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Geotechnical characterization of subgrade soils on Arba Minch-Wolaita Sodo main road to Zefine town

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ABSTRACT

Construction of the various pavement layers is very much dependent on the geotechnical characteristics of the sub grade soils. The aim of this paper is to characterize the subgrade soils of Arba Minch - Wolaita Sodo main road to Zefine town. To achieve these objectives, twenty soils sample pits were selected from different representative parts of the existing road at 1km interval. The laboratory test results showed that the NMC ranges from 9.29% to 15.86%, Percentage finer ranges from 63.36% to 78.31%, LL ranges from 31.53% to 60.27%, PI ranges from 6.49% to 39.02%, GI ranges from 4 to 31, OMC ranges from 14.00 % to 17.74 %, MDD ranges from 1.74 g/cc to 1.98g/cc, CBR ranges from 2.05% to 9.08% and CBR swell ranges from 1.05% to 3.66%. Based on this results the study area was characterized as silt and clay soils, and for the soils classification under A-4, A-5 and A-7-6 according to AASHTO soil classification system and from all soil samples the subgrade strength class based on CBR value, for the soil samples, from TP1 to TP 3 were S1 and TP9, TP16, TP18 and TP19 were S4; and the remaining soil samples S3 class.

Keywords— *Subgrade Soil, Geotechnical Characterization*

1. INTRODUCTION

Geotechnical characteristics of the sub grade soils affect the riding quality and serviceability of the road in the construction of pavement, since all soils are not used as a subgrade material for the reason there are less bearing capacity and high swelling soils which cause problems.

To achieve this twenty sampling pits areas selected to understand the basic characteristics of the sub grade soil, such as natural moisture content, particle size distribution, specific gravity, Atterberg limits (LL and PL), compaction (OMC and MDD), CBR and CBR swelling potential tests were concerned. (ERA, Site Investigation Manual, 2013).

2. LITERATURE REVIEW

2.1 GEOTECHNICAL CHARACTERIZATION OF SUBGRADE SOIL

All roads, whether they are built above or below the ground surface, use naturally occurring subgrade soils as the basic foundation and construction materials, the performance of a road is significantly affected by the geotechnical characteristics of the subgrade (ERA, Site Investigation Manual, 2013).

Geotechnical characteristics of a subgrade soils have major influence on the performance and construction of a pavement structure because subgrade provides the plat form for construction of pavement structure and its purpose is to support the pavement structure without fail. (US Department of Transport Federal Highway Administration, May 2006).

According to (ERA, Site Investigation Manual, 2013) the AASHTO Soil classification system, soil is classified into seven major groups, A-1 through A-7. Soils classified under groups A-1, A-2 and A-3 are coarse grained soils where 35% or less of the particles pass through the 75 µm sieve size. Soils where more than 35% pass the 75 µm are classified under groups A-4, A-5, A-6 and A-7. Soils where more than 35% pass the 75 µm sieve size are mostly silt and clay-size materials.

To evaluate the quality of a soil to use as a sub-grade material, the group index (GI) is also used along with the groups and subgroups of the soil. The group index is written in parenthesis after the group or subgroup designation.

3. MATERIALS AND METHDOLOGY

Table 1: The AASHTO or ASTM Designation Soil Laboratory Tests (ERA, Site Investigation Manual, 2013)

Test Category	Name of Test	Test Designation	
		AASHTO	ASTM
Index properties	Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating	T 265	D 2216
	Test Method for Specific Gravity of Soils	T 100	D854 D5550
	Method for Particle-Size Analysis of Soils	T 88	D 422
	Test Method for Classification of Soils for Engineering Purposes	M 145	D 2487 D 3282
	Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils	T 89 T 90	D 4318
Compaction	Test Method for Laboratory Compaction of Soil Using Modified Effort (4.5kg Hammer for 450 mm height)	T 180	D 1557
Strength	Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils	T193	D 1883

