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Assessing the Performance of Subgrade and Unbounded Pavement Materials and Their Effect on Pavement Distress of Alaba-Sodo Exisiting Road; Ethiopia

[1]Defaru Katise, [2]Nazrawit Aklilu, [3]Dr. Ramesh Kumar Verma
[1]Lecture, [2]Investigator and [3]Profesor in Geotechnical Engineering
Civil Engineering Faculty; Arba Minch Institute of Technology

Abstract **:- Since material properties play a significant role to determine the performance of pavement layers. In Ethiopia, now a day, pavement distress is the main problem of roads affecting its intended purposes. This research study is undertaken at Alaba-Sodo road, which is located in SNNPRS, is one of the roads affected by distresses. The main objective of this study is to assess the performance of subgrade and unbound pavement materials and their effect on pavement distress through condition survey and laboratory tests.**

Among the total sample units of 199 along the selected road sections, 71 sample units were selected by using systematic random sampling technique. For those selected sample units PCI values were determined in order to know the stations for sample collection for laboratory tests. Based on the PCI values, eight sample locations were identified out of these six locations were selected from severely distressed and two locations were selected from good sections. From eight identified sample locations three samples were taken from each layers of sub-grade, sub-base and base course. Therefore, total of 24 material samples were taken for the laboratory tests. The major tests such as CBR test, Compaction Test, Atterberg limit test, Sieve Analysis were conducted for the above mentioned three layers and ACV, AIV, LAA and Flakiness Index were conducted only for base course material to check performance of the pavement materials.

Out of the surveyed 71 sample units, 1.41% is excellent, 5.63 is very good, 14.08% is good, 23.94% is fair, 28.17% is poor, 21.13% is very poor and 5.63 is failed. The overall laboratory test result shows that the distresses that are frequently observed on the road surface were significantly influenced by subbase and base course materials.

Key words: Performance of subgrade and Unbounded materials, AASHTO and ERA standards, Geotechnical properties, Pavement condition index, Pavement distress

1. INTRODUCTION ON BACKGROUND

Subgrade and granular material layers must be investigated and constructed properly thoroughly in order to achieve the overall desire of pavement performance. In Ethiopia, now a day, pavement distress is the main problem of roads affecting its intended purposes. And it is mostly characterized by failure of all kinds; like surface deformation, cracks, disintegration, surface defects etc. There is no just one reason for each type of failure. Factors affecting the pavement performance are climate, material properties, structure and traffic load (ERA, PRAOM, 2013).

The research area; Alaba- Sodo road is the main part of Addis Alaba- Sodo-Abaminch road and which is flexible asphalt paved road. This study only focuses on Alaba-Sodo 68 km long and one of the reconstructed roads in Ethiopia which is located in the SNNPRS Ethiopia and its operation was started in 2010. It is a two lane-paved 7m wide carriageway with 1.5m gravel shoulders on each side.

2. STATEMENT OF THE PROBLEM

The maintenance of the road to well accessible asphalt standard is considered to have a crucial role in road performance. But currently the Alaba–Sodo road pavement is prematurely damaged by serious distress with alligator/fatigue cracks, rutting, potholes, block cracking and others cracks and disintegration that can cause traffic hazards, taking long time for travel, affecting economic and industrial growth of nearby zones and cities like Wolaita, Kambata, Hadiya, Shashemene and Hawassa. The accessibility, users comfort and national/ social development of the above mentioned zones and cities and increasing vehicle operating cost are directly and indirectly affected by road distress.

Therefore, this research has been done in order to assess the performance of subgrade and unbound pavement material quality and to relate the material quality with the pavement distresses. Because the characteristics of sub-grade, sub-base and base course layer material properties have a considerable impact on the performance of the pavement.

3. OBJECTIVES

3.1 General objective

The general objective of this research was to assess the performance of sub-grade and unbound pavement materials and their effect on pavement distress.

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3.2 Specific objectives

- To determine the types, severity and density of the pavement distress based on pavement condition index (PCI).
- To assess the performance of sub-grade and unbound pavement materials by conducting laboratory tests like Atterberg limit, sieve analysis, compaction test, CBR, AIV, ACV, LAA and Flakiness Index.
- To indicate the effect of performance of subgrade and unbound pavement layers on pavement distress for possible pavement maintenances

4. LOCATION OF THE STUDY AREA

This study is conducted in Alaba- Sodo existing road which is located in southwestern part of Ethiopia. It connects Addis Ababa, the capital of Ethiopia with some SNNPRS towns. The distance between Alaba to Sodo is generally 72 km but the exact study location starts at the Bilate River Bridge which is 4.5km away from Alaba town and terminates in Sodo Town. Therefore the total length of the route is 68km. The geographic positions of the total road falls between 7° 18' N latitude to 38° 05' E longitude and 6° 02' N latitude 37° 33' E longitude. The location map of the study road is shown below (Associated Engineering Consultants, 2006).

