URBAN DEVELOPMENT DIRECTORATE (UDD)

Government of the People's Republic of Bangladesh

Mobilization Report

ON

Engineering Geological and Geo-Physical Surveys

Under

Preparation of Payra-Kuakata Comprehensive Plan Focusing on Eco-Tourism

Package No. 7 (Seven)

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Submitted by

Environmental & Geospatial Solutions (EGS)

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EXECUTIVE SUMMARY

Urban Development Directorate (UDD) has decided to introduce suitable development plan for Amtali, Taltoli, Barguna Sadar and Pathargata upazila of Barguna dristrict and Galachipa, Rangabali and Kalapara upazila of Patuakhali dristrict. As such, UDD has initiated the project titled 'Preparation of Payra-Kuakata Comprehensive Plan Focusing on Eco-Tourism'. Engineering Geological and Geo-Physical study is one of the important development module of this project. In this development plan, subsurface geological and geotechnical information's consider as an important tool for a durable and sustainable urbanization.

To know the subsurface soil condition of the study area, several Geophysical and Geotechnical surveys will be carried out up to 30 meters depth. To accomplish engineering geological and geo-physical surveys following investigations should be execute: geo-morphological 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 Down-hole seismic test; conducting Down-hole seismic test, Multi-Channel Analysis of Surface Wave (MASW) and single Microtremor Measurment. Laboratory test of soil samples such as Grain Size analysis, Atterberg Limits determination, Specific Gravity determination, Direct Shear Test, Unconfined Compression strength determination, Triaxial Test, Consolidation Test etc. need to be performed, which will give more qualitative and quantitative information about the subsurface. Regarding these, tentatively 90 numbers of boreholes, 25 nos of MASW, 40 nos of Microtremor Measurement and 15 nos of Down-hole seismic survey sites have been selected in the Project area.

Field and laboratory investigation data will be analyzed and result will be integrated with all information's in a module which can 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, liquefaction etc.

From above geotechnical and geological data base 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 these mentioned investigation also gives an 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. On the other hand, if the infrastructures are built according to this risk informed physical land-use plan, the long-term maintenance cost will be reduced and the developed structure will withstand against the potential natural calamity.

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Abbreviations

ASTM : American Society for Testing and Materials
AVS30 : Average Shear Wave velocity of 30 meter depth
BH: Borehole
MASW : Multi-Channel Analysis of Surface Wave
N value : Soil resistance or compactness
PGA : Peak Ground Acceleration
PS logging : Primary and Shear wave logging (Down-hole seismic test)
SA : Spectral Acceleration
SPT : Standard Penetration Tests
UDD: Urban Development Directorate
EGL : Existing Ground Level
GWL : Ground Water Level

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1. INTRODUCTION

1.1. Background

Bangladesh can earn money in local and also in foreign exchange by opening an environmental friendly tourist recourse at Barguna and Patuakhali dristrict. The spot, if properly developed, would become an excellent holiday resort and tourist center. The success of developing Barguna and Patuakhali district as a tourist center, seaport land area and industrial zone depends much on good communication facilities and availability of modern amenities. Moreover, the proposed sea port and industrial zone would generate lots of new financial activities including huge vehicular traffic such as air, rail, road and water. This phenomenon would have both positive and negative impacts on the socio-economic condition and existing land use pattern of the region. The proposed planning package would guide such probable changes in the socio-economic condition and landuse pattern of the region, and would also address the adverse impact of such changes.

Landuse planning is an impotent component for a modern urban development. A paradigm shift in landuse planning has beed taken place by mainstreaming disaster risk reduction in landuse planning in Bangladesh. This phenomenon involves integrating earthquake risk investigation in landuse planning in particular. Therefore attempt has been taken to incorporate a rigorous geological and geotechnical site characterization, including a potential risk analysis in preparing Payra-Kuakata Comprehensive Plan Focusing on Eco-Tourism.

Urban development is being increasing very fast in Bangladesh. The government has planned to develop Barguna and Patuakhali district as a tourist center, seaport and industrial zone. However, risk sensitive urban planning is very important in such a disaster prone country like Bangladesh for a risk resilient urban development in these cities and surrounding area. Among those cities Amtali, Taltoli, Barguna Sadar and Pathargata upazila of Barguna dristrict and Galachipa, Rangabali and Kalapara upazila of Patuakhali dristrict is most disaster prone area because of the area is located near coastal area and relativlly less seismo-tectonically active zones. So this area covers the assessment and management of Geohazard like; earthquake and ground subsidence, and hydrometorological hazards in predominantly urban context. Considering the geohazard threat of the populated urban and rural areas of the project, UDD has taken many initiatives for a rigorous geological and geotechnical (engineering geology) site characterization of the 7 (Seven) upazilas, including Amtali, Taltoli, Barguna Sadar, Pathargata, Galachipa, Rangabali and Kalapara upazila under ‘Preparation of Payra-Kuakata Comprehensive Plan Focusing on Eco-Tourism’.

Therefore the geological and geotechnical site characterization of the areas including potential seismic hazard assessment and ground subsidence risk analysis are an important component for rick sensitive landuse planning of the populated urban and rural area. In here, Environmental & Geospatial Solutions (EGS) has been entrusted to conduct this project work.

1.2. Client: About Urban Development Directorate (UDD)

Urban Development Directorate (UDD) was established through a government order in 17th July 1965. This directorate is working under the Ministry of Housing and Public Works. Since its inception, UDD is contributing in developing Master Plan/Land Use Plan for small, medium and large town and cities of Bangladesh. Thus it is contributing in development of the localities and lifestyle of peoples of Bangladesh in direct and indirect ways.

vision of UDD is to augment the quality of life of the people by improving the environment through planned development activities for adequate infrastructure, services and utility provision, to make optimum utilization of resources especially land and to ensure a geographically balance urbanization. It also aims to reduce local and regional disparity by alleviating poverty and to create good governance in the country through people participation and empowering of woman.

1.3. Location and Accessibility

Barguna district (Barisal division) area 1831.31 sq km, located in between 21°48' and 22°29' North latitudes and in between 89°52' and 90°22' East longitudes. It is bounded by Jhalokati, Barisal, Pirojpur and Patuakhali districts on the North, Patuakhali district and Bay of Bengal on the South, Patuakhali district on the East, Pirojpur and Bagerhat districts on the West. Amtoli, Taltoli, Patharghata and Barguna Sadar upazila are selected as a project area from Barguna district.

On the other hand, Patuakhali district (Barisal division) area of 3220.15 sq km, located in between 21°48' and 22°36' North latitudes and in between 90°08' and 90°41' East longitudes. It is bounded by Barisal district on the North, Bay of Bengal on the South, Bhola district on the East, Barguna district on the West. The land of the district is composed of alluvial soil of the meghna basin and of a number of small char lands. Galachipa (Including New Created Rangabali Upazila) and Kalapara upazila are selected as a project area from Patuakhali District.

Kuakata a scenic sea beach on the South of Bangladesh. The most important attraction of the beach is that one can see both sunrise and sunset from some of its locations. Situated 320 km from Dhaka and 70 km from the Patuakhali district headquarters, Kuakata is part of Latachapli and Dhulasar unions of Kalapara upazila. On the other hand, Amtali upazila of Barguna District is on the way to Kuakata from Barisal. The only highway towards Kuakata from Barisal is running through Amtali upazila. Due to the reason, both Kalapara and Amtali upazila have been undertaken for “Preparation of Eco-Tourism Development Plan for Kuakata Coastal Region” to develop tourism in the area in an integrated and comprehensive manner on a regional planning concept. The best way to reach Kuakata from Dhaka is to first travel to Barisal by road, water, or air, and then to take the bus or boat/launch for the destination. The Bangladesh Road Transport Corporation introduced a direct bus service from Dhaka to Kuakata via Barisal. Besides, on the west of Kuakata, there is a reserve forest, Fatrar Char by name, which is part of Sundarbans and is a unique location for tourism development. Sonar char of Rangabali upazila is also a place of panoramic beauty. There is ample opportunity for tourism development in the area. Moreover, Paira Bandar, the third sea port has already been established at Ravnabad Channel near Kuakata, which would act as catalyst for radical change in the overall urbanization in the region.

Table: Area, Population and Density of the Project Area:

Name of District	Name of the Upazila	Area		Population	Density of total Population per Sq.Km
		Sq. Km	Acre		
Barguna	Barguna Sadar Upazila	454.38	112279.74	261343	575
Barguna	Pathargata Upazila	387.36	95718.74	163927	423
Barguna	Amtali Upazila (Including Taltoli Upazila)	720.75	178101.2	270802	376
Patuakhali	Galachipa (Including New Created Rangabali Upazila)	1268.37	313421.05	361518	285
Patuakhali	Kalapara Upazila	491.89	121548.67	237831	484
Total		**3322.77**	**821074**	**1295421**	**389.86**

Source: BBS, 2011

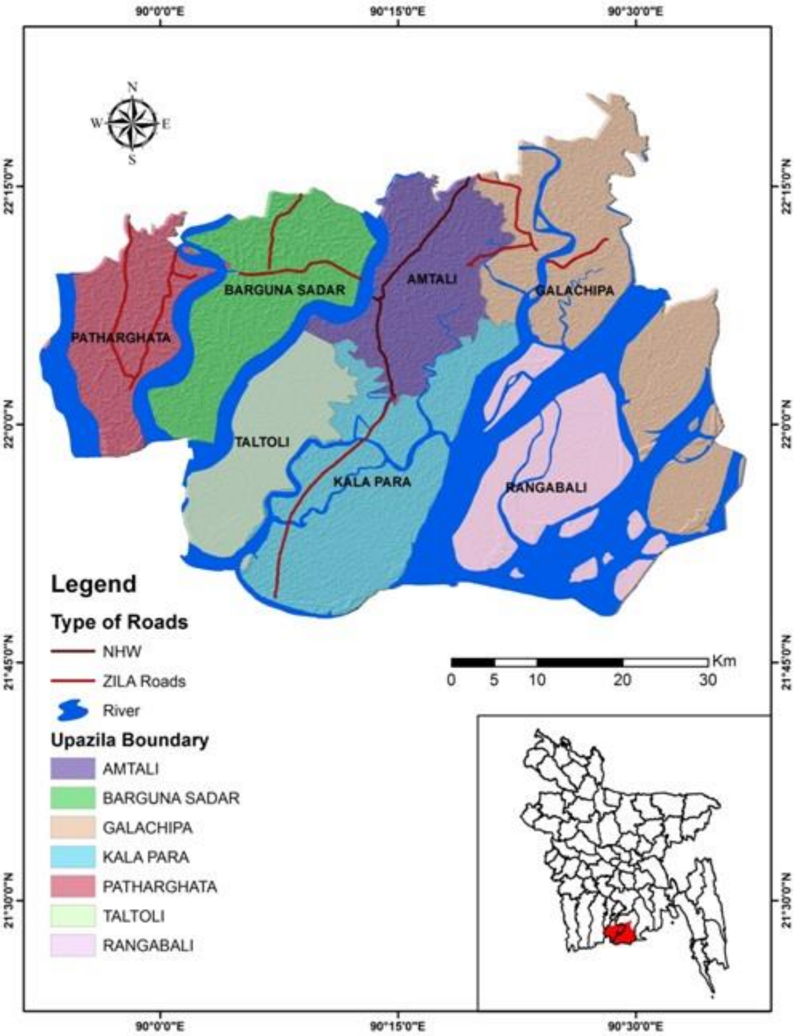


Figure 1.1 Location map of the project area

2. AIM AND OBJECTIVES

The main objective of the research is to carry out a Engineering Geological and Geo-Physical Survey of the 7 (Seven) upazila including Amtoli, Taltoli, Barguna Sadar and Patharghata of Barguna district and Galachipa, Rangabali and Kalapara upazila of Patuakhali district under Preparation of Payra-Kuakata Comprehensive Plan Focusing on Eco-Tourism. The main objective will be achieved through accomplishment of the following sub-objectives:

i. Preparation of Geological and geomorphologic map of the study area.
ii. Sub-surface lithological 3D model development of the study area.
iii. Preparation of Soil classification map by using geophysical and geotechnical investigations of the study area.
iv. Development of engineering geological map based on AVS30 values of the study area.
v. Foundation layers delineation and determination of engineering properties of the sub-soil.
vi. PGA, Sa (T) Maps of 5% damping at 0.2 and 1.0 second periods values of 10% exceedance probability during next 50 years for local site condition determination of the study area.
vii. Risk Sensitive Building Height determination of the study area.
viii. Formulation of Policies and plans for mitigation of different types of hazards, minimizing the adverse impacts of climate change and recommend possible adaptation strategies for the region.