3.1 LOCATION AND ACCESSIBILITY OF THE STUDY AREA

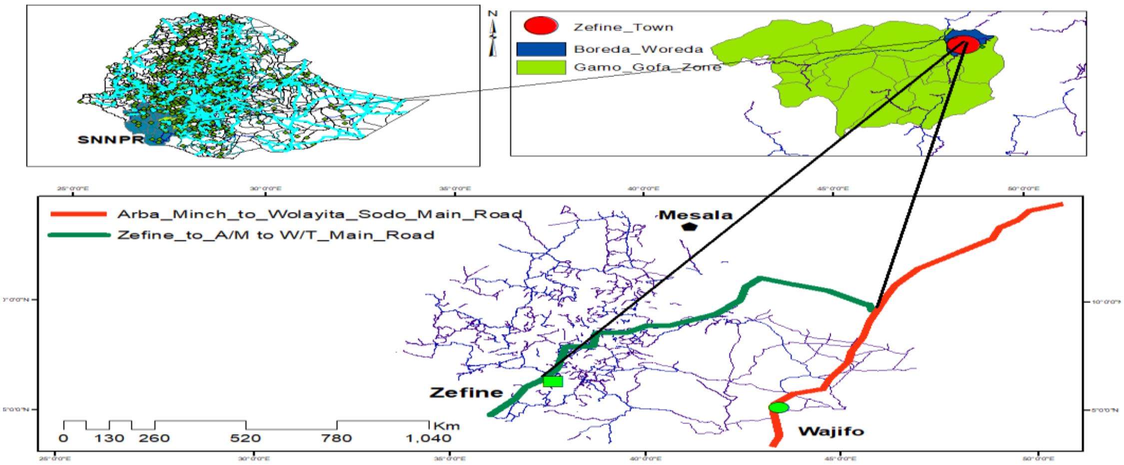

Fig. 1: Location of Arba Minch-Wolaita Sodo Main Road to Zefine Town

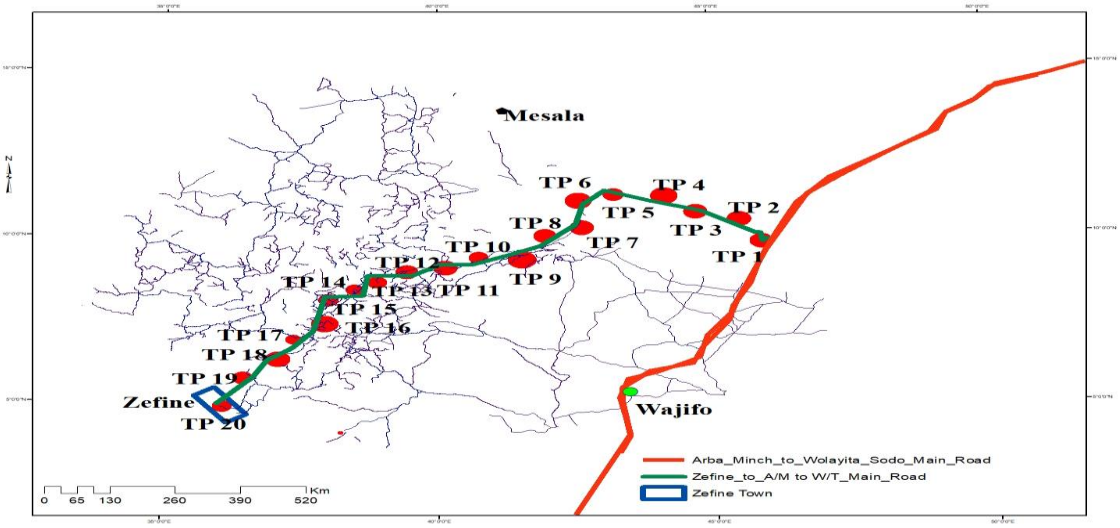

Fig. 2: Arba Minch-Wolaita Main Road to Zefine Town Test Pits Location

4. RESULTS AND DISCUSSION

This paper involved the characterization of the subgrade soil for pavement construction.

The most important parameters used in this paper study were, NMC, Gs, grain size analysis, Atterberg limit, compaction, CBR swell potential and CBR tests of the subgrade soils.

4.1 NMC AND GS TEST RESULTS FOR ALL SOIL SAMPLES

Table 2: NMC and Gs Test Results

Sample No.	Field bulk density (g/cc)	NMC %	Gs
TP1	1.94	15.86	2.73
TP2	1.92	14.25	2.80
TP3	1.95	15.23	2.76
TP4	1.98	11.42	2.70
TP5	1.99	12.05	2.68
TP6	2.02	12.08	2.69
TP7	2.04	11.74	2.69
TP8	2.00	10.46	2.68
TP9	1.99	9.89	2.66
TP10	2.03	11.42	2.65
TP11	2.01	12.39	2.70
TP12	2.01	10.80	2.67
TP13	2.00	11.43	2.70
TP14	1.99	9.62	2.66
TP15	2.02	12.04	2.69
TP16	2.02	9.29	2.70
TP17	2.02	12.36	2.70
TP18	2.01	10.81	2.70
TP19	2.01	11.73	2.70
TP20	2.04	12.05	2.66

4.2 THE GRAIN SIZE ANALYSIS TEST RESULTS FOR ALL SOIL SAMPLES

Table 3: The Grain Size Analysis Test Results for all Soil Samples

	Coarser grain size soil			Finer grain size soil	
Sample No.	Gravel %	Coarse Sand %	Fine Sand %	Silt %	Clay %
TP1	2.40	13.78	6.56	32.26	45.00
TP2	2.55	10.72	11.65	35.78	39.30
TP3	2.80	12.17	9.55	33.98	41.50
TP 4	3.02	3.44	15.26	52.70	25.60
TP 5	7.21	13.72	2.90	50.50	25.60
TP 6	9.21	12.51	9.06	44.02	25.20
TP 7	9.90	17.67	9.06	37.86	25.50
TP 8	7.17	10.23	12.03	41.08	29.50
TP 9	9.26	13.27	10.00	42.66	24.80
TP 10	7.71	13.71	9.07	41.71	27.80
TP 11	8.12	5.94	15.68	49.97	20.30
TP 12	8.35	11.21	9.00	40.64	30.80
TP 13	6.41	10.08	10.37	44.64	28.50
TP 14	9.36	12.51	8.26	39.61	30.25
TP 15	2.78	7.74	12.83	45.86	30.80
TP 16	6.10	5.89	10.73	44.08	32.20
TP 17	10.15	12.72	10.60	40.53	26.00
TP 18	4.42	9.24	11.40	52.14	22.80
TP 19	4.80	8.89	10.67	56.39	19.25
TP 20	6.45	10.76	7.05	48.23	27.50

