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Geotechnical Study of Sub-Surface Sediments in Sirajgonj Town and its Adjoining Areas, Bangladesh

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Abstract. Engineering bore logs of 86 holes, installed in the Sirajgonj town of Bangladesh and adjoining areas, were used to identify the geotechnical characteristics of the sub-surface sediments. The study area was divided into four major zones on the basis of surface and sub-surface geological characters, engineering properties of soil, such as lithology, atterberg limit, consistency, SPT, bearing capacity, plasticity, compaction, consolidation and compressibility etc., and geotechnical map. Each zone can be used for different types of construction purposes, characterized by specific engineering properties. Detailed engineering geological information should be used for sustainable land-use planning and development to reduce environmental hazards.

Keywords: geotechnical study, land-use planning, Sirajgonj, Bangladesh

Introduction

Sirajgonj is one of the first growing towns in Bangladesh with respect to population and development. People started to fill up nearby low-lying areas to construct civil structures without any plan. As a result they have been facing disastrous environmental problems, like foundation failure and structural subsidence etc. Similar problems have been recently recorded in and around many towns such as Pabna, Chandpur, Shibgonj, Dhaka, Keranigonj in Bangladesh and abroad (Shamsuzzaman *et al.*,2005; 2004a & b, 2003; BWDB, 2002; Asaduzzaman *et al.*, 1999, 1996; Mulder *et al.*, 1996; Natani, 1996; Prame, 1996; Suhari, 1996; Khan *et al.*, 1991). The most important geological factors that have to be considered in urban development are the suitability of the soils and rocks for foundations, sources of hazards, sub-surface as well as surface geological data etc. For more safe and sustainable urbanization, the planners and developers have to consider engineering geological factor before planning, designing and constructing or developing the area.

The engineering geological investigations of the area in detail are non-existent though several papers have been published on geomorphology, urban geology, sedimentation and hydrology of the surrounding areas (Shamsuzzaman *et al.*, 2005, 2004a & b, 2003; Rahman, 2001a & b; Islam, 2000; BWDB, 1985; Chowdhury, 1973; Coleman, 1969). The main aim of the present study is to determine the geotechnical status of the study area and prepare a geotechnical map, which will be helpful in urban planning and development of the area.

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The study area occupies the Jamuna and Karatoya floodplain deposits measuring 301 sq.km. It extends between 23° 22′ and 24°32′N latitudes and 89°34′ and 89°45′E longitudes (Fig. 1) and is located about 100 km, northwest from Dhaka. The principal drainage systems of the area are the Jamuna, Karatoya, Katakhal and Ichhamoti Rivers. The town is connected with the surrounding districts by metal roads, railways and rivers.

Materials and Methods

The following materials and data from different sources as well as direct fieldwork were used in the present study:

a. Overall geological information (Geological Survey of Bangladesh).
b. Topographic sheets (Survey of Bangladesh, 1991, 1967, 1954, 1952, 1921).
c. Satellite imagery (hard and soft copies of SPOT satellite image of 1989. (SPARRSO, 1989).
d. Climate, population, culture, historical, geographical and other relevant information (Anon,1978).
e. Sub-soil investigation reports (LGED, 1990-2005; NBSI, 1990-2005; CPSI, Bogra, 1990-2005; Soil Associates Engineering, Dhaka, 1998-2000).
f. Deep tubewell borelog data and soil-type map (Bangladesh Agricultural Development Corporation, 1990-2001).
g. Town development planning and land-use map (Sirajgonj Pourashava).
h. Field data from direct field surveying and local people. Sub-soil samples were also collected by hand augers to determine their engineering properties.

