GLOBAL JOURNAL OF BIO-SCIENCE AND BIOTECHNOLOGY

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CORRELATION OF GEOPHYSICAL AND GEOTECHNICAL INVESTIGATIONS FOR SEISMIC HAZARD ASSESSMENT IN DHAKA CITY, BANGLADESH

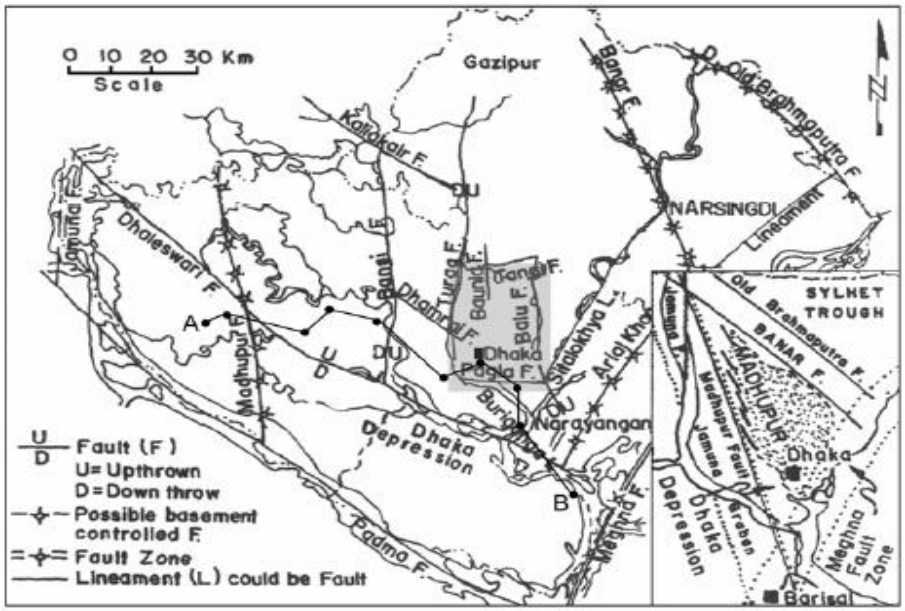
Md. Shakhawat Hossain[1], B.M. Rabby Hossain[2], A.K.M Fayazul Kabir[3], A.S.M Woobaid Ullah[3], A.S.M Maksud Kamal[3], Chowdhury Quamruzzaman[3]
[1]Assistant Manager, Geophysical Division, BAPEX, Dhaka, Bangladesh
[2]Geologist, Premier Minerals Limited, Bangladesh
[3]Department of Geology, Dhaka University, Dhaka-1000, Bangladesh

ABSTRACT
In order to assess seismic hazard for Dhaka city, an approach has been conducted by correlating geophysical (PS logging, shallow seismic and micro tremor) and geotechnical (SPT) methods. In this research work seven sites have been selected where both geophysical and geotechnical surveys have been conducted. From PS logging, SPT and Shallow Seismic (without source) S-wave velocity is calculated. Micro tremor method is used to determine predominant period and amplification. S-wave velocity is converted to AVS30 (average S-wave velocity to 30m) and then amplification because there is a relation between S-wave velocity and amplification, generally low S-wave velocity gives high amplification and high S-wave velocity gives low amplification. To accomplish the objective, the four methods have been correlated based on AVS30 and amplification. The AVS30 derived from PS logging, shallow seismic and SPT gives more or less similar values but amplification derived from micro tremor analysis deviates moderately to highly, the possible reason for this deviation may be noise or instrumental errors.

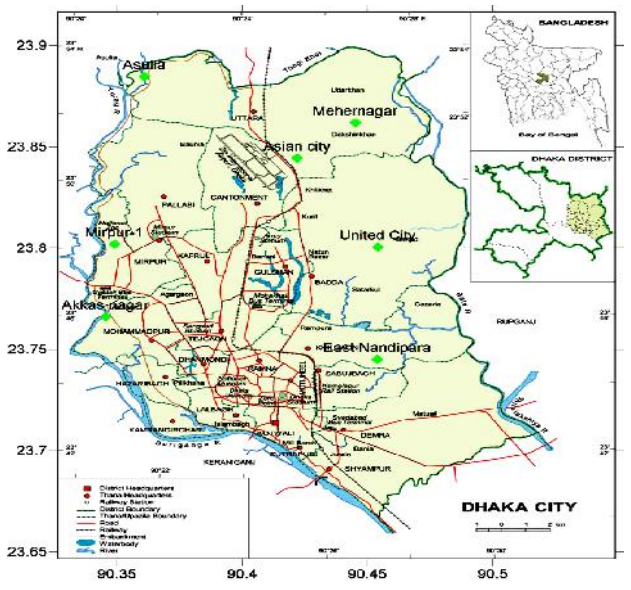
KEYWORDS: AVS30 Method, Correlation, Dhaka City, Geophysical and Geotechnical Investigations, Ground amplification, Microtremor, Seismic Hazard Assessment.

