Influence Of Subsurface Courses Materials On Pavement Performance: A Case Study in Yebu-Agaro Road

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Abstract— The properties of subsurface materials would vary from place to place while it is true the performance of pavement along the route also differs. The research study had been undertaken at Yebu-Agaro road section with the main objective to determine the Influence of Subgrade Soil on pavement performance. In order to realize the desired objective, a systematic methodology was adopted which includes field investigation, field test and laboratory tests. While the purposive sampling method was used to extract soil samples from the road section that are severely damaged showing different failures types and non-distress surface. Those severe types of failures observed along the road section are reflective crack, pothole, rutting, alligator crack and block crack. From these failure types, five representative samples were extracted at different locations along the failures section and one non-distress pavement of road section using a manual hand auger. The analyses of soil samples were carried out based on the Geotechnical properties such as wash gradation, Atterberg limit, and Modified proctor test, California Bearing Ratio (CBR) and field test, as well as Axle load analysis. It was found out that the liquid limit of subgrade soil varies from 33% -60.5% and the plasticity index from 20.3% -30.1% while there was a significant increase in moisture content at field and observed beyond the OMC in the laboratory result due to the distress of pavement affected by water infiltration through cracks, that tend to reduce the dry density. The recorded soaked CBR values of subgrade soil materials range between 8% -13%, which was below the 15% minimum value specified by ERA manual. However, the existing CBR values of the subgrade soils indicate a poor material used for pavement structures. According to ASSHTO, the soil is classified as A-2-6 and A-7-6 category which means the existing soils are fair to poor as a sub-grade material while USCS classification shows that the soil falls into SC group. In addition, the failures that are frequently observed on the road surface were significantly influenced by subgrade soil. For the sub-base layer materials, it was noted to have satisfied the minimum requirements as compared with standard specification, except deficiency of its thickness. For the base course materials, inferior qualities of material were used at some section. The overall results showed that, heavy vehicles or traffic loads are one of the major causes of road failure along the study road section. Hence, the influence of other factors such as poor drainage courses, level of ground water table, variety of geologic materials along the road route and poor construction materials should be thoroughly addressed before the start of the rehabilitation of the road section in the future. Finally a possible remedial measure is recommended for every observed failure or distress on the pavement condition of the study area in order to sustain the design life of the pavement.

Index Terms—Axle loads, Characteristics of subsurface materials, CBR values, ERA standard, Geotechnical properties, Influence of subgrade soil, Pavement failure.

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1 Introduction

Pavement components may be generally described as the structural materials placed on top of a subgrade layer. The characteristic of the soil bed over which the entire pavement system rests on represents subgrade soils [2]. The properties of soil may vary from place to place due to the variation in soil formation, drainage condition and climate. When the soils within the possible corridor for the road vary in strength significantly, it is clearly desirable to locate the pavement on the stronger soils, if this does not have other constraints.

Thus, since the selection process of route corridor influence the pavement structure and the construction costs, a thorough investigation should be done on the characteristics of subgrade. Failures of roads are being observed before their design period and are greatly affecting the economic growth of the country. Such failures could be overcome by undertaking through investigation of the subgrade material and the materials overlaying the subgrade and incorporating it into the design [2]. Some part of Ethiopia is covered by expansive soils of which, along the main trunk roads were constructed. Currently, different construction activities are taking place in the road sector on this soil type. It had been observed that construction on expansive soils, inevitable that results to numerous problems. The causes of these problems are not given proper attention in Ethiopia.

Most of the roads constructed in Ethiopia on this type of soils failed before their expected design life has reached [10]. A road pavement is a structure of superimposed layers of selected and processed materials that are placed on the basement soil or subgrade. Flexible pavements constructed for heavy duty vehicles are composed of asphaltic layers (wearing, binder and base course) and sound sub base layer which laid over a well compacted and strong subgrade foundation.

The main structural functions of a pavement is to support the wheel loads applied to the carriageway and ultimately distribute them to the underlying subgrade layer [8]. The pavement is designed and constructed based on the most economical combination of layers that guarantees adequate dispersion of the incident wheel stresses so that each layer in the pavement does not become overstressed during the design life of the highway [7].

Due to the Economic growth of a country the movement of traffic volume and loads on roads is going on increasing from year to year with alarming rate all over the world. Such heavy traffic growth demands need better performance roads for efficient transport of agricultural, commercial and industrial products without delay from one location to others. The repetitive traffic loading that the road experiences during its service life combined with environmental factors causes deformation, fatigue cracking, instability and other forms of deterioration which ultimately degrade and reduces the serviceability and durability of pavement structures [4].

