RCC works to be completed within the schedule period considering rainy days, therefore successful bidder shall use following -

(a) ***Mobile Batching Plant:*** Successful Bidder shall set up two mobile batching plant of capacity 6 to 10 cum/hr. along with the concrete pumps.

(b) ***Shuttering Materials:*** A minimum of 3000 sq.m of sturdy steel shuttering along with safety dismountable pipe scaffolding arrangements shall be arranged at the site.

(c) ***Concrete Vibrators:*** 10 sets of pneumatic needle vibrators to be provided,

(d) ***Laboratory*** : About 40 sets of Concrete testing cubes with UTM for testing shall be provided at site. Other Laboratory equipments viz., Slump cone etc. shall be provided.

(e) The Contractor shall make his own arrangements for protection of Concrete due to rains with required Tarpulin/PV sheets covers and also water pumping machinery required arrangements for proper curing of concrete.

1.5. Landfill Construction

The Sanitary Landfill shall have protective measures against pollution of ground water and surface water, emission of dust, wind blown, litter, bad odour, fire hazard, bird menace, pest or rodents, green house gases, slope instability, erosion etc. The sanitary landfill site consists of

waste filling area and infrastructure support facilities. The support infrastructure (i.e., the access road, equipment shelters, weighing bridge, temporary waste storage space, demarcation of landfill areas for stockpiling cover materials and liner material, drainage facilities, leachate collection, and treatment facilities etc) will be located in the layout. Since there is an availability of adequate cover material at the site and the water table is far below, trench landfill is more suitable. Grading required for landfill development will produce excavate which will be safely stockpiled and used as cover material for the landfill operations. In order to avoid surface and groundwater contamination, the excavated site is lined with low permeability (having permeability coefficient not greater than 1 x 10-7 cm/sec) natural clay or amended soil (bentonite 10%) of about 900 mm thick and 1.5 mm thick HDPE geo-membranes. Leachate collection lateral pipes should be provided above the membranes in 300 mm thick silty sand layer and 300 mm coarse sand layer. The 160mm collection (feeder) pipes should be provided at a spacing of 15m c/c. Perforations should be laid at a slope of 1 in 100. Header pipes (315 mm dia) should be provided connecting up to the leachate treatment plant. The detailed specifications and construction methodology and tests etc are detailed below;

1.6. Specifications for Compacted Clays & Amended Soil for Landfill Liners

A competent barrier made of compacted soils – clays or amended soils – is normally expected to fulfill the following requirements:

a) hydraulic conductivity of 10^{-7} cm/sec or less;

b) absence of shrinkage cracks due to desiccation;

c) absence of clods in the compacted clay layer;

d) adequate strength for stability of liner under compressive loads as well as along side slopes; and

e) Minimal influence of leachate on hydraulic conductivity.

Clays of high plasticity with very low values of permeability (usually well below the prescribed limit), exhibit extensive shrinkage on drying, as well as tend to form large clods during compaction in the relatively dry state. Their permeability can also increase on ingress of certain organic leachates. Well compacted inorganic clays of medium plasticity, either natural or amended, appear to be most suitable for liner construction.

According to various investigations, soils with the following specifications would prove to be suitable for liner constructions: Percentage fines – between 40 and 50%; plasticity index – between 10 and 30%; liquid limit – between 25 and 30%; clay content – between 18 and 25%. It is necessary to perform detailed laboratory tests and some field trial tests prior to liner construction to establish that the requirements pertaining to permeability, strength, leachate compatibility and shrinkage are met.

1. Design Process

The design process for a compacted soil liner consists of the following steps:

I. Identification of borrow area or source of material – in-situ or nearby.

II. For in-situ soils, conducting field permeability tests to assess suitability of the natural soil in its in-situ condition.

III. Laboratory studies on liner material (from in-situ or nearby locations), comprising of soil classification tests, compaction tests, permeability tests, strength tests, shrinkage tests, compaction tests, permeability tests.

IV. Identification of source of additive, if natural soil does not satisfy liner requirements – natural clay from not too distant areas or commercially available clay such as bentonite (**Annexure – 2** – Soil Bentonite Laboratory Test Report attached).

V. Laboratory studies (as detailed in (iii) above) on soil – additive mixes using different proportions of additive to find minimum additive content necessary to achieve the specified requirements.

VI. Field trial on test pads, to finalise compaction parameters (layer thickness, number of passes, speed of compactor), as well as to verify that field permeability of the compacted soil lies within pre-specified limits.

2. Laboratory Studies

For amended soils, the following tests should be conducted to arrive at the minimum additive content.

Additive Composition: Grains size distribution, plasticity tests and mineralogy tests, are performed to identify the clay content, activity and clay mineralogy of the additive.

Host Material Composition: Grain size distribution and plasticity tests are performed on the host material, to assess that the host material will mix readily with the additive. Clean , usually mix readily with clays and bentonites. Cohesive hosts are more difficult to mix due to balling effect yielding uneven mixing. The host material must be sufficiently dry for proper mixing. The host material must be sufficiently dry for proper mixing.

Soil-Additive Compaction Tests: Standard Proctor (or modified) tests are undertaken with variable quantities of additives mixed to the soil, usually in increments of 2 to 5 percent. The influence of the additive on dry density and optimum moisture content are evaluated [Fig. 17.27 (a)].

Soil-Additive Permeability Tests: Permeability tests are conducted on as compacted-then-saturated samples of amended soil with different percentages of additive, each sample compacted to maximum density at optimum water content [Fig. 17.27(b)]. It is possible to identify a minimum additive content, from a series of tests, which may be required to achieve the desirable hydraulic conductivity.

Analysis of Laboratory Results:

Field engineers usually require a compaction specification, which states the minimum acceptable dry density as well as the acceptable range of water content. It is usually possible to arrive at a narrow acceptable range of water content and dry density as shown in Fig. 17.28. A step-by-step process of elimination is to be adopted to identify this acceptable range of water content and dry density, which should then be communicated to the field engineer.

3. Field Trial Test Pads

The construction of a field trial test pad prior to under taking construction of the main liner has many advantages. One can experiment with compaction equipment, water content, number of passes of the equipment, lift thickness and compactor speed. Most importantly, one can conduct extensive testing, including quality control testing and hydraulic conductivity tests, on the test pad. The test pad should have a width which is significantly more than the width of the construction vehicles (>10 m) and greater length. The pad should ideally be the same thickness as the full-sized liner, but may sometimes be thinner. The in-situ hydraulic conductivity may be determined by the sealed double ring infiltrometer method. In in-situ tests on test pads, the hydraulic conductivity is measured under zero over burden stress. Hydraulic conductivity measured on a

test pad, should be corrected for the effects of overburden stress, based on results of laboratory conductivity tests performed over a range of compressive stresses.

4. Construction Aspects

Compacted Clays: The typical sequence of construction for compacted clay liners is as follows:

(a) Clearing of borrow area by removal of shrubs and other vegetative growth.

(b) Adjustment of water content in the borrow area – sprinkling or irrigating for increasing the water content and ripping and aerating for lowering the water content.

(c) Excavation of material.

(d) Transportation to site in haulers or through conveyor systems (short distance).

(e) Spreading and leveling of a thin layer (lift) of soil (of thickness about 25 cm).

(f) Spraying and mixing water for final water content adjustment.

(g) Compaction using rollers.

(h) Construction quality assurance testing.

(i) Placement of next lift and repetition of process till final thickness is achieved.

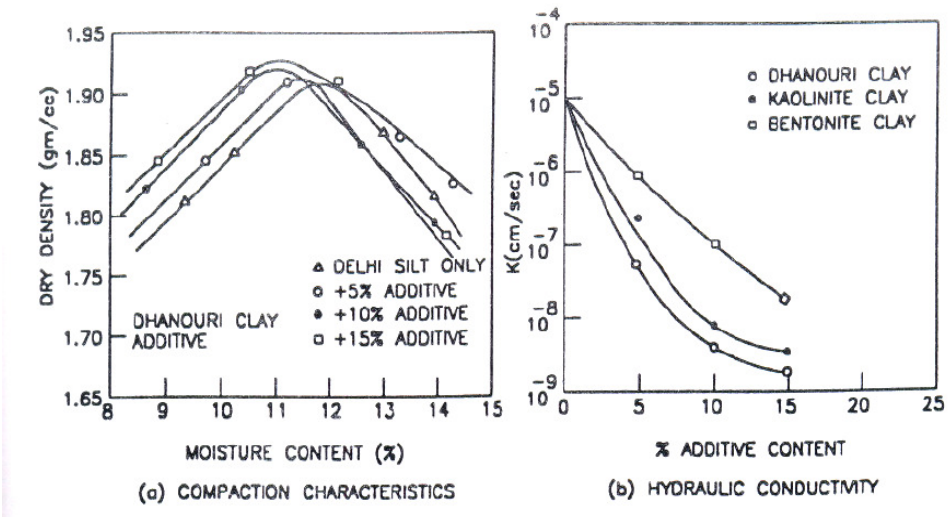


Fig. 17.17 (a) & (b): Influence of Additives on Compaction Characteristics and Hydraulic Conductivity of Sandy Silt

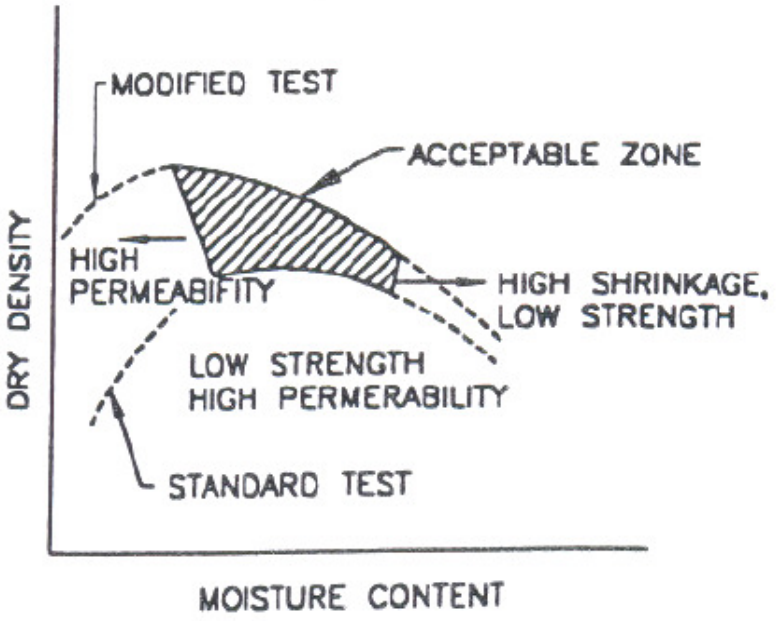


Fig. 17.28: Identification of Acceptable Zone for Liner Compaction

The two fold objectives of soil compaction are (a) to break and remould the clods into a homogenous mass, and (b) to densify the soil. If the compaction is performed such that the required density at the specified moisture content is obtained, the required permeability will be achieved in the field. Regulations generally require that a minimum 100 cm thick compacted clay liner be constructed. This thickness is considered necessary so that any local imperfections during construction will not cause hydraulic short-circuit of the entire layer. Compacted soil liners are constructed in a series of thin lifts. This allows proper compaction and homogeneous bonding between lifts. Generally, the lift thickness of clay liners is 25 to 30 cm before compaction and about 15 cm after compaction. It is important that each lift of clay liner be properly bonded to the underlying and overlying lifts. If this is not done, a distinct lift interface will develop, which may provide hydraulic connection between lifts.

Sheep foot rollers are best suited for compacting clay liners. Rollers with fully penetrating feet have a shaft about 25 cm long. Unlike partially penetrating rollers (pad-footed rollers), the fully penetrating sheep foot roller (Fig. 17.29) can push through an entire soil lift and remold it. In addition to increasing bonding between lifts, one should maximize the compactive energy by considering factors such as roller weight, area of each foot, number of passes and the speed of the roller.

The lifts are typically placed in horizontal layers. However, when liners are constructed on the side slopes, the lifts can be placed either parallel to the slope (for slopes up to 2.5 Horizontal : 1 Vertical, due to limitations of compaction equipment) or in horizontal lifts (Fig. 17.30). Horizontal lifts require a width which is at least the width of one piece of construction equipment (usually 3 to 4 m).

Amended Soils : The process of construction of amended soil liners is similar to that for compacted clay liners with the modification that the additive is introduced in two ways by in-place mixing or by central plant method. In the latter technique, soil and additive are mixed in a pugmill or a central mixing plant. Water can also be added in the pugmill either concurrently with bentonite or in a separate processing step. The central mixing plant method (Fig. 17.31) is more effective than in-place mixing and should be adopted. The use of small truck mounted concrete batching plants for mixing bentonite can also be examined.

The quality of the mix must be checked to ensure uniformity and correctness of the additive. A minimum of five trial runs should be made to check the quality of the mix visually and using grain size analysis. The permeability should also be checked using the field mix, compacted in the laboratory.

5. Construction Control

During construction, quality control is exercised to ensure that the constructed facility meets the design specifications.

Borrow area material control and amended soil control involves the following tests : (a) grain size distribution; (b) moisture content; (c) Atterberg's limits; (d) laboratory compaction tests; and (e) laboratory permeability tests. The frequency of testing varies from one test per 1000 cu.m, to one test per 5000 cu.m.

Compacted soil liner control involves the following tests: (a) in-situ density measurements; (b) in-situ moisture content measurements; (c) laboratory permeability tests on undisturbed samples; (d) in situ permeability tests; (e) grain size distribution and Atterberg's limits of compacted samples. The frequency of the testing for in-situ density and moisture content may be as high as 10 tests/hectare/lift whereas the other tests may be conducted at a lower frequency of about 2 tests/hectare/lift [Sharma and Lewis (1994)].

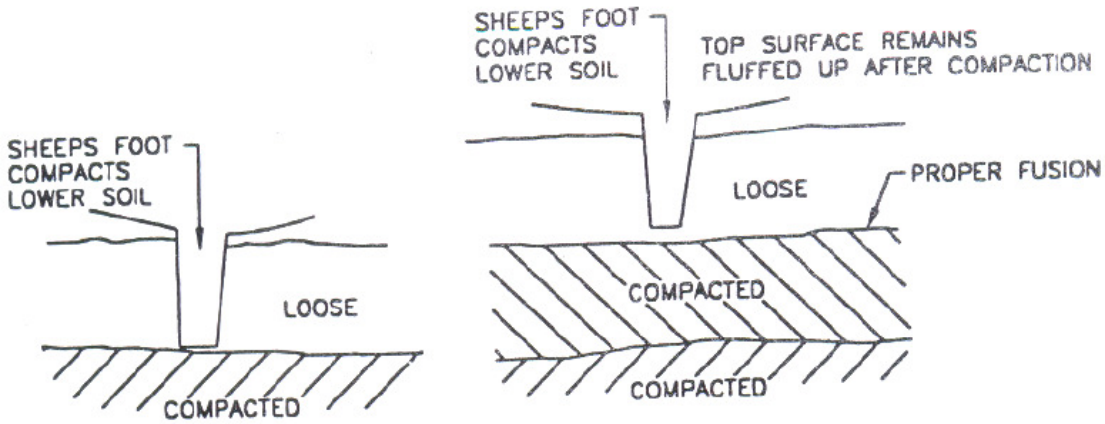


Fig. 17.29: Full Penetration During Kneading Compaction (Sheeps Foot Roller)

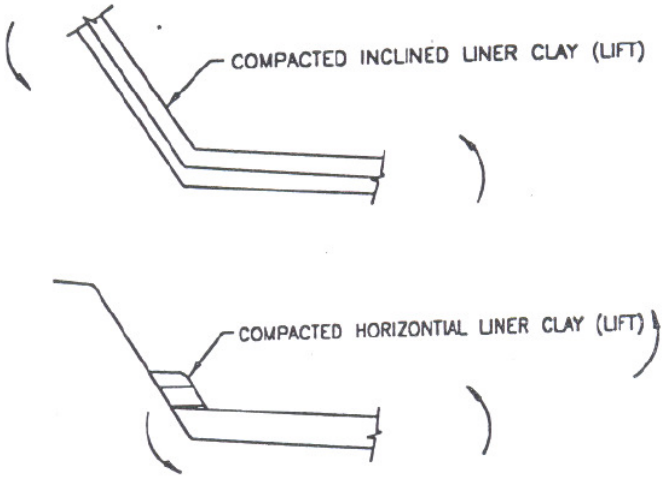


Fig. 17.30: Construction of Inclined and Horizontal Side Slope Liners

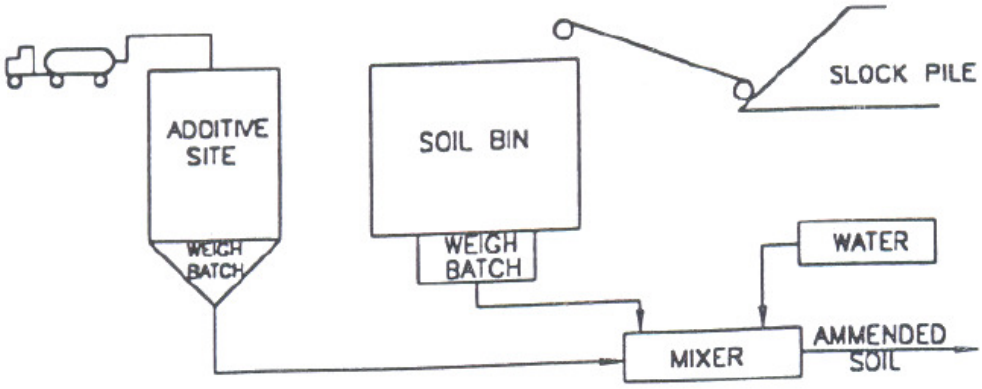


Fig. 17.31: Flow Diagram For Soil-Additive Mixing

Specifications for Geomembrane

A High Density Poly ethylene (HDPE) geomembrane of minimum thickness of 1.5 mm is to be laid over the compacted clay/amended soil with no gaps along the surface of contact.

Specifications

The geomembrane is normally expected to meet the following requirements:

a) It should be impervious

b) It should have adequate strength to withstand subgrade deformations and construction loads

c) It should have adequate durability and longevity to withstand environmental loads

d) The joints/seams must perform as well as the original material.

Typical specification for geomembrane liners are given in Table 17.5. The specifications are only suggestive and need to be refined by a geosynthetics specialist for each landfill site.

