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Geotechnical Assessment of Barrow Area Materials Earthen Small Dam for the Proposed Lower Porali River Basin District Lasbela, Baluchistan– A Case Study

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Abstract. This study aimed to investigate the geotechnical characteristics of the soil district Lasbela, Baluchistan, in the Porali river basin. Tests were carried out on the sample soil, including particle size analysis, Atterberg's limit tests, bulk and dry density, natural moisture content and modified proctor. The plasticity index and particle size study indicated that the soil was classified as A-1-a by AASHTO and as GP by the Unified Soil Classification System (USCS); Atterberg, A. (1911); D-2487 (1996). Maximum dry density and optimum moisture content values of soil samples evaluated TP-01, 03 and 05, 2.263 g/cc, 2.256 g/cc, 2.247 g/cc and optimum moisture content is 6.2, 7.1 and 7.5% respectively. The soil was proposed that the soil in road subgrade and other construction works would be excellent as a filling material and need alteration to enhance its sub-base and road base material properties.

Keywords: geotechnical, borrow area investigations, test pit logs, district Lasbela Baluchistan

Introduction

Lasbela is a district that lies in the southern part of Balochistan. The population of Lasbela is about 574,292 is estimated and the ratio of the Muslim population is upto 97% compared to other minorities like Hindus and Christian. A significant proportion of the population speaks Balochi and Sindhi languages. There is another famous language in Lasi, which is also primarily spoken, the source of this language is Sindhi or Jadgali. The studied area where the geotechnical investigations are exposed is about 232 Km northwest of Karachi, Pakistan and 32 Km from District Lasbela, Balochistan, on the Karachi to Quetta road. The area of study is easily accessible and lies in the toposheet no. 35 0/3 in between latitudes: 27°,25′,24″ N to 25°,26′,06″ and longitude: 68°,09′,10″ E to 66°,11′,05″ E (Fig. 1).

Geotechnical investigation is always needed for any engineering structures, buildings or dams. The research can range from fundamental analysis of surface soils with a few shallow test pits to extensive *in-situ* soil study and laboratory tests. The soil takes on an active role only when the civil engineer needs to use it as a building material. The ground along which the road or dam has to be built or the track has to be laid is not always at the correct level for constructing highways

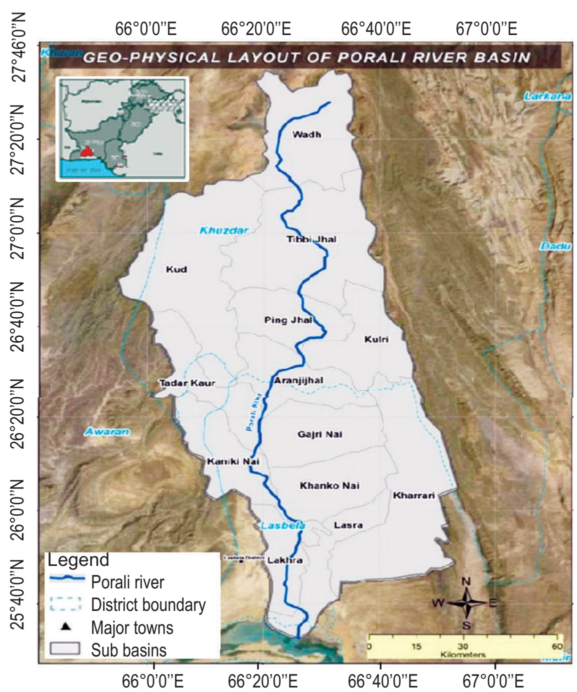

Fig. 1. Pakistan map showing geophysical layout of study area.

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and dams. The soil must then be cut in places and other places must be built up or filled with soil. The Engineering Geologist discovered that soil filling is not done by only dumping soil. Engineered fills, such as earth embankments, must be created to withstand the loads imposed by the road or railway track. Soil is often used to build earth dams, an engineered filling designed to keep water out (Shashi and Manoj, 2005).