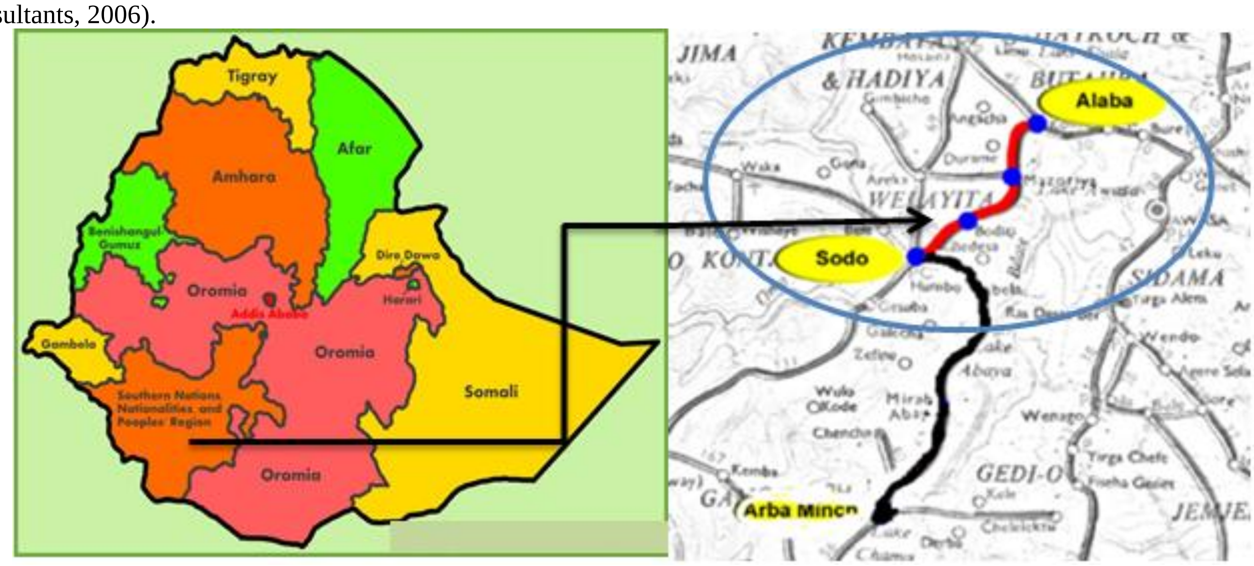

Figure1: The Alaba – Sodo road stretch

5. RESEARCH METHODOLOGY

5.1 Sample size and Sampling Technique for PCI

For this research objective, the study road stretch was divided into sections based on preliminary site visit. Each section was divided into sample units. The type and severity of pavement distress was differentiated visually and then the quantity of the distress was measured. The distress data were used to calculate the PCI for each sample unit. The PCI of the road sections were determined based on the PCI of the inspected sample units within the sections. Therefore, road was sectioned in to five different sections as shown in Table 1. Among the five sections, the three sections (Alaba-Adilo, Shone-Buge and Buge-Boditi) were selected and the number of these divided sample units as shown in Table 2 with 200m length according to ASTM D6433 Manual.

Table 1: Road sections selected for detail survey

No. of section	Station (km)	Start town/village	End town/village (length)	Pavement condition survey
1	0+000–15+000	Alaba	Adilo=15km	Selected for survey
2	15+000– 26+100	Adilo	Shone=11.1km	Selected for survey
3	26+100– 33+400	Shone	Buge=7.3km	Selected for survey
4	33+400– 50+800	Buge	Boditi =17.4km	Relatively good condition
5	50+800– 68+000	Boditi	Sodo =17.2km	Relatively good condition

Table 2: The number of sample units in each divided sections

No. of section	Station (km)	Start-End (length)	Total number of sample units	Remark
1	0+000–15+000	Alaba-Adilo =15km	15,000/200 =75	surveyed
2	15+000– 26+100	Adilo-Shone =11.1km	11,100/200 =55.5	Not selected for survey
3	26+100– 33+400	Shone-Buge =7.3km	7,300/200 =36.5	surveyed
4	33+400– 50+800	Buge- Boditi=17.4km	17,400/200 =87	surveyed
5	50+800– 68+000	Boditi-Sodo=17.2km	17,200/200= 86	Not selected for survey

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From table 2, some sections were needed to survey due to problems observed during site visit which stated in remark column. Therefore, the next steps such as the determination of PCI value for each sample unit and average PCI value for each section were continued after determinations of sample units of each section.

5.2 Pavement Condition Survey Procedures

The PCI provides an objective and rational basis for determining maintenance and repair needs and priorities. Continuous monitoring of the PCI is used to establish the rate of pavement deterioration, which permits early identification of major rehabilitation needs. The Pavement Condition Index (PCI) is determined by measuring pavement distress with a numerical indicator based on a scale of 0 to 100. For each distress measured, there are deduct values depending upon the nature of the distress, its severity and quantity. The deduct values are summed, adjusted to take into account the total number of distresses identified, and then subtracted from 100 to give the PCI index for the pavement (ASTM D6433, 2007).

