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Investigating The Index and Physical Properties of Soils to Be Used as Subgrade Material (In Case of Gilgel-Beles, Ethiopia)

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Annotation: Investigating the index properties and identifying the characteristic of the soil is very important for construction works as well as for further studies in the future as an input. The properties of the soil such as plasticity limit, liquid limit and plastic index of the soil are basic properties of the soils; which affect the design in highway construction. The objective of this research was to know the index, physical properties of soils and classify the soils on basis of their properties through Gilgel-beles town. To achieve the objective of this study, disturbed and undisturbed samples from different parts of the town were collected. To determine the properties of soil the test was conducted by using ASTM standard test procedure. Based on the laboratory test results the properties of soils of the study area were specific gravities range from 2.6 to 2.72, clay fraction 23-54.6%, silt fraction 14.9-50.5%, sand fraction 20.82-39.1% and gravel fraction 0-1.4%, liquid limit 30 – 52.5%, plastic limit, 24.9 – 40.5% and plastic index 5 – 19.5%. The test results showed that the soil found in the study area from all samples are almost fine grained soil consisting of sand in nature. According to USCS classification system of plasticity chart, most of the soil of the study area falls below A-Line in ML region, and TP-3, TP-5 and TP-7 in MH region, which have high plasticity (LL>50%) and the classification soils found in Gilgel-Beles town were ML, MH and CL. And also, according to AASTHO soil classification, the study area soils were dominantly categorized in A-7-5 and A-7-6 which is poor for sub-grade materials. Based on the compaction test, maximum dry density (MDD) ranges from1.57 to 1.81 g/cm3 with optimum moisture content from 17 to 35.38 %. which is poor for sub-grade materials.

Keywords: Investigating, index, physical, Gilgel-Beles

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1. Introduction

Investigating the index properties and identifying the characteristic of the soil is very important for construction works as well as for further studies in the future as an input. The geotechnical engineers are mainly interested on the *index properties* of soils and classify the soils on the basis of their properties. The properties of the soil such as plasticity limit, liquid limit and plastic index of the soil are basic properties of the soils; which affect the design in highway construction. A detailed and comprehensive geotechnical investigation is an essential requirement in designing of those civil engineering structures, which requires adequate knowledge of sub surface bearing capacity conditions at the sites of the proposed structures (Murthy,1990). Every civil engineering work involves the determination of soil type and its associated engineering application. The common problems faced by civil engineers are related to bearing capacity and compressibility of soil and seepage through the soil. The possible solution to these problems is arrived at based on the study of the physical and index properties of the soil (Dagnachew, 2011). Lack of understanding about the properties of the soil can lead to the construction errors that are costly in effort and material (Giovanna, 2007). The suitability of a soil for any construction works should be determined based on its engineering characteristics and not on visual inspection (Bowles, 1984). However, soil investigations would be high expensive to conduct an extensive investigation of a whole site. Engineers have found that there is strong correlation between engineering properties and Atterberg limits of fine-grained soils (Arora, 2004). Therefore, the objective of this research paper is to know the index, physical properties of soils and classify the soils on the basis of their properties. A fine-grained soil can exist in solid, semisolid, plastic, viscous or fluid state depending on its water contents. The Swedish soil scientist Albert Atterberg commonly used the liquid and plastic limits to classify fine-grained soils, in current engineering practice (ASTM, 2004). Index parameters of soils include liquid limit, plastic limit, shrinkage limit, and activity. Such parameters are useful to classify soils and provide correlations with engineering soil properties (Jemal 2014). The Liquid Limit is arbitrarily the water content, in percentage, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The Plastic Limit is the lowest moisture content of a soil that will permit a sample to be rolled into threads of 3 mm diameter without the threads breaking (Teferra and Leikun, 1999).

