American Journal of Civil Engineering
2023; 11(4): 44-53
http://www.sciencepublishinggroup.com/j/ajce
doi: 10.11648/j.ajce.20231104.12
ISSN: 2330-8729 (Print); ISSN: 2330-8737 (Online)

An Experimental Investigation on the Causes of Flexible Pavement Failures: A Case Study on Tarcha - Yalo Road Section

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To cite this article:
Hailemichael Debalke Damota, Abel Tesfaye, Anteneh Geremew. (2023). An Experimental Investigation on the Causes of Flexible Pavement Failures: A Case Study on Tarcha - Yalo Road Section. *American Journal of Civil Engineering*, *11*(4), 44-53. https://doi.org/10.11648/j.ajce.20231104.12

Received: January 2, 2023; **Accepted**: October 31, 2023; **Published**: November 24, 2023

Abstract: This study has been conducted on Tarcha-Yalo Road segment. The objective of this study is to investigate the causes and remedial measures for asphalt pavement distresses. To meet the objective a systematic methodology is used to investigate field survey and laboratory tests were carried out. Soil samples were collected using purposive techniques of sampling from severely damaged and non-damaged sections. Severely damaged section distresses were corrugation, block cracking, ravelling and stripping. Based on selection, the representative samples of soil was collected for the three failed and two non-failed section from the study area. The condition survey has been conducted for the evaluation of pavement condition and the average PCI of the study area fall in the average PCI value indicates the pavement performance condition of the total road length (47.4 km) is under category of good (60%) and very good (40%) condition of pavement condition rating. Average thicknesses of each layer of failed sections were measured and Asphalt 2.13cm, base course 10.5cm, and sub-base 11.67cm. And the average thicknesses of non-failed sections were 3.35cm for asphalt, 9cm for base course and 12.5 cm for sub base. According to AASHTO and Unified Soil Classification of soil Subgrade was A-7 and SC, sub base A-2-4 and GP and base course A-1-a and GW respectively. An average LL, PL and PI of failed sections of base course (5%, 0%, 5%), sub-base (33.33%, 25%, 8.33%) and subgrade (52.5%, 31.33%, 21.33%) whereas an average LL, PL and PI of the non-failed sections were (4.5%, 0%, 4.5%), (35.5%, 25.5%, 10%) and (46.5%, 33%, 13.5%) for base course, sub base and sub grade materials respectively. Compaction (MDD (g/cc), OMC (%)) of failed section of base course (1.73, 10.92), sub base (1.67, 12.23) and sub-grade (1.58g/cc, 20.33% whereas the non-failed sections were (1.76, 9.95), (1.74, 11.1), (1.65, 14.4) for base course, sub base and sub grade respectively. The CBR% of base course 80%, sub-base 60% and sub-grade 9% obtained. The Los Angeles Abrasion test values of sub base and base course were sampled with two trials of tests for each. Based on the laboratory test result and condition survey the pavement failure is due to insufficient thickness design, improper compaction, heavy traffic load, and poor drainage, absence of shoulder and poor-quality of construction materials. Finally it is recommended that the periodic maintenance such as fog seal, slurry seal and crack sealing for failed section in Tarcha-Yalo road section.

Keywords: Pavement Distress, Distress Type, Laboratory Tests, ERA 2013, Condition Survey

1. Introduction

Transportation infrastructure plays an important role in a country's economic growth and development of any country in the world. Transportation infrastructures are land transportation infrastructure, water transportation infrastructure and air transportation infrastructures. The major accessible transportation for whole society of any country people day today activities is land transportation and it is either paved or unpaved roads. Currently, the construction industry is one of the biggest industries in Ethiopia contributing 10% to Gross domestic product (GDP). This industry is an enormously important part of economic growth of the country. The economic growth of the country depends on availability and utilization of physical infrastructures. Reports indicate that about fifty eight percent (58%) of the federal capital budget of Ethiopia is consumed by the construction industry mainly by the road subsector that generates significant employment opportunities. It needs to be emphasized that road construction in Ethiopia is the means through which development are achieved. Growth in agricultural output, which will constitute the primary basis for growth in the economy of Ethiopia, is dependent on transport availability, mainly road transport-, which needs to be efficiently integrated with the rural communities as well as with the urban centers.