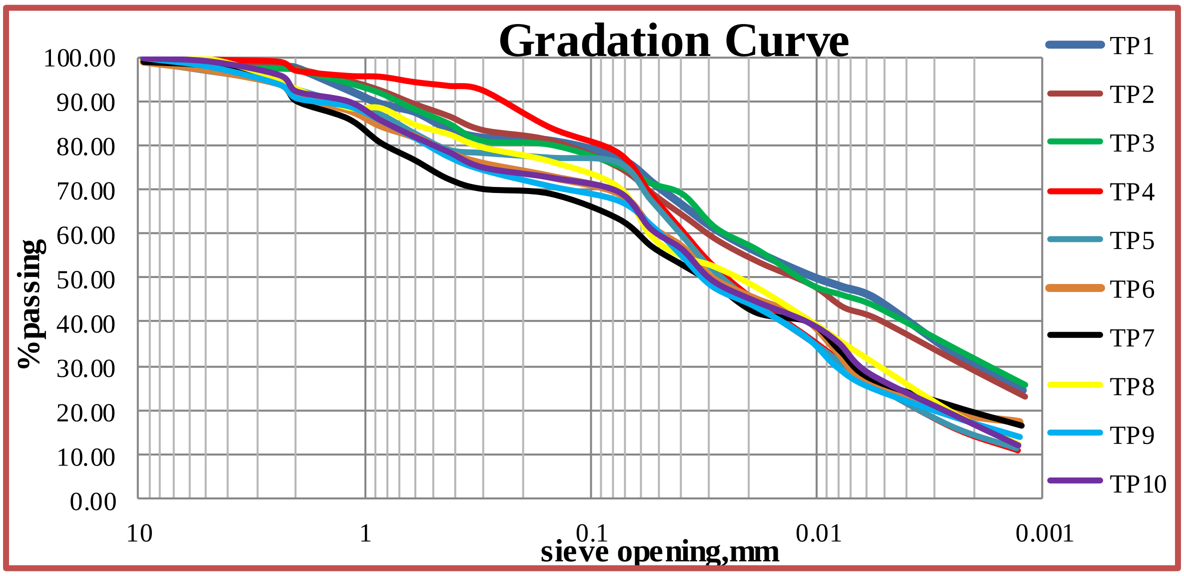

Fig. 3: Gradation Curves of the Study Area from TP1 to TP10

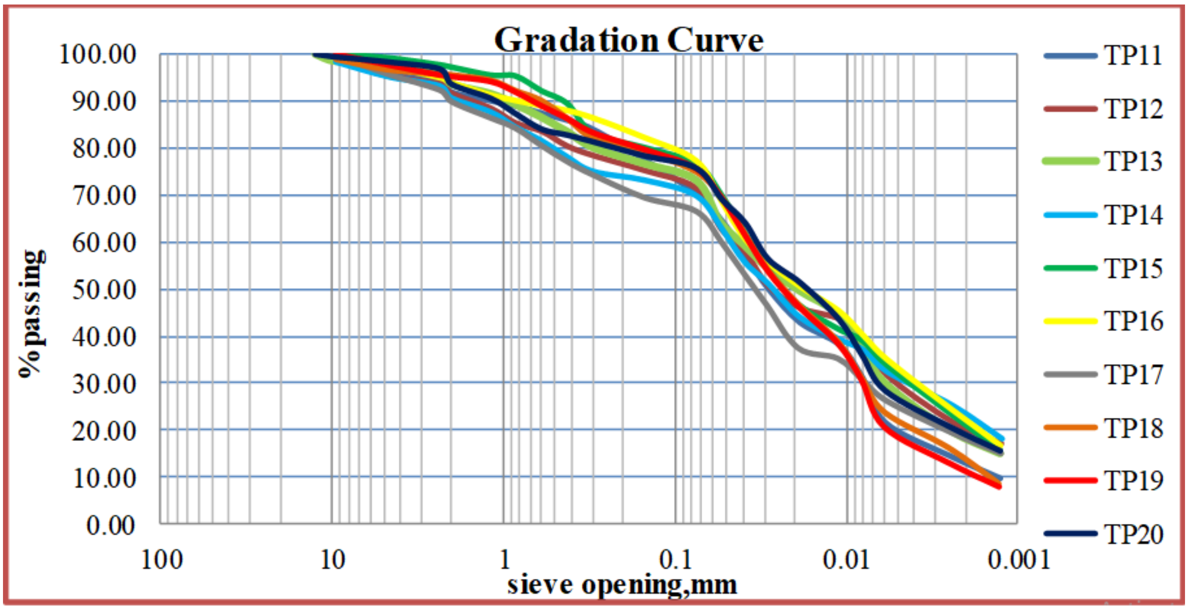

Fig. 4: Gradation Curves of the Case Area from TP11 to TP20