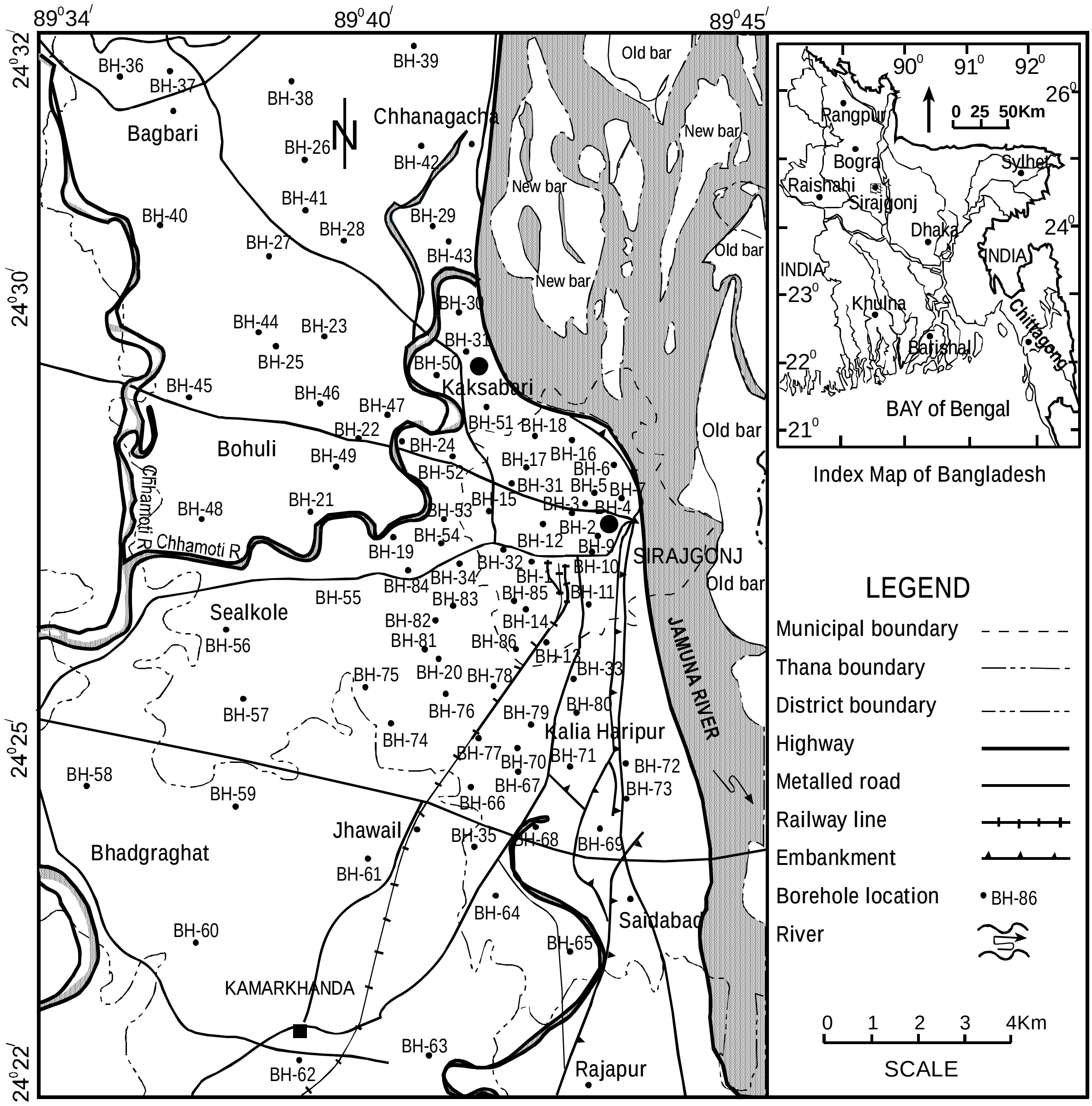

Fig. 1. Location map of the study area.

Besides the use of the existing data, various types of maps, published and unpublished reports and documents relevant to the field of study and laboratory analysis were also consulted. At first a preliminary morphogeological map was prepared with the aid of SPOT satellite image, topographic maps, thana map (LGED, 2000) and visual and digital image interpretation techniques. The sub-surface undisturbed soil samples of different morphologic units were studied in shallow cores through auguring and coring to identify the geotechnical characters of soil. The final morphogeological map was then prepared, where major morphogeological units have been delineated by integrating morphologic and lithologic data. The SPT-zonation map were prepared on the basis of SPT value and sub-surface stratigraphic cross-section. Finally, the geotechnical map has been prepared considering the morphogeological features, engineering properties of the soil and the sub-surface stratigraphy.

Index properties, mechanical properties and bearing capacity of soil were calculated after determining individual parameter using standard methods.

Results and Discussion

It is essential to know the engineering properties of the soil for heavy construction. For it, the index properties of soil (moisture content, void ratio, unit weight, liquid limit, plastic limit, shrinkage limit, plasticity index and liquidity index), mechanical properties of soil (compaction, cons olidation, shear strength, unconfined compression test and permeability) and bearing capacity of the soil were calculated (Table 1).

For measurement of the bearing capacity of the sub-surface soils, standard penetration test (SPT) was done. The bearing capacity is the ability of the foundation sediments and soils to support superimposed load without causing failure or rupture of the supporting soil (Sehgal, 1988). 86 Engineering boreholes were used to calculate the SPT curve (Fig. 2). The SPT zonation maps (Fig. 3.) have been prepared on the basis of SPT value of different engineering boreholes according to which each zone has been divided into high, moderate and low strength zones.The high SPT strength indicates high suitability of soil for heavy construction and vice versa.

Plasticity is defined as the property of soil, which allows it to be deformed rapidly, without rupture, elastic rebound and volume change (Punmia, 1994). During construction of an engineering structure, it is pre-requisite to identify the plasticity behaviour of the soil of that area, because plasticity indicates the bearing capacity. Plasticity index is the first condition to determine the plasticity of soils. For the preparation of geotechnical map (Fig. 4), the geological map, subsurface lithology and geotechnical characteristics of soils were taken into consideration. The mapped area has been divided into the following 4 major zones:

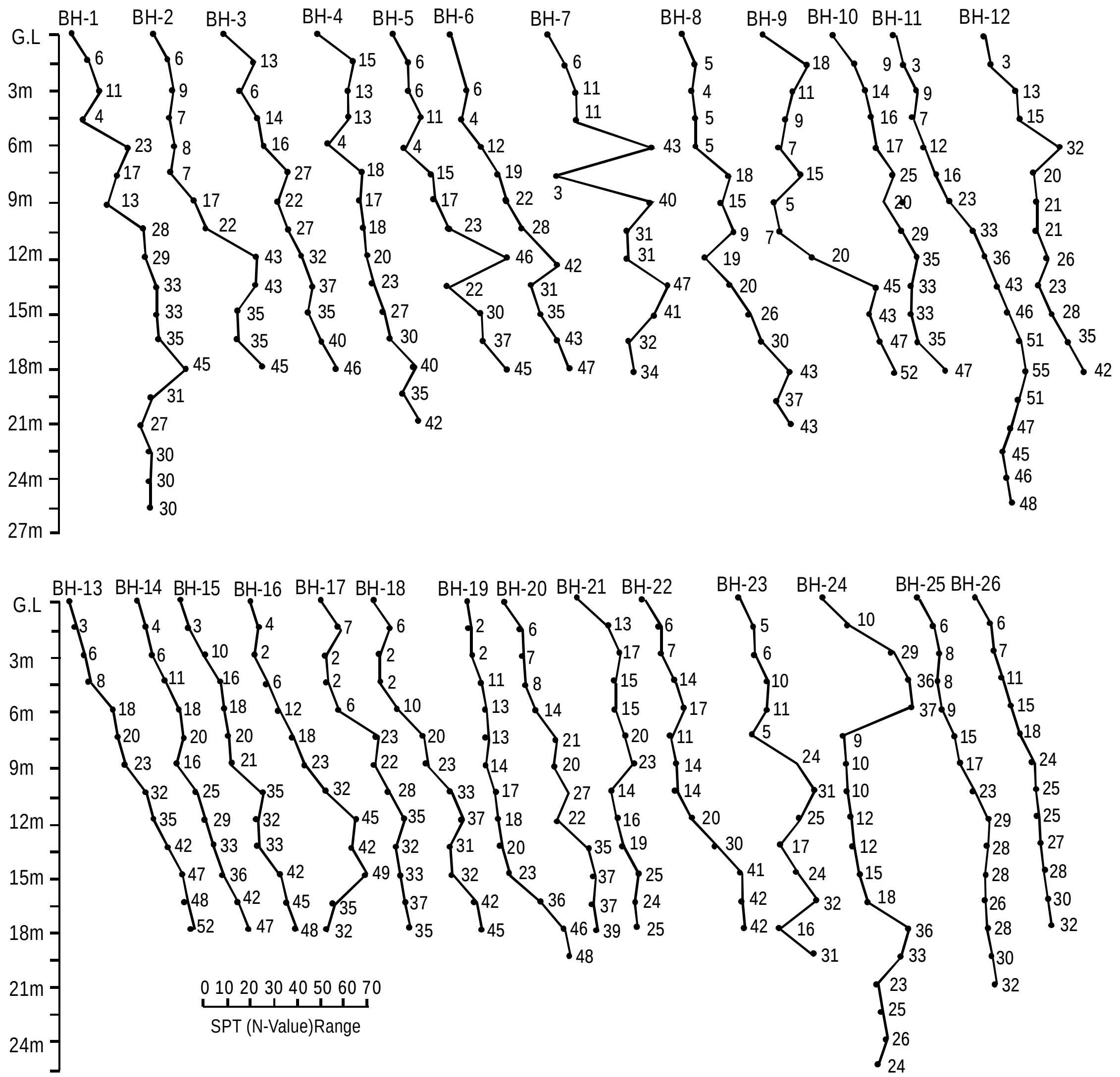

Fig. 2. SPT Curve of different engineering boreholes of Sirajgonj town and its adjoining areas upto the depth of 18 m (LGED, NBSI, RHD, SAE; 1990-2005).

Table 1. Physical and geotechnical properties of near surface soils in the Sirajgonj town and its adjoining areas (from NBSI, CPSI, SAE, LGED, RHD, 1990-2001 and laboratory tests)