In site investigations, estimating geotechnical properties of soils using basic field tests is a frequent procedure. For practical engineers, these tests are simple, affordable and tangible (Rastegarnia *et al*., 2017; Kayabas, 2015; Sivrikaya *et al*., 2013; Sivrikaya and Tougrol, 2006). The geotechnical properties of distinct soils are extensively researched to examine their parameters and determine potential relationships between them (Mostafaei *et al*., 2019; Boadu, 2018; Foroutan *et al*., 2018; Lawson *et al*., 2018; Motaharitabari and Shooshpasha, 2018).

Any soil is the product of the breakdown of the earth's crustal rocks. The action of chemical and mechanical forces that have been exerted for countless ages on the parent rock formations has brought about this destruction or weathering. Therefore, the soil may be classied into two groups: residual soil, e.g., Transported and Laterite soil, e.g., aeolian soil, alluvial soil, glacial soil, etc. (Wright and Dixion, 2003). The assessment of a geotechnical analysis for any field is impossible without high-quality surface and subsurface soil samples (Kalwar *et al*., 2021). However, no work has been carried out in detail on the geotechnical characteristics of the Porali river basin material. Novelty and practical implications of this study are overlapping as, China-Pakistan Economic Corridor (CPEC) is considered one of the major construction project in Baluchistan Pakistan. Thus, the present study is aimed at studying the geotechnical aspects of soil from the study area for use in the construction industry. Identification of such materials near the construction zone could play huge part in cost effectiveness and time efficiency.

Geological background. The study area is a coastal city along the Arabian sea, so the coastal area of Pakistan receives a vast volume of fluvial and alluvial sediments annually which is transported by many rivers like Indus (Sindh), Ulhas, Tapti, Narmada, Hab, Porali and Hinglo, there is some other small tributaries, all these agents transport tons of sediments into the Arabian sea. Among all these agents, one of the major contributors is Indus (Sindh) river, which alone transports about 400-500 MT yearly (Chaudry *et al*., 2002; Milliman *et al*., 1984). The outflow area of the Indus (Sindh) river and its tributaries is about 551-700 km^2 (Chaudry *et al*., 2002; Bender *et al*., 1995). There is a substantial uncommon variation in the water flow and sediment load; only three months of the monsoon season that from June to August, mark 60% of the total discharge (Chaudry *et al*., 2002). The Porali river and its tributaries encounter different types of rocks during their flow towards the Arabian sea, petrologically, the range is composed of igneous, sedimentary and metamorphic rocks, geo-chronological; the range is from Pre-Cambrian to Holocene (recent) in age. Thus, different varieties and nature's sediments are found (Chaudry *et al*., 2002; Bender *et al*., 1995). Large semidiurnal tides of 1-8 m hit the Arabian sea (Roonwal, 1997) and those are influenced by monsoon winds' seasonal current circulation twice yearly (Chaudry *et al*., 2002; Hastenrath and Greischar, 1989; Cutler and Swallow, 1984; Wyrtki *et al*., 1971). This environment is in the same favour of re-working, sorting, transporting and accumulating grains along the coast. It is to be noted that the morphology of the shoreline also influences the trapping of sediments and gives them a suitable environment for deposition, either temporarily or permanently, along the coastline. This coastline of Balochistan (Makran) amid the study area is under ongoing active tectonics, as shown in Fig. 2. The Arabian plate is sub-ducting under the Eurasian plate (Jon and Birnie, 1979; Klaus and Quittmeyer, 1979). This kind of tectonics introduces a massive volume of sediment shaved off from the undergoing Arabian plate (White, 1979) to the marginal region in the form of the accretionary prism. There is no reliable statistical data about the sediments, those were shaved off tectonically (Kazmi and Jan, 1997).

Research background. Transported in Pakistan occurs extensively and is generally used for various earthworks and engineering constructions such as road pavements, airport pavements, embankments, earth dams, etc. To be best placed to take the building and design decisions and conclusions, there is also a need to examine any transport source.

