STABILIZATION OF CLAY SOIL USING A-3 SOIL IN SUBGRADE MATERIALS

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ABSTRACT

The aim of this paper work is stabilization of clay soil using A-3 soil in subgrade material of Arba Minch - Wolaita Sodo main road to Zefine town by taking the three soil samples test peats, because this road giving transportation purpose for the community with continuous maintenance on some part of the road; thus, geotechnical characterization and stabilization of Problematic soil is very important. To achieve these objectives three soils sample pits were selected from different representative parts of the existing road at 1km interval. To understand the basic characteristics of the sub grade soil, such as field dry density, 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. The test results showed that the NMC ranges from 14.25% to 15.86%, the field dry density ranges from 1.67g/cc to 1.69g/cc, percentage finer ranges from 75.08% to 77.26%, LL ranges from 56.65% to 60.27%, PI ranges from 37.27% to 39.02%, GI ranges from 28 to 31, OMC ranges from 16.46 % to 17.65 %, MDD ranges from 1.74 g/cc to 1.80g/cc, CBR ranges from 2.05% to 2.46% and CBR swell ranges from 3.20 % to 3.66%. Based on these results the study area was characterized as clay soil, and for the soil classification under A-7-6 according to AASHTO M145 soil classification system. From the three test pits samples (from TP1 to TP3) were unsuitable to use as a subgrade material for pavement construction based on [10] manual specification; thus, for the unsuitable subgrade soils, stabilize by mechanical method of stabilization by A-3 soil, with different percentages ratio (10% , 15% and 20% of locally available selected material that is A3 soil) by weight, were used to get appropriate mixing ratio, finally it was found that 20% mixing of A-3 soil were efficient to use those as a subgrade material.

Keyword: - *Clay Soil, Mechanical Stabilization*

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1. INTRODUCTION

Expansive soils are problematic due to the performances of their clay mineral constituent, which makes the exhibit the shrink- swell characteristics. These behaviors make expansive soils in appropriate for direct engineering application so to make them more feasible for construction purposes, numerous materials and techniques have been used to stabilize the soil [5].

Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. There are many methods of stabilizing soil to gain the required engineering characteristics of the subgrade soil. These methods range from mechanical (compaction, excavation and mixing of different soils) to chemical stabilization (lime, cement and asphalt) [4]. Most of these methods were relatively expensive to be implemented the best way is to use mechanical stabilization by A-3 soils with relatively cheap costs.

Arba Minch-Wolaita Sodo main road to Zefine town, the road is located in Gamo Gofa zone in SNNPR at a distance of 423km from Addis Abeba. This study work was planned to stabilize mechanically the engineering properties of unsuitable subgrade soil with good bearing capacity (A-3 soil) after site investigation, because around the study area within 5km distance there exist A3 soil that has been chosen.

1.1. Statement of the Problem
The road that lies on Arba Minch –Wolaita Sodo main road to Zefine town has various problems. The primary cause of the road failure is the poor quality of the subgrade soil, because the existing road is extremely corrugated and has many potholes and rutting. Thus, the geotechnical characteristics of the subgrade soils must be known and the researcher studied the stabilization of the soils to use it as a subgrade material for pavement construction since the road was constructed without any geotechnical characterization of the subgrade material and it has been used for transportation purpose in the community with at least one time maintenance per year.

1.2 The Significance of the Study
- Give better understanding about the behavior of the clay soil .
- Find counter measures for unsuitable parts of the sub-grade soils.
- Apply safe and economic stabilizer type(A-3 soil) and its ratio to be determined

1.3 Objectives of the Study
1.3.1 General Objective
Stabilization of clay soil using A-3 soil in subgrade materials
1.3.2 Specific Objectives
- To characterize the problematic soil (clay soil).
- To classify the subgrade soils based on the laboratory tests results.
- To suggest engineering solution for safe and economic stabilization method.
- To evaluate the stabilized subgrade soils to use as a subgrade material.

2. Literature review
Soil stabilization is a process whereby increased strength and stability of the soil is attained mainly by mechanical or chemical means. The most common improvements attained through stabilization include better soil gradation, reduction of plasticity index or swelling potential, increase in the durability and strength [6].
Soil stabilization is the change of one or more soil engineering properties, by mechanical or chemical means, to create a suitable subgrade soil material possessing the desired engineering characteristics. Soils may be stabilized to increase strength and durability or to prevent erosion and dust generation. Regardless of the purpose for stabilization, the desired result is the creation of a soil material or soil system that will remain in place under the design to be used conditions for the designing life of the project [12].

2.1 Mechanical Stabilization
Mechanical stabilization is the process of improving the properties of the soil by changing its gradation. It is usually achieved by adding a different material in order to improve the grading or decrease the plasticity of the original material. The physical properties of the original material will be changed, but no chemical reaction is involved [8]. The main methods of mechanical stabilization can be categorized in to compaction, mixing or blending of two gradations. The stabilization can be accomplished by uniformly mixing the material and then compacting the mixture. As an alternative, additional fines or aggregates maybe blended before compaction to form a uniform, well graded, dense soil-aggregate mixture, after compaction, the aggregates consist of strong, well graded, angular particles of sand and gravel which provide internal friction and incompressibility to a soil, the fines also provide cohesion and impervious to a soil, these are composed silt and clay, Thus the quantity of binder should be sufficient to provide internal friction to the soil, but it should not cause swelling [7].
Finally the blended soil should be possessed both internal friction and cohesion. In the case of mechanical stabilization, unlike other stabilizing agents, the proportion of the stabilizing material exceeds 10% and may be as high as 50%, the mixture will normally be compacted at or near OMC to obtain satisfactory densities [11].

2.2 Chemical Stabilization
Chemical stabilization is a method of improving the engineering properties of a material by adding chemical substances. It is used for a wide range of purposes including, improving the bearing capacity and strength of pavement layers, delay certain chemical reactions that are harmful to road soils or aggregates, dry out soil where the moisture content is too high for successful compaction, make soil less permeable where necessary, reduce the plasticity of soils used in road construction and thereby reducing the effect of moisture variations, changing clay to a more granular and workable material and reducing swelling and shrinkage properties [6].

