

Appraisal of Geotechnical Characteristics of Ormara Soil, Baluchistan, Pakistan

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Abstract: Ormara is located 240 km west of Karachi which is a coastal and port city (25° 16' 29N, 64° 35' 10E) of Pakistan. Present study evaluates engineering properties of soils of Ormara for future construction plans and possible expansions in the area. Fifty bore holes were done in study area at depths of 20m, 40m and some (10 bore holes) were 60m deep. The study area was divided into three major zones i.e. Foot hills, on-shore and off-shore. Groundwater was encountered at depths of 2.75m on onshore and offshore zones and at 3.65m depth in foothill zone. Laboratory testing i.e. moisture content (12 to 38 %), liquid limit (from 26 to 34), plasticity index (10 to 18) of soil samples indicate that soils are low plastic to moderate plastic in nature. Soil samples of granular soils indicate angles of internal friction (ϕ) varying from 26°- 36° in upper sand layers while 26° to 30° in lower silt layers (encountered after the clay layer) and Cohesion ranges 0 to 0.04kg/cm² in all three zones. Further, unconsolidated undrained triaxial compression tests on a clayey soil sample indicated an undrained cohesion value of 28 kPa. Density values ranges from 1.6 to 2.05gm/cm³. Consolidation ($C_v = 0.20$ to 0.40 cm²/minute, $C_c = 0.149$ to 0.17) has been calculated for clay layer. Chemical tests carried out on soil samples indicated that soil and water both are reactive aggressively and may cause corrosion to steel and concrete disintegration.

Keywords: Ormara, geology, soils, geotechnical characteristics.

Introduction

Ormara, located 240 km west of Karachi, is a coastal and port city (25° 16' 29N, 64° 35' 10E) of Pakistan. Ormara is about 10km long headland (Fig 2) and is at higher elevation from surrounding coastal areas of Gwadar and Jiwani. Geologically it is a part of Ormara microplate and situated to the west of Ornach-Nal Fault system (Kukowski 2000).

In the present study to determine the geotechnical characteristics of Ormara soils, in-situ drilling and engineering tests (such as the field standard penetration test, cone penetration test, chemical testing (as per ASTM standards) were carried out in the field. In the second phase, laboratory tests (such as gradation, Atterberg's limits, direct shear, consolidation, tri-axial test) were conducted to classify and predict the in-service behavior of soils. In addition, chemical testing of soil and water (pH, total dissolved solids, salinity, sulphate and chloride content as per BS standards) were conducted. Overall all, 50 bore holes were done at offshore, onshore and foothill zones at depths of 20m, 40m and some (10 samples) at 60m depth (Fig. 4). Rotary and percussion drilling methods were used to drill boreholes (Braja, 1975, Bowles, 1996). Aqua bentonite slurry of suitable consistency was circulated as a drilling fluid to provide stability to boreholes (Dimitri and Judd, 1970, Braja, 1975).

Materials and Methods

Published literature on engineering properties of soils in Ormara is not available. Being a part of Makran

subduction zone, most of the work carried out is related to tectonics, seismology and earthquake and tsunami related hazards of the area. In the following a summary of geological research work carried out in the Makran Subduction Zone is presented. Vredenburg (1921) worked on foraminiferal assemblages of Sindh and coastal areas and established data for classifying numerous complicated Tertiary beds. Snead (1966, 1968, 1969) discussed geology of Makran and described landforms of Sonmiani beach (Lasbela district) and identified different types of weathering and their products. Platt et al. (1985) worked on sedimentology of Makran subduction zone. Their field observations in the emergent part of the Makran accretionary prism show that a mid-Miocene to early Pliocene slope and shelf sedimentary sequence was deposited directly on abyssal-plain turbidites without any detectable stratigraphic or structural discordance. Minshull et. al (1992) discussed sedimentation types and deformation patterns in Makran accretionary wedge. They calculated the consolidation rates and porosities of different strata. According to Minshull et. al (1992), 7-km-thick column of sands and quartzolitic turbidites are incorporated into this wedge in a series of deformed thrust sheets. Porosities were calculated from the seismic migration velocities. Siddiqui and Ahmed (2002) classified Oysters in three genera (*Crassostrea*, *Saccostrea* and *Ostrea*). These include *Crassostrea gryphoides*, *C. madrasensis*, *C. belcheri*, *C. glomerata*, *Saccostrea cucullata*, *S. echinata*, *Ostrea nomads*, *O. folium* and *O. cristagalli*. Two species *Ostrea nomads* and *O. cristagalli*, were reported for the first time from Pakistan.