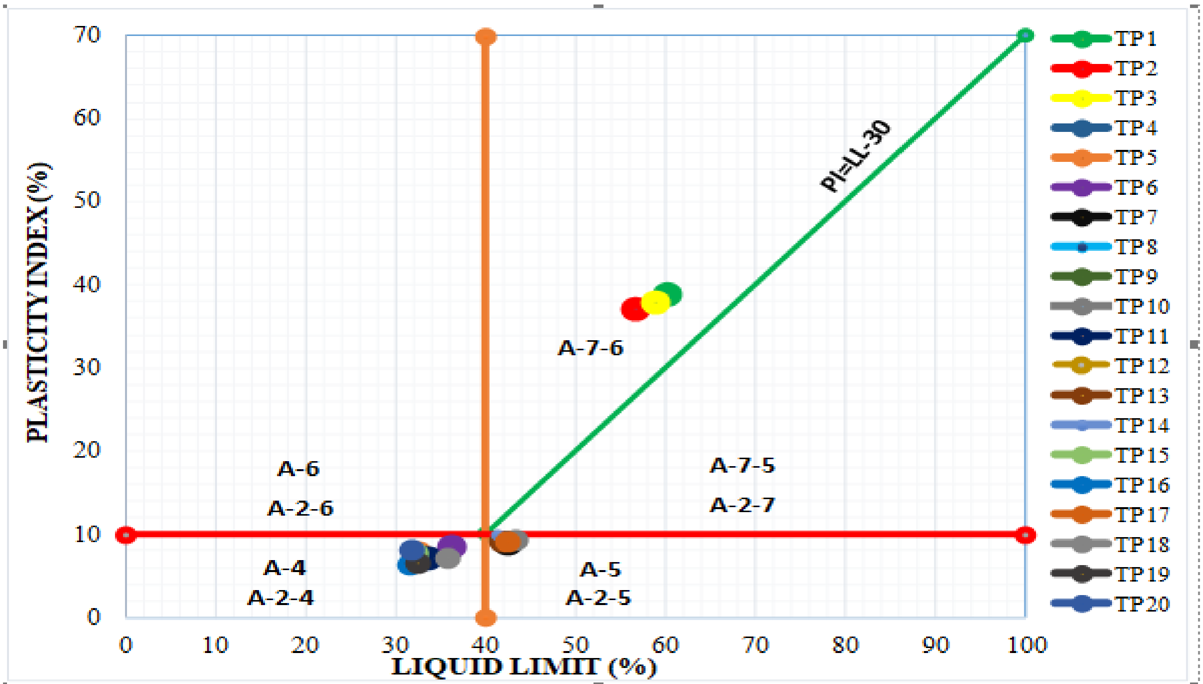

Fig. 5: The Study Area Soil Classification Chart According to AASHTO System

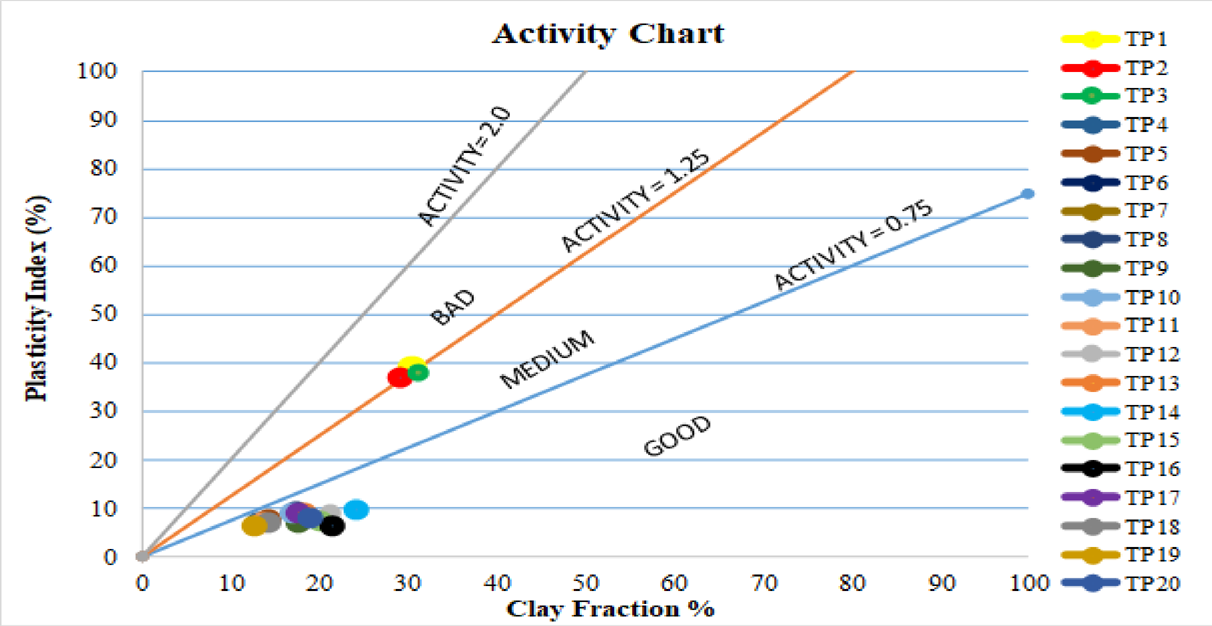