Borehole No.	Engineering geologic unit	Geologic units	Particle size						Atterberg limit			Specific gravity	Natural moisture content (%)
			Sand %	Silt %	Clay %	D_{10} in mm	D_{30} in mm	D_{60} in mm	Liquid limit (LL)%	Plasticity limit (PL)%	Plasticity index (PI)%		
BH-1	III	Natural levee, Channel, Meander Scar, Crevasse splay	94-75	06-25	-	0.09-0.04	0.15-0.08	0.18-0.12	28-30	25-26	3-4	2.66-2.67	21.28-22.63
BH-2	III	Natural levee, Channel, Meander Scar, Crevasse splay	85-82	15-18	-	0.06-0.01	0.09-0.01	0.15-0.02	25-26	22-23	3-4	2.75-2.73	20.60-43.10
BH-3	III	Natural levee, Channel, Meander Scar, Crevasse splay	84-75	16-25	-	0.06-0.02	0.15-0.04	0.15-0.03	27-29	22-23	5-6	2.65-2.68	28.64-31.66
BH-4	III	Natural levee, Channel, Meander Scar, Crevasse splay	91-70	9-30	-	-	-	-	30-32	27-28	3-4	2.66-2.65	30.96-36.55
BH-5	III	Natural levee, Channel, Meander Scar, Crevasse splay	80-70	15-23	5-7	-	-	-	38-42	33-36	5-6	2.64-2.69	25.56-31.23
BH-6	III	Natural levee, Channel, Meander Scar, Crevasse splay	67-43	40-52	3-5	-	-	-	37-39	33-34	4-5	2.67-2.66	25.02-31.3
BH-7	III	Natural levee, Channel, Meander Scar, Crevasse splay	82-75	15-20	3-5	-	-	-	36-38	32-33	4-5	2.65-2.61	21.25-23.64
BH-8	III	Natural levee, Channel, Meander Scar, Crevasse splay	95-90	5-10	-	0.15-0.043	0.28-0.07	0.1-0.045	22-24	21-22	1-2	2.65-2.66	20.10-35.99
BH-9	III	Natural levee, Channel, Meander Scar, Crevasse splay	96-88	4-12	-	-	-	-	23-27	22-25	1-2	2.65-2.66	16.45-28.04
BH-10	III	Natural levee, Channel, Meander Scar, Crevasse splay	95-85	5-15	-	0.1-0.03	0.22-0.05	0.32-0.08	26-25	24-29	2-3	2.66-2.68	21.5-33.70
BH-11	III	Natural levee, Channel, Meander Scar, Crevasse splay	95-90	5-10	-	0.15-0.043	0.27-0.06	0.03-0.9	26-25	25-23	1-2	2.66-2.70	20.57-26.18
BH-12	III	Natural levee, Channel, Meander Scar, Crevasse splay	95-92	5-8	-	0.15-0.05	0.4-0.1	0.64-0.14	26-25	25-23	1-2	2.63-2.61	24.87-38.99
BH-13	III	Natural levee, Channel, Meander Scar, Crevasse splay	95-90	3-7	2-3	-	-	-	20-25	18-22	2-3	2.67-2.70	21.04-30.12
BH-14	II	Floodplain	90-85	8-12	2-3	-	-	-	43-46	24-26	19-20	2.66-2.68	21.5-33.70
BH-15	II	Floodplain	85-80	13-17	2-3	-	-	-	42-45	29-31	13-14	2.65-2.66	16.45-28.04
BH-16	I	Flood basin, Abandoned Channel, Ox-bow lake	75-65	10-15	15-20	-	-	-	48-56	20-22	25-34	2.69-2.68	26.44-32.02
BH-17	I	Flood basin, Abandoned Channel, Ox-bow lake	75-65	10-15	15-20	-	-	-	42-44	25-26	17-18	2.69-2.68	26.44-32.08
BH-18	I	Flood basin, Abandoned Channel, Ox-bow lake	75-65	15-20	10-15	-	-	-	46-62	19-30	27-32	2.70-2.68	31.04-36.12
BH-19	III	Natural levee, Channel, Meander scar, Crevasse splay	98-95	2-5	-	-	-	-	25-27	24-25	1-2	2.63-2.60	23.86-37.10
BH-20	II	Floodplain	90-74	10-26	-	-	-	-	40-38	25-20	15-18	2.65-2.69	20.86-24.93
BH-21	III	Natural levee, Channel, Meander scar, Crevasse splay	90-80	10-20	-	-	-	-	24-27	19-20	5-7	2.67-2.69	21.63-25.13
BH-22	III	Natural levee, Channel, Meander scar, Crevasse splay	95-80	5-20	-	-	-	-	26-30	22-25	4-5	2.66-2.68	20.96-24.14
BH-23	II	Floodplain	92-70	8-30	-	0.08-0.03	0.17-0.08	0.25-0.13	47-52	30-32	17-20	2.66-2.67	24.55-34.20
BH-24	III	Natural levee, Channel, Meander scar, Crevasse splay	90-94	10-6	-	0.075-0.09	0.2-0.15	0.4-0.2	23-25	22-23	2-3	2.64-2.66	18.65-24.57
BH-25	I	Flood basin, Abandoned Channel, Ox-bow lake	45-50	15-20	40-30	-	-	-	56-67	26-27	30-35	2.59-2.71	18.43-25.37
BH-26	II	Floodplain	60-65	10-15	30-20	-	-	-	48-42	30-22	18-20	2.65-2.72	22.13-26.49
BH-27	II	Floodplain	60-70	28-20	12-10	-	-	-	44-42	32-25	12-17	2.69-2.67	25.44-30.12
BH-28	II	Floodplain	75-80	13-10	12-10	-	-	-	46-49	29-30	17-19	2.64-2.69	28.56-32.15
BH-29	II	Floodplain	80-85	13-10	7-5	-	-	-	43-42	33-27	10-15	2.69-2.67	30.12-36.56
BH-30	IV	Active Channel	98-99	2-1	-	-	-	-	-	-	-	2.66-2.64	15.26-20.96
BH-31	IV	Active Channel	97-98	3-2	-	-	-	-	-	-	-	2.64-2.62	14.26-18.21
BH-32	II	Floodplain	68-75	20-15	12-10	-	-	-	43-45	31-28	12-17	2.69-2.67	25.02-31.3
BH-33	II	Floodplain	70-75	15-20	15-5	-	-	-	47-51	34-33	13-18	2.67-2.66	25.03-30.2
BH-34	I	Flood basin, Abandoned Channel, Ox-bow lake	50-60	15-20	35-20	-	-	-	56-67	26-29	30-38	2.67-2.66	33.6-34.3
BH-35	I	Flood basin, Abandoned Channel, Ox-bow lake	-	10-12	90-88	-	-	-	45-55	10-13	35-42	2.59-2.67	30.84-34-47

Table 1. (Continued from previous page)

