

# Government of the People's Republic of Bangladesh

Ministry of Housing and Public Works **Urban Development Directorate (UDD)** 

# **Preparation of Development Plan for Fourteen Upazilas**

Package-04

(Saghata Upazila, District: Gaibandha; Sariakandi Upazila and Sonatala Upazila, District: Bogra)

# FINAL SURVEY REPORT

GEOLOGICAL SURVEY Of

Saghata Upazila, Gaibandha

June, 2017

**Mepc** Modern Engineers Planners & Consultants Ltd.

### Letter of Transmittal

Ref No.: MEPC/UDD/2017/62

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То

The Project Director

"Preparation of Development Plan for Fourteen Upazilas" Project

Urban Development Directorate (UDD)

82 Segun Bagicha, Dhaka-1000.

# Subject: Submission of the Final Survey Report on Geological of Saghata Upazila, Gaibandha.

Dear Sir,

I have the pleasure to submit herewith the Final Survey Report on Geological of Saghata Upazila, Gaibandha District under "**Preparation of Development Plan for Fourteen Upazilas Project**" Package No: 04 (Saghata Upazila, District- Gaibandha; Sonatala Upazila and Sariakandi Upazila, District- Bogra) for your kind information and further action.

Thanking you and assuring you of our best services.

**Best Regards** 

.....

.....

(Engr. A. Sobahan) Managing Director of MEPC (Shamim Mahabubul Haque) Team Leader, Package-4

### **Executive Summary**

An extensive geo-scientific investigation is one of the fundamental prerequisite for any sustainable infrastructural development initiative. In this context, a systematic study including geophysical, geotechnical as well as geological study has been done in the proposed project area. The study would be useful for planning, designing and future maintenance of the project area. Moreover, the current study would also be beneficial for the planners as well as the concerned authorities to take relevant decisions pertaining to disaster risk reduction and mitigation. This geological survey work has been carried out in the project area under the package-4 (covering Saghata Upazila of Gaibandha District) project titled 'Preparation of Development Plan for Fourteen Upazilas' a initiative of Urban Development Directorate (UDD).

Saghata, the smallest upazila of Gaibandha Zila. The upazila occupies a total area of 231.02 sq.km. It is located between 25<sup>0</sup>02' and 25<sup>0</sup>14' north latitudes and between 89<sup>0</sup>29' and 89<sup>0</sup>40' east longitudes. The upazila is bounded on the north by Gaibandha Sadar upazila, east by Fulchhari Upazila and Islampur Upazila of Jamalpur Zila, south by Saghata Upazila and Saghata Upazila of Bogra Zila and west by Gobindaganj Upazila and Palashbari Upazila.

To accomplish the project objective, a detail geotechnical and geophysical investigation have been carried out. As a part of geotechnical investigation a total of 19 boreholes were drilled to get a clear idea about physical and mechanical properties of the soil. A geophysical study was conducted by means of 3 nos down-hole seismic test (PS logging) and 5 nos. of Multi-channel Analysis of Surface Wave (MASW) Test to estimate the shear wave velocity Laboratory testing of soil samples such as Grain Size Analysis, Natural Moisture Content, Direct Shear Test, etc has been performing in the laboratory which will give more qualitative and quantitative information about the subsurface materials.

The upper soils of the study area are mostly alluvium Silt and alluvium Sand. Fine to Medium grained Sand has been found by increasing of depth. The SPT N value ranges of those Soils are varies from 5 to 50. From the Down hole seismic Test (PS Logging) the average shear wave velocity (AVS 30) up to 30 m are 152 to 164m/s. According to MASW test result, the velocities of the soil strata below 160 m/s upto depth 4.7m from existing ground level which indicate are the soil upto this depth soft or loose in nature. But the velocities of all the test locations are gradually improved with increasing of depth.

Results will be integrated in a module by which it is possible to produce sub-surface lithological 3D model of different layers, engineering geological mapping based on AVS30, Seismic Hazard Assessment Map (risk sensitive micro-zonation maps), soil type map, seismic intensity map, Peak Ground Acceleration (PGA) and recommended building height maps for both high rise building and low rise building, liquefaction and Ground Failure Map etc.

Above test result would give a clear idea about the geo-hazard status of particular landscape where newly urban developing activities or any other mega infrastructure project is going on and this mentioned investigation also gives idea about the vulnerability of existing build up infrastructure of a particular area. Based on these results, proper management techniques as well as other necessary adaptation process could be addressed before or after the development activities in the studied area. It is to be mentioned that the long-term maintenance cost will be reduced and the developed structure will withstand against the potential natural hazards if the infrastructures are built following the risk informed physical land-use plan.

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# List of Abbreviations/Acronyms

ASTM	: American So	ociety for Testing and Materials
AVS30	: Average She	ear Wave velocity of 30 meter depth
BH	: Borehole	
EGL	: Existing Gro	ound Level
GWL	: Ground Wat	er Level
MASW	: Multi-Chann	el Analysis of Surface Wave
MEPC	: Modern Eng	ineers Planers & Consultants Ltd.
nos	: numbers	
N value	: Soil resistant	ce or compactness
PGA	: Peak Ground	d Acceleration
PGV	: Peak Ground	d Velocity
PS logging	: Primary and	Shear wave logging (Down-hole seismic test)
SA	: Spectral Acc	celeration
SPAC	: Spatial Auto	correlation
SPT	: Standard Per	netration Tests
UDD	: Urban Devel	lopment Directorate

### **CHAPTER ONE: INTRODUCTION**

#### **1.1 Background of the Study**

With the increasing of population growth, economic growth and increasing life expectance of the peoples in Bangladesh, rapid urban expansion is the common phenomena right now. In this consequences, the present trend of planning practice is very much poor, mostly oriented towards planning of major cities and towns in Bangladesh but not in all other towns or growth centers because involves of huge amount of financial allocation/grants. Recent policy of Bangladesh Government, the Upazila has been recognized as the most significant tier of administration. So that these areas are need to be planned and developed to accommodate all social, economic, administrative, infrastructure services and service facilities for the region. The current government's intention is to reflect the national policy of bringing development administrative and service facilities to the door step of rural masses and to ensure better delivery of government services to the people. Realizing the fact and importance of formulating development plans for Upazilas, Urban Development Directorate has come up with a great initiative to plan those areas. At the first phase of this initiative UDD has decided to prepare development plan for 14 Upazilas all over Bangladesh into five different packages. For each package separate consultancy team has been appointed to carry out that job more fruitfully. Modern Engineers Planners and Consultants Ltd. (MEPC) have been selected for package-4 (Saghata Upazila of Gaibandha District and Sariakandi Upazila and Sonatala Upazila of Bogra District) by project evaluation committee of UDD.