Figure 2: Some sample pavement condition surveys on Shone-Buge subsection

5.3 Selection of the Sample Site and Sampling technique for Laboratory tests

To assess the performance of pavement layers of the engineering properties of materials are determined by carrying out different laboratory tests. Samples were collected for laboratory tests as per present pavement conditions/pavement condition index (PCI) values. Those locations were selected as severely distressed and non-distressed pavement condition.

Hence, it was decided to collect six (6) stations from severely distressed section and two (2) from good (non-distressed) sections for sampling. Three samples were taken from Alaba-Adilo section at stations of 1+600-1+800km, 9+600-9+800 km and 10+200-10+400 km. Two samples were taken from Shone-Buge section at stations of 31+500-31+700 km and 32+100-32+300 km and, and three samples were taken from Buge-Boditi section at stations of 41+000-41+200km, 42+800-43+000km and 43+200-43+400km and check the effect of pavement layers properties on distresses. Therefore, eighteen (18) and six (6) samples will be taken from severely distressed sections and non-distressed sections respectively. Generally, 24 Soil and aggregate samples were collected from both condition of surface. Hence, laboratory tests conducted were summarized in table below.

Table 3: Material Laboratory Tests conducted and their Procedures

S.No	Tests conducted	Test method/standard
1	Liquid limit(LL)	AASHTO T89 / ASTM D 4318
2	Plastic Limit (PL)	AASHTO T90/ ASTM D 4318
3	Grain size analysis	AASHTO T 88 / ASTM D 422
4	Moisture- Density Relations of Soils	AASHTO T180-97 / ASTM D2937
5	Soil classification	AASHTO M145
6	California Bearing Ration (CBR)	AASHTO T-193 and T-180
7	Aggregate Crush Value	British Standard 812, Part 110; (ERA FPDM, 2013).
8	Aggregate Impact Value	British Standard 812, Part 112, 1990
9	Los Angeles Abrasion	AASHTO T96-99
10	Flakiness Index	British Standard 812, Part 105; (ERA FPDM, 2013).

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6. RESULTS AND DISCUSSIONS

6.1 Pavement Condition Survey

The pavement condition survey was made on selected sections by following ASTM D6433 Manual methods as discussed in chapters 3 to establish the stations for taking sample for the laboratory tests. This was done by dividing road pavement into different sections. Each section was divided into different sample units. Pavement condition survey was mainly done in order to differentiate the severely distressed sections and good sections of the road and then to take sample from both sections. Before starting of the detailed pavement evaluation, the entire road length was visually assessed and an attempt was made to identify the current condition of the road and the types of distresses occurred on the road prism.

Table 6: PCI and PCR values for Alaba-Adilo section

Sample unit No	Alaba-Adilo			Alaba-Adilo		
	The Value based on assumed standard deviation			The Value based on actual standard deviation (Additional Sample Units)		
	Station 0+000-15+000; 15km	PCI Value	PCR	Station 0+000-15+000; 15km	PCI Value	PCR
1	0+000-0+200	29.5	Poor	0+200-0+400	6	Failed
2	1+200-1+400	40	Poor	1+600-1+800	3	Failed
3	2+400-2+600	32	Poor	3+000-3+200	33	Poor
4	3+600-3+800	52	Fair	4+400-4+600	24	Very poor
5	4+800-5+000	33	Poor	5+800-6+000	38	Poor
6	6+000-6+200	26	Poor	7+400-7+600	27	Poor
7	7+200-7+400	28	Poor	8+800-9+000	18	Very poor
8	8+400-8+600	47	Fair	10+200-10+400	16	Very poor
9	9+600-9+800	74	Very Good	11+600-11+800	54	Fair
10	10+800-11+000	59	Good	13+000-13+200	66	Good
11	12+000-12+200	58	Good	14+600-14+800	30	Poor
12	13+200-13+400	48	Fair	-	-	-
13	14+400-14+600	29	Poor	-	-	-
	Total-1	**555.5**		**Total-2**	**315**	
Weighted Average = (Total-1+Total-2)/24=36.27						

The above Table 6 shows the values of PCI and PCR values that determined from assumed and actual standard deviation of the section Alaba- Adilo and which indicates the pavement need suitable maintenance works because weighted average PCI value can be rated as poor condition of pavement surface.

