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Site Selection of Deep Sea Port in Bangladesh : A Geotechnical Study

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Abstract : During the last few decades different organizations carried out soil investigation programs only for the construction of onshore structures. So far it is concerned that there had been no soil investigation programs performed in the sea for the construction of offshore structures. Therefore, none of the previous soil investigation data can be used for the selection of suitable locations of offshore structures. In the above context, the Ministry of Shipping has decided to carry out a detailed offshore soil investigation program to establish a deep sea port in Bangladesh. The Ministry appointed the authors as Geotechnical Experts to review previous onshore data to select soil parameters to carry out the offshore soil investigation. The geotechnical evaluation of the offshore data recommended a suitable location of the proposed deep sea port. This paper presents the results of the evaluation and recommendations made, as well as describing the scope and objective of the offshore soil investigation.

INTRODUCTION

The Ministry of Shipping of Bangladesh Government has intended to have a full-scale techno-economic feasibility study for the construction of a deep sea port in Bangladesh by assessing the overall impact on the economic in general and the two existing ports in particular. This paper deals only with the technical aspects of the first phase study especially the geotechnical assessment for site selection of deep sea port. The initial stage of this work involved review and analysis of previous onshore data (Table 1). The evaluation of the previous data suggested five candidate sites for deep sea port as marked S1 to S5 (Fig.1). The subsequent stage of this work included execution of offshore field investigation in those candidate sites as well as laboratory tests of soil samples. The field investigation was planned to conduct Standard Penetration Tests (SPT) at three (3) locations for offshore area (Fig. 2).

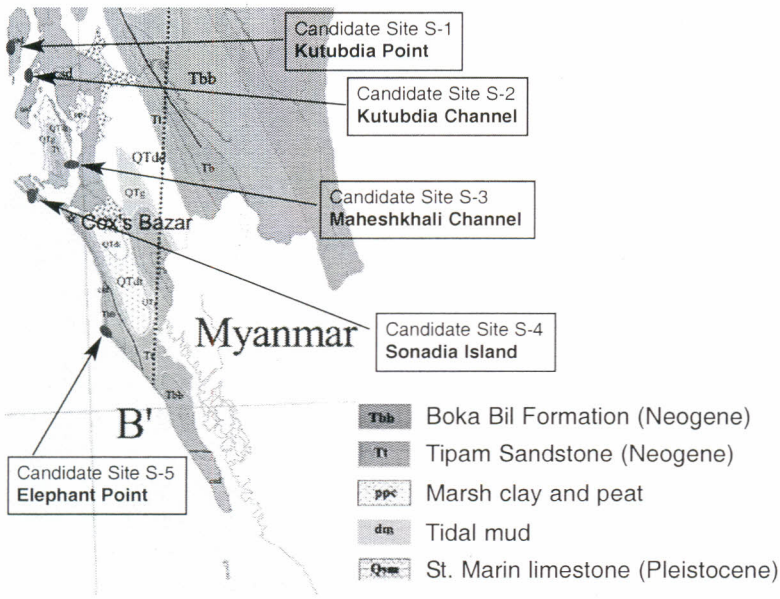
Based on the preliminary data and Geological Survey Map of Bangladesh, a brief geotechnical assessment has been made to have an idea of prospective locations of deep sea port. A complete soil investigation program considering analysis of foundation system will be carried out in second phase of the study to validate the results of this work (Fig.3).

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Table 1: Information of Previous Onshore Soil Investigation

Public & Private Organisations	Soil Testing Companies	Soil Investigation Sites	Number of Bore Holes	Date of Investigation	Proposed Development
Mr. Sukendhu Bikash Das	Soil Prokaushali & Survey	Banskhali.Ctg	3	November 2006	Commercial Bldg
Assoconsultant Ltd.	Mrittika Prokaushali	Banskhali.Ctg	4	February 1993	Cyclone Shelter
LGED	LGED Lab.	Cox's Bazar	2	August 2006	Resort/Hotel
Bangladesh Navy	Mrittika Prokaushali	Cox's Bazar	4	April 1995	Barrack
Ministry of Shipping	National Soil Engineers	Teknaf	8	June 2003	Teknaf Port
Ministry of Education	Mrittika Prokaushali	Baharchara	2	June 1996	Primary School



