LOCAL GOVERNMENT DEPARTMENT
GOVERNMENT OF SINDH

R E P O R T

O N

GEOTECHNICAL INVESTIGATION

FOR

MALIR RIVER EXPRESSWAY KARACHI

VOLUME-1 (BRIDGES INVESTIGATION)

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1. INTRODUCTION:

Local Government Department, Government of Sindh has embarked the construction of 38-kilometre-long Malir Expressway as the shortest alternative route to connect the Super Highway with the city centre. It will be a four-lane expressway along the Malir River starting from Hino Chowk and ending at the Super Highway (M-9) near Kathore.

M/s EA Consulting (Pvt) Limited are providing engineering consultancy for the project.

The project involves the construction of a number of fly-over bridges that would span over the existing bridges across the Malir River. In order to evaluate subsoil conditions and to obtain soil parameters for the design of foundations, a program of geotechnical investigation was undertaken at the site. The task of geotechnical investigation was awarded to 'Geotechnical Services', Karachi. The field work was accomplished in March, 2018.

The program of investigation consisted of drilling 4 boreholes each 30.0 m deep except BH-2 which was drilled upto 39.0 m below existing ground level.

In order to ascertain the degree of compactness / consistency of substrata, standard penetration tests (SPTs) were performed wherever found feasible. Moreover, core samples were extracted using double tube core barrel.

Laboratory testing program was developed and selected soil/rock samples were tested in the laboratory of Geotechnical Services, Karachi.

This report presents a review of subsoil investigation performed at the project site. The field and laboratory data has been analyzed for the evaluation of allowable bearing pressure. The recommendations regarding the type and bearing capacity of foundation are incorporated in the report.

2. DESCRIPTION OF INVESTIGATION:

Field Investigation:

The program of investigation consisted of executing 4 boreholes. Boring was performed using rotary method.

Following are the details of boreholes:

Boring No	Chainage	Interchange	Co-ordinates		Depth (m)
			Northing	Easting	
BH-1	0+000	DHA Karachi Interchang-1	24.8321549	67.0868994	30
BH-2	9+000	Korangi Shah Faisal Interchang-2	24.8747467	67.1447565	39
BH-3	15+000	Malir Quaidabad Interchang-3	24.8662	67.2036863	30
BH-4	25+000	Open (near Memon Goth)	24.9248304	67.2713587	30

The location of boreholes is shown on layout plan appended to this report.

During the course of boring, standard penetration tests were performed wherever found feasible. This test was conducted in accordance with ASTM Designation D-1586. The standard penetration resistance or the `N'-value of the SPT is an index of relative density/consistency of granular/cohesive substrata.

Disturbed samples were obtained through split spoon sampler used in the standard penetration tests. These samples were carefully examined to identify the soil types at various depths. The samples were placed in plastic containers, marked with borehole number, depth and subsequently, dispatched to the laboratory.

Rock core drilling was carried out using double tube core barrel in conjunction with tungsten carbide bit. After each run of the core barrel, percent core recovery and rock quality designation (RQD) were determined. The cores were stored in wooden core boxes. Wooden markers indicating depth and run numbers were inserted between each core run. The core boxes were, then, transported to the laboratory for testing. Some of the cores were sealed with molten wax and treated as undisturbed samples.

Laboratory Testing:

In order to arrive at a rational evaluation of the geotechnical properties of substrata encountered at the site, a comprehensive program of laboratory testing was undertaken. The tests were performed to determine classification, strength and chemical characteristics. The testing was generally performed in accordance with relevant American Society for Testing and Material (ASTM) standards.

Following tests were performed on the representative samples in the laboratory:

- Grain size analysis
- Atterberg limits
- Unconfined compression
- Density & Moisture
- Total salts
- Sulphate content
- Chloride content
- pH value

The results of laboratory tests are appended to this report.

Observations were regularly made in boreholes to determine the position of ground water table. The position of water table is indicated on the borelogs.

3. GEOLOGY & SEISMICITY:

3.1 Geological History & Formation:

The geological studies have revealed that the soil formations in this area are fresh and slightly weathered, recent and subrecent shoreline deposits. These deposits are derived from Gaj / Manchar formation of lower Moicene to Middle / Upper Miocene to Pliocene age. Quarternary deposits are represented by an extensive Conglomerate which unconformably overlies the Manchar rocks and slightly overlaps on to the Gaj series. Alluvial sands and gravels are of comparatively `Recent' origin.

The Gaj formation consists of mostly limestone with subordinate shale and sandstone. The limestone is friable to hard and at placed fossiliferious. This formation overlies Nari formation which consists of harder limestone beds and shale.

Overlying Gaj formation is Manchhar formation. This formation is composed of sandstone, clay beds, cemented sand and gravel (Conglomerate) and shell concrete. The clays are of various colors and consistency. Sandy layers are also found interbedded with clay and gravel.

3.2 Seismicity of the Region:

According to the Uniform Building Code (1997), Karachi and its adjoining areas fall in Seismic Zone-2B.

