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GEOTECHNICAL SURVEY REPORT

VOLUME – I

(MAIN PLANT AREA)

Contractor for Site Investigation Services:

Zishan Engineers (Pvt.) Ltd.

156, 1st Floor, Bangalore Town, Tipu Sultan Road, P.O. Box 12595, Karachi-Pakistan.
(92-21) 4385354, 4550639, 4550958 & 4550984 Fax: (92-21) 4533430 E-mail: contact@zishanengineers.com
Web site: www.zishanengineers.com

Geotechnical Investigation Contractors:

SOIL TESTING SERVICES

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GENERAL

Oil & Gas Development Co. Ltd. (OGDCL), as the Operator of the Qadirpur Gas field intends to install additional gas compression Facilities at Qadirpur Plant for the compression of natural gas.

OGDCL has engaged China Petroleum Engineering and Construction Corporation (CPECC) as EPC Contractor for Development of Gas Compression Project.

CPECC have appointed Zishan Engineers (Pvt.) Ltd. (ZEL) as their contractors for site investigation services for the project, to carry out survey and soil investigation of the plant site, New Eastern Header and New Eastern Manifold.

ZEL's associates Soil Testing Services – (Geotechnical Engineers and Testing Laboratory) have physically carried out soil investigation work at Qadirpur Gas Field.

The following sections (Volume I & II) give details of the Geotechnical Investigation carried out at Qadirpur site, subsurface conditions at site, results of laboratory tests, recommendations for cement type, Bearing capacities for Foundation Design and estimated capacities for piles etc.

CONTENTS

1.0 INTRODUCTION

Oil and Gas Development Company Limited (OGDCL) have drawn up a plan for the installation of Gas Compression at Qadirpur Gas Field, province of Sindh.

The field is located at a distance of 8 km from Ghotki in Sindh Province. Qadirpur gas field was discovered in March 1990. After installation of gas gathering facilities and plant, gas production was started in Sep. 1995.

China Petroleum Engineering and Construction (Group) Corporation (CPECC) are the main Contractor for the project. **M/s. Zishan Engineers (Pvt) Limited (ZEL)** have been engaged as contractor for site investigation services by CPECC.

In order to evaluate the foundation design parameters it was deemed necessary to conduct a programme of soil investigation at the site of the project.

M/s. Soil Testing Services were entrusted to carry out the soil investigation programme. Scope of work included drilling of boreholes, carrying out field tests, collection of soil samples, laboratory testing and preparation of report including recommendations regarding foundation design. Field investigations and laboratory work were carried out in April-May 2007. Laboratory testing of samples collected from the boreholes was carried out at Soil Testing Services Laboratory, Karachi.

This report presents a detailed account of subsoil investigations carried out at the project site. Details of subsurface investigations have been presented in section 2.0 of this report. Depth and sequence of subsurface strata is described in section 3.0 and results of laboratory tests are discussed in the following section. In section 5.0 recommendations regarding foundation design are presented. Salient features of the report have been summarised in the concluding section.

Appendices include boreholes & Test Pits location plan, borehole & Test Pit logs, Elevations and locations of Boreholes and Test Pits, laboratory test results and Photographs.

2.0 DETAILS OF INVESTIGATION

2.1 Methodology

In order to obtain adequate subsurface information an investigation programme was chalked out. This geotechnical investigation programme comprised drilling of boreholes, carrying out field testing, obtaining soil samples, transportation of these samples to testing laboratory and conducting laboratory tests on selected samples.

2.2 Drilling of Boreholes

- 25 Nos. boreholes each upto 20 m depth within plant area.

Details of boreholes and test pits are presented in Table 2.1

Table 2.1 Details of Boreholes / Test Pits

Borehole/Test Pits	Location	Drilled Depth (Meter)
BH-1 to BH-25	Main Plant	20
TP-1 to TP-30	Centre Line of Proposed Roads	1.5

Boreholes location was planned in a manner to obtain fair amount of information about subsoil conditions up to considerable depth. Location of boreholes is shown in Borehole Location Plan in appendix A. Depth of all the boreholes is shown in table 2.1. Logs of the borehole are included in appendix B.

Details of all boreholes and test pits are included in appendix C, while Logs of the borehole and tests pits are included in appendix B.

The boreholes were generally drilled by rotary/wash boring method. In this method soil is cut by the constant rotation of various types of bits. Drilling fluid, which is either water or bentonite slurry, is circulated through drilling rods. The returning fluid lifts loosened material. Casings are used to prevent the hole from caving in. A drive shoe of hard steel protects the bottom of the casing. This shoe has a larger diameter than the casing, which reduces friction between the casing and the hole-wall.