INTRODUCTION

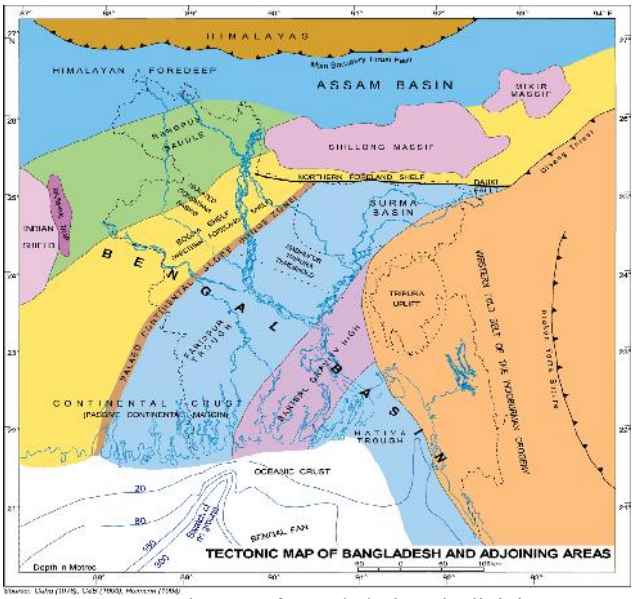
Seismic hazard is a physical phenomenon, such as ground shaking or ground failure, which is associated with an earthquake which may produce adverse effects on human activities. Due to economic and administrative focal-point, there has been a phenomenal growth of buildings and other structures in the mega city, Dhaka (Map-1). The city Attains one of the highest values of seismic hazard (Comprehensive Disaster Management Programme (CDMP), 2009) among twenty cities of the world (Map-2). Dhaka, the ancient city and the capital of Bangladesh, is located in the central part of the country and lies between 23°40”N-23°54”N latitude and from 90°20”E-90°31”E longitude (Map-3).



Map 1: Tectonic map of Dhaka region—after EPC/ MMP 1991 and Khandoker 1987(inset). Area under shade indicates the study area.



Map-2: Location map of the study area with data collection point (Source: Banglapedia, 2004: [DVD], Dhaka, Bangladesh).



Map 3: Tectonic map of Bangladesh and adjoining areas (Source: Banglapedia, 2004 : [DVD], Dhaka, Bangladesh)

The main objective of the study is to evaluate seismic hazard through geophysical and geotechnical investigations and to build a correlation between geophysical and geotechnical tools for determining share wave velocity, correlation between geophysical and geotechnical tools for determining ground amplification, find out the best method for determine share wave velocity, build up empirical equation between amplification derived from AVS30 and amplification derived from microtremor and to find out predominant period and amplification from microtremor data and correlate with S-wave velocity.

METHODOLOGIES

To complete the investigation seven sites have been selected where both geophysical (PS Logging, Shallow Seismic, and Microtremor) and geotechnical (SPT) surveys have been conducted. PS logging measures the travel time with depth and from which S-wave velocity (Matsueda, f. & Kawaharadah., (1994) is calculated. Shallow seismic (without source) survey uses natural seismic source to measure ambient vibration and from which S-wave velocity can be calculated. The Standard Penetration Test (Fletcher, G.F.A., 1965) gives SPT- N values to calculate S-wave velocity (Ohta, Y., Goto, N., Kamagi, H. & Shiono, K., (1976). Microtremor method (Nakamura, Y., 1989, Nogoshi, M. & Igarashi, T., 1970) measures low amplitude ambient vibration and is used to determine predominant period and amplification. A procedure has been followed which is reflected in the following diagram (Figure-1).