Aims and objectives of research. This research aims to determine the geotechnical properties of the soil of the Porali river basin. The objectives include:

- Use the Unified Soil Classification System (USCS) and AASHTO standards to classify the soil correctly.
- To decide the characteristics of compaction and the characteristics of strength as defined by the ASTM standards.

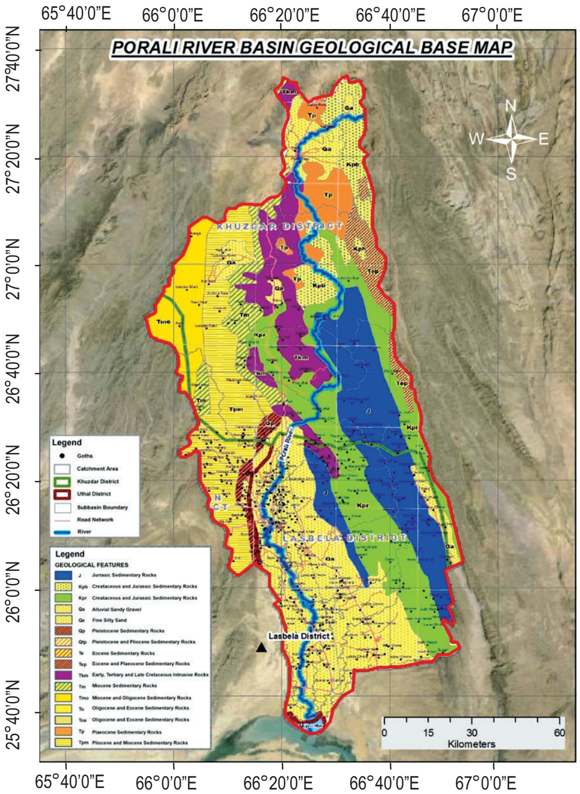


Fig. 2. Geological map of the study area.

Research justification. In the tropics and subtropics, transported soil is one of the essential materials used in earthwork engineering construction. The use of transported soil is prevalent for building and civil engineering work. Therefore, this incredible advantage is used by Lasbela, the town of Baluchistan and its environs.

One of the critical origins of these transported soils in the Porali river basin is the borrowing site at the Porali river basin; hence, the need to investigate this transported source and better understand its properties and qualities in terms of engineering use.

Materials and Methods

The soil collected from the "center" borrowing pit at the Porali river basin, Lasbela Baluchistan, is used for this analysis, as shown in Fig. 7. The disturbed sampling method used, the borrowing area investigation, requires collecting representative soil samples from the eight 3 m x 3 m x 3 m trail pits (Khan *et al*., 2011). Soil samples from a depth of 0.30 m to 3.00 m were obtained.

A total of fourteen borrow area soil samples were collected from the eight different borrow areas: Muree, Kunar-01, Kunar-02, Langro, Nimmi, Soordeer and Kundi Kashari. GPS coordinates are shown in Table 1.

Different tests were carried out on the sample soil in the laboratory, including Particle size analysis, Atterberg's limit tests, bulk and dry density, natural moisture content and modified proctor. According to the ASTM standards, a compaction test on the sample soil was performed to evaluate the maximum dry density (MDD) and optimum moisture content (OMC). The apparatus, according to (Gopal and Rao, 2011; Garg, 2005; Jean, 1997), is as follows, standard compaction equipment conforming to ASTM standards, a mold having an internal diameter of 6″ (15.24 cm), an internal sufficient height 4.6″ (11.7 cm), sieve no: 4, balance sensitive to 1 g and 0.1 g. Thermometer controlled over (105-110 °C), crucibles, jars (graduated), mixing tools (pan, scoop, trowel, spatula). The soil was compact in five layers with a rammer of 4.5 Kg dropped from a height of 18 inches (45.7 cm) and a blow of 56 uniformly distributed on each layer and the result is as shown in Fig. 3-5.