3. METHODOLOGY

3.1. Approach

The methodology of the study is as follows:

1) Collection of relevant existing data, reports, maps, DEM of the study area.
2) Section of all the geotechnical and geophysical tests/survey locations base on the existing data and geomorphological units of the project area.
3) Collection of both geotechnical and geophysical data at field level. Following investigations given in Table that will be conducted for the preparation of engineering geological maps for the Project area:

Name of Upazila	Name of investigations			
	Borelog with SPT *(upto 30m)*	PS logging *(30m depth)*	MASW *(30m depth)*	Single Microtremor
Amtoli, Taltoli, BargunaSadar, Patharghata, Galachipa, Rangabali and Kalapara	90	15	25	40

4) Laboratory test of 90 numbers of boreholes will be conducted for investigating geotechnical properties of soil samples.
5) Geophysical data (PS Logging, MASW,and Microtremor survey) analysis for calculating AVS30 will be done by using some types of advanced international softwares.
6) Preparation of engineering geological map is to develop the geotechnical and geophysical characteristics of the soft sub-surface sedimentary deposits. In this investigation, the GIS technique, the advanced international software and hardware will be used, which makes the system′s performance steady with good expansibility. These information are often used for foundation engineering, seismic hazard assessment. The purpose of engineering geological investigations is to generate AVS30 maps for the targeted areas. The investigated area will be differentiated into

number of potential grid sizes as per requirement of the study and consulting with Project Director. AVS30 will be calculated for each grid of the targeted areas.

7) To find out Engineering geological and geo-physical condition in and around the project area.
8) Conduct on jobs training for the officers and staffs of UDD.
9) To organize a workshop and seminar to present the research findings to different professionals.
10) Preparation of report based on data generated from the study.

3.2. Strategic Methodology

The methodology consists of both field and laboratory investigations. To conduct this project work, geomorphological, geotechnical and geophysical data of soil will be collected, analysed and interpreted. Geomorphological data will be collected from satellite image (provided by UDD) of the study area to prepare a geomorphological map. Geotechnical data will be collected from field investigations *i.e.,* boring, standard penetration test (SPT), and laboratory investigations *i.e.,* soil physical properties test, consolidation test, direct shear test and triaxial test of undisturbed soil sample. Geophysical data will be collected from down-hole seismic test (PS logging); Multi-channel analysis of surface wave (MASW) and Singles Microtremor survey. The total works will be conducted through the following methodology-

a) Geological and Geomorphologic Mapping

Using aerial photographs, high resolution satellite images and field investigation both the regional and local geological maps will be prepared to delineate the surface and near-surface outcrops and attitudes of geological structures. On the other hand for preparing geomorphologic map digital elevation model (DEM) and other satellite images will be used. The geomorphologic map is verified by field data and by collecting relevant existing data. This map will provide all background information for the preparation of the hazard maps of the project site.

b) Sub-surface 3D model of different layers through geo-technical investigation

According to grid pattern, Standard penetration test locations are selected and drilling for identifying the geological characteristic of sub-surface soft sedimentary rocks. Description of different layer of the soil, its sedimentary characteristics, structure, lithology etc will be reflected in 3D model. Engineering properties of different soil layer: SPT value, soil strength and foundation layer etc are also being described. Computing all the results of soil properties and geotechnical properties preparation of 3D model for sub surface information of different layers of the area can be done using GIS and other software. 3D subsoil modeling would illustrate the sub-soil condition and behavior of specific area.

c) Engineering geological mapping based on AVS30

In this investigation, Geophysical data will be collected by using PS Logging, Multi-channel Analysis of Surface Wave (MASW), and Microtremor test/survey in the field and analyses those data for identifying average shear wave velocities (Vs) in a project area. The purpose of identifying average shear wave velocities (Vs) is to generate AVS30 maps for the targeted areas. These information are often used for foundation engineering and seismic hazard assessment.

d) Seismic hazard assessment

The purpose for preparation of localized seismic hazard maps is to make the structural design and to address other mitigation options following seismic intensity. For preparation of seismic hazard maps, historical earthquake data and damage information are needed. The response of the soil layers in-term of the amplification factor of the soft-soil need to be developed based on the engineering properties of the sub-soil. The main outcomes of the seismic hazard assessment are Peak Ground Acceleration (PGA), Response Spectrum Sa(T) of 5% damping at 0.2 and 1.0 second periods values of 10% exceedance probability during next 50 years for upper soft local soil by using these amplification factor. Liquefaction and Ground Failure Map is also conducted from PGA, water level and triaxial test. Liquefaction is addressed by high-moderate- low zone in round from 100m*100m to 250m*250m grid size. Finally intensity map is prepared and also the vulnerable zones for high rise and low rise building will be identified.

e) Training/Workshop

On-the-job training, sometimes called direct instruction, is one of the earliest forms of training (observational learning is probably the earliest). It is a one-on-one training located at the job site, where someone who knows how to do a task shows another how to perform it. It will be arranged during the course of investigation.

3.3. Detail Procedures Of Survey/Testing

The method of testing/surveying, application, Instrumentation and previous works of Geophysical and Geotechnical investigation are given below-

3.3.1. Test Detail And Procedure Of Downhole Seismic Test (Ps Logging)

Seismic down hole test is a direct measurement method for obtaining the shear wave velocity profile of soil stratum. The seismic down hole test aims 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 7kg 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, 9 records were taken and then used to calculate the shear wave velocity. The first arrival time of an elastic wave from the source to the receivers at each testing depth can be obtained from the downhole seismic test.

Figure 3.1 Field Data Acquisition by PS logger

When two geophones are used (in special case) at that situation, two geophones are lowered in the hole by keeping them 1.5m apart. There exists two ways of moving geophone either upward or downward. Say, if the hole is 30m then the bottom geophone is kept at 30m and then the top geophone will be at 28.5m and then we bring these geophones upward by taking reading after each meter and for downward is vice versa. In Downhole Seismic, an accelerometer mounted to a wooden plank source is used to trigger data collection.

Figure3.2 Main Component of the Freedom Data PC

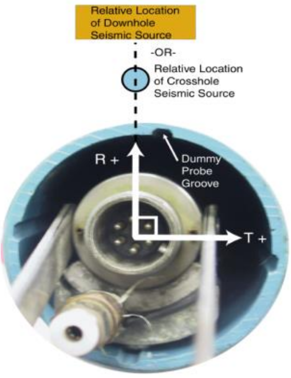


Figure 3.3: Receiver Orientation in Sinco casing

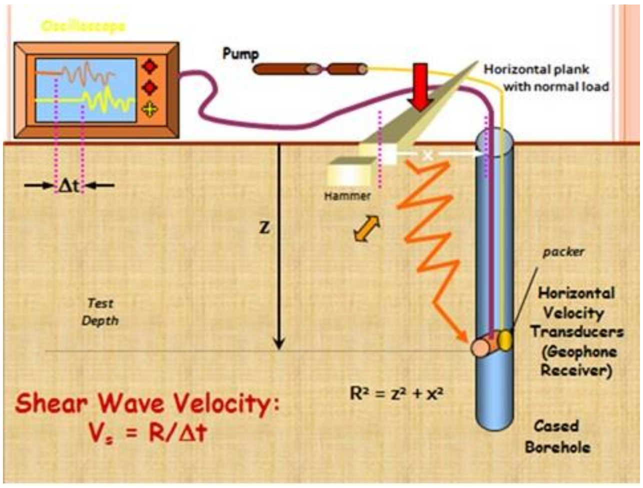


Figure 3.4 Calculation of Shear Wave Velocity by Down hole Seismic, where R_1=Distance between source to top geophone and R_2=Distance between source to bottom geophone

Figure 3.5 To set the wooden plank and sand bag 3.0 meters from a borehole

Figure 3.6To attach the trigger to a hammer.

Figure 3.7 To connect the air pump with a battery.

Figure 3.8 To connect the computer with cables which are connected to the geophone.

Figure 3.9 Make sure that the air bag at the geophone works. Then, put the geophone into the borehole and fix the safety rope with the holder

Figure 3.10 Hit the wooden plank in 3 directions which are on the left, right and vertical directions.

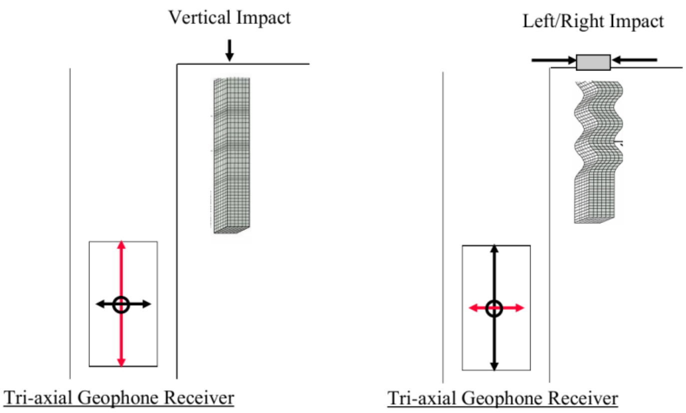


Figure 3.11 Triaxial geophone behavior.

Analysis and Calculation from PS Logging

P-wave travel time is calculated by the first arrival of either peak or trough in the seismic trace and P-wave is characterized by higher frequency and lower amplitude. On the other hand, shear wave is characterized by lower frequency but high amplitude.

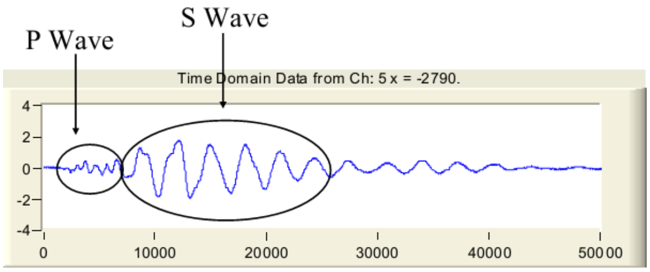


Figure 3.12 P wave and S wave in the Computer Window

S wave travel time is calculated from the first cross as we hit in both direction of the wooden plank so there generate opposite phase shear waves in radial and transverse direction and cross at some points.