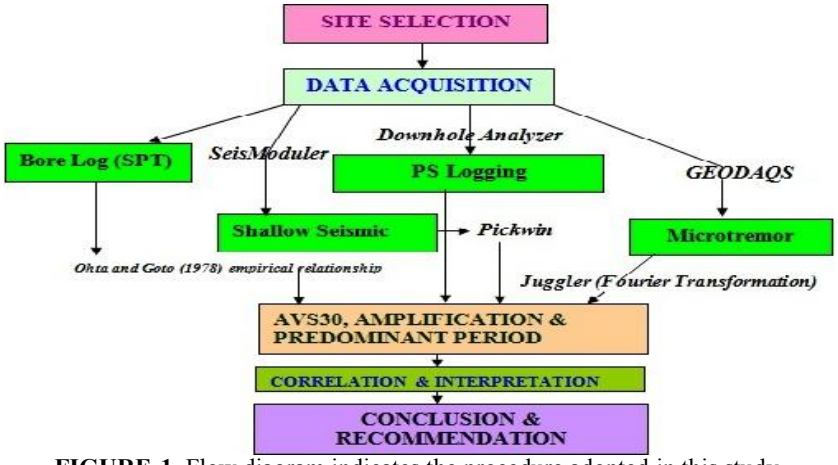


FIGURE-1. Flow diagram indicates the procedure adopted in this study

Interpretation and Correlation

The velocity of S-wave is usually slower in the surface portion than in the consolidated portion deep underground. S-wave travels roughly orthogonal to the ground surface and multi reflection phenomena occur in the surface layer. Amplification of seismic energy depends on soil character

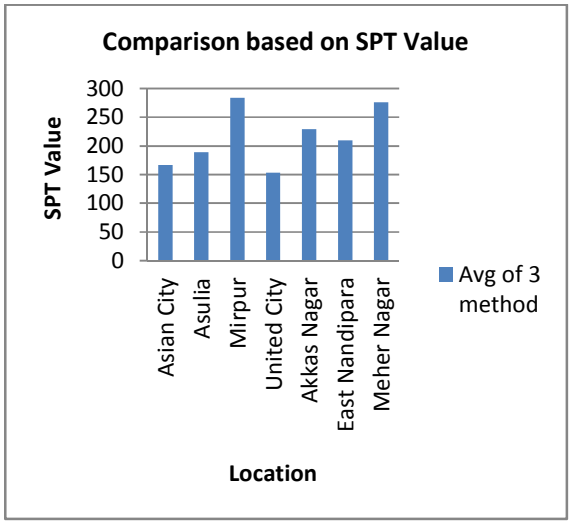
and is called Ground amplification. The ground vibrates greatly with the appearances of certain period (frequency) known as predominant period. Interpretation and Correlation are made on the basis of AVS30 and ground amplification.

Interpretation & Correlation based on AVS30

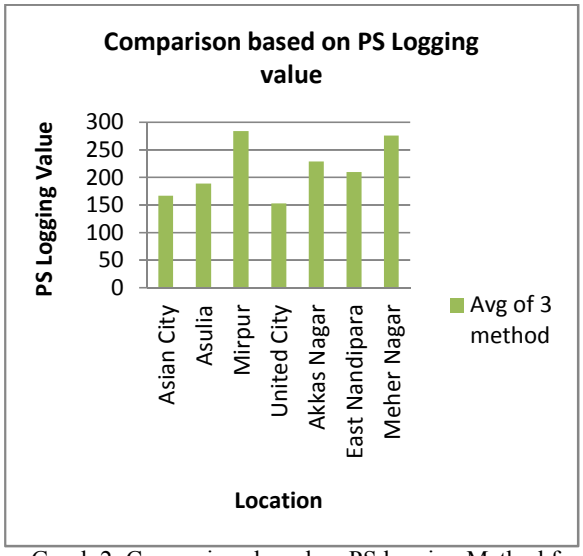
From overall data analysis, it is appears that the Average S-wave Velocity to 30m (AVS30) derived from different methods (SPT, PS Logging, Shallow Seismic) give more or less similar values. However, if the data could be gathered more precisely then might have got closer results. The AVS30 from the locations namely, Asian City, Asulia, Mirpur, United City, Akkas Nagar, East Nandipara, Meher Nagar of Dhaka city have been averaged from SPT, PS Logging, Shallow Seismic for interpretation.