Results and Discussion

The laboratory investigation results of the Porali river basin soil are summarized in Table 2. From Table 2, it is perceived that the passing percentage of 200 no. sieve is approximately 0.6% which shows that the soil is non-plastic at Atterberg's (1911). A compaction test conducted in 1999 was used to evaluate the moisture content of the Porali borrowing site transmitted by the soil in Texas.

Particle size distribution. Soil consists of an assemblage of different sizes and shapes of distinct particles. The study of grain size aims to group these particles into different size ranges and determine the relative proportions of each size content by dry weight.

Table 1. Location of test pits and co-ordinates

Description (depths)	Structure name	Co-ordinates	
		Northing	Easting
Test Pit 1 (3m)	Muree	2933594.713	237564.752
Test Pit 2 (3m)	Kunar-01	2931270.25	236713.42
Test Pit 3 (3m)	Kunar-02	2930621.63	236466.84
Test Pit 4 (3m)	Langro	2928711.744	235691.617
Test Pit 5 (3m)	Nimmi	2934761.516	238400.21
Test Pit 6 (3m)	Soordeer	2933686.452	237085.145
Test Pit 7 (3m)	Kundi	2931345.654	235951.19
Test Pit 8 (3m)	Kashari	2924821.519	234463.8

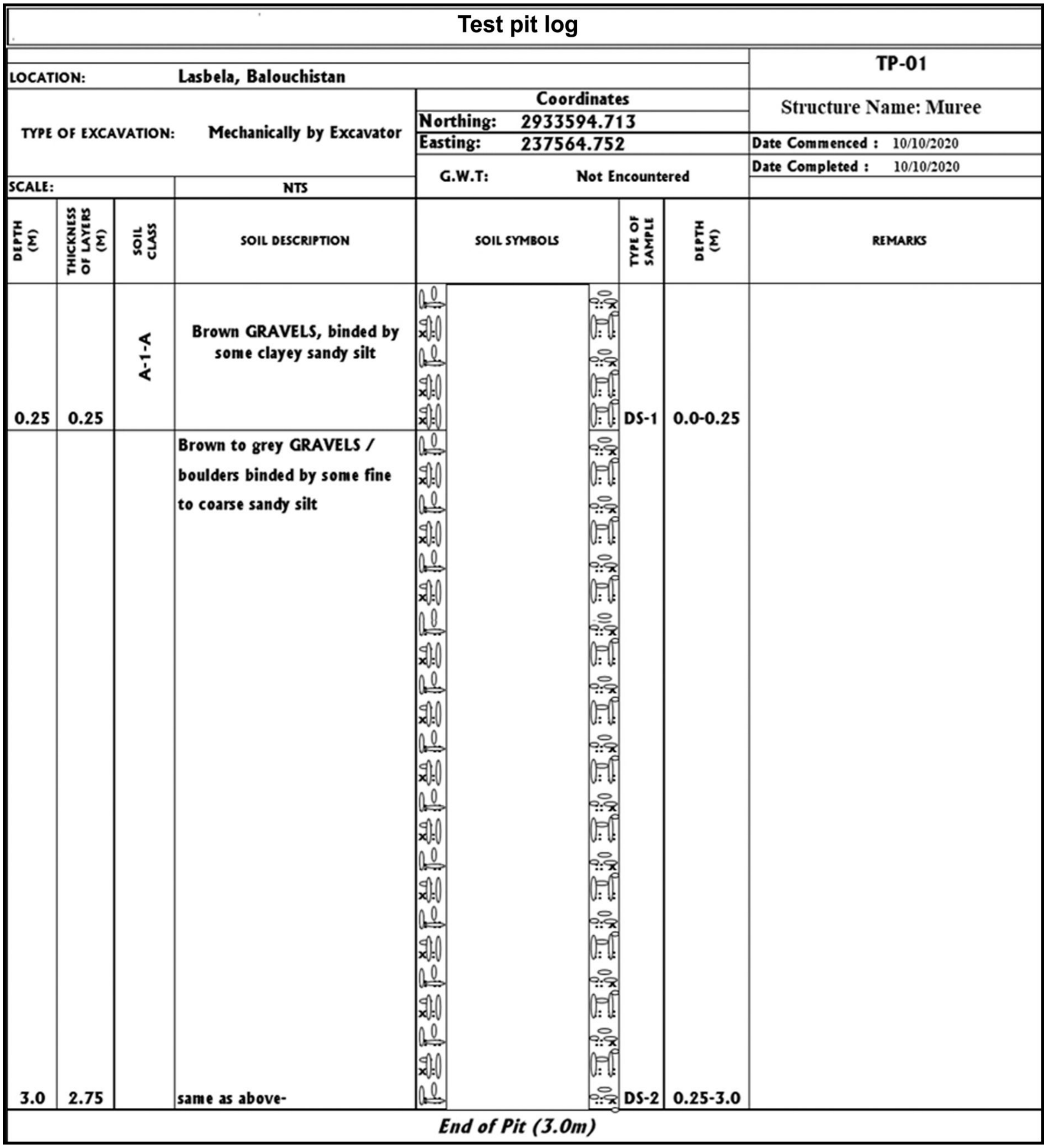


Fig. 3. Test pit log 01.

According to the Unified Soil Classification System ASTM D-2487 (1996), the soil is graded based on the grain size analysis results in 1996. The grain size analysis of the soil samples examined shows that gravel sizes range from 39.6% to 52.0%, silt sizes range from 25.3% to 33.7%, fine sand sizes range from 12.5% to 16.5% and medium sand and clay sizes vary from 5.2% to 8.4%. The clay particles were absent in one soil sample and the clay sizes ranged from 0.3% to 0.5% in the remaining soil samples.