2.3 Selection of the Stabilization Method

The geotechnical engineers should have responsible for selecting or specifying the correct stabilizing method, technique, and quantity of material required depending on economy and safety of the pavement structure.

In this thesis work based on the field and laboratory results indicates that, the subgrade soil at a three location (from TP1 to TP3), have low load-bearing strength, because of an excess of clay with its high swelling potential, so stabilize the soil by locally available selected material (fine sand soil or A-3 soil based on AASHTO soil classification), mixed with unsuitable subgrade soils in appropriate proportional ratio by weight, for this purpose mechanical stabilization method was used.

2.4 Previous Works on Mechanical Stabilization of Clay Soils:-

According to [13] Studied Modification of Clay Using fine sand (A-3) Soil; Clay soil classified as A-7-6 according to AASHTO soil classification system, the clay was modified with fine sand (A-3) soil sieved out from river sand. The clay was replaced with fine sand (A-3) soil at 0, 10, 20, and 30 to 100% by weight of the clay soil. Grain size analysis tests and Atterberg limit tests were carried out on each of the clay-fine sand (A-3) soil mixtures to evaluate the effect of fine sand (A-3) soil on the clay soil. Results showed that the liquid limit of the clay reduced from 59.3% at 0% fine sand (A-3) soil replacement to 23.4% at 80% fine sand (A-3) soil replacement. The plasticity index reduced from 32.5% at 0% fine sand (A-3) soil replacement to 6.6% at 60% fine sand (A-3) soil replacement. These represent 60% reduction in liquid limit and 80% reduction in plasticity index. Fine sand (A-3) soil is therefore an appropriate material for modification of clayey soils, but for his research he was not include the engineering properties of soil such as compaction and CBR tests.

Based on [2] Studied on sand as a soil stabilizer**;** that clayey soils often exhibit undesirable engineering behavior such as low strength, swelling and shrinkage characteristics etc. To improve these properties, the common method followed is stabilization. An experimental program carried out in his study aims the physical mechanisms of stabilization of an expansive soil by adding an inert material (sand). The study aimed to analyze the effect of stabilization on the variation of soil consistency and the results have shown that soil consistency improved appreciably. For his findings of the laboratory testing procedures presented substantial improvement in strength with the addition of sand percentages up to 60% by weight of soil, as well a noticeable alteration in the moisture-density relation. The soil tested could be used as subgrade material in pavement structures.

According to [3] Studied sand: An additive for stabilization of swelling clay Soils an experimental program carried out in his study seeks to understand the physical mechanisms of stabilization of an expansive soil by adding an inert material (sand) at various forms; mixing and intercalation layers of sand. The first aim of his study is to analyze the effect of stabilization on the variation of soil consistency. The results show a marked improvement in soil consistency. He can be also seen that the addition of sand is capable of reducing the swelling action of the soil.

3. Materials and Methodology

Table 1 Soil Sample Location of the Study Area

S/No.	Location	Depth (m)	Northing	Easting	Elevation (m)
TP1	A soil sample from the link of Arba Minch Wolaita main road to Zefine town at the station of 423Km distance from Addis Ababa.	1.3	6º31’09.618’’	37º46’49.902’’	1221
TP2	A soil sample1Km distance from TP1 at Koka kebele.	1.5	6º31’27.580’’	37º46’19.840’’	1327
TP3	A soil sample1Km distance from TP2 at Cidho kebele.	1.5	6º31’49.866’’	37º45’54.396’’	1390

The huge accumulation of A-3 soil occurs along the side of Hamesa river at Korga kebele, the location of the soil sample taken for soil testing was, 6º30’57’’ North, 37º 49’00’’East and its elevation is 1210m,the laboratory tests results indicates that, it was a fine sand soil (A-3 soil) , based on [1].

Table 2 Summary of Tests Conducted, Test Method, and Type of Sample

Tests conducted	Test method or standard	Type of Sample
Natural Moisture Content	ASTM D 2216	Disturbed
Specific Gravity Test	ASTM D854	Disturbed
Sieve Analysis	ASTM D 422	Disturbed
Atterberg Limit (LL&PL)	ASTM D 4318	Disturbed
Moisture- Density Relations of Soils	ASTM D1557	Disturbed
CBR and CBR Swell at OMC and MDD	ASTM D1883	Disturbed

4. Results and Discussion

This study involved the characterization of the subgrade clay soil and stabilization of the problematic soil by considering economy and safety for pavement construction; thus, mechanical stabilization method by locally available selected material (A3 soil) with appropriate proportional ratio was used.

The most important parameters used in this thesis study were field dry density, NMC, Gs, grain size analysis, Atterberg limit, compaction, CBR swell potential and CBR tests of the clay soils.

4.1 Field Dry Density, NMC and Gs Test Results for the three Soil Samples

Table 3 Field Dry Density, NMC and Gs Test Results

Sample No.	Field bulk density (g/cc)	NMC %	Field dry density (g/cc)	Gs
TP1	1.94	15.86	1.67	2.73
TP2	1.92	14.25	1.68	2.80
TP3	1.95	15.23	1.69	2.76

4.2. The Grain Size Analysis Test Results for the three Soil Samples

Table 4 The Grain Size Analysis Test Results for the three Soil Samples

Sample No.	Coarser grain size soil			Finer grain size soil		
	Gravel %	Coarse Sand %	Fine Sand %	Silt %	Clay %	Clay Fraction Size<0.002 mm
TP1	2.40	13.78	6.56	32.26	45.00	30.50
TP2	2.55	10.72	11.65	35.78	39.30	29.00
TP3	2.80	12.17	9.55	33.98	41.50	31.00

