Wheata Grain Silos Project

1. Introduction

The Building and Road Research Institute (BRRI) , University of Khartoum was requested by Wheata Grain Silos Co. to undertake a detailed geotechnical investigation program for the proposed silos in Port Sudan City. The proposed area is 90m by 100m. The investigation included drilling of 10 boreholes, performing in-situ and laboratory tests to reveal sub-soil profiles and reporting on the results with analysis and recommendation for foundation alternatives and treatments for the proposed structures on site.

This report presents the results of field and laboratory testing programs. The field work was conducted during August 2003.

The laboratory testing and geotechnical report were completed in the following weeks.

2. Project Description

The site is located in Port Sudan. The Proposed structures consist of 16 silos arranged in 3 rows. A Head house is located in the middle of the east side. (See Fig. 1).

3. Field Investigation

A total of 10 boreholes were realized in this soil investigation. The depths of these boreholes is ranged between 15m – 25m. The locations of the boreholes are shown in (Fig. 1).

The boreholes were drilled by a continuous flight auger Acker AD-II type rig. Disturbed soil samples were collected at each change of soil strata or at one meter intervals where soil conditions did not change. These were kept in plastic bags, labeled and transported to BRRI soil mechanics laboratory for visual inspection and testing.

The soil conditions at this site didn't allow taking undisturbed samples. Standard penetration tests (SPT) were performed at a depth interval of 1.5m. A split spoon sampler, 50mm in diameter was driven by the blows of a standard hammer weighing 64kg and falling freely from a height of 760mm. The number of blows required to give a tube penetration of 300mm was taken as SPT-N value of the soil tested at a specified borehole depth.

4. Laboratory Testing

Laboratory testing was conducted to evaluate the geotechnical and chemical properties of the soils encountered during the boring.

The laboratory testing procedures followed were in general conformance with those recommended in British Standard BS 1377 (1990) and the soils were classified according to the Unified System for Classifying Soils (USCS). The laboratory tests performed included the following:-

4.1 Atterberg Limits

These tests were carried out on representative soil samples and the results are shown in Appendix (A).

4.2 Grain Size Distribution

These tests were carried out on representative soil samples taken at different depths of the boreholes. The results of these tests re shown in Appendix (B).

4.3 Chemical Tests

Chemical Tests were carried out on soil samples taken from selected depths in some boreholes. The results of conducted tests indicated the presence of sulphate and chloride contents of the soil. The results are shown in Table (1).

5. Soil Profile

The ten boreholes drilled at the locations shown in Fig. (1) indicated a general subsoil profile that consists of silty sand followed by coralline deposits.

The silty sand was exposed at the surface of all boreholes. Its thickness varies from 2.0 to 4.0m. The silty sand contains variable amounts of corals and gravel. The silty sand is very loose to loose.

A very dense to hard coralline silty sand layer (SPT>50) was identified below the top layer and extended to 7.0m in boreholes No. 1and No. 2 and to 8.0m in boreholes No. 3, No. 4 and No.8.

A medium weathered coralline deposits with silty sand or silty clayey sand was encountered below the above mentioned layer and extend to 19.0m depth almost in all boreholes.

A very hard weathered disintegrated coralline limestone (SPT>50) was encountered below 19m depth and extended down to the bottom of the boreholes.

6. Ground Water

The ground water table was encountered at 1.50 m depth during this site investigation. This shallow depth is expected to be a factor in design and construction of foundation system.

7.0 Discussion of the Results in Relation to Foundation Design and Construction

7.1 Introduction

This section of the report presents a discussion of the results of the investigation and the recommendations of the foundation for the proposed structure. Suitable foundation type shall be designed such that the soil bearing capacity is not exceeded and expected settlement are within tolerable limits.

The results of Atterberg Limits indicated that values of liquid limits are all below 33%. This indicates that the fines (i.e. silt and clays) are non-plastic to low plastic.

The shear strength parameters established from SPT results were used to check the possibility of bearing capacity failures at different foundation depths.

Different values of SPT varying from 2 to more than 50 were encountered at this site. This variability in the strength of the soil (values of SPT) is characteristic of the coralline mixed deposits of the coastal red sea areas.

7.2 Foundation Alternatives

The factors which influence the choice of the type of foundations are:-

(1) The strength and volume change characteristics of the subsoil when subjected to loads from the superstructure and to environmental changes.

(2) The magnitudes and nature of the loads from the superstructure.

The specific factors from this site which control or affect the selection of the foundation types and their suitable depths are discussed below.

The soil profile may be roughly divided into four zones as follows:-

(a) The top silty sand layer of thickness varying from 2.0 to 4.0 was considered as very loose to loose. This layer is very weak and cannot be used as bearing stratum for the foundation without adopting special treatment.

(b) A very dense to hard coralline silty sand layer (SPT>50) extended to 7.0m or 8.0m.

(c) A medium weathered coralline deposits with silty sand or silty clayey sand was encountered below the above mentioned layer and extended to 19.0m depth.

(d) A weathered disintegrated coralline lime stone stratum with SPT > 50 was encountered below 19.0m depth down to the bottom of the boreholes (25m).

From the above mentioned layers and the profile of individual boreholes it is clear that there is a large variability of soil formation due to the nature of the coralline mixed deposits of the costal red sea areas.

The weathered limestone formation can act as a good support whenever the option of deep formations is considered.

7.3 Silos Foundation

The silos can be founded on soil by means of footings, rafts (or mats) of the beam and slab type or flat slab type, piles or piers, with cap, depending upon the load and soil conditions. When footings are used, strap beams may be provided connecting the columns at their base, to overcome the effects of differential settlements.