Correlations of Map Units

- Q1g** Girujan Clay (Pleistocene and Neogene)
- Qva** Valley alluvium and colluvium
- QTdd** Dihing and Dupi Tila Formation Undivided
- QTdt** Dupi Tila Formation (Pleistocene and Pliocene)
- de** Estuarine deposits

Fig.1: Geological Survey Map of Candidate Sites S-1 to S-5

Source : Reproduced from Geological Survey Map of Bangladesh

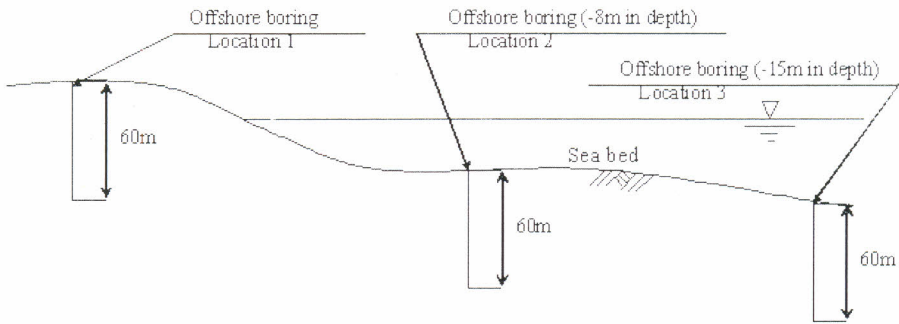


Fig 2. Typical Section of Offshore Boring Locations

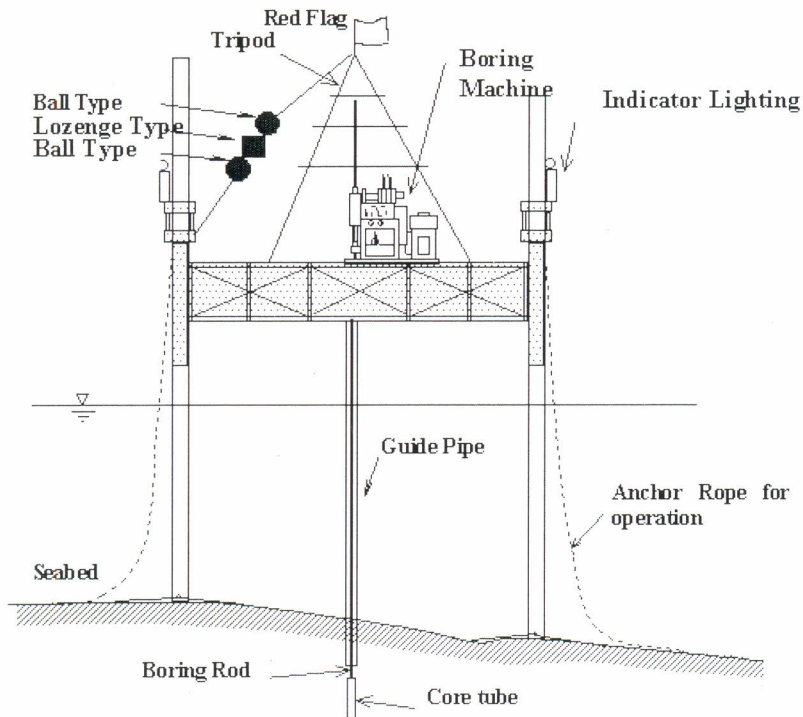


Fig 3. Equipment for Offshore Boring (barge with spud pile type)

DATA ANALYSIS

The geotechnical assessment of the five candidate sites involved analysis of soil parameters, scrutiny data, and plotting soil strata profile of bore logs. The laboratory tests were carried out on 30 disturbed samples and 10 undisturbed samples obtained from each boring location to find out the physical and engineering properties of soil. To identify the general behaviour of soil, available data were grouped together based on the similar properties. The stratification lines were estimated to examine the actual in-situ changes between layers of all bore logs. Subsurface and groundwater conditions were also recorded at borehole locations. The soil profiles of the five candidate sites were compared among themselves to get the best possible location of the proposed deep sea port.