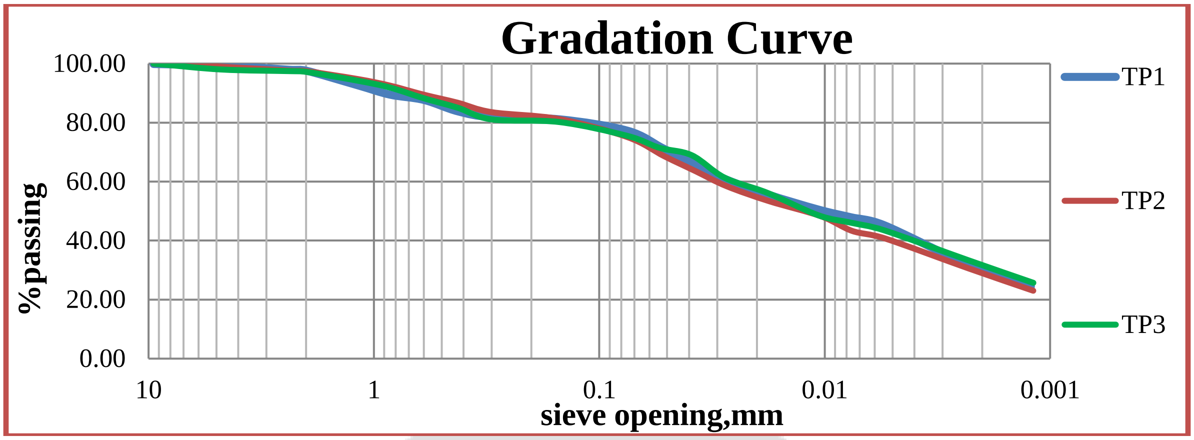

Figure 1 Gradation Curves of the Study Area from TP1 to TP3

4.3 Atterberg Limit, Compaction, CBR Swell and CBR test results.

Table 5 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

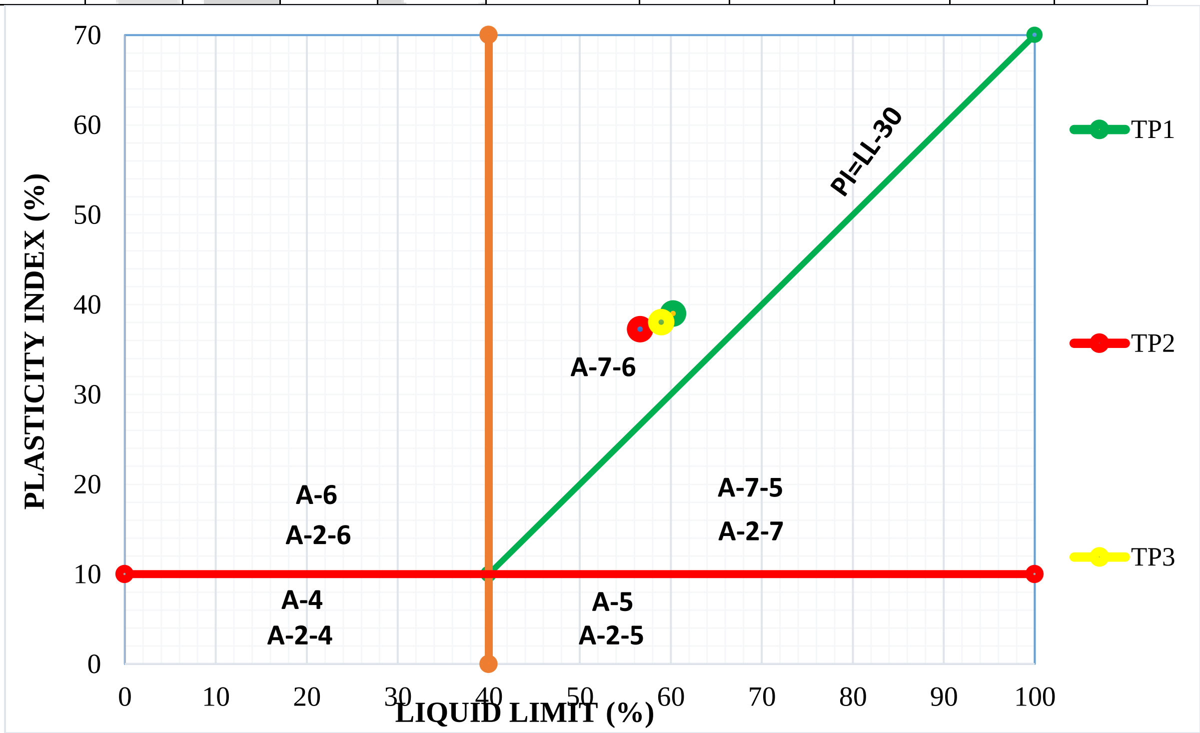

Figure 2 The Three Soil Samples, Soil Classification Chart According to AASHTO System