Subsurface geological and geotechnical investigation has been considered in this study for a durable and sustainable urban environment. Initially this work is to determine subsurface soil condition of the project area up to 30 meter depth from ground surface and evaluating of natural geological and hydro-meteorological hazards such as earthquake, landslide and ground failure which integrate the consequence into the design of the infrastructure.

Following investigations and surveys activities has been carried out which are geomorphological survey; drilling of boreholes and preparation of borehole logs; collection of undisturbed and disturbed soil sample as per standard guide line; conducting standard penetration tests (SPTs); drilling of boreholes and casing by PVC pipe for conducting Downhole seismic test, conducting Down-hole seismic test and conducting Multi-Channel Analysis of Surface Wave (MASW). Geologic and geomorphologic conditions of the study area is not much complex, the area is mostly covered by loose sediments of floodplain deposits. Most of the area is plain in nature but some low or marshy land also occurred and almost everywhere soils are resent fluvial type of deposit which is much soft and thicker.

Following soil sample test such as Grain Size Analysis, Natural Moisture Content, Specific Gravity, and Direct Shear Test has been performing in the laboratory which will give more qualitative and quantitative information about the subsurface materials. These field and laboratory data will be analyzed and produce risk sensitive micro-zonation maps of the project area.

#### 1.2 Scope of Work

The aim of this work is to determine subsurface soil condition of the project area and evaluating of natural geological and hydro-meterological hazards such as earthquake, liquefaction, ground failure and integrate the consequence into the design of the infrastructure. The main objective will be achieved through accomplishment of the following sub-objectives:

- a) Preparation of Geological map of the study area;
- b) Preparation of sub-surface lithological 3D model of different layers through geotechnical investigation;
- c) Preparation of engineering geological mapping based on AVS30;
- d) Determination of soil type in the project area;
- e) Foundation layer identification;
- f) Preparation of Seismic Hazard Map;
- g) Finally intensity map is prepared for high rise and low rise building.

#### **1.3** Brief Description of the Area

Saghata, the smallest upazila of Gaibandha Zila, in respect of both area and population came into existence in 1905 as a thana and was upgraded to upazila in 1984. Nothing is definitely known about the origin of the upazila name. It is said that in the past some Hindu Shah family settled in the present place of upazila adjacent to a Ghat of the river Jamuna. The place got prominent as a business centre due to the great contribution of that Shah family. Consequent upon the effect of these two words Shah and Ghat, the place was named as Saghata. It is generally believed that the upazila was named Saghata of the time of its creation.

The upazila occupies a total area of 231.02 sq.km. It is located between  $25^{0}02$ ' and  $25^{0}14$ ' north latitudes and between  $89^{0}29$ ' and  $89^{0}40$ ' east longitudes. The upazila is bounded on the north by Gaibandha Sadar upazila, east by Fulchhari Upazila and Islampur Upazila of Jamalpur Zila,

south by Saghata Upazila and Saghata Upazila of Bogra Zila and west by Gobindaganj Upazila and Palashbari Upazila.

Jamuna and Bangali is the main river of Saghata Upazila. Jamuna River passes through the east side of the upazila. Three are 10 km of navigable water network and 30 km of navigable network during the monsoon.





Source: LGED

## **CHAPTER TWO: METHODOLOGY**

The methods and materials used to carry out of these activities have been described below:

#### 2.1 Test Details and Procedure of Down-Hole Seismic Test (Ps Logging)

Main objectives of downhole seismic test to measure the travelling time of elastic wave from the ground surface to some arbitrary depths beneath the ground. The seismic wave was generated by striking a wooden plank by a sledge hammer. The plank was placed on the ground surface at around 1 m in horizontal direction from the top of borehole. The plank was hit separately on both ends to generate shear wave energy in opposite directions and is polarized in the direction parallel to the plank.

The shear wave emanated from the plank is detected by a tri-axial geophone. The geophone was lowered to 1 m below ground surface and attached to the borehole wall by inflating an air bladder. Then, the measurements were taken at every 1 m interval until the geophone was lowered to 30 m below ground surface. For each elevation, 3 records were taken and then used to calculate the shear wave velocity.



Source: Field Survey, 2016 Plate-1: Downhole Seismic Test data logger

#### 2.1.1 Procedure of Field Work and Analysis

a) A wooden plank with an approximate dimension of 2 ft x 1 ft x 2 ft is fixed to the ground. The wooden plank is placed about 1m from the borehole as shown in Plate-2.



Source: Field Survey, 2016

#### Plate-2: Wooden Plank as the Vibration Source

b) Cables are wired from the geophone Plate 3 and the trigger to the data acquisition unit Plate 4. Signals in the vertical, radial and transverse directions are recorded by the data acquisition unit.



Source: Field Survey, 2016

**Plate-3: Geophone** 



Source: Field Survey, 2016

Plate-4: Data Acquisition Unit

c) The geophone is lowered into the borehole as shown in Plate 5 Then, air is pumped into the air bag to fix the geophone to the casing (PVC pipe) at 1 m interval in depth basically.



Source: Field Survey, 2016 Plate-5: Geophone Lowering In the Borehole

d) Excitations are generated by hitting the wooden plank in three directions by the hammer.



Source: Field Survey, 2016

**Plate-6: Direction of Excitations** 

e) Data is recorded in the data acquisition unit. Figure 2.1 illustrates a typical dataset in obtaining the arrival time of S-wave. Hitting the wooden plank in opposite directions generates signals as shown in the figure. The time that two curves begin to separate is the arrival time of shear wave. By doing the same analysis for every depth, S-wave profiles are obtained throughout the depth of the borehole.





Figure 2.1: Determination of the Arrival Time of S-Wave

f) Using the raw data of the test depth (D), the shortest pass (R) and the recorded arrival time of S-wave (t) in the inclined path is calculated to the travel time,  $t_c$ , in the vertical path as shown in Figure 2.2.



$$t_c = D \frac{t}{R}$$

Where

 $t_{\rm c}$  is the corrected travel time

*D* is the testing depth from ground surface,

*t* is the first arrival time from test*R* is the distance between the source an receiver

(Source: Auld 1977)



g) By plotting the corrected travel time versus depth, the velocity of every 1 m interval is calculated from (Auld 1977)

$$V_d = \frac{\Delta D}{\Delta t_c} [Auld \ 1977]$$

Where,  $\Delta D$  is depth interval showing similar slope and  $\Delta t_c$  is the corrected travel time difference of  $\Delta D$ .

### 2.2 Test Details and Procedure of Multi-Channel Analysis of Surface Wave (MASW)

Multichannel Analysis of Surface Wave (MASW) is recent and very popular method for computation of shear wave velocity. This method is widely used for seismic microzonation. A MASW is a seismic surface method, widely used for subsurface characterization and is increasingly being applied for seismic microzonation and site response studies (Anbazhagan and Sitharam, 2008). It is also used for the geotechnical characterization of near surface materials (Park and Miller, 1999; Xia et al., 1999; Miller et al., 1999; Anbazhagan and Sitharam, 2008). MASW is used to identify the subsurface material boundaries, spatial and depth variations of weathered and engineering rocks (Anbazhagan and Sitharam, 2009). We have used the MASW system consisting of 12 channels Geode seismograph with 12 vertical geophones of 10 Hz capacity.