TYPICAL VALUES FOR GEOMEMBRANES MEASURED IN PERFORMANCE TESTS

Sl.No.	Property	Typical Value
1.	(a) Thickness	1.5 mm (60 mil)
	(b) Density	0.94 gm/cc
2.	Roll Width x length	6.5. m x 150 m
	Tensile Strength	
	a) Tensile Strength at yield	24 kN/m
	b) Tensile Strength at Break	42 kN/m
	c) Elongation at Yield	15%
	d) Elongation at Break	700%
	e) Secant Modulus (1%)	500 MPa
3.	Toughness	
	a) Tear Resistance (initiation)	200N
	b) Puncture Resistance	480 N
	c) Low Temperature Brittleness	-94ºF

Sl.No.	Property	Typical Value
4.	Durability a) Carbon Black b) Carbon Black Dispersion c) Accelerated Heat Ageing	 2% A-1 Negligible strength changes after 1 month at 110ºC
5.	Chemical Resistance a) Resistance to Chemical Waste Mixture b) Resistance to Pure Chemical Reagents	 10% strength change over 120 days 10% strength change over 7 days
6.	Environmental Stress Crack Resistance	1500 hrs
7.	Dimensional Stability	±2%
8.	Seam Strength	80% or more (of tensile strength)

Design Aspects

The following components have to be designed/checked for in the case of geomembranes :

a) anchor trench

b) sliding along slopes

c) allowable weight of vehicle

d) uneven settlement

e) panel layout plan

Construction/Installation of Geo-membranes

Although the construction activities for geomembrane installation are not as time consuming as clay liner construction, the quality control tests are intensive. The surface of compacted clay/ amended soil must be properly prepared for installation of synthetic membrane. The surface must not contain any particles greater than 1.25 cm (0.5 in) size. Larger particles may cause protuberance in the liner. The panel layout plan should be made in advance so that travels of heavy equipment on the liner. Seaming of panels within1.0m of the leachate collection line location should be avoided if possible; this issue can be finalized during the layout plan. The sub base must be checked for footprints or similar depressions before laying the liner. The crew

should be instructed to carry only the necessary tools and not to wear any heavy boots (teninis shoes are preferred). Laying of the synthetic membrane should be avoided during high winds [24 KMPH or more]. Seaming should be done within the temperature range specified by the manufacturer.

Several types of seaming methods are available. The following are some of the commonly used seaming techniques: thermal-hot air, hot wedge fusion, extrusion welding (fillet or lap), and solvent adhesive. The manufacturer usually specifies the types of seaming to be used and in most cases provides the seaming machine. Manufacturer's specifications and guidelines for seaming must be followed. Seaming is more of an art even with the automatic machines. Only persons who are conversant with the machine and have some actual experience should be allowed to seam. For HDPE, hot wedge fusion and extrusion welding type seaming are commonly practiced.

Geo-membranes must be covered with protective soil as soon as possible. Enough volume of soil should be stockpiled near the site so that it can be spread on the finished membrane as soon as the quality control test results are available and the final inspection is over. Synthetic membranes can be damaged by hoofed animals. Bare membrane should be guarded against such damage by fencing the area or by other appropriate methods.

At least 30cm of fine sand or silt or similar soil should be spread on the membrane as a protective layer. The soil should be screened to ensure that the maximum particle size is 1.25cm or less. The traffic routing plan must be carefully made so that the vehicle(s) does not travel on the membrane directly. Soil should be pushed gently by a light dozer to make a path. Dumping of soil on the membrane should be avoided as much as possible. One or two main routes with extra thickness of soil (60-90cm) should be created for use by heavier equipment for the proposes of soil moving .Even the utmost precaution and quality control during installation will be meaningless if proper care is not taken when covering the membrane. Slow and careful operations are the key to satisfactory soil spreading.

The geomembrane bid specification should include warranty coverage for transportation installation and quality control tests. The cost of a project may increase due to the warranty. The experience of the company (both in manufacturing and installation), quality control during manufacturing and installation, physical installation should be asked in the bid so proper comparisons among different bidders can be made.

Tests of several physical properties of the membrane must be performed before installation. Usually most of these tests are performed at time of manufacturing in the manufacturer's laboratory. The owner may arrange for an independent observer to oversee the tests, conduct the tests in an independent laboratory, or use a "split sampling" technique. This issue of responsibility for pre installation quality control tests must be clearly mentioned or resolved during the bidding process. The following are test used for quality control purposes: (a) sheet thickness, (b) melt

index,(c) percentage carbon black,(d) puncture resistance,(e) tear resistance, (f) dimensional stability,(g) density,(h) low temperature brittleness, (i) peel adhesion, and (j) bonded seam strength.

The quality control tests that are performed during installation include the following:

(a) Inspection of surface of compacted clay/ amended soil layer.

(b) Verification of the proposed layout plan.

(c) Check roll overlap.

(d) Checking anchoring trench and sump.

(e) Testing of all factory and field seams using proper techniques over full length.

(f) Destructive seam strength test.

(g) Patch up repair.

All the HDPE pipes and liner materials shall be procured from an approved manufacturer by the Project Manager and the Contractor shall submit the procurement details along with QAP for approval of SIPMIU for all the materials to the Project Manager before procurement of the same. The Quality control procedures to be conducted at the manufacturing plant by third party inspection team appointed by SIPMIU for the purpose. The manufacturers test certificates and the tested batch details to be provided as detailed in the approved QAP.

Specifications for Geosynthetic Clay Liner (GCL)

Geosynthetic Clay Liner (GCL): The GCL is factory manufactured hydraulic barrier consisting of granular sodium bentonite clay, sandwiched between, supported and encapsulated by two geo-textiles, held together by needle punching.

GEOTEXTILE PROPERTIES	TEST METHOD	TEST FREQUENCY	REQUIRED VALUES
Woven Geotextile Mass Per Area	ASTM D 5261	20,000 m²	140 g/m² average
Non-Woven Geotextile Mass Per Area	ASTM D 5261	10,000 m²	200 g/m² average
BENTONITE PROPERTIES	TEST METHOD	TEST FREQUENCY	REQUIRED VALUES
Bentonite Moisture	API 13 A	1 per 50 tonnes	14% max.
Bentonite Swell Index	ASTM D 5890	1 per 50 tonnes	24 ml/2g min.
Bentonite Fluid Loss	ASTM D 5891	1 per 50 tonnes	18 ml max.
GCL PROPERTY	TEST METHOD	TEST FREQUENCY	REQUIRED VALUES
Bentonite Mass/Area[2]	ASTM D 5993	6,000 m²	4.8 kg/m2 min. @ 12% 4.29 kg/m2 min. @ 0%
GCL Tensile Strength[3]	ASTM D 6768	6,000 m²	10 kN/m MARV
GCL Peel Strength[3]	ASTM D 6496	6,000 m²	6.5 N/cm) min.
CBR Puncture Strength	EN ISO 12236	25,000 m²	1.6 kN min.
GCL Index Flux[4]	ASTM D 5887	Weekly	1 x 10-8 m3/m2/sec max.
GCL Hydraulic Conductivity[4]	ASTM D 5887	Weekly	5 X 10^{-9} cm/sec max.

Delivery, Storage & Handling

A. General:

Conform to the manufacturer's requirements and ASTM D5888 unless otherwise specified.

B. Delivery:

1. Deliver material to the site only after the Third party Quality Assurance (QA) Inspector accepts required submittals.

2. Material shall be covered with a waterproof plastic covering resistant to ultraviolet degradation.

3. Ship less than one month prior to scheduled installation unless otherwise approved by engineer.

4. Each roll shall be marked with the following information:
   a. manufacturer's name
   b. product identification
   c. roll number

C. Handling:

The TPQA inspector shall verify that proper handling equipment exists which does not pose any danger to installation personnel or risk of damage or deformation to the liner material itself. Suitable handling equipment is described below:

Spreader Bar Assembly - A spreader bar assembly shall include both a core pipe or bar and a spreader bar beam. The core pipe shall be used to uniformly support the roll when inserted through the GCL core while the spreader bar beam will prevent chains or straps from chafing the roll edges.

- Stinger - A stinger is a rigid pipe or rod with one end directly connected to a forklift or other handling equipment. If a stinger is used, it should be fully inserted to its full length into the roll to prevent excessive bending of the roll when lifted.
- Roller Cradles - Roller cradles consist of two large diameter rollers spaced approximately 3 inches apart, which both support the GCL roll and allows it to freely unroll. The use of roller cradles shall be permitted if the rollers support the entire width of the GCL roll.
- Straps – A properly structured and supported pole or "carpet puller" can be used to unload GCL rolls onsite. As an alternative, straps that are appropriately rated can be used as an approved lifting method to unload GCL rolls.

D. Storage:

1. Store rolls in space allocated by Project Manager. Space should be at high ground level or elevated above ground surface.
2. Stack no more than 3 rolls high.
3. Protect rolls from UV, precipitation, other sources of moisture, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions.
4. An additional tarpaulin or plastic sheet shall be used over the stacked rolls to provide extra protection for GCL material stored outdoors.
5. Preserve integrity and readability of roll labels.
6. Bagged bentonite material shall be stored and tarped next to GCL rolls unless other more protective measures are available. Bags shall be stored on pallets or other suitably dry surface which will prevent undue prehydration.

E. GCL Inspection upon Delivery:

1. Each roll shall be visually inspected when unloaded to determine if any packaging or material has been damaged during transit.
2. Repairs to damaged GCL shall be performed as per standard specification.
    a. Rolls exhibiting damage shall be marked and set aside for closer examination during deployment.
    b. Minor rips or tears in the plastic packaging shall be repaired with moisture resistant tape prior to being placed in storage to prevent moisture damage.
    c. GCL rolls delivered to the project site shall be only those indicated on GCL manufacturing quality control certificates.

d. For needle punched GCLs, the presence of free-flowing water within the packaging shall require that roll to be set aside for further examination to ascertain the extent of damage, if any. Free-flowing water within the packaging of unreinforced GCLs shall be cause for rejection of that roll.

Product Qualifications:

- The GCL product supplied to the project shall be in full accordance with the requirements of this section.
- The GCL shall be manufactured by mechanically bonding the geo-textiles using a needle punching process as described in Section 1.3 to enhance frictional and internal shear strength characteristics.
- The needle punched GCL shall thermally heat set the nonwoven fibers where they protrude from the second geotextile (woven or nonwoven depending upon product) to more permanently secure the reinforcement in place. Other means may be used to lock the fibers in place if the process demonstrates similar performance to the thermal heat set process.
- In order to maintain these characteristics, no glues, adhesives or other non-mechanical bonding processes shall be used in lieu of the needle punch process. Their use to enhance the physical properties of the GCL is permitted.

All the HDPE pipes and liner materials shall be procured from an approved manufacturer by the Project Manager and the Contractor shall submit the procurement details along with QAP for approval of SIPMIU for all the materials to the Project Manager before procurement of the same. The Quality control procedures to be conducted at the manufacturing plant by third party inspection team appointed by SIPMIU for the purpose. The manufacturers test certificates and the tested batch details to be provided as detailed in the approved QAP.

1.9 Specifications for Geotextiles - PP Non Woven Needle Punched :

This Non woven geotextile are made of polypropylene materials used as a filter or a protective layer for landfill liner system. The various test methods and physical properties are given below;

Physical Properties

Properties	Standard	Unit	NW	NW	NW	NW	NW
Mass/Unit Area	ASTM D 5261	Gms/sq.mt	100	135	150	200	250
Tensile- Wide Width - MD	ASTM D 4595	kN/m	7	9	11	14	16
Tensile- Wide Width - CD	ASTM D 4595	Kn/M	6.6	8	10	12	14
Elongation	ASTM D 4595	%	55	55	55	55	55
Grab Strength – MD	ASTM D 4632	N	350	450	550	600	800
Grab Strength - CD	ASTM D 4632	N	300	400	475	525	700
Grab Elongation	ASTM D 4632	%	60	60	60	60	60
Trapezoidal- MD	ASTM D 4533	N	150	200	250	300	350

Trapezoidal - CD	ASTM D 4533	N	130	175	220	265	300
Mullen Burst	ASTM D 3786	kPa	1000	1550	2050	2400	3000
Puncture Strength (CBR)	ASTM D 6241	N	1100	1300	1550	1940	2330
Dynamic Resistance (Cone Drop)	ASTM D 4751	mm	20	18	15	14	12
Opening Size	ASTM D 4491	Microns	110	100	85	85	70
Permittivity	ASTM D 4491	sec	2	1.7	1.5	1.34	1.2
Permeability	ASTM D 4491	m/s	0.004	0.0037	0.0034	0.0036	0.0035
Flow Rate – 10 cm head	ASTM D 4491	l/sq.mt/s	195	170	125	95	90
UV Stability @ 500 hrs.	ASTM D 4355	%	70	70	70	70	70

All the HDPE pipes and Geo liner materials shall be procured from an approved manufacturer by the Project Manager and the Contractor shall submit the procurement details along with QAP for approval of SIPMIU for all the materials to the Project Manager before procurement of the same. The Quality control procedures to be conducted at the manufacturing plant by third party inspection team appointed by SIPMIU for the purpose. The manufacturers test certificates and the tested batch details to be provided as detailed in the approved QAP.

4.3 Leachate Collection & Removal System

Leachate refers to the liquid that has passed through or emerged from solid waste and contains dissolved and suspended materials from solid waste. Leachate should be collected and treated to prevent contamination of ground water. Leachate collection system to collect 30 cum/day of quantity comprises a network of HDPE pipes known as feeder pipes (160 mm dia) and header pipes (315 mm dia).

4.4 Leachate Holding/ Leachate Treatment tank

The leachate from the landfill is conveyed to a Leachate Holding/Treatment Tank. The tank shall be in two units. The quality of leachate is a function of waste characteristics and climatic conditions, especially precipitation. The leachate is generally expected to be high in TDS, BOD and Heavy metals. Leachate Collection Unit is allowed to settle and the grit gets accumulated at the bottom of the tank and the suspended particulates along with liquid enter into the filtration unit. Filtration Unit- In filtration unit, filtration media in the form of gravels, pebbles etc. are provided. The liquid when passes through the media, the floating particles get arrested and liquid is collected and let out into a drain

Drawings

2.1.1. **Employer's Drawings:-**The drawings listed in the Tender document are Employer's drawings and are provided by the Employer as a guideline of the specifications and work. All data and information furnished in the drawings by the Employer is given in good faith but the Employer does not accept the responsibility for the completeness and accuracy thereof. The same shall be verified by the contractor promptly pointing out errors or discrepancies thereof to the Engineer. Drawings are provided as Volume 3 of the bid documents.

2.1.2. **Contractor's Drawings:-**All drawings provided by the Contractor shall be on standard size sheets, prepared on computer with Auto CAD Latest revision and shall show particulars in a title block located in the lower right hand corner, in addition to the name of Contractor and equipment manufacturer, date, scale, drawing, revision number (R0 for drawings submitted initially, R1, R2 etc. for drawings submitted subsequently). A blank space shall be provided for the Engineer's approval stamp and provision shall be made for detail of revisions to be recorded. All drawings submitted by the supplier shall use the English language. All drawings shall be clearly and fully cross-referenced to the other drawings as relevant.

2.1.3. **The Contractor's attention is drawn to the Specification Document (Volume III) for more information on the drawing requirement.**

Supplementary Information

1.1.1. Co-operation: The Contractor shall establish full co-ordination with the officials of ULBs, SIPMIU and the Programme Consultants and extend co-operation to complete work.

1.1.2. Records procedures and reports: A work order book shall be maintained by the contractor at site/workshop for taking instructions from employer or his representative. The Contractor shall maintain records pertaining to the quality of installation / erection work and inspection, testing, compliance with all technical requirements in respect of all this works as described before. The Contractor shall submit such records to the Employer after the completion of any particular work before submitting the bill. The Contractor shall also maintain the cement/ steel consumption / material details etc. The Contractor shall proceed with Concrete works only on approval of the pour card by the Project Manager.

1.1.3. Personnel:-The contractor shall depute sufficient staff to carry out installation, the maintenance and repair work efficiently and satisfactorily. The Contractor shall undertake to comply with applicable legislation and the code of labour law on matters of health, hygiene and safety, and shall assume responsibility for works required in the event of any change in applicable regulations. The contractor shall provide all necessary superintendence during the execution of works and during maintenance. The Contractor's staff shall include adequate and competent persons with proven suitable, previous experience on similar contracts to supervise the works and sufficient skilled, semi-skilled and unskilled labour to ensure completion of works in time. The Contractor shall not remove any representative or skilled labour from the site without prior approval of the Employer's Representative for the proper fulfilling of the contractors obligations under the contract. The contractor or a competent and authorized agent or representative approved in writing by Employer on the basis of qualification and experience to be furnished by the contractor, which approval may at any time be withdrawn, is to be constantly on the works and shall give his whole time to the superintendence of the work.

1.1.4. Public Authorities: - The Contractor shall comply with all rules & regulations, bye laws and directives given from time to time by any local or public authority in connection with this work and shall himself pay fees or charges which are leviable on him without any extra cost.

1.1.5. Safety:-The Contractor will be responsible for safety of the material supplied and kept in joint custody of the employer and the contractor till completion of contract. The Contractor shall at his own expense arrange for the safety of his labour / supervisor staff employed by him directly or indirectly for performing the work, as per statutory requirement. The Contractor shall report any accident or unusual occurrence with the work at site that take place to employer immediately with the action, which he might have taken.

1.1.6. Acquaintance with Site and Work Conditions:-The Bidder shall study the site and general conditions in respect of approaches, labourers, climate and the data included in the tender documents and get it verified with actual inspections of the site, before submitting the

tender. In case of doubt about any item or data included in the tender, the same shall be got clarified in pre-bid meeting. Once the tender is accepted, it shall be concluded that the Contractor has verified and made himself conversant with all the details required for completing the work as stipulated conditions and specifications.

1.1.7. Store Shed Meter Repairs Shop, Office etc:-The Contractor shall make necessary arrangement at his own cost for store shed, meter repairs shop/ office, meter test bench etc. The Contractor shall consider all the costs related to required personnel, sheds, establishment of lab and equipments in his quote and no costs /claim will be entertained in this regard.

1.1.8. Quality Control: This Section 6 shall be read in conjunction with the Standard Specification provided along with Bid Document (Volume III).

Personnel Requirements

Using Form PER-1 and PER-2 in Section 4 (Bidding Forms), the Bidder must demonstrate it has personnel that meet the following requirements:

No.	Position	Total Work Experience [years]	Experience In Similar Work [years]
1	Project Manager (Graduate Civil Engineer)- 1 No	8	3
2	Site Engineer- Civil (Graduate)-1 No	3	2
3	Site Supervisor (Diploma Civil Engineer)-1 No	3	2

Equipment Requirements

Using Form EQU in Section 4 (Bidding Forms), the Bidder must demonstrate it has the key equipment listed below:

No	Equipment Type and Characteristics	Min. Number Required
1	Excavator cum loader	1 No.
2	Mobile Weigh Batch type concrete mixers	2 Nos.
3	Needle Vibrators	5 Nos.
4	Dewatering Pumps 5 HP	1 No
5	Smooth wheeled, Vibratory Roller	1 No.
6	Auto level set	1 No.
7	Shuttering material	1000 Sqm
8	Trucks / Tippers	1 No.
9	Road roller (Tandem vibrator)	1 No
10	Pug mill to mix soil & Bentonite	1
11	Water tankers with pump & sprinkling arrangements	2
12	Laboratory for testing fineness, consistency, setting time compressive & tensile strength of cement; compressive & flexural strength of Cement concrete and proof stress; elongation, tensile strength, bending & re-bending of reinforcement steel;, Cubes for testing, UTM; Soil characteristics testing including permeability test	Either Laboratory to be established or Testing arrangement to be made with accredited laboratory with prior approval of client.