Fig. 6: Soil Classification Based on Activity Chart for the Study Area

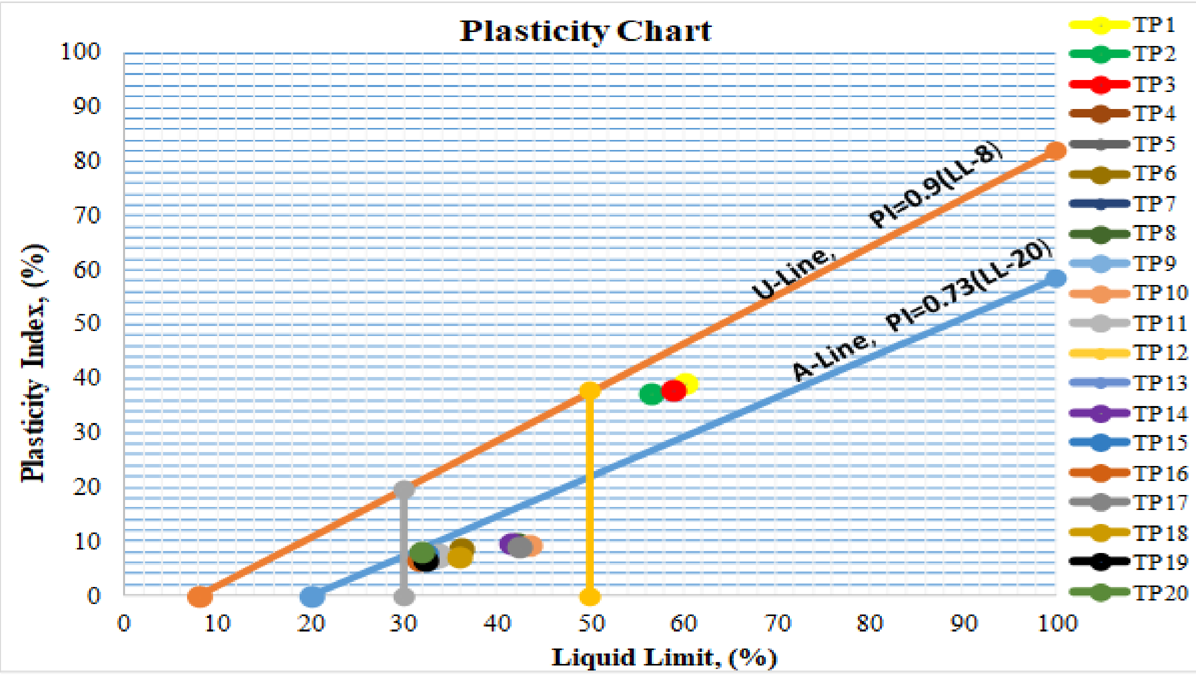

Fig. 7: Soil Classification Based on Plasticity Chart for the Study Area