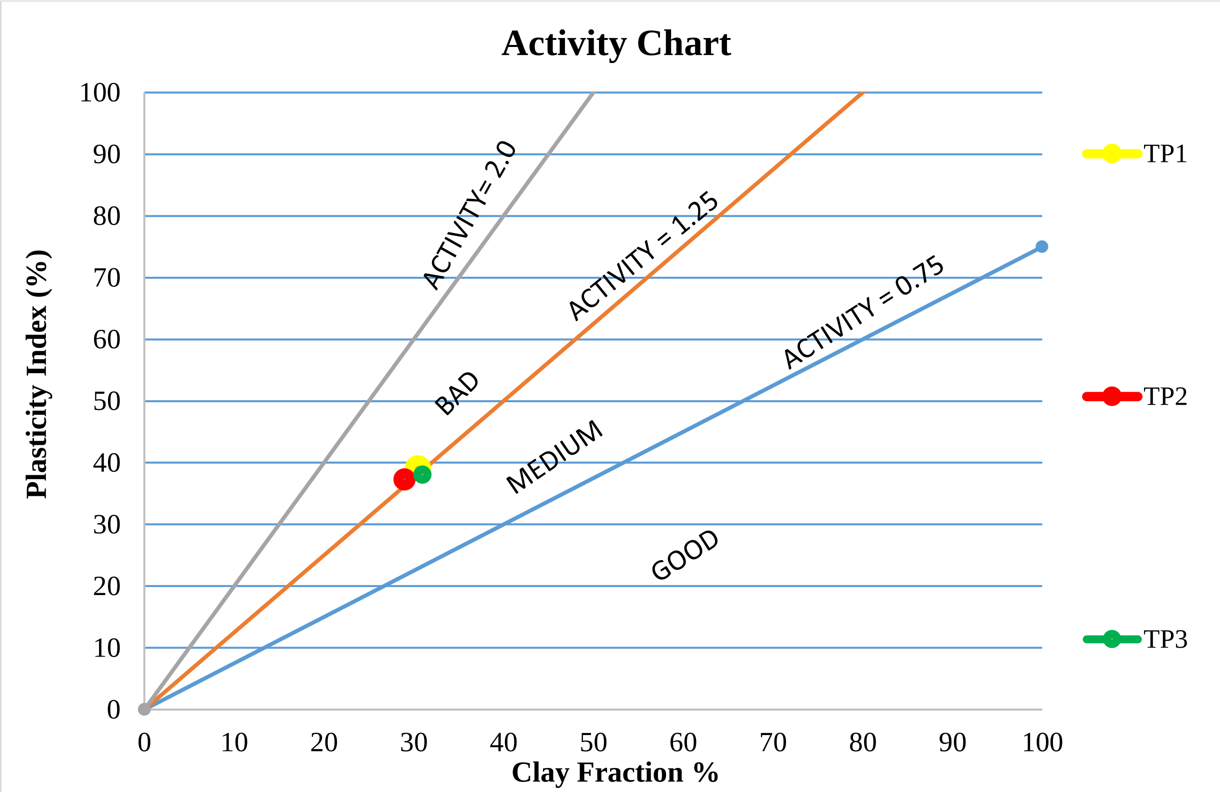

Figure 3 Soil Classification Based on Activity Chart for the three Soil Samples.

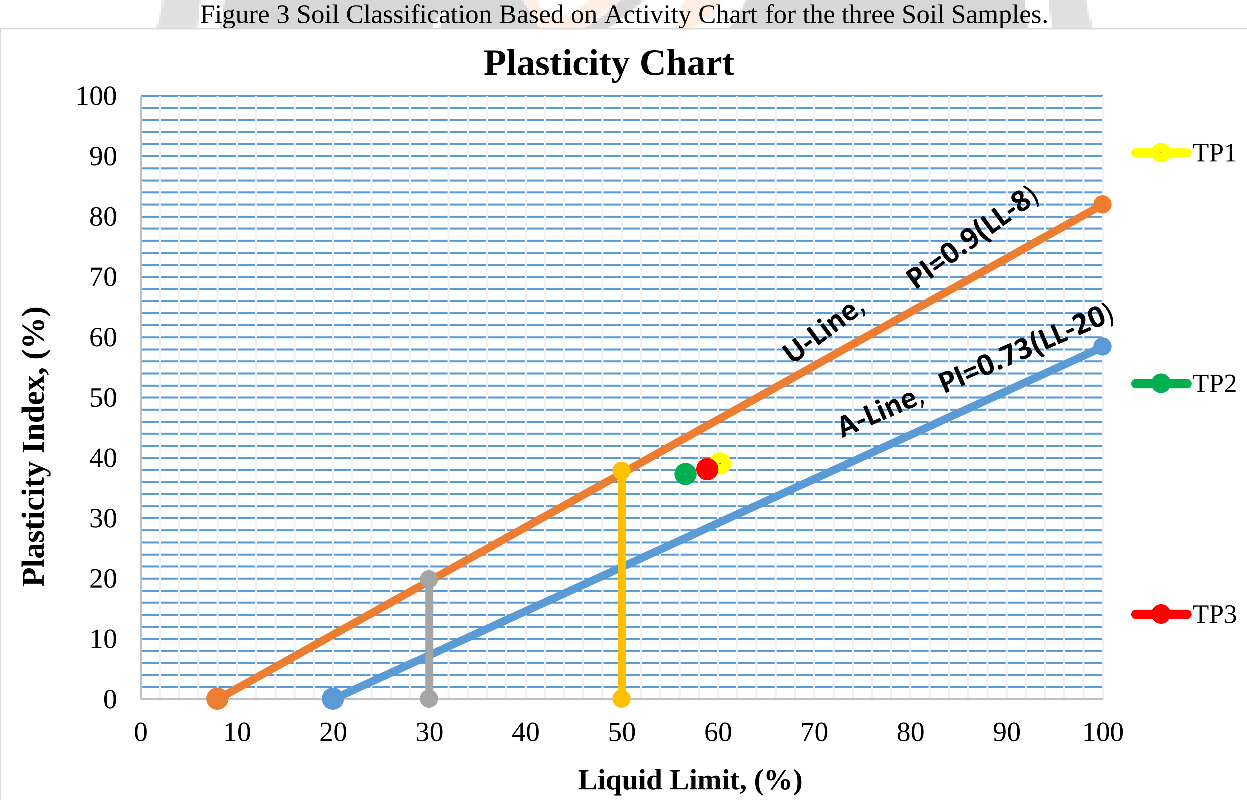

Figure 4 Soil Classification Based on Plasticity Chart for the three Soil Samples.