The Geology of Ormara area is generally composed of shale, argillaceous sandstone, sandstone with alternating beds of clay, clayey silt and shaley beds. Lithostratigraphic units exposed are Gawader and Jiwani formations (Shah, 1977). In the Makran coastal area, many mud volcanoes were observed, which shows that the whole area is tectonically very active which suggests building high stresses underground (Jordan, 2008). Sondh volcano in Guzbal village was observed, which was not active during fieldwork but dried mud flow around its neck and periphery were not so old that shows active behavior. Ormara platform in the present study was divided into offshore, onshore and foot hill zones for better understanding and sample collection. Starting from sea-side, the first zone is designated as offshore zone. Ormara offshore platform dips to sea at an angle of about 3 to 5° which indicates fault blocks. It is composed of Miocene-Pleistocene sediments mainly consist of mudstones and sandstones. At a distance of 25m from the shore face, water-sediment interface is at about 9m depth (Fig. 3).

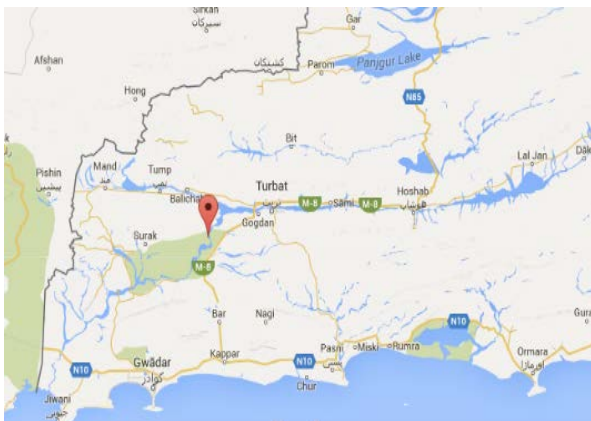


Fig. 1 Study area, Ormara.



Fig. 2 Ormara headland and bays.

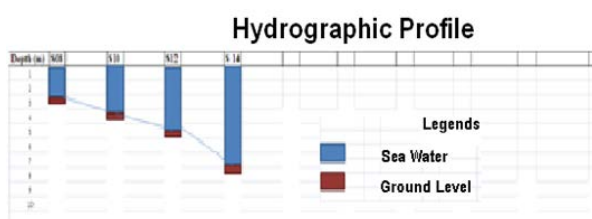


Fig. 3 Water depth along offshore Zone.

Generally, tides fluctuate between 0.5m to 3.2m. Sea floor in this zone is uneven and water waves are wind-driven that break upon shore. At places, sea water has piled up sand in the form of domes. Ormara onshore zone stretches from foot hills to offshore zones and its width is about 2 km. This zone is comprised of wave cut platforms and isolated terraces that are broad with gentle slopes. Ormara onshore platform and terraces contain waves deposited minor micro-conglomerate, calcareous sand, silt and clay, relics of corals and oyster shells (Siddiqui and Ahmed, 2002) and weeds. Aprons of sea sands mixed with land derived sediments are common in on shore zone. Foothill zone is composed of ridges and isolated faulted blocks. The sediments forming these deposits range in age from Miocene to Recent. Quaternary deposits cap some of the terraces which are at about 500m elevation. The annual average rainfall in Ormara is about 150mm that makes the soils saline and desert conditions prevail there. Being an arid area, differential weathering has created uneven terrain. In addition to this salt weathering, honey comb structures and slaking are present. At places, flushing of soft and weathered material has produced hoodoos. Overall dip of outcrops is towards south whereas they extend east-west (Gill, 2007).



