Geotechnical Investigation and Effect of Moisture Content on Subgrade CBR Values; Arbaminch-Chencha Existing Road; Ethiopia

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Abstract : **In the flexible pavements sub-grade is the undermost layer for pavement structure constructed on it and used to resist traffic load. Hence, subgrade geotechnical behaviors are considered as measuring parameters of the pavement design and performance. But, here Arbaminch-Chencha road is constructed as gravel road twelve years so far without any geotechnical investigation.**

The aim of this research is geotechnical investigation and effect of moisture content on CBR of the subgrade soil of Arbaminch-Chencha road. This is to classify and characterize this subgrade according to its geotechnical properties, to identify effect of moisture on subgrade CBR for selected three soil classes.

To achieve these objectives, seventeen representative test samples collected along the existing road. Laboratory investigations performed for in-situ moisture content, specific gravity, grain size analysis, Atterberg's limit test for all pit samples. And then soils are classified. After classification of soils; laboratory moisture – density relationship and CBR values are determined. The effect of moisture on its CBR was observed for specified soil classes. For all tests the apparatus and the procedures used for analysis were done according to ASTM and AASHTO standards.

According to AASHTO soil classification, Arbaminch-Chencha road subgrade soils classified as coarse and fine grained soil; but dominated by fine grained soil class.

As per observed, laboratory maximum dry density of this soil ranges from 1.36 gm./cc to 2.11 gm./cc and OMC range from 10 % to 30%. And four day soaked CBR Values are ranges from 3 % to 49 % under specification of 95% MDD.

Effect of moisture revealed as, CBR value reduced 4% to 28% at dry side whereas 25% to 59% at wet side of OMC and MDD of specified soil classes.

Saturation after 48 to 96 hours, CBR reduced from 17% to 30% whereas 96 to 144hours reduced 7% to 20%. But, continuous and linear reduction observed in finer soil classes.

Key words: Sub Grade, classification, Characterization, Moisture Content and CBR.

1. INTRODUCTION

In the highway pavement structure, sub-grade is a naturally consolidated and/or constructed layer to resist traffic load which provides a suitable foundation for the pavement layer constructed on it. Hence, sufficient information on soil class, characteristics and mechanical properties (basically California Bearing Ratio) of foundation material is very important for engineering constructions; such as road projects.

Arbaminch-Chencha road is found in Gamo Gofa Zone, in southern Ethiopia; which is constructed twelve years before (in 2005). This road is currently gravel paved with having heavy traffic flow. Hence, it gives large transportation purpose for different areas around and far from the road. Areas using this road are to and from Arbaminch-Dorze, Chencha, Ezo, Ditta, Dara Malo (Waca), Abassa, and to other currently developing small towns and villages. This encourages the social and economic development activities of these areas by transporting an industrial raw products (textiles) and wide agricultural products (fruits; Apple, Apple mango etc.), potato, maize, animals for meat) of the Arbaminch-Chencha highlands.

Although, with having heavy traffic flow and transportation purpose by small vehicles to heavy trucks, it is till now a low class gravel road constructed so far without any geotechnical investigation on its subgrade soil. As information collected from Gamo-Gofa road and transport office, Arbaminch-Chencha road is constructed under this office as a client and they informed for this research work as no soil investigation conducted during that time at all.

But now a day this road is under investigation by ERA for upgrading it to asphalt concrete level because of its heavy transportation purpose and the rapid development of community there. Since, every activity requires quality road as much as possible to transport different products as discussed in above paragraph.

Hence, the present research is directed on geotechnical investigation and effect of moisture content on CBR values on subgrade soil of Arbaminch-Chencha existing road.

2. STATEMENT OF THE PROBLEM

Investigation of soil and soil materials is so important since all infrastructure construction projects (like roads) use naturally occurring soils and soil Martials as the basic foundation as well as construction materials. Unlike man-made materials, the properties of these soil are highly variable and a function of the complex natural processes that occurred in the geologic past. And are heterogeneous, nonlinear material, and typically anisotropic instead of being isotropic. As a consequence, constructions like pavement structures are facing problems related with soils and soil materials available in the project site, whose properties are often unknown and of variable quality.

Arbaminch-Chencha road was constructed without any geotechnical investigation and has been giving transportation purpose for the community with continuous maintenance twice per year on most part of the road. These maintenances are conducting just before and after rainy season. This is because of the capacity of this road is not equivalent to its purpose; since it was gravel paved.

Most of this road section is found in different climate zones according to Ethiopian climate zoning. Particularly, there is high precipitation and low temperature is common at the end section of the study area; Dorze – Chencha section. Rain water stays for more than a week in poorly constructed side ditch during rainy seasons in this section. Not only climate problem, but also there is shallow ground water table near to the surface about 2 to 3m. This ground water "(BONO)" is used for day to day purpose of the area. Due to this, subgrade strength (CBR value) can be affected by long term moisture saturation. But when the road comes to the starting point of this research, climate is different from the above section; in which precipitation is low with high temperature.

The subgrade strength owing to its inconsistency or variable nature poses a challenge to come up with a perfect design of pavement on it. Since, the subgrade is always subjected to change in its moisture content due to precipitation, capillary action, flood or abrupt rise of water table. Change in moisture content causes change in the subgrade strength. And it becomes quite essential for an engineer to understand the exact nature of dependence of subgrade strength on moisture content.

Therefore, this research is helpful to know the geotechnical behavior and effect of moisture content on CBR values of the subgrade soil was studied.

3. OBJECTIVE OF THE STUDY

3.1 General Objective

The general objective of this research is geotechnical investigation for subgrade and effect of moisture content on its subgrade CBR values of Arbaminch-Chencha existing road.

3.2 Specific Objectives

The specific objectives of this research work are:

- To classify and characterize subgrade soils found along Arbaminch-Chencha road alignment; for road construction purpose. By using in-situ moisture content, specific gravity, grain size analysis test and atterberg's limt tests
- To determine laboratory compaction characteristics and subgrade CBR values of subgrade in the Arbaminch-Chencha road and
- To experiment and evaluate the effect of moisture content on subgrade CBR in this road alignment

4. METHODOLOGY

To achieve the objectives, seventeen (17) sampling pits areas selected and their geographical location is determined in field using GPS reading. From these sample pits, disturbed subgrade soil samples were excavated to a maximum depth of 1.5 meters and collected for laboratory investigation (as per ERA site investigation manual 2013).

Laboratory tests were conducted for natural moisture content, specific gravity, Atterberg's limit test, grain size analysis on all seventeen samples. And moisture–density relationship, CBR and CBR swelling under OMC is performed on ten specified pit samples.

Lastly, the effect of moisture content on CBR values is evaluated for different soil classes by (1) by varying moisture content during preparation of CBR specimens before (dry side) and after (wet side) OMC; (2) by extending saturation period beyond 96hours (4days) to 144hours (6days). During any activity for this research, special attentions paid for the sack of tropical residual soil properties; even though there is no given standard to investigate such type of soils.

For 17 pit samples of subgrade soil along road stretch, pit chainage was started from Chano (pit -1; stationed 9+160 by considering 0+000 station at Arbaminch town) and proceeded to Chencha town (pit -17; stationed 27+200) as shown in figure 4.1. Chano town exists 9km from Arbaminch to east on the Addis Ababa Arbaminch main highway.

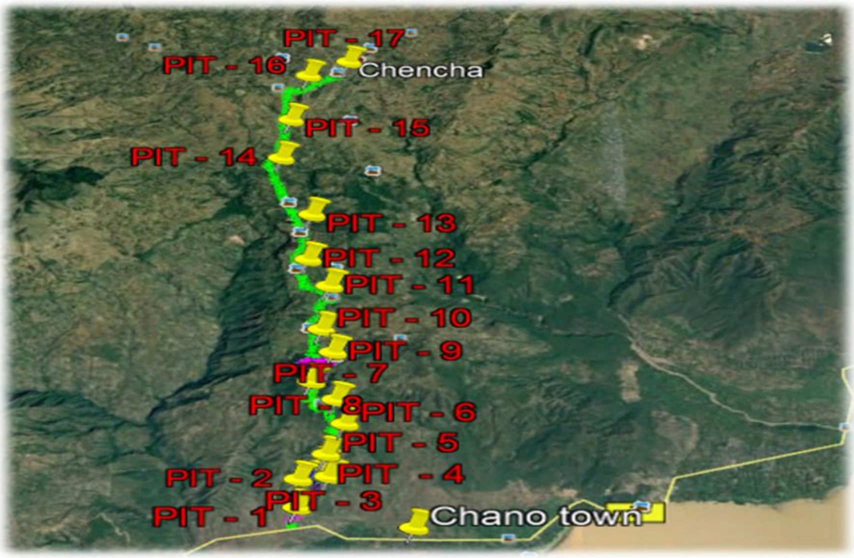

Figure 4.1; Arbaminch – Chencha - Chano Road Profile (Google earth.com)

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Location of pits taken some distance offset right hand side(RHS) or left hand side(LHS) from centerline of road, since road is under use. So that is impossible to dig pits just at centerline of road which was justified in the following table 4.1.