The researcher would like to ascertain whether certain types of pavement distress are progressive, leading to eventual failure of the road, or whether they are non-progressive. Excessive movement of flexible pavements, which eventually result in uneven riding qualities, may mostly be caused by poor qualities of the sub grade, sub base, base course or wearing course and due to improper drainage system [7]. Considering remedial measures for defects or reconstruction or overlay, it is imperative that the engineer takes into account, various parameters that are necessary for proper evaluation of the existing pavement condition [1]. Road Failure as the inability of a normal road to carry out its functional services is not providing a smooth running surface for operating vehicles. Most roads in Ethiopian today are characterized by failure of all kinds like surface deformation, cracks, disintegration, surface defects etc. and there is not just one reason for each type of failure. Factors affecting the pavement performance are climate, material properties, structure and traffic load. The movement of the sub grade is the major cause of road pavement failure which makes road network unsafe and not suitable to the road users [6]. The research study was focused on the Influence of subsurface courses on Pavement performance along Yebu-Agaro road Section. It is located in South- West Ethiopia, Oromia National Regional State, Jimma zone. The estimated road length was about 25kms. The existing road is originally paved, but its entire length has now observable to have a deteriorated pavement surface considerably. The results of this study will provide reliable technical information about the properties of subgrade soil along the failure section of Yebu-Agaro a road pavement.

The strength of subgrade soil is a major factor for the performance of the pavement. So the movement of the sub-grade is one of the causes of road pavement failure. Road failure could be in the forms of cracks, potholes, deformation, disintegration, surface defects etc. which makes the road network unsafe and not suitable to the road users. The performance of a pavement depends on the quality of its embankments and existing condition of road bed (ERA Manual, 2000).

The pavement can no longer absorb and transmit the wheel loading through the road structure when layers have failed for various reasons, as through aging, inadequate design, poor construction and maintenance practices, low bearing capacity of the materials or the gradual degradation of the strength of the road due to increased traffic flow and load and/or due severe climatic conditions, decreasing subgrade strength in conjunction with inadequate surface/subsurface drainage facilities and so on [7]. Every vehicle, which passes over a road, causes a moment, very small, but significant deformation of the road pavement structure. The passage of many vehicles has a cumulative effect, which gradually leads to permanent deformation and road surface deterioration [8].

Asphalt pavement roads are designed and constructed to serve the upcoming traffic that reveal during the service life of the road. Different factors taken in to account in the design and construction of AC pavements include the characteristics of the traffic, climatic conditions, material as well as structural properties and other elements which have significant impact on the overall performance of the road [4].

In the study area, various defects had been seen as contributory factors that will affect the subsurface courses materials on performance which needs in-depth analysis as essential basis to provide useful information on foundation soils; therefore before any road projects to be laid out on the ground a detailed geotechnical properties of soil was to be carried out. It is for this reason that geotechnical properties of subsurface material condition must be analyzed and to be checked if the suitability of the existing materials in Yebu-Agaro Road has been satisfied the standard specifications set by Ethiopian Road Authority (ERA).

Before the construction of any Road project work which is layout on the earth's surface, its geotechnical properties of subsurface condition must be analyzed and the suitability of a soil for a particular use should be determined based on its engineering characteristics and not on visual inspection or apparent similarity to other soils. Analysis is essential because it provides useful information on foundation soils before any civil engineering projects are to be carried out.

Currently Condition of a road some part of Yebu-Agaro road is failed by different types of failures such as reflective crack, block crack , pothole, rutting and alligator crack , so it's not suitable for driving even also affect the vehicle operating cost for the road users. Misunderstanding the nature of soils and their properties can lead to construction errors that are costly in effort and material. It is for this reason that this research study to undertake investigation of subgrade soil on asphalt pavement performance along Yebu-Agaro road.

Figure 1.1 Current Condition on some Sections of Yebu-Agaro Road

The main objective of the research project was to investigate the influence of subsurface course materials on pavement performance along Yebu -Agra Road Section, while the specific Objectives are:

□ To identify types of pavement failures in relation to subsurface performance.
□ To determine the existing soil properties within the damaged section and non-distress asphalt Pavement surface.
□ To compare the existing properties with the Standard set by ERA.
□ To determine the strength of the subgrade soil and its relationship with the thickness of the asphalt pavement layers.

The main road users from Yebu–Agaro is being affected by the failure of this road. Based on the existing theories and principles, this research project focused on the general objectives to investigate the influence of subsurface courses on performance on asphalt pavement in the study area.