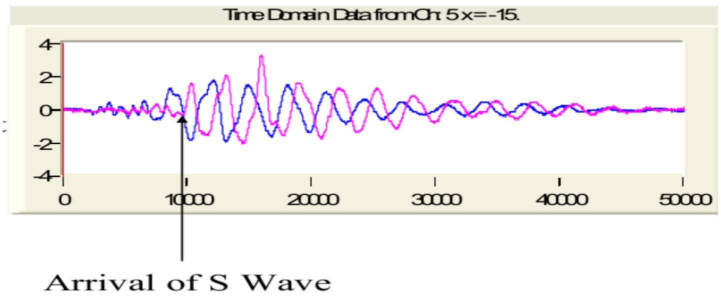


Figure 3.13 Arrival of S wave

Moreover, bounty of engineering geological parameters of soil can be determined whenever shear wave and compressional wave velocity is known. The Shear Modulus (G), Constrained Modulus (M) , Poisson Ratio (ν) and Young Modulus(E) of the soil profiles are calculated using the following formula:

$$G = \rho V_S^2$$

$$M = \rho V_P^2$$

$$\nu = [0.5(\frac{V_P}{V_S})^2 - 1]/[(\frac{V_P}{V_S})^2 - 1]$$

$$E = 2G(1+\nu)$$

Where, *p*is the local soil mass density (unit weight divided by gravity) obtained from the boring log information is taken 2 gm/cc for based on SPT results.

Besides, the average shear wave velocity upto 30 m depth has been determined using the following equation.

$$T_{30} = \sum \frac{Hi}{Vi}$$

$$AVS\ 30 = \frac{30}{T_{30}}$$

Where, Hi : Thickness of i th layer and $30 = \sum Hi$

Vi: S-wave velocity of i th layer

Instrument List

The PS logging test equipments are listed below-

1. One Freedom NDT PC
2. Two High Sensitive Tri-axial Geophones.
3. Two set Cable/Air lineSpool
4. Wooden Plank.
5. 7kg weight Hammer.

Figure 3.14 Freedom Data PC with P-SV Downhole Source and 1 Tri-axial Geophone Receiver used in Crosshole Seismic Investigations

Application of PS Logging Test

Downhole Seismic (PS Logging) system is useable for providing information on dynamic soil and rock properties for earthquake design analyses for structures, liquefaction potential studies, site development, and dynamic machine foundation design. The investigation determines shear and compressional wave depth versus velocity profiles. Other parameters, such as Poisson's ratios and moduli, can be easily determined from the measured shear and compressional wave velocities. The PS Logging is a downhole method for the determination of material properties of soil and rock.

3.3.2. Test Detail And Procedure Of Multi-Channel Analysis Of Surface Wave (MASW)

MASW utilizes the frequency dependent property of surface wave velocity, or the dispersion property, for Vs profiling. It analyses frequency content in the data recorded from a geophone array deployed over a moderate distance.

The processing of MASW is schematically summarized in Figure 2-15. The principle MASW is to employ and arrange a number of sensors on the ground surface to capture propagating Rayleigh waves, which dominates two-thirds of the total seismic energy generated by impact sources. If the tested ground is not homogeneous, the observed waves will be dispersive, a phenomenon that waves propagate towards receivers with different phase velocities depending on their respective wavelength (see Figure 3-15).

From field observation, the data in space-time domain (for instance, the left plot in Figure 3-15) is transformed to frequency-velocity domain by slant-stack and Fast Fourier transform using

$$S(\omega,c)=\int e^{-i\frac{\omega}{c}x}U(x,\omega)\,dx$$

where $U(x,\omega)$ is the normalized complex spectrum obtained from the Fourier transform of $u(x,t)$, ω is the angular frequency, c is the testing-phase velocity and $S(\omega,c)$ is the slant-stack amplitude for each ω and c, which can be viewed as the coherency in linear arrival pattern along the offset range for that specific combination of ω and c. When c is equal to the true phase velocity of each frequency component, the $S(\omega,c)$ will show the maximum value. Calculating $S(\omega,c)$ over the frequency and phase-velocity range of interest generates the phase-velocity spectrum where dispersion curves can be identified as high-amplitude bands. The dispersion curve is, then, used in inversion process to determine the shear wave velocity profile of the ground.

In theory, a phase-velocity spectrum can be calculated for a known layer model **m** and the field setup geometry. This process is called forward modeling. The inversion process tries to adjust assumed layer model as much as possible through several iterations in order to make the calculated spectrum looks similar to the dispersion curve obtained from the field test. Once the algorithm can match the calculated with the measured one, the assumed model will be considered as the true profile.

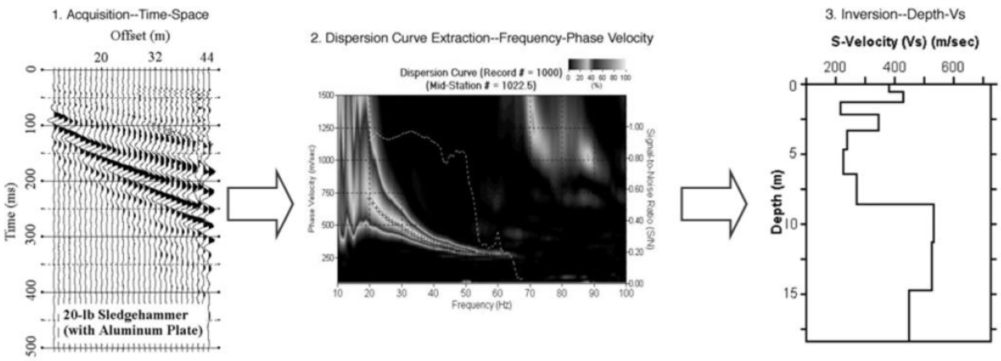


Figure 3.15 MASW data processing (Park et al., 1999)

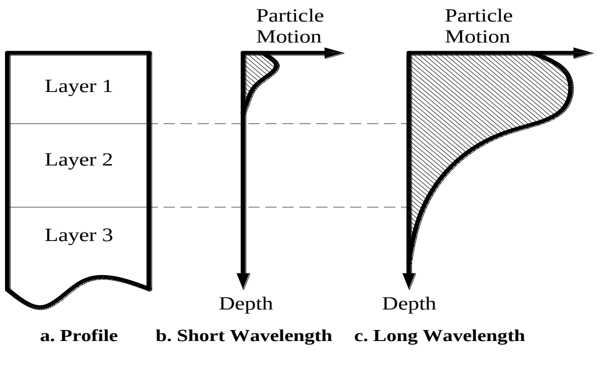


Figure 3.16 Rayleigh wave dispersion in layer media (Rix, 1988)

Active Source Data Acquisition

The active MASW method was introduced in GEOPHYSICS in 1999. This is the most common type of MASW survey that can produce a 2D VS profile. It adopts the conventional mode of survey using an active seismic source (e.g., a sledge hammer) and a linear receiver array, collecting data in a roll-along mode. It utilizes surface waves propagating horizontally along the surface of measurement directly from impact point to receivers. It gives this VS information in either 1D (depth) or 2D (depth and surface location) format in a cost-effective and time-efficient manner. The maximum depth of investigation (z max) is usually in the range of 10–30 m, but this can vary with the site and type of active source used.

Seismic energy for active source surface wave surveys can be created by various ways, but we used a sledgehammer to impact a striker plate on the ground since it is a low-cost, readily available item. To signal to the seismograph when the energy has been generated, a trigger switch is used as the interface between the hammer and the seismograph. When the sledgehammer hits the ground, a signal is sent to the seismograph to tell it to start recording.

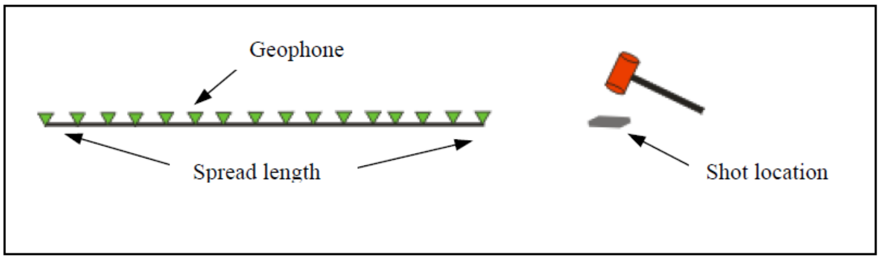
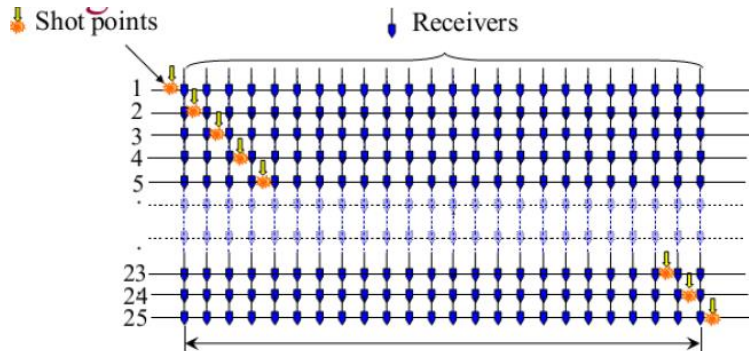


Figure 3.17 Schematic of linear active source spread configuration

During our field work we used 12 channels with 3m interval, 6 m source (sledge hammer) offset, 0.125 ms sample interval, 2 seconds record length and auto trigger option. And the active source spread configuration for the station 20 was like below:



Survey Line Length

(Number of Sources= Number of Receivers + 1)

Figure 3.18 MASW Field Data Acquisition

At every station one data was acquired by stacking (6 times hammer hit) to enhance the data quality.

Analysis of MASW

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.

$$\rho(\omega, r) = J_0(\omega r / c(\omega)) \quad \text{-------------------(1)}$$

Where, r is the distance between receivers, ω is the angular frequency, c(ω) is the phase velocity of the waves, J_0 is the first kind of Bessel function. The phase velocity can be obtained at each frequency using equation (1). Figure 3-19 shows an example of dispersion curve of the survey, the frequency range between 15 and 50 Hz.