Annexure I:

R E P O R T

O N

GEOTECHNICAL INVESTIGATIONS IN GREATER SHILLONG PLANNING AREA FOR ABD TA 4779 - IND,

1.0 **INTRODUCTION**

Sub - Soil Investigation was carried out at Mawiong,Shilong to find out the engineering properties of soil and to determine the depth of foundation and safe bearing capacity.

1.01 This report consists of field investigation and laboratory analysis along with the rational interpretation of test results and recommendation regarding the safe bearing capacity

1.02 All the field investigations and laboratory analysis were conducted as per relevant I.S. Code of practice for soil testing

2.0 **FIELD INVESTIGATION**

2.01 Field investigation was started on 25.02.2009 and completed on 28.02.2009

Field investigation consists of Auger boring with the help of outer casing and inner boring tube upto a maximum depth of 16.5 m

2.02 **STANDARD PENETRATION TEST (S.P.T.)**

The S.P.T were conducted by using standard split spoon sampler as per IS: 2131. Number of blows required to drive the sampler for first 15cm is neglected and the blows for the next 30cm is considered and expressed in

2.03 **DISTURBED / UNDISTURBED SAMPLES**

Disturbed and undisturbed samples were collected during the process of boring and were sealed for testing. The samples were sent to laboratory for testing as immediately as possible to avoid loss of moisture etc.

2.04 **GROUND WATER LEVEL**

The ground water level has been shown in bore hole log enclosed herewith.

3.0 **LABORATORY TEST**

Selected soil samples were analysed in the laboratory as per I.S: 2720 and the following tests were conducted and corresponding results of the tests have been furnished in the tabular form.

The following tests were conducted.

I) Natural Moisture Content

ii) Specific gravity

iii) Bulk density and Dry density

iv) Shear Strength

v) Grain Size analysis

vi) Atterberg Limits

4.1 BEARING CAPACITY OF THE FOUNDATION

Based on Standard Penetration Resistance value

q_a = $((q (N_q-1) s_q d_q i_q + 0.5 B \gamma N_\gamma s_\gamma d_\gamma i_\gamma W') / F) \times 10$ t / m^2

Where

N_q, N_γ = Bearing capacity factors

s_q, s_γ = Shape factors

For square footing $s_q = 1.2$ $s_\gamma = 1$

B = Width dia of foundation in cm

$d_q = d_\gamma$ = Depth factors = 1.00 for $\phi < 10^0$

= $1 + 0.1 (D_f / B) \times \text{sqrt} (N_\phi)$ for $\phi > 10^0$

ϕ = Angle of shearing resistance of soil in degrees

N_ϕ = $\tan^2 (45^0 + \phi / 2)$

D_f = Depth of foundation in cm

N_ϕ = $\tan^2 (45^0 + \phi / 2)$ = 1

i_q = Inclination factors = $(1- (\alpha / 90))^2$

i_γ = Inclination factor = $(1- (\alpha / \phi))^2$

α = Inclination of the load to the vertical in degrees

q = Effective surcharge at the base level of foundation in kgf / cm^2

γ = Bulk unit weight of foundation soil in kgf / cm^3

W' = Water table correction factor

F = Factor of safety

4.2 **FROM C-Ø VALUE :**

For bearing capacity of the following formula has been adopted as per I.S: 6403 - 1981.

q_s = $((q (N_q-1) s_q d_q i_q + 0.5 B \gamma N_\gamma s_\gamma d_\gamma i_\gamma W') / F) \times 10$ t / m^2 (whenC=0)

q_s = $\{(C\ 5.14\ S_c\ d_c\ i_c)/F\} \times 10$ t/m^2 (When $\phi = 0$)

Where

C = Cohesion in Kgf/cm^2

S_c = Shape factor

For square $S_c = 1.3$

d_c = Depth Factor = $1+ 0.2 (D_f/B) \times \text{sqrt.}\ (N_\phi)$

ic = iq = Inclinition Factors = $\{1 -(\alpha /90)\}^2$

Calculation of Bearing capacity

Based on Standard Penetration Resistance value

For BH.NO - 1

At depth D_f = 150 cm

Average N -value = (48 + 78 + 100) / 3 = 75.33 Say N=75

For N = 75.00 ϕ = 45.83° ϕ_{cor} = 45.83° Say 45°

For ϕ = 45° N_q = 34.87 N_γ = 271.74

S_q = 1.2 S_γ = 0.80

$d_q = d_\gamma$ = $1+0.1\,(150/200)\times\tan(45+45/2)$ = 1.18

α = 0° $i_\gamma = i_q$ = 1.00

γ = 0.002 Kgf/cm^2

γ' = 0.001 Kgf /cm^2

q = 0.001 x 150 = 0.15 kgf/cm^2

W' = 0.5

F = 2.5

q_a = {(0.15x(34.87-1) x1.20 x1.18 x1.00+0.50 x 200 x0.002 x 271.74 x 0.8 x 1.18 x1.00 x 0.50)/2.5} x 10

= 216.34 t/m^2

Calculation of Bearing capacity

From Shear Test Results

For BH.NO - 1

ϕ = 40° ϕ_{cor} = 40°

For ϕ = 40° N_q = 64.20 N_γ = 109.42

S_q = 1.2 S_γ = 0.80

$d_q = d_\gamma$ = 1+ 0.1 (150 / 200) x tan (45 + 40 / 2) = 1.16

α = 0° $i_\gamma = i_q$ = 1.00

γ = 0.002 Kgf/cm^2

γ' = 0.001 Kgf /cm^2

q = 0.001 x 150 = 0.15 kgf/cm^2

W' = 0.5

F = 2.5

q_a = {(0.15x(64.2-1) x1.20 x1.16 x1.00+0.50 x 200 x0.002 x 109.42 x 0.8 x 1.16 x1.00 x 0.50)/2.5} x 10

= 93.40 t/m^2

For BH.NO - 6

At depth D_f = 300 cm $\phi = 0^o$

C = 0.29

d_c = 1+ 0.2 (300/200)x $\tan^2 45^o$ = 1.30

S_c = 1.30

q_a = {(0.29 X 5.14 X 1.30 X 1.30 X 1.00)/2.5} x 10 t/m^2

= 10.08 t/m^2

NET SAFE BEARING CAPACITY (t/m^2) AT VARIOUS DEPTHS

Bore Hole No.	Depth (m)	From N-Value	From C-ø value
1	1.5	216.34	93.40
	2.0	267.18	115.78
	2.5	321.88	140.78
	3.0	380.43	229.50
2	1.5	260.74	93.40
	2.0	321.13	115.78
	2.5	386.06	140.78
	3.0	455.53	195.04
3	1.5	216.34	93.40
	2.0	267.18	115.78
	2.5	321.88	140.78
	3.0	380.43	229.50

NET SAFE BEARING CAPACITY (t/m^2) AT VARIOUS DEPTHS

Bore Hole No.	Depth (m)	From N-Value	From C-ø value
4	1.5	181.94	109.22
	2.0	225.21	136.22
	2.5	269.68	164.02
	3.0	319.26	195.04
5	1.5	181.94	80.14
	2.0	225.21	99.56
	2.5	269.68	120.30
	3.0	319.26	166.35
6	1.5	-	-
	2.0	-	-
	2.5	-	-
	3.0	14.76	10.08

RECOMMENDATION

From field and laboratory investigations, the following recommendations have been made for the purpose of design of foundation at the site.

A. For bore hole locations 1,2,3,4 & 5

1. Type of foundation : R.C.C Shallow foundation

2. Recommended Net safe bearing capacity:15.00 t/m^2 (considering jointed Rock)

3. Depth of Foundation :150 cm

B. For bore hole location 6

1. Type of foundation : R.C.C Shallow foundation

2. Net safe bearing capacity: 10.0 t/m^2

3. Depth of Foundation : 300 cm

N - VALUE CORRECTION

Depth (m)	Bore Hole No.1		Bore Hole No.2		Bore Hole No. 3	
	Observed N - value	Corrected N - value	Observed N - value	Corrected N - value	Observed N - value	Corrected N - value
1.5	48	45	55	50	45	42
3.0	78	60	88	67	93	70
4.5	100	69	100	69	88	62
6.0	109	70	109	70	97	63
7.5	110	67	108	66	110	67
9.0	109	64	120	69	Refusal	69
10.5	112	63	121	67	-	-
12.0	122	65	129	69	-	-
13.5	120	62	Refusal	69	-	-
15.0	Refusal	60	-	-	-	-
16.5	Refusal	59	-	-	-	-

Depth (m)	Bore Hole No.4		Bore Hole No. 5		Bore Hole No. 6	
	Observed N - value	Corrected N - value	Observed N - value	Corrected N - value	Observed N - value	Corrected N - value
1.5	53	49	50	46	-	-
3.0	82	63	75	58	-	-
4.5	70	51	97	67	8	8
6.0	83	55	115	74	67	46
7.5	92	57	128	77	103	63
9.0	130	74	Refusal	74	-	-
10.5	110	62	-	-	-	-
12.0	Refusal	65	-	-	-	-
13.5	Refusal	67	-	-	-	-

Type of Boring : Auger Drilling
Ground Elevation: EGL

BORE HOLE NO. 01

Date Started : 25.02.2009
Date Completed : 25.02.2009

DESCRIPTION OF STRATA	DEPTH (m)	STRATA	SAMPLE COLLECTED D/S	SAMPLE COLLECTED U/S	GROUND WATER LEVEL	S.P.T V/S DEPTH (20 40 60 80)	N - VALUE
Little brown soil mixed with weathered rock	1.0		1.5	Undisturbed sample could not be taken.	G.W.L. ± 0.0		48
	2.0						
Weathered rock mixed with quartzite rock	3.0		3.0				78
	4.0		4.5				100
	5.0						
	6.0		6.0				109
	7.0		7.5				110
Quartzite rock	8.0						
	9.0		9.0				109
	10.0		10.5				112
Weathered rock	11.0						
	12.0		12.0				122
	13.0		13.5				120
Quartzite rock	14.0						
	15.0		15.0				Refusal
	16.0		16.5				Refusal

D/S = Disturbed Sample U/S = Undisturbed Sample S.P.T. = Standard Penetration Test

SOIL & FOUNDATION CONSULTANT. Depth of Sampler = 0.45 m

Type of Boring : Auger Drilling
Ground Elevation: EGL

BORE HOLE NO. 02

Date Started : 25.02.2009
Date Completed : 26.02.2009

DESCRIPTION OF STRATA	DEPTH (m)	STRATA	SAMPLE COLLECTED D/S	SAMPLE COLLECTED U/S	GROUND WATER LEVEL	S.P.T V/S DEPTH (20 40 60 80)	N - VALUE
Soil mixed with quartzite rock	1.0						
Weathered stone	2.0		1.5				55
	3.0		3.0				88
Quartzite stone mixed with little lime stone.	4.0			Undisturbed sample could not be taken.			
	5.0		4.5				100
Quartzite stone	6.0		6.0		G.W.L. ± 0.0		109
Weathered rock mixed with quartzite rock	7.0		7.5				108
	8.0						
	9.0		9.0				120
Quartzite rock	10.0		10.5				121
	11.0						
	12.0		12.0				129
	13.0		13.5				Refusal

D/S = Disturbed Sample U/S = Undisturbed Sample S.P.T. = Standard Penetration Test

SOIL & FOUNDATION CONSULTANT. Depth of Sampler = 0.45 m

Type of Boring : Auger Drilling
Ground Elevation: EGL

BORE HOLE NO. 03

Date Started : 27.02.2009
Date Completed : 27.02.2009

DESCRIPTION OF STRATA	DEPTH (m)	STRATA	SAMPLE COLLECTED D/S	SAMPLE COLLECTED U/S	GROUND WATER LEVEL	S.P.T V/S DEPTH (20 40 60 80)	N - VALUE
Brown soil with weathered rock.	1.0		1.5	Undisturbed sample could not be taken.	G.W.L. ± 0.0		45
	2.0						
Quartzite rock	3.0		3.0				93
	4.0		4.5				88
	5.0						
	6.0		6.0				97
Quartzite rock of different layer	7.0		7.5				110
	8.0						
	9.0		9.0				Refusal

D/S = Disturbed Sample U/S = Undisturbed Sample S.P.T. = Standard Penetration Test

SOIL & FOUNDATION CONSULTANT. Depth of Sampler = 0.45 m

Type of Boring : Auger Drilling
Ground Elevation: EGL

BORE HOLE NO. 04

Date Started : 27.02.2009
Date Completed : 28.02.2009

DESCRIPTION OF STRATA	DEPTH (m)	STRATA	SAMPLE COLLECTED D/S	SAMPLE COLLECTED U/S	GROUND WATER LEVEL	S.P.T V/S DEPTH (20 40 60 80)	N - VALUE
Little brown soil mixed with sedimulutation rock	1.0		1.5	Undisturbed sample could not be taken.	G.W.L. ± 0.0		53
	2.0						
	3.0		3.0				82
	4.0		4.5				70
	5.0						
Quartzite rock	6.0		6.0				83
	7.0		7.5				92
	8.0						
	9.0		9.0				130
	10.0						
	11.0		10.5				110
	12.0		12.0				Refusal
	13.0		13.5				Refusal

D/S = Disturbed Sample U/S = Undisturbed Sample S.P.T. = Standard Penetration Test

SOIL & FOUNDATION CONSULTANT. Depth of Sampler = 0.45 m

Type of Boring : Auger Drilling
Ground Elevation: EGL

BORE HOLE NO. 05

Date Started : 28.02.2009
Date Completed : 28.02.2009

DESCRIPTION OF STRATA	DEPTH (m)	STRATA	SAMPLE COLLECTED D/S	SAMPLE COLLECTED U/S	GROUND WATER LEVEL	S.P.T V/S DEPTH (20 40 60 80)	N - VALUE
Little soil with weathered rock.	1.0		1.5	Undisturbed sample could not be taken.	G.W.L. ± 0.0		50
	2.0						
Weathered rock mixed with quartzite rock	3.0		3.0				75
	4.0		4.5				97
	5.0						
	6.0		6.0				115
Quartzite rock	7.0		7.5				126
	8.0						
	9.0		9.0				Refusal

D/S = Disturbed Sample U/S = Undisturbed Sample S.P.T. = Standard Penetration Test

SOIL & FOUNDATION CONSULTANT. Depth of Sampler = 0.45 m

PROJECT : Geotechnical Investigations in Greater Shillong Planning Area for ADB TA 4779-IND

Type of Boring : Auger Drilling
Ground Elevation: EGL

BORE HOLE NO. 06

Date Started : 28.02.2009
Date Completed : 28.02.2009

DESCRIPTION OF STRATA	DEPTH (m)	STRATA	SAMPLE COLLECTED D/S	SAMPLE COLLECTED U/S	GROUND WATER LEVEL	S.P.T V/S DEPTH (20 40 60 80)	N - VALUE
Garbage (Debris)	1.0		1.5		G.W.L. ± 0.0		-
	2.0						
Silty clay grey in colour	3.0		3.0	3.5			7
	4.0		4.5				8
Weathered rock	5.0						
	6.0		6.0				67
	7.0		7.5				103
	8.0						

D/S = Disturbed Sample U/S = Undisturbed Sample S.P.T. = Standard Penetration Test

SOIL & FOUNDATION CONSULTANT. Depth of Sampler = 0.45 m

PHYSICAL PROPERTIES

Bore Hole No.	Depth (m)	Moisture Content (%)	Specific gravity	Bulk Density (gm/cc)	Dry Density (gm/cc)	Void Ratio
1	1.5	15.16	2.67	-	-	-
	3.0	24.20	2.69	-	-	-
	4.5	10.67	2.66	-	-	-
	6.0	5.97	2.66	-	-	-
	7.5	7.12	2.67	-	-	-
	9.0	9.07	2.68	-	-	-
	10.5	7.91	2.66	-	-	-
	12.0	3.56	2.67	-	-	-
	13.5	6.33	2.68	-	-	-
	15.0	7.13	2.68	-	-	-
	16.5	8.01	2.68	-	-	-
2	1.5	15.44	2.67	-	-	-
	3.0	5.56	2.69	-	-	-
	4.5	4.19	2.66	-	-	-
	6.0	5.43	2.66	-	-	-
	7.5	9.35	2.67	-	-	-
	9.0	5.01	2.68	-	-	-
	10.5	6.55	2.66	-	-	-
	12.0	4.21	2.67	-	-	-
	13.5	6.52	2.68	-	-	-
3	1.5	14.63	2.67	-	-	-
	3.0	23.94	2.69	-	-	-
	4.5	9.03	2.66	-	-	-
	6.0	7.18	2.66	-	-	-
	7.5	6.65	2.67	-	-	-
	9.0	6.71	2.68	-	-	-

PHYSICAL PROPERTIES

Bore Hole No.	Depth (m)	Moisture Content (%)	Specific gravity	Bulk Density (gm/cc)	Dry Density (gm/cc)	Void Ratio
4	1.5	15.46	2.67	-	-	-
	3.0	6.88	2.69	-	-	-
	4.5	4.45	2.66	-	-	-
	6.0	5.47	2.66	-	-	-
	7.5	9.17	2.67	-	-	-
	9.0	9.18	2.68	-	-	-
	10.5	8.54	2.66	-	-	-
	12.0	4.25	2.67	-	-	-
	13.5	8.14	2.68	-	-	-
5	1.5	17.43	2.67	-	-	-
	3.0	23.59	2.69	-	-	-
	4.5	8.72	2.66	-	-	-
	6.0	7.75	2.66	-	-	-
	7.5	6.36	2.67	-	-	-
	9.0	7.40	2.68	-	-	-
6	1.5	15.18	2.67	-	-	-
	3.0	12.77	2.69	-	-	-
	3.5	13.65	2.69	1.80	1.58	0.70
	4.5	5.38	2.66	-	-	-
	6.0	5.58	2.66	-	-	-
	7.5	10.60	2.67	-	-	-

"N.B.: The Bulk Density, Dry Density & Void Ratio can not be worked out due to undisturbed samples are not availaable.