TABLE I: CORRELATION BASED ON AVS30

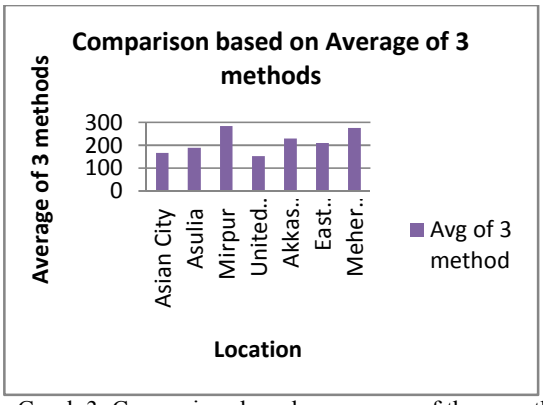
LOCATION	AVS30(m/s)			
	SPT	SHALLOW SIESMIC	PS LOGGING	Avg of 3 methods
Asian City	163	126	213	167
Asulia	207	207	152	189
Mirpur	308	238	307	284
United City	132	191	136	153
Akkas Nagar	202	276	211	229
East Nandipara	221	136	275	210
Meher Nagar	261	227	340	276



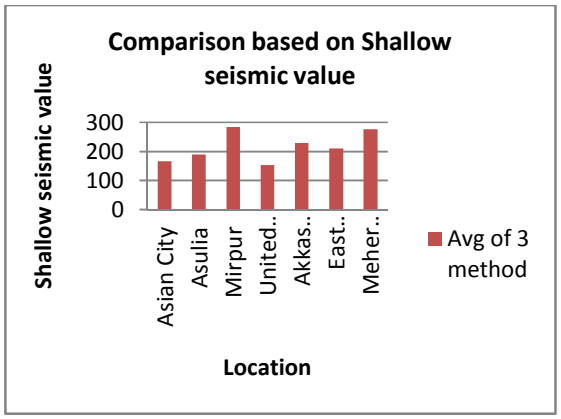
GRAPH 1: Comparison based on SPT methods for seven study area



Graph 2: Comparison based on PS logging Method for seven study area

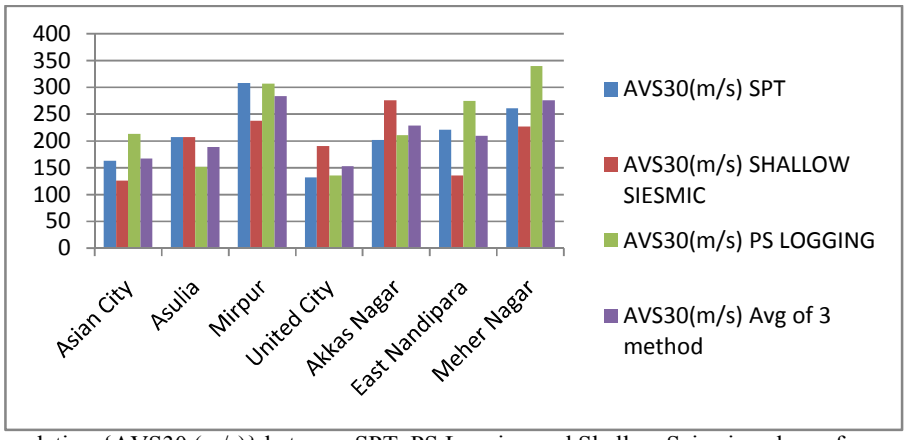


Graph 3: Comparison based on average of three methods for seven study area



Graph 4: Comparison based on Shallow seismic values for seven study area

The lithological description of different locations based on their AVS30 are made with reference to Site categories in NEHRP Provisions (Martin,1994), for example at Asian City the AVS30 is 167m/s from the site categories this value falls under NEHRP category E (Table-2) which defines the lithology to be soft clays.



GRAPH 5: Correlation {AVS30 (m/s)} between SPT, PS Logging and Shallow Seismic values of seven study area.

TABLE III: SITE CATEGORIES IN NEHRP PROVISIONS (MARTIN, 1994)

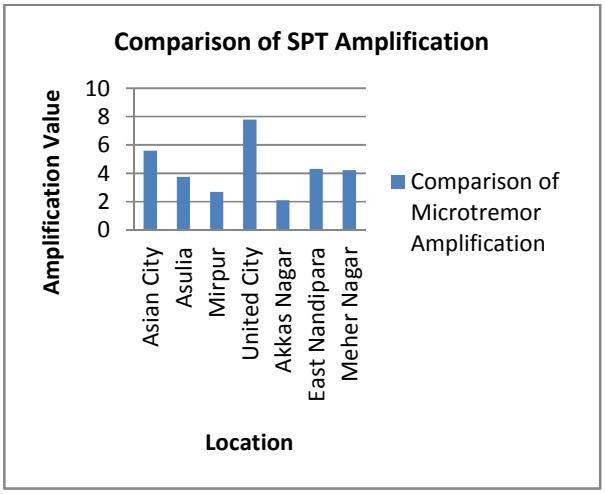
NEHRP Category	Description	AVS30(m/s)
A	Hard rock	>1500
B	Firm to Hard rock	760-1500
C	Dense soil, soft rock	360-760
D	Stiff soil	180-360
E	Soft clays	<180
F	Special study soil>36m thick	