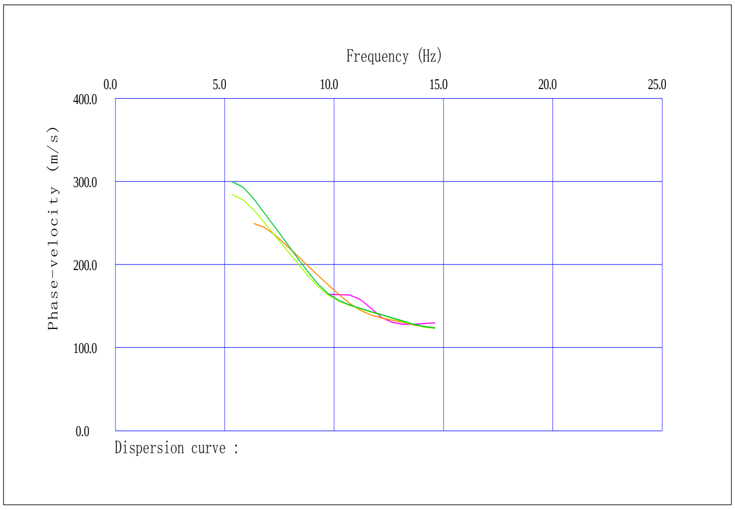


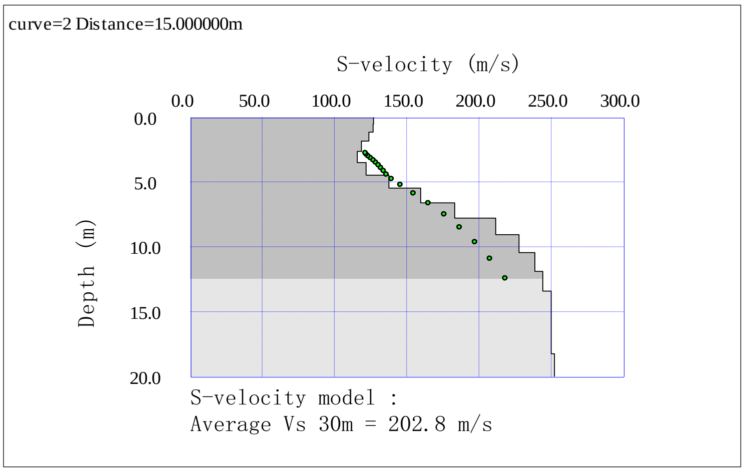
Figure 3.19 Dispersion Curve

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 (Vp) and Vs (Kitsunezaki et. Al.., 1990):

$$Vp = 1.29 + 1.11Vs \quad \text{-------------------------} \quad (2)$$

Where Vp and Vs are the P-wave velocity and S-wave velocity respectively in (km/sec).

These calculations are carried out along the measuring line, and the S-wave velocity distribution section was analyzed, then summarized to one dimensional structure; SeisImager software can also give a 2-D velocity model (for active), a sample of which is shown in Fig. 3-20.



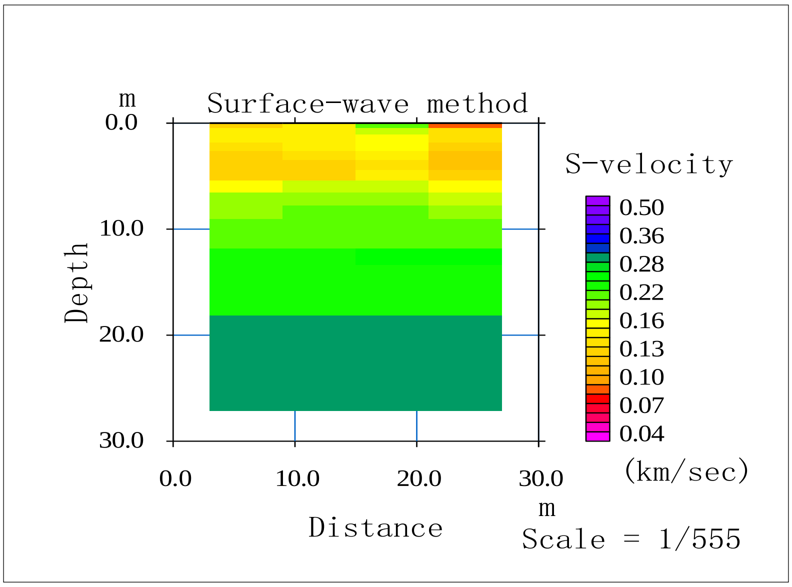


Figure 3.20 One dimensional Velocity Structure and 2 D velocity Model

Figure 3-21 shows an example of dispersion curve for passive MASW and phase velocity versus frequency as a sample. A one dimensional inversion using a non-linear least square method has been applied to the phase velocity curves and one dimensional S-wave velocity structures down (Figure 3-22).

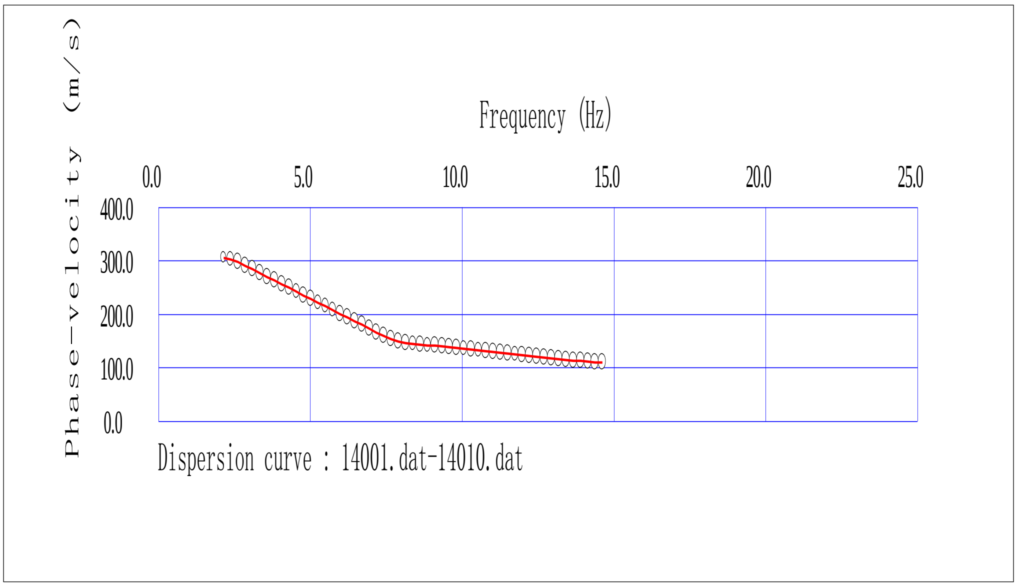


Figure 3.21 Dispersion Curve for Passive MASW

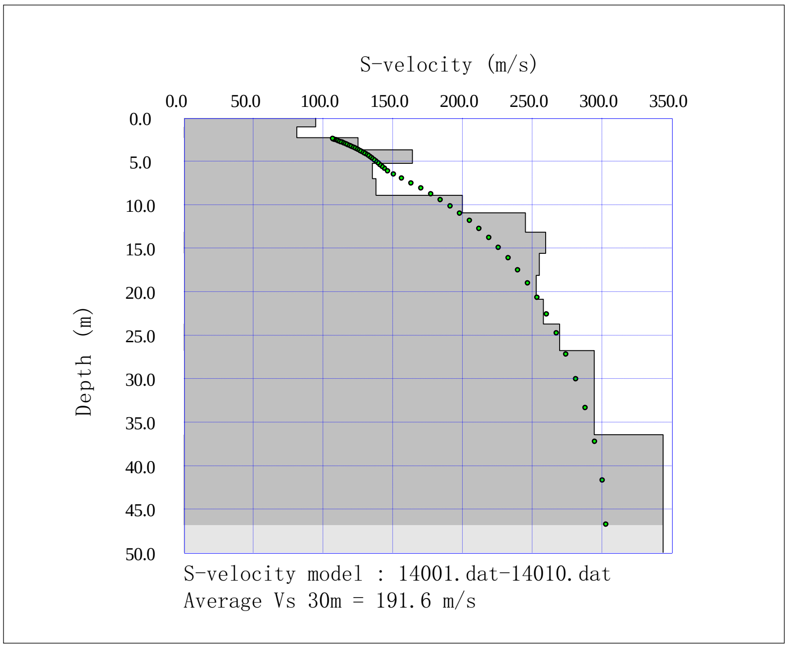


Figure 3.22 One dimensional velocity structure for Passive MASW

Calculation of AVS 30

The AVS30 can be calculated as follows:

$T_{30} = \sum(Hi/Vi)$

AVS 30= $(30/ T_{30})$

Where, Hi= Thickness of the i th layer and $\sum$Hi= 30

Vi= S wave velocity of the I th lay

3.3.3. Test Detail And Procedure Of Microtremor Measurement (Single Microtremor)

Microtremor method is a practical and economical seismic survey since it has potential to explore deep soils without a borehole. Microtremors are the phenomenon of very small vibrations of the ground surface even during ordinary quiet time as a result of a complex stacking process of various waves propagating from remote man-made vibration sources caused by traffic systems or machineries in industrial plants and from natural vibrations caused by tidal and volcanic activities. Observation of microtremors can give useful information of dynamic properties of the site such as predominant period, amplitude, peak ground acceleration and shear wave velocity.

Single Microtremor observation

Method

1) The transfer function of surface layer

$$S_T = \frac{\text{Hor. spectrum at surface}}{\text{Hor. spectrum at base}} = \frac{S_{HS}}{S_{HB}}$$

2) Vertical component of MT is affected by Rayleigh wave at surface, but no effect at base and no amplification of vertical waves.
Define the effect of Rayleigh wave as;

$$E_S = \frac{\text{Ver. spectrum at surface}}{\text{Ver. spectrum at base}} = \frac{S_{VS}}{S_{VB}}$$

3) To eliminate the effect of Rayleigh wave, define new transfer function as;

$$S_{TT} = \frac{S_T}{E_S} = \left(\frac{S_{HS}}{S_{VS}}\right) x \left(\frac{S_{VB}}{S_{HB}}\right) = \left(\frac{S_{HS}}{S_{VS}}\right) \quad \left(\frac{S_{VB}}{S_{HB}} \to 1.0\right)$$

$$H/Vspectrum = \frac{Hs}{Hv} = \frac{\sqrt{F_{NS} x F_{EW}}}{F_{UD}}$$

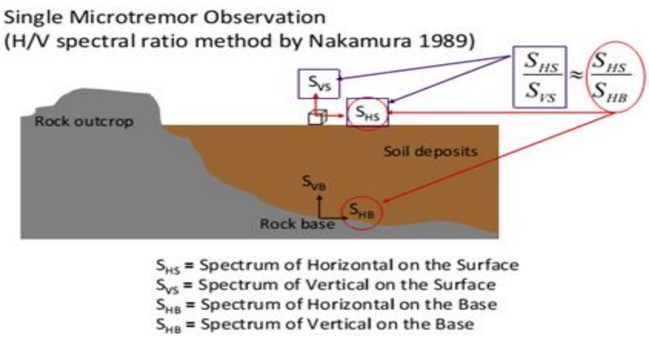


Figure 3.23 Fundamental of SingleMicrotremorobservation

Field Data Acquisition System

Microtremor observations are performed using portable equipment, which is equipped with a super-sensitive sensor, a wire comprising a jack in one site and USB port in another site, and a laptop computer is also used. The microtremor equipment has been set on the free surface on the ground without any minor tilting of the equipment. The N-S and E-W directions are properly maintained following the directions arrowed on the body of the equipment. The sampling frequency for all equipments is set at 200Hz. The low-pass filter of 40Hz is set in the data acquisition unit. Like the seismometer or accelerometer, the velocity sensor used can measure three components of vibrations: two horizontal and one vertical. The natural period of the sensor is 2 sec. A global positioning system (GPS) is used for recording the coordinates of the observation the available frequency response range for the sensor is 0.5-20Hz. sites. The length of record for each observation was 10~20 min.In all fields of this project this data acquisition system has be applied.

Figure 3.24 Field data acquisition of Single microtremor

3.3.4. Standard Penetration Test (SPT) Method

The Standard Penetration test (SPT) is a common in situ testing method used to determine the geotechnical engineering properties of subsurface soils. The test procedure is described in the British Standard BS EN ISO 22476-3, ASTMD1586. A short procedure of SPT N-value test is described in the following paragraph.