CHEMICAL ANALYSIS
at G.L - 0.50m

Sample No	pH	Sulphate (mg/1)	Clorides (mg/1)
1	6.6	72	87
2	6.7	76	84
3	6.9	79	85
4	6.8	77	88
5	6.8	79	87
6	6.9	78	86

SHEAR TEST RESULTS

BoreHole No.	Depth (m)	Unconfined		Direct shear test	
		C (kgf/cm^2)	ϕ^o	C (kgf/cm^2)	ϕ^o
1	1.5	-	-	-	40°
	3.0	-	-	-	42°
	4.5	-	-	-	44°
	6.0	-	-	-	42°
	9.0				41°
	10.5	-	-	-	43°
	12.0	-	-	-	44°
	15.0	-	-	-	44°
2	1.5	-	-	-	40°
	3.0	-	-	-	41°
	4.5	-	-	-	42°
	6.0	-	-	-	44°
	7.5				44°
	10.5	-	-	-	44°
	12.0	-	-	-	44°
3	1.5	-	-	-	40°
	3.0	-	-	-	42°
	4.5	-	-	-	43°
	6.0	-	-	-	44°
	7.5	-	-	-	44°

SHEAR TEST RESULTS

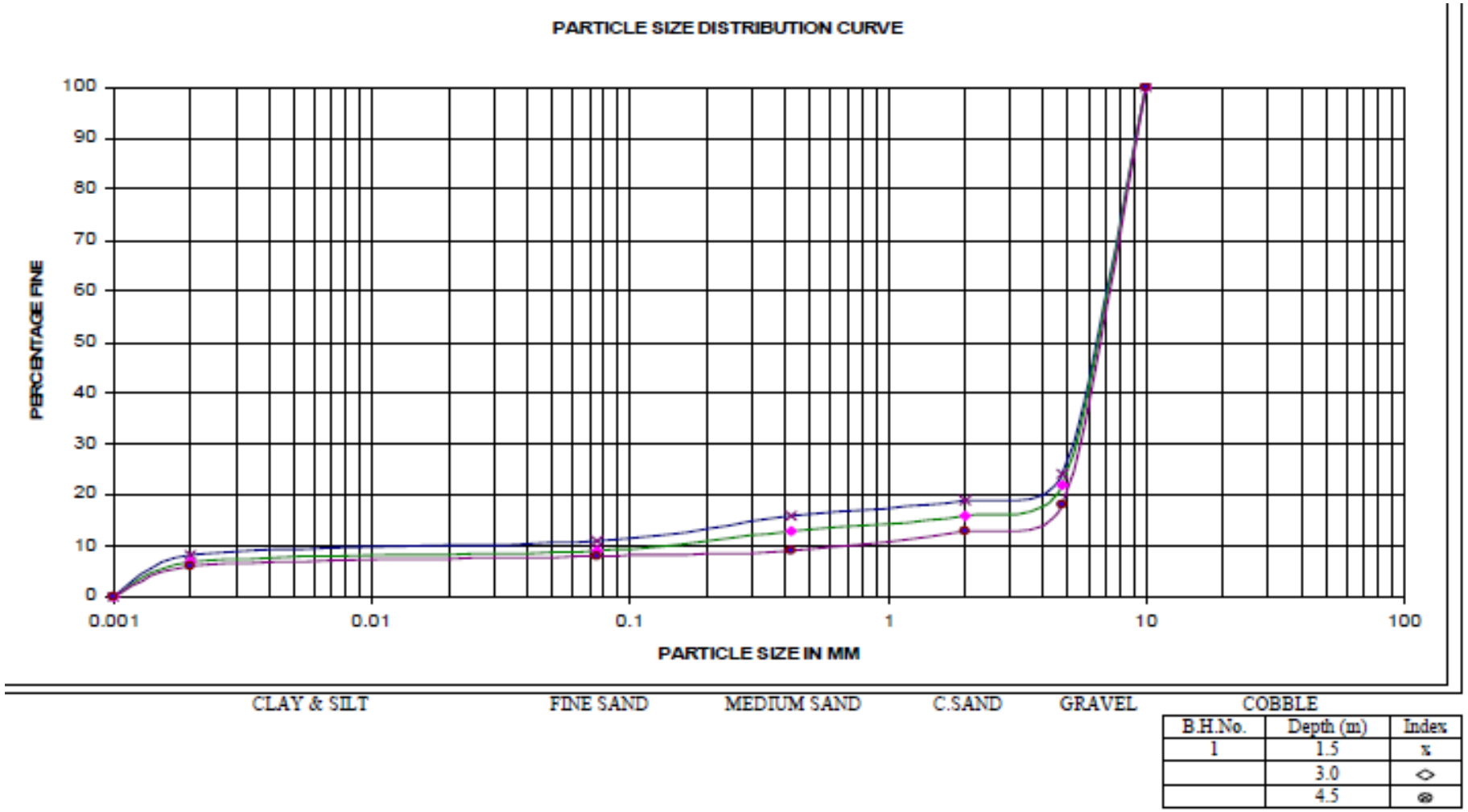
BoreHole No.	Depth (m)	Unconfined		Direct shear test	
		C (kgf/cm^2)	ϕ°	C (kgf/cm^2)	ϕ°
4	1.5	-	-	-	41°
	3.0	-	-	-	41°
	4.5	-	-	-	43°
	7.5	-	-	-	43°
	10.5	-	-	-	44°
	12.0	-	-	-	43°
5	1.5	-	-	-	39°
	3.0	-	-	-	40°
	6.0	-	-	-	42°
	7.5				42°
	9.0	-	-	-	44°
6	3.5	0.29	-	-	-
	4.5	-	-	-	42°
	7.5	-	-	-	43°

GRAIN SIZE ANALYSIS

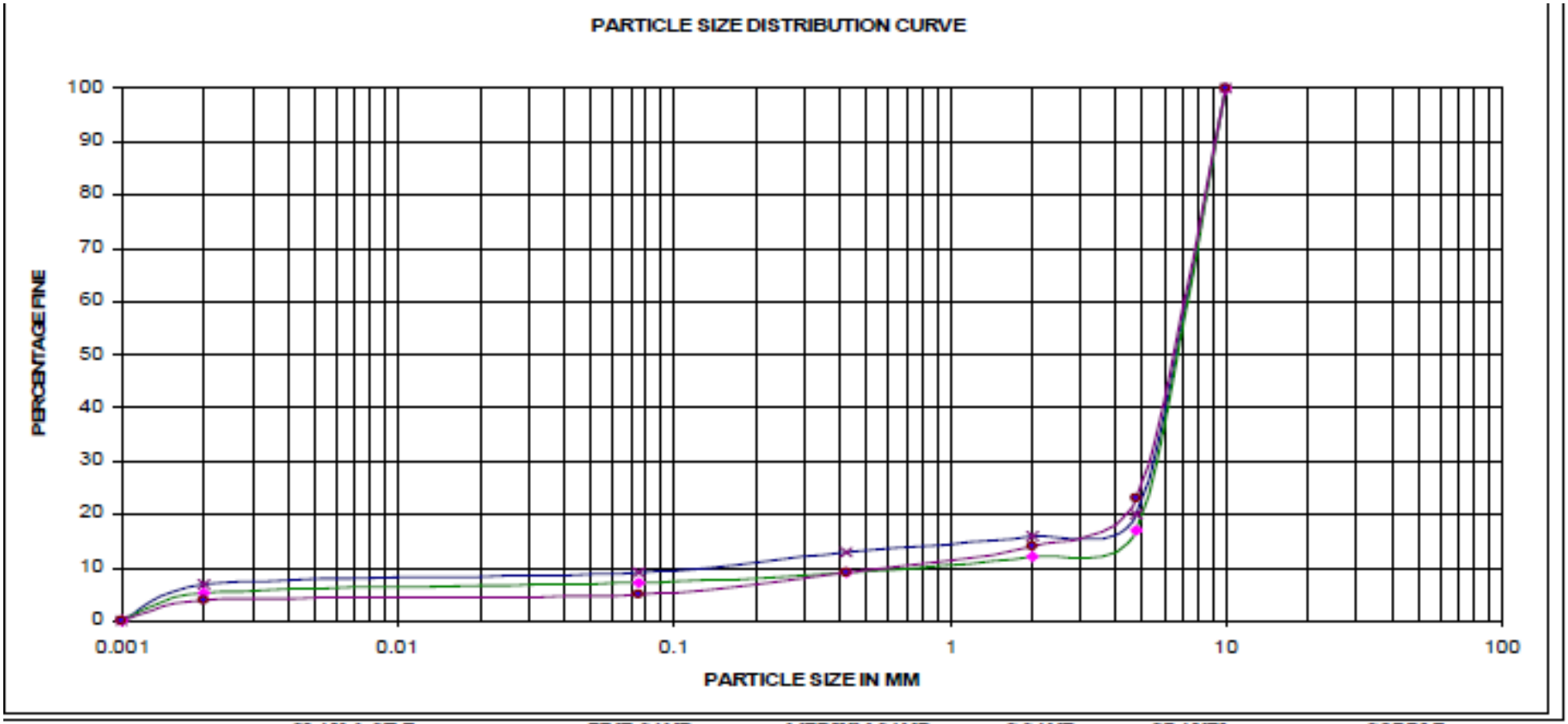
Bore Hole No.	Depth (m)	Silt & Clay (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)
1	1.5	11.00	5.00	3.00	5.0	76.0
	3.0	9.00	4.00	3.00	6.0	78.0
	4.5	8.00	1.00	4.00	5.0	82.0
	6.0	9.00	4.00	3.00	4.0	80.0
	7.5	7.00	2.00	3.00	5.0	83.0
	9.0	5.00	4.00	5.00	9.0	77.0
	10.5	6.00	3.00	4.00	8.0	79.0
	12.0	5.00	5.00	3.00	6.0	81.0
	13.5	4.00	6.00	4.00	7.0	79.0
	15.0	3.00	4.00	6.00	5.0	82.0
	16.5	1.00	2.00	3.00	5.0	89.0
2	1.5	9.00	3.00	4.00	5.0	79.0
	3.0	8.00	4.00	3.00	4.0	81.0
	4.5	5.00	4.00	5.00	9.0	77.0
	6.0	6.00	3.00	4.00	8.0	79.0
	7.5	5.00	2.00	3.00	5.0	85.0
	9.0	3.00	2.00	5.00	8.0	82.0
	10.5	3.00	4.00	2.00	4.0	87.0
	12.0	4.00	3.00	3.00	6.0	84.0
	13.5	2.00	1.00	2.00	5.0	90.0
3	1.5	11.00	3.00	4.00	5.0	77.0
	3.0	4.00	3.00	3.00	6.0	84.0
	4.5	4.00	2.00	5.00	7.0	82.0
	6.0	3.00	4.00	2.00	4.0	87.0
	7.5	5.00	2.00	3.00	5.0	85.0
	9.0	2.00	1.00	2.00	5.0	90.0

GRAIN SIZE ANALYSIS

Bore Hole No.	Depth (m)	Silt & Clay (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)
4	1.5	12.00	2.00	3.00	5.0	78.0
	3.0	4.00	3.00	2.00	4.0	83.0
	4.5	3.00	3.00	5.00	4.0	85.0
	6.0	4.00	1.00	4.00	5.0	86.0
	7.5	2.00	1.00	3.00	4.0	90.0
	9.0	3.00	2.00	4.00	2.0	89.0
	10.5	2.00	1.00	2.00	4.0	91.0
	12.0	4.00	1.00	3.00	3.0	89.0
	13.5	2.00	2.00	2.00	4.0	90.0
5	1.5	9.00	3.00	4.00	12.0	72.0
	3.0	4.00	1.00	4.00	5.0	86.0
	4.5	4.00	2.00	5.00	7.0	82.0
	6.0	2.00	1.00	2.00	4.0	91.0
	7.5	3.00	4.00	2.00	4.0	87.0
	9.0	2.00	1.00	2.00	3.0	92.0
6	1.5	-	-	-	-	-
	3.0	62.00	9.00	4.00	15.0	10.0
	4.5	4.00	2.00	5.00	7.0	82.0
	6.0	3.00	4.00	2.00	4.0	87.0
	7.5	2.00	1.00	2.00	3.0	92.0



B.H.No.	Depth (m)	Index
1	1.5	x
	3.0	◇
	4.5	⊗



B.H.No.	Depth (m)	Index
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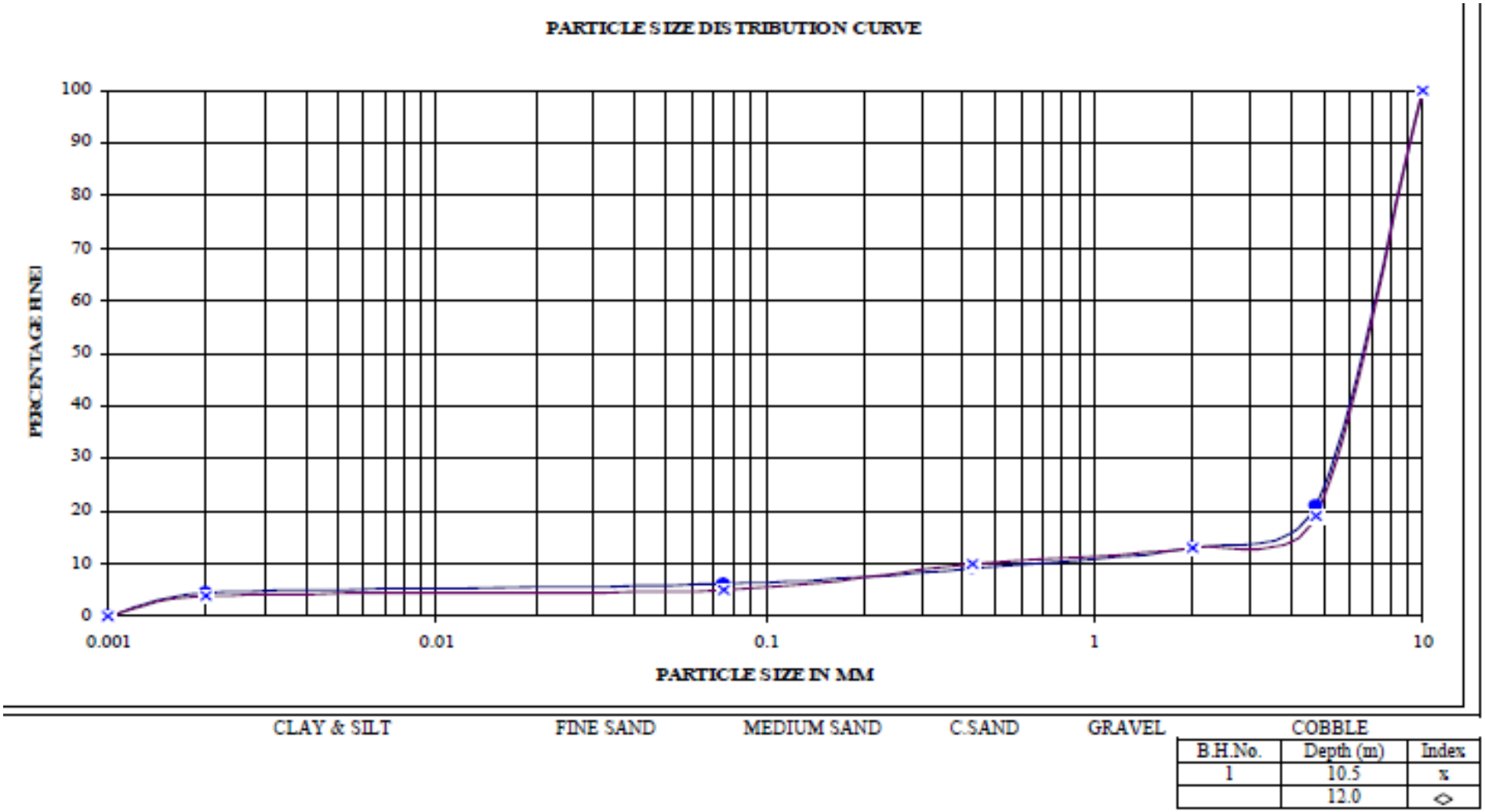
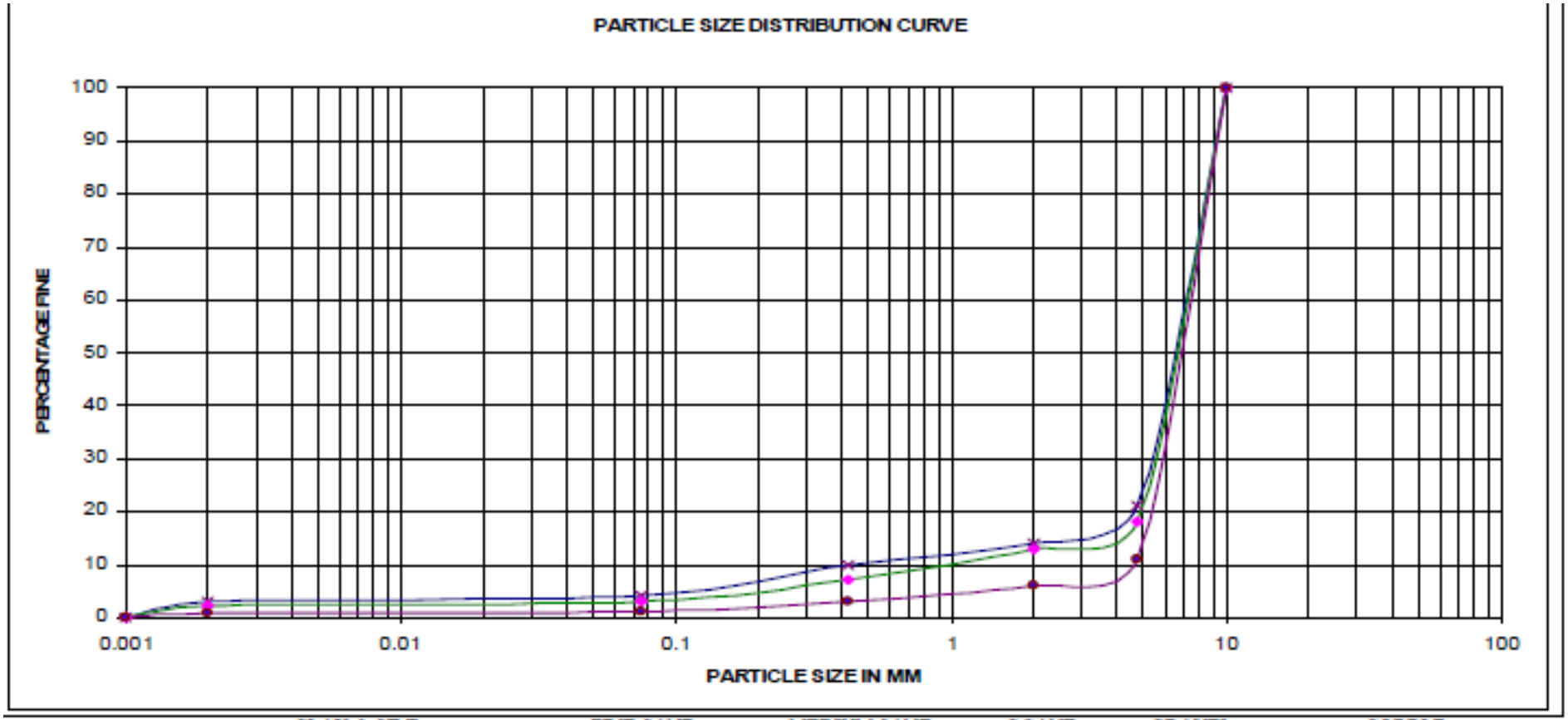
	7.5	◇
	9.0	⊗