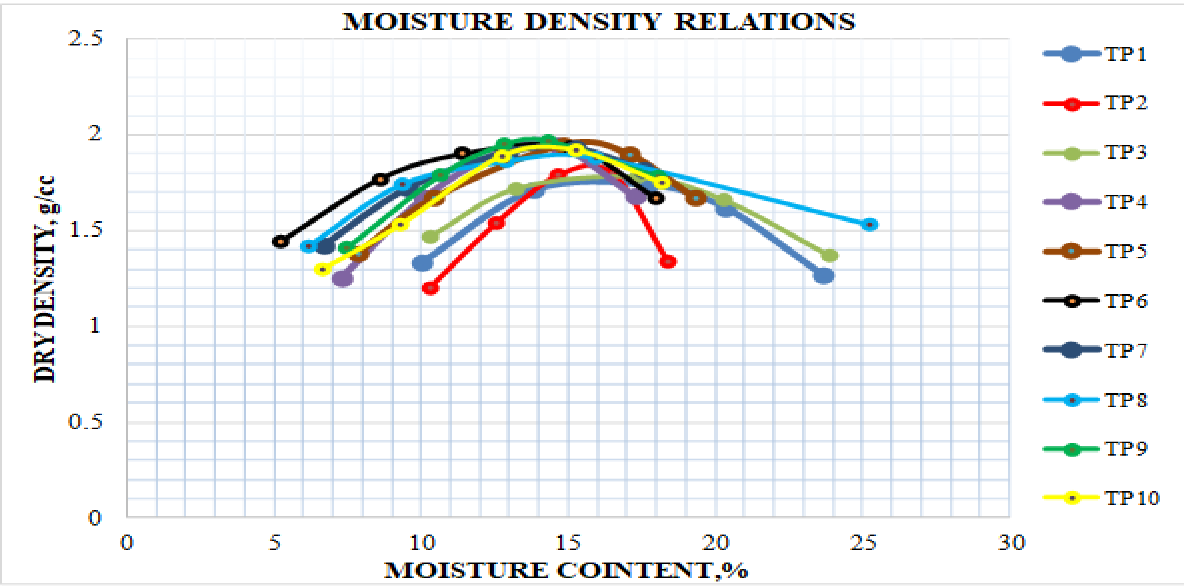

Fig. 8: Moisture Density Relations of (from TP1 to TP10)

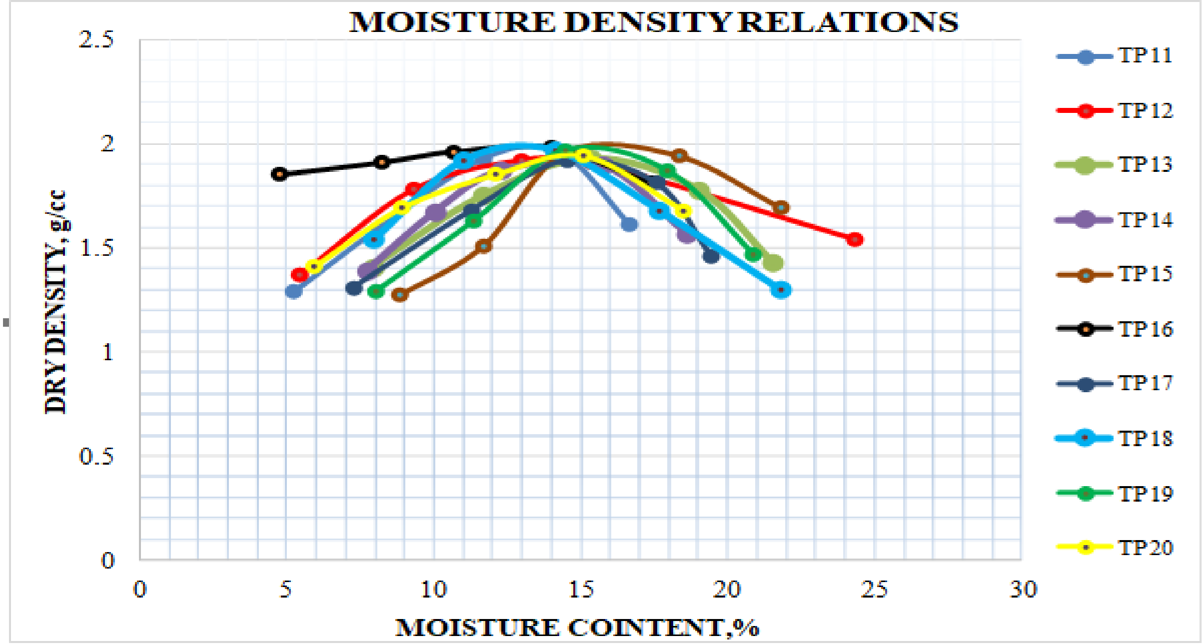

Fig. 9: Moisture Density Relations of (from TP 11 to TP 20)