Engineers are continually searching for simplified tests that will increase their knowledge of soils beyond that which can be gained from visual examination without having to resort to the expense, detail, and precision required with engineering properties tests. These simplified tests provide indirect information about the engineering properties of soils. There are two main variables in parent materials that affect soils, grain size and composition. Grain size is the main determinant of soil texture. Texture influences the soil structure, consistency, cation exchange capacity, profile drainage, moisture retaining capacity and organic content (Braja, 2006). The

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determination of different fractions of soil particles help to identify the soil type as well as to estimate many other engineering properties (Arora, 2004).

2. Materials and Methods

2.1 Study Area

Gilgel-Beles is the administrative city of Metekel Zone which is found in Benishangul Gumuz regional state, in Western Ethiopia. The geographical coordinate of the town is 11°00'0.00''N latitude and 36°00'0.00''E longitude. It is Located at a distance of 676km from West of Addis Ababa and at 396km from North of Assosa. It is bordered on the West by Sudan, on the North and East by the Amhara Regional state, and along south and southwest by Kamashi Zone. The topography of the zone presents undulating hills slightly sloping down to low land Plateaus having an altitude range from 600-2800 meter above sea level. The surrounding of Metekel zone has a wide climatic range varied from hot to warm moist lowlands and hot to warm sub humid lowlands (Bewuketu, 2016). Gilgel-Beles town is predominantly covered with yellowish, black and gray soils. The yellowish, colored soils are found on rolling topography with higher elevation and well drainage condition. The black and gray soils, which cover the central and large part of the town, are found on flat topography of the town with lower elevation and unfavourable drainage condition. The location of the study area (Gilgel-Beles), on the map of Benishangul Gumuz regional state is shown in figure-1 (Muktar, 2013) .

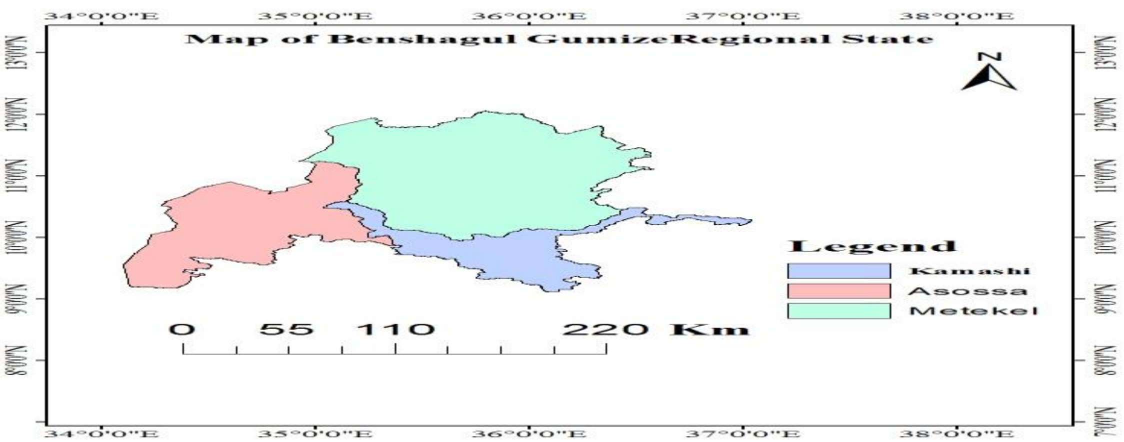

Figure- 1 The location of the study area

(Source: administrative map of BenshangulGumuz regional state)

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2.2 Study Design and Sampling Methods

The soil specimens for this study were collected from Gilgel-Beles town. Prior to sampling, identification of sampling area has been done by walk-over and visual site investigation to consider the different soil types and to take sample evenly in the whole town. From the selected areas representative disturbed and undisturbed soil samples were collected from open pits by direct excavation manually at the average depths of 1.5m and 3m. Accordingly, ten sampling areas were selected from different locations of the town which are supposed to represent all types of the soils found in the town from preliminary site investigation. From the selected areas representative disturbed and undisturbed soil samples were collected from open pits by direct excavation manually at the average depths of 1.5m and 3m. Then these samples were taken to the laboratory by taking care for the undisturbed samples. All of the test pits were excavated up to depth of 3m except TP-2