Soil class. All the soil in test pit holes, the soil has been classified in GP, GP-GM, GM and SM types when classified through the Unified Soil Classification System are presented in Table 2. The soil from test pit holes was classified in A-1-a through soil classification system (AASHTO T-27).

Moisture density relationship test (modified proctor). Moisture density relationship using 4.5 Kg rammer and 475 mm drop is commonly known as the modified proctor test. These tests were conducted on samples from test pits per AASHTO specification T-180. This test's primary purpose is to find maximum density and optimum moisture content, which is used to estimate the percentage of compaction from the field density test. Three selected soil samples from eight borrow areas were subjected to the standard proctor compaction test. Maximum dry density and optimum moisture content values of soil samples evaluated TP-01, 03 and 05, 2.263 g/cc, 2.256 g/cc, 2.247 g/cc and optimum moisture content is 6.2% to 7.1 and 7.5% respectively. Figures 3, 4, 5 and 6 indicate the graphical representations of the typical proctor compaction test results of the soil samples studied.

Based on the above results, the overall dry density value of 2.256 g/cc (Figs. 4 and 5) also shows that the soil is

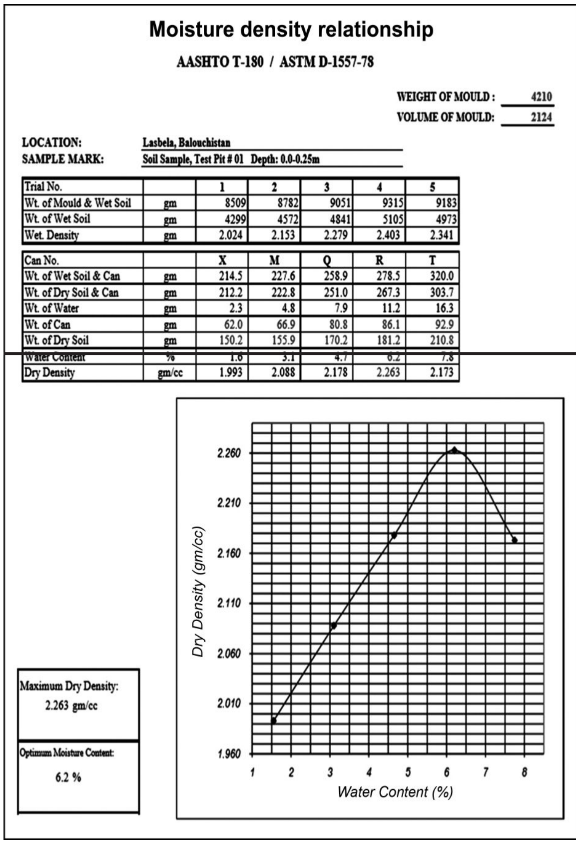


Fig. 4. Test pit 01, moisture density relationship.