For the intended purpose, samples were collected from the worst road failure locations of the embankments of the road section. The soil samples were analyzed based on Geotechnical analysis. Yebu-Agaro asphalt Road was considered to have highly loaded traffic volume as it serves as a Link Road for the transport of coffee products. Relative to this, the strength of the subsurface courses plays a vital role for the appropriate performance of the asphalt pavement in order to:

□ Minimize the damage/failure of the upper layer of the pavement.
□ Reduce the traffic accident, otherwise leads to loss of life and property.
□ Enhance easy movements of automobiles/vehicles and solve transportation problems.
□ Reduce socioeconomic problems of the surrounding community.
□ Use the result of the research study for rehabilitation of asphalt pavement.
□ Proper understanding the types of distresses and possible causes of damage on asphalt pavement may lead to correct application of remedial measures.
□ Provide detailed information on how the Geotechnical properties of soil affect pavement performance.

2 RESEARCH METHODOLOGY

2.1 Project location and topography

The study area started at Yebu town with an elevation of 1,906m above mean sea level (a.s.l.) and ends Agaro town at an elevation of 1675 m ASL. Then route of the Road, passing through different kebeles of various elevations. Therefore, the route of the road descends and ascends thereafter from the starting to end points. Generally the altitude ranges on the order of 1500-2300 m above mean sea level. The topography of the road terrain can be classified as flat and rolling terrain [5].

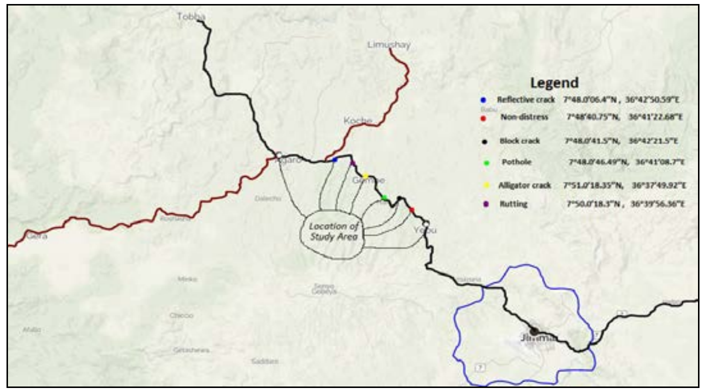

Figure 2.1: Road failure point locations with coordinates along Yebu-Agaro road by using Google earth

2.2 Climate

The Project Climate has a rainy season from April to October and Dry Season until into February continuing into March. The duration of the rainy season is longer in the vicinity of the project of a road project and the mean annual rainfall is in the order of 2000mm. The mean maximum temperature ranges 20°C - 25°C and the mean minimum temperature is 10°C -15°C [5].

2.3 Study Procedure

The procedure utilized throughout the conduct of this research study is as follows: Reviewed related literatures on relevant areas of influence of sub surface courses, materials on pavement performance includes articles, reference books, research papers, standard specifications like ERA, AASHTO and ASTM. Necessary data collection, organization, comparison and analysis were obtained, and then subsequently compared the results to preexisting literature and standard specifications. A conclusion and recommendation are drawn based on the results, as well as appropriate remedial measure to be taken on each distress type of pavement failures.

2.4 Data collection technique

The purposive collection technique was used by selecting particular parameters to have certain characteristics as applied in this research project. It is projected to be normally targets at particular Geotechnical parameters.

2.5 Study design

The research study was conducted by using both experimental and analytical methods. Qualitative and quantitative studies were employed. Qualitative study gives impression on the findings where a quantitative study was used to describe the numerical aspects of the research findings, based from laboratory results.

2.6 Study variables

Independent variable: The independent variables in this research included:
Grain size / Gradation, moisture content, Atterberg limits, Compaction test, Axial load, thickness of asphalt pavement, California bearing ratio (CBR) and DCPT

Dependent variable: Influence of subsurface courses, materials on pavement performance.

2.7 Software and instruments

The following instruments and software were used for the research project study:
Meter tape, plastic bags, manual hand auger equipment, laboratory equipment's, GPS and field test instrument DCP test, Digital Camera for documentation, MS word and Excel into analysis laboratory data and display research data were used.

2.8 Data Collection Process

In order to attain the purpose of this research work ethical considerations were concentrating on in the context of quantitative and qualitative research. Before starting any data collection formal letter was obtained from JIT and an official permission was obtained from ERA Regional Jimma Office District.