The measuring procedure in this project is shown as follows:

- i. To decide the measuring line
- ii. To set receivers along the line at the ground surface. The intervals of each geophone are 3m.
- iii. To set an acrylic board at a half interval outside the line
- iv. To shoot it vertically. Then generated elastic waves are recorded by receivers.
- v. To shift the acrylic board between second receiver and the third receiver, and shoot it vertically. Then generated elastic waves are recorded at receivers.
- vi. To iterate this procedure up to setting the acrylic boards at a half interval outside the other side of the line.

The data acquisition parameters are given in Table 2.1.

Seismic refraction							
Number of channels	12						
Geophone spacing	3m						
Array length	33m						
Sampling rate	1ms						
Record length	2 sec						
Natural frequency of Geophone	10 Hz						
Source	8 kg hammer						
Shot number	13 points, 11 between geophones and 2 outside of measuring line						

**Table 2.1: MASW Data Acquisition Parameters** 

Source: Park and Miller, 1999; Xia et al. 1999; Miller et al. 1999; Anbazhagan and Sitharam, 2008.

#### 2.2.1 Analysis of MASW

Data processing consists of two main steps: (i) Obtaining the dispersion curves of Rayleigh wave phase velocity from the records; (ii) Determining the V s profiles from which the Vs30 values are calculated (see Figure 2.3). In the phase velocity analysis, SPAC (Spatial Autocorrelation) method (Okada, 2003) is employed. Okada (2003) shows Spatial Autocorrelation function  $\rho$  ( $\omega$ , r) is expressed by Bessel function.

$$\rho(\omega, r) = J_0(\omega r / c(\omega)) [Okada, 2003]$$

Where, r is the distance between receivers,  $\dot{\omega}$  is the angular frequency,  $c(\dot{\omega})$  is phase velocity of waves,  $J_{\theta}$  is the first kind of Bessel function. The phase velocity was obtained at each frequency using equation (2). A one dimensional inversion using a non-linear least square method has been applied to the phase velocity curves. In the inversion, the following relationship between P-wave velocity ( $V_p$ ) and  $V_s$  (Kitsunezaki et. al., 1990):

$$Vp = 1.29 + 1.11Vs$$
 [Kitsunezaki et. al., 1990]

Where,  $V_s$  is S-wave velocity (km/s),  $V_p$  is P-wave velocity (km/s). In order to assume density  $\rho$  (g/cm3) from S-wave velocity, the relationship of Ludwig et al. (1970) is used.

$$\rho = 1.2475 + 0.399Vp - 0.026Vp^{2}$$
 [Ludwig et al. (1970)]

These calculations are carried out along the measuring line, and the S-wave velocity distribution section was analyzed.



MASW Raw field data





Dipersion for Rayleigh wave



Shear wave velocity profile



Figure 2.3: Main Step of the MASW Processing Technique

#### 2.3 Test Details and Procedure of Standard Penetration Test

The geotechnical boreholes have been constructed using wash boring method. In this investigation, 19 numbers of boreholes have been prepared at Saghata Upazila. The borehole logs are enclosed in the Appendix C. The boring method has been described in the following section.

#### 2.3.1 Drilling

The bore holes are being drilled through mechanical percussion wash boring method at the locations previously decided. As 30 m boring is so complicated and time consuming moreover it has done continuously to the end to prevent the possibility of caving of the boring wall, is will been decided to send two sets of worker who will work in 8 hrs until desired depths will be achieved. In this manner the estimated time for boring execution will 20- shifts and 19- shifts are considered for mobilization, assemble and disassemble of the equipment, site cleanup and backfill the bore holes to their pre-existing condition.

#### 2.3.2 Data Collection

The field data are being collected according to the respective standard methods. First of all the location, areal coverage, topography, geomorphology of the test site are note down. The soil sample collection procedure is mentioned in the section 2.3.4. While SPT soil samples are collected. At the same time, the ground water table is note down.

#### 2.3.3 SPT Execution

As it mentioned earlier, the geotechnical boreholes will be constructed using mechanical boring method. The depth of those boreholes is to 30m. In this method N values (standard Penetration Test) is counted and soil sample also be taken in every 1.5m depth interval. The subsequent procedure which has been followed during the field work is furnished as follows:

- i. Drill a 100-200 mm (2.5-8 in) diameter exploratory boring to the depth of the first test.
- ii. Insert the SPT sampler (also known as a Split-spoon Sampler) into the boring. The shape and dimensions of this sampler are shown in Figure 4. It is connected via steel rods to a 63.5 kg (140 lb) hammer, as shown in Figure 5.
- iii. An automatic tripping mechanism (in case of rotary drilling used this technique in this investigation), raise the hammer a distance of 760 mm (30 in) and allow it to fall. This energy drives the sampler into the bottom of the boring. Repeat this process until the sampler has penetrated a distance of 450 mm (18 in), recording the number of hammer blows required for each 150 mm (6 in) interval.

- iv. Compute the N-value by summing the blow counts for the last 300 mm (12 in) of penetration. The blow count for the first 150 mm (6 in) is retained for reference purposes, but not used to compute N because the bottom of the boring is likely to be disturbed by the drilling process and may be covered with loose soil that fell from the sides of the boring.
- v. Extract the SPT sampler, then remove and save the soil sample (disturbed sample).
- vi. Drill the boring to the depth of the next test and repeat steps 2 through 6 as required.



Source: http://eeg.geoscienceworld.org/content/gseegeosci/12/2/161/F2.large.jpg

Figure 2.4: Split-spoon Sampler



Source: http://www.valueerror.com/pennstate/ce\_lab/wp-content/uploads/2014/05/download.jpeg

Figure 2.5: The SPT Sampler in Place in the Boring with Hammer

#### 2.3.4 Soil Sampling

Two main categories of soil samples are collected, undisturbed and disturbed. Undisturbed samples, which are required mainly for shear strength and consolidation tests, are obtained by techniques which aim at preserving the in-situ structure and water content of the soil. In boreholes, undisturbed samples can be obtained by withdrawing the boring tools (except when hollow-stem continuous-flight augers are used) and driving or pushing a sample tube into the soil at the bottom of the hole. The sampler is normally attached to a length of boring rod which can be lowered and raised by the cable of the percussion rig. When the tube is brought to the surface, some soil is removed from each end and molten wax is applied, in thin layers, to form a seal approximately 25mm thick: the ends of the tube are then covered by protective caps. Undisturbed block samples can be cut by hand from the bottom or sides of a trial pit. During cutting, the samples must be protected from water, wind and sun to avoid any change in water content: the samples should be covered with molten wax immediately they have been brought to the surface. It is impossible to obtain a sample that is completely undisturbed, no matter how elaborate or careful the ground investigation and sampling technique might be. In the case of clays, for example, swelling will take place adjacent to the bottom of a borehole due to the reduction in total stresses when soil is removed and structural disturbance may be caused by the action of the boring tools; subsequently, when a sample is removed from the ground the total stresses are reduced to zero.