Table 4.1 Summary of Pit Location for each sample

pit	Chainage (Station)	**Location Coordinate**		
		Latitude (N)	Longitude (E)	Altitude(m) from msl
1	9+160	6'07'10.49''	37'34'32.01''	1262.3
2	10+200	6'07'34.24''	37'34'31.67''	1343.86
3	11+100	6'07'35.10''	37'34'42.12''	1404.88
4	12+000	6'7'47.01''	37'34'44.35"	1451.5
5	13+060	6'07'56.35''	37'34'47.43''	1502
6	14+320	6'08'23.95''	37'34'55.85''	1612.23
7	15+380	6'8'46.02''	37'34'49.88"	1732.788
8	16+500	6'09"3.27"	37'34'36.37''	1818.41
9	17+660	6'9'29.10''	37'34'46.41"	1958.0352
10	19+900	6'9'49.70''	37'34'39.24"	2132.1
11	21+000	6'10'32.41''	37'34'41.51''	2220.46
12	22+040	6'10'58.54''	37'34'27.53''	2377.41
13	23+300	6'11'46.05''	37'34'27.02"	2462.78
14	24+220	6'12'36''	37'34'6.50''	2559.68
15	25+400	6'13'33.36''	37'34'6.93''	2559.41
16	26+420	6'14'13.77''	37'34'5.33''	2604.34
17	27+200	6'14'41.66''	37'34'39.6''	2690.75

4.1 GEOTECHNICAL INVESTIGATION

Geotechnical investigations to be conducted are summarized in the following table 4.2

Table 4.2 Summary of tests conducted, standards, and their significance

S.No	Tests conducted	Test method/standard	Pits investigated	Selection
1	In-situ moisture content (w)	AASHTO T 265 or ASTM D 2216	All 17 pits	All 17 pits
2	Specific Gravity(Gs)	AASHTO T100 or ASTM D854	All 17 pits	All 17 pits
3	Liquid limit(LL)	AASHTO T89 / ASTM D 4318	All 17 pits	All 17 pits
4	Plastic Limit (PL)	AASHTO T90/ ASTM D 4318	All 17 pits	All 17 pits
5	Sieve analysis	AASHTO T 88 / ASTM D 422	All 17 pits	All 17 pits
6	Moisture- Density Relations of Soils	AASHTO T180-97, / ASTM D2937	For 10 from 17 pits	Pit 1,2,3,5,6,8,11,12,14 and 16
7	CBR and swell at OMC and MDD	AASHTO T-193	For 10 from 17 pits	Pit 1,2,3,5,6,8,11,12,14 and 16
8	Effect of moisture content on CBR	AASHTO T-193	For 3 from 17 pits	Pit 1,5, and 14

Selection of pits for various tests was made on the following criteria: (1) variability of subgrade soil along the roadway, (2) consideration on samples taken from these variable locations are representative for overall subgrade along this road. And also (3) distance of minimum of 2 to 3 km distance between these pits as much as possible as per ERA pavement design manual; vloume1, 2013. Manual recommends taking strength test samples with limit of 2 to 5km to have economical design. Since, it is too costly to design subgrade CBR with in shorter distance less than 2km.

4.2 Effect of Moisture Content on CBR Values of Subgrade

The variation of moisture in soils has great adverse impact on quality and performance of structures constructed on it. Since, increase in moisture content in substructure material decreases the engineering quality of soil; like load bearing capacity. The variation of moisture content in soil and soil materials may be developed most likely from climate change as discussed in chapter two.

Thus, Arbamich-chencha road has two different climate zones; these are (1) road near Arbaminch (about 9 km from 19km total road) which has more hot time and more evaporation than precipitation per year and (2) the second part is road near Chencha (about 10 km from 19km total road) part in which there is more precipitation and low temperature, shallow ground water table (2m to 3m). Hence, moisture fluctuation and its effect on subgrade bearing capacity were expected, particularly during rainy seasons.

This research work was conducted to study moisture effect on subgrade CBR value in two ways: (1) Preparing CBR specimens with water contents at dry side and wet side of OMC and (2) preparing CBR specimens at OMC but varying the degree of saturation (period of saturation).

Three soil classes (pit-1; A-2-4 soil class, pit-5; A-7-5 soil class and pit-14; A-4 soil class) were selected for the above tests. These selections were made on the bases of soil classification, CBR values and to cover over all study area along the road.

4.2.1 Effect of Moisture Content on CBR Values by drying and wetting

Materials used in this section were the same as used in normal (conventional CBR test) CBR test in section 4.1. Air dried soil materials passing 19mm prepared and modified if material has larger size than 19mm.

The variable parameter selected in this case was moisture content. Two moisture contents were selected on dry side of OMC and two on wet side as discussed in chapter five and other parameters were kept constant as much as possible.

So that, four CBR specimens were prepared; two CBR specimens at dry side and two on wet side. Each CBR specimen from these soil classes was compacted by energy of 56 blows per layer to make variables other than moisture content constant. Dry density and moisture contents were determined. Then after, these remolded CBR specimens were soaked for 96 hours with surcharge load of 4.56kg. Initial and final readings for percentage of swelling were taken before and after soaked for determination of swelling.

4.2.2 Effect of Moisture on CBR values by Period of Saturation

The second way performed here to evaluate effect of moisture content on CBR values of subgrade was extended saturation period. Commonly, it is popular to use 96 hour's soaked CBR values of subgrade for the design of pavement structures. This was accepted by considering 96 hours saturated is the worst and CBR value at this period is the lowest and no effect could be observed.

However, this condition may difficult to accept in some conditions such as at area in which there is high rainfall and low temperature soaking CBR specimens for 96 hours can't saturate fully whereas at areas in which there is low rainfall and high temperature soaking CBR specimens for 96 hours not logical. Since, in the first case moisture can affect CBR values by gradual saturation for longer time than 96 hours. And for the second case 96 hours soaked CBR values are not economical because of no such effect could be expected.

Thus, for this research the effect of moisture content was studied by varying saturation period 0, 2(48 hours), 4(96 hours) and 6(144 hours) days on CBR specimens from those selected soil samples.

To do so, four CBR specimens from above three soil classes were prepared by OMC and compacted in 56 blows per layer. Materials used here were the same material as materials used in s**ection 4.2.1.** These specimens (unsoaked, 2 days soaked, 4 days soaked and 6 days soaked) were soaked for corresponding saturation periods under surcharge load of 4.56kg. Dry density, moisture content and percentage of swelling all were determined the same way as procedures taken in conventional CBR test AASTO T193.

But moisture content was taken from three points (top about 2 cm below from the top edge of the mold, middle and bottom about 2cm above from the bottom edge of the mold) from single CBR specimen and determined as per ASTM D2216/AASHTO T265. Then the average of three is used for density determination of CBR specimen for each soil.

CBR values and percentage of swelling for every unsoaked, soaked for 2, 4 and 6 days specimens were determined as described. And overall observed, analyzed, tables and figures are collected in section 5.2.

5. RESULTS AND DISCUSSIONS

5.1 Geotechnical Investigation

In this chapter, investigation results discussed are: in-situ moisture content, specific gravity, soil classification tests such as sieve analysis and Atterberg's limit (Liquid limit, Plastic limit, and Plasticity Index value) are presented. Soils are classified. Then laboratory moisture-density characteristics and CBR test under normal conditions (at OMC and MDD) were explained.

The effect of moisture content observed under moisture content other than OMC and extended degree of saturation period results are presented here. All the laboratory results are summarized in tables and figure in the following sections.

5.1.1 In-Situ Moisture Content

Methods of determination of in-situ moisture contents in samples collected from 17 pits are presented in section 4.1. The results obtained from these tests are presented in table 5.1. As their results indicated that there was variation of moisture content observed from pit to pit (table 5.1) along the road. The variation was most likely due to the location of pits with respect to their elevation and weather condition. This was not only the reason but also soil by itself varies from pit to pit along the road. In-situ moisture content was relatively higher at higher elevations near Chencha and the reverse was also true. Pit samples containing fine soil content had the greater in-situ moisture than those containing lesser fine soil or more coarser particles.

Soils here under study for this research, the in-situ moisture content obtained from laboratory undisturbed and disturbed samples by ASTM D2216/ASHTO T-265 range in between 10 % to 44% except pit 16 has 73%(which was relatively higher and close to its liquid limit). The average of all test results was 30.15 % which is more likely in range of silty and clayey soil. Since, most part of soils in the study area was dominated by fine grained soil class.

5.1.2 Specific Gravity

Method to determine the specific gravity is described in section 4.1. From that, results of specific gravity at 20 ^{0}c of seventeen pit samples are tabulated in table 5.1. Specific gravity of soil solids may vary with varying the mineralogical content of the soil.