Quantitative and qualitative data were utilized based on the necessary input parameters for the analysis by comparing with ERA manuals. The data collection process includes field visual inspection, Field investigation, sampling representative samples in preparation for laboratory test, field test, measurements. The surface of a Road distress along the Road section classified as according to their extent or rates of damages. Field test results compare with a laboratory test, and then finally the results from laboratory test were compared with Standard Specification.

2.9 Field work activities

A preliminary visual survey was undertaken along Yebu-Agra Road section. Field observations, Field tests and measurements were carried out and representative samples were taken for laboratory tests. Results from field tests and measurements were compared with the results from laboratory tests.

Moreover, results from laboratory tests were compared with ERA Standard Specifications. During the field observation, it was necessary to begin by conducting visual inspection and site inventory of the whole stretch of the Yebu-Agaro Road section. The initial site visit was taken on the whole portion of the road and at the same time the damaged and non-damage sections were identified for further detailed site observation.

After finishing the initial visual inspection and categorizing the conditions of the road failures with that of non-failures along the road section. The next step was then to select the representative locations for sampling based on their failure conditions and non-failure location; the researcher selected five (5) samples test pits that represent the types of failures observed along the Road section and one non-distress samples from the study area.

For each condition test pit was extracted for laboratory testing as well as field tests. For each layer layer of the embankment of the Road section Approximately 45 Kg was collected for testing in the laboratory.

2.9.1 Pavement condition survey

In order to determine the extent/rate of damage observed from the visual inspection would become reliable, proper identification was made to select representative sections and to evaluate the state of the existing pavement by assessing the physical conditions of the existing pavement along a road.

The following representative photographs can show the type and extent of failures along the road. In the figure below, there were five major types of distresses observed along the study area of Yebu-Agaro Road. The researcher had organized the possible distress types based on the existing condition of the pavement surface together with the extent of damage.

The following Figures show the different photos taken from the field Observation of the different types of distress along Yebu-Agaro Road section.

Figure 2.2. Pavement defects in the study area

2.9.2 Field investigation of the existing pavement thickness.

Based on the field observation and investigation, the width of the existing road surface is measured using a meter tape during test pitting and sampling. The road has an average of 6m carriageway, while the pavement edges were difficult to establish because the camber of the road had changed due to repetitive raveling and erosion. Hence the width of the road is established mostly by judgment and measurement. The thickness of the road materials is measured in each test pit using a meter tape.

Hereunder is the Table showing the different layer thickness of the existing Pavement.

Table 2.1 Existing thickness of the materials of the road layers

<table>
<tr><th rowspan="2">No</th><th rowspan="2">Failure Types</th><th colspan="3">Average Thickness of road layers(cm)</th><th>Average thickness of non- distress pavement(cm)</th></tr>
<tr><th>Asphalt Layer</th><th>Base</th><th>Sub-base</th><td rowspan="2">Asphalt layer=5.5</td></tr>
<tr><td>1</td><td>Reflective Crack</td><td>5.3</td><td>10</td><td>14</td></tr>
<tr><td>2</td><td>Pothole</td><td>5.2</td><td>12</td><td>17</td><td rowspan="2">Base course=17</td></tr>
<tr><td>3</td><td>Rutting</td><td>5.1</td><td>11</td><td>15</td></tr>
<tr><td>4</td><td>Alligator Crack</td><td>5.4</td><td>13</td><td>14</td><td rowspan="2">Sub-base=19</td></tr>
<tr><td>5</td><td>Block Crack</td><td>5.4</td><td>15</td><td>17</td></tr>
</table>

2.10 Laboratory tests

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Enough representative samples were collected from embankments of the road section with worst road failure and immediately after extracting samples from the road section of the study area, these were transported to the laboratory of Ethiopian Road Construction Cooperation Jimma District Laboratory. Before starting Laboratory test, these samples were first air-dried under the sun to allow moisture to evaporate before starting the required test. The tests were performed according to the AASHTO Specification [6], [1] and ASTM following the procedures that have been discussed on the soil mechanics laboratory manual by Braja, M. D [3].
The following tests were undertaken such as Atterberg Limits, Grain size Analysis, Compaction Tests, and California Bearing Ratio (CBR) Tests were made to understand the general behavior of the road materials of the failure section and Field test such as DCP test and sand cone replacement test.

3 RESULTS AND DISCUSSION

3.1 Field Test results

3.1.1 Pavement Condition Survey results

The pavement condition surveys and investigation along the study area revealed that different types such as surface defect, surface deformation, cracks and problems related to road failures along the road section have been existed.