Soft clays are extremely sensitive to sampling disturbance, the effects being more pronounced in clays of low plasticity than in those of high plasticity. The central core of a soft clay sample will be relatively less disturbed than the outer zone adjacent to the sampling tube. Immediately after sampling, the pore water pressure in the relatively undisturbed core will be negative due to the release of the in-situ total stresses. Swelling of the relatively undisturbed core will gradually take place due to water being drawn from the more disturbed outer zone and resulting in the dissipation of the negative excess pore water pressure: the outer zone of soil will consolidate due to the redistribution of water within the sample. The dissipation of the negative excess pore water pressure is accompanied by a corresponding reduction in effective stresses. The soil structure of the sample will thus offer less resistance to shear and will be less rigid than the in-situ soil.

A disturbed sample is one having the same particle size distribution as the in-situ soil but in which the soil structure has been significantly damaged or completely destroyed; in addition, the water content may be different from that of the in-situ soil. Disturbed samples, which are used mainly for soil classification tests, visual classification and compaction tests, can be excavated from trial pits or obtained from the tools used to advance boreholes (e.g. from augers

and the clay cutter). The soil recovered from the shell in percussion boring will be deficient in fines and will be unsuitable for use as a disturbed sample. Samples in which the natural water content has been preserved should be placed in airtight, non-corrosive containers: all containers should be completely filled so that there is negligible air space above the sample.

All samples should be clearly labeled to show the project name, date, location, borehole number, depth and method of sampling; in addition, each sample should be given a serial number. Special care is required in the handling, transportation and storage of samples (particularly undisturbed samples) prior to testing. The types of tube samplers used in this study are described below.

#### **Thin-walled Sampler**

Thin-walled samplers (Figure 2.6) have been used to collected undisturbed samples from boreholes. These samplers are used in soils which are sensitive to disturbance such as soft to firm clays and plastic silts. The sampler does not employ a separate cutting shoe, the lower end of the tube itself being machined to form a cutting edge. The internal diameter may range from 35 to 100 mm. The area ratio is approximately 10% and samples of first-class quality can be obtained provided the soil has not been disturbed in advancing the borehole. In trial pits and shallow boreholes the tube can often be driven manually.



Figure 2.6: Thin-Walled (Shelby Tube) Sampler

#### Split-spoon sampler

Split-spoon samplers (Figure 2.7) have been to collect disturb samples. It consists of a tube which is split longitudinally into two halves: a shoe and a sampler head incorporating air-release holes are screwed onto the ends. The two halves of the tube can be separated when the shoe and head are detached to allow the sample to be removed. The internal and external diameters are 35 and 50 mm, respectively, the area ratio being approximately 100%, with the result that there is considerable disturbance of the sample. This sampler is used mainly in sands, being the tool specified in the standard penetration test (SPT).



Source: http://foundationeng.blogspot.com/

Figure 2.7: Undisturbed (Split-Spoon) Sampler

#### 2.3.5 Carrying out Different Engineering Tests on Soil Sample

A wide variety of laboratory tests is performing on soils to measure number of soil parameters. Some soil properties are intrinsic to the composition of the soil matrix and are not affected by sample disturbance, while other properties depend on the structure of the soil as well as its composition, and can only be effectively tested on relatively undisturbed samples. Some soil tests measure the direct properties of the soil, while others measure "index properties" which provide useful information about the soil without directly measuring the property desired.

The test types and standard which have been following given in the following section. Before explaining each of the engineering tests, the standard followed in each test is mentioned here:

- ✓ Natural Moisture Content Tests are performing on selected samples according to ASTM D420-69.
- ✓ Specific Gravity Tests is performing on selected soil Samples, according to ASTM D854-83.

✓ Grain size Analysis Tests is conducting on available representative disturbed & undisturbed soil samples, collected from different strata according to ASTM D421-38 and D422-63.

#### **Natural Moisture Content Tests**

Moisture content was determined from selected samples according to ASTM D420-69. The water content of a soil sample is the ratio of the weight of the water in the sample to its dry weight it is usually expressed as a percentage. The soil sample is weighed both in natural state and in oven dry state and the moisture content is calculated by dividing the loss of weight of the sample by its dry weight.

#### **Specific Gravity Test**

Specific gravity of soil particles ( $G_s$ ) is defined as the ratio of the mass of given volume of soil particles to the mass of an equal volume' of water at 4<sup>o</sup>c. 1 he specific gravity for most natural soils falls in general range of 2.60 to 2.80. To determine the specific gravity of soil sample, 25 gm of oven dried soil sample is thorough pulverized and is placed in a calibrated pyenometer. Water is poured inside the pyenometer until its top is slightly below the calibrated mark. The mixture is then boiled thoroughly in order in eliminate all the air bubbles. More water is then added to the mixture till it over-night. The temperature is then recorded and the bottle is weighed.

The specific gravity G<sub>s</sub> is given by:

 $G_s \mathrel{x} W_s$ 

\_\_\_\_\_

 $G_s =$ 

 $W_{s\,-}\,W_1+W_2$ 

Where

 $G_t = Specific gravity of water$ 

 $W_s$  = the weight of oven dry soil (25gnis)

 $W_1$  Weight of flask + soil + water

 $W_2 = Weight of flask + water$ 

#### Grain size Analysis Test-

This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser,

larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles. This test is carried out ASTM D421-38 & D422-63.

#### Sieve Analysis

- 1. Write down the weight of each sieve as well as the bottom pan to be used in the analysis.
- 2. Record the weight of the given dry soil sample.
- 3. Make sure that all the sieves are clean, and assemble them in the ascending order of sieve numbers (#4 sieves at top and #200 sieve at bottom). Place the pan below #200 sieve. Carefully pour the soil sample into the top sieve and place the cap over it.
- 4. Place the sieve stack in the mechanical shaker and shake for 10 minutes.
- 5. Remove the stack from the shaker and carefully weighs and record the weight of each sieve with its retained soil. In addition, remember to weigh and record the weight of the bottom pan with its retained fine soil.