Considering the impacts of road transport on the growth of the economy of the country, the Ethiopian urban and rural road networks needs an effective way of management practice to enhance cost efficiency, serviceability and performance quality. Road construction and utilization in Ethiopia are the means through which development strategies are achieved. As Ethiopia is economically growing significantly during globalized age, it needs the entire construction infrastructure to be well integrated to bring a fast and outstanding economic development [1].

The largest highway and road network in the world consists of flexible pavement. Even if the highways are well designed and properly constructed, they may still require maintenance, the extent of which depends on various factors, including the type of pavement. Functional deterioration is manifested by a change in the surface condition of the pavement in the form of deterioration in ride quality, which can be measured by simple methods; it is also possible to restore the pavement to its original condition by applying a profile correction layer and a new surface course. Normally, the term pavement refers only to the surface course. However, in highway design, it means the entire thickness of the pavement, including the surface course, base course, and subgrade. It is a hard and tough crust built up over the natural subgrade to provide a stable and level or apartment surface for vehicles. It is a structure consisting of superimposed layers of material over the natural subgrade that's primary and most important function is to transfer and distribute the axle loads of vehicles to the subgrade. The structure of the pavement should provide acceptable ride quality, adequate skid resistance, and minimal noise pollution [13].

Failure of flexible pavements is common in worldwide due to design, material quality, changing traffic volumes, and environmental factors. Researchers recognized that the cause of flexible pavement failure depends on traffic load, environmental factors, drainage problems, material quality problems, defects in workmanship, etc. Flexible pavements are affected by many factors that affect their functional performance and serviceability performance. Factors such as excessive traffic loads, temperatures, water, design and construction errors, and lack of maintenance cause flexible pavements to deteriorate rapidly over time [2]. The main causes of asphalt pavement failure are fatigue cracking caused by excessive vertical compressive and horizontal tensile stresses in the upper subgrade and lower portion of the asphalt layer due to repeated traffic loading, and rutting deformation caused by compaction and shear deformation of the subgrade. Excessive vertical surface deflections in flexible pavements have always been a major problem and are used as a criterion for pavement design [3]. The pavement structure is a combination of subgrade, base course, and surface course applied to a subgrade to carry the traffic load and distribute it to the road subgrade [2]. The effect of poor drainage on pavement condition increases moisture content and decreases pavement strength. Therefore, poor drainage leads to premature pavement failure [4]. Similarly, under the combined effect of traffic, environment and climatic conditions, road pavements tend to crack eventually [5].

In Ethiopia, recently constructed roads are reported to deteriorate rapidly after being opened to traffic. This includes excessive loads, climatic changes, poor drainage, and inferior pavement materials. Recently, pavement damage has been a major problem, unnecessarily delaying traffic flow, affecting pavement esthetics, causing vehicle breakdowns, and most importantly, causing traffic accidents that have resulted in loss of life and property [6]. This damage affects pavement safety and ride quality by causing premature failure and traffic hazards. Most of the factors that lead to deterioration of pavement conditions are structural problems, poor quality of material, improper use of flexible pavements, and maintenance problems. Therefore, this case study aims to identify the causes of deterioration of flexible pavements. In addition, the study seeks to explore the causes of various deteriorations of flexible pavements by considering laboratory testing of pavement construction materials such as subgrade, base, and sub-base, as well as other road-related factors to determine the effects of these parameters on pavement deterioration. The results would help Ethiopian road authorities in the initial identification of various forms of pavement deterioration and determine the need for maintenance measures and activities. They need more help in early repair or maintenance and in assessing the future financial needs required to keep the road functional. [7]