Table 1 Sampling depth and location of sampling area

Test pit	Pit location	Sampling depth(m)	Visual Observed color
TP – 1	Adebabay	1.5	Red color
		3	Yellow color
TP – 2	Meniray	1.5	Gray color
		2.8	Gray color
TP – 3	Mariam	1.5	Black color
		3	Gray color
TP – 4	Hidsa sefer	1.5	Gray color
		3	Yellow color
TP – 5	02 kebele	1.5	Black color
		3	Gray color
TP – 6	Memeran college	1.5	Red color
		3	Yellow color
TP -7	Mesekel adebabay	1.5	Black color
		3	Gray color
TP – 8	Tena tabya	1.5	Gray color
		3	Red color
TP -9	Mazoreya	1.5	Red color
		3	Yellow color

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TP – 10	Chagni mwucha	1.5	Red color
		3	Red color

Table 2 Global coordinates of sampling areas

Test Pit	Location	Northing	Easting	Elevation (m)
TP – 1	Adebaby	11°09.7555	036°20.5565	1031
TP – 2	Meniray	11°09.6916	036°20.5340	1049
TP – 3	Mariam	11°10.1514	036°20.1266	1031
TP – 4	Hidsa sefer	11°10.2015	036°20.1075	1032
TP – 5	02 kebele	11°09.3428	036°20.4122	1034
TP – 6	Memeran college	11°09.8794	036°20.3592	1023
TP – 7	Mesekel adebabay	11°09.6287	036°20.5887	1023
TP – 8	Tena tabya	11°09.4499	036°20.7076	1047
TP – 9	Mazoreya	11°09.4499	036°20.707	1037
TP – 10	Chagni mwucha	11°09.4806	036°20.6883	1039

Figure 2 Test pit locations on map of Gilgel-Beles town (Source: Google Map)

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2.3 Procedure for Laboratory Tests

The procedure followed to run this test is according to ASTM standard with designations D422 and D1140. According to ASTM D422 the distribution of particles, finer than 75μm can be done by hydrometer test. In this test, wet preparations of soil sample for particle size analysis were used (ASTM, 2004). The material is washed until the wash water becomes clear. The material retained on the 75μmsieve is collected and dried in an oven for 24 hours. It is then sieved through the set of fine sieves of the size 4.75mm, 2mm, 1mm, 600μm, 425μm, 212μm, 150μm and 75μm. The material retained on each sieve is collected and weighted. The sample of soil passing No. 200 was transferred to large dish and soaked until the water becomes clean, then the clean water was decanted. After the sample has dried in the hydrometer test 50grams of soil was taken and soaked for 24 hours by adding dispersing agent. The samples were taken to the laboratory by taking care for the undisturbed samples. The data consisted of about 20 laboratory test results under the same conditions. The tests included Atterberg Limits, moisture content, specific gravity and particle size distribution tests. The liquid limit (LL) was determined by the Casagrande method as specified by ASTM D4318. The liquid limit tests were carried out on soil samples passing a No. 40 sieve. The plastic limit (PL) was determined by the rolling thread method as specified in ASTM D 4318.The particle size distribution test was performed to determine the percentage of different grain sizes contained within a soil by ASTM D422 (ASTM, 2004).

3. Results and Discussions

From the graph presented in Figure 3 and the summary of grain size analysis shown on Table 3, Laboratory result of a soil was found. The results obtained from the grain size analyses indicates that the dominant proportion of soil particle in the research area is clay, which have clay content ranging from 20.3 % to 53%, silt faction 19.5% to 50. 5%, sand fraction20.1% to 30.7% and gravel content ranging from 0% to 1.4%, which shows that the soils for almost all samples are fine grained soil with consists of sand in nature. The result of Atterberg Limit of the soil samples is shown on Table 3. The soil in the Gilgel-Beles town has Liquid Limit ranging from 30% to 63.2%, Plastic Limit ranges from 26.4% to 45.2% and Plastic Index from 4% to 28.6%.

According to USCS classification system of plasticity chart in figure 4, most of the soil of Gilgel-Beles town falls below A-Line in ML region (LL<50%). This means that the dominant soils under the study area are categorized in silty with low plasticity characteristics.