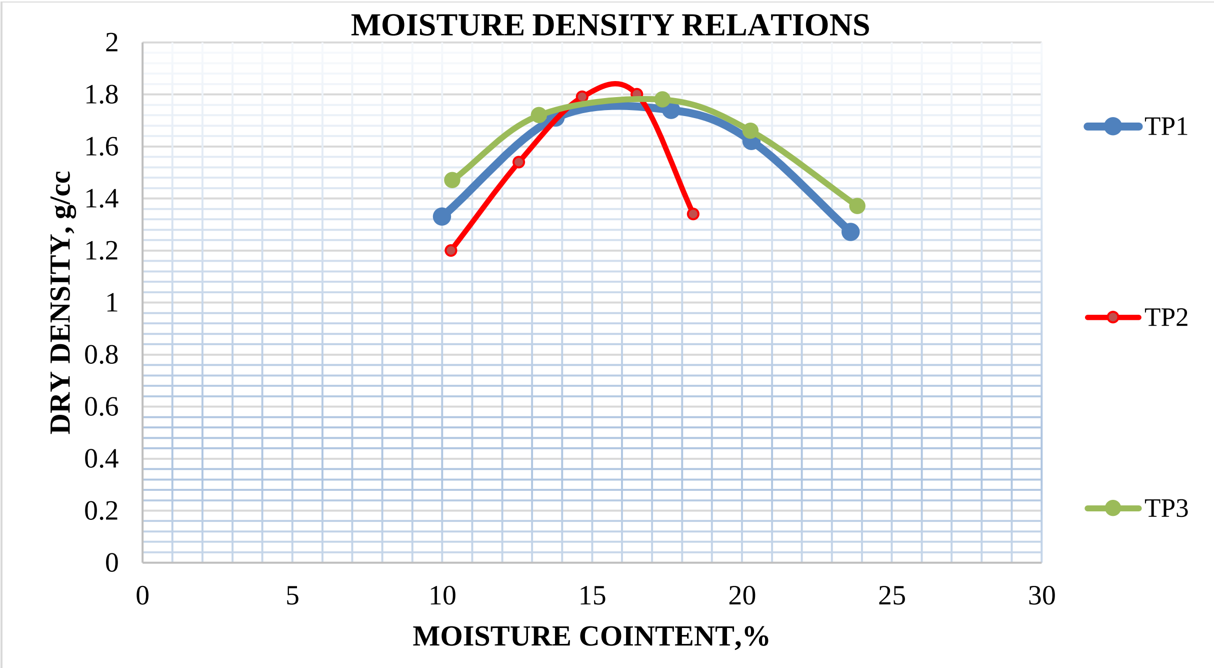

Figure 5 Moisture Density Relations of (from TP1 to TP3)

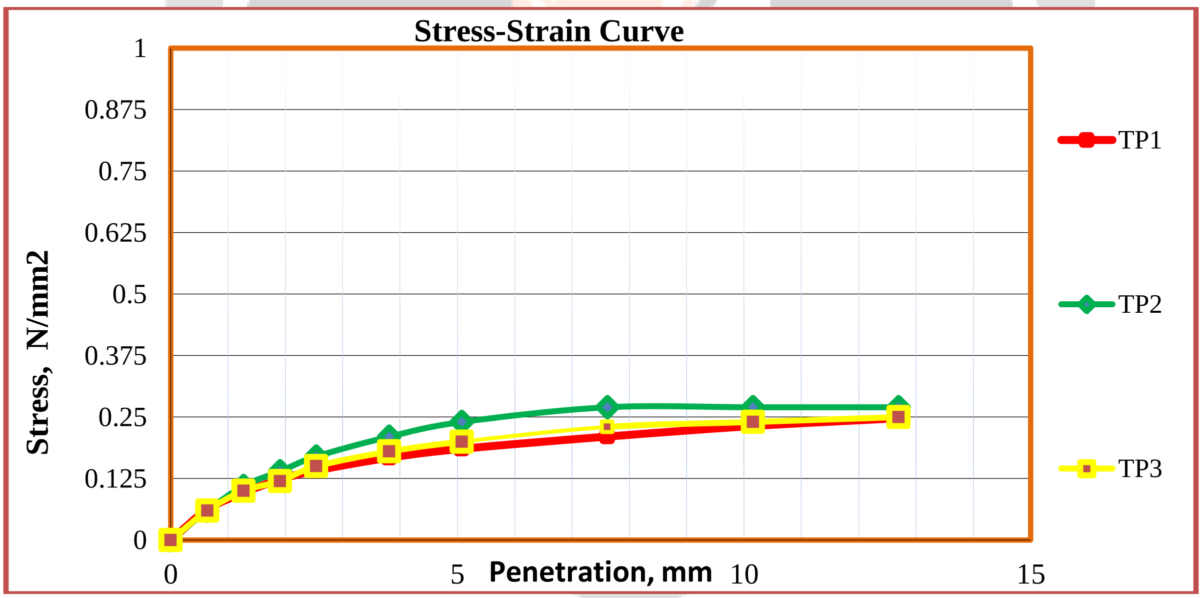

Figure 6 Stress Vs Strain Curves of TP1 to TP3soil samples.

Generally; The soil samples from TP1 to TP3, were unsuitable to use as a subgrade materials based on [8] specification; thus, those soils should be treated with appropriate improving method before using as a subgrade soils.

4.4 Mechanical Stabilization of TP1 by Adding Selected Material (A-3 soil)

The grain size analysis tests for TP1 by adding A3 soil, the trials started from 10 %, 15% and 20 % of A3 soil by mass.

Table 6 The Grain Size Analysis for TP 1 with 10%, 15% and 20% A-3 soil

Samples	Gravel%	Sand %		Finer %	
		Coarse Sand %	Fine Sand %	Silt %	Clay %
A-3 soil	17.30	31.62	44.58	6.5	
Stabilization of TP1					
TP1	2.4	13.78	6.56	32.26	45.00
TP1 + 10% A-3 soil	4.21	17.04	12.47	25.78	40.50
TP1 + 15% A-3 soil	6.11	20.35	17.68	21.36	34.5
TP 1 + 20% A-3 soil	8.48	23.00	20.03	18.99	29.50