Interpretation & Correlation based on Ground Amplification

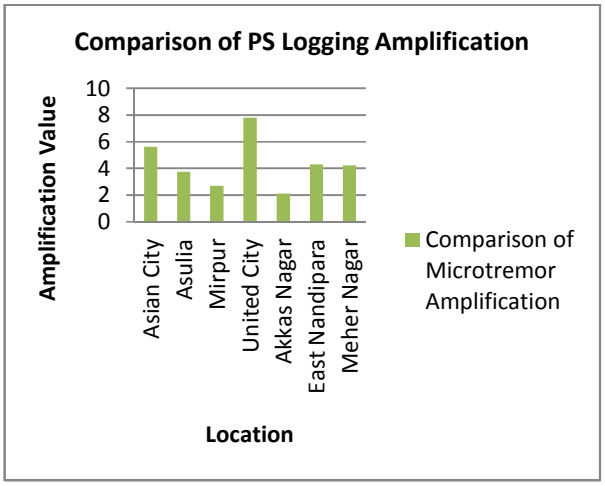
TABLE IIIII; AMPLIFICATIONS AND SEISMIC HAZARD RANKS (KAMAL, 2004)

Amplification	Rank
1 to 2	Low Hazard
2 to 3	Moderately Low Hazard
3 to 5	Moderate Hazard
>5	Relatively High Hazard

From the graph-6, 7, 8, 9 respectively shows that amplification values derived from SPT, PS Logging and Shallow Seismic are more or less similar.



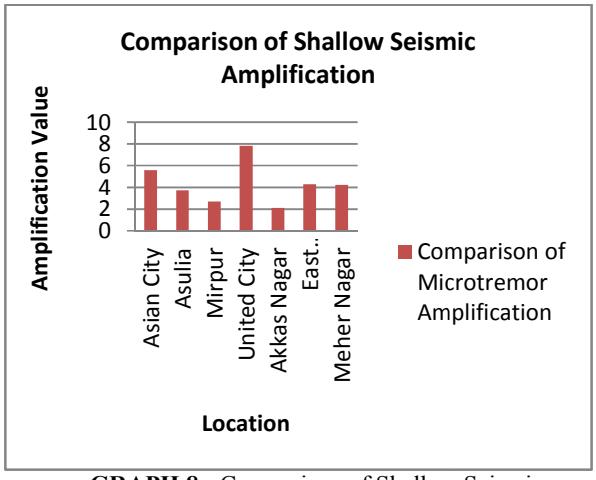
GRAPH 6: Comparison of SPT Amplification methods for seven study area



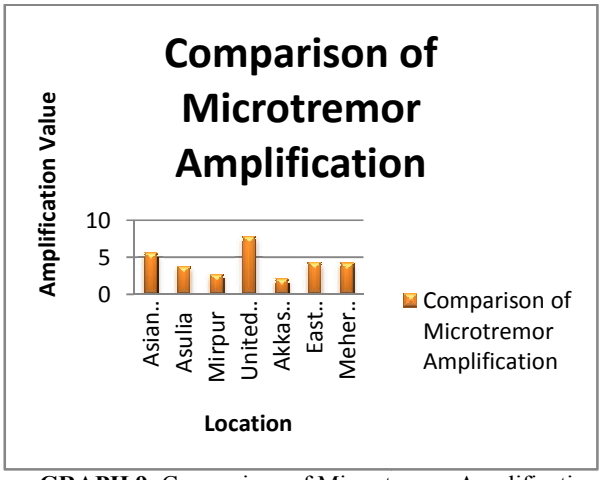
GRAPH 7: Comparison of PS logging Amplification for seven study area

TABLE IV: CORRELATION BASED ON GROUND AMPLIFICATION

LOCATION	METHOD					
	SPT	SHALLOW SIESMIC	PS LOGGING	Average	MICROTREMOR	
	Amp	Amp	Amplification	Amplification	Amplification	Predominant Period
Asian City	2	2.6	1.8	2.15	5.6	0.53
Asulia	1.8	1.8	2.15	1.90	3.75	0.75
Mirpur	1.5	1.7	1.5	1.60	2.7	1.3
United City	2.25	1.9	2.2	2.15	7.8	0.78
Akkas Nagar	1.8	1.6	1.75	1.75	2.11	0.75
East Nandipara	1.73	2.2	1.6	1.85	4.3	0.66
Meher Nagar	1.65	1.73	1.45	1.60	4.23	0.34