For that of AASTHO classification system, the test result summarized in Table 3 and plasticity chart on Figure 5 which shows that the dominant soils under the study area are categorized in A-2-6, A-2-7and A-7-6 which is poor quality and unsuitable for using as sub-grade materials for highway construction. According to ERA manual, the soil classified as a poor quality soil is not suitable to be used as a subgrade material (ERA,2013). The Activity value of the soil under investigation of the study area ranges from 0.16-0.95. This implies that most soils through the study area fall in inactive range, which indicates that the sample is inactive to swelling whenever there is fluctuation of moisture. The results of specific gravity test indicate that the specific gravity of soils of the study area ranges from 2.4-2.84%, which is in the range of typical specific gravity values of inorganic soils.

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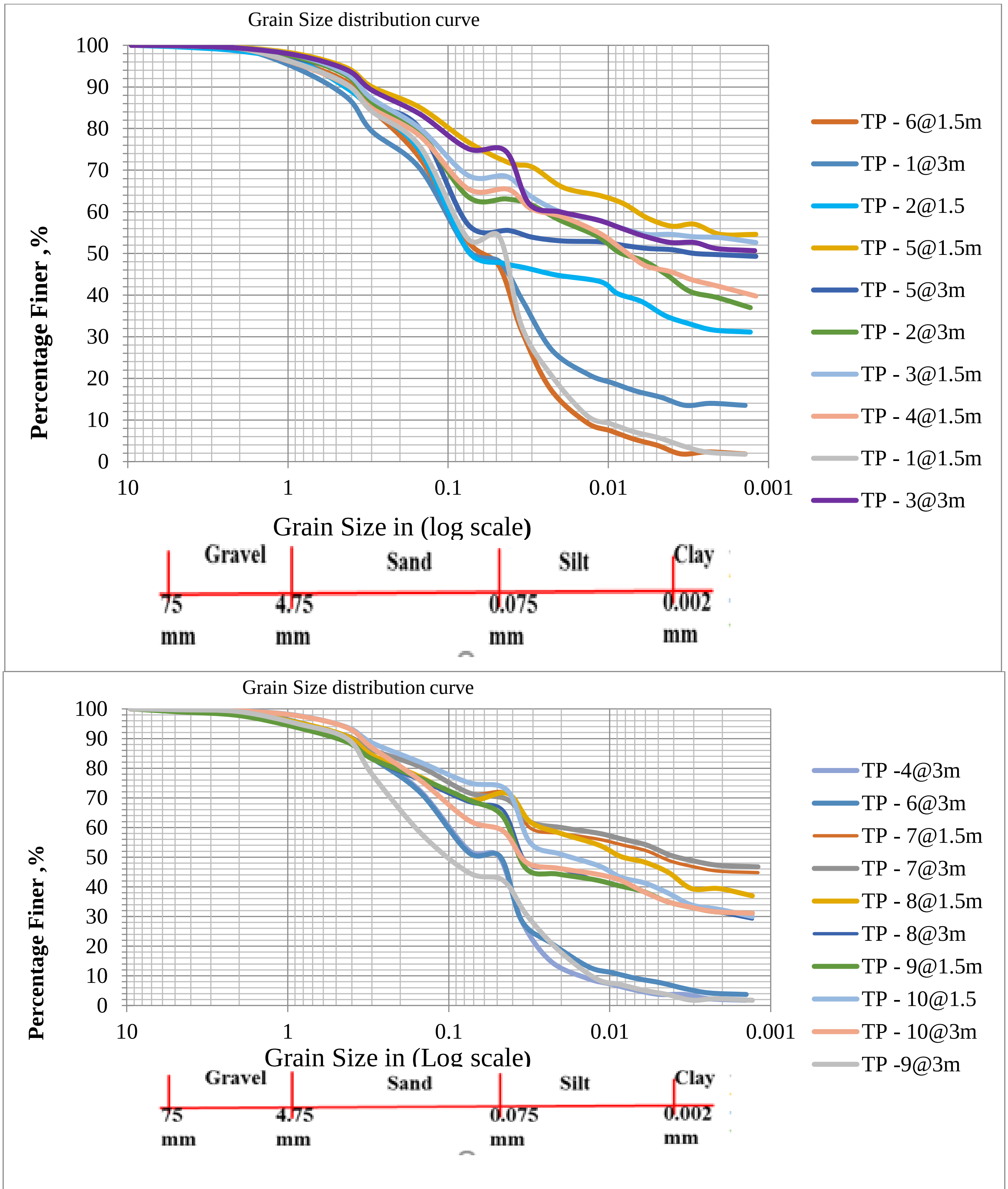