Developing countries have lost billions of dollars' worth of valuable infrastructure due to the deterioration of their roads. If their governments do not do much to maintain their roads, they will lose billions more. Major road networks built at great expense have not been adequately maintained and have been used and abused more than expected. If this continues, the deterioration of roads will increase rapidly as the old pavements crumble and the new ones outlast the initial period when the effects of neglect are barely felt [11]. Ethiopia is covered by different soil types. Currently, various construction activities are taking place in the road and construction sectors on different soil types. It was found that construction on some soils faces numerous problems and the causes of these problems are not studied in depth in Ethiopia. The factors affecting road deterioration are very complex in nature and vary from place to place [12]. Therefore, a thorough study of the deterioration mechanisms in different climates and soil conditions is needed before arriving at a definitive strategy for road improvement. We are aware of the need for a detailed study that includes all types of roads in the country with different traffic and soil conditions [8]. Most roads built in Ethiopia on any type of soil fail before their expected life span, in some cases even within a few months of their completion. Ethiopia's economic growth is highly dependent on the agricultural sector [6]. Therefore, development efforts to change the existing socio-economic conditions of the country will also depend on the efficiency of this sector in the foreseeable future. However, better performance of the agricultural sector and sustainable economic growth of the country as a whole would be achieved by improving the basic infrastructure. Consequently, the road network has been identified as a serious bottleneck to the country's economic development [8].

In Ethiopia, it is common to see flexible pavements along the Tarcha-Yalo Road highway corridor due to various causes that have not been investigated. These flexible pavements due to various causes lead to the following problems that will be investigated in this study. The road section of Tarcha-Yalo Road shows damage due to the following causes: Traffic load, climatic conditions, poor drainage, improper construction and others. This problem causes structural and superficial damage to the pavement, such as various types of cracks, surface deformation, some surface defects, and the decay of binders in the pavement. The condition of the vehicles is affected by these problems and causes damage to the vehicles, which in turn drives up maintenance costs and leads to traffic accidents. In addition, this leads to a reduction in the level of service (LOS) of the road, which also similarly leads to an increase in vehicle operating costs. This is the main problem of the study area.

In this study, an experimental investigation of flexible pavement construction materials is conducted to investigate the cause of flexible pavement failure. In order to achieve the objectives of this research project, all the requirements must be fulfilled, starting from the literature review, sample collection, conducting the appropriate laboratory tests and analyzing the results obtained from the input data. Finally, the results will be compared with already available specifications and then a conclusion and recommendation will be formulated for the stakeholders.

1.1. Statement of Problem

Construction of roads involves substantial investment and thus proper maintenance of those assets is of paramount importance in the world particularly developing country. The road user cost, comfort and safety are influenced to an outsized extent by its state of maintenance. The standard of roads may be a critical indicator of a nation’s economic vitality because a poor road transport system can constrain the situation of economic activity, hamper the mixing of economic markets, limit the gains from specialization and eventually become a serious barrier to growth and competitiveness. In developing countries, large road networks built at great expense, are inadequately maintained and used more heavily than the planning values [9]. The most deficiencies affecting our transportation system aside from inadequate capacity and insufficient pavement thickness include poor riding quality, weak and distressed bridges/culverts, congested sections, excessive axle loading, and lack of wayside amenities and enforcement. Among various modes, roads and road transport has come to occupy a dominant position within the transportation. Factors that contributed during this direction are flexibility, door to door service, reliability and speed [10].

A good road management is necessary, and maintenance and rehabilitation action must be taken with good timing. Pavement rehabilitation activities, though not as spectacular as the construction ones, are of major importance for development of transportation infrastructure. Major economic losses will continue unless improved capabilities for rehabilitation design are provided to meet today’s highway traffic needs, as most projects today include rehabilitation design. Improved pavement quality condition [11]. According to Yetnayet Bihon Semunigus [1] the road condition in Ethiopia about 52% was in poor condition from 1997-2014 and 22% was in good condition and about 26% is under fair condition. After one year the construction, it is common to see pavement distresses along the highway corridor from Tarcha-Yalo road section due to different uninvestigated causes. And these pavement distresses due to different causes lead to the following problems and they will be studied in this research.