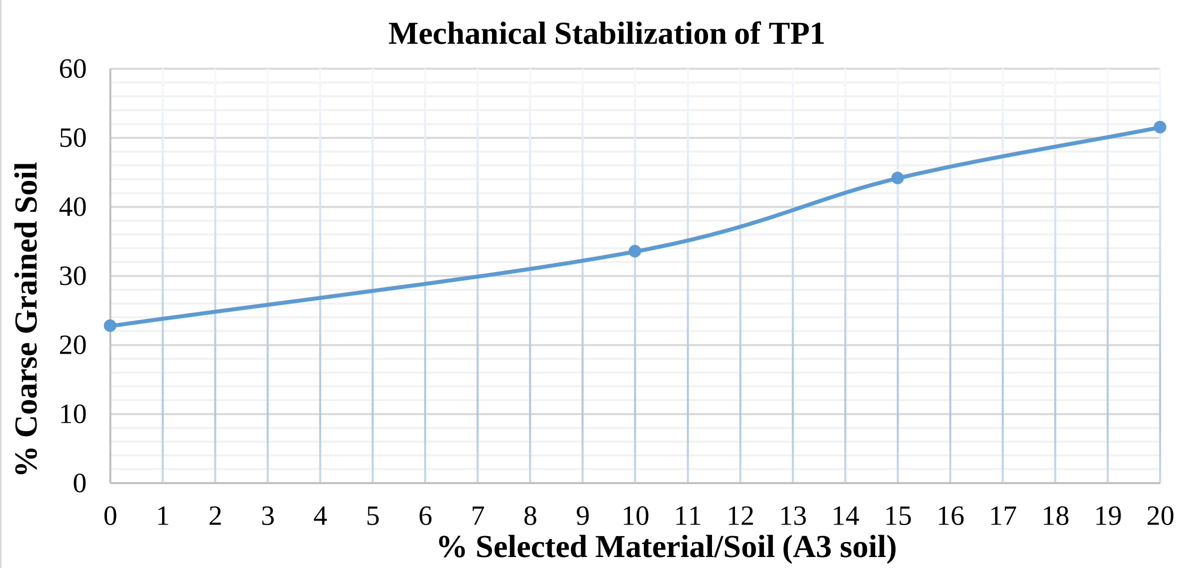

Figure 1 Increase in Course Grained Soil with Increase in Selected Material (A-3 soil) .

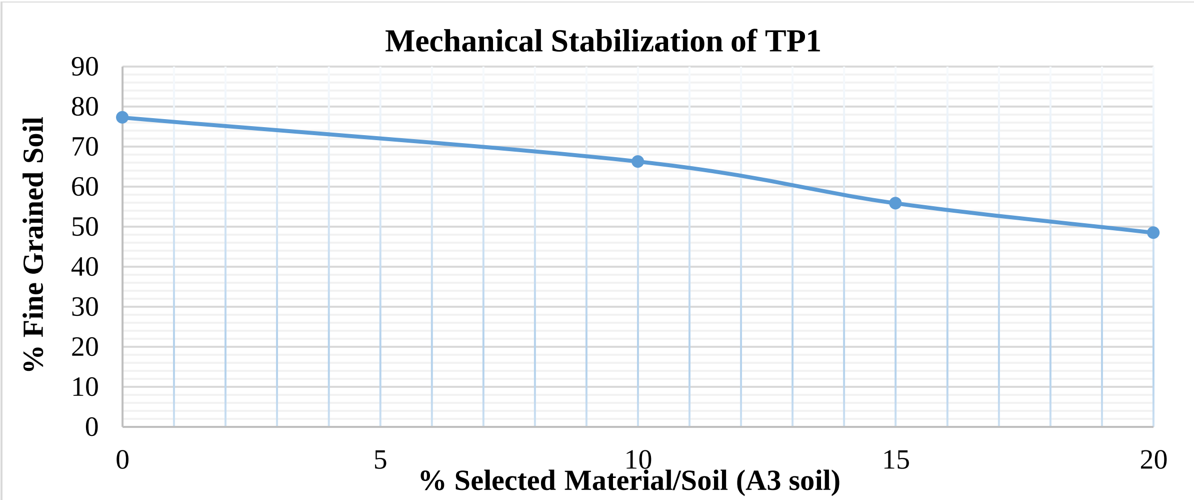

Figure 2 Decrease in Fine Grained Soil with Increase in Selected Material (A-3 soil) .

Table 7 The LL, PL, Compaction, CBR Swell and CBR Tests for TP1 with 10%, 15% and 20% A-3 soil

Sample No.	% fine	LL %	PL %	PI %	GI	MDD g/cc	OMC %	CBR Swell %	CBR %
Selected Material (A-3 soil)	6.50	-	-	0 (NP)	0	2.01	10.00	0.75	27.54
TP1	77.26	60.27	21.25	39.02	31	1.74	17.65	3.66	2.05
TP1+ 10% Selected Material (A-3 soil)	66.28	53.90	19.52	34.38	21	1.80	16.64	2.90	3.49
TP1+15% Selected Material (A-3 soil)	55.86	45.07	18.33	26.74	14	1.83	15.97	2.40	4.30
TP1+20% Selected Material (A-3 soil)	48.49	34.25	17.33	16.92	7	1.86	15.07	1.84	5.10

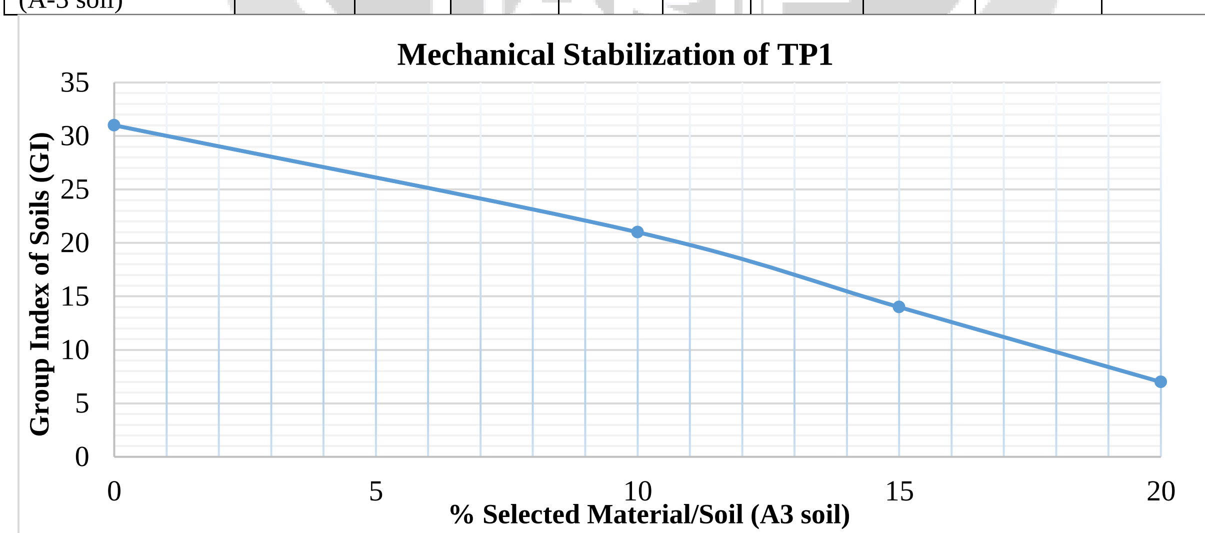

Figure 3 Decrease in GI value with Increase in Selected Material (A-3 soil) .