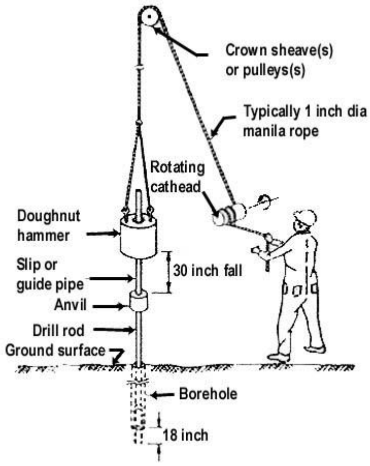


Figure 3.25 The SPT sampler in place in the boring with hammer, rope and cathead (Adapted from Kovacs, et al., 1981)

The test in our field uses a thick-walled sample tube, with an outside diameter of 50 mm and an inside diameter of 35 mm, and a length of around 650 mm. This is driven into the ground at the bottom of a borehole by blows from a slide hammer with a weight of 63.5 kg (140 lb) falling through a distance of 760 mm (30 in). The sample tube is driven 150 mm into the ground and then the number of blows needed for the tube to penetrate each 150 mm (6 in) up to a depth of 450 mm (18 in) is recorded. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance" or the "N-value". In cases where 50 blows are insufficient to advance it through a 150 mm (6 in) interval the penetration after 50 blows is recorded. The blow count provides an indication of the density of the ground, and it is used in many empirical geotechnical engineering formulae.

The main objective of SPT is as follows:

a) Boring and recording of soil stratification.
b) Sampling (both disturbed and undisturbed).
c) Recording of SPT N-value
d) Recording of ground water table.

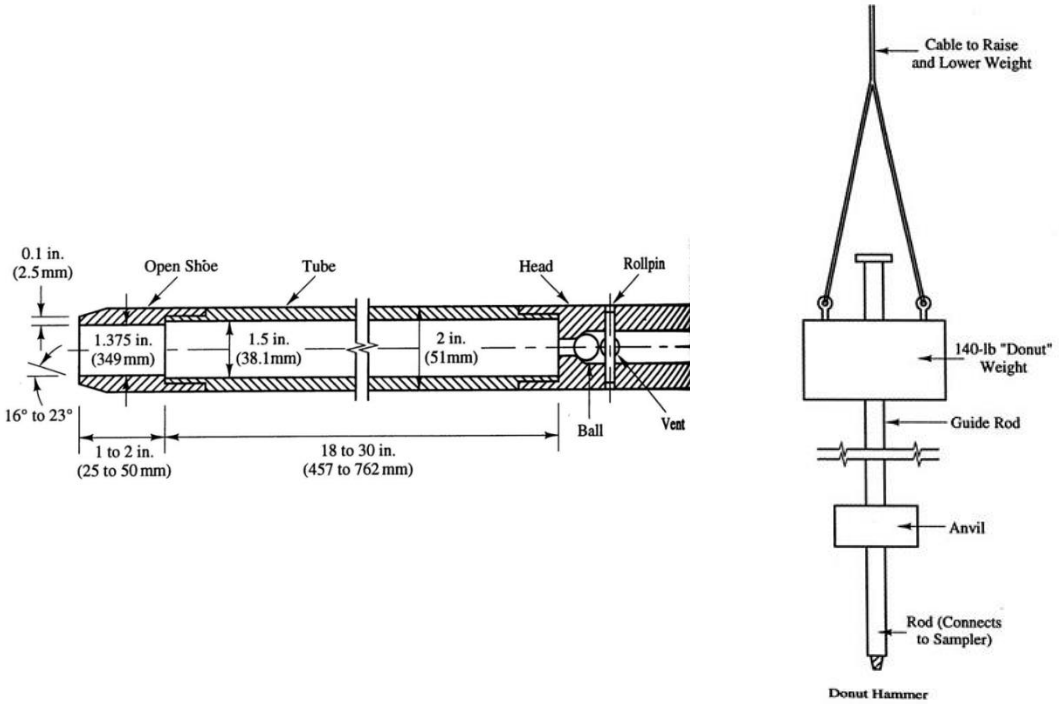


Figure 3.26 SPT Sampler and Donut Hammer

3.3.5. Grain Size Analysis (Sieve And Hydrometer Analysis)

Purpose:

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.

Standard Reference:

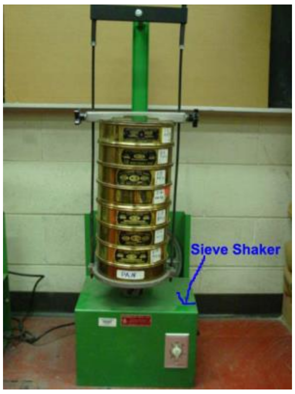
ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils

Significance:

The distribution of different grain sizes affects the engineering properties ofsoil. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.

Equipment:

Balance, Set of sieves, Cleaning brush, Sieve shaker, Mixer (blender), 152H Hydrometer, Sedimentation cylinder, Control cylinder, Thermometer, Beaker,Timing device.



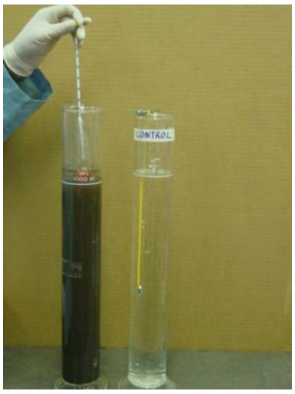


Figure 3.27 Grain size analysis test equipment

3.3.6. Specific Gravity Determination

Purpose:

This lab is performed to determine the specific gravity of soil byusing a pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

Standard Reference:

ASTM D 854-00 – Standard Test for Specific Gravity of Soil Solids by Water Pycnometer.

Significance:

The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil.

Equipment:

Pycnometer, Balance, Vacuum pump, Funnel, Spoon.

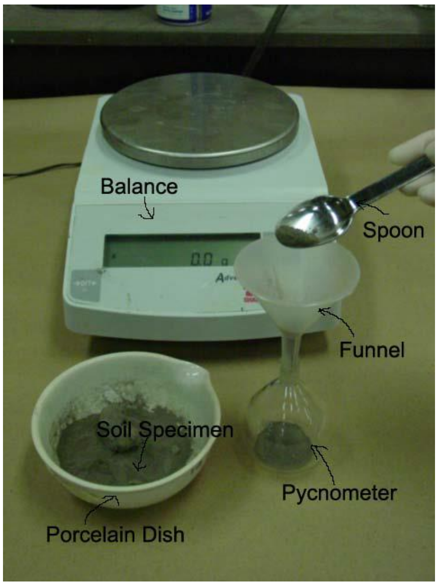


Figure 3.28 Specific gravity test equipment

3.3.7. Atterberg Limits Determination

Purpose:

This lab is performed to determine the plastic and liquid limits of a fine grained soil. The liquid limit (LL) is arbitrarily defined as the water content, inpercent, at which a pat of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit(PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

Standard Reference:

ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and

Plasticity Index of Soils

Significance:

The Swedish soil scientist Albert Atterberg originally defined seven “limits ofconsistency” to classify fine-grained soils, but in current engineering practice onlytwo of the limits, the liquid and plastic limits, are commonly used. (A third limit,called the shrinkage limit, is used occasionally.) The Atterberg limits are based onthe moisture content of the soil. The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic (flexible) state. Theliquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. The shrinkage limit is the moisture content that defines where the soil volume will not reduce further if the moisture content is reduced. A wide variety of soil engineering properties have been correlated to the liquid andplastic limits, and these Atterberg limits are also used to classify a fine-grained soil according to the Unified Soil Classification system.

Equipment:

Liquid limit device, Porcelain (evaporating) dish, Flat grooving tool with gage, Eight moisture cans, Balance, Glass plate, Spatula, Wash bottle filled with distilled water, Drying oven set at 105°C.

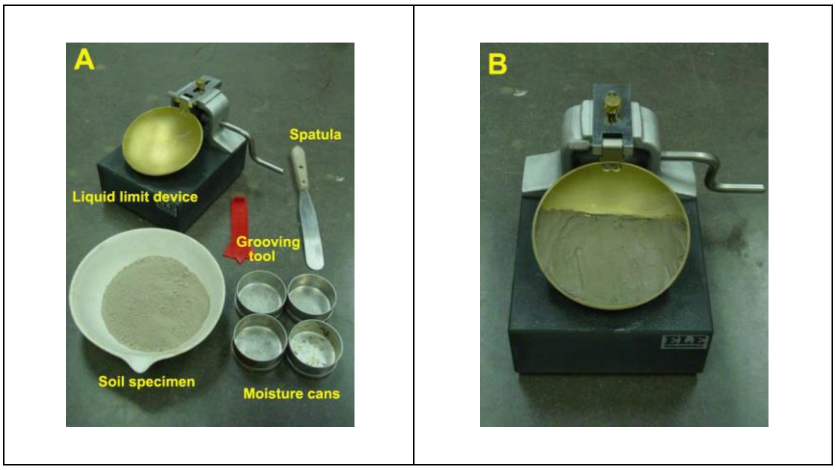


Figure 3.29 Atterberg limits test equipment

3.3.8. Direct Shear Determination

Purpose:

To determine the shearing strength of the soil using the direct shear apparatus.

Standard Reference:

ASTM D 3080- to measure the shear strength properties of soil.

Significance:

In many engineering problems such as design of foundation, retaining walls, slab bridges, pipes, sheet piling, the value of the angle of internal friction and cohesion of the soil involved are required for the design. Direct shear test is used to predict these parameters quickly. The laboratory report cover the laboratory procedures for determining these values for cohesion less soils.

Equipment:

Direct shear box apparatus, Loading frame (motor attached), Dial gauge, Proving ring, Tamper, Straight edge, Balance to weigh upto 200 mg, Aluminum container and Spatula.

Figure 3.30 Direct Shear test equipment

3.3.9. Unconfined Compression Test

Purpose:

To determine shear parameters of cohesive soil.

Standard Reference:

ASTM D2166- To determine shear parameters of cohesive soil.

Significance:

It is not always possible to conduct the bearing capacity test in the field. Some times it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remoulded soil sample. Now we will investigate experimentally the strength of a given soil sample.

Equipment:

Loading frame of capacity of 2 t, with constant rate of movement.Proving ring of 0.01 kg sensitivity for soft soils; 0.05 kg for stiff soils.Soil trimmer, Frictionless end plates of 75 mm diameter (Perspex plate with silicon grease coating), Evaporating dish (Aluminum container).
Soil sample of 75 mm length, Dial gauge (0.01 mm accuracy), Balance of capacity 200 g and sensitivity to weigh 0.01 g, Oven, Sample extractor and split sampler, Dial gauge (sensitivity 0.01mm), Vernier calipers.

Figure 3.31 Unconfined Compressiontest equipment

3.3.10. Triaxial Test (Unconsolidated-Undrained)

Purpose:

To find the shear of the soil by Undrained Triaxial Test.

Standard Reference:

ASTM D2850-70-To find the shear of the soil by Undrained Triaxial Test.

Significance:

The standard consolidated undrained test is compression test, in which the soil specimen is first consolidated under all round pressure in the triaxial cell before failure is brought about by increasing the major principal stress. It may be perform with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

Equipment:

3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes, Rubber ring, An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side, Stop clock, Moisture content test apparatus, A balance of 250 gm capacity and accurate to 0.01 gm.