1) The road section from Tarcha-Yalo road section shows different types of distresses which caused traffic operation costs because of traffic delay and less comfort and riding quality. This problem may leads to pavement structural and surface failures such as: different types of cracks, surface deformation, some surface defects and disintegration of pavement aggregate from binding materials. This is the main problem of the study area will be studied and the study is limited to field survey and laboratory investigation of pavement layers which is geotechnical properties of pavement layers such as subgrade, sub base and base course.
2) The travel time and speed of the vehicle at this highway section is affected due to the pavement defects leading to delays. During the delay, the consumption of vehicle fuel will increase and correspondingly emissions to the environment which causes air pollution and the delay of market and business interaction of societies. To evaluate pavement serviceability and functionality of the road (pavement performance), the pavement condition index evaluation will be carried on to define the serviceability of pavement.
3) Due to pavement distress, the condition of vehicles will be adversely affected causing vehicle damages resulting in increasing maintenance costs and this leads to traffic accidents. In addition, it leads to reduction of level of service (LOS) of the road which similarly leads to increases in vehicle operating costs.

1.2. Research Questions

The research questions to be answered and discussed in this study are listed below:

1) Which locations in the study area are most affected or severely damaged, including factors causing deficiencies?
2) What are the technical characteristics of the flexible pavement layers and how much do they vary from standard specifications?
3) What remedial measures are in place to improve the existing condition of the flexible pavement?

1.3. Objective

1.3.1. General Objective

The general objective of the study is to investigate the causes of defects in flexible pavements and their remediation on the asphalt concrete pavement in the highway section from Tarcha to Yalo.

1.3.2. Specific Objectives

1) Identify the locations of serious damage to flexible pavements and the factors that cause this damage.
2) Determine the existing technical characteristics of the pavement layers and compare them with standard specifications.
3) Propose remedial measures to improve the existing condition of the flexible pavement.

1.4. Significance of the Study

The purpose of this study is to investigate the causes of failure of flexible pavements in the structural layers (subgrade, base course, and sub base) using experimental studies of construction materials. Upon completion of the research, the following results are expected:

1) The causes of pavement failure on the Tarcha - Yalo road section will be investigated.
2) All of the above research questions will be answered.
3) The results of the study will be used by relevant government agencies, especially ERA, as well as other researchers.
4) The report of this study will be used as a supporting document for other related roads when they are engaged in similar projects.
5) Finally, appropriate remedial measures for pavement damage in Ethiopia in general and on the project and neighborhood roads in particular will be determined based on the results of this study.

1.5. Scope and Limitation of the Study

The objective of this study was to investigate the causes of failure of flexible pavements due to base course materials, sub base, subgrade and their geotechnical properties on the Tarcha - Yalo road section as a case study. In this context, laboratory tests on the engineering material properties (grading, compaction tests, CBR, Proctor tests (MDD, OMC)) and Los Angeles abrasion test will be performed on the selected highway section with a length of 51.2 km and the change in traffic volume compared to design will be evaluated. The laboratory tests will be conducted at the five proposed stations of the deficient section. Finally, possible remedial actions are proposed in relation to each cause of the type of deterioration. The study will be based on three test pits from the existing deteriorated roadway section and two test pits from the non-degraded roadway section.

Figure 1. *Flow chart showing study design.*

2. Materials and Methods

2.1. Material Required

The type of sampling technique used is a non-probability sampling technique (purposive sampling method) because most of the parts of roads in the study areas are not subjected to many distresses. The total number of populations of experimental is 9 samples for severely failed section of pavement and 6 samples for non-failed section of the selected route for laboratory tests, traffic volume change and the types of flexible pavement distresses existing road section was divided into five sections and total sample units that have been taken for condition survey were 37 within the range of study area which covers a distance of 47.4 km from Tarcha town to Yalo Rural town. The total sample population for experimental work is 15 and for condition survey or pavement condition evaluation was 37 sample units with spacing of 1km and the number of sample to be surveyed were 37 in numbers.