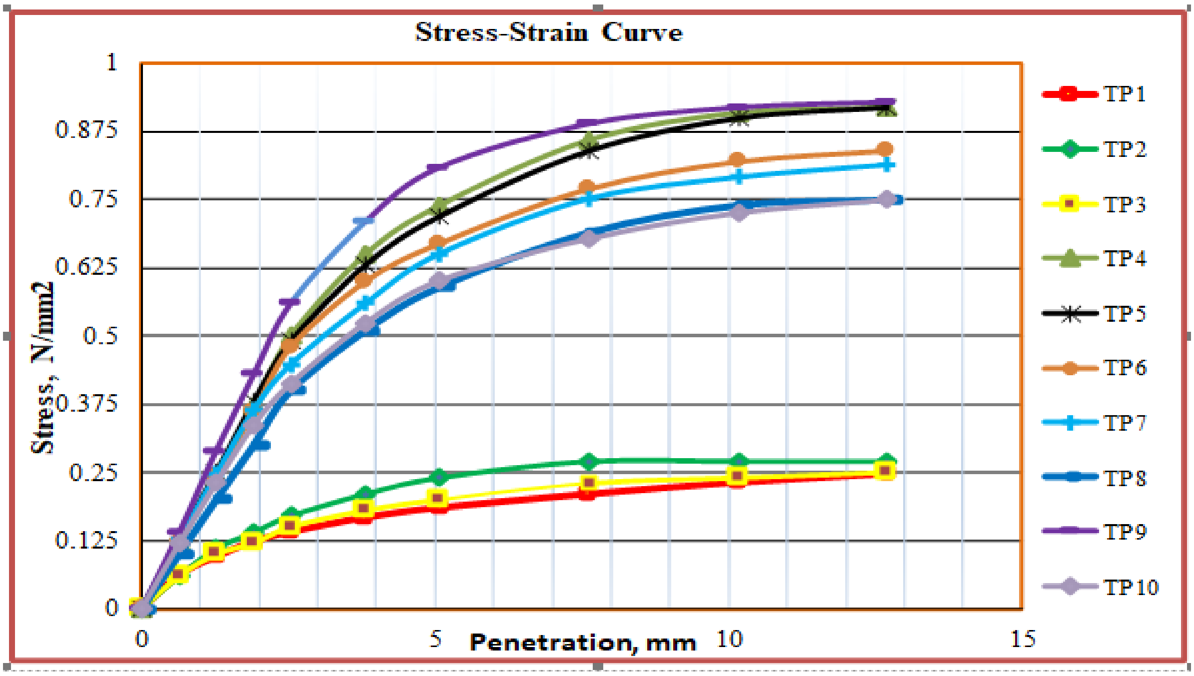

Fig. 10: Stress Vs Strain Curves of (from TP1 to TP10)

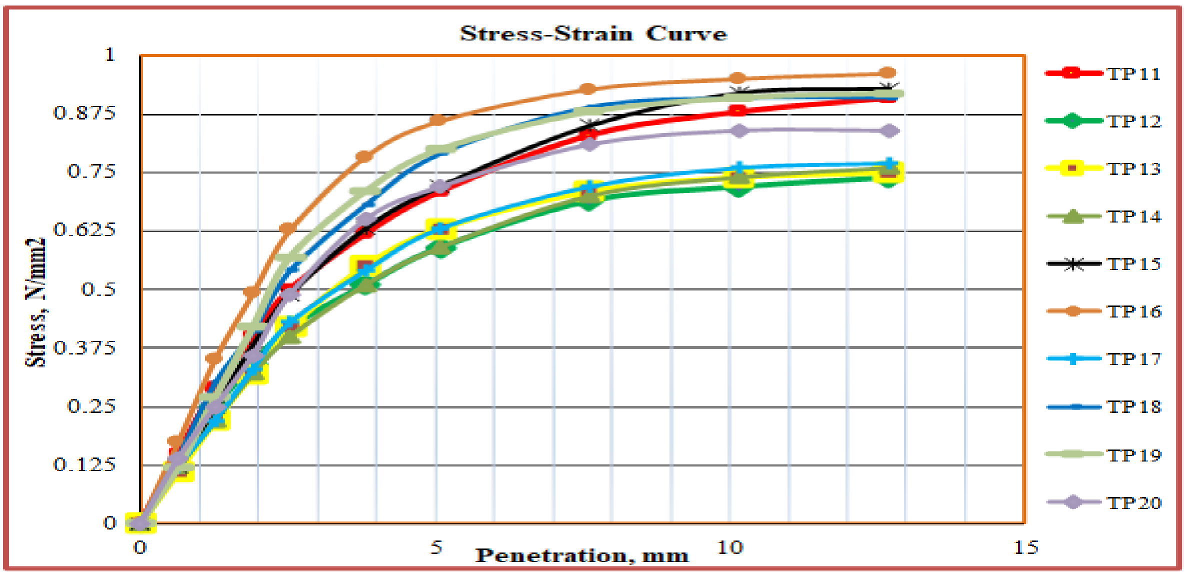

Fig. 11: Stress Vs Strain Curves of (from TP11 to TP20)