Borehole No.	Engineering Geologic Unit	Unit weight (g/cc)		Soil classification USC	Porosity	Void ratio	Permeability	Consistency	SPT	Direct shear test		Plasticity
		Wet weight	Dry weight							Angle of Internal friction (degree)	Cohesion (TSF)	
BH-1	III	1.85-1.82	1.53-1.48	ML-MH	Low to Medium	0.9-1.3	Moderate to Low	Medium to Hard	6-30	35°-30°	0.0-0.045	Low
BH-2	III	1.85-1.82	1.52-1.30	ML-MH	Low to Medium	1.1-1.2	Mederate to Low	Medium to Hard	6-45	31°-29°	0.04-0.05	Low
BH-3	III	1.85-1.82	1.44-1.32	ML-MH	Low to Medium	0.9-1.4	Moderate to Low	Stiff to Hard	13.46	38°-30°	0.09-0.20	Low
BH-4	III	1.88-1.86	1.44-1.36	ML-MH	Low to Medium	1.1-0.9	Moderate to Low	Stiff to Hard	13.42	31°-32°	0.11-0.09	Low
BH-5	III	1.70-1.78	1.36-1.35	ML-MH	Low to Medium	0.9-1.0	Moderate to Low	Mediumj to Hard	4-45	32°-27°	0.02-0.01	Low
BH-6	III	1.92-1.87	1.54-1.42	SL-MH	Low to Medium	0.8-0.9	Moderate to Low	Medium to Hard	4-47	29°-33°	0.14-0.06	Low
BH-7	III	1.80-1.79	1.48-1.46	ML-MH	Low to Medium	0.9-1.0	Moderate to Low	Medium to Hard	6-47	33°-30°	0.05-0.06	Low
BH-8	III	1.94-1.83	1.62-1.35	ML-MH	Low to Medium	1.2-1.3	Moderate to Low	Medium to Hard	4-43	36°-29°	0.04-0.11	Low
BH-9	III	1.84-1.76	1.56-1.38	ML-MH	Low to Medium	1.1-1.3	Moderate to Low	Medium to Hard	5-52	31°-28°	0.00-0.11	Low
BH-10	III	1.83-1.78	1.50-1.42	ML-MH	Low to Medium	0.9-1.1	Moderate to Low	Medium to Hard	9-47	32°-33°	0.06-0.16	Low
BH-11	III	1.85-1.81	1.53-1.43	ML-MH	Low to Medium	1.1-1.2	Moderate to Low	Medium to Hard	9-48	29°-30°	0.05-0.04	Low
BH-12	III	1.79-1.73	1.43-1.24	ML-MH	Low to Medium	1.1-1.4	Moderate to Low	Stiff to Hard	13-42	31°-32°	0.18-0.02	Low
BH-13	III	1.86-1.81	1.54-1.46	ML-MH	Low to Medium	1.1-1.3	Moderate to Low	Soft to Hard	3-52	32°-30°	0.01-0.05	Low
BH-14	II	1.87-1.84	1.52-1.47	CL-CH	Low	1.2-1.5	Low	Medium to Hard	4-47	32°-31°	0.01-0.04	Medium
BH-15	II	1.89-1.83	1.59-1.47	CL-CH	Low	1.1-1.4	Low	Soft to Hard	3-48	31-32	0.00-0.06	Medium
BH-16	I	1.75-1.74	1.38-1.35	CL-MH	Low	0.8	Low to very Low	Soft to Hard	2-49	32-30	0.06-0.05	High
BH-17	I	1.75-1.76	1.38-1.36	CL-MH	Low	0.9	Low to very Low	Soft to Hard	2-37	32-30	0.01-0.06	High
BH-18	I	1.74-1.75	1.37-1.34	CL-MH	Low	0.6	Low to very Low	Soft to Hard	2-45	32-30	0.06-0.05	High
BH-19	III	1.87-1.82	1.52-1.46	SP-MH	Low to Medium	0.80-1.0	Moderate to Low	Soft to Hard	2-48	31-28	0.00-0.11	Low
BH-20	II	1.86-1.75	1.53-1.40	SP-ML	Low	-	Low	Medium to Hard	6-39	31-27	0.04-0.08	Medium
BH-21	III	1.84-1.80	1.51-1.43	SP-MH	Low to Medium	-	Moderate to Low	Stiff to very Stiff	13-25	32-31	0.41-0.05	Low
BH-22	III	1.85-1.79	1.53-1.44	SP-MH	Low to Medium	-	Moderate to Low	Medium to Hard	6-42	28-29	0.03-0.05	Low
BH-23	II	1.84-1.76	1.48-1.31	SM-MH	Low	-	Low	Medium to Hard	5-13	34-33	0.05-0.07	Medium
BH-24	III	1.89-1.82	1.59-1.46	SP-MH	Low to Medium	-	Moderate to Low	Stiff to Hard	10-37	33-34	0.06-0.08	Low
BH-25	I	1.76-1.74	1.46-1.39	CH-ML	Low	0.7	Low to very Low	Medium to very Stiff	6-32	23-24	0.06-0.04	High
BH-26	II	1.88-1.85	1.51-1.48	CL-ML	Low	1.0-1.3	Low	Medium to very Stiff	6-32	34-32	0.00-0.04	Medium
BH-27	II	1.78-1.80	1.45-1.43	CL-ML	Low	-	Low	-	-	-	-	Medium
BH-28	II	1.76-1.75	1.31-1.30	CL-OL	Low	-	Low	-	-	-	-	Medium
BH-29	II	1.68-1.72	1.44-1.40	CL-OL	Low	-	Low	-	-	-	-	Medium
BH-30	IV	1.85-1.83	1.48-1.43	SP	High	-	High	-	-	-	-	Non-plastic
BH-31	IV	1.89-1.83	1.53-1.48	SP	High	-	High	-	-	-	-	Non-plastic
BH-32	II	1.82-1.80	1.47-1.43	ML-OL	Low to Medium	-	Low	-	-	-	-	Medium
BH-33	II	1.79-1.80	1.45-1.43	ML-OL	Low to Medium	-	Low	-	-	-	-	Medium
BH-34	I	1.64-1.75	1.30-1.35	OH-OL	Low	-	Low	-	-	-	-	High
BH-35	I	1.70-1.77	1.44-1.42	OH-OL	Low	-	Low	-	-	-	-	High

Table 1. (Continued from previous page)

Borehole No.	Engineering geologic unit	Compressibility	Suitability of the material: Value for the foundation characteristics	Suitability of the material: Workability as construction materials	Remarks
BH-1	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-2	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-3	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-4	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-5	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-6	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-7	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (Caste in situ pile)
BH-8	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-9	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-10	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. column footing)
BH-11	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-12	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-13	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-14	II	Medium	Fair to good bearing value	Fair	Shallow to medium foundation possible with care
BH-15	II	Medium	Fair to good bearing value	Fair	Shallow to medium foundation possible with care
BH-16	I	High	Poor bearing value	Poor	Very deep foundation required and bad for civil structure
BH-17	I	High	Poor bearing value	Fair	Very deep foundation required and bad for civil structure
BH-18	I	High	Poor bearing value	Poor	Very deep foundation required and bad for civil structure
BH-19	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-20	II	Medium	Fair to good bearing value	Fair	Shallow to medium foundation possible with care
BH-21	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-22	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (Caste in situ pile)
BH-23	II	Medium	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-24	III	Low to very Low	Fair to good bearing value	Fair	Shallow foundation is possible (R. C. C. Square footing)
BH-25	I	High	Poor bearing value	Poor	Very deep foundation required and bad for civil structure
BH-26	II	Medium	Fair to poor bearing value	Fair	Shallow to medium foundation possible with care
BH-27	II	Medium	Fair to poor bearing value	Fair	Shallow to medium foundation possible with care
BH-28	II	Medium	Fair to poor bearing value	Fair	Shallow to medium foundation possible with care
BH-29	II	Medium	Fair to poor bearing value	Fair	Shallow to medium foundation possible with care
BH-30	IV	Very Low	Good bearing value	Good	Very suitable for civil structure but it is affected by bank erosion
BH-31	IV	Very Low	Good bearing value	Good	Very suitable for civil structure but it is affected by bank erosion
BH-32	II	Medium	Fair to poor bearing value	Fair	Shallow to medium foundation possible with care
BH-33	II	Medium	Fair to poor bearing value	Fair	Shallow to medium foundation possible with care
BH-34	I	High	Poor bearing value	Poor	Very deep foundation required and bad for civil structure
BH-35	I	High	Poor bearing value	Poor	Very deep foundation required and bad for civil structure