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Table 5.1: Laboratory in-situ moisture and specific gravity summary

Pits	Chainage (station)	Depth sampled(m)	In situ moisture content (w %)	Specific Gravity Gs(at 20 ^{0}c)	Elevation(m) From M.s.l
Pit - 1	9+160	0.50	10.53	2.63	1262.30
Pit - 2	10+200	0.75	11.41	2.67	1343.86
Pit - 3	11+100	0.50	10.88	2.65	1404.88
Pit - 4	12+00	0.50	14.97	2.62	1451.50
Pit - 5	13+060	0.75	23.18	2.68	1502.00
Pit - 6	14+320	1.20	41.17	2.75	1612.23
Pit - 7	15+380	0.50	24.90	2.70	1732.79
Pit - 8	16+500	0.50	9.88	2.64	1818.41
Pit - 9	17+660	0.50	31.95	2.69	1958.04
Pit - 10	19+900	0.50	35.23	2.73	2132.10
Pit - 11	21+000	0.50	42.00	2.62	2220.46
Pit - 12	22+040	1.15	28.28	2.68	2377.41
Pit - 13	23+300	0.75	31.26	2.72	2462.78
Pit - 14	24+220	0.75	37.25	2.65	2559.68
Pit - 15	25+400	0.75	43.58	2.66	2559.41
Pit - 16	26+420	1.50	73.09	2.65	2604.34
Pit - 17	27+200	0.75	42.99	2.67	2690.75

The results of specific gravity vary from soil class to soil class. Hence, its values of the study area varies from 2.62-2.75 which is in the range of typical specific gravity values of gravel, sand, silt and clay soils. The lower values represent coarser soils and the higher values are for finer soils.

5.1.3 Grain Size Analysis

The grain size analysis test performed to have group of soil grains with in their corresponding sizes which are helpful for plasticity characteristics and soil classification. Here table 5.2 is developed as summary for seventeen pit samples from grain size observations and analyzed results.

The grain size analysis results indicate that the dominant proportion of particle in the study area is fine soil (silt and clay) of average percentage of 44.17% and the second dominancy by sand size of average of 39.07% and the last was gravel of average of 16.46%. As observed in table above, soils are finer and finer when it approaching to higher elevation along the road. Therefore, finer soils are found around Chencha town.

Table 5.2: Summary of grain size analysis of all 17 pits

PITS	Chainage(Stations)	AASHTO T88; % ge of pass			% ge of soils		
		4.75mm	0.425mm	0.075mm	Gravel(>4.75 mm)	Sand(4.75 - 0.075)	fine(< 0.075mm)
1	9+160	59.79	31.18	25.30	40.26	34.44	25.30
2	10+200	81.04	44.85	31.28	18.96	49.76	31.28
3	11+100	47.22	16.72	14.36	52.78	32.86	14.36
4	12+000	81.65	35.82	17.59	18.35	64.07	17.59
5	13+060	96.69	80.81	62.89	3.31	33.8	62.89
6	14+320	99.52	91.83	73.23	0.48	26.29	73.23
7	15+380	73.06	46.27	26.37	26.94	46.69	26.37
8	16+500	43.81	12.15	4.66	56.19	39.15	4.66
9	17+660	92.55	64.23	46.45	7.46	46.1	45.45
10	19+900	94	68.19	51.96	6.00	42.04	51.96
11	21+000	64.04	21.72	16.62	35.96	47.42	16.62
12	22+040	99.36	82.29	63.83	0.64	35.53	63.83
13	23+300	93.5	63.11	53.09	6.50	40.41	53.09
14	24+220	96.37	79.18	65.39	3.63	30.98	65.39
15	25+400	99.3	74.01	54.1	0.71	45.2	54.1
16	26+420	98.59	91.04	76.96	1.41	21.63	76.96
17	27+200	99.77	86.28	71.96	0.23	27.81	71.96

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5.1.4 Atterberg Limits test results

As described in chapter four, results of Atterberg limits (liquid limit, plastic limit) are determined according to AASHTO T-89 and T-90 standard test methods. Typical liquid limit test flow curve is given in Figure 5.1 for sample pit-1.

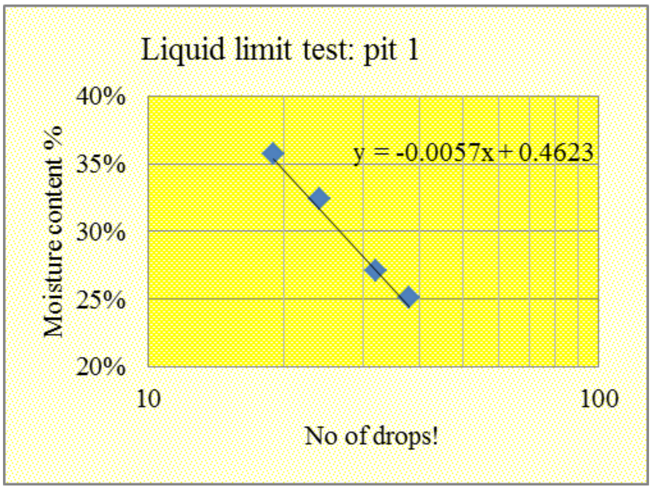

Figure 5.1; Typical liquid limit curve

Table 5.3: Summary Sheet For Atterberg,s Limit Test Results

PITS	Chainage(Stations)	Atterberg,s limit			Liquidity Index LI=(w-PL)/LL-PL)	Consistency by LI
		LL %	PL %	PI %		
1	9+160	31.98	23.91	8	-1.66	Solid state
2	10+200	35.64	24.12	12	-1.10	Solid state
3	11+100	23.54	20.71	3	-3.48	Solid state
4	12+000	25.58	-	NP	0.59	Solid state
5	13+060	49.71	35.63	14	-0.88	Solid state
6	14+320	71.95	37.1	35	0.12	plastic state
7	15+380	28.52	22.85	6	0.30	plastic state
8	16+500	-	-	NP	-	Solid state
9	17+660	46.5	36.58	10	-0.47	Solid state
10	19+900	49.87	36.66	13	-0.08	Solid state
11	21+000	21.29	-	NP	-	Solid state
12	22+040	35.89	30.13	6	-0.29	Solid state
13	23+300	43.17	32.97	10	-0.29	Solid state
14	24+220	37.61	28.41	9	0.93	plastic state
15	25+400	46.16	33.31	13	0.80	plastic state
16	26+420	87.31	58.77	29	0.50	plastic state
17	27+200	45.77	26.57	19	0.85	plastic state

(Note: LI<0 is semi-solid or solid state, LI=0 is very stiff state, LI=1 is very soft state, 0<LI<1 is plastic state and LI>1 is liquid state.)

Values of liquid limit and plastic limits of pit samples were determined as described in chapter four and their values are given in table 5.3.

As indicated in table 5.3, results obtained from laboratory tests consists both plastic and none plastic soil. Lower plastic index dictates some amount silt content and predominance of sand. None plastic result show supremacy of sand soil since sandy soils change from the liquid state to the semi-solid relatively abruptly. Sandy soils are Cohesion-less and they have no plasticity phase as stated in chapter two.

Liquidity index was calculated for all the samples and tabulated in table 5.3. It indicates the subgrade condition on the site as given in the same table. From this the subgrade soils from pit 14 to 17 are under plastic state. Also PI greater than 20% is bad for subgrade material for pavement design as ERA site investigation and pavement design manual 2013.

5.1.5 Soil Classification; (AASTH M145)

Soils in this research are classified according to AASHTO classification system and are also evaluated by group index whether they are suitable for subgrade for highway construction.

As emphasized; soil classification system depended on classification test conducted for grain size analysis and Atterber’s limit test. With having these test results obtained from laboratory; subgrade soils from the study area were classified here below according to AASHTO soil classifications system.

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Soils are grouped under both granular materials (35% or less passed on 0.075mm sieve) and silty-clay materials (> 35% passed by 0.075mm) general class. These general classified soil classes are divided in to sub-classification subgroups as A-1 to A-7 and corresponding soil descriptions are also given in Table 5.4.