2.3 Excavation of Test Pits

A total of thirty test pits were excavated along central line of proposed roads upto a depth of 1.5 meter below present ground level.

The test pits were excavated manually. Depth and sequence of soil layers as observed in the test pits were recorded on test pit logs, which are included in appendix B.

2.4 Field Density Test

Field density tests were conducted in all the test pits to assess in situ density of the natural soil. Sand-cone method was employed for carrying out field density tests. Results of field density tests are presented in on test pit logs in appendix A of the report. The field density tests were carried in accordance with the specification ASTM D – 1556.

2.5 Standard Penetration Tests

Standard penetration tests were carried out at regular intervals of depth in soil layers to assess the in-situ compactness of various soil layers.

Standard penetration test is by far the most popular and economical method of obtaining subsurface information. A number of foundation design procedures make use of SPT results. Testing method essentially consists of driving a split spoon sampler of specified dimensions a distance of 46 cm into the soil at the bottom of the borehole. A 63.5-kg hammer falling free from a height of 76 cm is used to drive the sampler. Number of blows required to drive the 30.5cm is recorded as ‘N’ value. The standard penetration tests were carried in accordance with the specification ASTM D – 1586.

2.6 Collection of Samples

2.6.1 Collection of Disturbed Samples

Collection of representative samples forms an essential part of investigation programme. Disturbed soil samples were obtained from the split spoon sampler after performing standard penetration test (SPT). Disturbed samples were used to classify the soil type and depth of occurrence of different layers.

2.6.2 Collection of Undisturbed Samples

Undisturbed samples were extracted by means of thin walled Shelby tube.

2.6.3 Collection of Water Samples

In order to determine the chemical characteristics of water, water sample was collected from the boreholes. The sample was preserved in airtight bottle and sent to the testing laboratory.

3.0 SUBSURFACE CONDITIONS

3.1 Depth and Sequence of Strata

Depth and sequence subsurface strata at the site have been assessed through information/data obtained from drilling, field-testing and laboratory test results. Borehole logs are included in appendix B.

3.2 Groundwater Table

Ground water table was encountered in all the boreholes. Average depth water is about 2.5 meter.

4.0 LABORATORY TEST RESULTS

In addition to field testing, a number of laboratory tests were also conducted on selected samples. Results of these tests are helpful in classification of soil/rock, determining engineering properties such as strength & compressibility and assessing chemical characteristics of subsoil. Laboratory test results are included in appendix section of the report. Brief description of all the laboratory tests and testing standards is given in the following sections.

4.1 Grain Size Analysis

A soil consists of an assemblage of discrete particles of various sizes and shapes. The object of grain size analysis is to group these particles into separate range of sizes and to determine the relative proportions by dry weight of each size range. On the basis of results of grain size analysis, soil is classified according to the Unified Soil Classification System.

Grain size analysis is conducted in two stages. Particles size distribution of coarse- grained soils is performed by sieve analysis while hydrometer test is conducted to establish distribution of fine-grained soil. A total of eighty eight grainsize analyses were carried out as per ASTM D- 422.

4.2 Atterberg Limits

Atterberg Limits Tests include determination of the liquid limit, the plastic limit and the shrinkage limit. These limits are used to determine plasticity characteristics of fine-grained soil. Liquid limit (LL) is the moisture content at which a soil passes from the liquid to the plastic state as the moisture is removed. Plastic Limit (PL) is the moisture content at which the soil passes from the plastic to the semisolid state, as the moisture is removed. Plasticity Index (PI) is the difference of moisture content at liquid and plastic limits (PI = LL – PL).

Atterberg Limits for eighty eight soil samples were determined. Results of these tests are presented in the appendix section.

4.3 Direct Shear Test

Direct shear test or box test is one of the simplest tests for measuring the shear strength of soil. In this test, one portion of soil is made to slide along another by increasing the horizontal shear force. This test provides the angle of internal friction (ø) and the cohesion (c), which are important parameters for calculation of bearing capacity of soil. Twenty five samples were tested results of these tests are given in the appendix.

4.4 Unconfined Compressive Strength

Twenty six unconfined compression tests were conducted on undisturbed samples collected from the boreholes. Values of unconfined compression strength of samples are presented in this report as appendix.

4.5 Consolidation Test

Ten undisturbed samples were tested for one dimensional consolidation characteristics. e-log p curves are appended to this report. Shape of these curves indicates moderate pre-consolidation effect. It may be noted that the consolidation test was performed in accordance with requirements of ASTM Designation D-2435.

4.6 Compaction/CBR Tests

In order to obtain compaction characteristics of top soil, modified AASHTO compaction test was conducted on the samples of all the test pits collected from test pits. These tests were carried out in accordance with ASTM/AASHTO procedure.