PARTICLE SIZE DISTRIBUTION CURVE
PERCENTAGE FINER
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
PARTICLE SIZE IN MM
CLAY & SILT
FINE SAND
MEDIUM SAND
C.SAND
GRAVEL
COBBLE
B.H.No.
Depth (m)
Index
1
10.5
x
12.0
◇



B.H.No.	Depth (m)	Index
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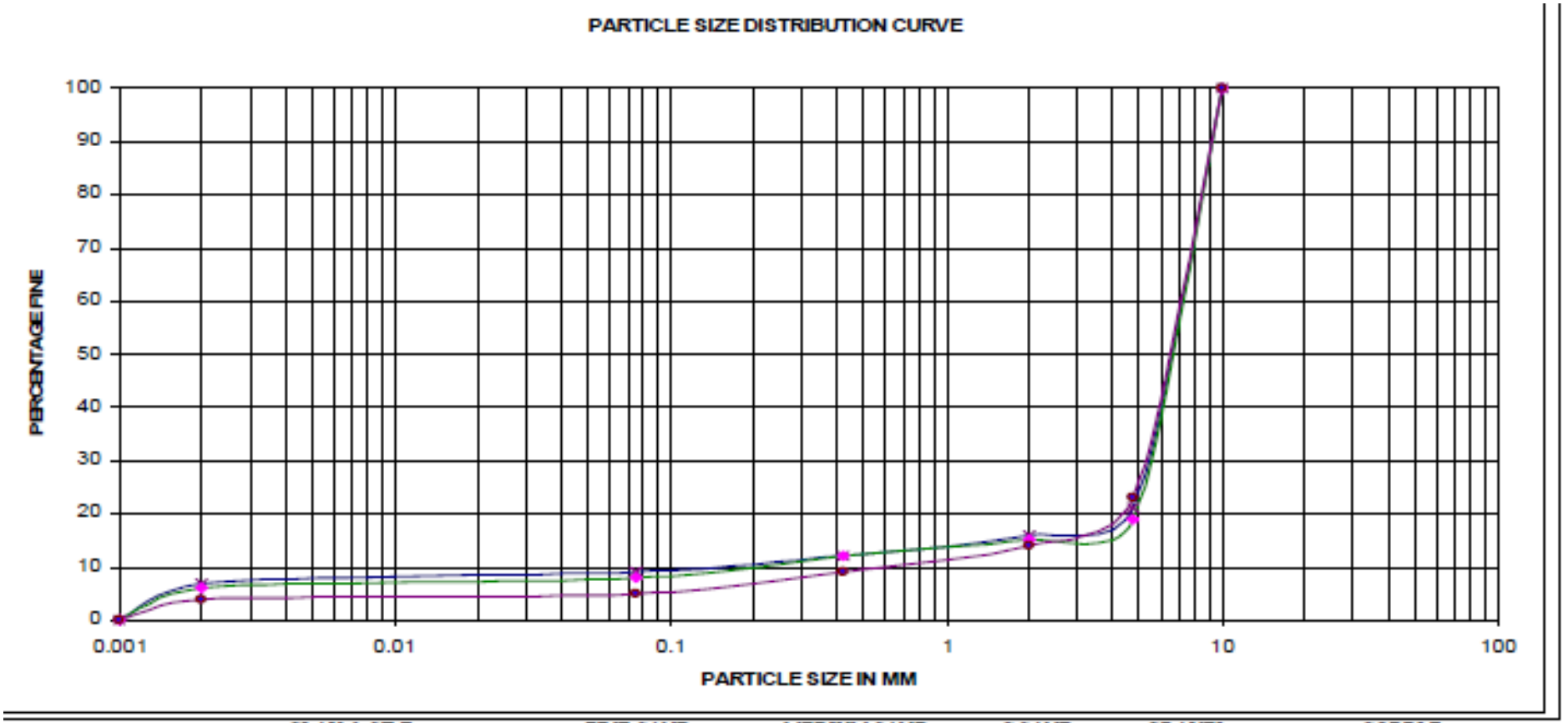
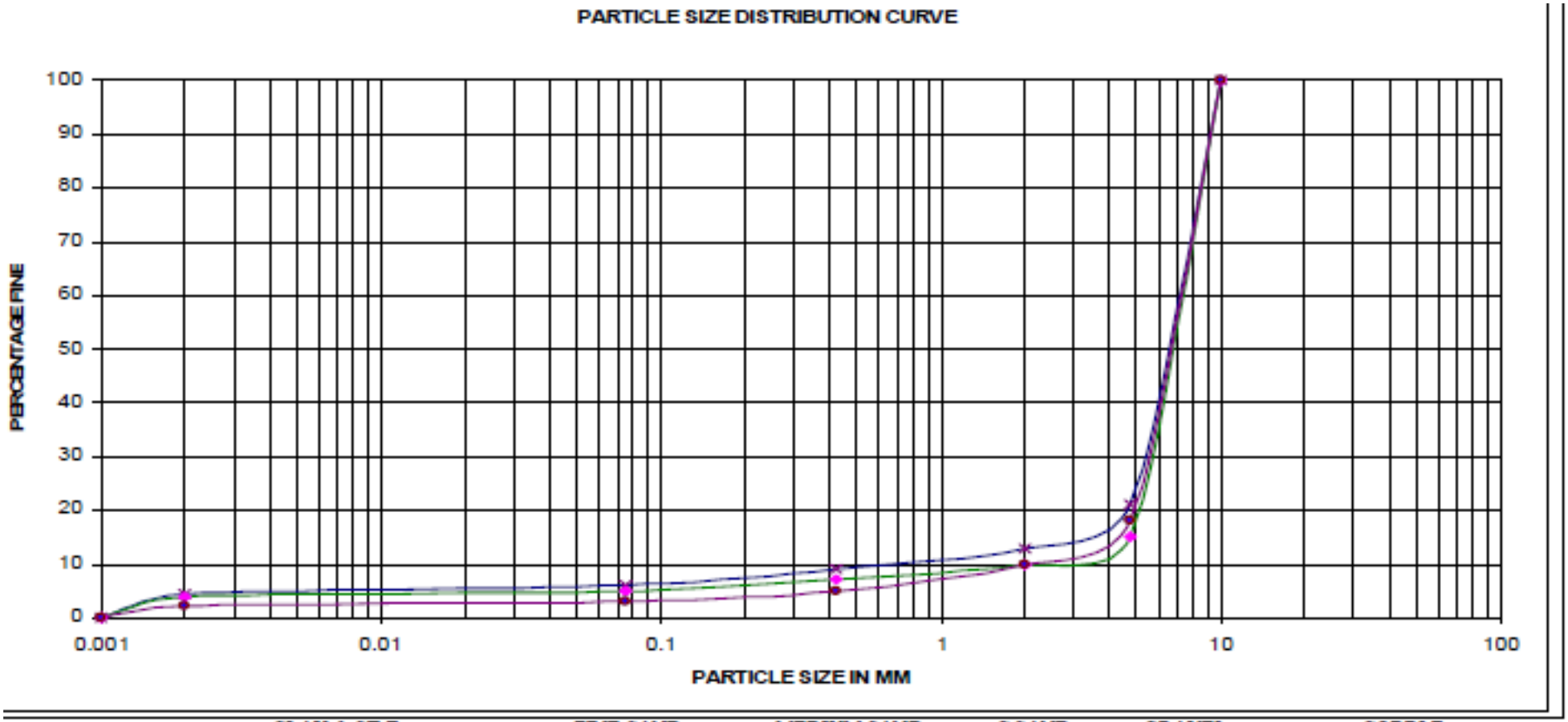
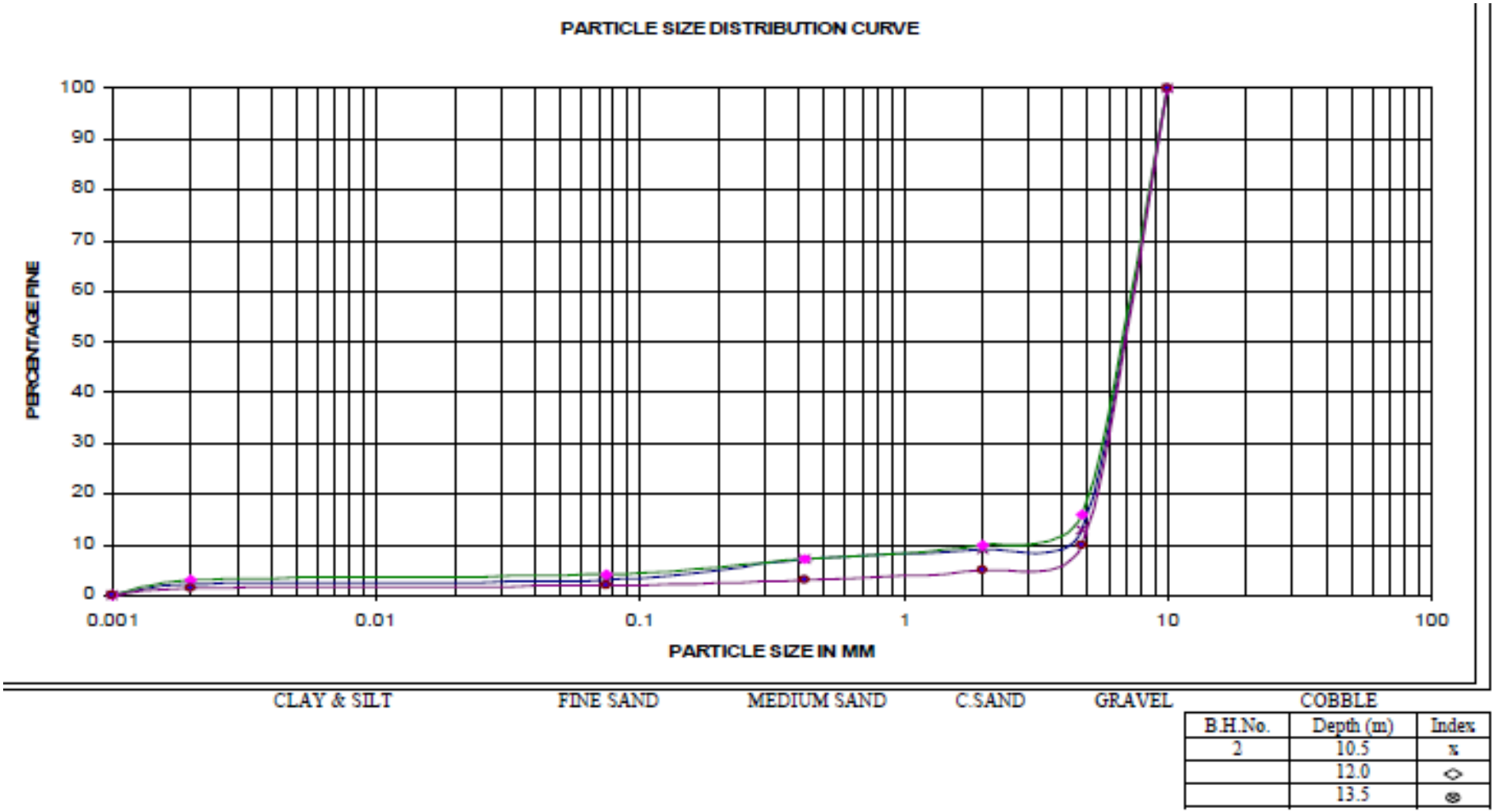
	15.0	◇
	16.5	⊗



B.H.No.	Depth (m)	Index
2	1.5	x
	3.0	◇
	4.5	⊗



B.H.No.	Depth (m)	Index
2	6.0	x
	7.5	◇
	9.0	⊗



B.H.No.	Depth (m)	Index
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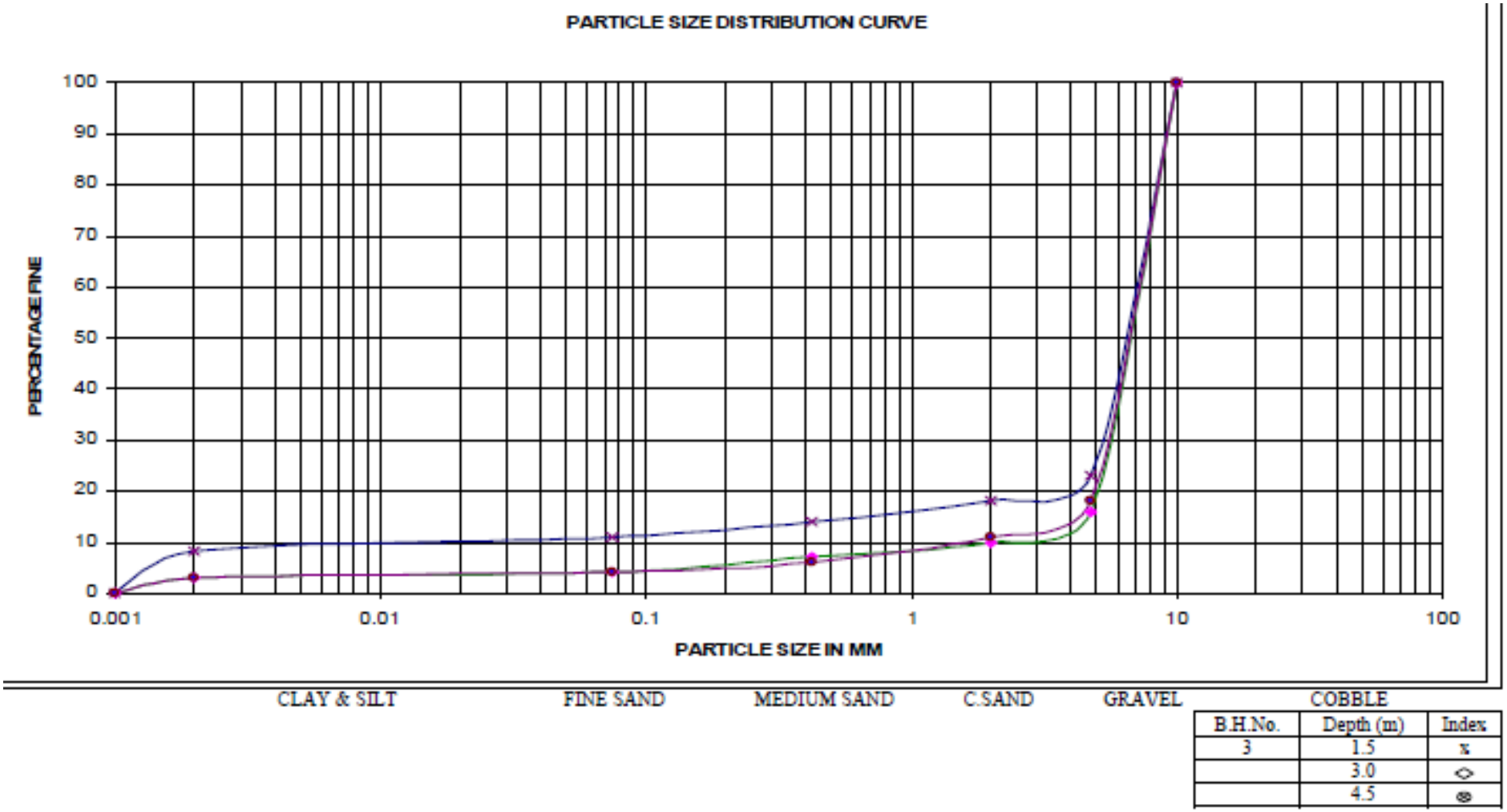
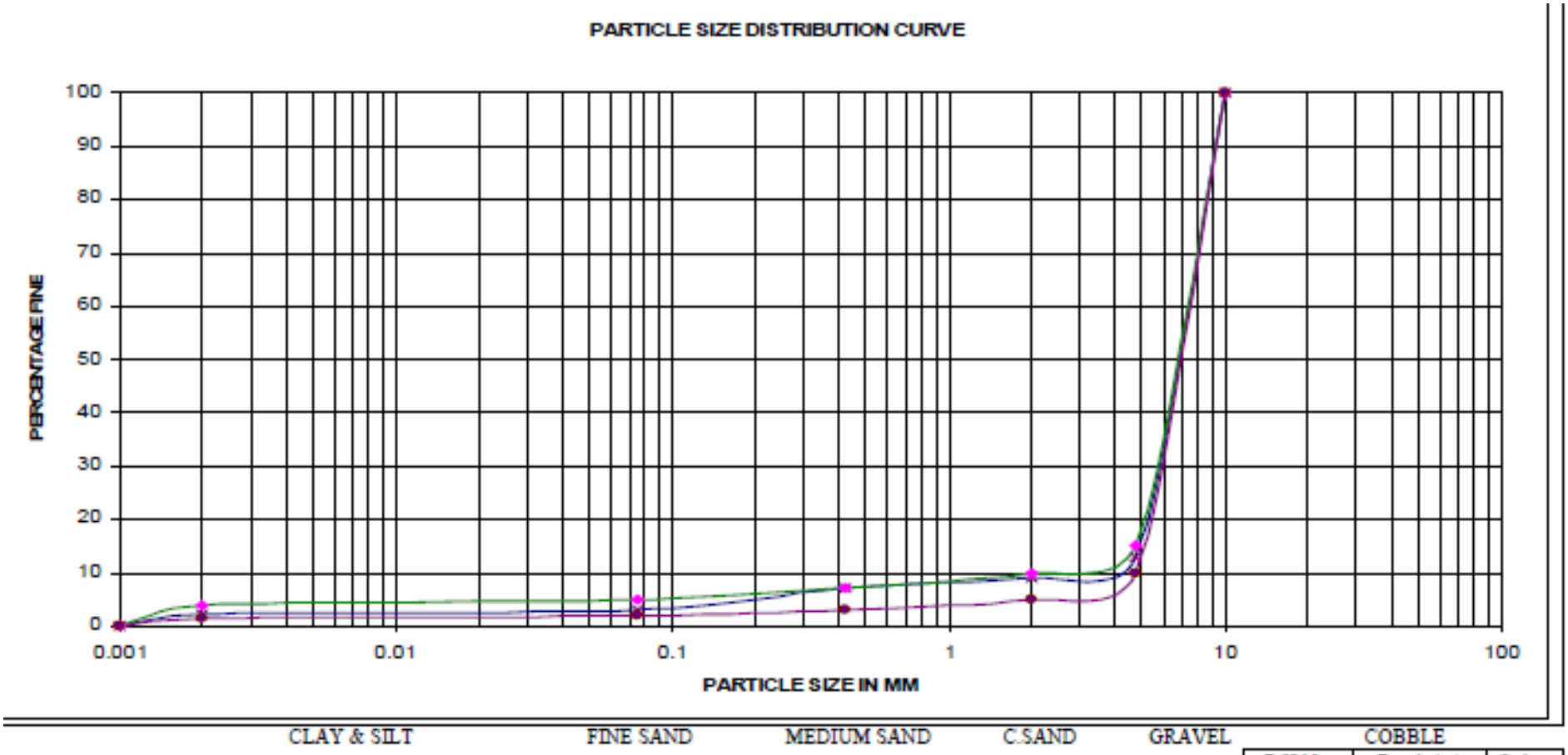
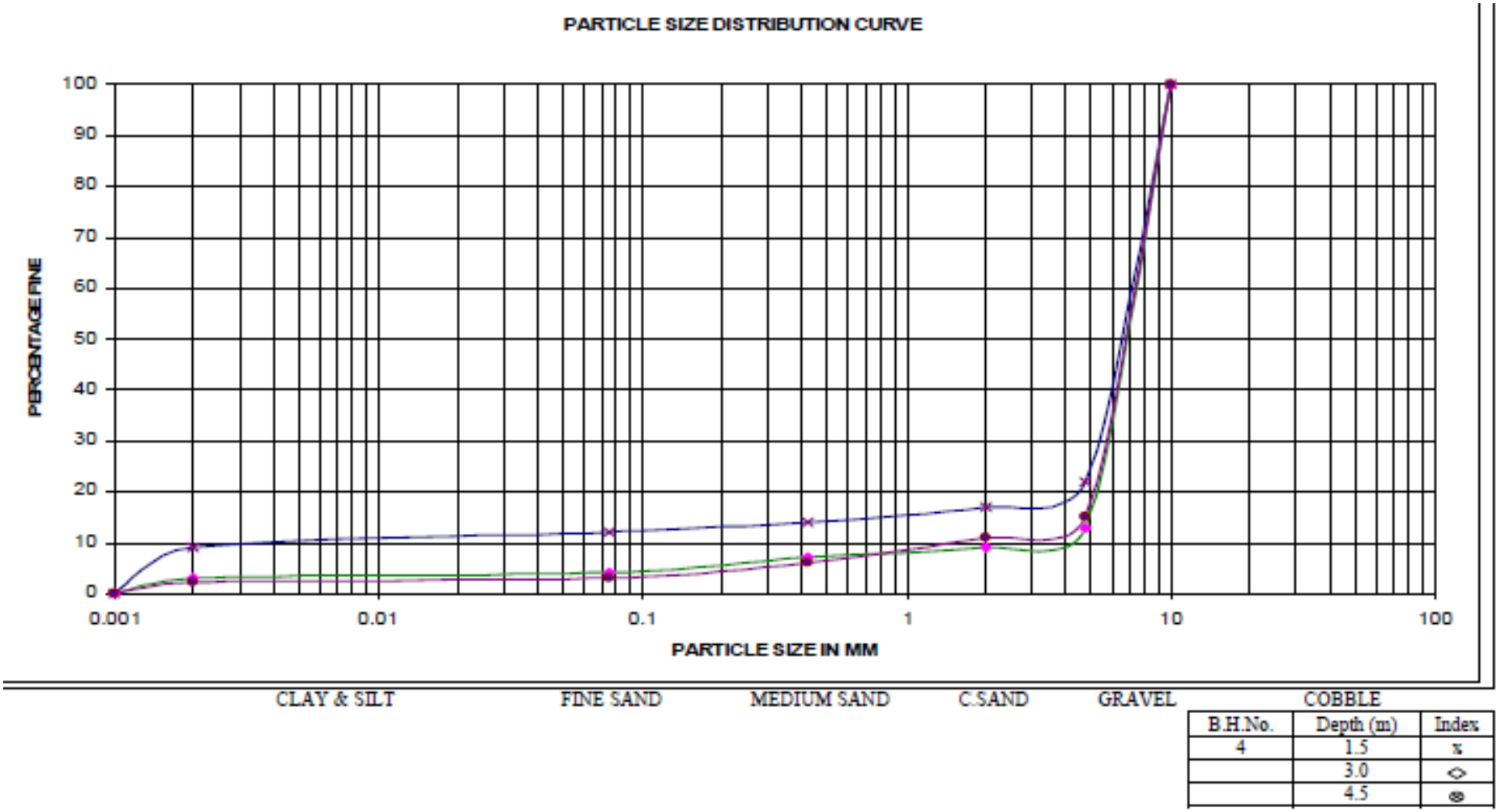
	12.0	◇
	13.5	⊗