Table 5.4: AASHTO Soil Classification System

Pits	Sieve analysis % ge of pass			Atterbeg's Limit			Soil classification	
	2mm	0.425mm	0.075mm	LL %	PL %	PI %	AASHTO M145	AASHTO Descriptions
1	44.59	31.18	25.34	31.98	23.91	8	A-2-4(0)	Silty gravel with Sand
2	64.63	44.85	31.28	35.64	24.12	12	A-2-6(0)	Silty/clay gravel With Sand
3	31.69	16.72	14.36	23.54	20.71	3	A-2-4 (0)	Silty Gravel With Sand
4	54.02	35.82	17.59	25.58	-	NP	A-3 (0)	Fine Sand
5	95.03	80.81	62.89	49.71	35.63	14	A-7-5 (9)	Clay Soil
6	97.35	91.83	73.23	71.95	37.1	35	A-7-5 (31)	Highly Plastic Clay
7	56.27	46.27	26.37	28.52	22.75	5	A-2-4 (0)	Low Plastic Silt
8	27.45	12.15	4.66	-	-	NP	A-1-a (0)	Gravel-Sand Mixtures
9	81.29	64.23	46.45	46.5	36.58	10	A-5 (3)	Low Plastic Silt
10	85.97	68.19	51.96	49.87	36.66	13	A-7-5 (5)	Highly Plastic Silt
11	44.67	21.72	16.62	21.29	NP	NP	A-3 (0)	Fine Sand
12	97.16	82.29	63.83	35.89	30.13	6	A-4 (3)	Low Plastic Silt
13	80.13	63.11	53.09	43.17	32.97	10	A-5 (4)	Low Plastic Silt
14	90.07	79.18	65.39	37.61	28.41	9	A-4 (5)	Low Plastic Silt
15	93.21	74.01	54.1	46.16	33.31	13	A-7-5 (6)	Clay Soil
16	97.72	91.04	76.96	87.31	58.77	29	A-7-5 (30)	Clay Soil
17	96.12	86.28	71.96	45.77	26.57	19	A-7-5 (14)	Low Plastic Clay

Classification is further observed using AASHTO M 145 plasticity chart; which is developed by plotting plastic index (%) verses liquid limit result (%) as shown in figure 5.2. this figure is needed for only subgrade soil classes under sub-grouped of A-4, A-5, A-6 and A-7; since it considered only silty-clay main soil group.

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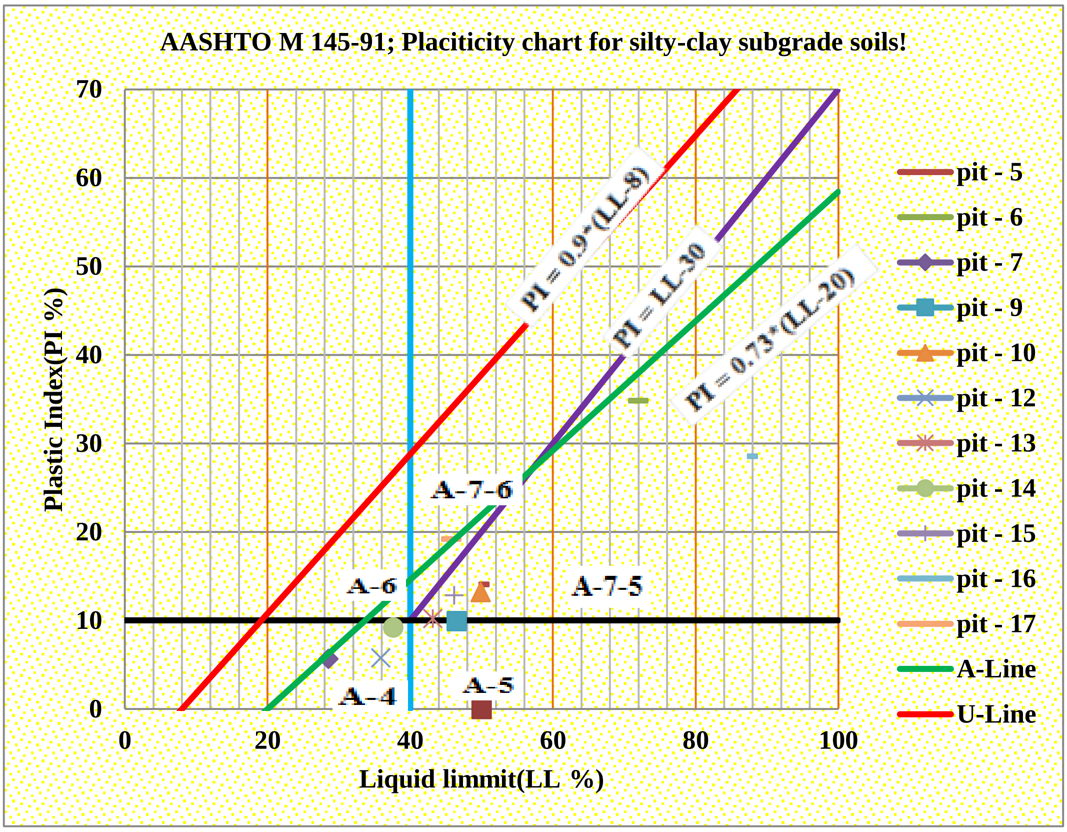

Figure 5.2: AASHTO M 145 plasticity chart of soil classification

As table 5.4 and figure 5.2 presented; subgrade soils along Arbaminch-Chencha existing road are classified in general group of granular materials (A-1,A-2, A-3) and silty-clay materials (A-4, A-5 and A-7) with their corresponding sub-group as A-1-a, A-3, A-2-4, A-2-6, A-3 and A-4, A-5, A-7-5 respectively.

AASHTO soil class grouped under A-1 (Pit-8) was the best whereas grouped under A-7(pits-5, 6, 15, 16 and 17) were the worst for subgrade material for road construction. Off course, problems were observed there in the field also during site survey and sample collection for these pit locations. But, in actual condition of this road it was not as such worst; since the road is under use with proper maintenances provided.

From overall, it is revealed that soils in Arbaminch-Chencha existing road is dominated by fine grained soil classes. This is 59% fine grained (10 from 17 pits) whereas 41% is coarse grained soils (7 from 17 pits).

5.1.5.1 Evaluating subgrade soil by using group index (GI)

Table 5.5: Evaluating Subgrade Soil According To Group Index

PIT No.	Chainage (Stations)	GI	Soil Class			
			AASHTO-145		As per ERA(2013) specification	
			Group	Rating as a subgrade	subgrade categories	Suitability as Subgrade by GI
1	9+160	0	A-2-4(0)	Excellent to Good	Good - Very Good	Good
2	10+200	0	A-2-6(0)	Excellent to Good	Good - Very Good	Good
3	11+100	0	A-2-4 (0)	Excellent to Good	Good - Very Good	Good
4	12+000	0	A-3 (0)	Excellent to Good	Good - Very Good	Good
5	13+060	9	A-7-5 (9)	pair to poor	Bad - Medium	Bad
6	14+320	31	A-7-5 (31)	pair to poor	Bad - Medium	Bad
7	15+380	0	A-2-4 (0)	Excellent to Good	Good - Very Good	Good
8	16+500	0	A-1-a (0)	Excellent to Good	Good - Very Good	Good
9	17+660	3	A-5 (3)	pair to poor	Bad - Medium	Medium
10	19+900	5	A-7-5 (5)	pair to poor	Bad - Medium	Bad
11	21+000	0	A-3 (0)	Excellent to Good	Good-Very Good	Good
12	22+040	3	A-4 (3)	pair to poor	Bad - Medium	Medium
13	23+300	4	A-5 (4)	pair to poor	Bad - Medium	Medium
14	24+220	5	A-4 (5)	pair to poor	Bad - Medium	Bad
15	25+400	6	A-7-5 (6)	pair to poor	Bad - Medium	Bad
16	26+420	30	A-7-5 (30)	pair to poor	Bad - Medium	Bad
17	27+200	14	A-7-5 (14)	pair to poor	Bad - Medium	Bad

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Soils are evaluated by their group index properties to indicate the suitability of subgrade for road construction. Group index was calculated as granular soils with zero group indexes and fine soils of different group index values are tabulated in table 5.6. Zero group index results indicate soils of the study area with good quality material be used for sub-grade.
AASHTO and ERA standards separated soils for the suitability for subgrade according to its soil rating criteria. Depending on soil group and group index results determined; soil in Arbaminch-Chencha road 41% excellent to good and 59% pair to poor rating as subgrade material as per AASHTO standard whereas 41% good and 18% medium and 41% bad as per ERA suitability of soil as subgrade.
Hence, Subgrade materials classified as A-2-6, A-4, A-5 and A-7-5 will require a layer of subbase material if used as subgrade. Whereas Soils classified as A-1-a, A-2-4, and A-3 can be used satisfactorily as subgrade or subbase material.

5.1.6 Moisture-density relationship
Natural subgrade compaction is common and purposeful to have compaction characteristics of it. It is required to densify the existing subgrade materials for overlaying pavement structures. Results of moisture density relationship were also used to in the preparation of CBR test specimens.
From this test, the required parameters are maximum dry density (MDD g/cc) and optimum moisture content (OMC %) which were determined from different densities achieved by different moisture contents. With having different densities and moisture contents density- moisture curve was plotted as curve plotted for pit-16 as shown in figure 5.3 and MDD and OMC were obtained as follow.