Table 7: the results of the pavement condition survey (PCI) on section-2 (Shone-Buge):

Sample unit No	Shone-Buge		
	The Value based on assumed standard deviation		
	Station 26+100-33+400; 7.3km	PCI Value	PCR
1	26+100-26+300	52	Fair
2	26+700-26+900	59	Good
3	27+300-27+500	42	Fair
4	27+900-28+100	39	Poor
5	28+500-28+700	41.5	Fair
6	29+100-29+300	41	Fair
7	29+700-29+900	57	Good
8	30+300-30+500	76	Very Good
9	30+900-31+100	41.5	Fair
10	31+500-31+700	37.5	Poor
11	32+100-32+300	34	Poor
12	32+700-32+900	42	Fair
	Total-1	**562.5**	
The Value based on actual standard deviation (Additional Sample Units)			
1	26+300-26+500	88	Excellent
2	30+100-30+300	54	Fair
	Total-2	**142**	
Weighted Average = (Total-1+Total-2)/12 = 50.32			

The above Table 7 shows the values of PCI and PCR values that determined from assumed and actual standard deviation of the section Shone-Buge and which indicates the pavement need suitable maintenance works because weighted average PCI value can be rated as fair condition of pavement surface.

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Table 8: PCI and PCR values for Buge-Boditi section

Sample unit No	Buge-Boditi			Buge-Boditi		
	The Value based on assumed standard deviation			The Value based on actual standard deviation (Additional Sample Units)		
	Station 33+400-50+800; 17.4km	PCI Value	PCR	Station 33+400-50+800; 17.4km	PCI Value	PCR
1	33+400- 33+600	58	Good	33+600-33+800	72	Very Good
2	34+800- 35+000	57	Good	34+400-34+600	47	Fair
3	36+200 36+400	47	Fair	35+200-35+400	32	Poor
4	37+600 37+800	54	Good	36+000-36+200	55	Fair
5	39+000- 39+200	16	Very Poor	36+800-37+000	12	Very Poor
6	40+400- 40+600	18	Very Poor	37+800-38+000	23	Very Poor
7	41+800- 42+000	28	Poor	38+600-38+800	56	Good
8	43+200- 43+400	11	Very poor	39+400-39+600	25	Very Poor
9	44+600- 44+800	13	Very Poor	40+200-40+400	31	Poor
10	46+000- 46+200	18	Very Poor	41+000-41+200	4	Failed
11	47+400- 47+600	15	Very Poor	42+000-42+200	20	Very Poor
12	48+800- 49+000	18	Very Poor	42+800-43+000	73	Very Good
13	50+200- 50+400	36	Poor	43+600-43+800	7	Failed
14				44+400-44+600	17	Very Poor
15				45+200-45+400	33	Poor
16				46+200-46+400	50	Fair
17				47+000-47+200	58	Good
18				47+800-48+000	40	Poor
19				48+600-48+800	43.5	Fair
20				49+400-49+600	46	Fair
	Total-1	**389**		**Total-2**	**744.5**	
	Weighted Average = (Total-1+Total-2)/33 = 34.35					

The above Table 8 shows the values of PCI and PCR values that determined from assumed and actual standard deviation of the section Buge-Boditi and which indicates the pavement need suitable maintenance works because weighted average PCI value can be rated as poor condition of pavement surface.

Table 9: Percentage of pavement condition rating

PCR	**Total Number of PCR on the three surveyed sections**	**Percentage of PCR (%)**
Excellent	1	1.41
Very Good	4	5.63
Good	10	14.08
Fair	17	23.94
Poor	20	28.17
Very Poor	15	21.13
Failed	4	5.63
Total	71	

Percentage of PCR was also presented in figure3 below.

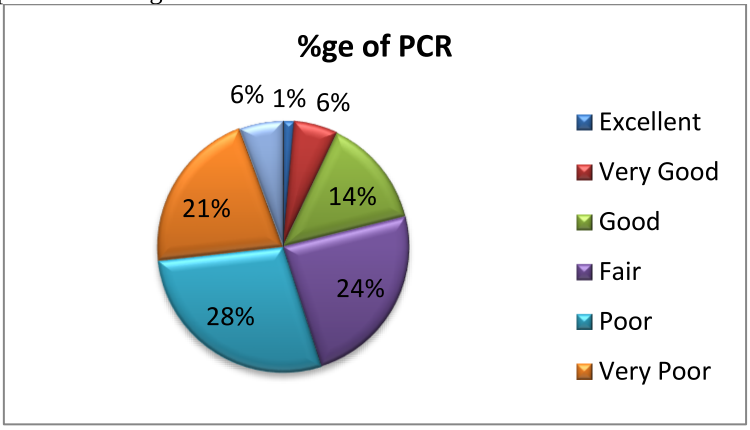

Figure 3: Percentage of pavement condition rating

The above all results and discussion are only about the three selected sections out of the total five sections of the study. But the remained two sections are almost in the same condition with the surveyed three sections. Therefore, this implies that the whole 68km road rated as poor and fair condition and it needs suitable maintenance works.

6.2 Laboratory Test Results and Discussion

The engineering properties of materials were determined by carrying out different tests such as Atterberg Limits, Gradation, Soil Classification, compaction, CBR, ACV, AIV, LAA and Flakiness Index tests in the laboratory.