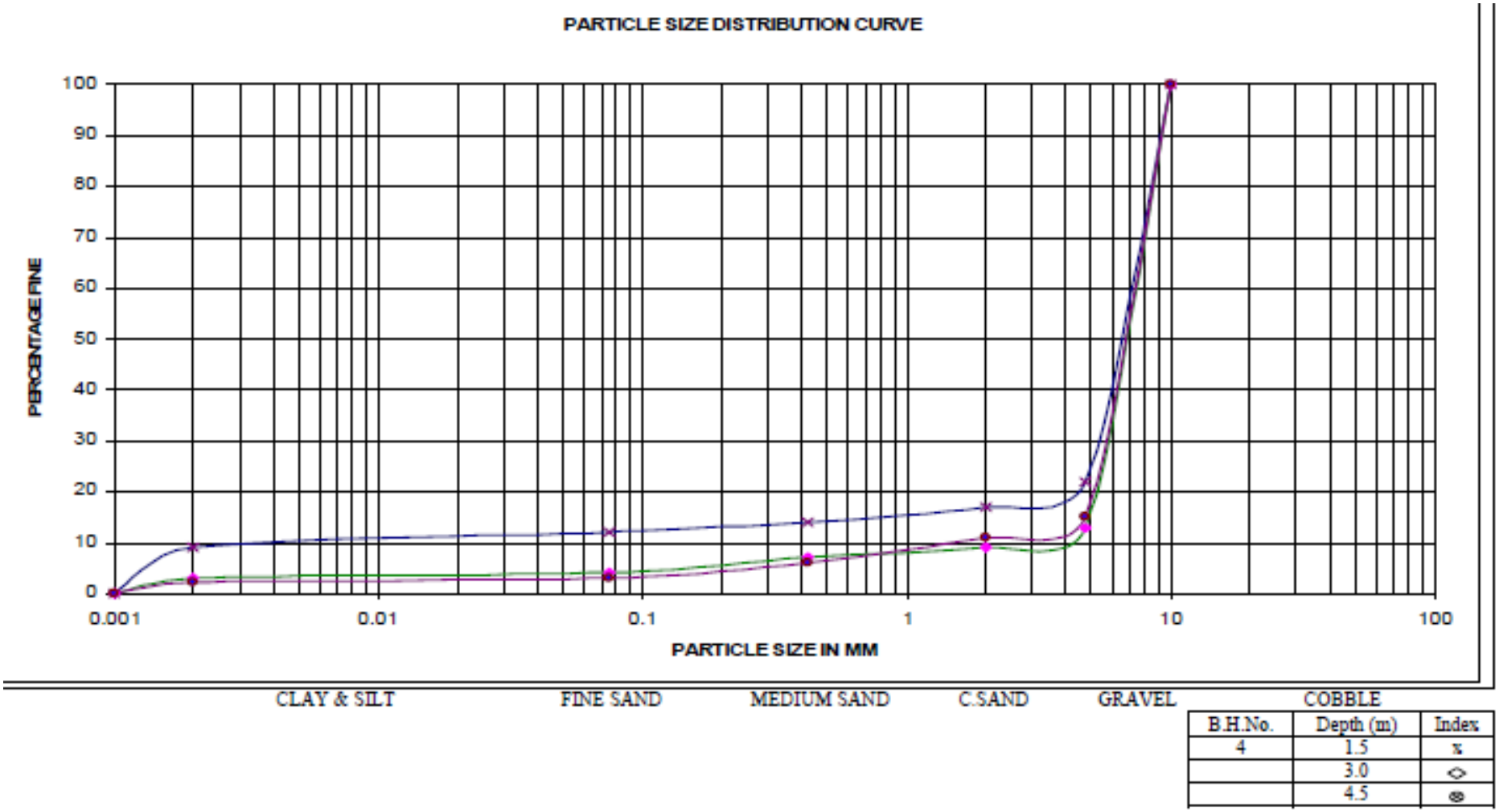
B.H.No.	Depth (m)	Index
3	1.5	x
	3.0	◇
	4.5	⊗



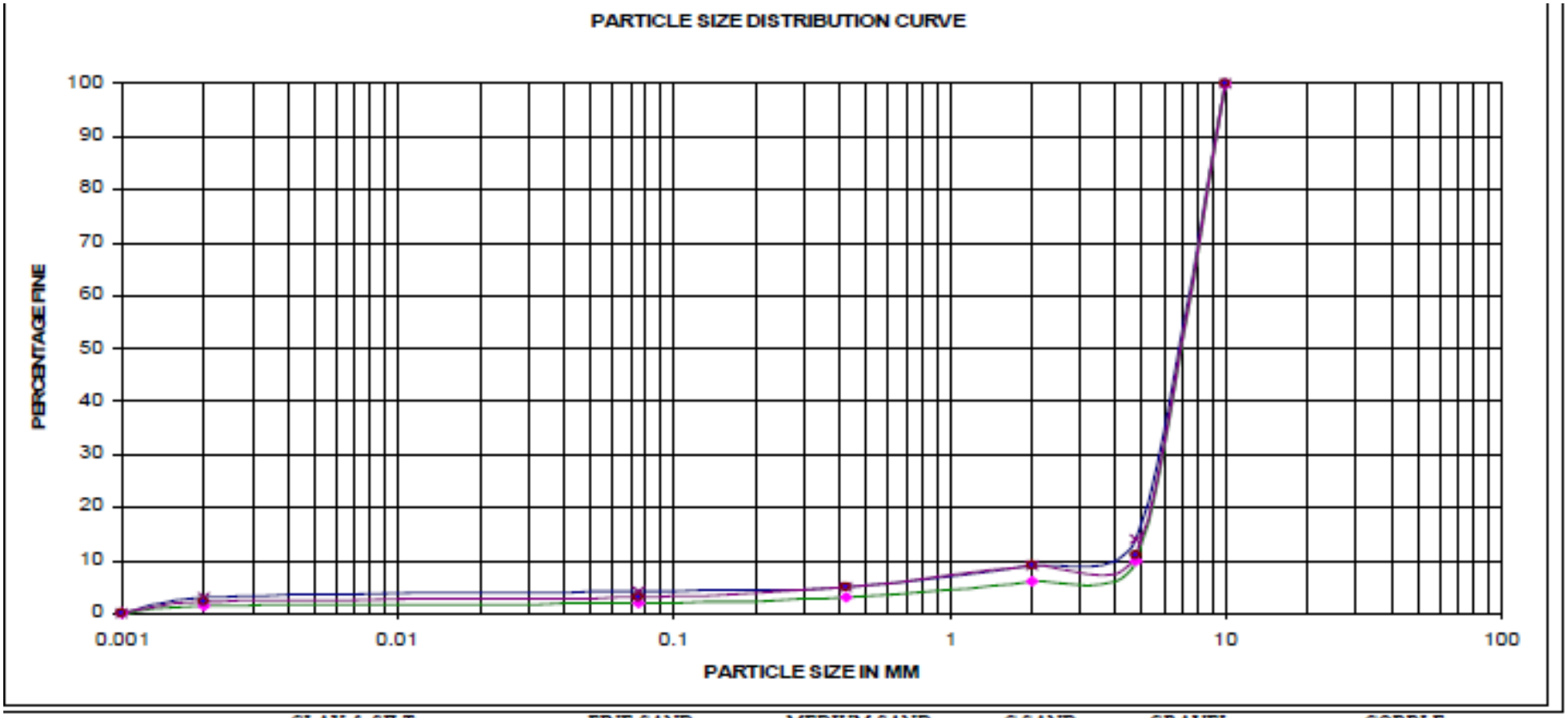
B.H.No.	Depth (m)	Index
3	6.0	x
	7.5	◇
	9.0	⊗



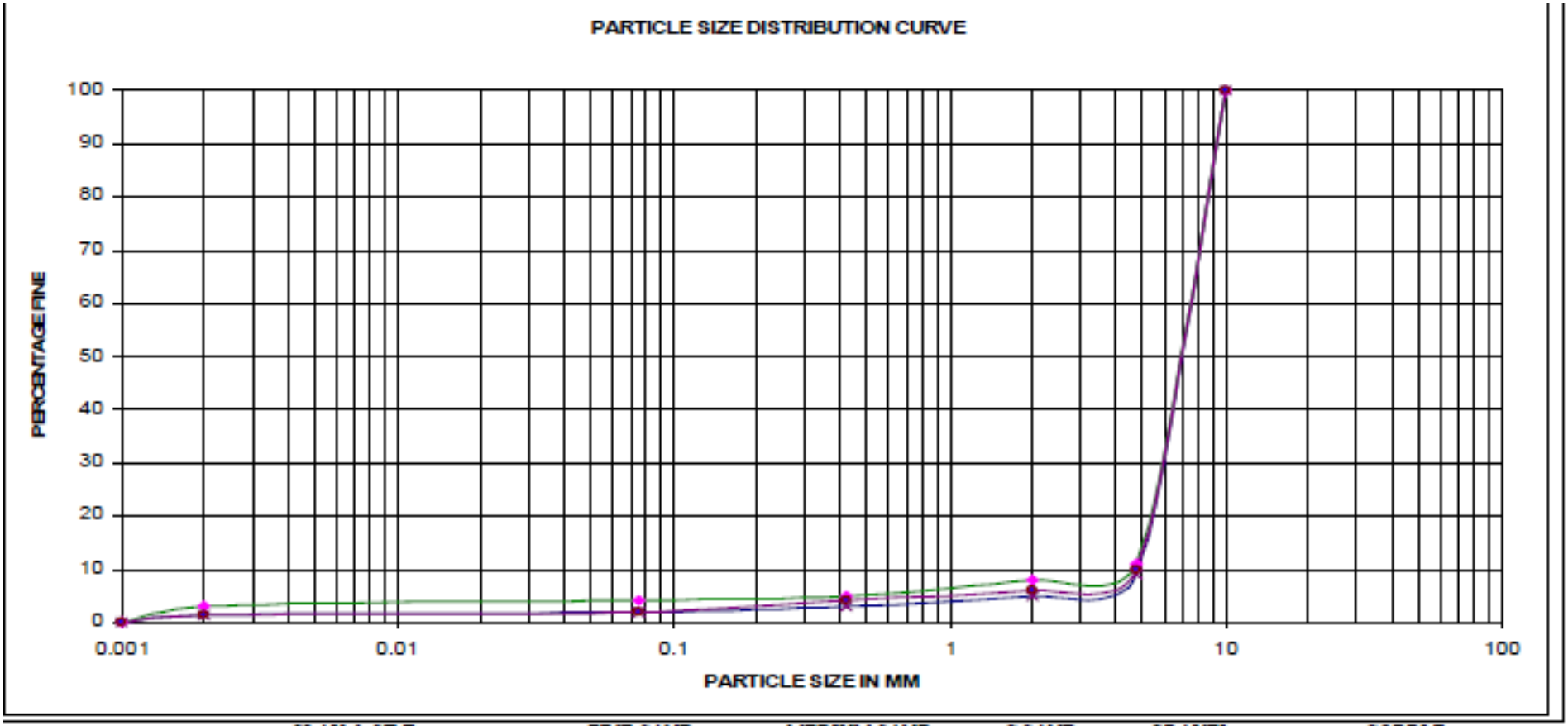
B.H.No.	Depth (m)	Index
4	1.5	x
	3.0	◇
	4.5	⊗



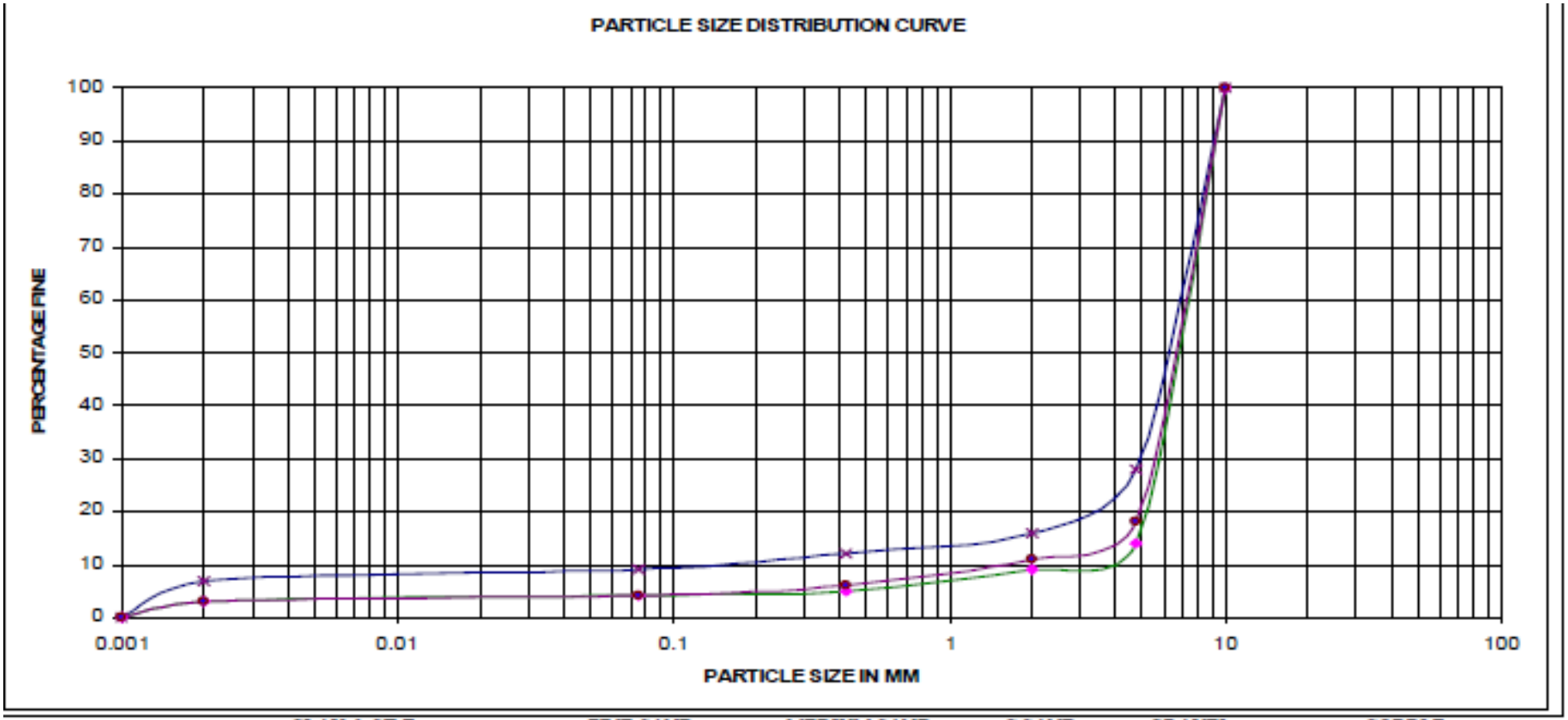
B.H.No.	Depth (m)	Index
4	1.5	x
	3.0	◇
	4.5	⊗