Figure 3.32 Triaxial test equipment

3.3.11. Consolidation Tests

Purpose:

This test is performed to determine the magnitude and rate of volume decrease that a laterally confined soil specimen undergoes when subjected to different vertical pressures. From the measured data, the consolidation curve (pressure-void ratio relationship) can be plotted. This data is useful in determining the compression index, the recompression index and the preconsolidation pressure (or maximum past pressure) of the soi. In addition, the data obtained can also be used to determine the coefficient of consolidation and the coefficient of secondary compression of the soil.

Standard Reference:

ASTM D 2435 - Standard Test Method for One-DimensionalConsolidation Properties of Soils.

Significance:

The consolidation properties determined from the consolidation test are used to estimate the magnitude and the rate of both primary and secondary consolidation settlement of a structure or an earthfill. Estimates of this type are of key importance in the design of engineered structures and the evaluation of their performance.

Equipment:

Consolidation device (including ring, porous stones, water reservoir, and load plate), Dial gauge (0.0001 inch = 1.0 on dial), Sample trimming device, glass plate, Metal straight edge, Clock, Moisture can, Filter paper.

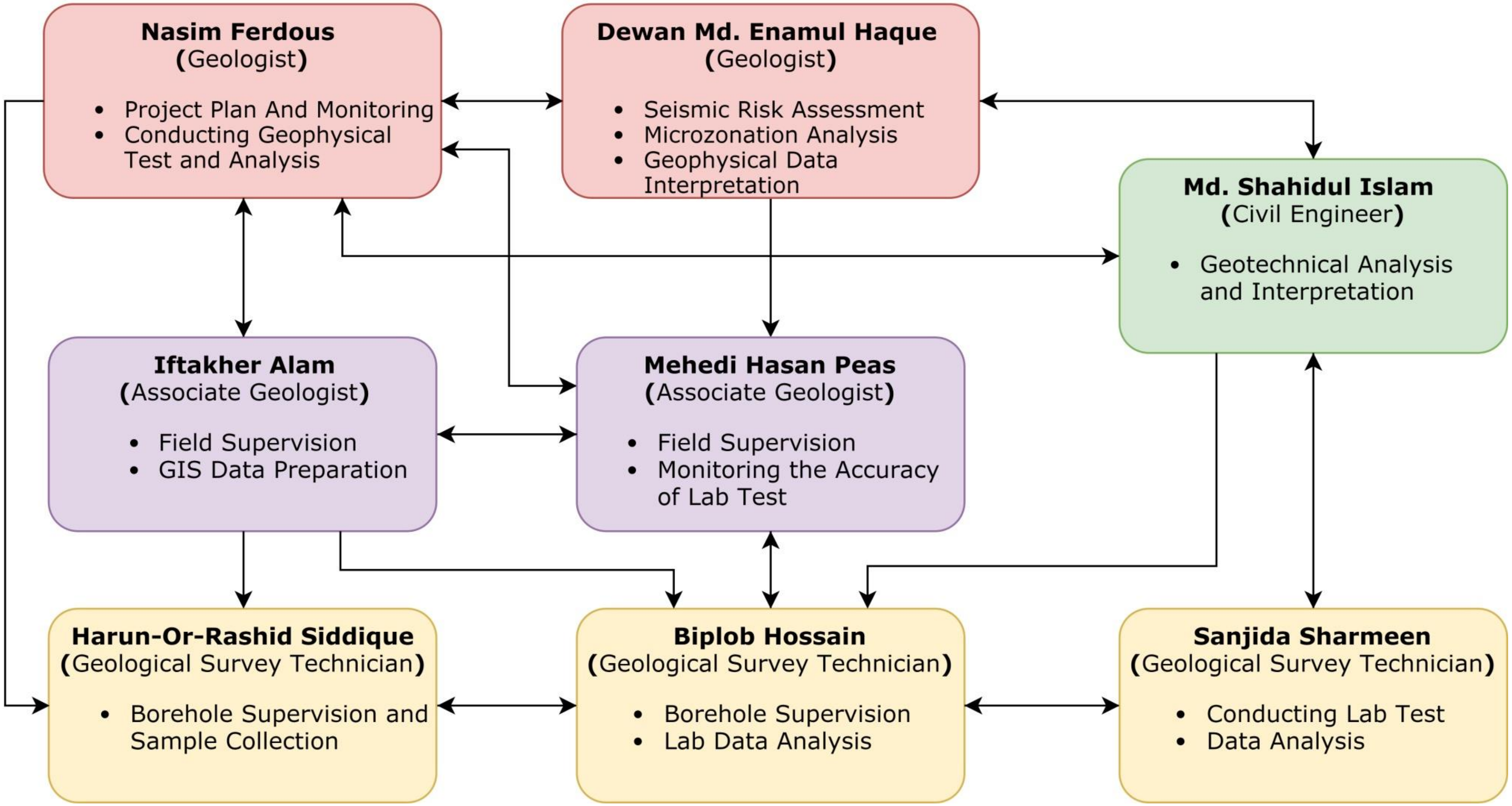
Figure 3.33 Consolidation Testsequipment

4. PROJECT PERSONNEL

i) Professional Staff							
Name of Staff	Firm/Organization	Area of Expertise	Position Assigned	Task Assigned	Home	Field	Total
1. Nasim Ferdous	Environmental & Geospatial Solutions (EGS)	Geophysics, Engineering Geology & Geo-technical engineering	Geologist	(i) To conduct and supervise boreholes for geological surveys for the study area; (ii) To check and monitor the accuracy of the borehole preparation process, collected sample and data for the geological survey; (iii) To conduct lab test of the collected samples and interpretation of the results of the lab test and (iv) Any other related jobs assigned by PD	1	2	3
2. Dewan Md. Enamul Haque	Advisor, EGS; Assistant Professor, University of Dhaka	Geologist; Natural Hazards and Climate Related Risk Assessment and Management Specialist	Geologist	(i) To conduct and supervise boreholes for geological surveys for the study area; (ii) To prepare seismic hazard, vulnerability, damage and risk assessment map for the area, (iii) To prepare micro zonation map for the area. (iv) To provide land use based interpretation of seismic hazard map for developing guidelines to prepare risk sensitive land use plan (v) Any other related jobs assigned by PD.	2	1	3
3. Md. Shahidul Islam	Consultant, EGS; Assistant Professor, University of Dhaka	Engineering Geology and Geotechnical Expert	Civil Engineer	(i) To assess the strength of road, buildings and other infrastructures to measure seismic vulnerability; (ii) Any other related jobs and (iii) Assist PD and PM in preparing plans and reports.	2	1	3

Name of Staff	Firm/Organization	Area of Expertise	Position Assigned	Task Assigned	Home	Field	Total
4. Iftakher Alam	Environmental & Geospatial Solutions (EGS)	Geophysics, Hydro-Geology	Associate Geologist	(i) To assist the geologist in preparation of seismic hazard, vulnerability, damage and risk assessment map for the area, (ii) To assist the geologist in preparation of micro zonation map for the area. (iii) To assist the geologist for land use based interpretation of seismic hazard map for developing guidelines to prepare risk sensitive land use plan (iv) Any other related jobs assigned by PD.	1	1	2
5. Mehedi Hasan Peas	Environmental & Geospatial Solutions (EGS)	Geophysics & GIS Data Management	Associate Geologist	(i) To assist the geologist in conducting and supervising boreholes for geological surveys for the study area; (ii) To assist the geologist in checking and monitoring the accuracy of the borehole preparation process, collect samples and data for the geological survey; (iii) To assist the geologist in conducting lab test of the collected samples and interpretation of the results of lab test; (iv) To assist the geologist in preparation of micro zonation map for the area and (v) Any other related jobs assigned by PD.	1	1	2
6. Biplob Hossain	Environmental & Geospatial Solutions (EGS)	Engineering Geology	Geological Survey Technician	(i) To prepare boreholes for geological surveys for the study area; (ii) To collect samples and data for the geological survey; (iii) Any other related jobs assigned by PD	0	1	1
7. Sanjida Sharmeen	Environmental & Geospatial Solutions (EGS)	Engineering Geology	Geological Survey Technician	(i) To assist the geologist in conducting lab test of the collected samples; (ii) Any other related jobs assigned by PD	1	0	1
8. Harun-Or-Rashid Siddique	Environmental & Geospatial Solutions (EGS)	Geology & Geotechnical Data Management	Geological Survey Technician	(i) To prepare boreholes for geological surveys for the study area; (ii) To collect samples and data for the geological survey and (iii) Any other relates jobs assigned by PD.	0	1	1
				Total man-months		**16**	

Key Personnel Activities



5. PROJECT OFFICE

5.1. Client

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Director
Urban Development Directorate, (UDD)
Office Address: 82, Segunbagica, Dhaka - 1000.

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Senior Planner and Project Director
Preparation of Payra-Kuakata Comprehensive Plan Focusing on Eco-Tourism
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5.2. Consultant

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Attention : NASIM FERDOUS, Coordinator,
Engineering Geology and Geotechnical Unit, EGS.
Environmental & Geospatial Solutions
Facsimile : +88 01719519911
E-mail : ferdous.nasim1@gmail.com

6. WORK PLAN

An intensive Geological and Geomorphological, Geotechnical, and Geophysical survey will be carried out for site characterization and sustainable development plan at Amtali, Taltoli, Barguna Sadar and Patharghata upazila of Barguna district and Galachipa, Rangabali and Kalapara upazila of Patuakhali disrtict of Bangladesh. So geotechnical and geophysical investigations are essential tools for seismic risk assessment in this project area. To accomplish this project, our team will start geotechnical and geophysical investigations on 10/07/2018 and it will take 30 to 40 days to acquire all data. The geophysical investigations include PS-logging, Single Microtremor and Multi-channel Analysis of Surface Wave (MASW). The geotechnical investigations will contain geotechnical boreholes with Standard Penetration Test (SPT) and sample collection (disturbed and undisturbed samples). The geotechnical laboratory tests, such as Atterberg limits, grain size analysis, specific gravity determination, direct shear test, Unconfined compression strength, triaxial tests and consolation test will be conducted to prepare subsurface geological and geotechnical model for bearing capacity and settlement estimation. The average shear wave velocity up to the depth 30 m (AVS 30) will be determined interpreting the geophysical and geotechnical SPT data and geological and geotechnical subsurface model. An engineering geological map using AVS 30 will be prepared for site specific seismic hazard assessment.