Figure 3 Grain size distribution curve

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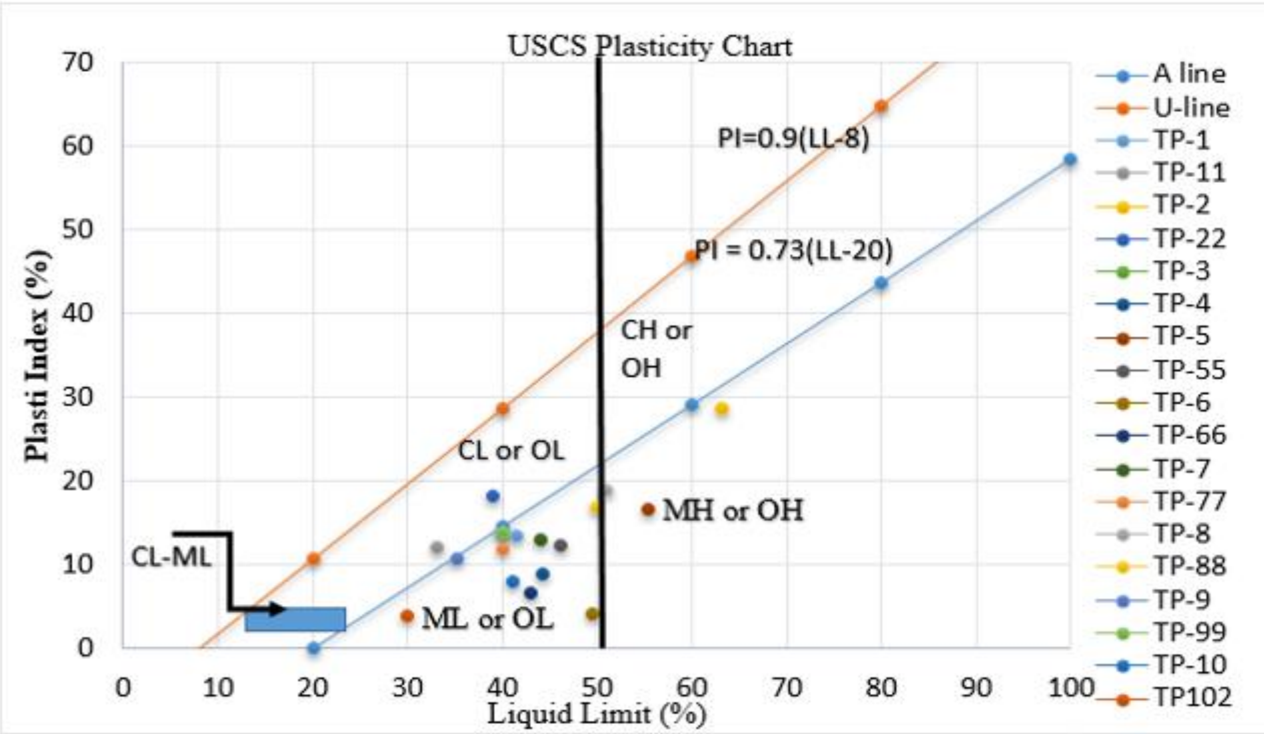