Table 3.1 Test pits location of distress and non-distress

No	Samples Location	Distress types
1	7°48.0′06.4′′N , 36°42′50.59′′E	Reflective cracking
	7°48.0′41.5′′N, 36°42′21.5′′E	Block crack
	7°48.0′46.49′′N, 36°41′08.7′′E	Pothole
	7°50.0′18.3′′N , 36°39′56.36′′E	Rutting
	7°51.0′18.35′′N, 36°37′49.92′′E	Alligator crack
2	7°48.0′40.75′′N , 36°41′22.68′′E	Non –distress Pavement surface

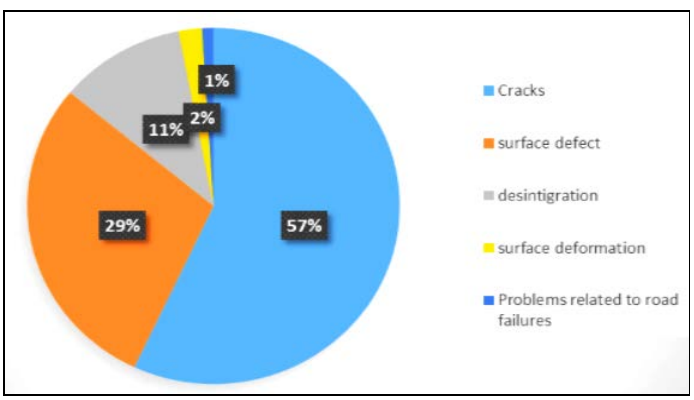

Figure 3.1: Common distress types obtained during Field survey

In Figure 3.1, there were five (5) major types of Road failures observed along the study area of Yebu-Agaro Road section. It was organized the possible distress types based on the existing Road condition of the pavement surface together with the extent of damage. The detailed Road inventory was carried out along road section. In order to evaluate the carrying capacity of the materials to the traffic loading at its service time, the analysis was made. From the traffic analysis, the cumulative Standard Axle is 3.052 Million. According to the ERA pavement design manual, the Traffic Class is "T5" with ESAs ranging from 3-6 million. The thickness of each layer of the embankment of the road section is a function of the ESAs and the CBR of the sub-grade layer. From the CBR test, the sub-grade strength class can be classified as S_4 with CBR ranges 8%-13%. Hence, according to the ERA road design manual, the thickness of the base course and sub-base course for traffic class T5 with ESAs of 3.0-6.0 million should be at least 20cm and 25cm, respectively. Based from the actual measurement, the average thickness of the base course was 9.4 cm and that of the sub-base course was 14cm. This showed that the base and the sub-base course were not be able to carry the traffic loading at its service time.

3.2 Laboratory Test Results

3.2.1 Grain Size Analysis

Table 3.2 Comparison of ERA Standard and Actual Observation (Base Course)

Sieve size, mm	Reflective cracking	Pothole	Rutting	Alligator crack	ERA specification	Non-distress pavement
28					100	
20	72.4	70.0	75.0	74.8	80-100	72
10	45.9	45.0	52.7	47.4	55-80	45
5	27.6	26.3	29.8	30.3	40-60	33
2.36	16.9	15.3	20.3	18.6	30-50	23
0.425	6.1	5.5	7.9	6.4	12-27	10
0.075	4.7	4.4	5.1	4.7	5-15	5

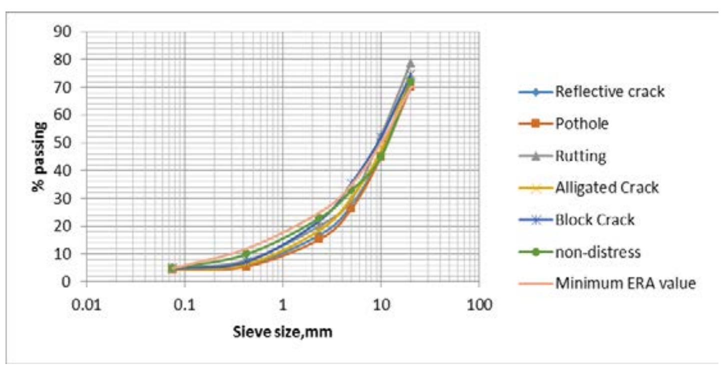

Figure 3.2 Comparison of ERA Standard and Actual Observation (Base Course)

3.2.1.1 Grain Size Analysis Base Course material:

In case of Base **course** materials Cu =25, which is greater than 4 shows a wide variation of size particles. Cc =4, indicates poor graded particles, According to USCS, the % of sand retained above 2mm was greater than 15% so; base material at is classified as poorly graded gravels with sand.