The tentative location of Standard Penetration Test, Multi-channel Analysis of Surface Wave (MASW), PS Logging (Downhole Seismic) test and Single Microtremor are as follows:

Standard Penetration Test (SPT) Locations

BH_ID	Latitude	Longitude		BH_ID	Latitude	Longitude
BH-01	21.81184	90.12337		BH-46	22.06561	89.93202
BH-02	21.83506	90.23598		BH-47	22.07317	89.98623
BH-03	21.89527	90.04013		BH-48	22.10378	89.99477
BH-04	21.85506	90.10119		BH-49	22.08903	90.05245
BH-05	21.87723	90.1313		BH-50	22.07441	90.0919
BH-06	21.86557	90.19448		BH-51	22.07723	90.1555
BH-07	21.89246	90.23793		BH-52	22.08203	90.20732
BH-08	21.90849	90.06557		BH-53	22.09129	90.2582
BH-09	21.93089	90.11411		BH-54	22.102	90.31017
BH-10	21.9115	90.14508		BH-55	22.1196	90.34388
BH-11	21.9115	90.19448		BH-56	22.03292	90.36621
BH-12	21.92625	90.2415		BH-57	22.01661	90.50767
BH-13	21.89256	90.33653		BH-58	22.11727	90.53993
BH-14	21.91325	90.41933		BH-59	22.11624	89.92992
BH-15	21.81014	90.49104		BH-60	22.15523	89.96041
BH-16	21.93934	90.05312		BH-61	22.17217	90.01743
BH-17	21.96657	90.08463		BH-62	22.13591	90.07411
BH-18	21.93923	90.16649		BH-63	22.11556	90.09478
BH-19	21.95743	90.19448		BH-64	22.15509	90.11319
BH-20	21.98479	90.22532		BH-65	22.15245	90.19983
BH-21	21.94815	90.27687		BH-66	22.14114	90.24388
BH-22	21.98798	90.3682		BH-67	22.14114	90.29328
BH-23	21.9696	90.4407		BH-68	22.15274	90.35399
BH-24	21.91135	90.52324		BH-69	22.11591	90.39466
BH-25	21.98925	89.96466		BH-70	22.13549	90.45012
BH-26	22.00823	90.00339		BH-71	22.19706	89.96794
BH-27	22.00699	90.04978		BH-72	22.20504	90.08204
BH-28	22.01318	90.08649		BH-73	22.19391	90.11768
BH-29	22.01516	90.14755		BH-74	22.19659	90.1565
BH-30	22.00336	90.19448		BH-75	22.2017	90.21091
BH-31	22.00336	90.24388		BH-76	22.17904	90.25221
BH-32	22.01079	90.28317		BH-77	22.19495	90.29923
BH-33	21.94583	90.34772		BH-78	22.1948	90.34655
BH-34	22.0279	90.42706		BH-79	22.18707	90.39209
BH-35	21.96708	90.57786		BH-80	22.17279	90.41948
BH-36	22.03548	89.96959		BH-81	22.19	90.46916
BH-37	22.03668	90.02465		BH-82	22.23528	90.13023
BH-38	22.03934	90.06089		BH-83	22.24781	90.2582
BH-39	22.05771	90.11861		BH-84	22.22893	90.30565
BH-40	22.04605	90.1426		BH-85	22.25024	90.32611
BH-41	22.03063	90.21613		BH-86	22.23775	90.37757
BH-42	22.04601	90.25206		BH-87	22.21599	90.41121
BH-43	22.03769	90.31976		BH-88	22.28785	90.40904
BH-44	22.07519	90.49437		BH-89	22.28279	90.46112
BH-45	22.04085	90.53056		BH-90	22.33646	90.45877

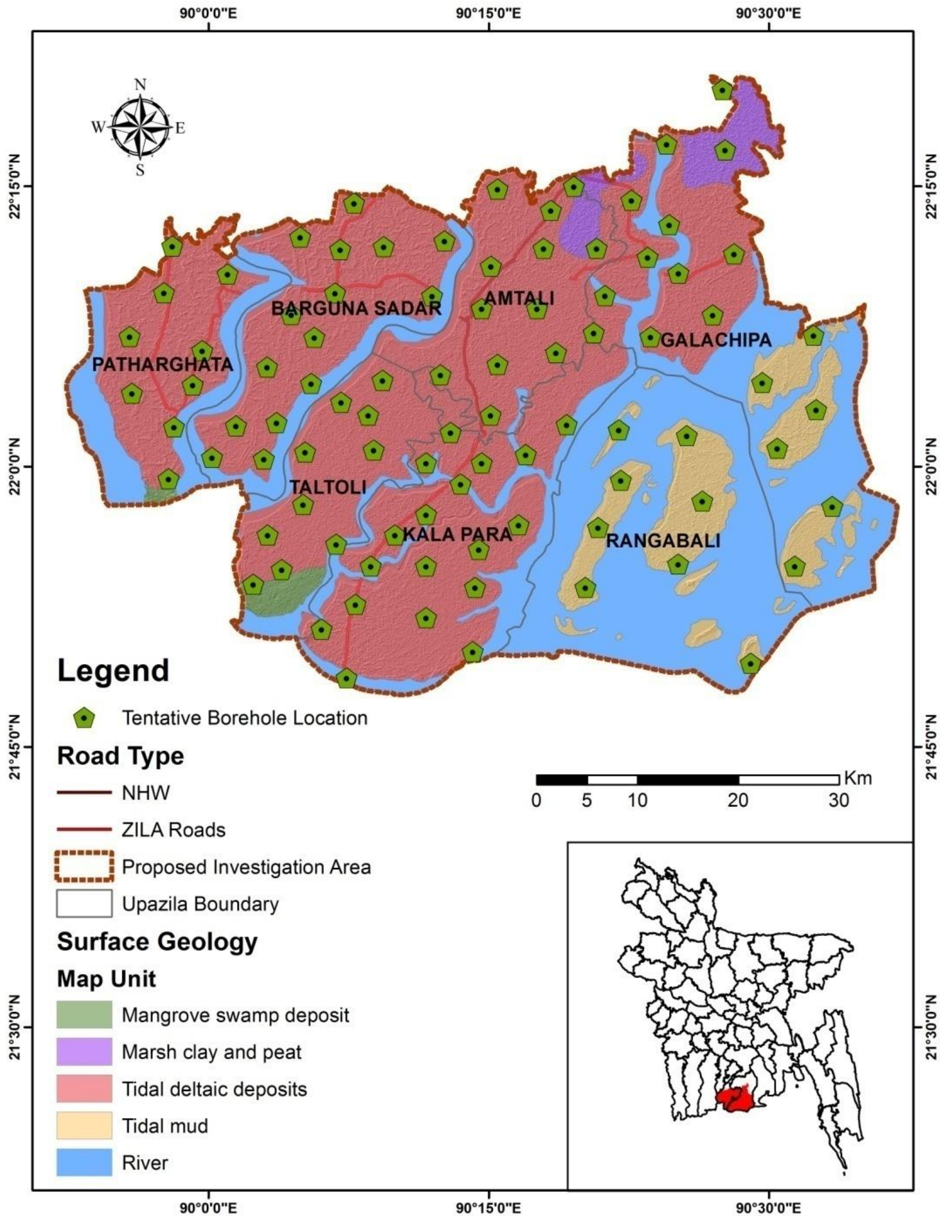

Figure 6.1 Tentative sites location for Borehole (SPT test)

MASW Survey Locations

ID_MASW	Latitude	Longitude		ID_MASW	Latitude	Longitude
MASW01	21.91495	90.09752		MASW14	22.17232	90.15216
MASW02	21.87011	90.17206		MASW15	21.94557	90.09064
MASW03	22.0734	90.23047		MASW16	22.11334	90.2753
MASW04	21.97021	90.17502		MASW17	22.10709	90.22895
MASW05	21.92912	90.38927		MASW18	22.01435	90.21807
MASW06	22.00032	90.40109		MASW19	22.05102	90.47718
MASW07	22.09064	89.92504		MASW20	22.21838	90.12695
MASW08	22.13016	90.00817		MASW21	22.20615	90.30252
MASW09	22.16262	89.97264		MASW22	22.062	90.31676
MASW10	22.14077	90.08432		MASW23	21.92616	90.21159
MASW11	22.04556	90.19077		MASW24	22.25772	90.42413
MASW12	22.01624	90.45615		MASW25	22.1584	90.39068
MASW13	22.07808	90.06384		MASW14	22.17232	90.15216

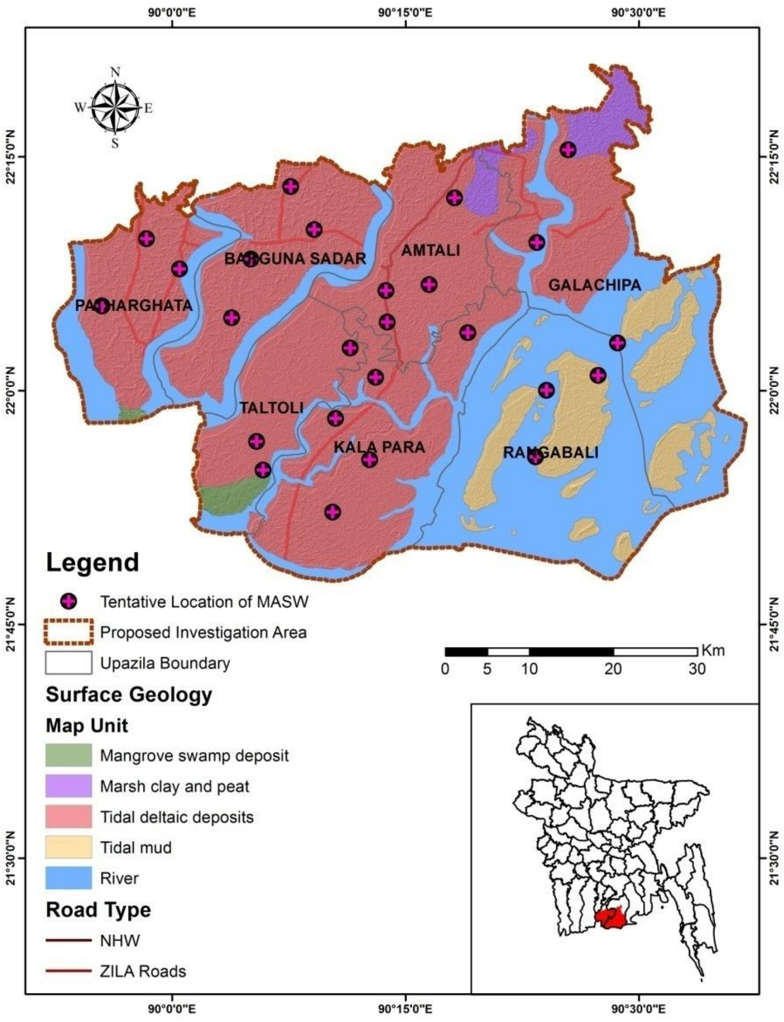

Figure 6.2 Tentative sites location for MASW survey

PS Logging Test Locations

ID_PS	Latitude	Longitude
PS01	21.86557	90.19448
PS02	21.89256	90.33653
PS03	21.93934	90.05312
PS04	21.98479	90.22532
PS05	22.0279	90.42706
PS06	22.06561	89.93202
PS07	22.03934	90.06089
PS08	22.07723	90.1555
PS09	22.04085	90.53056
PS10	22.14114	90.24388
PS11	22.1196	90.34388
PS12	22.17217	90.01743
PS13	22.19659	90.1565
PS14	22.22893	90.30565
PS15	22.28279	90.46112