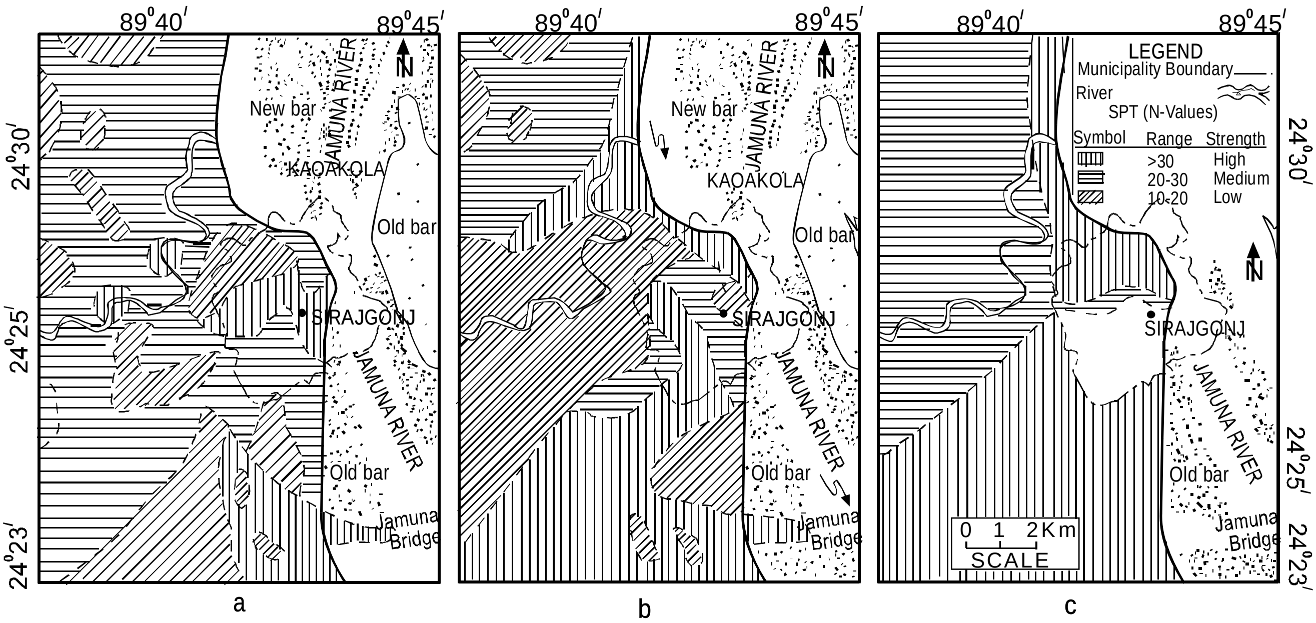

Fig. 3. SPT (N values) zonation map of Sirajgonj town and its adjoining areas, (**a.** upto depth of 6 m, **b.** upto depth of 6 to 12 m and **c.** upto depth of 12 to 18 m).

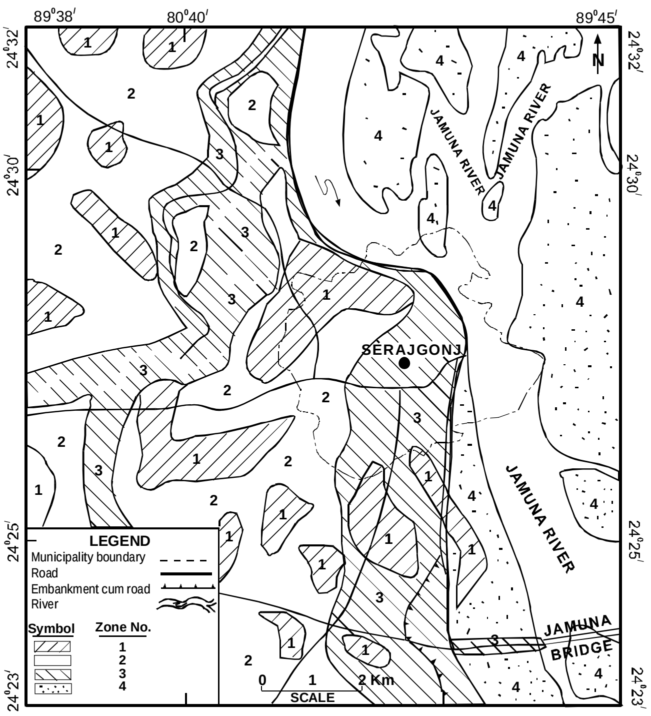

Fig. 4. Geotechnical map of Sirajgonj town and its adjoining areas.

Zone 1: This zone is mainly composed of light gray to gray kaolinitic clay (Fig. 5), decomposed and partially decomposed vegetable matter and light gray silty clay, which are found in flood basin, ox-bow lake and abandoned channel. The sediments of this zone are poorly compacted, highly plastic, cohesive and compressive. The plasticity index and liquid limit of Casagrande (1976) have been plotted in the plasticity chart (Fig. 5), the soil type of this unit is mainly CH-OH (llay-organic clay). The consistency of soil of this zone is very soft to hard when dry and SPT-value varies from 1 to 26. It is a very weak foundation layer and very deep foundation will be required for any civil construction with normal foundation.