Table 3.3 Comparison of ERA Standard and Actual Observation (Sub-Base Course)

Sieve size, mm	Reflective cracking	Pothole	Rutting	Alligator crack	ERA minimum specification	Non-distress pavement
37.5	93.9	96.34	92.77	95.43	98	80
28	82.6	83.7	74.45	85.67	70	70
20	71.4	66.51	63.13	75.09	60	60
10	45.5	42.55	44.7	55.49	38	40
5	29.23	28.15	35.05	39.61	29	30
2.36	19.43	16.98	18	19	18	25
0.425	8.6	6.36	11	9	9	12
0.075	6.7	5.42	18.33	8.73	6	5

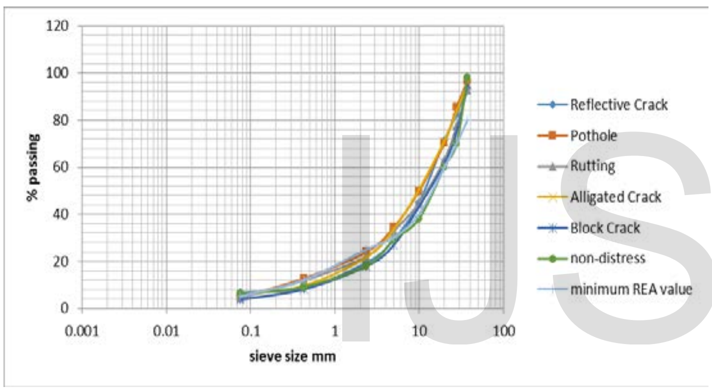

Figure 3.3 Comparison of ERA Standard and Actual Observation (Sub-Base Course)

3.2.1.2 Grain Size Analysis Sub-base material:

For the Bub-base materials Cu =22.5, which is greater than 4 shows a wide variation of size particles, Cc =2. 5, indicates well graded particle. According to USCS, the % of sand retained above 2mm was greater than 15% so; sub-base material at is classified as well-graded gravels with silt.

3.2.1.3 Grain Size Analysis Subgrade soil material:

The **Subgrade** materials taken from all failed sections, the samples are classified as Clay sand.

3.2.2 Atterberg's limit test results

Table 3.5 Atterberg's limit test for Base course, Sub-base and Sub-grade materials is tabulated in the following table.

Type of failure	Base-course			Sub-base			Sub-grade		
	LL	PL	PI	LL	PL	PI	LL	PL	PI
Reflective crack	3.9	0	3.9	24.8	22.5	2.3	33.3	13	20.3
Pothole	3.5	0	3.5	24.5	18.6	5.9	49.9	24.6	25.3
Rutting	3.7	0	3.7	24.4	21.1	3.3	56.2	26.1	30.1
Alligator crack	4.2	0	4.2	19.5	15.6	3.9	52.4	28.8	23.6
Block Crack	5.9	0	5.9	22	17.6	4.4	52.6	24.6	28
Non-distress pavement	5.8	0	5.8	22.1	18.5	3.6	60.5	33.1	27.4

3.2.2.1Atterberg's limits analysis

□ For base course (i.e. LL < 25% and PI <6%), it satisfied the specification; grouped into A-2-4 in AASHTO soil classification system and USCS as poorly graded gravels with sand (GP).

□ For sub-base course (i.e. LL < 35% and PI <25%), it satisfied the specification; grouped into A-2-4 in AASHTO soil classification system and USCS as well-graded gravels with clay (GW-GC).

□ For sub-grade soil (i.e. LL < 80% and PI <55%), it satisfied the specification; grouped into A-7-6 in AASHTO soil classification system and USCS as Clay sand with gravel (SC).

3.2.3 California Bearing Ratio (CBR) Test analysis

Table 3.6 California Bearing Ratio (CBR) result

CBR Test	Base Course			Sub-base			Subgrade		
	Failure	Non-distress	ERA value	Failure	Non-distress	ERA value	Failure	Non-distress	ERA value
CBR values	39-59	65	>80	43-57	61	>30	9-13	14	>15
CBR swell	0.007-0.04	0.002	0	0.54-0.083	0.051	0.001	0.327-0.885	0.5104	0.2

The sub-grade strength class for CBR ranges with an average of 8% to 14%. This results can be classified as S_4.