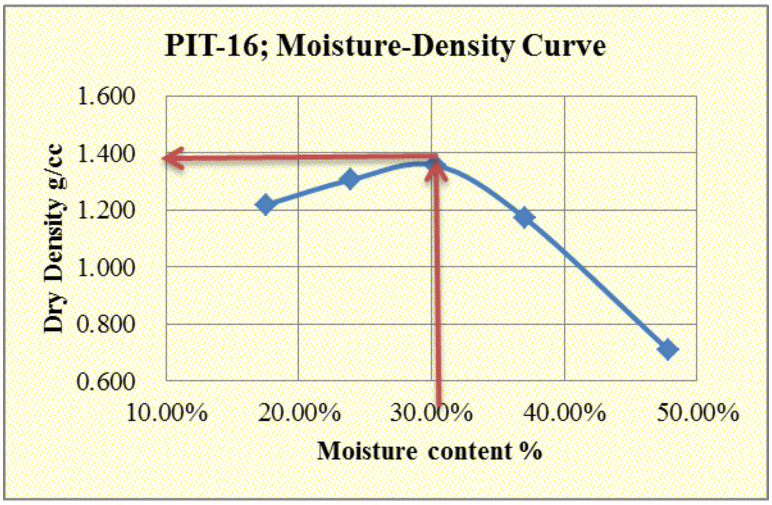

Figure 5.3: Typical Modified proctor compaction test curve

Therefore, by the same way moisture density relationship results were determined and summarized here in table 5.6.

Table 5.6: Summary for Laboratory Moisture- Density Relationship

S.No.	PITS	Chain age (Stations)	AASHTO T180		AASHTO M-145
			OMC%	MDD g/cc	
1	1	9+160	11.09	1.95	A-2-4(0)
2	2	10+200	12.86	1.92	A-2-6(0)
3	3	11+100	12.16	2.02	A-2-4 (0)
4	5	13+060	21.64	1.61	A-7-5 (9)
5	6	14+320	24.44	1.58	A-7-5 (31)
6	8	16+500	9.47	2.11	A-1-a (0)
7	11	21+000	23.81	1.70	A-3 (0)
8	12	22+040	16.82	1.90	A-4 (3)
9	14	24+220	15.66	1.67	A-4 (5)
10	16	26+420	30.31	1.36	A-7-5 (30)

The results obtained for maximum dry density ranges from 1.36 to 2.11 g/cc for optimum moisture content 9.47 to 30.31%. This indicates that the lower values of density are the result of more clay soil with having low bearing capacity whereas the higher values of density are for granular soil materials; which are suitable for subgrade material to withstand traffic loading. The reverse is true for OMC.

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5.1.7 California Bearing Ratio and Swell

As per table 4.2, analyzed results of CBR and percentage of swelling under OMC and MDD for ten pit samples are presented here according to given specifications. Since, it is recommended that subgrade CBR values are required for construction specifications according to AASHTO and ERA design manuals. Hence, subgrade of highways to be compacted in the field at 93%, 95% and 97% of MDD heavy compaction value obtained in the laboratory to achieve the corresponding CBR values.

To achieve these specifications; CBR observations were already recorded for three different energy level (10, 30 and 65 blows per layer). Analysis of CBR values for above specifications was performed. Here pit-1 was used to show the way of finding CBR results for all specified pit samples in table 5.7 and in figure 5.4 and 5.5.

Table 5.5 describes the CBR values determined at 10 blows per layer only. Nothing is new that; the same way of calculation was done for 30 and 65 blows per layer.

Table 5.7: Typical CBR Analysis under 10 blows/layer

pit - 1	pen/n piston area(mm2)	1935	Penetration Rate (mm/Min)	Standard Load	2.54 mm pen	5.08 mm pen
	Ring Factor N/div	21.98	1.27		6.9 Mpa	10.3 Mpa
	Blows/layer	10			13.2kN	20.0kN
Pen/n (mm)	Gauge reading	Load (N)= Reading*Ring Factor	Stress N/mm2 = Load(N)/piston Area	*Corrected Load kN	Standard Load (kN)	CBR %
0	0	0.00	0.00			
0.64	15	325.35	0.17			
1.27	37	802.53	0.41			
1.91	66	1431.54	0.74			
2.54	82	1778.58	0.92	1.85	13.20	14.02
3.18	91	1973.79	1.02			
3.81	101	2190.69	1.13			
4.45	108	2342.52	1.21			
5.08	115	2494.35	1.29	2.55	20.00	12.75
7.62	126	2732.94	1.41			

*Corrected load is determined from corrected load-penetration curve.

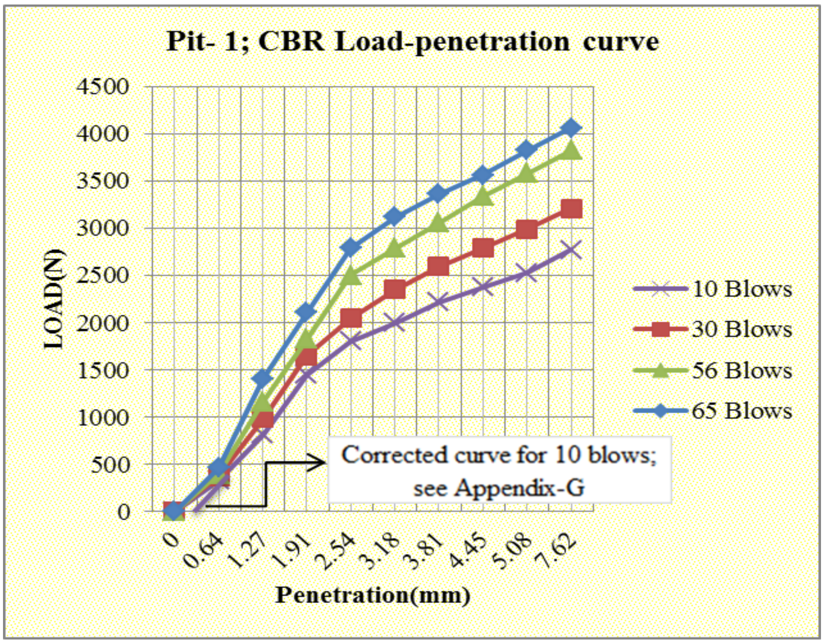
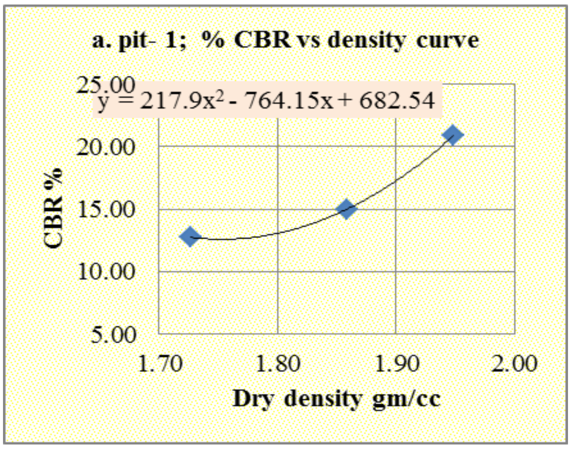


Figure 5.4: CBR Laboratory test Load-penetration curve

Now, to obtain CBR values at specification of 93%, 95% and 97% MDD; figure 5.5 are plotted (a) for CBR to dry density and (b) for percentage of swelling to dry density. These curves are very important to have desired specification by moving on curves as per AASHTO and ERA standards. CBR and swell values were determined by using equation found in corresponding curves; y-values as CBR or swell values whereas x-values for dry density.

By the similar way overall CBR and swelling results for 10 pit samples were presented in table 5.9 with including corrected load-penetration curves.



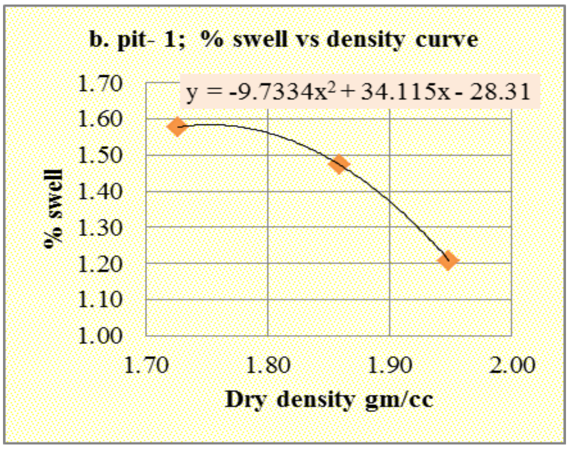


Figure 5.5: CBR and %ge of Swelling vs Dry density curve for required specification

CBR value for 56 blows per layer was determined here; which was used directly without any analysis in section 5.2 to evaluate the effect of moisture content on CBR. The another purpose of this value here is; to estimate it with respect to other 10, 30 and 65 blows per layer in which it lays. As figure 5.4; CBR value for 56 blows per layer is located below 65 and above 10, 30 blows per layer.