#### Hydrometer Analysis Test

For hydrometer analysis, 50gms of the oven dry sample is taken and 125 mL of the dispersing agent (sodium hexameta phosphate (40 g/L)) solution has been added and the mixture is stirred until the soil is thoroughly wet. The soil has been left to soak for at least ten minutes. While the soil is soaking, 125mL of dispersing agent into the control cylinder has been added and the cylinder is filled by distilled water to the mark of 1000 cc. the reading at the top of the meniscus formed by the hydrometer stem is taken. A reading less than zero is recorded as a negative (-) correction and a reading between zero and sixty is recorded as a positive (+) correction. This reading is called the zero correction. The meniscus correction is the difference between the top of the meniscus and the level of the solution in the control jar (Usually about +1). The control cylinder is shaken in such a way that the contents are mixed thoroughly. The hydrometer and thermometer are inserted into the control cylinder and the zero correction and temperature have been noted respectively. the soil slurry into a mixer by adding more distilled water are transferred, if necessary, until mixing cup is at least half full. Then the solution for a period of two minutes has been mixed. Immediately the soil slurry into the empty sedimentation cylinder has been transferred. Distilled water up to the mark has been added. After an elapsed time of one minute and forty seconds, very slowly and carefully the hydrometer has been inserted for the first reading. The reading is taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. Hydrometer readings after elapsed time of 2 and 5, 8, 15, 30, 60 minutes and 24 hours have recorded. For hydrometer analysis, meniscus correction to the actual hydrometer reading has been applied and corrected hydrometer reading has been

calculated. From those corrected hydrometer reading percent finer is calculated and the grain size curve diameter versus the adjusted percent finer are plotted on the semi-logarithmic sheet.

#### **Direct Shear Tests**

To determine shear characteristics, direct shear tests on 60 mm x 60 mm x 20 mm thick specimens prepared from selected disturbed and undisturbed samples were performed according to ASTM D3080-72. The results of a direct shear test on a cohesion less and cohesive soil can be presented in a summary table & by stress-strain curve. A stress-strain curve normally consists of shear stress; various shear displacement for both the undisturbed and the remolded tests under a specified normal load. The normal load usually varies from 1/3kg/cm<sup>2</sup> to 1 kg/cm<sup>2</sup>. Another curve of normal stress verses shearing stress will give angle of internal friction and cohesion for cohesive soil.

# CHAPTER THREE: SURVEY RESULT AT SARIAKANDI UPAZILA

#### **3.1** Geophysical Investigations

The main objectives of these investigation to estimate local site effects against earthquakes and the task has been segregated by three-fold: 1) To determine shear wave velocity profile at various sites, 2) To classify soil conditions according to seismic design specifications and 3) To analyze soil amplifications in the area. Field measurements of shear wave velocities were conducted in Sariakandi Upazila and described in below.

Shear wave velocity profile (Vs profile) in the field were carried out by two geophysical exploration methods namely 1) seismic downhole test and 2) Multichannel Analysis of Surface Wave (MASW).

Seismic downhole test is a direct measurement method for obtaining the shear wave velocity profile of soil stratum. However, the test requires borehole which is not time and cost effective for the project. Multichannel analysis of surface waves (MASW) is a non-invasive technique which can be used to determine the Vs profile at sites. In this project, the seismic downhole and MASW tests were performed at 3 and 5 locations respectively. Locations of seismic downhole test and MASW tests are shown in Map 3.1. The GPS coordinate of the test locations are showing in Table 3.1.



#### Map 3.1: Locations Map of the Geophysical Tests at Saghata Upazila

Source: MEPC

Unazila	Tost/ Survey			Coor	Data		
Name	Name	ID	Location Name	Latitude	Longitude	Acquisition Data	
		BH-17	Kazi Azhar Ali High School, Bonarpara union	25.16704	89.52582	30/08/2016	
	Downhole Seismic Test (PS Logging)	BH-07	Saghata Govt. Primary School (near kochua union porishid), Kochua union	25.11574	89.51626	01/09/2016	
		BH-03	Saghata Pilot High School, Saghata union	25.10831	25.10831 89.58458		
Saghata		MASW 1	Dimla Padumsahar Govt School Field, Padumsahar Union	25.18788	89.53841	30/08/2016	
	Multichannel analysis of	MASW 2	Muktanagar High School Field, Near Muktanagar Union Parishad Complex	25.16128	89.5689	30/08/2016	
	surface waves (MASW)	MASW 3	Jummarbari Adarsho College, Jummarbari Union	25.05703	89.55974	01/09/2016	
		MASW 4	Barkona High School Field, Kamaler Para Union	25.07987	89.54942	01/09/2016	
		MASW 5	Saghata Degree College, Gharidaha Union	25.10612	89.57624	01/09/2016	

Table 3.1: Down	-hole Seismic T	<b>Fest (PS logging)</b>	and MASW Ter	st Locations
	note betonne i			5t Llocations

Source: Field Survey, 2016



MASW 1: Dimla Padumsahar Govt School Field, Padumsahar Union



MASW 2: Muktanagar High School Field, Near Muktanagar Union Parishad Complex



MASW 5: Saghata Degree College, Gharidaha Union

Source: Field Survey, 2016

#### Plate-7: MASW Data Acquisitions at Saghata Upazila



BH-03, Saghata Pilot High School, Saghata union



Source: Field Survey, 2016

#### Plate-8: PS logging Data Acquisitions at Saghata Upazila

#### 3.1.1 Down-Hole Seismic (PS Logging) Test Results

As a fundamental parameter, shear wave velocity is required to define the dynamic properties of soils. If the soil velocity is less then 180m/s, it can be say as loose or soft soil. Estimation of shear wave velocity (Vs)/average shear wave velocity (AVS) and mapping is a way to characterize varying site conditions, and it can also be used to model earthquake-related ground shaking. Estimation of AVS aims to generate a map of estimated shear wave velocities for the upper 30m of the subsurface. Further this map can be used for seismic site response analysis i.e., to determine peak ground acceleration (PGA) and spectral acceleration (SA) values of both bedrock and ground surface. In this context, Downhole seismic test data acquisition has been completed at Sariakandi Upazila in three different locations on date 1<sup>st</sup> September 2016.

The average shear wave velocity (AVS) of each PS logging test are tabulated in Table 3.2. Work plan of the test depth was 30m, however, in some locations did not reach the geophone to the 30 m in depth due to adverse conditions of PVC.

Depth from Existing	oth from AVS 5 xisting		AVS 10			AVS 15			AVS 20			AVS 25			AVS 28 to AVS 30			
Ground Level	BH-03	BH-07	BH-17	BH-03	BH-07	BH-17	BH-03	BH-07	BH-17	BH-03	BH-07	BH-17	BH-03	BH-07	BH-17	BH-03	BH-07	BH-17
5m	86 m/s	91 m/s	92 m/s	114 m/s	113 m/s	120 m/s	0 m/s	:2 m/s	s5m/s									
10m							13	13	13	142 m/s	141 m/s	149 m/s	48 m/s	48 m/s	58 m/s			
15m													4	4	÷	152 m/s	153 m/s	164 m/s
20m																		
25m																		
30m																		

 Table 3.2: Summary of PS Logging Test Result

Source: Field survey, 2016

According to down hole seismic test results, the average shear wave velocities upto depth 30 are 165ms to 169m/s. It is indicate the soil of this area is soft or loose in nature. But actual soil condition (soil type, engineering properties and seismic behavior of soil) will be known when all the field data (SPT and soil laboratory test result, down hole seismic test result and MASW test result) has been integrated in a module to produces different type of maps including micro-zonation map of the project area.