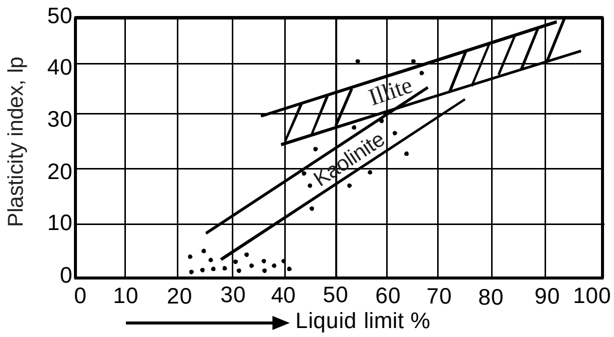

Fig. 5. Liquid limit versus plastic index for the common clay minerals (Modified after Grim, 1962).

Zone 2: This zone comprises mainly of grayish to brownish yellow silty clay, often black to gray organic rich kaolinitic clay (Fig. 5), decomposed and partially decomposed grass roots, animal burrows and silty sands of flood plain sediments. These sediments are low compacted, medium plastic, cohesive and medium compressible. The plasticity index and liquid limit of Casagrande (1976) have been plotted in the plasticity chart (Fig. 6). The soil type of this unit is mainly CL-ML (clay-silt), which is low to medium plastic. The consistency of soils of this unit is soft to hard and SPT-values vary from 3 to 48. It is a good foundation layer and is suitable for construction of low to moderately high-rising buildings with normal foundation.

Zone 3: This zone comprises mainly yellowish gray to gray silty clay, silty sand and fine to very fine and medium-grained sands of natural levee, crevasse splay and meander scar sediments. The sediments of this unit are moderate to high compact, low plastic and low to very low compressible. Plotting of the plasticity index and liquid limit in the Casagrande (1976) plasticity chart (Fig. 6) indicates that the soil type of

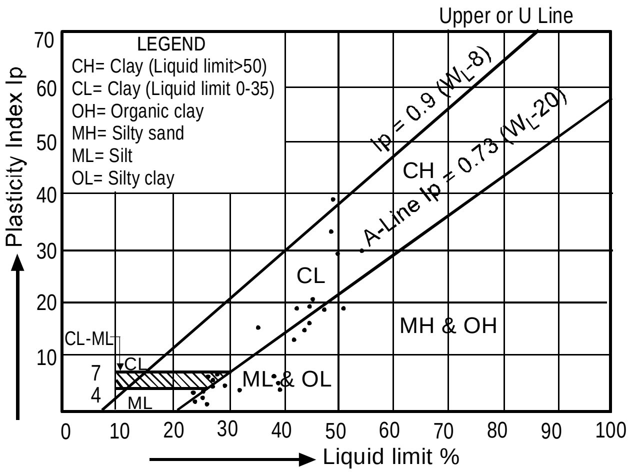

Fig. 6. Position of cohesive sub-soil of Sirajgonj town and adjoining areas on the Casagrande Plasticity Chart (Eden, 1963).

this zone is SP-MH (medium to coarse sand-silty sand micaceous) to ML-MH (silt-silty sand). The consistency of soil is stiff to hard and SPT-values vary from 10 to 55. This zone is generally situated above flood level and shallow foundation is required for construction of low to moderately high-rising buildings.

Zone 4: This zone consists of active channel deposits, which are mainly light brown to gray, fine to medium-grained sand with little sandy silt and silty sand. These sediments are moderately compact, non-plastic and low to very low compressible. According to Bowels (1984), the soil type of this unit is SP (poorly graded sand). Although this zone bears good foundation layer for construction, it has a major problem of being situated in high bank erosion of the Jamuna River each year. So, permanent urbanization is not suitable in this area. The sediments of this unit may be used for filling land and construction materials.

Conclusion

From the study of overall geotechnical aspects, it is suggested that the soil test must be done carefully before construction of any civil engineering structure. With reference to SPT zonation map and geotechnical map, zone-1 does not seem suitable for heavy construction as very deep foundation (mat or pile) is required for construction of buildings. Zone-2 is moderately suitable for heavy construction with shallow to medium foundation (R.C.C square or column footing). Zone-3 is the most suitable area for heavy construction, with normal foundation depth of 3 to 6 m below the surface. Zone-4 is unsuitable for heavy construction and permanent urbanization in this area is not suggested.

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References

Anon, 1978. *Bangladesh District Gazetteers*, Pabna, 348 p.

Asaduzzaman, A.T.M., Nasreen, N., Olsen, H. 1999. Urban geology of Dhaka, Bangladesh. *Atlas of Urban Geology* **11:** 68.

Asaduzzaman, A.T.M. 1996. Urban Geology and Environmental Aspects of Dhaka City, Bangladesh. Manual on Environmental and Urban Geology of Fast-Growing Cities. ST/ESCAP 1734. *Atlas of Urban Geology* **9 11:** 1-12: 7, ESCAP, Bangkok, Thailand.

Bangladesh Agricultural Development Corporation (BADC) 1990-2001. *Groundwater Quality and Deep Tubewell Borelog Data, in Pabna Town and its Adjoining Areas. Bangladesh*. Report of the People's Republic of Bangladesh.

Bangladesh Water Development Board (BWDB), 2002. *Ganges Left Bank Erosion Protection at Panka Naryanpur.* Main Report, 110 p.

Bangladesh Water Development Board (BWDB), 1985. *Groundwater Development Zones Characteristics and Potentials of Pabna and Sirajgonj Districts*. Report No. 466.

Bowles, J.E. 1984. *Physical and Geotechnical Properties of*

Soils, 578 p. 2[nd] edition, McGraw-Hill Book Company, New York, USA.