Table 5.9: CBR specification summary for CBR laboratory test results

pit	Chanaige(station)	specification	93 % of MDD g/cc	95 % of MDD g/cc	56 Blows/layer	97 % of MDD g/cc
1	9+160	Specified DD g/cc	1.82	1.86	1.92	1.90
		CBR at Specified DD (%)	13.57	15.03	18.56	17.13
		Swell at Specified DD (%)	1.54	1.48	1.39	1.38
2	10+200	Specified DD g/cc	1.79	1.82	1.86	1.86
		CBR at Specified DD (%)	17.13	18.01	18.52	18.52
		Swell at Specified DD (%)	1.41	1.33	1.27	1.27
3	11+100	Specified DD g/cc	1.88	1.92	1.96	1.96
		CBR at Specified DD (%)	33.82	37.16	41.58	41.58
		Swell at Specified DD (%)	0.46	0.42	0.37	0.37
5	13+060	Specified DD g/cc	1.50	1.53	1.56	1.56
		CBR at Specified DD (%)	4.74	5.53	6.75	6.63
		Swell at Specified DD (%)	2.96	2.83	2.63	2.59
6	14+320	Specified DD g/cc	1.47	1.50	1.54	1.54
		CBR at Specified DD (%)	4.51	5.11	5.69	5.69
		Swell at Specified DD (%)	6.03	5.39	4.83	4.83
8	16+500	Specified DD g/cc	1.97	2.01	2.05	2.05
		CBR at Specified DD (%)	44.35	46.70	49.72	49.22
		Swell at Specified DD (%)	0.33	0.31	0.31	0.30
11	21+000	Specified DD g/cc	1.58	1.61	1.64	1.64
		CBR at Specified DD (%)	11.40	12.61	13.95	13.95
		Swell at Specified DD (%)	0.95	0.60	0.19	0.19
12	22+040	Specified DD g/cc	1.76	1.80	1.84	1.84
		CBR at Specified DD (%)	16.10	17.37	18.83	18.83
		Swell at Specified DD (%)	1.01	0.89	0.77	0.77
14	24+220	Specified DD g/cc	1.56	1.59	1.62	1.62
		CBR at Specified DD (%)	9.57	10.48	10.54	11.35
		Swell at Specified DD (%)	1.69	1.59	1.42	1.51
16	26+420	Specified DD g/cc	1.26	1.29	1.32	1.32
		CBR at Specified DD (%)	3.39	3.86	4.40	4.40
		Swell at Specified DD (%)	4.18	3.84	3.49	3.49

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So that, CBR value of the subgrade on the Arbaminc-Chencha road ranges 3.39% to 44.35%, 3.86% to 46.70% and 4.40% to 49.22% per specification of 93%, 95% and 97% MDD respectively. The maximum swell result observed are 6.03%, 5.39% and 4.83%; and 4.18%, 3.84% and 3.49% for pit 6 and 16 under specification of 93%, 95% and 97% MDD respectively. These shows the CBR values are considerably reduced near Chencha town.

Hence, the soil has high swell value and cannot be used as subgrade soil or requires some kind of treatment and or replacement by good materials Whereas the minimum is 0.3% for pit 8 under specification of 97% MDD which is the very suitable for subgrade. Generally, subgrade soil in present research area was of CBR values various from 3.39% (unsuitable) to 49.22% (Suitable) with the average CBR value of 17%(suitable for highway subgrade construction).

5.2 Effect of Moisture on CBR Values of subgrade

5.2.1 Effect of Moisture on CBR Values by varying moisture

This section was observed in section 4.2; for selected three different soil classes. So that soil classes used for the effect of moisture content are tabulated here in table 5.10 with their soil group and CBR already determined in table 5.9.

Table 5.10: Soil Classes used for Effect of Moisture on CBR

Selected soil Class	AASHTO M145	%CBR at OMC; 56 blows/layer, 4days soaked	Descriptions
Pit - 1	A-2-4(0)	18.56	Silty gravel with sand mixture
Pit - 14	A-4(5)	10.54	Silty soil
Pit - 5	A-7-5(9)	6.75	Clay soil

For these three soil classes; CBR values were determined for four CBR specimens from each soil classes. These CBR specimens; two from dry side and other two from wet side as described in chapter four.

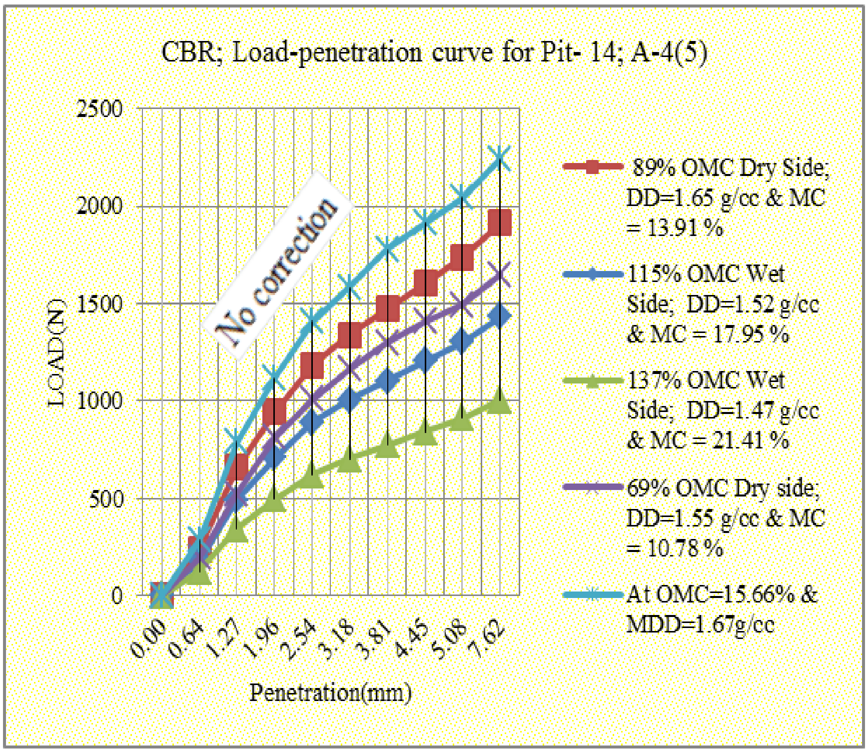

Figure 5.6: Penetration-Load curve for typical soil class

Here is load-penetration curve plotted in figure 5.6 for soil class A-4(5) and results of all three soil classes are summarized in table 5.11 to present the effect of moisture content. Figure 5.6 describes its effect by graphically of CBR values for different moisture contents other than OMC.

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Table 5.11: Summary of Effect of moisture on CBR by drying and wetting

Direction	Descriptions		Pit – 1(A-2-4(0))		Pit – 5(A-7-5(30))		Pit – 14 (A-4(5))	
Dry Side	Water amount		97% OMC Dry Side;	54% OMC Dry Side	87% OMC Dry Side;	69% OMC Dry Side;	89% OMC Dry Side;	69% OMC Dry side;
	Moisture content%		8.77	5.95	18.92	14.94	13.91	10.78
	% CBR	2.54	18.11	15.64	6.09	5.24	8.89	7.57
Effect by drying	wrt OMC &MDD %CBR		96.49	83.33	90.24	77.61	84.38	71.88
	% CBR Reduced		3.51	16.67	9.76	22.39	15.62	28.12
MDD & OMC	Moisture content%		11.08		21.64		20.08	
	Density g/cc		1.95		1.61		1.67	
	% CBR by 56 blows	2.54pen/n	18.56		6.75		10.54	
Wet Side	Water amount		116% OMC wet side ;	145% OMC wet side	105% OMC Wet side;	126% OMC Wet side;	115% OMC Wet Side;	137% OMC Wet Side;
	Moisture content%		12.82	16.2	22.65	27.22	17.95	21.41
	% CBR	2.54	14.16	9.71	4.77	2.76	6.67	4.67
Effect by drying	wrt OMC &MDD %CBR		75.44	51.75	70.66	40.90	63.28	44.30
	% CBR Reduced		24.56	48.25	29.34	59.10	36.72	55.70

Table 5.11 presents the effect of moisture content on CBR values of both dry and wet sides of three subgrade soil classes. In which CBR values obtained here were compared with respect to CBR values (at middle three columns in table 5.11; which were directly used from table 5.9 for 56 blows per layer for corresponding soil classes).

The effect was revealed in figure 5.6 and table 5.11, wet side has the highly reduced the CBR values of soils. Even though, approximately the same amount of water added and/or reduced from OMC. To see here; for soil class A-2-4(0): 46% (100%-54%) OMC reduced to have CBR value of 15.64% and 45% (145%-100%) OMC added to have CBR value of 9.71% for dry and wet side of OMC respectively. From this; CBR value at wet side was 62% of dry side. Which means it is 38% less than dry side CBR value. The same is true for other two soil classes A-7-5(30) and A-4(5) as emphasized in table 5.11.

To summarize from table 5.12 for three soil classes; table 5.12 created here only for percent CBR reduced due to variation of moisture content for both dry and wet side of OMC with respect to (wrt) CBR at OMC.