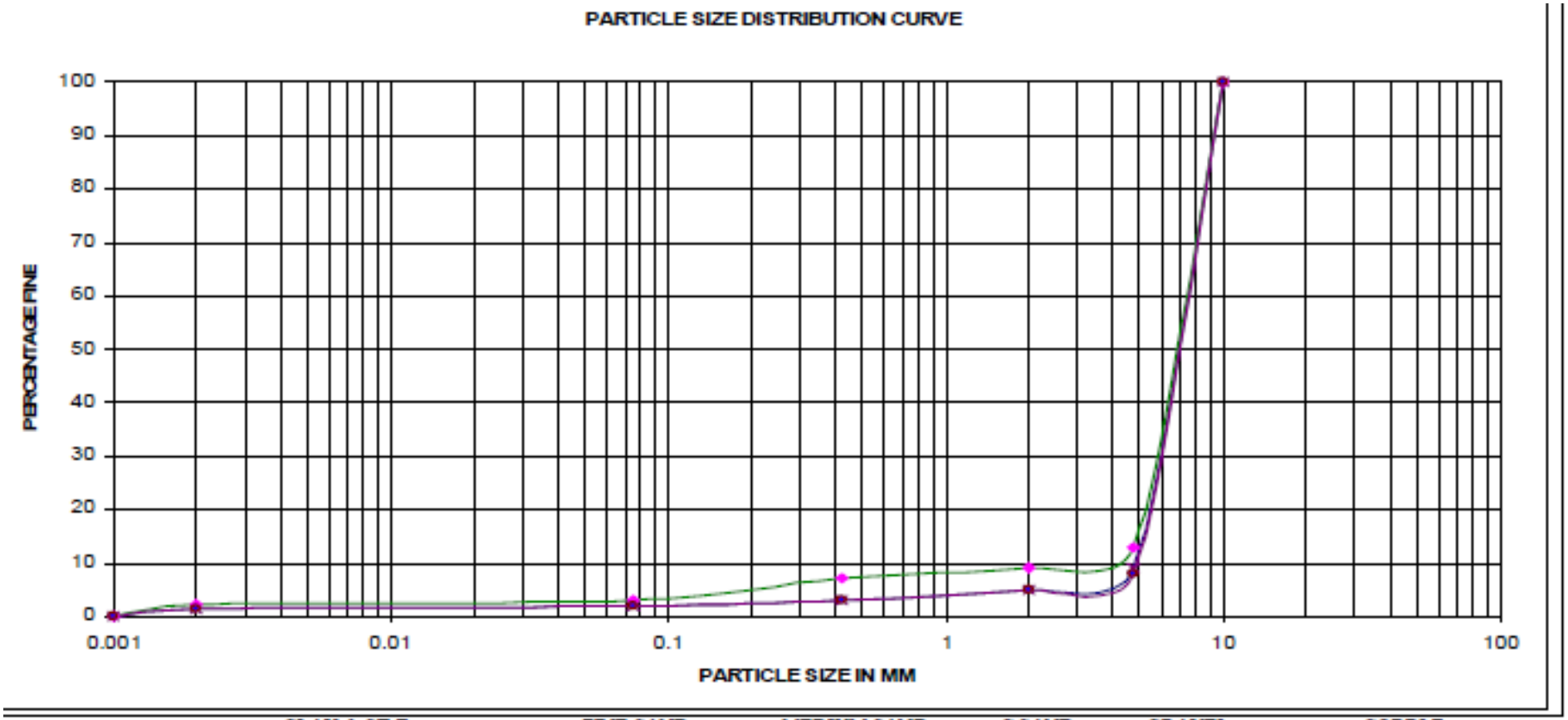
B.H.No.	Depth (m)	Index
4	6.0	x
	7.5	◇
	9.0	⊗



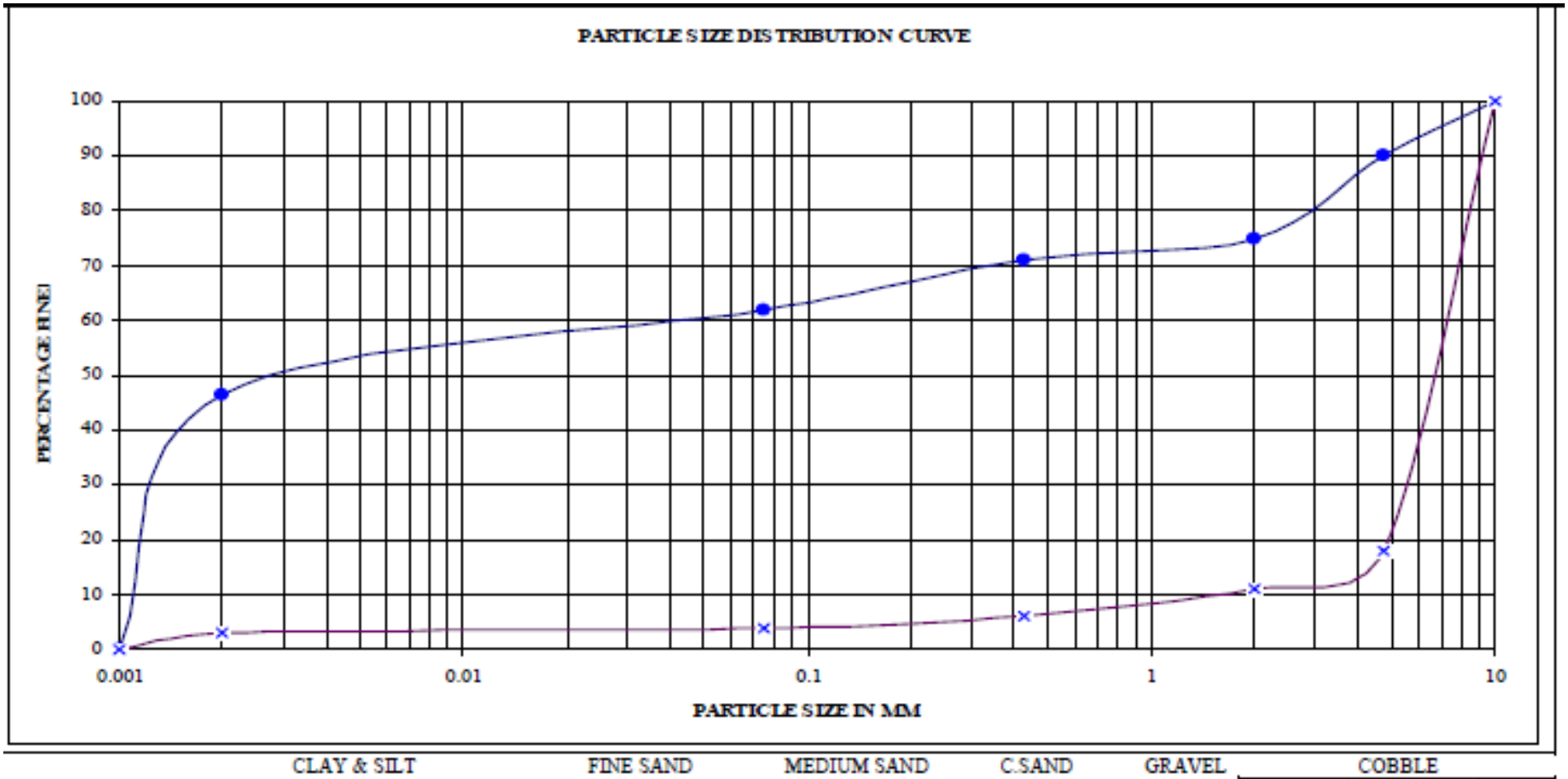
B.H.No.	Depth (m)	Index
4	10.5	x
	12.0	◇
	13.5	⊗



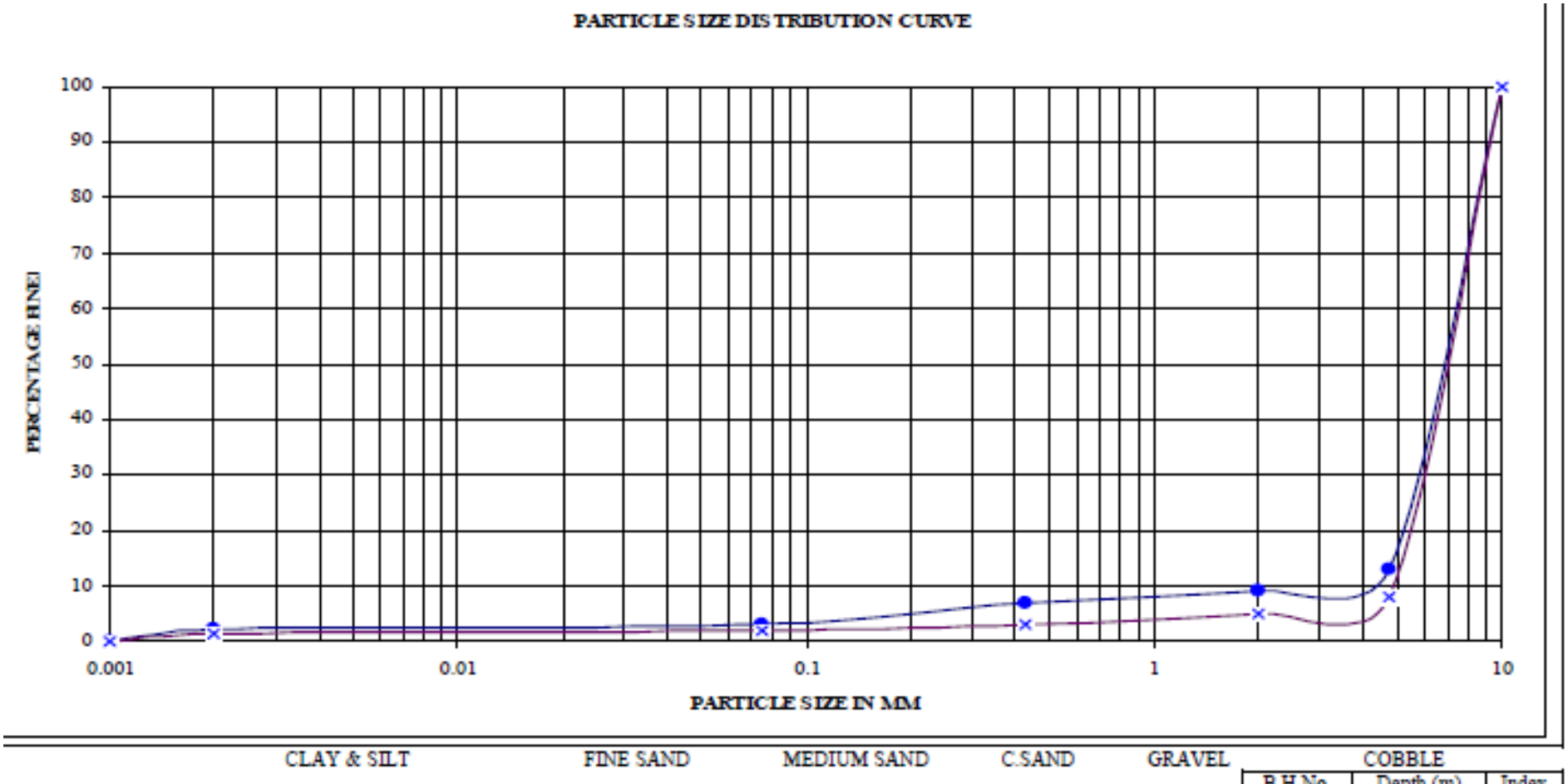
B.H.No.	Depth (m)	Index
5	1.5	x
	3.0	◇
	4.5	⊗



B.H.No.	Depth (m)	Index
5	6.0	x
	7.5	◇
	9.0	⊗



B.H.No.	Depth (m)	Index
6	3.0	x
	4.5	◇



B.H.No.	Depth (m)	Index
6	6.0	x
	7.5	◇

Annexure II:

Annexure 2 :Tests on Soil & Bentonite Mixing

SOIL ANALYSIS FOR THE PROJECT OF SOLID WASTE MANAGEMENT (CONSTRUCTION OF SANITARY LANDFILL SITE AT MAWIONG)

1. The sanitary landfill site of Mawiong area consist mainly of feldspathic quartzite. It is the Shillong Group of metamorphic rocks of Precambrian age. The rocks are highly jointed. The mineral content of the rocks are mostly quartz, feldsper and very less amount of mica. The rocks are also partially weathered. The rocks are permeable in nature due to the presence of joints, fractures and weathering effect. During rainy season water may percolate from the SWM site through joints and fractures and may pollute the soil, nearby streams, lakes and ground water of this area. The soil cover of the area is very thin and silty clay in nature. But in nearby areas of the SWM site thick beds of lateritic clayey soil is available at a distance of 3 km towards Barapani.

2. To make the SWM site into an impervious one we have to add 10 % of Bentonite alongwith the silty clay to laminate the area. For this purpose the following three soil samples had been collected from three different locations of Shillong area for Laboratory analysis.

1. Lateritic soil sample from Mawiong which is only 3.5 km away from SWM site.
2. Soil sample from SWM site of Mawiong.
3. Soil sample from Smit area which is about 25 km away from the SWM site.

3. The following laboratory tests were conducted on the above mentioned samples.

They are –

1) Gradation test,
2) Liquid limit and Plastic limit,
3) Standard proctor test
4) Permeability test

4. The summary of the results of laboratory analysis are given below:

Summary of results

Sample No	Test No	Name of test	Result
1	i	Proctor test	
	a	Virgin soil	MDD= 1.69gm/cc OMC = 21%
	b	with 10% Bentonite by weight	MDD= 1.70gm/cc OMC = 23.4%
	ii	Gradation	% silt and clay (Passing .075mm sieve) =80%
	iii	Plasticity	LL=58% PL=35% PI= 23%
	iv	Permeability (Coeff of Permeability) K=	
	a	Virgin soil	K=9.20x10^{-8} cm/sec
	b	with 10% Bentonite by weight	K=2.85x10^{-8} cm/sec

Annexure-7 Draft Final DPR-Solid Waste Management Plan for Greater Shillong Planning Area 1

2	i	Proctor test	
	a	Virgin soil	MDD= 1.66gm/cc OMC =13.5%
	b	with 10% Bentonite by weight	MDD= 1.67gm/cc OMC = 15.8%
	ii	Gradation	% silt and clay (Passing .075mm sieve) =18%
	iii	Plasticity	LL=Non Plastic PL=Non Plastic
	iv	Permeability (Coeff of Permeability) K=	
	a	Virgin soil	K=1.80x10^{-4} cm/sec
	b	with 10% Bentonite by weight	K=2.07x10^{-5} cm/sec
3	i	Proctor test	
	a	Virgin soil	MDD= 1.66gm/cc OMC = 16%
	b	with 10% Bentonite by weight	MDD= 1.70gm/cc OMC =17%
	ii	Gradation	% silt and clay (Passing .075mm sieve) =35%
	iii	Plasticity	LL=Non Plastic PL=Non Plastic
	iv	Permeability (Coeff of Permeability) K=	
	a	Virgin soil	K=1.30x10^{-5} cm/sec
	b	with 10% Bentonite by weight	K=9.41x10^{-8} cm/sec

5. From the study of the laboratory analysis of the above mentioned samples it appears that the sample No.1 which is collected from Mawiong area (3.5 km away) site is suitable for laminating the SWM site. The lateritic silty clay soil after amended with 10 % Bentonite the coefficient of permeability result is K = 2.85 x 10 $^{-8}$ cm/Sec. which will be suitable for SWM site as an impervious layer.

6. The basic requirement of the compacted clay liner is that it should have permeability below prespecified limit (10 $^{-7}$ cm/sec.) and that this should be maintained during the design life of landfill. For this purpose sample No.1 is recommended which is available nearby areas with admix of 10 % Bentonite.