Average Value of maximum dry density is 1.90gm/cc while optimum moisture content is varies from 8 to 12 %.

Three point CBR tests were performed on samples collection from test pits. CBR value was found to be in the range of 05 to 20.

4.7 TDS, Sulphates, Chlorides, pH

Sulphate in groundwater or soil can attack concrete placed in the ground or on surface. A reaction takes place between the sulphate and the aluminate compounds present in the cement, causing crystallisation of complex compounds. The expansion, which accompanies crystallisation, induces stresses in the concrete, which results in mechanical disintegration.

Measurement of sulphate content enables the ground condition to be assessed with respect to potential sulphate attack. Appropriate precautionary measure, such as the use of Sulphate Resisting Cement can be adopted on the basis of test result.

Results of chemical tests carried out on soil/water samples are presented in the appendix section.

5.0 GEOTECHNICAL RECOMMENDATIONS (For Main Plant Area)

5.1 Soil Types

The project site is underlain by following principal subsurface deposits.

(1) Silty Clay/Clayey Silt. (Cohesive)

belonging to CL-ML group of Unified system

(2) Fine to medium, silty SAND (Cohesionless)

belonging to SM group

Appended bore logs show sequence of occurrence of the above deposits at various tested locations.

Ground water on an average occurs about 2.5 m below present ground level. Ground water is subject to normal seasonal fluctuations with the passage of time.

5.2 Foundation Types

Based on test results following two foundation types have been considered in the analysis for Plant area.

(a) Conventional Shallow Footing

(b) Pile Foundations

5.3 Bearing Capacity of Shallow Footings

Recommended values of Net Allowable Bearing Capacity are summarised in Table 5.1.

Table 5.1 Bearing Capacity of Shallow Footing (For main Plant Area)

Depth Below Present Ground (m)	Net Allowable Bearing Capacity (kg/cm^2)
2.0	1.00
3.0	1.40

At the recommended bearing pressures given in Table 5.1, footings will be adequately safe against shear failure as will as possibility of excessive differential settlement.

5.4 Modulus of Subgrade Reaction

Values of modulus of Subgrade reaction (k) may be required for structural design of footings. Based on test results and empirical interpretation, K values are given in Table 5.2

Table 5.2 Modulus of Subgrade Reaction

Depth Below Present Ground (m)	Modulus of Subgrade Reaction (NN/m^2)
2.0	11
3.0	15

5.5 Pile Capacities

Heavily loaded structures shall have to be supported or Pile Foundations.

Tentative pile capacity values are summarised in Tables 5.3.

Table 5.3 Tentative Pile Capacity Values (For main Plant Area)

Pile Diameter (mm)	Effective Embedded Length (m)	Total Allowable Capacity (tons)
560	15	50
	15	75
760	15	80
	20	120

5.6 Confirmatory Testing

All pile capacity values given in Tables 5.3 and 5.4 have been computed from static formulae which suffer from theoretical limitations. These values shall, therefore, verified by full scale load tests at specific locations of structures, abutments/piers of bridge over river. Pile capacity values be suitably adjusted if warranted by results of pile load tests.

5.7 Compaction / CBR

Following parameters are suggested for compaction central and design of road pavements.

Max Dry Density (Modified)	:	1.90 g/cc
Optimum Moisture	:	12 per cent
Design CBR of Subgrade Compacted to 95% modified Dry Density	:	07

5.8 Seismic Design

Based on tests results and empirical interpretation, following parameters may be adopted as per UBC-97 and ACI-318 for RCC Design for seismic forces.

Soil Profile	:	S_D
Ca	:	0.28
Cv	:	0.40
Shear Wave Velocity	:	650 m/sec

5.9 Type of Cement

Subsurface possess excessive amount of harmful sulphate salts. As such, all underground concrete works be carried out with type V sulphate resistant cement.

6.0 CONCLUSIONS

Salient features of this report are summarised hereunder:

- Geotechnical investigation for Qadirpur Gas Compression Project (Main Plant Area) was carried out in April-May 2007.
- Twenty Five boreholes were drilled. Depth of these boreholes is shown in respective borelogs. In addition to this thirty test pits each 1.5-meter deep were also excavated at the project site.
- Standard penetration tests were conducted at regular interval in the borehole.
- Depth and sequence of subsurface strata are presented in section 3.0.
- Ground water table was encountered at an average depth of 2.5-m in all the boreholes.
- Recommendations regarding foundation design are presented in section 5.0 of the report.
- Use of Sulphate resistant cement is recommended for all underground concrete works.