6.2.1 Atterberg limit tests for Sub-grade, subbase & base course materials

Table 10: Results of Atterberg limit tests for Sub-grade, subbase & base course materials

Section	Station	PCR	Subgrade Soil			Subbase			Base Course		
			LL	PL	PI	LL	PL	PI	LL	PL	PI
			%	%	%	%	%	%	%	%	%
Alaba-Adilo	1+600-1+800	Failed	46	25	21	32	23	9	21	19	2
	9+600-9+800	Very good	43	22	21	35	27	7	21	20	1
	10+200-10+400	Very poor	39	23	16	34	24	10	22	22	NP
Shone-Buge	27+900-28+100	poor	23	N/A	NP	36	31	5	24	17	7
	32+100-32+300	poor	40	21	19	30	23	5	32	N/A	NP
Buge-Boditi	33+600-33+800	Very good	50	24	26	33	23	10	22.5	N/A	NP
	41+000-41+200	Failed	40	16	24	27	20	7	23	20	2
	47+400-47+600	Very poor	39	18	21	31	25	6	22	17	5

According to ERA Manual, 2013, the subgrade soils with PI values less than 30% and LL< 60 are suitable subgrade materials, for the seasonally wet tropical climate all suitable sub-base materials shall have a maximum Plasticity Index of 12 and Liquid Limit of not exceeding 45 and the base course material which is the fine fraction of a GB1 material shall be non-plastic when determined in accordance with AASHTO T-90. Therefore, Atterberg test results of all station of the subgrade and subbase materials shows that the materials fulfilled the requirement of the ERA specification. This indicates that the subgrade and subbase materials are in a good performance. This implies that the distress on the surface layer is not because of these two materials.

Among the total 8 station intervals only the base course materials of three station results fulfilled the minimum requirement of ERA specification. i.e. these test value shows that all station interval materials were fulfilled the minimum requirement of ERA specification except materials at station 1+600-1+800, 9+600-9+800, 27+900-28+100, 41+000-41+200 and 47+400-47+600 and which also indicate that the base course materials are not in a good performance.

6.2.2 Sieve Analysis Test Result for Subbase Materials

For the entire road stretch, red ash blended with soil is used as a sub-base material, and sieve analysis was conducted on this material and the result shows that the samples which are tested are within minimum and maximum limit of ERA specification. For sample, station 10+200-10+400 was presented in Table 11 and Figure below.

Table 11: Sieve analysis result for subbase material at station 10+200-10+400

PARTICLE SIZE DISTRIBUTION BY SIEVING TEST METHODS: AASHTO 27/AASHTO 11										
Sub base										
Sieve size(mm)	**Trial one**			**Trial two**				**Final Result**		
	Wt. of sample retained(g)	**%ge retained**	**%ge pass**	**Wt. of sample retained(g)**	**%ge retained**	**%ge pass**	**Average %ge retained**	**Average %ge pass**	**Lower limit**	**Upper Limit**
50	**0**	0	**100**	0	-	**100**	0	**100**	**100**	**100**
37.5	211	3.01	**96.99**	337	3.52	96	3.26	**96.74**	80	100
20	812	11.58	**88.42**	1449	15.12	81	13.35	**83.39**	60	100
5	2015	28.73	**56.69**	3124	32.60	49	30.66	**52.73**	30	100
1.18	1645	23.45	**33.23**	1647	17.19	32	20.32	**32.41**	17	75
0.3	1332	18.99	**14.24**	1954	20.39	11	19.69	**12.71**	9	50
0.075	654	9.32	**4.92**	549	5.73	5	7.53	**5.19**	5	25
Pan	345	4.92	0	523	5.46	0				
Total	**7014**			**9583**						

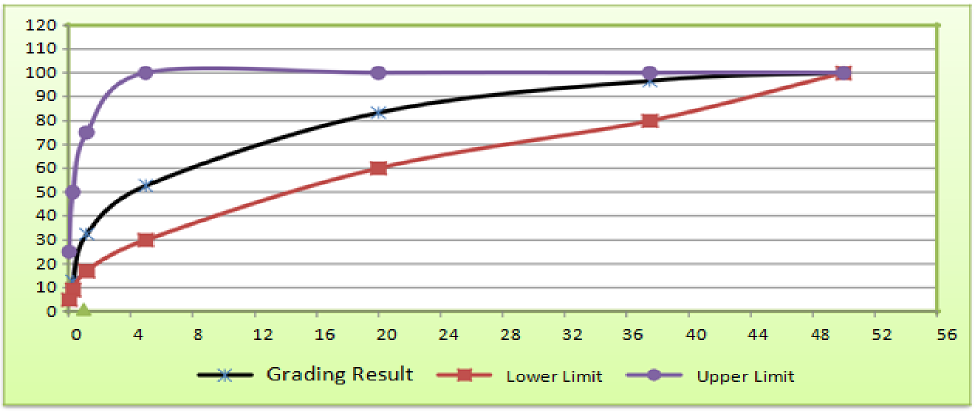

Figure 4: Gradation result graph for base course material at station 10+200-10+400

By similar way, Alaba-Adilo, Shone- Buge and Buge-Boditi sections subbase material revealed that sieve analyses represents material remained within ERA specification. Therefore, subbase material is fair for pavement construction and traffic loading.