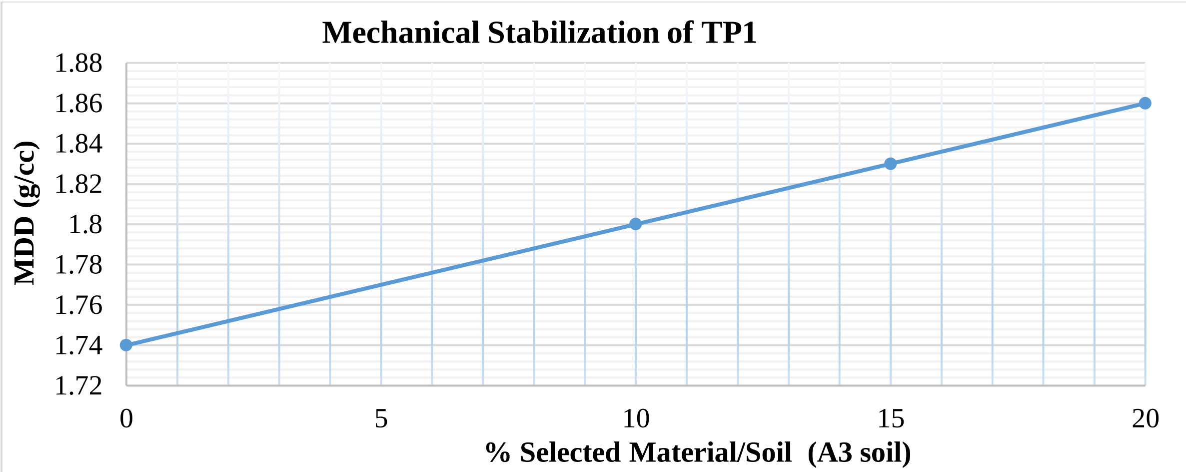

Figure 4 Increase in MDD with Increase in Selected Material (A-3 soil) .

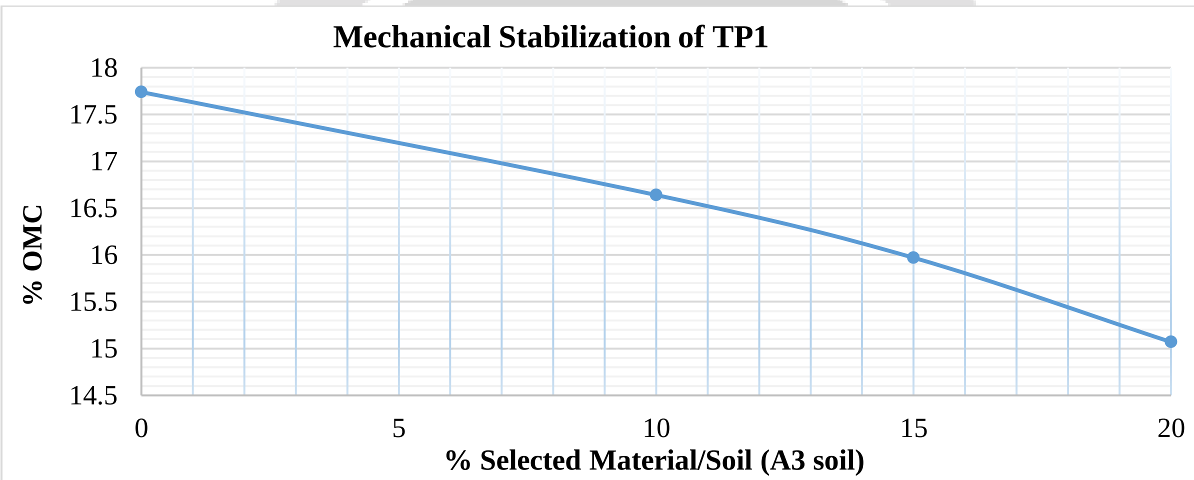

Figure 5 Decrease in OMC with Increase in Selected Material (A-3 soil).

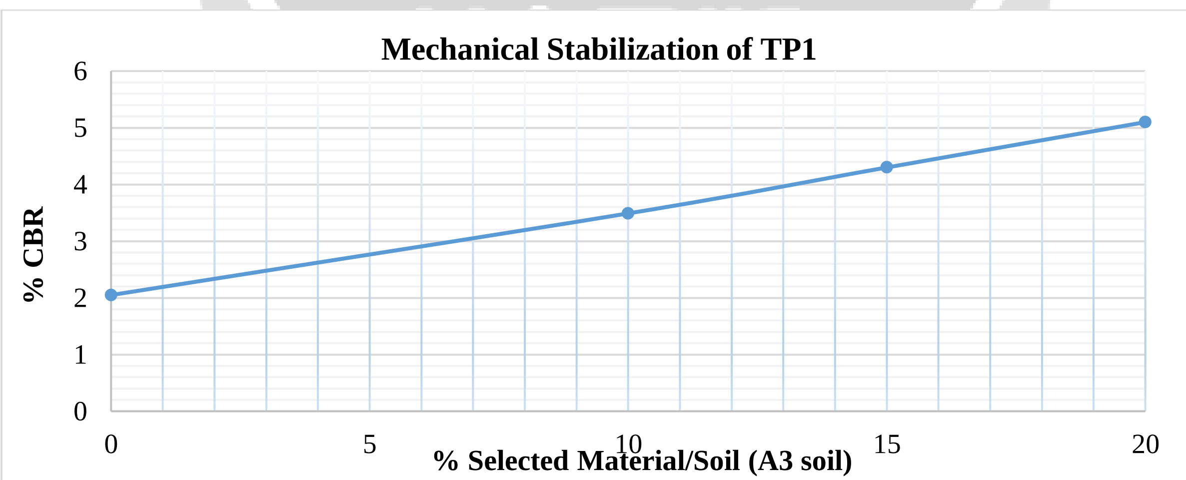

Figure 6 Increase in CBR value with Increase in Selected Material (A-3 soil).