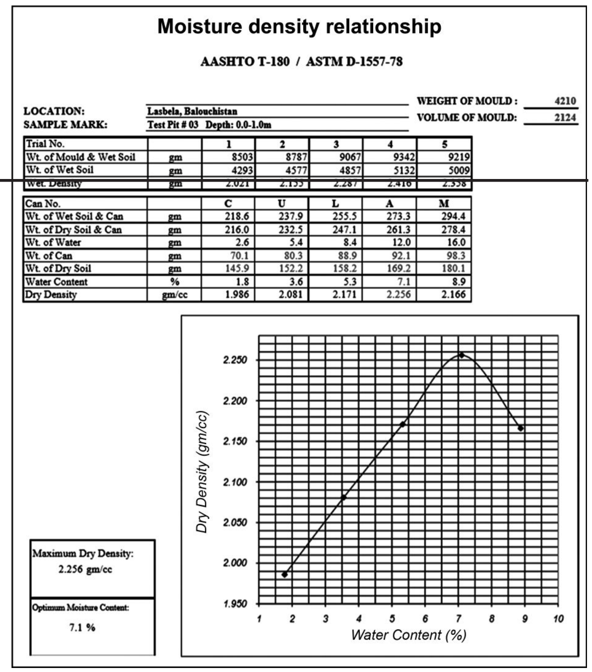
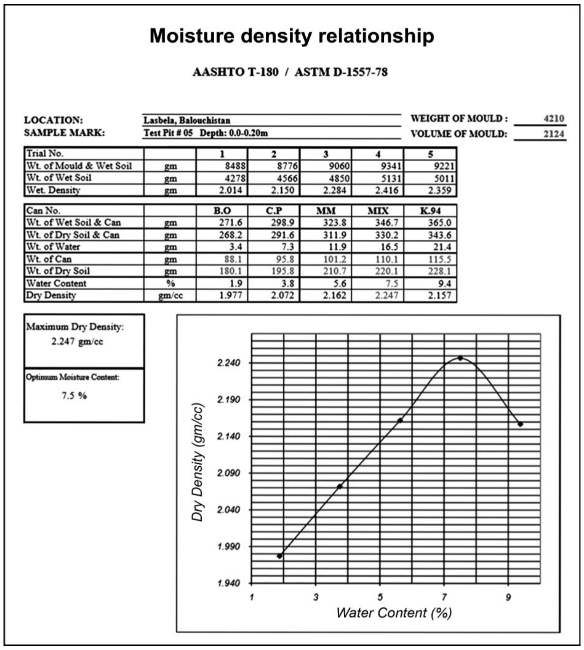


Fig. 5. Test pit 03, moisture density relationship.