The shear wave velocities at every 1m interval of each site are given in Appendix 1 at tabular and also graphical format.

#### 3.1.2 MASW Survey Result

To predict subsurface shear-wave interval velocities, multi-spectral analyses of surface waves (MASW) are popularly used. Shear wave velocities can also extract additional velocity-related information such as mechanical properties of soils and rocks. In general, MASW data compare favorably to other geophysical methods for predicting interval velocities. Furthermore,

comparisons to vertical seismic profiles correlate well with MASW predicted shear wave interval velocities. In this perspective, MASW test has been completed at five different locations at Sariakandi Upazila by 1<sup>st</sup> September 2016 and field raw data has been processed and also interpreted. The results of the MASW test are enclosed in Appendix B at tabular and also graphical format.

According to MASW test result, the velocities of the soil strata below 160 m/s upto depth 4.7m from existing ground level which indicate are the soil upto this depth soft or loose in nature. But the velocities of all the test locations are gradually improved with increasing of depth. The average shear wave velocities upto depth 30 m from 191.3 to 221.1m/s of the area. The detail MASW survey results are shown in Table 3.3.

MASW 1		MA	SW 2	MA	SW 3	MA	SW 4	MASW 5		
Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	
(m)	(m/s)	(m)	(m/s)	(m)	(m/s)	(m)	(m/s)	(m)	(m/s)	
0.0	137	0.0	153	0.0	149	0.0	160	0.0	124	
0.7	137	0.7	143	0.7	140	0.7	161	0.7	121	
1.5	135	1.5	140	1.5	137	1.5	160	1.5	118	
2.5	137	2.5	141	2.5	139	2.5	159	2.5	123	
3.5	144	3.5	147	3.5	147	3.5	165	3.5	135	
4.7	156	4.7	157	4.7	158	4.7	176	4.7	148	
5.9	169	5.9	167	5.9	169	5.9	186	5.9	160	
7.3	182	7.3	176	7.3	179	7.3	197	7.3	172	
8.8	197	8.8	185	8.8	189	8.8	206	8.8	183	
10.4	214	10.4	195	10.4	202	10.4	216	10.4	194	
12.1	232	12.1	204	12.1	219	12.1	225	12.1	208	
13.9	250	13.9	219	13.9	229	13.9	236	13.9	221	
15.8	264	15.8	221	15.8	235	15.8	251	15.8	233	
17.9	272	17.9	224	17.9	239	17.9	267	17.9	240	
24.3	280	24.3	225	24.3	242	24.3	278	24.3	248	
AVS 30- 212m/s		AVS 30-	- 193.1m/s	AVS 30-	- 200.1m/s	AVS 30-	- 221.1m/s	AVS 30-	· 191.3m/s	

 Table 3.3: Summary of MASW Test Results

	Velocity below 160m/s	Velocity 160m/s to 200m/s	Velocity to 240m/s	200m/s
	Velocity 240m/s			
	to 280m/s	Velocity above 280m/s		
Source: Fi	eld survey, 2016			



#### Map 3.2: Locations Map of the Standard Penetration tests (SPT) at Saghata Upazila

Source: MEPC

#### **3.2** Geotechnical Investigations

To ensure safety of human beings and materials, geotechnical investigations have become an essential component of every construction, it includes a detailed investigation of soil strength, composition, water content, and other important soil characteristics. Investigation borings with standard penetration test were conducted in order to know vertical geological conditions. The borings with SPT were carried out at 19 points at Saghata Upazila.

#### 3.2.1 Standard Penetration Test (SPT) Log Analysis and Interpretation

SPT is a common in-situ testing method used to determine the geotechnical engineering properties of subsurface soils. It was developed in the late 1920s and has been used extremely in North and South America, the United Kingdom, Japan, and elsewhere. Because of this long record of experience, the SPT is well-established in engineering practice. It is performed inside exploratory boring using inexpensive and readily available equipment, and thus adds little cost to a site characterization program. Although the SPT also is plagued by many problems that affect its accuracy and reproducibility, it probably will continue to be used for the foreseeable future, primarily because of its low cost. However, it is partially being replaced by other test methods, especially on larger and more critical projects.

All the borings has to be conducted and preparation of field bore log by visual classification has to be done in the presence of the experienced technical personnel. The borehole records have to be taken that include soil type, nature of sample, soil moisture content and consistency, SPT blow counts (N Value), ground water observation and apparent origin (fill, alluvium, recent sediments, etc.) and daily field logs have been prepared. The bore locations are given in following Table 3.4 and the geotechnical borehole log are enclosed in the below section.

BH ID	Location	Coordinate			
	Location	Latitude	Longitude		
BH-01	Padum Sahar School	25.051339	89.526433		
BH-02	Bharatkhali U.P	25.18895	89.584756		
BH-03	Saghata Union Parisad	25.111067	89.584728		
BH-04	Jummar Bari	25.055542	89.563986		
BH-05	Kamaler Para	25.083972	89.536056		
BH-06	Kachua	25.110986	89.525011		
BH-07	Kachua Union More	25.101389	89.528017		
BH-08	Ulla Sonatala	25.134689	89.525097		
BH-09	Ghunia Daha	25.099331	89.575056		

 Table 3.4: Bore Hole Information Summary at Saghata Upazila

PH ID	Location	Coordinate			
BHID	Location	Latitude	Longitude		
BH-10	Holdia	25.086222	89.586333		
BH-11	Saghata Thana	25.166833	89.527611		
BH-12	Saghata School	25.091897	89.584675		
BH-13	Padum Sahar U.P	25.047236	89.525042		
BH-14	Bonarpara	25.157031	89.526425		
BH-15	Bonarpara College	25.169883	89.522078		
BH-16	Bonarpara Clinic	25.162475	89.523742		
BH-17	Ajhar Ali Model School	25.161197	89.529253		
BH-18	Bonarpara Upazila	25.156794	89.522239		
BH-19	Saghata Dak Banglaw	25.165400	89.530725		

Source: Field survey, 2016

While boring and SPT testing, soil samples are being visually classified in the following way:

Sieve	Soils	Designations
+No 4 (4.76mm)	Gravel	
No.4 to No 10(2.00mm)	Coarse	Sand
No. 10 to No 40 (0.42mm)	Medium	Sand
No. 40 to No 200 (0.07mm)	Fine	Sand
No.200	Silt or Clay	

Some soil has one dominant lithology with minuscule amount of other soil type. In such cases, minor soil sample are written in the following manner with along with dominant soil type.