Figure 4 Plasticity chart according to Unified Soil Classification System

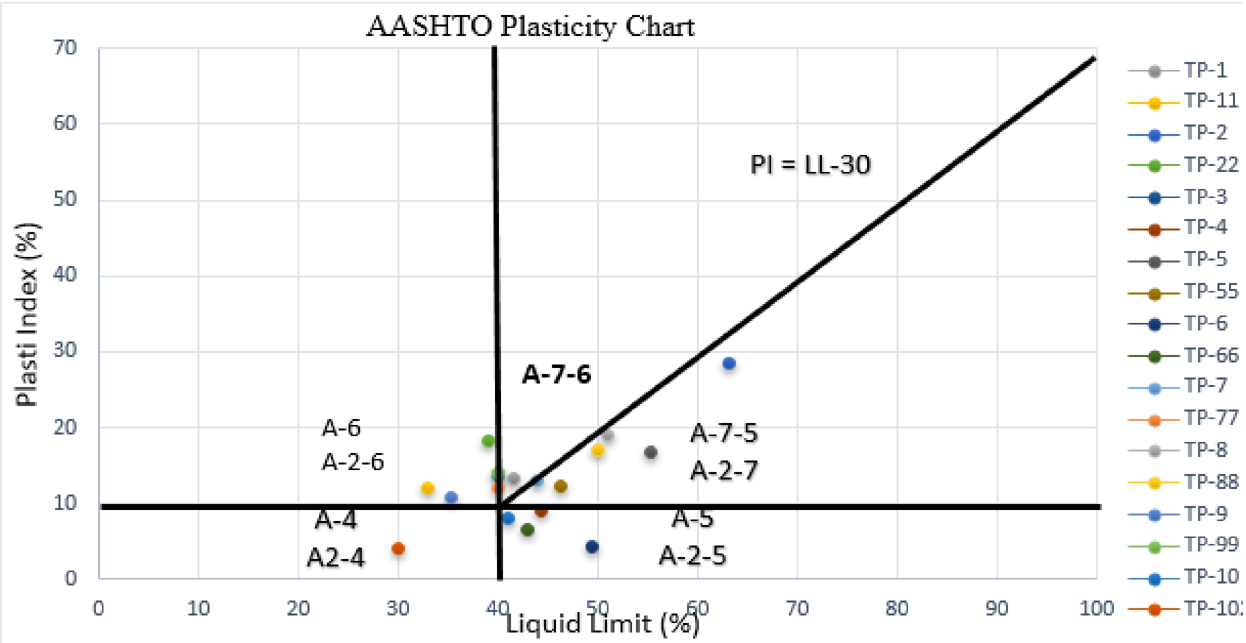

Figure 5 AASHTO Soil classification plasticity chart

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Table 3 Summary of Laboratory Test Results

Sample No	Specific gravity (Gs)	Percentage of particle size				Atterberg Limit Result			Activity (A)	classification	
		Gravel	Sand	Silty	Clay	LL	PL	PI		USCS	AASHTO
1	2.40	0.68	30.86	41.2	30.5	41.6	28.2	13.4	0.57	ML	A-7-6
	2.55	0.8	30.4	19.5	47.3	33	20.9	12.1	0.89	CL	A-2-6
2	2.68	1.4	20.1	40.1	37.9	63.2	34.5	28.6	0.95	MH	A-7-5
	2.73	0.68	25.8	26.6	46.9	39	20.6	18.3	0.49	CL	A-2-6
3	2.64	0.64	25.6	20.7	53	40.1	26.4	13.7	0.25	CL	A-7-6
	2.71	0.67	20.1	39.2	40	45	30	15	0.29	ML	A-7-6
4	2.67	0.76	30.7	37.8	30.8	44.3	35.2	9.0	0.22	ML	A-5
	2.77	0.04	30.2	50.2	20.3	43	30	13	0.64	ML	A-7-6
5	2.84	0.5	22.7	42.1	34.6	55.3	38.6	16.7	0.31	MH	A-2-7
	2.82	0.82	26.0	49.7	24.2	46.2	33.7	12.4	0.25	ML	A-2-7
6	2.65	0.44	26.6	50.5	23	49.5	45.2	4.3	0.19	ML	A-2-5
	2.70	0.0	28.7	41	30.3	43	36.4	6.6	0.16	ML	A-2-5
7	2.64	0.3	27.3	45.5	27	44	30.9	13.1	0.29	ML	A-2-7
	2.65	0.2	27.5	44.9	27	40	28	12	0.26	MH	A-2-6