3.3 Traffic Data

Table 3.6: Average Annual daily Traffic in Yebu –Agaro road section in 2005 (G.C)

Type of Vehicle	$AADT_o$ in one directional flow	Traffic Growth Rate(i)
Car	112	2.8%
Buses	200	5%
Trucks	292	4%
Truck and trailer	36	2%

Source: Ethiopian Road Asset Management System; Addis Ababa

Table 3.7: Result of Traffic Analysis

Vehicle Type	AADT (1-direction)	i	$AADT_1=AADT_o(1+i)^n$	T (Million)	DF	CESAL
Car	112	2.8 %	115.136	0.48	0.0004	0.000192
Buses	200	5%	210	0.964	0.48	0.135000
Trucks	292	4%	303.68	1.280	1.84	2.355200
Truck and trailer	36	2%	36.72	0.072	7.80	0.561600
(CESAL)total=3.052 Million Axles						

3.4 Laboratory compaction test result

□ The **Base course** laboratory test maximum dry density was in the range 1.76g/cm3 to 1.84g/m3 while the optimum moisture content from 7.57% to 8.43 %.

□ Likewise, the **Sub- Base course** laboratory test maximum dry density was in the range 1.71g/cm3 to 1.84g/m3, while the optimum moisture content ranges from 7.21% to 10.33 %.

□ The **Subgrade soil** laboratory test maximum dry density was between 1.67g/cm3 to 1.71g/m3 while optimum moisture content ranges from 13.68% to 20.06%.

3.4.1 Compression of Field density and laboratory compaction test of subgrade materials

The moisture contents in failed sections (6.36% to 12.3%) and non-distress pavement (3.56%) were found out to have an increase of moisture content in the field than the optimum moisture content obtained in the laboratory test. This is due to poor drainage during the rainy season and due to infiltration through the cracks and pothole on the road surface. At the same time, decrease in dry density is observed. The compaction at section at failures section (81.58% to 85.51%) and non-distress (89.13%) The decrease in dry density could be due to the increase of moisture content above the optimum or due to poor compaction effort during construction.

3.4.2 Compression of Field density and laboratory compaction test of sub-base materials

The moisture contents at failed section showed 20.81% to 27.3% and non-distress pavement of 20.07% increased of moisture content in the field than the optimum moisture content obtained in the laboratory test. This finding was due to poor drainage during the rainy season and due to infiltration through the cracks and pothole on the road surface. At the same time, decreased in dry density is observed. The compaction at failed sections ranges from 79.37% to 83.3%, and non-distress of 84.5%. The decrease in dry density could be the effect of the increase of moisture content above the optimal or due to poor compaction effort during construction phase.

3.4.3 Compression of Field density and laboratory compaction test of Base course materials

The moisture contents at failed sections from 24.57% to 33.53% and non-distress pavement of 21.45%. There was an increased of moisture content in the field than the optimum moisture content obtained in the laboratory test. This was due to poor drainage during the rainy season and due to water infiltration through the cracks and potholes. While the compaction at failed sections from 68.78% to 71.24% and non-distress section of 75.43%. The decrease in dry density could be caused by the increased of moisture content due to poor compaction effort during construction similar with the subbase material problem.

3.5 Dynamic Cone penetration test results

Table 3.9: Comparison of Results (Dynamic Cone Penetration Test results and Laboratory Test results)

Type of Failures	Layer Types	Av. Rate DCP (mm/blow)	The DCP value of CBR (%)	CBR (%) Test of Laboratory Value at 2.54mm
Reflective Crack	Base Course	3.00	73	51
	Sub-Base	5.00	61	52
	Subgrade	24.65	7	13
Pothole	Base Course	4.00	58	39
	Sub-Base	6.00	42	53
	Subgrade	21.20	9	11
Rutting	Base Course	3.00	69	59
	Sub-Base	6.00	41	67
	Subgrade	21.40	9	11
Alligator Crack	Base Course	3.00	63	55
	Sub-Base	7.00	46	43
	Subgrade	22.35	10	8
Block Crack	Base Course	4.00	65	56
	Sub-Base	6.00	46	54
	Subgrade	21.95	11	13
Non-distress pavement	Base Course	3	77	56
	Sub-Base	6	48	61
	Subgrade	19.15	11	20

3.6 Types of failures and proposed remedial measures along road Section of study area.

Table 3.10: Observed most common type of distresses on asphalt pavement and its remedial measures