Fig. 4 Site investigation Plan and boreholes location.

Rotary and percussion drilling methods were used to drill boreholes (Braja, 1975, Bowles, 1996). Samples were collected with relevant standard observations and pertinent laboratory tests were performed. Results were justified with engineering practices and conclusions were drawn.

Results and Discussion

Three soil layers were defined on the basis of exploration and classification of soil as shown in table 1.

Standard penetration test, performed at interval of one meter, revealed low to moderate value showing loose to moderately dense sand with gravel (L1b) in foot hills zone and this value increases with depth. When clayey silt is encountered and while in case of offshore and onshore zones, N-value is moderate (<8) up to 8m showing loose to moderately dense sand layer with traces of sea shells (L1a). A drastic decrease in N-

value at 10 m to 23m due to presence of soft clay layer (L 2) was noted, which shows this is very soft till 23 m and becomes moderately stiff after 25 m. At places, this value increases after 30m and reaches its maximum at depth of 40m, where fine clayey silt layer (L3) is present. Unit weight values for the subsurface soil strata layers encountered during the investigations were 1.6 to 2.05gm/cm³. This showed that soil encountered at site was moderate to highly dense. Clay layer (L2) starting from 12m also contains organic matter at depth of 24m, in ratio of about 20 to 30%.

Table 1 Layer designation on the basis of borehole drilling.

		Classification	Presence in Zones	Depth
Layer1	Layer 1a	Silty sand with sea shells	Offshore and Onshore	Up to 8 m
	Layer 1b	Silty sand with Gravels	Foot hill	Up to 2 m
Layer 2		Silty clay	Offshore, Onshore zones	12m to 42m
Layer 3		Clayey silt	Offshore, Onshore and foothill zones	42m to onward

Results of classification test indicated that granular soils mostly comprise of poorly graded silty sand with gravels SP-SM (Layer 1 b) (only in foot zone), silty sand (SM) (Layer 1a) and silty clay (CL) (Layer 2) (in Offshore and Onshore zones) and clayey silt (Layer3) soil groups (in offshore, on –shore and foot hill zones) according to Unified Soil Classification System (USCS). The soils layers (L2 and L3) contain fines (passing sieve No. 200) ranging from 10 to 60%. (n=60). This shows that layer 1b has been derived by weathering of nearby ridges evidenced the presence of gravel mixed sea derived sediments; any how this layer has been dominated by sand. This layer makes the top of sediment which are underlined by clayey silt (L3), which dominantly contain silt with clay (10 to 40%) and is very stiff, as blows >40 have been recorded even at 15m. The absence of clay layer (L2) in foothill zone may be due to far distant and height, where sea could not deposit the marine clay. Similarly, offshore and onshore area contains silty sand (L1a) with sea shell indicating that this layer has been deposited by sea deposition. This layer is then followed by clayey layer (L2) of grey color and then followed by clayey silt (L3) layer, which is similar to clayey silt layer (L3) of foothill zone. The laboratory tests were performed on selected sixty soil samples, which yielded natural moisture content ranging from 12 to 38% (Q=12-38, n=60). These values are quite significant which indicate that soil is moist at margin of offshore zone and onshore zone anyhow moisture content decreases as one moves away from offshore zone. Moreover, top layer L1a found in offshore and on shore zones is moister than L1b found in foothill zone. Consistency limits tests results indicated that the soils (layer 2) have liquid limit (LL) ranging from 26 to 34 and plasticity index (PI) varies from 10 to 18 (in all the three zones) (n=30). Since, consistency test is performed on cohesive soil like clay, and in this study, layer 2 has been designated as clay which also contains silt in