The detailed results of laboratory analysis are given as under:-

Sample1 Reddish silty clay (virgin soil)

Name of test : 1. Determination of MDD & OMC (Standard Proctor test)

Proctor test result (IS:2720-VII)

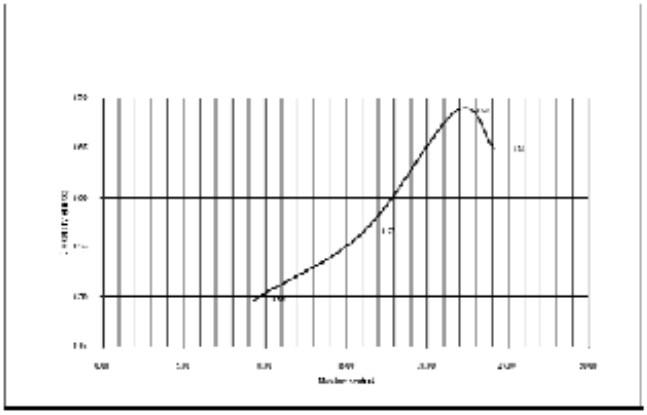
1 Size of mould = 10 cm dia x 12.73 cm height
2 Capacity of mould = 1000 cc
3 Rammer = 2.6 Kg x 310mm
4 No of layer = 3
5 Blows per layer = 25

(a) *Density determination*

		Test No	1	2	3	4
1	Mass of mould + soil	(gm)	3630	3810	4050	4040
2	Mass of empty mould	(gm)	1993	1993	1993	1993
3	Mass of compacted soil	(gm)	1637	1817	2057	2047
4	Bulk density	(gm/cc)	1.64	1.82	2.06	2.05
5	Dry density	(gm/cc)	1.50	1.57	1.69	1.65

(b) *Moisture content determination*

1	Container No		A2	A7	N1	N6
2	Mass of cont + wet soil	gm	48.87	51.64	56.62	60.45
3	Mass of cont + dry soil	gm	45.92	46.2	48.44	51.23
4	Mass of water present	gm	2.95	5.44	8.18	9.22
5	Mass of emptycontainer	gm	14.19	12.36	11.04	13.07
6	Mass of dry soil	gm	31.73	33.84	37.4	38.16
7	Moisture content	%	9.30	16.08	21.87	24.16



Maximum dry density (MDD) = 1.69gm/cc
Optimum moisture content (OMC) =21.0 %

2 Gradation test
Silt and Clay = 80%
3 Liquid limit = 58%
Plastic limit = 35%

Sample1 **Reddish silty clay (with 10% Bentonite by weight)**

Name of test : 1. Determination of MDD & OMC (Standard Proctor test)

Proctor test result (IS:2720-VII)

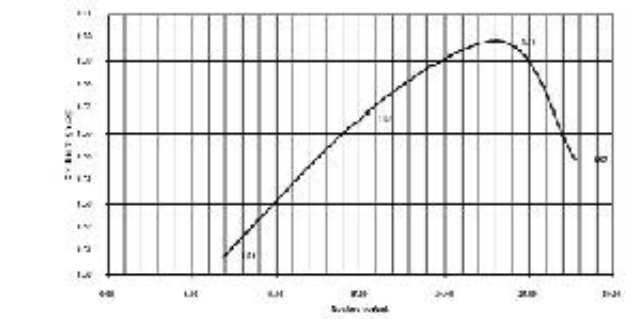
1	Size of mould	=	10 cm dia x 12.73 cm height
2	Capacity of mould	=	1000cc
3	Rammer	=	2.6 Kg x 310mm
4	No of layer	=	3
5	Blows per layer	=	25

(a) *Density determination*

		Test No	1	2	3	4
1	Mass of mould + soil	(gm)	3710	3910	4090	4100
2	Mass of empty mould	(gm)	1993	1993	1993	1993
3	Mass of compacted soil	(gm)	1717	1917	2097	2107
4	Bulk density	(gm/cc)	1.72	1.92	2.10	2.11
5	Dry density	(gm/cc)	1.61	1.67	1.70	1.65

(b)*Moisture content determination*

1	Container No		N5	N6	N1	N6
2	Mass of cont + wet soil	gm	41.35	42.6	50.12	53.89
3	Mass of cont + dry soil	gm	39.54	38.61	43.1	45.3
4	Mass of water present	gm	1.81	3.99	7.02	8.59
5	Mass of emptycontainer	gm	12.97	12.1	13.2	14.36
6	Mass of dry soil	gm	26.57	26.51	29.9	30.94
7	Moisture content	%	6.81	15.05	23.48	27.76



Maximum dry density (MDD) = 1.70gm/cc

Optimum moisture content (OMC) =23.4 %

Annexure-7 Draft Final DPR-Solid Waste Management Plan for Greater Shillong Planning Area **4**

4 Name of test : Falling head Permeability test

Sample1. **(Virgin soil)**			
Length of soil sample L= .		12.73	cm
Diameter of soil sample =		10	cm
Area of soil sample,A =		78.5	sqcm
Area of stand pipe, a =		0.44	sqcm
Initial head h1 =		100	cm
Final head h2 =		85	cm
Time =	35 hrs	126000	sec
Coefficient of permeability , K=(2.303aL/At) log h1/h2			
K=	9.20×10^{-8}	**cm/sec**	

Sample1. (**with 10% Bentonite by weight**)			
Length of soil sample L= .		12.73	cm
Diameter of soil sample =		10	cm
Area of soil sample,A =		78.5	sqcm
Area of stand pipe, a =		0.44	sqcm
Initial head h1 =		90	cm
Final head h2 =		84	cm
Time =	48 hrs	172800	sec
Coefficient of permeability , K=(2.303aL/At) log h1/h2			
K=	2.85×10^{-8}	**cm/sec**	

Sample2 (virgin soil)

Name of test : **1. Determination of MDD & OMC (Standard Proctor)**

Proctor test result (IS:2720-VII)

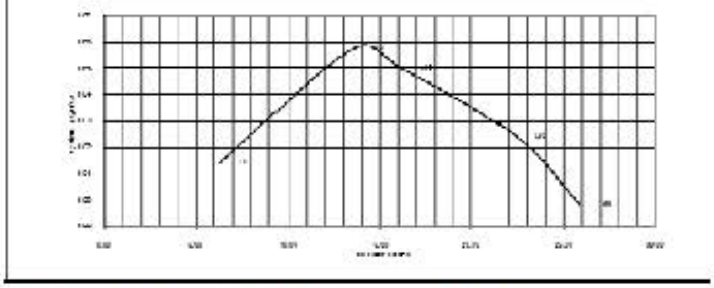
1 Size of mould = 10 cm dia x 12.73 cm height
2 Capacity of mould = 1000cc
3 Rammer= 2.6 Kg x 310mm
4 No of layer = 3
5 Blows per layer 25

(a) *Density determination*

		Test No	1	2	3	4	5
1	Mass of mould + soil		3710	3874	3910	3980	4005
2	Mass of empty mould	(gm)	1993	1993	1993	1993	1993
3	Mass of compacted soil	(gm)	1717	1881	1917	1987	2012
4	Bulk density	(gm/cc)	1.72	1.88	1.92	1.99	2.01
5	Dry density	(gm/cc)	1.61	1.66	1.65	1.62	1.60

(b) *Moisture content determination*

1	Container No		5	4	8	9	10
2	Mass of cont + wet soil	gm	64.17	56.2	64.43	61.56	75.03
3	Mass of cont + dry soil	gm	61.25	51.15	57.36	52.23	62.84
4	Mass of water present	gm	2.92	5.05	7.07	9.33	12.19
5	Mass of emptycontainer	gm	15.29	13.73	13.63	10.43	15.75
6	Mass of dry soil	gm	45.96	37.42	43.73	41.8	47.09
7	Moisture content	%	6.35	13.50	16.17	22.32	25.89



Maximum dry density (MDD) = 1.66 gm/cc
Optimum moisture content (OMC) =13.50%

2 Gradation
Silt and clay =18%
3 Liquid limit = Non Plastic
Plastic limit = Non Plastic

Name of test : **Sample2 (with 10% Bentonite by weight)**

1. Determination of MDD & OMC (Standard Proctor)

Proctor test result (IS:2720-VII)

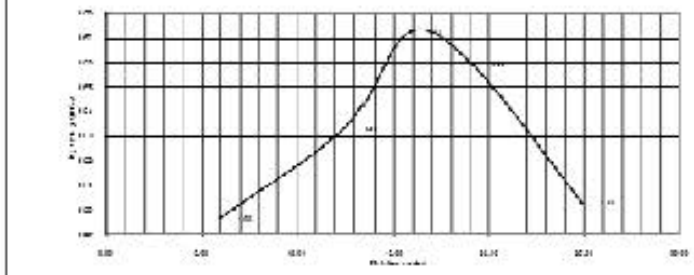
1 Size of mould = 10 cm dia x 12.73 cm height
2 Capacity of mould = 1000cc
3 Rammer= 2.6 Kg x 310mm
4 No of layer= 3
5 Blows per layer= 25

(a) *Density determination*

		Test No	1	2	3	4	5
1	Mass of mould + soil		3684	3830	3930	3970	3995
2	Mass of empty mould	(gm)	1993	1993	1993	1993	1993
3	Mass of compacted soil	(gm)	1691	1837	1937	1977	2002
4	Bulk density	(gm/cc)	1.69	1.84	1.94	1.98	2.00
5	Dry density	(gm/cc)	1.60	1.63	1.67	1.66	1.60

(b) *Moisture content determination*

1	Container No		B2	B7	B3	B11	B13
2	Mass of cont + wet soil	gm	54.23	43.02	51.88	45.19	37.3
3	Mass of cont + dry soil	gm	51.98	39.65	47.1	40.36	32.54
4	Mass of water present	gm	2.25	3.37	4.78	4.83	4.76
5	Mass of emptycontainer	gm	14.06	12.63	16.89	15.19	13.43
6	Mass of dry soil	gm	37.92	27.02	30.21	25.17	19.11
7	Moisture content	%	5.93	12.47	15.82	19.19	24.91



Maximum dry density (MDD) = 1.67 gm/cc
Optimum moisture content (OMC)=15.80%

2 Gradation
Silt and clay =18%
3 Liquid limit = Non Plastic
Plastic limit = Non Plastic

4 Name of test : Falling head Permeability test

Sample2. **(Virgin soil)**			
Length of soil sample L= .		12.73	cm
Diameter of soil sample =		10	cm
Area of soil sample,A =		78.5	sqcm
Area of stand pipe, a =		0.44	sqcm
Initial head h1 =		100	cm
Final head h2 =		10	cm
Time =	0.25 hrs= 15 min	900	sec
Coefficient of permeability , K=(2.303aL/At) log h1/h2			
K=	$1.8x10^{-4}$	cm/sec	

Sample2. (**with 10% Bentonite by weight**)			
Length of soil sample L= .		12.73	cm
Diameter of soil sample =		10	cm
Area of soil sample,A =		78.5	sqcm
Area of stand pipe, a =		0.44	sqcm
Initial head h1 =		85	cm
Final head h2 =		69	cm
Time =	2 hrs	7200	sec
Coefficient of permeability , K=(2.303aL/At) log h1/h2			
K=	$2.07x10^{-6}$	cm/sec	

Sample3 (virgin soil)

Name of test : 1 Determination of MDD & OMC (Standard Proctor)

Proctor test result (IS:2720-VII)

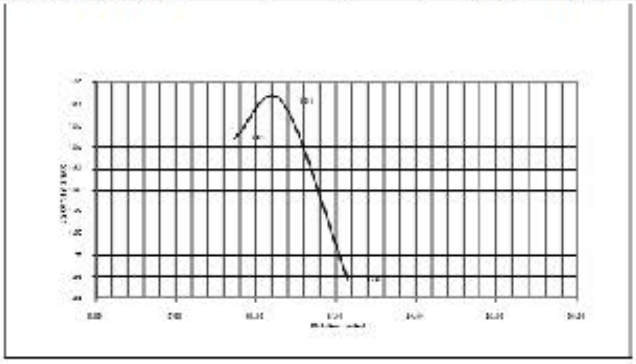
1	Size of mould =	10 cm dia x 12.73 cm height
2	Capacity of mould=	1000 cc
3	Rammer=	2.6 Kg x 310mm
4	No of layer=	3
5	Blows per layer=	25

(a) *Density determination*

		Test No	1	2	3
1	Mass of mould + soil	(gm)	3757	3825	3798
2	Mass of empty mould	(gm)	1993	1993	1993
3	Mass of compacted soil	(gm)	1764	1832	1805
4	Bulk density	(gm/cc)	1.76	1.83	1.81
5	Dry density	(gm/cc)	1.62	1.64	1.56

(b)*Moisture content determination*

1	Container No		4	2	8
2	Mass of cont + wet soil	gm	66	73.71	67.44
3	Mass of cont + dry soil	gm	61.74	67.3	59.78
4	Mass of water present	gm	4.26	6.41	7.66
5	Mass of emptycontainer	gm	12.36	12.27	11.35
6	Mass of dry soil	gm	49.38	55.03	48.43
7	Moisture content	%	8.63	11.65	15.82



Maximum dry density (MDD) = 1.66 gm/cc

Optimum moisture content (OMC) =16.0 %

2 Gradation

Silt and clay = 35%

3 Liquid limit = Non Plastic

Plastic limit = Non Plastic

Sample3 : (with 10% Bentonite by weight)

Name of test : **1 Determination of MDD & OMC (Standard Proctor)**

Proctor test result (IS:2720-VII)

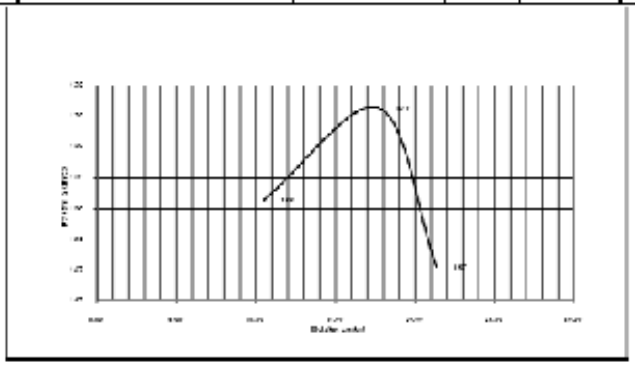
1	Size of mould =	10 cm dia x 12.73 cm height
2	Capacity of mould =	1000 cc
3	Rammer=	2.6 Kg x 310mm
4	No of layer=	3
5	Blows per layer=	25

(a) *Density determination*

		Test No	1	2	3
1	Mass of mould + soil	(gm)	3850	3990	4020
2	Mass of empty mould	(gm)	1993	1993	1993
3	Mass of compacted soil	(gm)	1857	1997	2027
4	Bulk density	(gm/cc)	1.86	2.00	2.03
5	Dry density	(gm/cc)	1.68	1.70	1.67

(b)*Moisture content determination*

1	Container No		C1	C5	C3
2	Mass of cont + wet soil	gm	35.3	40.39	37.85
3	Mass of cont + dry soil	gm	33.2	36.23	33.56
4	Mass of water present	gm	2.1	4.16	4.29
5	Mass of emptycontainer	gm	13.1	12.76	13.46
6	Mass of dry soil	gm	20.1	23.47	20.1
7	Moisture content	%	10.45	17.72	21.34



Maximum dry density (MDD) = 1.70 gm/cc
Optimum moisture content (OMC) =17.0 %

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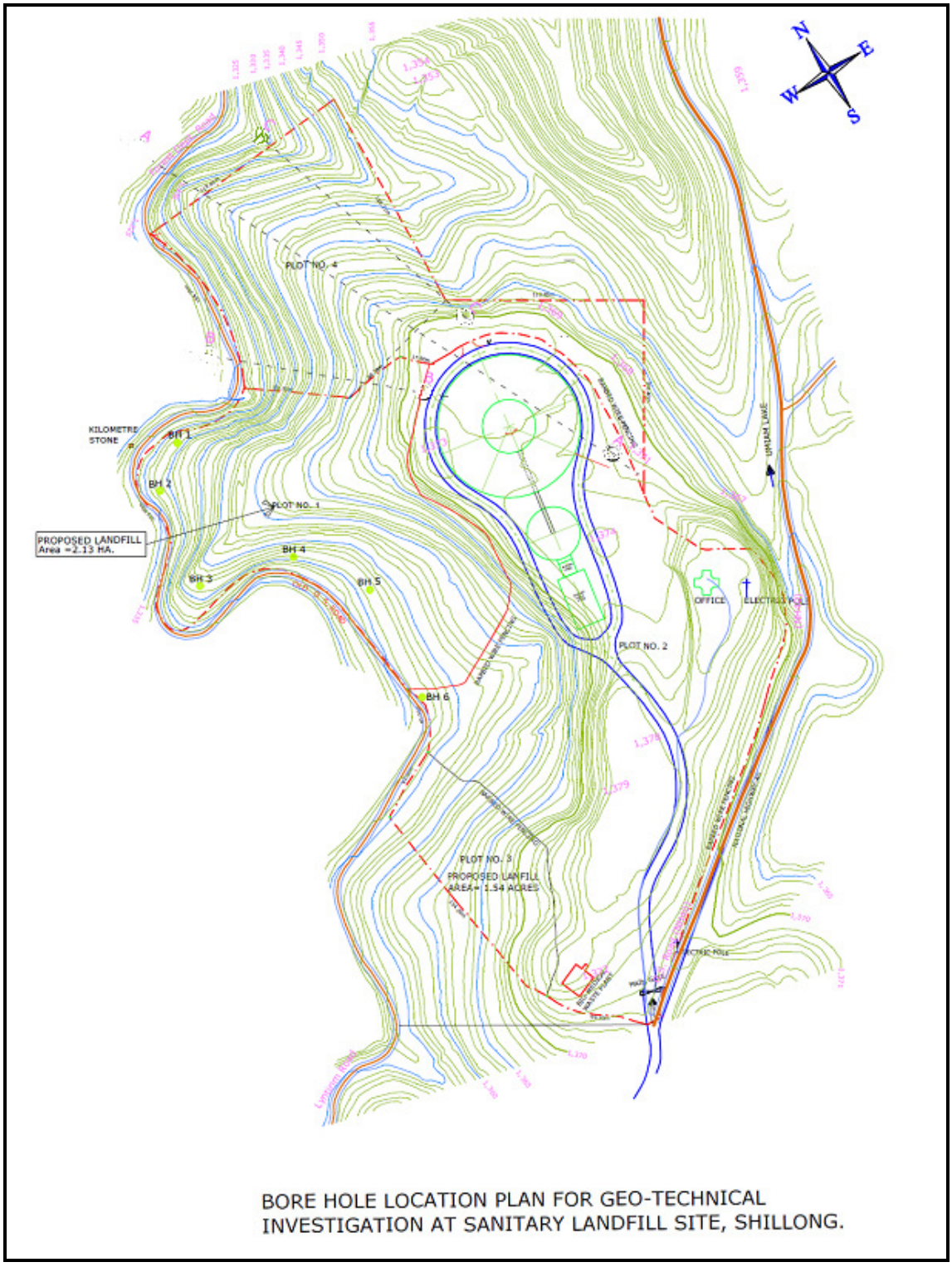
4. Name of test : Falling head Permeability test

Sample3. **(Virgin soil)**			
Length of soil sample L= .	12.73		cm
Diameter of soil sample =	10		cm
Area of soil sample,A =		78.5	sqcm
Area of stand pipe, a =		0.44	sqcm
Initial head h1 =		91	cm
Final head h2 =		47	cm
Time = 1 hrs		3600	sec
Coefficient of permeability , K=(2.303aL/At) log h1/h2			
K= 1.30×10^{-5} cm/sec			

Sample3. (**with 10% Bentonite by weight**)			
Length of soil sample L= .	12.73		cm
Diameter of soil sample =	10		cm
Area of soil sample,A =		78.5	sqcm
Area of stand pipe, a =		0.44	sqcm
Initial head h1 =		83	cm
Final head h2 =		68	cm
Time = 42 hrs		151200	sec
Coefficient of permeability , K=(2.303aL/At) log h1/h2			
K= 9.41×10^{-8} cm/sec			


N
E
W
S
PLOT NO. 4
KILOMETRE STONE
BH 1
BH 2
PLOT NO. 1
PROPOSED LANDFILL
Area =2.13 HA.
BH 4
BH 3
BH 5
BH 6
OFFICE
PLOT NO. 2
PLOT NO. 3
PROPOSED LANDFILL
AREA= 1.54 ACRES
BORE HOLE LOCATION PLAN FOR GEO-TECHNICAL
INVESTIGATION AT SANITARY LANDFILL SITE, SHILLONG.