TYPE OF DISTRESS	POSSIBLE CAUSES	SUGGESTED MAINTENANCE WORKS
Reflective cracking	□ Differential movement between the asphalt and concrete layers and can deteriorate further under heavy traffic.	Crack seal/fill
Pothole	□ Continued deterioration of another type of distress, such as cracking, raveling, or a failed patch after pieces of the original pavement surface have been dislodged □ Weak spots in the base or subgrade Severity of the surrounding distress and traffic action accelerate potholes	Temporary repair through filling it with a pre-mixed asphalt patching material. Permanent repair through filling it with new base and surface material
Rutting Crack	□ Consolidation or lateral movement of any of the pavement layers or the subgrade under traffic. □ Insufficient design thickness □ Lack of compaction □ Weaknesses in the pavement layers due to moisture infiltration Weak asphalt mixtures	Cold mill and overlay or thin surface patch
Alligator crack	□ Excessive loading , Weak surface, base, Thin surface or base and Poor drainage	Full-depth patch
Block Crack	□ Mix was placed too dry □ Fine aggregate mix with low penetration asphalt & absorptive aggregates □ Aggravated by high traffic volume	Any surface treatment or thin overlay
Raveling	□ Lack of compaction, construction of a thin lift during cold weather, dirty or disintegrating aggregate, too little asphalt in the mix, or overheating of the asphalt mix.	Surface treatment, such as seal coating, surface dressing, thin overlaying of surface

4 CONCLUSIONS

Based on the pavement condition survey and laboratory test results, the following conclusions are drawn:

The pavement condition along the study area has been affected by different failure types such as cracks, disintegrating, surface defect and other factors related to road pavement deterioration. It was revealed that routine and periodic maintenance activities were not undertaken regularly along the study area. For the subgrade soil, the results of the investigation along Yebu-Agaro road showed that the road pavement structures are described under the A-2-6 and A-7-6 category of soils. This means that the soils is from fair to poor subgrade materials according to AASHTO and USCS, of which categorize the soil into Clay sand (SC). The liquid limit varies from 33% to 60.5% and Plasticity index of 20.3% to 30.1%. The soaked CBR values of subgrade soil materials shows from 8% to 13% as compared with 15% minimum specified. Therefore, the failures frequently observed on the road surface are not significantly influenced by subgrade soil.

On the other hand, the CBR value of subgrade soil, the value ranges 8% to14%. According to the ERA road design manual, the thickness of the base course and sub-base course for traffic class T5 with ESAL of 3.0-6.0 million should be at least 20cm and 25cm, respectively. The average thickness of the existing road layer of the base course is 12.2 cm, while the sub-base course is 14.8cm. Hence, the base and the sub-base course will not be able to carry the traffic loading throughout its service life. At this point, the traffic load may be one of the major causes of road failures along study area.

The moisture contents in failed sections with values ranging from 6.36% to 12.3% and non-distress pavement of 3.56% were due to the increase in moisture content in the field which was more than that of OMC obtained in the laboratory test. This is due to poor drainage condition during the rainy season, while the infiltration of rain water through cracks and pothole on the road surface were imminent leading to a decrease in dry density was observed. Tthe compaction at failed sections showed 81.58% to 85.51% and non-distress of 89.13%. Therefore, the decrease in dry density may be caused by the increase of moisture content above the optimal or due to poor compaction effort during construction.

The materials used for the sub-base layers satisfied the minimum standard requirements, but not on thickness as per approved design during the construction. From the investigation, it was found that the base course material along Yebu-Agaro Road section did not satisfy the standard requirements set by ERA which was observed as one contributory factor to the pavement damage.

However, in order to correct those noted deficiencies in the research project area, the following are suggested:

□ Scarification and reconstruction of the distress road section specially the affected areas by raveling. The sections with various sizes of potholes should be patched with good quality asphalt and distress sections of pavement with poor material due to drainage problems should be removed and replaced to required depth. Adequate longitudinal drainage, cross drainages and other drainage facilities should be provided in order to control the drainage problem. Seal coats shall be applied to prevent infiltration of water through cracked surfaces.

□ The influence of other factors such as poor drainage courses, the level of the groundwater table, variety of geologic materials along the road route and poor construction materials should be thoroughly addressed before beginning rehabilitation the road section in the future.

- Timely pavement maintenance practices should be employed to reduce pavement failure.
- Detail investigation should be carried out in project areas; also the properties of material and method of construction should be according to the design specification of the project in order to serve the design period of a project in order to avoid the failure.
- It is further recommended that in-depth investigation should be undertaken on the other parts of Ethiopia, where asphalt pavement is to be constructed with similar soil types and topography to avoid similar problems that have been encountered within the study area.

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