1.	Trace	1 to 10%
2.	Little	10 to 25%
3.	With	25 to 35%

SPT- N value is also note down while SPT Testing. Then the collected soil samples are being cross checked with SPT-N values to ensure quality data collection.

Based on N-values, other very useful soil parameters may be obtained from the co-relation charts given by different research workers. Two such useful co-relations for cohesive and non-cohesive soils after K. Terzaghi are given below:

N volues	Condition	Relative	Angle of Internal	Moist Unit Weight
IN-Values	Condition	Density	friction (Degree)	(Pcf)
0-4	Very Loose	0-15%	$28^{0}$	70-100
4-10	Loose	15-35%	28 <sup>0</sup> -30 <sup>0</sup>	95-125
10-30	Medium dense	35-65%	30 <sup>0</sup> -36 <sup>0</sup>	110-130
30-50	Dense	65-85%	36 <sup>0</sup> -41 <sup>0</sup>	110-140
Over 50	Very dense	85-100%	Over 41 <sup>0</sup>	> 130

Table 3.5: Values of Relative Density (Dr.), Friction Angle and Unit Weight of Noncohesive soil based on N-values

Source: K. Terzaghi

# Table 3.6: Values of Unconfined Compressive Strength based on N-values for Cohesive Soil (Approximate)

N-values	Condition Unconfined Compressive Strength (Te					
Below 2	Very soft	Below 0.25				
2-4	Soft 0.25-0.50					
4-8	Medium stiff	0.50-1.00				
8-16	Stiff	1.00-2.00				
16-32	very stiff	2.00-4.00				
Over 32	Hard	over 4.00				

Source: K. Terzaghi

In the above table the shear strength of cohesive soil is equal to ½ of unconfined compressive strength and the angle of shearing resistance is equal to zero. It should be remembered that the co-relation for cohesive soil is not always much reliable.

The lithology is already written down in a standard format and has been attached in the Appendix 3.

### **CHAPTER FOUR: CONCLUSION**

Saghata Upazila and its adjoining areas is mostly comprises by monotonous flood plain area except few depression. Soil quality of the project area is is varying as morphological difference, that's why geological, geotechnical and geophysical investigations has been carried out such a pattern to cover all morphological unit. In this consequences, 11 boreholes with SPT, 3 downhole seismic tests and 5 MASW program has been completed in the field as a part of this survey investigation. During this survey, soil samples (disturbed and undisturbed) are also collected for further laboratory test which will give idea about the soil engineering properties. This investigation data will be analyzed and integrated in a module from which it can possible to generate geomorphologic map, sub-surface litho-logical 3D model of different layers, engineering geological mapping based on AVS30, Seismic Hazard Assessment Map (risk sensitive micro-zonation maps), soil type map, seismic intensity map, Peak Ground Acceleration (PGA) and recommended building height maps for both high rise building and low rise building etc.

Above investigation and outcomes would give a clear idea about the geo-hazard status of particular landscape where newly urban developing activities or any other mega infrastructure project is going on and this mentioned investigation also gives idea about the vulnerability of existing build up infrastructure of a particular area. Based on these results, proper management techniques as well as other necessary adaptation process could be addressed before or after the development activities in the studied area. It is to be mentioned that the long-term maintenance cost will be reduced and the developed structure will withstand against the potential natural hazards if the infrastructures are built following the risk informed physical land-use plan.

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# **APPENDICES**

# Appendix-1



#### **Downhole Seismic Test (PS Logging) Results and Graphs**

Tested Date	Fested Date(dd/mm/yyyy) : 01/09/2016					Source : 7kg Sledge Hammer		
Location : Saghata Pilot High School, Near Saghata						Downhole Receiver : Tri-axial Geophone		
Upazila Cor	Upazila Complex, Saghata Upazila							·
PS Id : BH-03						Reco	ordi	ing Equipment <sup>,</sup> Freedom Data PC
Coordinate : Lat 25 10831 Long 89 58/58						Borehole Information : Grouted Cased		
	- Lui 20	n Inotru	monto Do	unhala Ca	iomio	Cool		
Operator : 1	ne Olso	ninstrui	nents Dov	wnnole Se	ISINIC	Casir	ng	Diameter : 75mm PVC Casing
system		~				~		
Time arrival (s)	Recorded Geophone Depti from Existing Ground Level (n	Source Saint Distance (m), R	Corrected Travel Time for Compretional Wave, tc=D*t/R (s)	Interval Time,ΔTs	Shear Wave Velocity Vs, Vs=D/tc (m/s)	Average Shear Wave Velocit	(m/s)	Graphical Representation of Vs
Existing Groun	d Level			-				Profile No. Saghata BH-03
0.031895	-1	1.41	0.0226	0.0226	44			
0.037086	-2	2.24	0.0332	0.0106	94	/S 5	62	-1
0.043143	-3	3.16	0.0409	0.0078	129	₹.	~	
0.050931	-4	4.12	0.0494	0.0085	118	-		
0.056987	-5	5.10	0.0559	0.0065	155			-4 - 5
0.063044	-6	6.08	0.0622	0.0063	159	-		
0.069966	-7	7.07	0.0693	0.0071	141	9,	4	
0.075158	-8	8.06	0.0746	0.0053	188	11 <sup>1</sup>		
0.081215	-9	9.06	0.0807	0.0061	163			
0.088137	-10	10.05	0.0877	0.0070	143			10
0.093328	-11	11.05	0.0929	0.0052	191	-		-10
0.098520	-12	12.04	0.0982	0.0052	191	3 15	0	
0.103/11	-13	13.04	0.1034	0.0052	191	AVS	13	E-13 -
0.108903	-14	14.04	0.1086	0.0052	192	-		±
0.115009	-15	15.03	0.1154	0.0067	149			
0.121010	-10	17.03	0.1208	0.0054	184	_		-16 -
0.12/939	-1/	10.03	0.1277	0.0069	144	\$ 20	5	
0.133130	-10	10.03	0.1329	0.0052	192	AX.	-	
0.130391	-19	20.02	0.1304	0.0035	200 220	-		-19 -
0.140917	-20 _21	20.02	0.1407	0.0043	20U 1//		_	
0.147039	- <u>-</u> 21	21.02	0.1477	0.0009	199	<u>م</u>		
0.159088	-22	23.02	0.1529	0.0052	182	\$ 2	48	-22 -
0 165145	-24	20.02	0.1650	0.0061	165	A .	÷	
0 169471	-25	25.02	0.1603	0.0001	231	-		
0 173797	-26	26.02	0 1737	0.0043	231			-25 -
0 178989	-27	27 02	0 1789	0.0052	192			1000
0.184180	-28	28.02	0.1841	0.0052	192	S 2	52	
	<u> </u>	<u>-</u> -				₹¥`	-	
						1		U 100 200 300 400 Vs (m/s)