Following are the seismic parameters for Karachi Region:

Seismic Parameters	Value
UBC Zone	2B
Max Peak Ground Acceleration	0.16 – 0.24g
Magnitude (Richter Scale)	6.0 – 7.0
Intensity (MM Scale)	VII – VIII

4. SUBSURFACE CHARACTERISTICS:

4.1 General Stratification:

The stratigraphy and the subsurface conditions have been evaluated on the basis of boring logs supported by field and laboratory test results.

Borehole BH-1:

In this borehole, subsoil investigation has revealed that top 10.50 m consist of fill and soft to firm organic clay. The organic matter has an odor. The soft nature of this deposit is manifested by SPT blow counts as well as the laboratory test results. The deposit has nearly 100% degree of saturation and the very high natural moisture content.

Beneath the clay deposit, substrata comprise of very dense, gravelly, coarse SAND. This deposit is underlain by friable to medium hard, SANDSTONE that continues upto the investigated depth of 30.0 m.

The substrata may be generally described as follows:

1. Blackish gray, soft to firm, silty CLAY / clayey SILT
2. Gray, very dense gravely, coarse SAND
3. Grayish brown, friable to medium hard, SANDSTONE

Borehole BH-2:

A study of borelog BH-2 shows that top 6.0 m consist of medium dense, silty SAND / sandy SILT. From 6.0-27.50 m substrata comprise of alternate layers of SAND and hard, clayey SILT. This is followed by very dense, sandy GRAVEL and medium hard to hard, SANDSTONE that continues upto the investigated depth of 39.0 m.

The principal subsurface deposits can be described as follows:

1. Brown, medium dense, silt SAND / sandy SILT
2. Gray, dense, fine to coarse SAND
3. Brown, hard, clayey SILT
4. Brown, cemented SAND with interlayers of clay
5. Brown, hard, clayey SILT with interlayer of sand
6. Gray, very dense, sandy GRAVEL
7. Yellowish brown, medium hard to hard, SANDSTONE

Borehole BH-3:

An assessment of borelog BH-3 has revealed that top 2.5 m consist of SAND and very stiff, clayey SILT. From 2.5-7.0 m, substrata comprise of dense, silty / clayey, fine to coarse SAND. Beneath the sand deposit, there occurs a thin layer of hard, silty CLAY / SHALE deposit. This is followed by very dense, SAND / sandy GRAVEL hard, clayey SILT. This is followed by soft CLAYSTONE that extends upto the explored depth of 30.0 m.

The principal lithological units can be classified as follows:

1. Brown, medium dense, fine to coarse SAND
2. Brown, very stiff, clayey SILT
3. Gray, dense, silty / clayey, fine to coarse SAND
4. Brown, hard, silty CLAY / SHALE
5. Brown, very dense, fine to coarse SAND, some silt

Borehole BH-4:

Subsoil investigation has revealed that top 2.50 m consist of medium dense, gravelly SAND. From 2.50-9.0 m substrata comprise of very dense, sandy GRAVEL. This is underlain by very dense, sandy SILT and soft, CLAYSTONE that continues upto the investigated depth of 30.0 m.

1. Brown, medium dense, gravely coarse SAND
2. Brown, very dense, fine to coarse SAND
3. Gray, very dense, sandy GRAVEL
4. Brown, soft, CLAYSTONE

The exact sequence of occurrence of these deposits is shown on borelogs appended to this report.

4.2 Ground Water Table:

Following Table 3.1 presents position of ground water table in 4 boreholes

T A B L E 3.1

POSITION OF GROUND WATER TABLE

Boring No.	Chainage	Depth of Water Table (m)
BH-1	0+000	2.50
BH-2	9+000	12.20
BH-3	15+000	2.50
BH-4	25+000	23.00

5. FOUNDATION RECOMMENDATIONS:

5.1 General:

Foundations of structures are considered satisfactory if they satisfy the following requirements:

a) The foundation must be safe against the possibility of shear failure

b) The foundation must not undergo excessive settlements

c) It must be placed at sufficient depth below ground surface so as to be safe from erosion, scouring action of water and seasonal variations.

5.2 Foundation Type:

The selection of foundation type depends upon the type of structure, site conditions, structural loads and the subsoil conditions

It is, recommended that the proposed flyover- bridge be supported on pile foundation.

5.3 Pile Foundations:

5.3.1 Pile Input Data:

Following pile data is provided by the consultants:

Pile diameter	:	1000 mm
Load per Pile	:	300 MT

5.3.2 Pile Length & Allowable Capacity:

As discussed in chapter 3, there are significant variations in substrata present in all boreholes. Hence, following section presents allowable pile capacities for each borehole separately.

Table 5.1 presents allowable pile capacities of 1000 mm diameter pile with total embedded lengths.