Table 5.12: Effect of Moisture reduction of CBR from OMC &MDD

Directions	**Pit – 1(A-2-4(0); Silty Gravel with Sand)**	**% CBR Reduced wrt CBR at OMC**
Dry Side	54% OMC Dry Side; DD=1.80 g/cc & MC =5.95 %	16.67
	97% OMC Dry Side; DD=1.87 g/cc & MC = 8.77 %	3.51
Wet Side	116% OMC wet side ; DD=1.76 g/cc & MC = 12.82%	24.56
	145% OMC wet side ; DD=1.68 g/cc & MC = 16.12 %	48.25
	Pit - 5 (A-7-(30)5; Clay Soil)	
Dry Side	69% OMC Dry Side; DD=1.47 g/cc & MC = 14.94 %	22.39
	87% OMC Dry Side; DD=1.55 g/cc & MC = 18.92%	9.76
Wet Side	105% OMC Wet side; DD=1.49 g/cc & MC = 22.65%	29.34
	126% OMC Wet side; DD=1.35 g/cc & MC = 27.22%	59.10
	Pit – 14 (A-4(5); Silty Soil type)	
Dry Side	69% OMC Dry side; DD=1.55 g/cc & MC = 10.78 %	28.13
	89% OMC Dry Side; DD=1.65 g/cc & MC = 13.91 %	15.63
Wet Side	115% OMC Wet Side; DD=1.52 g/cc & MC = 17.95 %	36.72
	137% OMC Wet Side; DD=1.47 g/cc & MC = 21.41 %	55.70

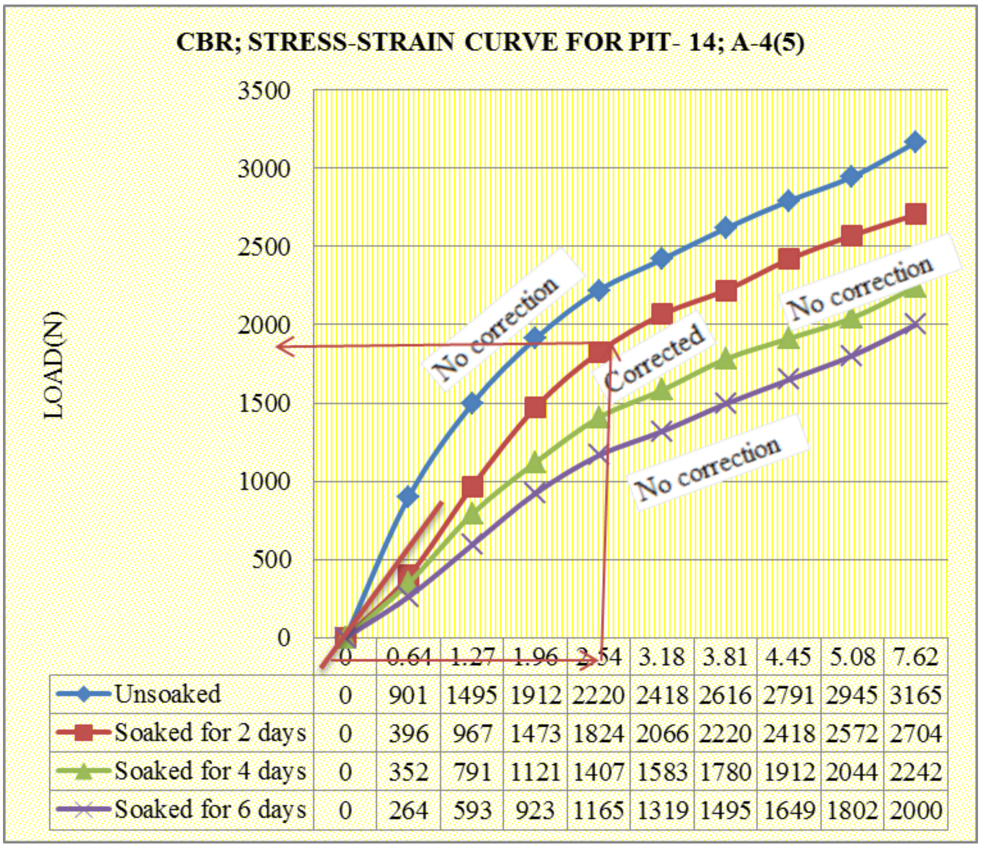
As results and effect of moisture content presented, wet side has highly reduced CBR values than dry side and various in degree with in different soil classes. Finer soils have highly reduced than coarser soils.

Generally, at dry side of OMC; CBR reduced by 16.67% whereas at wet side reduced by 48.25% for A-2-4 soil class by reduced and added moisture content of 54% and 145% of OMC respectively. By the same way CBR reduced by 22.39% and 59.1% of dry and wet side of A-7-5 soil class by reduced and added moisture content of 69% and 126% of OMC; and 28.13% and 55.70% dry and wet side of OMC for A-4 soil class by added and reduced moisture by 69% and 137% of OMC respectively.

When wet side CBR is compared with dry side values; wet side reduced 31.58%, 36.71% and 27.57% more than dry side for A-2-4(0), A-7-5(30) and A-4(5) soil classes respectively.

5.2.2 Effect Moisture on CBR by Varying Saturation Period

This is the second way in which the effect of moisture content on CBR values by period of saturation. For that results analyzed and summarized from laboratory data as per section 4.2. To discuss the way of analysis and evaluation, CBR values under different degree of saturation period {unsoaked, for 2 days(48 hours), 4 days(96 hours) and 6 days(144 hours) for soil class A-4(5) were plotted below.



	0	0.64	1.27	1.96	2.54	3.18	3.81	4.45	5.08	7.62
Unsoaked	0	901	1495	1912	2220	2418	2616	2791	2945	3165
Soaked for 2 days	0	396	967	1473	1824	2066	2220	2418	2572	2704
Soaked for 4 days	0	352	791	1121	1407	1583	1780	1912	2044	2242
Soaked for 6 days	0	264	593	923	1165	1319	1495	1649	1802	2000

Figure 5.7: Typical Load-penetration curve for effect of saturation on CBR

96 hours soaked CBR results are simply taken from section 5.1.7 at 56 blows per layer; this is why it was included there in section 5.1.7. Hence, it was already determined; no need of test conducted for this saturation period CBR value here again.

The effect of moisture on subgrade CBR values in this section was presented in figure 5.8. The variation of (a) CBR with saturation period and (b) CBR with moisture was observed from chart drawn here in figure 5.8. And combined chart was present in figure 5.9.

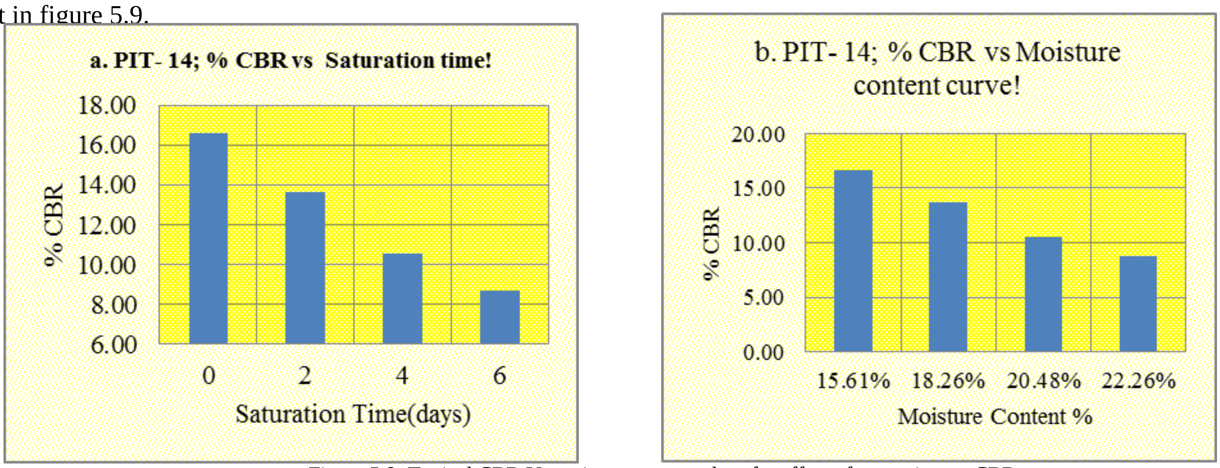


Figure 5.8: Typical CBR Vs moisture content chart for effect of saturation on CBR

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By the same manner the effect was observed for all three soil classes in appendix-I and summarized here in table 5.13.

Table 5.13: Effect of moisture content on CBR by saturation summary

pits	AASHTO T 180	Saturation Period(days)	Moisture content %	% Swelling	CBR 2.54mm penetration
1 (A-2-4(0); Silty gravel sand mixture)	MDD g/cc	0	11.31	0	26.83
	1.95	2	14.42	1.21	21.9
	OMC%	4	16.05	1.39	18.77
	11.8	6	16.97	1.46	17.45
5 (A-7-5(9); Clay Soil)	MDD g/cc	0	21.07	0	10.87
	1.61	2	22.78	2.2	8.4
	OMC%	4	25.1	2.63	6.75
	21.64	6	26.79	2.84	5.43
14 (A-4(5); Silty soil)	MDD g/cc	0	15.61	0	16.63
	1.67	2	18.26	1.23	13.66
	OMC%	4	20.48	1.42	10.54
	15.66	6	22.26	1.51	8.73

As effect observed; reduction of CBR varies with saturation period for all different soil classes. But the reduction is different in different soil class. Thus, for finer soils (A-7-5(30)) saturation water increases linearly whereas for coarser soils (A-2-4(0)) saturation water increases highly at initial stage up to saturation time 2 days and gradually decreases as emphasized in figure 5.9.