RESULTS

The subsurface geological data of the investigated area confirmed the formation of clayey sedimentary deposit (csd) as also reported in Geological Survey Map of Bangladesh, where it is termed as Beach and Dune Sand formation (Fig.1). Three soil layers were observed in all candidate sites (Table 2& 3). Based on the soil Standard Penetration Tests (SPT) data (Table 4), soil profile is presented in Fig.4. The actual in-situ gradual changes between layers differed clearly as depicted on the boring logs. Subsurface and groundwater conditions varied between borehole locations. The stratification lines based on the preliminary data should not be considered in the main sub-structure design of the proposed deep sea port. In authors' opinion a detailed soil investigation is to be carried out before finalisation the foundation system.

Table: 2 Engineering Properties of Soil Layer¹

<u>Layer</u>	<u>Soil Description</u>	<u>Unit Weight,</u>	<u>Frict. Angle</u>
Layer-1	Topsoil, soft clayey silt	105, pcf	10-15
Layer-2	Loose to Medium dense Silty fine Sand with Clay	115, pcf	28-30
Layer-3	Medium Dense to very dense Sand with Silt trace clay	125, pcf	33-35

Layer 1: Topsoil

Layer 1 is Topsoil, consists of very soft low plastic clayey silt. SPT blow counts of in this layer varied between 1 and 2, with an average of 1. Depth of this layer was observed between 2 m to 4 m. The layer is susceptible to consolidation under applied structural loads and considered unsuitable for foundation.

Layer 2: Loose to Medium Dense Silty Fine Sand with Clay

Soil observed in layer two was silty fine sand with clay, medium dense to dense in consistency. Layer 2 started at a depth between 1.5 m and 4.5 m and extended to a depth of about 9 m. SPT blow counts in this layer varied between 5 and 33, with an average between 9 and 27. This layer seems to be of sedimentary/ tidal deposit

and is suitable for light weight structure foundation with slight soil modification/improvement. Unit weight of soil for this layer can be considered as 115 pcf,¹ and $f= 28^\circ$. As this layer also consist of easy erodable soil, so special measures should be taken for scouring problem.

Layer 3: Medium Dense to very Dense Sand with Silt Trace Clay

Soil in layer 3 consists of sand with silt, trace clay. This layer is grey in colour and soil consistency in this layer is medium dense to very dense. Layer 3 was observed at a depth of 9.5 m and continued to the end of the boring. SPT blow counts varied between 25 and 60 in this layer, with an average of between 38 and 60. Unit weight of soil for this layer can be considered as 125 pcf¹, and $f= 33^\circ$. This layer seems to be suitable for deep foundation of heavy offshore structures.

Table 3: Unit Friction and End Bearing Capacity for Pile Capacity^{2,3 & 4}

Depth` ft	Soil description	Friction, fs Tsf	End bearing qb, Tsf
3	Layer-1	0.084	5
7	r (Pcf) =105	0.161	6
10	$\phi =15$	0.225	8
13	$c=$	0.282	8
16		0.332	9
20	Layer-2	0.392	15
23		0.444	16
26	r (Pcf) =115	0.491	23
30	$\phi =28$	0.531	34
33	$c=$	0.566	26
36		0.596	20
39		0.621	17
43		0.652	26
46	Layer-3	0.677	22
49		0.696	20
52	r (Pcf) =125	0.711	17
56	$\phi =33$	0.720	26
59	$c=$	0.725	22
62		0.725	20
66		0.720	23
69		0.711	26
66		0.720	23
72		0.698	28
75		0.681	36

79		0.659	34
82		0.634	34
85		0.604	34
89		0.571	34
92		0.534	34
95		0.494	34
98		0.450	34

Table 4: Combined Soil Profile Data (S-1-S-5, Kutubdia Point to Elephant Point)