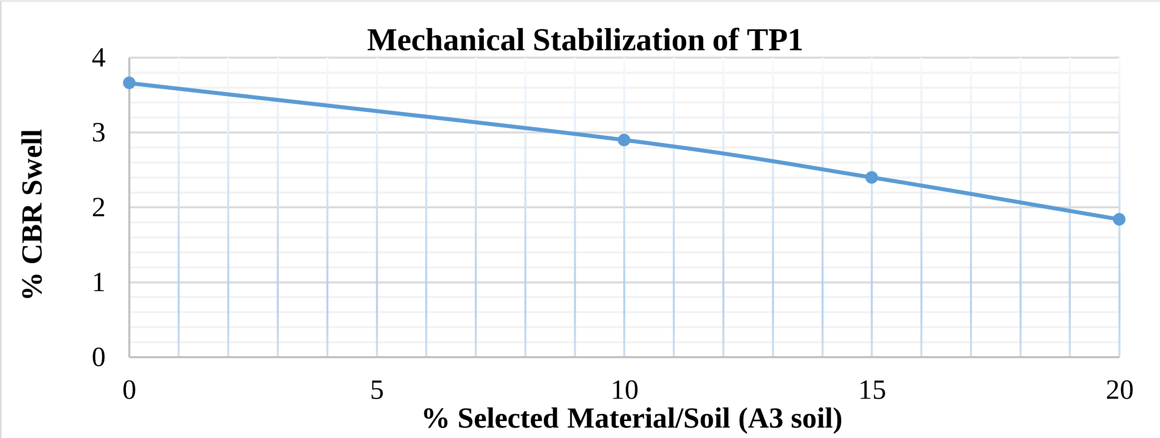

Figure 7 Decrease in CBR Swell with Increase in Selected Material (A-3 soil)

4.5 Mechanical Stabilization of the Test Results for TP2 and TP3 with 20% selected material (A-3 soil)

Table 8 The Grain Size Analysis Test Results for TP2 & TP3 by Adding 20% selected material (A-3 soil).

Samples	Gravel%	Sand %		Finer %	
		Coarse Sand %	Fine Sand %	Silt %	Clay %
TP2 + 0% selected material (A-3 soil)	2.55	10.72	11.65	35.78	39.30
TP2 + 20% selected material (A-3 soil)	8.57	17.54	25.75	23.94	24.20
TP 3 + 0% selected material (A-3 soil)	2.80	12.17	9.55	33.98	41.50
TP3 + 20% selected material (A-3 soil)	8.26	23.04	18.18	24.22	26.30

Table 9 The LL, PL, Compaction, CBR Swell and CBR Tests for TP2 & TP3 with 20% selected material (A-3 soil).

Parameter	TP2 + 0% selected material (A-3 soil)	TP2 + 20% selected material (A-3 soil)	TP3 + 0% selected material (A-3 soil)	TP3 + 20% selected material (A-3 soil)
LL (%)	56.65	30.53	58.94	31.65
PL (%)	19.37	15.54	20.91	16.30
PI (%)	37.27	14.99	38.03	15.36
GI	28	4	29	4
MDD (g/cc)	1.80	1.89	1.78	1.88
OMC (%)	16.50	14.67	17.36	15.61
CBR Swell (%)	3.20	1.63	3.40	1.72
CBR (%)	2.46	5.43	2.15	5.31

4.6 **Generally Stabilization Study were Summarized as**

- Increasing stabilizer ratio of A-3 soil by mass decreasing the percentage fineness and increasing the grain size.
- Increasing stabilizer ratio of A-3 soil by mass decreases liquid limit of the soil.
- Increasing stabilizer ratio of A-3 soil by mass decreases plastic index of the soil.
- Increasing stabilizer ratio of A-3 soil by mass decreases group index of the soil.

- Increasing the stabilizing ratio of A-3 soil by mass decrease the OMC value.
- Increasing the stabilization ratio of A-3 soil by mass increases MDD value.
- Increasing stabilizer ratio of A-3 soil by mass decreases CBR swells value of the soils.
- Increasing stabilizer ratio of A-3 soil by mass increases CBR value of soils.

5. CONCLUSIONS

This study is to characterize the clay soil and improvements achieved on the engineering properties of unsuitable subgrade soils by mechanical stabilization method with adding locally available selected material (A3 soil) by considering safety and economy, because Ethiopia is a developing country, so as a geotechnical engineer find the solution depending on safety and economy.

For this study field investigation, field dry density tests and laboratory tests conducted for NMC, grain size analysis, Gs, Atterberg limits (LL & PL), compaction (OMC & MDD), CBR and CBR swell tests were done, finally the mechanical stabilization was done using 10%, 15% and 20% A3 soil ratio by mass with unsuitable soil, all the test procedures were based on ASTM laboratory tests standards.

From the study the following findings are deduced:-

1. The improvements on engineering properties of clay soil to use as a sub grade material were observed on gradation size, PI, GI, MDD, OMC, CBR swell potential and CBR values.
2. Finally the laboratory tests results indicates that mixing of 20% selected material (A3 soil), the index and engineering property of TP1 to TP3 were improved to use as a sub grade soil and it satisfies the ERA manual specification to use the soil as subgrade material [9].

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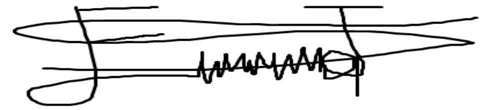

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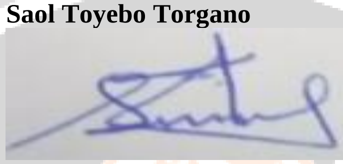

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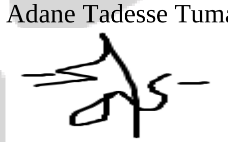

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