Table 5.14 presents the variation of CBR due to saturation period as discussed above and shows CBR values respect to 4 days soaked CBR (which is taken from table 5.9 for 56 blows).

Table 5.14: Summary sheet of Effect of moisture content on CBR

pits	AASHTO T 180	%CBR				Effect with respect to 4day soaked CBR(%)
		Saturation Period(days)	Moisture content %	% Swelling	2.54mm pen/n	
1(A-2-4(0);Silty grave with sand mixture)	MDD g/cc	0*	11.31	0	26.83	142.98
	1.95	2	14.42	1.21	21.9	116.67
	OMC%	4	16.05	1.39	18.56	100
	11.8	6	16.97	1.46	17.45	92.98
5(A-7-5(9); Clay soil)	MDD g/cc	0	21.07	0	10.87	160.98
	1.61	2	22.78	2.2	8.4	124.39
	OMC%	4	25.1	2.63	6.75	100
	21.64	6	26.79	2.84	5.43	80.49
14(A-4(5); Silty Soil)	MDD g/cc	0	15.61	0	16.63	157.81
	1.67	2	18.26	1.23	13.66	129.69
	OMC%	4	20.48	1.42	10.54	100
	15.66	6	22.26	1.51	8.73	82.81

*Note: Zero saturation period means CBR test conducted without soaking.

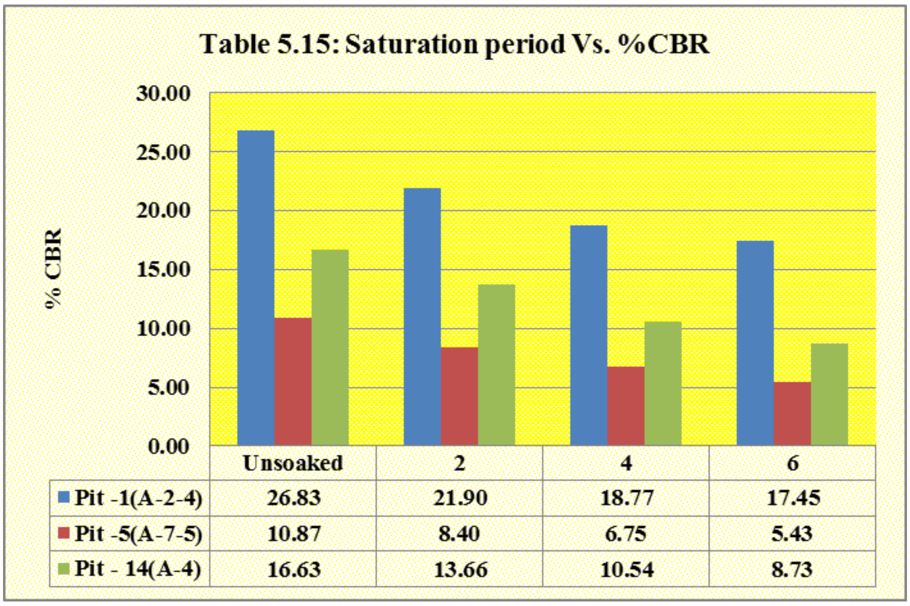

Figure 5.9: Effect of Saturation on CBR; % CBR vs Saturation period chart

Saturation has continuous adverse effect on subgrade strength (CBR) for both coarse grained and fine grained soil classes. Here, results showed that the reduction of CBR varies with saturation period for different soil classes. For example: A-2-4 soil class has 82%, 70%, 65% for 2, 4 and 6 days saturated CBR values with respect to unsoaked CBR value. Whereas A-7-5 soil class has 77%, 62% and 50% with respect to unsoaked CBR value and 82%, 63% and 53% with respect to unsoaked CBR for soil class of A-4.

From this, coarser soil classes (A-2-4 and A-4) reduced more just before 48hours saturation and decreases slightly after 96hours whereas finer soil classes (A-7-5) reduced CBR gradually up to 144hours and continuous somewhat more degree than above soil classes. But, the effect is more in fine grained soils than coarse grained soils. Hence, unsoaked CBR values of soil classes vary from 43% (coarser soil class) to 61% (for finer soils) higher than 4 days soaked values.

Here in figure 5.10; the effect of moisture content by saturation period was nicely described for 2 to 4 and 4 to 6 days.

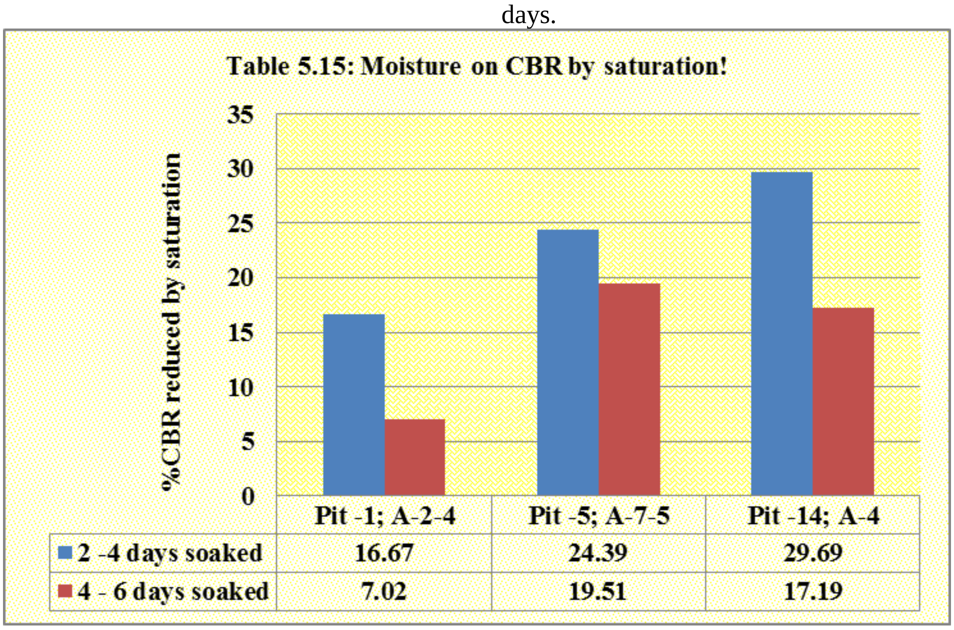

Figure 5.10: Effect of Saturation on CBR; % CBR vs Saturation period chart

The effect of Saturation after 4th day in coarser soil classes (like Pit 1; A-2-4) was less reduced when compared with the effect on finer subgrade soil classes (Pit 5; A-7-5). So that, Saturation after 96 hours to 144 hours has reduced CBR of 7.02 %(Pit – 1; A-2-4) to 19.51 %(Pit -5; A-7-5)

6. CONCLUSION

IN GENERAL, SUBGRADE SOIL ALONG ARBAMINCH-CHENCHA EXISTING ROAD HAS DIFFERENT SOIL CLASSES, ENGINEERING CHARACTERISTICS AND CBR VALUES; AND ALSO MOISTURE EFFECT. SO THAT, BASED ON THE LABORATORY INVESTIGATION RESULTS ON THIS SUBGRADE SOIL, THE FOLLOWING CONCLUSIONS CAN BE DRAWN:

1) The in-situ moisture content of this subgrade ranges from 10 to 44% whereas the specific gravity is ranges from 2.62 to 2.75.
2) Subgrade soil classified by AASHTO M145 classification system as: A-1-a, A-2-4, A-2-5, A-2-6, A-3, A-4, A-5, A-7-5, and which was dominated by fine grained soil class.
3) From Moisture-density relationship, optimum moisture content(OMC%) ranges from 10% to 30% whereas maximum dry density (MDD g/cc) ranges from 1.36 to 2.11 g/cc. for general concept dry density decreases when the road comes to Chencha from Arbaminch.
4) Some of the pits in the road are good for both subgrade and subbase material for road construction purpose. For example, pit 3 and 8 having PI of 3% and NP, 95% MDD CBR value of 37% and 47 % respectively. Hence, these subgrade materials are good for construction of sub base.
5) Effect of moisture content on CBR was different for different soil classes before and after OMC. As observed, CBR value reduced 4% to 28% at dry side whereas 25% to 59 % at wet side of OMC and MDD of specified soil classes. This indicates that, wet side reduced CBR values 21% to 31% more than dry side.
6) Saturation after 48 to 96 hours, CBR reduced from 17% to 30% whereas 96 to 144hours reduced 7% to 20%. But, more reduction observed in finer soil classes. Therefore, saturation beyond conventional soaking period is significant in the areas in which there is high precipitation; low evaporation and shallow ground water is expected

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