T A B L E 5.1

ALLOWABLE CAPACITY OF PILE FOUNDATION

Borehole	Interchange	Pile Dia (mm)	Total embedded Length (m)	Bearing Stratum	Allowable Pile Capacity (MT)
BH-1	DHA Karachi Interchang-1	1000	23	SANDSTONE	311
BH-2	Korangi Shah Faisal Interchang-2	1000	15	Very dense, SAND	314
BH-3	Malir Quaidabad Interchang-3	1000	16	-do-	304
BH-4	Open (near Memon Goth)	1000	12	Very dense, sandy GRAVEL	317

Table A, B, C & D at the end of chapter presents spreadsheets of statically computed allowable compression capacities of 1000 mm diameters pile for a range of embedded lengths. These capacities have been computed using a safety factor of 2.5.

5.3.3 Pile Load Tests:-

The statically computed compression capacities must be verified by conducting a full scale pile load test carried to atleast two times the working load on index pile (test pile). The test must be conducted in accordance with ASTM D-1143.

5.3.4 General Considerations for Pile Foundations:-

1. The pile capacities are for vertical axial loads in compression only.

2. During piling, it is imperative that the bearing stratum is properly identified. Proper borelog must be maintained for each pile. In case recommended bearing stratum is not encountered within stipulated length, the matter must be referred to the geotechnical engineer.

3. Before commencing concreting, the bottom of borehole should be cleansed of loosened soil, mud or any other debris.

4. Concreting should be done using a tremie pipe. During concreting it should be ensured that the bottom of tremie pipe is always submerged in concrete. The precaution is necessary to prevent `necking' of soil.

5. The concrete should have a slump of about 150mm so that it may freely pass through the tremie pipe. If necessary, a plasticizer must be used in concrete to improve workability.

6. **In borehole BH-1, due to presence of soft clay at top 10 m, it is recommended that permanent steel liner must be used at top 10 m length of pile. Minimum gauge of the steel liner must be 6 mm.**

5.4 Allowable Bearing Capacity for Retaining Walls:

For Borehole BH-1:

As discussed earlier, top 10.50 m comprise of soft, organic clay. The soft nature of this deposit is manifested by SPT blow counts and high moisture content. This is underlain by very dense, gravelly, coarse SAND and friable to medium hard, SANDSTONE.

Due to presence of soft clay deposit upto 10.50 m depth, it is recommended that the retaining walls for approach ramps be supported on short piles.

Allowable pile capacity of 600 mm diameter pile with embedded length of 12.0 m should be adopted as 60 MT.

Allowable pile capacity of 760 mm diameter pile with embedded length of 12.0 m should be adopted as 100 MT.

For Borehole BH-2:

It is recommended that retaining walls for approach ramps will be supported on strip footing.

A study of borelog BH-2 shows that top 6.0 m consist of medium dense, silty SAND / sandy SILT. This is underlain by alternate layers of SAND and hard, clayey SILT.

Allowable bearing capacity for strip footing placed at **1.0 m** depth should be taken as **1.00 tsf.**

For Borehole BH-3:

In borehole BH-3,top 2.5 m consist of SAND and very stiff, clayey SILT. From 2.5-7.0m, substrata comprise of dense, silty / clayey, fine to coarse SAND.

Allowable bearing capacity for strip footing placed at **1.0 m** depth should be taken as **1.50 tsf.**

For Borehole BH-4:

Subsoil investigation has revealed that top 2.50 m consist of medium dense, gravelly SAND. From 2.50-9.0 m substrata comprise of very dense, sandy GRAVEL.

Allowable bearing capacity for strip footing placed at **1.0 m** depth should be taken as **1.50 tsf.**

5.5 Seismic Coefficients:

For Borehole BH-1:

According to the Uniform Building Code (1997), the soil profile type falls in "S_D" category corresponding to 'stiff soil'.

Following table gives seismic zone, seismic zone factor, soil profile type and seismic coefficients.

Seismic zone	Zone factor 'z'	Soil profile Type	Seismic Coefficient 'Ca'	Seismic Coefficient 'Cv'
2B	0.20	'S_D'	0.28	0.40

For Borehole BH-2, BH-3 & BH-4:

According to the Uniform Building Code (1997), the soil profile type falls in "S_C" category corresponding to 'very dense, soil and soft rock'.

Following table gives seismic zone, seismic zone factor, soil profile type and seismic coefficients.

Seismic zone	Zone factor 'z'	Soil profile Type	Seismic Coefficient 'Ca'	Seismic Coefficient 'Cv'
2B	0.20	'S_C'	0.24	0.32

5.6 Cement Type:

American Concrete Institute (ACI) gives the requirements for concrete exposed to sulphate (SO_4) containing solutions. The ACI standards are given below:

Sulphate Exposure	Water Soluble Sulphate in Soil (%)	Sulphate in Water (mg/lit)	Cement Type
Negligible	0.00-0.10	0-150	OPC
Moderate	0.10-0.20	150-1500	Type II
Severe	0.20-2.00	1500-10000	Type V
Very Severe	Over 2.00	Over 10000	Type V plus pozzolan

Sulphate content in ground water has been found to be excessive. It is therefore recommended sulphate resistant cement be used in foundation in contact with soil.

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