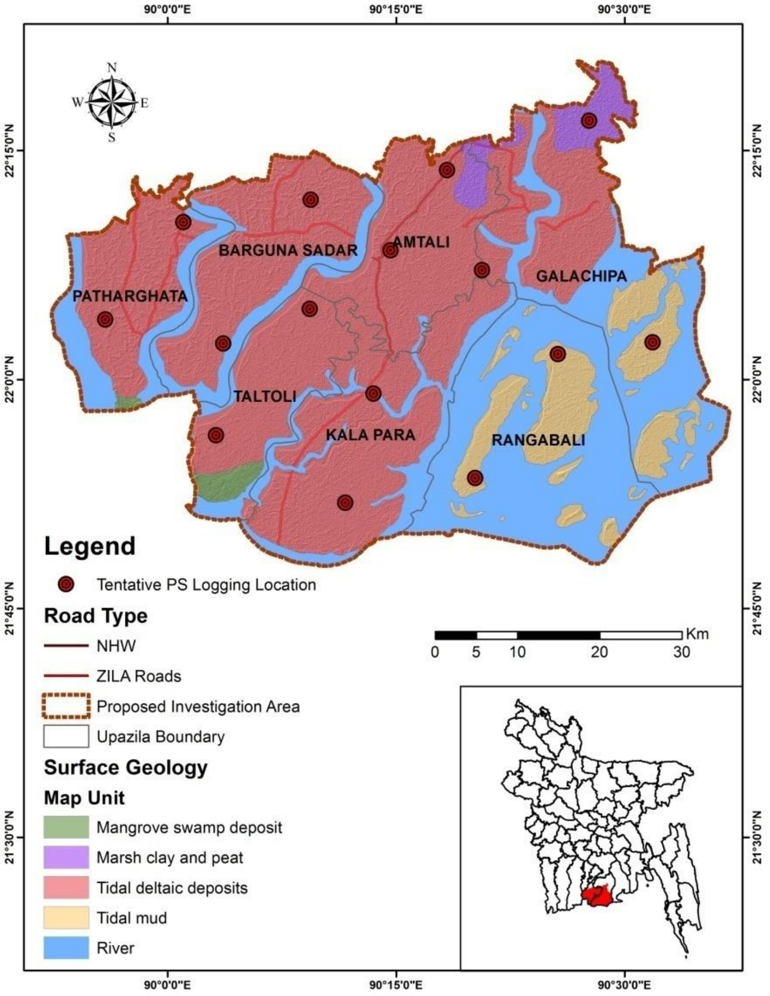

Figure6.3 Tentative sites location for PS Logging test

Single microtremor survey Locations

ID_Microtremor	Latitude	Longitude	ID_Microtremor	Latitude	Longitude
MT01	21.9277	90.06547	MT21	22.18291	89.99211
MT02	22.10243	90.16991	MT22	22.09788	90.09244
MT03	21.84198	90.11228	MT23	22.19211	90.08727
MT04	22.07329	90.28337	MT24	21.96831	90.13312
MT05	21.89959	90.1692	MT25	22.14925	90.12303
MT06	21.94392	90.4188	MT26	22.13456	90.31911
MT07	21.97012	90.36335	MT27	22.17212	90.27634
MT08	21.84925	90.33145	MT28	21.99149	90.25949
MT09	22.02006	89.9498	MT29	22.18707	90.39209
MT10	22.09919	89.96589	MT30	22.09125	90.51378
MT11	22.14282	89.93635	MT31	22.05164	90.50757
MT12	22.0159	90.02526	MT32	22.23048	90.16105
MT13	22.12097	90.04692	MT33	22.21605	90.26183
MT14	22.01509	90.11827	MT34	22.0356	90.30026
MT15	22.14955	90.18859	MT35	22.22702	90.32673
MT16	21.83377	90.17823	MT36	21.89537	90.20609
MT17	21.90594	90.2776	MT37	22.20694	90.45494
MT18	22.10259	90.36954	MT38	22.24603	90.3891
MT19	21.98923	90.47889	MT39	22.31095	90.47075
MT20	21.99993	90.4267	MT40	22.17423	90.45004

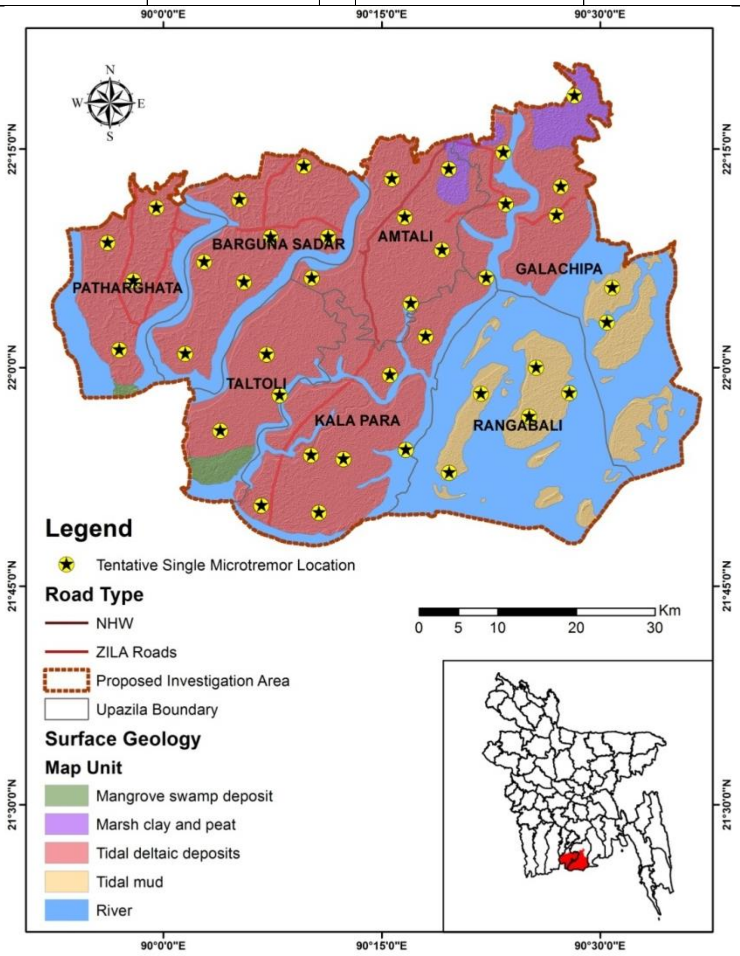

Figure6. 4 Tentative sites location for single microtremor survey

6.1. Time Schedule

Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan)

Activities	PLAN START	PLAN DURATION	ACTUAL START	Actual DURATION	% COMPLETE	Working Periods						
						21 Jun to 20 Jul 2018	21 Jul to 20 Aug 2018	21 Aug to 20 Sep 2018	21 Sep to 20 Oct 2018	21 Oct to 20 Nov 2018	21 Nov to 20 Dec 2018	21 Dec 2018 to 20 Jan 2019
Site Selection for Geotechnical & Geophysical Works including Mobilization and demobilization	7/10/2018	20	7/10/2018	20	0%							
Conducting boring : SPT and Sample collection	7/16/2018	25	7/16/2018	25	0%							
Conducting Geophysical Test: Downhole seismic (PS logging), MASW & Microtremor	7/22/2018	20	7/22/2018	20	0%							
Lab Test and Analysis	8/1/2018	90	8/1/2018	90	0%							
Data Processing & Interpretation	8/30/2018	115	8/30/2018	115	0%							
Secondary data Collection	8/15/2018	75	8/15/2018	75	0%							
Deliveries						Working Periods						
Mobilization Report	6/21/2018	15	6/21/2018	15	100%							
Inception Report	6/21/2018	30	6/21/2018	30	0%							
Review Report	7/21/2018	31	7/21/2018	31	0%							
Geo-technical & Geophysical test Report	9/7/2018	75	9/7/2018	75	0%							
Draft Report	11/21/2018	30	11/21/2018	30	0%							
Final Report	12/21/2018	30	12/21/2018	30	0%							

6.2. Deliveries

The following reports will be submitted to the UDD on or before the following dates:

Serial no.	Deliveries	Submission date
1	Mobilization Report	05/07/2018
2	Inception Report	20/07/2018
3	Report on review of (i) Morphotectonic and Neotectonic studies of Bangladesh and its surrounding areas, (ii) Geodynamic model of Bangladesh, (iii) Updating fault model.	20/08/2018
4	Report on geophysical and geotechnical investigations, lab test and engineering geological mapping	20/11/2018
5	Draft report on Data relating to Geo-technical and Geo-physical Survey including Laboratory test results including seismic hazard assessment and its interpretation	20/12/2018
6	Final Report on seismic hazard assessment and its interpretation	20/01/2019

7. RESOURCE ALLOCATION

Geophysical Test		
SL No.	**Name of Test/Survey**	**Test Category**
1	PS Logging	Down-hole Seismic Test (DS)
		Cross-hole Seismic Test (CS)
2	Multi-channel Analysis of Surface Wave	Active
3	Small Scale Microtremor Measurement (SSMM)	Passive
4	Microtremor Survey	Single Array
		MT Array
5	Electrical Resistivity Survey	Vertical Electrical Sounding (VES)
		2D Resistivity (Electrical Tomography)
		Spontaneous Potential (SP)

Geotechnical Test	
SL No.	**Name of Test/Survey**
In-Situ (Field)	
1	Standard Penetration Test (SPT)
2	Field Permeability Test
3	Field Van Shear Test
4	Pressure Meter Test
5	Field Density Test
Laboratory Test	
1	Water Content Determination
2	Organic Matter Determination
3	Density (Unit Weight) Determination
4	Specific Gravity of Soil Particles Determination
5	Relative Density Determination
6.	Grain Size Analysis
7	Atterberg Limits
8	Moisture-Density Relation(Compaction) Test
9	Permeability (Hydraulic Conductivity) Test
10	Consolidation Test
11	Unconfined Compression Strength(UCS) Test
12	Direct Shear Test
13	Tri-axial Compression Test (UU)

INSTRUMENT LISTS

Geophysical Equipment's

1.		Down-hole/Cross-hole Seismic Logger OLSON INSTRUMENTS, U.S.A.
2.		Multi-channel Analysis of Surface Wave (MASW) Survey Instrument. EXPLORATION SEISMOGRAPH PASI MOD. ANTEO
3.		4 pole Resistivity Meter OYO JAPAN
4.		MicrotremorSurvey Instrument Japan

Geotechnical Equipment's

1		Two sets of Standard Penetration Test Boring Rig
2		ELE International Triaxial Instrument
3		One Dimensional Consolidation Test Instrument ELE International
4		Direct Shear Test Instrument ELE International

5		Oven
6		Sieve shaker
7		Hydrometer

8. LIMITATION AND MITIGATION APPROACH

The project "Engineering Geological and Geo-Physical Surveys" will contribute to develop a sustainable development plan for Barguna and Patuakhali district in Bangladesh. However, the project is quite challenging. The entrusted Consultant, EGS, of UDD, for this project, who has to accomplish the assigned task with limited time period. Accessibility of the project area is quite difficult, due to inadequate road network and numerous isolates char areas. Another limitation of the project is the availability and accessibility of secondary data. So we have to engage a team having a number of technicians, geologist and specialists; and we will do that accordingly. UDD will provide sufficient support regarding the secondary data issue. Thus the project will be much costlier than expected initially.

9. CONCLUSION

An intensive Geological and Geomorphological, Geotechnical, and Geophysical survey will be carried out for site characterization and sustainable development plan at Amtali, Taltoli, Barguna Sadar and Patharghata upazila of Barguna district and Galachipa, Rangabali and Kalapara upazila of Patuakhali disrtictof Bangladesh. From geotechnical and geological data base would give a clear idea about the sub-surface and surface status of particular landscape where newly urban developing activities or any other mega infrastructure project is going on and these mentioned investigation also gives an idea about the vulnerability of existing build up the 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. On the other hand, if the infrastructures are built according to this risk informed physical landuse plan, the long-term maintenance cost will be reduced and the developed structure will withstand against the potential natural calamity.