6.2.3 Sieve Analysis for Base Course:

For this road section crushed aggregate has been used as a base course material. All base course materials must have a particle size distribution and particle shape which provide high mechanical stability and should contain sufficient fines (amount of material passing the 0.425 mm sieve) to produce a dense material when compacted. But all stations interval results indicate the materials don‘t fulfilled the minimum requirement of the ERA standard, i.e. the materials are not uniformly graded except the station interval 9+600-9+800 and this implies the base course materials are not in a good gradation or performance. The graph and the table below show the base course sieves analysis according to AASHTO standard for station of 41+000-41+200.

Table 12: Sieve analysis result for base course material at station 41+000-41+200

PARTICLE SIZE DISTRIBUTION BY SIEVING TEST METHODS: AASHTO 27/AASHTO 11										
BASE COURSE					Nominal size 20					
Sieve size(mm)	Trial one			Trial two				Final Result		
	Wt. of sample retained(g)	%ge retained	%ge pass	Wt. of sample retained(g)	%ge retained	%ge pass	Average %ge retained	Average %ge pass	Lower limit	Upper Limit
50	0	-	100	0	-	100	0	100		
37.5	0	-	100	0	-	100	0	100		
28	29	0.37	99.63	264	-	100	0.19	99.81	100	100
20	1988	25.22	74.4	1760	28.74	71	26.98	72.83	90	100
10	3238	41.09	33.31	2197	35.87	35	38.48	34.35	60	75
5	1030	13.07	20.24	688	11.24	24	12.15	22.2	40	60
2.36	281	3.57	16.67	186	3.04	21	3.31	18.89	30	45
0.425	244	3.1	13.57	462	7.55	14	5.32	13.57	13	27
0.075	734	9.31	4.26	316	5.16	8	7.24	6.33	5	12
Pan	336	4.26		251	4.1					
Total	7880			6125						

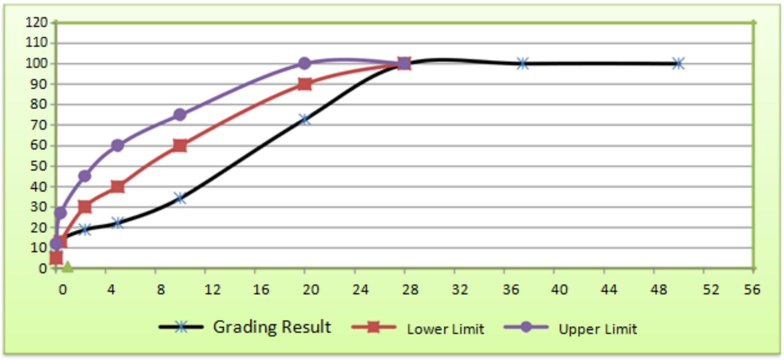

Figure 5: Gradation result graph for base course material at station 41+000-41+200

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Likewise, the gradation results for all remained stations are approximately the same with above station result except at station 9+600-9+800.

6.3 Soil Classification for Subgrade

In this study the AASHTO Soil Classification System was used. For this system the sieve sizes of 2mm, 425-µm, and 75-µm were used to determine the categories of soil. The table below shows the subgrade soil classification for the station interval 1+600-1+800 according to AASHTO Classification System.

Table 13: Results of subgrade soils classification

Section	Station	PCR	Subgrade Soil				AASHTO Soil Classification
			LL	PL	PI	%pass 0.075mm sieve	
Alaba-Adilo	1+600-1+800	Failed	46	25	21	66	A-7-6
	9+600-9+800	Very good	43	22	21	65	A-7-6
	10+200-10+400	Very poor	39	23	16	62	A-6
Shone-Buge	27+900-28+100	poor	23	N/A	NP	65	A-5
	32+100-32+300	poor	40	21	19	59	A-6
Buge-Boditi	33+600-33+800	Very good	50	24	26	51	A-7-6
	41+000-41+200	Failed	40	16	24	71	A-6
	47+400-47+600	Very poor	39	18	21	54	A-6

The above tables all stations of subgrade materials are on group of clayey soils and they were classified by ASSHTO which shows that general rating of a soil fair to poor as a sub-grade material.

As per Atterberg test, the base course materials satisfied the requirements only at station of 10+200-10+400, 33+600-33+800 and 32+100-32+300 but at remaining stations it does not, which have some plastic behavior.

Additionally, the sieve analysis of the all base course materials do not satisfied the minimum requirements of ERA specification except at station of 9+600-9+800.