Table 2. Particle size distribution and soil classification

TP No.	Sample	Depth (m)	Passing %														Atterber'g limits		Soil class
			2½"	2"	1½"	1"	¾"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200	LL	PI	
TP#01	DS	0.0-1.0	-	100	69.4	69.4	61.9	45.4	40.8	34.3	26.5	20.5	15.2	14.2	5.0	4.6	Non Plastic		GP-GM
	DS	1.0-2.0	-	-	100	81.4	81.4	76.4	71.4	60.4	46.2	37.7	30.2	23.9	17.3	4.6	Non Plastic		SM
TP#04	DS	3.0-4.0	100	88.1	65.0	34.6	29.6	26.5	23.6	17.8	12.4	9.3	6.7	4.4	3.2	2.7	Non Plastic		GP
TP#06	DS	6.0-7.0	100	77.7	66.6	50.1	42.7	36.8	33.0	26.4	15.8	4.5	8.8	2.8	2.3	2.0	Non Plastic		GP
	DS	9.0-10.0	100	66.3	31.0	31.0	23.9	20.0	17.6	11.1	6.3	4.4	2.8	1.6	0.9	0.6	Non Plastic		GP
TP#07	DS	0.0-1.0	100	77.9	54.6	24.0	17.3	15.4	14.2	11.8	8.9	6.6	4.5	2.8	1.8	1.4	Non Plastic		GP
	DS	4.0-5.0	-	-	100	57.2	49.0	39.9	30.7	19.3	8.8	5.9	4.6	3.7	3.0	2.6	Non Plastic		GP
TP#08	DS	7.0-8.0	-	100	86.5	62.1	57.9	51.2	45.8	34.5	23.0	17.2	10.0	4.7	2.7	2.3	Non Plastic		GP
	DS	9.0-10.0	100	49.3	36.6	21.1	17.7	8.0	5.4	2.7	1.7	1.3	1.0	0.8	0.7	0.6	Non Plastic		GP



Moisture density relationship

AASHTO T-180 / ASTM D-1557-78

LOCATION: Lasbela, Balouchistan
SAMPLE MARK: Test Pit # 05 Depth: 0.0-0.20m
WEIGHT OF MOULD : 4210
VOLUME OF MOULD: 2124

Trial No.		1	2	3	4	5
Wt. of Mould & Wet Soil	gm	8488	8776	9060	9341	9221
Wt. of Wet Soil	gm	4278	4566	4850	5131	5011
Wet. Density	gm	2.014	2.150	2.284	2.416	2.359

Can No.		B.O	C.P	MM	MIX	K.94
Wt. of Wet Soil & Can	gm	271.6	298.9	323.8	346.7	365.0
Wt. of Dry Soil & Can	gm	268.2	291.6	311.9	330.2	343.6
Wt. of Water	gm	3.4	7.3	11.9	16.5	21.4
Wt. of Can	gm	88.1	95.8	101.2	110.1	115.5
Wt. of Dry Soil	gm	180.1	195.8	210.7	220.1	228.1
Water Content	%	1.9	3.8	5.6	7.5	9.4
Dry Density	gm/cc	1.977	2.072	2.162	2.247	2.157

Maximum Dry Density: 2.247 gm/cc

Optimum Moisture Content: 7.5 %

Fig. 6. Test pit 05, moisture density relationship.

excellent for subgrade density (Garg, 2005; Bowles, 1992). Since the soil is suitable for subgrade material but very poor for road base development, we recommend soil modification using any stabilizing agents or methods that may include recent research that attempted to determine the impact of oil spillage on soil geotechnical properties Amaziah (2010).

It was possible to raise the soil to an appropriate sub-base content with the above. The same soil transported could be used in additional engineering projects in addition to the typical road, airfield, embankments and foundations (Mama and Osadebe, 2011; Nwakonobi *et al*., 2007). In virtually all civil engineering works, transported soil is practically useful.

Conclusion

Based on the borrow area investigations on the soil samples collected from the prospective areas, namely: Muree, Kunar-01, Kunar-02, Langro, Nimmi, Soordeer, Kundi, and Kashari. Borrow areas for the proposed lower Porali river basin district Lasbela, Baluchistan; the following conclusions have been arrived at:

- Almost all sub-soil in test pits consists of layers of gravel and boulders with varying amounts of silty sand.

The AASHTO classification system shows that the soil belongs to the A-1-a subgroup of the A-1 group, consisting of the granular content and the group's zero indexes. Khanna and Justo (2001) concluded that this group's soil is suitable for subgrade and embankment material. The higher the index of the soil group as a subgrade material, the poorer the soil. For highway and embankment materials, granular soil is usually favored.

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Conflict of Interest. The authors declare that they have no conflict of interest.

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