#### SHEAR WAVE VELOCITY MEASURMENTS FROM DOWNHOLE SEISMIC TEST (PS LOGGING)

Tested Date	ested Date(dd/mm/yyyy) : 01/09/2016					Source : 7kg Sledge Hammer		
Location : Saghata Govt. Primary School (near kochua						Dov	wnho	ole Receiver : Tri-axial Geophone
union porist	nid), Koc	hua uni	on , Sagha	ata Upazila	a			
PS ld : BH-07						Rec	cordi	ling Equipment: Freedom Data PC
Coordinate : Lat-25.11574 Long-89.51626						Bor	ehol	le Information : Grouted Cased
Operator · T	he Olso	n Instru	ments Dov	wnhole Se	ismic	Cas	sina	Diameter 75mm PVC Casing
system		in inourai			lonno	out	Jing	
oyotom	(j) th	۲				īt		
Time arrival (s)	Recorded Geophone Dep from Existing Ground Level (	Source Saint Distance (m),	Corrected Travel Time for Compretional Wave, tc=D*t/R (s)	Interval Time,ΔTs	Shear Wave Velocity Vs, Vs=D/tc (m/s)	Average Shear Wave Veloc	(m/s)	Graphical Representation of Vs
Existing Groun	d Level							Profile No. Saghata BH-07
0.032615	-1	1.41	0.0231	0.0231	43			
0.034571	-2	2.24	0.0309	0.0079	127	/S 5	1	-1 -
0.043169	-3	3.16	0.0410	0.0100	100	¥	0,	
0.050375	-4	4.12	0.0489	0.0079	126	-		
0.055916	-5	5.10	0.0548	0.0060	168			-4 -
0.064003	-6	6.08	0.0631	0.0083	120	-		
0.069831	-7	7.07	0.0691	0.0060	167	3 10		
0.075234	-8	8.06	0.0747	0.0055	181	NS I	VS 11:	
0.081164	-9	9.06	0.0807	0.0060	166			
0.088549	-10	10.05	0.0881	0.0074	134	-		
0.094003	-11	11.05	0.0936	0.0055	182	-		-10
0.099582	-12	12.04	0.0992	0.0056	1/8	3 15	32	
0.104816	-13	13.04	0.1045	0.0053	190	A A	13	<b>F-13</b>
0.100904	-14	14.04	0.1007	0.0042	239	-		
0.114159	-15	15.03	0.1139	0.0052	192	-		
0.121147	-10	17.03	0.1209	0.0070	140			-16 -
0.120303	-17	18.03	0.1207	0.0070	182	S 2(	41	
0 138154	_10	19.03	0.1380	0.0037	269	A	1	
0 142249	-20	20.02	0.1000	0.0001	203			-19 -
0 146342	-21	21.02	0.1462	0.0041	240	-		
0.153826	-22	22.02	0.1537	0.0075	133	2		
0.159751	-23	23.02	0.1596	0.0059	169	/S 2	148	-22 -
0.165457	-24	24.02	0.1653	0.0057	175	A	<b>,</b>	
0.169316	-25	25.02	0.1692	0.0039	259			25
0.173916	-26	26.02	0.1738	0.0046	217			-23
0.178417	-27	27.02	0.1783	0.0045	222	8		
0.183142	-28	28.02	0.1830	0.0047	211	VS :	153	-28
						A		0 100 200 300 400
								Vs (m/s)

#### SHEAR WAVE VELOCITY MEASURMENTS FROM DOWNHOLE SEISMIC TEST (PS LOGGING)

Tested Date(dd/mm/yyyy) : 30/08/2016						Sou	irce	: 7kg Sledge Hammer		
Location : Kazi Azhar Ali High School, Bonarpara union						Dov	Downhole Receiver : Tri-axial Geophone			
								•		
PS ld : BH-17							Recording Equipment: Freedom Data PC			
Coordinate	Coordinate : Lat 25 16704 Long 89 52582							Borehole Information : Grouted Cased		
		n Inctru	nonte Dov	vnholo So	ismio		vina			
		11 1150 01	nents Dov		151110	Cas	sing			
system	ч Ê	۲ ۲				≥				
Time arrival (s)	Recorded Geophone Depti from Existing Ground Level (r	Source Saint Distance (m), F	Corrected Travel Time for Compretional Wave, tc=D*t/R (s)	Interval Time, ΔTs	Shear Wave Velocity Vs, Vs=D/tc (m/s)	Average Shear Wave Velocit	(m/s)	Graphical Representation of Vs		
Existing Groun	d Level	5						Profile No. Saghata BH-17		
0.031051	-1	1.41	0.0220	0.0220	46	1				
0.038074	-2	2.24	0.0341	0.0121	83	VS 5	92			
0.044118	-3	3.16	0.0419	0.0078	128	A	•••	-2 - 5		
0.050162	-4	4.12	0.0487	0.0068	147	-				
0.055342	-5	5.10	0.0543	0.0056	178	_				
0.061386	-6	6.08	0.0606	0.0063	159	-		-> ]		
0.066567	-7	7.07	0.0659	0.0053	187	AVS 10 120				
0.072611	-8	8.06	0.0721	0.0062	163		-8 -			
0.078655	-9	9.06	0.0782	0.0061	163	-				
0.083466	-10	10.05	0.0831	0.0049	205					
0.089543	-11	11.05	0.0892	0.0061	163	-		-11 -		
0.094860	-1Z	12.04	0.0945	0.0054	187	3.15	35			
0.100937	-13	13.04	0.1000	0.0001	104	¥.	10	÷ 5		
0.100420	-14	14.04	0.1052	0.0045	162	-				
0.11674	-15	16.03	0.1115	0.0001	103					
0.110744	-10	17.03	0.1105	0.0052	206					
0.120090	-17	18.03	0.1199	0.0034	102	S 20	49	-1/		
0.123273	_10	10.03	0.1201	0.0052	177	- Š	4			
0.130314	-10	20.02	0.1346	0.0000	258	-		-20 -		
0 139957	-21	21.02	0.1398	0.0000	193	-				
0 145085	-22	22.02	0 1449	0.0002	195	2				
0 148591	-23	23.02	0 1485	0.0035	284	S 2	58	-23 -		
0.154635	-24	24.02	0.1545	0.0061	165	₹	1			
0.158088	-25	25.02	0.1580	0.0035	289					
0.162405	-26	26.02	0.1623	0.0043	231			-26		
0.167586	-27	27.02	0.1675	0.0052	193	6				
0.172766	-28	28.02	0.1727	0.0052	193	\S 2	164	-29		
0.176493	-29	29.02	0.1764	0.0037	268	A		0 200 400 600 800		
	[	r				1		Vs (m/s)		

#### SHEAR WAVE VELOCITY MEASURMENTS FROM DOWNHOLE SEISMIC TEST (PS LOGGING)

# Appendix-2













# Appendix-3



#### **Geotechnical Logs and Laboratory Test Results and Graphs**