Table 14; Compaction Test Results for Subgrade, Subbase and Base course materials

Section	Station	PCR	Subgrade Soil		Subbase		Base Course	
			MDD g/c3	OMC %	MDD g/c3	OMC %	MDD g/c3	OMC %
Alaba-Adilo	1+600-1+800	Failed	1.61	16.2	1.84	16	2.3	4
	9+600-9+800	Very good	1.56	19.5	1.91	11.5	2.4	3.6
	10+200-10+400	Very poor	1.78	15	1.88	12	2.2	4.1
Shone-Buge	27+900-28+100	poor	1.73	13.5	1.95	10.5	2.3	5.8
	32+100-32+300	poor	1.65	14.5	1.79	14	2.23	5.3
Buge-Boditi	33+600-33+800	Very good	1.45	21.5	1.82	13	2.4	3.8
	41+000-41+200	Failed	1.6	21	1.82	12	2.26	4.2
	47+400-47+600	Very poor	1.55	21	1.81	12.7	2.22	6.8

These results for subgrade, subbase and base course materials that were tested with modified proctor test and their samples compacted in five layers in a mold by a hammer in accordance with specified nominal compaction energy. So the dry density was determined based on the moisture content and the unit weight of compacted soil. The water content at which this dry density occurs was termed as the optimum moisture content (OMC). They also used the graph of moisture content verses dry density to determine their maximum values by graph reading.

6.4 CBR test with discussion

Table 15: CBR test for all stations of subgrade, Subbase and Base course materials

Section	Station	PCR	Subgrade Soil		Subbase		Base Course	
			CBR Value	% Swell	CBR Value	% Swell	CBR Value	% Swell
Alaba-Adilo	1+600-1+800	Failed	8.00	1.40	28.00	1.10	104.00	0.10
	9+600-9+800	Very good	12.00	1.20	38.00	0.65	108.00	0.07
	10+200-10+400	Very poor	13.00	1.20	39.00	0.90	80.00	0.12
Shone-Buge	27+900-28+100	poor	15.00	1.30	34.00	1.10	87.00	0.17
	32+100-32+300	poor	12.00	1.22	27.00	1.50	77.00	0.23
Buge-Boditi	33+600-33+800	Very good	7.00	1.35	21.00	1.40	105.00	0.06
	41+000-41+200	Failed	10.50	1.30	24.00	1.40	96.00	0.10
	47+400-47+600	Very poor	13.00	1.25	25.00	0.90	90.00	0.30

And also, the CBR test results fail to satisfy the minimum requirements of specifications at five stations of 10+200-10+400, 27+900-28+100, 32+100-32+300, 47+400-47+600 and 41+000-41+200 and at the remaining three stations it satisfied. This also implies the materials which are not uniformly graded. In conclusion, the base course material is not in a good performance and also it can be possible cause for distresses.

The results of the CBR tests for subgrade soils in Table 15 show that samples from all stations have CBR value of greater than 5%. Based on the ERA specification, these samples indicate as good subgrade materials. The percent swell test results also are below 2% which is an indication of less expansiveness of the soil, which is a good subgrade material. All values satisfied the minimum requirement, but variations of CBR result for different conditions indicate the surface layer is affected by some other factors. For instance, for the sub section of Buge-Boditi, the CBR value each station for very Good condition is 7, for failed condition it is 10.5 and for very poor condition it is 13. Here for all surface conditions the CBR value satisfied but the surface is distressed. Therefore, the cause for the distress is not the subgrade material but affected by other cause.

In ERA standard, the minimum soaked CBR for sub base material shall be 30% when determined in accordance with the requirements of AASHTO T-193. Subbase material results of stations 1+600-1+800, 32+100-31+300, 33+600-33+800, 41+000-41+200, and 47+400-47+600 shows the results of the CBR value of less than the minimum requirement of ERA standard for subbase materials (30%) and the remaining stations satisfy the ERA requirement. But for different condition the value of CBR vary accordingly. For example, for sub section of Buge-Boditi, the Sub base CBR value for failed condition (24) is greater than the CBR value (21) of very good condition. For both conditions the sub base material do not satisfied the requirement but the CBR value for the failed condition is relatively good. This implies that the surface layer is failed not only by the material quality but due other cause.

Base course material results of stations 10+200-10+400, 27+900-28+100, 32+100-32+300, 41+000-41+200 and 47+400-47+600 shows that the results of the CBR value of less than the minimum requirement of ERA standard for base course materials (≥100%) And the remaining stations satisfy the ERA requirement. However, for example, for the sub section of Alaba-Adilo, the CBR value of the base course material satisfied the requirement at station 1+600-1+800 and 9+600-9+800 but the surface is failed. This indicates that the surface layer is getting failed due to the material by itself and the surface layer affected by other unknown cause.