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8	2.66	0.4	29.4	37.3	32.4	51	31.4	19.5	0.52	MH	A-2-7
	2.7	0.8	29.5	40.5	38	50	33	17	0.43	MH	A-2-7
9	2.64	0.9	20.8	41..7	37.1	35.3	26	10.7	0.26	ML	A-2-6
	2.66	0.3	24.2	41.5	34.3	40	26	14	0.41	ML	A-2-6
10	2.62	0.0	25.0	42	33.1	41	33	8	0.19	ML	A-2-5
	2.6	0.0	27.0	41.3	31.1	30	26	4	0.13	ML	A-2-4

When we make a Comparison of Test Results with Previous investigated research in different parts of the country, the results are almost analogous to each other as shown in the table 4. The results of the soil tests through the study area was considerably similar with the finding of the research conducted at Adama town in terms of Clay content (Dagnachew, 2011). The result of this study is also analogous with the study conducted in Kemise town in the results of the activity value and classification results (Yimam, 2016). Moreover, an interesting similarity between the test results of this study area with that of the researches conducted at Burayu and Dessie town was observed with respect to the index tests results (Wubshet, 2015, Tesfaye, 2013). Generally, the soil of Gilgele-Beles town could be classified as silty and clayey sand soil with almost close characteristics with Adama and Kemise soils (Dagnachew, 2011, Yimam, 2016).

Table 4: Comparison of test results

	Result of Previous Research(Dagnachew, 2011)	Result of Previous Research(Yimam, 2016)	Results of Previous Research (Wubshet, 2015)	Result of Previous Research (Tesfaye, 2013)	Result of Current Research
Soil type	Silt &silt sand	silt	Red Clay	Silt	Silt soil &clayey sand
Location	Adama town	Kemise	Burayu	Dessie	Gilgele-beles
Clay content%	5.4 – 40.5	21.78-46.4	56-74	50.6-70.7	23-54.6
Liquid Limit %	29-73	36.8-67.5	66-72	61-88	30 - 52.5
Plastic Limit %	21-39	22.9-33.3	31-34	38-59	24.9 – 40.5

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Plastic Index%	5-34	12.1-34.7	36-40	22-38	5 – 19.5
Activity	-----	0.47-0.86	<0.75	--	0.13-0.87
Specific Gravity	2.4- 2.7	2.63-2.74	2.70-2.82	2.65-2.83	2.59-2.72
AASHTO classification	-	A-6, A-7-5/6	-	A-7-5	A-2-4/5, A-2-6/7, A-4, A-6, A-7-5/6

5. Conclusion

The samples of soils through the study area are almost showed fine grained characteristics which can be classified as a soil(silty) consisting of sand in nature. From the test result the physical and index properties of the study area were concluded as ranges natural moisture content from 19.68 %- 59.87%, specific gravities from 2.6 to 2.72, clay fraction from 23-54.6%, silt fraction from 14.9-50.5%, sand from 20.82-39.1%, gravel from 0-1.4%, liquid limit from 30 – 52.5%, plastic limit from 24.9 – 40.5% and plastic index from 5 – 19.5%. According to USCS classification system of plasticity chart, most of the soil of the study area falls below A-Line in ML region, and TP-3, TP-5 and TP-7 in MH region, which have high plasticity (LL>50%) and the classification soils found in Gilgel-Beles town are ML, MH and CL. And also, according to AASTHO classification system, the test result show that the dominant soils under the study area are categorized in A-7-5 and A-7-6 which is poor for subgrade materials. The maximum dry density (MDD) ranges from1.57 to 1.81 g/cm3 with the optimum moisture content ranges 17 to 35.38 %.

6. Acknowledgment

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