varying proportions. These results show that this layer contains soil with low values of plasticity indexes and has been termed as low plastic to moderate plastic soil. Direct shear test performed on soil samples of granular soils (L1a, L1b) indicated angles of internal friction (ϕ) varying from 26- 36° in upper sand layers while 26 to 30° in lower silt layers (L3) (encountered after the clay layer) and while C ranges 0 to 0.04kg/cm² in all three zones. (Q=26-30, n=10). This test was performed on layer 1a, 1b and layer 3 and results obtained indicate that layer 1(both L1a and L1b) is loose to moderate dense and poorly graded to well graded, similarly layer3 is estimated as well graded with some percentage of fine (clay), due to which angle of internal friction has been reduced to 30°. Two (02) Unconsolidated Undrained (UU) Triaxial compression tests on a clayey soil (layer 2) sample indicated an undrained cohesion value of 28 kPa at 35m depth. Consolidation parameters have been calculated as $C_v = 0.20$ to 0.40 cm²/minute, $C_c = 0.149$ to 0.17 for layer 2. These results show that layer 2 is highly compressible and may undergo settlement. Moreover, presence of organic matter at depth of 24m may cause secondary settlement. High to very high expected contact pressures from the heavy construction would result in higher localized depressions / settlements of an order of 65 to 100+ mm (Jonathan and Rodolfo, 2008; Jung et al., 2010). Groundwater was encountered in the boreholes at average depth of about 2.75m. In addition, four (04) piezometers were also installed in the drilled boreholes to study the fluctuation of water table. It was noted that the groundwater level may experience seasonal and tidal fluctuations and may rise to higher elevations about ± 1.5 m closer to shoreline and about ± 0.5 m farthest from shoreline as shown in figure 5.

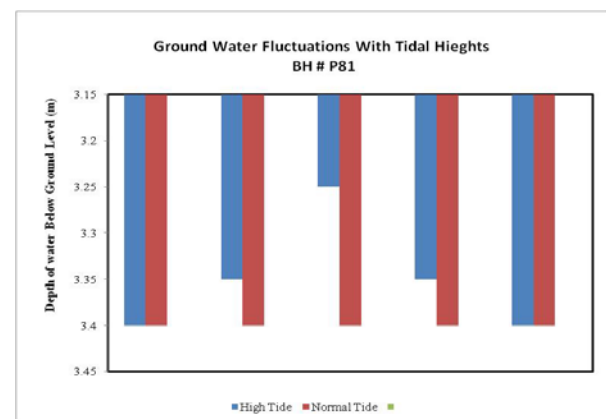


Fig. 5 Ground water fluctuation with sea tides.

Chemical tests carried out on selected two (02) soil samples indicated that soil and water both have reactive aggressivity and may cause corrosion to steel and concrete disintegration. Salt concentrations are shown in table 2. In such situations, ordinary Portland cement is not recommended and some special type of cement e-g sulphate resistant cement is used to avoid these reactions (Neville, 1977; ASTM, 1996; AASHTO, 1988).

Table 2 Concentration of different chemical elements.

Chemical Content	Soil	Water
chloride	500 ppm	500 ppm
sulphate	2000 ppm	2000 ppm
TDS	3000 ppm	2500 ppm
pH	7.5 to 8.55	5.5-6.5
Organic Matter	6.5 to 11.2	-

Conclusion

Based on literature study during this work, Ormara, is located in the area that is seismically active and source (Chaman Fault) distance is very close about 700 km and from its splays like Ornach-Nal fault (150 km), Ormara fault (25 km), Hoshab fault and Makran Coast Fault (100 km). Therefore, there is maximum potential of earthquake with magnitude of about 7. Sandy soil strata having N values < 5 (in offshore zone at depth of 1 to 15m and in onshore zone from 4 to 10m) show very loose, sensitive layers, which are susceptible to liquefaction, while foothill zone show less susceptibility for liquefaction. Although clayey soils are not susceptible to liquefaction potentials but low N values <6 (in offshore and onshore zones) may suffer considerable settlement and shear strength loss. Subsoil and groundwater at the site, contain high to moderate concentration of soluble sulphates, chlorides and other aggressive salts. Therefore, it is recommended that sulphate resistant cement up to plinth levels should be used for all concrete works.

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