6.5 Aggregate Test Results with Discussion for Base Course

Table 16: Result of ACV AIV, LAA and FI test for all base course materials

Section	Station	PCR	Aggregate Tests for Base Course			
			ACV	**AIV**	**LAA**	**FI**
Alaba-Adilo	1+600-1+800	Failed	16.90	18.40	18.60	20.70
	9+600-9+800	Very good	16.70	17.20	15.69	16.40
	10+200-10+400	Very poor	15.80	17.30	20.01	19.60
Shone-Buge	27+900-28+100	poor	17.40	15.60	21.06	21.60
	32+100-32+300	poor	18.20	18.40	23.48	22.10
Buge-Boditi	33+600-33+800	Very good	18.50	19.90	16.94	18.90
	41+000-41+200	Failed	16.40	16.80	19.74	21.50
	47+400-47+600	Very poor	16.00	17.30	17.65	13.50

According to ERA FPDM, a maximum value of ACV shall be 25 as per BS 812-110, 1990 standard, a maximum value of aggregate flakiness index shall be 35 as per ERA Specification Manual, the Los Angeles abrasion value shall not exceed 45% when determined in accordance with the requirements of AASHTO T-96(99) standard and AIV is shall not be greater than 30 % as per BS 812-112, 1990 standard. Therefore, aggregate test values show in above Table 16 fulfilled the requirement of the above mentioned specification or standards and coarse aggregate particle are in a good condition based on the objectives of the above tests.

6.6 Maintenance options for Pavement Distresses

The pavement maintenance in general consists of all the routine repair tasks necessary to keep the pavement, under normal conditions of traffic and normal forces of nature, as nearly as possible in its as-constructed condition. Department of the Army (TM-5-624), 1995 suggests maintenance options for different distress types with respect to their severity level.

The following table shows maintenance option for cracking, surface deformation, disintegration, and surface defects with their severity level.

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Table 17: Maintenance suggestion for Cracking

Pavement distress	Severity level	Maintenance Option
Alligator cracking	Low	Seal Coat
	Medium	Seal coat or Patching
	High	Thin hot-mix Overlay
Block cracking	Medium	Chip seal, seal coat or Thin hot-mix Overlay
Edge cracking	Low	Seal coat
	Medium	Patching
	High	Patching
Longitudinal and transversal cracking	Low	Clean and Seal
	Medium	Clean and Seal or Full-depth crack Repair
	High	Full-depth crack Repair

Table 18: Maintenance suggestion for surface deformation

Pavement distress	Severity level	Maintenance Option
Shoving	Medium	Thin hot-mix Overlay
	High	Thin hot-mix Overlay
Depression	Low	Patching
Rutting	Low	Slurry Seal, Patching
	Medium	Slurry seal, Patching, or Thin hot-mix overlay
	High	Patching, or Thin hot-mix overlay
Swell	Low	Thin hot-mix overlay
	Medium	Thin hot-mix overlay

Table 19: Maintenance suggestion for disintegration

Pavement distress	Severity level	Maintenance option
Potholes	Low	Patching
	Medium	Patching
	High	Patching
Raveling	Low	Crack sealing/ chip sealing
	Medium	Thin overlay
	High	Thin overlay

7. CONCLUSION AND RECOMMENDATION

7.1 Conclusion

- The pavement condition survey along the selected road sections showed that the different failure types such as alligator cracking, rutting, edge cracking, potholes, slippage cracking, block cracking, weathering and raveling, shoving, lane/ shoulder drop off, and depression were existing.
- The alligator cracking and rutting types of distress were dominating types of distress along the stretch. Based on the pavement condition survey 1.41% of road section was with PCR of Excellent, 5.63% of Very Good, 14.08% Good, 23.94% of fair, 28.17% of poor, 21.13% of very poor and 5.63% failed. The average PCI values for Alaba-Adilo, Shone-Buge, and Buge-Boditi were 36.27%, 50.32% and 34.35% respectively.
- The laboratory test results show that only the subgrade material satisfied but subbase material at some stations did not fulfill the strength test (CBR) requirement and the base course material did not satisfy the sieve and CBR requirements as per ERA, AASHTO and BS standards and these could also be one of the causes for the distress.
- The road section were full of distresses dominantly alligator cracks, surface rutting, and depressions. Therefore, these failures can be maintained by observing level of severity as per maintenance option already maintained.

7.2 Recommendation

Finally, the following points are recommended:

- Accordingly, existing road needs maintenances by the Ethiopian road Authority or any concerned entity. The pavement condition ratings should be updated every year and Routine as well as periodic pavement maintenance practices should be employed to reduce premature pavement failure
- The surface course, which is a mixture of aggregate and asphalt, should be considered in order to know causes of distresses in full confidence. So aggregate tests and bitumen tests for this layer should be conducted.
- Further study is recommended that is related with other expected causes of failures such as moisture variation within subgrade and pavement materials in order to select the most effective maintenance and/ or rehabilitation techniques.

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