4.3 ATTERBERG LIMIT, COMPACTION, CBR SWELL AND CBR TEST RESULTS

Table 4: Atterberg Limit, Compaction, CBR Swell and CBR Test Results

Sample No.	LL %	PL %	PI %	L_I	AASHTO Soil Clas.	Soil type	MDD g/cc	OMC %	CBR Swell %	CBR %
TP1	60.27	21.25	39.02	-0.14	A-7-6(31)	clay	1.74	17.65	3.66	2.05
TP2	56.65	19.37	37.27	-0.14	A-7-6(28)	clay	1.80	16.46	3.20	2.46
TP3	58.94	20.91	38.03	-0.14	A-7-6(29)	clay	1.78	17.36	3.40	2.15
TP4	32.02	24.67	7.35	-1.80	A-4(5)	Silt	1.95	14.66	1.20	7.20
TP5	32.34	24.82	7.53	-1.70	A-4(5)	Silt	1.95	14.84	1.35	7.05
TP6	36.20	27.62	8.59	-1.68	A-4(5)	Silt	1.94	15.04	1.40	6.89
TP7	42.33	33.33	9.00	-2.40	A-5(6)	Silt	1.93	15.22	1.42	6.49
TP8	42.25	32.50	9.75	-2.26	A-5(7)	Silt	1.88	15.96	1.80	5.77
TP9	32.90	25.71	7.19	-2.20	A-4(4)	Silt	1.97	14.29	1.06	8.13
TP10	43.35	34.00	9.35	-2.41	A-5(7)	Silt	1.92	15.25	1.60	5.98
TP11	33.54	26.25	7.29	-1.90	A-4(4)	Silt	1.96	14.29	1.10	7.21
TP12	41.88	32.67	9.21	-2.37	A-5(7)	Silt	1.91	15.38	1.60	6.07
TP13	41.83	32.67	9.16	-2.32	A-5(7)	Silt	1.93	15.32	1.40	6.13
TP14	41.45	31.67	9.78	-2.25	A-5(7)	Silt	1.90	15.71	1.82	5.74
TP15	32.26	24.50	7.76	-1.61	A-4(5)	Silt	1.96	14.49	1.30	7.13
TP16	31.53	25.04	6.49	-2.43	A-4(4)	Silt	1.98	14.00	1.05	9.08
TP17	42.46	33.33	9.13	-2.30	A-5(6)	Silt	1.92	14.52	1.45	6.23
TP18	35.83	28.64	7.19	-2.48	A-4(5)	Silt	1.97	14.08	1.08	7.87
TP19	32.30	25.73	6.57	-2.13	A-4(4)	Silt	1.97	14.47	1.10	8.23
TP20	31.77	23.56	8.21	-1.40	A-4(5)	Silt	1.94	15.12	1.28	7.05

4.4 GEOTECHNICAL CHARACTERIZATION OF SUBGRADE MATERIAL

- It was observed from the experimental results that, all soils samples were fine-grained soils and which were silt and clay material because more than 35% passing through the 0.075mm sieve, as (AASHTO, 2013).
- The sub-grade soils were classified as A-7-6, A-5 and A–4; thus, 15 % of the soil samples were clay and 85 % were silt according to (ERA, Site Investigation Manual, 2013).
- Based on the activity value, the soils samples from TP1 to TP 3 were active, and from TP4 to TP20 were inactive, as (Skempton, 1953).
- It was observed from the test results, the LL and PI values indicates that the soil samples; from TP1 to TP3 were unsuitable to use as a subgrade soil for pavement construction, because they have high swelling potential, and the remaining soil samples from TP4 to TP20 were good to use as a subgrade soil for pavement construction because of having low swelling potential, as (AASHTO, 2013).
- Classification of soils based on the value of GI, for soil samples from TP1 to TP3 were above twenty, so not good to use as a subgrade soils, and from TP4 to TP20 were good to use as a subgrade soils, according to (ERA, Site Investigation Manual, 2013).
- The CBR swelling potential values for the three samples (from TP1 to TP3) were above 2% ; thus, they were unsuitable to use as a sub grad soils and for the soil samples from TP4 to TP20 the value were below 2%, therefore they were good to use as a subgrade soil for pavement construction, as (ERA, Site Investigation Manuals, 2002)
- The CBR values for the soil samples, from TP1 to TP3 were below 5% so they were unsuitable to use as a subgrade soils for pavement construction, and for the soil samples from TP4 to TP20 were fair to use as a subgrade soils for pavement construction, as (ERA, Pavement Design Manual Volume I Flexible Pavement and Gravel Roads, 2002).

Generally; the subgrade material for the soil samples from TP4 to TP20 were fair to use as a subgrade soil for pavement construction, however the soil samples from TP1 to TP3, were unsuitable to use as a subgrade materials based on (ERA, Pavement Design Manual Volume I Flexible Pavement and Gravel Roads, 2002) specification; thus, those soils should be treated with appropriate improving method before using as a subgrade soils.

5. CONCLUSION

This study is to characterize the subgrade material; for this paper laboratory tests conducted for NMC, grain size analysis, Gs, Atterberg limits (LL & PL), compaction (OMC & MDD), CBR and CBR swell tests were done

From the study the following findings are deduced:-

a) The test results showed that the subgrade material considered for this study were silt-clay soil as per (AASHTO, 2013) soil classification system.
b) As far as the engineering properties of the sub grade soils were studied, that from twenty soil samples, it was found that the three soil samples (from TP1 to TP3) were unsuitable to use as a subgrade soil, and the remaining were suitable to use as a subgrade material for pavement construction (ERA, Standard Technical Specification of Subgrade , Subbase , Base and Gravel wearing Courses, 2002).
c) From all soil samples the subgrade strength class based on CBR value, for the soil samples, from TP1 to TP 3 were S1 and TP9, TP16, TP18 and TP19 were S4; and the remaining soil samples S3 class (ERA, Pavement Design Manual Volume I Flexible Pavements, 2013).

6. ACKNOWLEDGEMENT

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