Cadd Planning and Sub-soil Investigator (CPSI), 1990-2005. *Sub-soil Investigation Reports for Construction of Various Buildings and Bridges under Sirajgonj and Pabna Towns and Adjoining Areas, Bangladesh*.

Casagrande, A. 1976. Liquefaction and Cyclic Deformation of Sands – a Critical Review. *Harvard Soil Mechanics Ser.* No. 88, Harvard Univ. Press, Cambridge, Mass., USA.

Chowdhury, M.L. 1973. Morphological processes in the lower Brahmaputra valley. *J. BNGA*, **1:** 19-29.

Coleman, J. M. 1969. Brahmaputra river channel processes and sedimentation. *Sedimentary Geology* **3:** 129-239.

Eden, W.J. 1963. CBD-43. Soil testing. *Canadian Building Digest*, 1[st] July, 1963.

Grim, R.E. 1962. *Applied Clay Mineralogy*, 422 p. McGraw Hill, New York, USA.

Islam, M.R. 2000. Urban Geology of Rajshahi City and its Adjoining Area, *M.Sc. Thesis*, 106 p. Department of Geology and Mining, University of Rajshahi, Bangladesh.

Khan, S.R., Das, S.K., Ali, R.M.E. 1991. Geology for land-use planning in tropical deltas: Greater Dhaka City (Keraniganj upazila), Bangladesh. *Atlas of Urban Geology* **5:** 33, ESCAP, Bankok, Thiland.

Local Government Engineering Department (LGED), 1990-2005. *Sub-soil Investigation Reports for Construction of Various Buildings and Bridges under Pabna Town and Adjoining Areas, Bangladesh*.

Local Government Engineering Department (LGED) 2000. Base Map, Pabna Sadar Thana, Scale: 1:50,000.

Mulder, E.F.J.de., Brucheman, A.J.Van., Claessen, F.A. M., Hannink, G., Hulsbergen, J.G., Satijn, H.M.C., 1996. Environmental impact assessment on land reclamation projects in Netherlands: a case history, Manual on Environmental and Urban Geology of Fast-Growing Cities (1996), ST/ESCAP 1734. *Atlas of Urban Geology* **96:** 38-44, ESCAP, Bangkok.

Natani, J.V. 1996 Geofactor ignorance in urban planning-leading to disaster: a case study of Jaipur. Manual on Environmental and Urban Geology of Fast-Growing Cities (1996). ST/ESCAP 1734. *Atlas of Urban Geology* **9 12:** 8-11, ESCAP, Bangkok.

North Bengal Sub-soil Investigator (NBSI), 1990-2005. *Sub-soil Investigation Reports for Construction of Various Buildings and Bridges under Sirajgonj and Pabna Towns and Adjoining Areas, Bangladesh*.

Prame, W.K.B.N. 1996. Geology, environment and urban planning in Sri Lanka with special reference to the Greater Colombo area: some problems and perspectives, Manual on Environmental and Urban Geology of Fast-Growing Cities (1996). ST/ESCAP 1734. *Atlas of Urban Geology* **9 12:** 29-30, ESCAP, Bangkok, Thailand.

Punmia, B.C. 1994. *Soil Mechanics and Foundations*, Laxmi Publication (Pvt.) Ltd., New Delhi, India.

Rahman, M.M., 2001a. Urban Geology of Rangpur Town and its Adjoining Areas. *M.Sc. Thesis*, 101 p. Department of Geology and Mining, University of Rajshahi, Bangladesh.

Rahman, M.S. 2001b. Urban Geology of Bogra Town and its Adjoining Areas. *M.Sc. Thesis*, 137 p. Department of Geology and Mining, University of Rajshahi, Bangladesh.

Roads and Highway Department (RHD), 1990-2001. *Sub-soil Investigation Reports for Construction of Various Buildings and Bridges under Sirajgonj Town and Adjoining Areas, Bangladesh*.

Sehgal, S.B. 1988. *A Text Book of Soil Mechanics*, CBS Publishers and Distributers, New Delhi, India.

Shamsuzzaman, M., Islam, M.S., Islam, M.B. 2005. Morphogeology of Pabna Sadar Upazila, Bangladesh for land-use planning. *Bangladesh J. Water Resource Res.* (BUET, Bangladesh), **20:** 65-79.

Shamsuzzaman, M., Islam, M.S., Islam, M.B., Zaman, M.N. 2004a. Geo-hazard assessment for urban development: a case study from Sirajgonj town and adjoining areas, Bangladesh. *J. Sci. Rajshahi University Studies*, Part-B **32:** 345-357.

Shamsuzzaman, M., Islam, M.B., Islam, M.S., Zaman, M.N. 2004b. Geo-hazard assessment for urban development: a case study from Pabna town and adjoining areas, Bangladesh. *J. Sci. Rajshahi University Studies*, Part-B **32:** 359-370.

Shamsuzzaman, M., Islam, M.B., Islam, M.S. 2003. Morphogeological Study of Sirajgonj Sadar Upazila, Bangladesh. *Bangladesh J. Geol.* **22:** 37-50.

Soil Associates Engineering (SAE), 1998-2000. *Sub-soil Investigation Reports for Construction of Various Buildings and Bridges under Sirajgonj and Pabna Towns and its Adjoining Areas, Bangladesh.*

SPARRSO (Space Research and Remote Sensing Organization), 1989, *SPOT Satellite imagery,* scale 1:50,000.

Suhari, S. 1996. Urban geology of greater Bandung, Indonesia. Manual on Environmental and Urban Geology of Fast-Growing Cities (1996). ST/ESCAP 1734. *Atlas of Urban Geology* **9: 12:** 12-20, ESCAP, Bangkok.

Survey of Bangladesh. (1921, 1952, 1954, 1967 and 1991) Toposheet, scale: **1:** 50,000.