GRAPH 8: Comparison of Shallow Seismic Amplification for seven study area



GRAPH 9: Comparison of Micro tremor Amplification for seven study area

But it was seen that the amplifications values which were derived from Microtremor analysis (Rodriguez, V. H. S. & Midorikawa, S., 2002), deviated moderately to highly from those values derived from other procedures, the possible reason for this deviation may be noise or instrumental errors. An empirical relationship between amplification derived from AVS30 and amplification derived from Microtremor is given below in Figure-2.

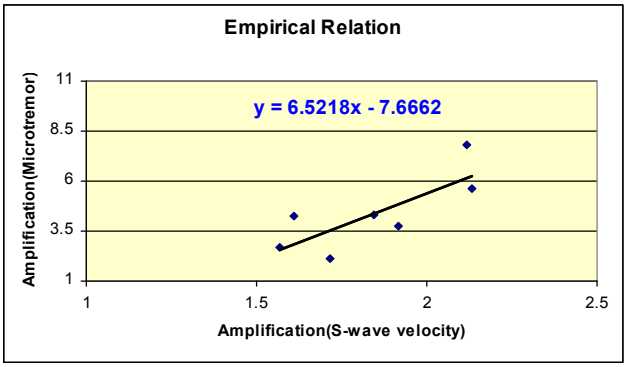


FIGURE -2: Empirical relationship between amplification Derived from AVS30 and amplification derived from microtremor.

CONCLUSION

Correlations of geophysical and geotechnical investigations based on AVS30 and amplification are the main requirement for seismic hazard assessment. AVS30s derived from SPT, shallow seismic and PS logging is more or less similar. AVS30s (derived from SPT, shallow seismic and PS logging) of Asian City, Asulia, Mirpur, United City, Akkas Nagar, East Nandipara, Meher Nagar are 167m/s, 189m/s, 284m/s, 153m/s, 229m/s, 210m/s, 276m/s and are reflected in the Graph-1, Graph-2, Graph-3 and Graph-4 respectively.

Amplifications derived from AVS30 (SPT, shallow seismic and PS logging) are more or less similar but amplifications derived from microtremor, deviate moderately to highly; the possible reason for this deviation may be noise or instrumental errors. So site characteristics are described based on amplification derived from AVS30. According to amplifications the hazard is ranked into four categories: low, moderately low, moderate and relatively high.

Amplifications of Asian City, Asulia, Mirpur, United City, Akkas Nagar, East Nandipara, Meher Nagar are 2.15, 1.90, 1.60, 2.15, 1.75, 1.85, 1.60 which are reflected in the Graph-6, Graph-7, Graph-8, Graph-9 respectively. Asian City, Asulia, United City fall under moderately low hazard rank and Mirpur, Akkas Nagar, East Nandipara, Meher Nagar fall under low hazard rank.

RECOMMENDATION

Ground amplification, predominant period and S-wave velocity are essential for seismic hazard assessment. SPT, shallow seismic and PS logging methods give amplification and S-wave velocity and microtremor method give predominant period and amplification. Amplifications derived from SPT, shallow seismic and PS loggings are more accurate than microtremor. Microtremor method is good for determining predominant period. AVS30 derived from PS logging and SPT are the most accurate. PS logging is expensive and time consuming, shallow seismic needs larger area and it is an indirect method for determination of S-wave velocity. The recommended investigations are:-

- Microtremor and SPT methods are sufficient for seismic hazard assessment in Dhaka City but combination of SPT, PS logging, shallow seismic and microtremor may give better seismic hazard assessment.
- A long term record of microtremor is necessary in order to properly differentiate the portion of signal and noise of the microtremor data in the wave form.
- Collection of large volume of reliable SPT and microtremor data for hazard assessment is needed.
- Driller should be trained to collect accurate SPT values.
- Microtremor and shallow seismic data should be collected when there is no traffic and any other disturbances.
- PS logging is the most authentic way for determining the S-wave velocity; so, for cross matching of the relevant data derived from SPT and shallow seismic, a few PS logging is necessary to be conducted.
- Shallow seismic provides S-wave velocity and the method itself is less expensive. Moreover, data collection, analysis and interpretation are very simple and easy.

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