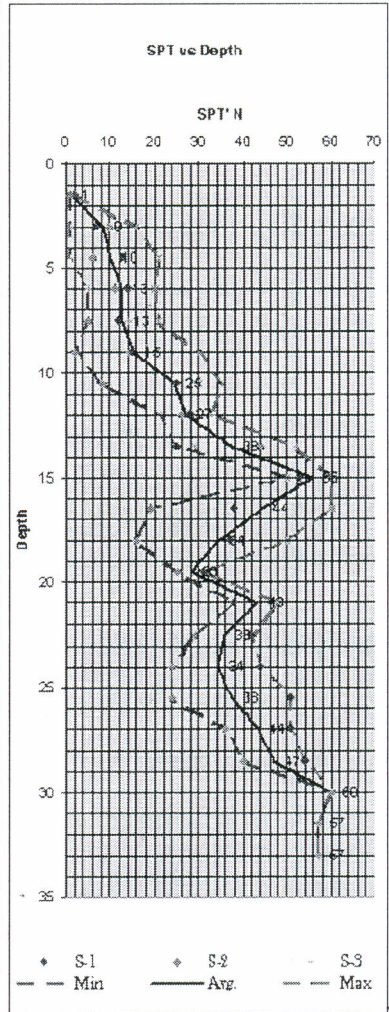
Depth m	SPT of Candidate sites S-1 to S-5			
	Minimum	Average	Maximum	
0				very soft medium plastic Clayey Silt, grey, water bearing (CL-ML)
1.5	1	1	2	
3.0	1	9	16	Sand, with silt, medium dense to dense (SP)
4.5	1	10	21	
6.0	5	13	20	$\gamma = 110 \text{ pcf}, \phi = 28^\circ$
7.5	5	13	21	
9.0	2	15	30	
10.5	8	25	35	
12.0	21	27	33	
13.5	25	38	52	Dense to very dense fine Sand, trace silt and clay (SP)
15.0	50	56	60	
16.5	19	44	60	$\gamma = 115 \text{ pcf}, \phi = 33^\circ$
18.0	16	34	50	
19.5	25	28	31	
21.0	38	43	48	
22.5	29	36	42	
24.0	24	34	44	
25.5	24	38	51	
27.0	36	44	51	
28.5	40	47	54	
30.0	60	60	60	
31.5	57	57	57	
33.0	57	57	57	

LEGEND

- Clay -Fine Sand -Fine
- Silt -Medium Sand - gravel

**Fig. 4: Combined Soil Profile (S-1-S-5, Kutubdia Point to Elephant Point)
SPT Blow Count's vs Depth**

Depth m	SPT of Candidate sites S-1 to S-5		
	Minimum	Average	Maximum
0			
1.5	1	1	2
3.0	1	9	16
4.5	1	10	21
6.0	5	13	20
7.5	5	13	21
9.0	2	15	30
10.5	8	25	35
12.0	21	27	33
13.5	25	38	52
15.0	50	56	60
16.5	19	44	60
18.0	16	34	50
19.5	25	28	31
21.0	38	43	48
22.5	29	36	42
24.0	24	34	44
25.5	24	38	51
27.0	36	44	51
28.5	40	47	54
30.0	60	60	60
31.5	57	57	57
33.0	57	57	57



S-1: Kutubdia Point; S-2 : Kutubdia Channel
S-3: Moheshkhali Channel; S-4: Sonadia Island
S-5: Elephant Point

CONCLUSIONS

The candidate sites S-1 to S-4 show more or less similar soil characteristics. Upper layer ranging from 0 to 4.5 m of soil sub strata is very soft to soft or very loose to loose sandy/ silty/ clayey sedimentary deposit, which is clearly documented in the Geological Map as classified as "Beach and Dune Sand" layer. The upper soft layer is followed by medium dense to very dense sandy silt/ sand/ silty sand. However, upper soft layer is absent in boring location at the site S-5, where hard silty clay layer starts at the ground surface level and extends till the end of boring as defined as "Sand Stone" in Geological Map.

This is authors' understanding that soil deposit is more or less similar characteristics from engineering point of view, except the site S-5, where founding layer starts at the existing ground level. Deep foundation Pile Tip can be ended within this layer. Therefore, the site S-5 seems to be the best suitable location from geotechnical as well as economical point of view for development of Deep Sea Port in future.

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