A shallow foundation system can be used for the proposed structure in this site if a suitable design and construction procedure is used. Considering the horizontal and vertical variability of the soil and the shallow depth of ground water (1.5m), the following procedure is recommended to be adopted: -

1) Removal of the top 1.5m and its replacement with a compacted selected fill to provide at least 2m of compacted fill below the foundation and floor slab.
2) The fill material should be from a typical road subbase material type. This material should be well compacted in layers of 200mm thickness to at least 95% of the maximum modified Proctor density and moisture content ($\pm$2%) of the optimum moisture. This compacted fill will provide a competent uniform support of a rigid layer beneath the structure.
3) The fill should be extended about 2.00m around the areas covered by the silos.
4) An allowable design bearing capacity of 200KN/m^2 can be used for design of a foundation on a compacted fill.

7.4 Head House Foundation

The same treatment adopted for the silos foundation should be tackled in this location. A pad footing is recommended to be placed at depth of 1.5m over a compacted fill of at least 0.8m depth beneath it. The fill should be well compacted in layers of thickness less than 0.2m to at least 95% of the maximum modified Proctor density. Allowable bearing capacity of 200KPa can be adopted for sizing the foundation of the building.

7.5 Chemical Test Results:

Table (1) shows the results of the sulphate and chloride contents tests carried on samples from 2.0 to 5.0m depth. It is well known that solid salts do not attack concrete, but when present in solution, they can react with hardened cement paste. Some soils contain sulphates, and the groundwater in such a solid is in effect a sulphate solution, and thus attack of cement can take place.

According to BS 8110:part 1: 1985, the concentration of sulphates (expressed as SO_3) in soils where concrete is exposed to sulphate attack is as follows:-

Class	Concentration of Sulphates SO3	
	Total SO3 %	SO3 in 2:1 water-soil extract g/l
1	Less than 0.2	Less than 1.0
2	0.2 to 0.5	1.0 to 1.9
3	0.5 to 1.0	1.9 to 3.1
4	1.0 – 2.0	3.1 – 5.6
5	Over 2.0	Over 5.6

For class (1) and Class (2) Ordinary Portland Cement (OPC) can be used with cement content of 330kg/m^2 and water/cement ratio of not more than 0.55 for the latter (i.e. Class 2).

The reported results indicate that the total sulphate contents correspond to Class (2) (i.e. 0.33 maximum), however the water soluble sulphates correspond to Class (1) (i.e. less than 1.0gm/l).

Hence, good quality OPC can be used. However, care must be taken with regard to the nature and movement of groundwater. OPC would not be recommended in acidic conditions i.e. water with PH less than 6.

In reality this is not the true picture, because the soil samples tested contained also chloride ions. Above certain threshold chloride ions attack both concrete and reinforcement. The situation is aggravated when sulphate resisting cement (V) is used on the assumption that chlorides and adversely affect sulphate resistance. So some standards, for example BS 8110:1:1985 severely limit the chloride content (Not more than 0.2%). For this reason, Type II cement offers the best compromise.

Pozzolanic cement is another alternative. But in all cases low-permeability of concrete is a decisive factor which determines the degree of sulphate or chloride attacks. This can be achieved by the use of appropriate cement (Type II or Pozzolanic Cement); low water/cement ratio, good compaction, and absence of cracking due to shrinkage, thermal effects or stresses in service. Moreover, the concrete must adequately be cured.

8. Conclusions and Recommendations:

8.1 Site Conditions

The report summarizes the results of the field and laboratory investigations performed for the proposed Wheata grain Silos in Port Sudan. A total of 10 boreholes with a maximum depth of 25m were drilled.

Field and laboratory tests were performed on representative soil samples taken from the boreholes to obtain the important data needed for the selection and design of the appropriate type of foundation.

From the analysis of the soil profile, Four main zones were identified. The silty sand layer at the top is recommended to be cut and replaced with a well compacted structural fill to a depth of 1.5m so as to be considered as a bearing layer for the foundation.

8.2 Foundation

A careful evaluation of the subsoil conditions and the level of water ground which greatly effected the strength of the foundation layer, suggested the use of shallow foundation to support the proposed structures.

It is recommended to remove 1.5m of native soil and replace it with a compacted fill to (+0.5) above surface level. This means to provide at least 2.0m of a well-compacted subbase material underneath the beam foundation and floor slab.

An allowable soil bearing pressure of 200KN/m^2 can be used for design. Details of design and construction of the foundations for the silos and the Head House are presented in section 7.3 and 7.4 respectively.

Chemical test results shows that the values of chloride and sulphate content increased over that allowed by the BS81110. The recommended precautions to be adopted are described in section 7.5.

8.3 General

BRRI should be contacted if the scope of the project as described is changed and if soil conditions different from those exposed at the boring locations are encountered.

BRRI should be provided with the final specifications and drawings for the silos and Head House foundation to verify that the recommendations given in this report were interpreted as intended.

Table (1): Chemical Tests Results

Serial No.	B.H. (No.)	Depth (m)	Sulphate Content (%) B.S. 1377:90:3:/5		Chloride Content(%) BS 1377:90:3/7
			Acid Extract	Water Extract (g/l)	
1)	2	4.0	0.22	0.09	0.25
2)	4	3.0	0.33	0.09	0.17
3)	7	4.0	0.29	0.11	0.32
4)	8	2.0	0.27	0.13	0.76
5)	9	5.0	0.01	0.07	0.38

Appendix (A)
Boreholes logs and summary of Laboratory test Results

Appendix (B)
Grain Size Distribution