2.2. Study Design

An experimental comparative study design was employed in the current study as illustrated in Figure 1.

2.3. Sample Preparation Procedures

In this study, investigating the causes of pavement distresses along Tarcha to Yalo road in selected study areas was targeted on subgrade material, sub base, base course material and traffic volume count samples and pavement condition evaluation. These sample materials was to be collected from five study sections, from each Section one test pits used. Each test pit contains three layers (Base course, sub base course and sub grade material). Totally, fifteen samples are collected from different locations representing the more distress sections and the pavement condition survey was done along the selected study section. The selected route for condition survey was 37.5km. Representative Samples were collected as recommended in AASHTO and ERA 2013.

Figure 2. *Photo of Sampling and preparation of samples for laboratory tests.*

2.4. Laboratory Tests and Condition Survey

The type of sampling technique used is a non- probability sampling technique (purposive sampling method) because most of the parts of roads in the study areas are not subjected to many distresses. Due to the time and budget constraint, the study would not cover all portions of (routes) road along Tarcha to Yalo road for experimental study. Only selected three stations of representative sections, out of five stations which have more distress and two sections which have no defect will be considered. From that selected Section of study areas, subgrade material samples will be collected according to ERA guidelines. Thirty (30) kg samples of natural soil of sub-grade, sub-base, and base course material should be collected from study sections of the pavement layer, and traffic volume count will be taken along with the conduct of the pavement layers investigation and the axle load of traffic will be analyzed. And according to ASTM D6433, each section was divided into sample units with homogenous or equal length of 1000m. The type and severity of pavement distress was assessed by visual inspection of the pavement sample units. The distress data were used to calculate the PCI for each sample unit. The PCI of the pavement section was determined based on the PCI of the inspected sample units within the section. Therefore, road was sectioned in five different sections as shown in Table 1. The sections were

37.5 km and total sample units were 37 and the number of sample to be surveyed were 37 with spacing of 1km.

Table 1. *Sections of study area in condition survey and laboratory sample collection.*

Station of road section to be surveyed	Road Section to be surveyed	Start point location			End point location			Length of the road section
		Latitude	Longitude	Altitude	Latitude	Longitude	Altitude	
63+800-70+800	Tarcha-Turi	7º09'15.12''N	37º10'06.3''E	1324m	7º07'13.45''N	37º11'11.68''E	1696m	7.0km
80+800-89+800	Waka-Tulema	7º03'41.13''N	37º11'04.02''E	2431m	7º00'45.09''N	37º14'16.14''E	2364m	9.0km
89+800-97+000	Tulema-Gesa	7º00'45.09''N	37º14'16.14''E	2364m	7º00'30.270''N	37º16'14.67'E	2237m	7.2.0km
97+000-103+300	Gesa-Elabacho	7º00'30.27''N	37º16'14.67'E	2237m	6º58'53.51''N	37º18'0.71''E	1769m	6.3km
103+300-111+300	Elabacho-Yalo	6º58'53.51''N	37º18'0.71''E	1246m	6º56'50.3''N	37º20'09.83''E	1278m	8.0km

2.5. Standards and Specification for This Study

Table 2. *Standards and Specification for this Study.*

S.no.	Tests to be performed	Codes and designation
1	Subgrade Preparation of disturbed sample	AASHTO-T_87 or ASTM-D-
1.1	Compaction tests	AASHTO-T_180 or ASTM-D-1557
	Atterbergs limit	
1.2.	Liquid limmit	AASHTO-T_89 or ASTM-D-4318
	Plastic limit and Plastic index	AASHTO-T_90 or ASTM-D-424
1.3.	Gradation soil	AASHTO-T_88 or ASTM-D-422
1.4	California Bearing ratio test	AASHTO-T_193 or ASTM-D-1883
1.5	Gradation sub base and base course	AASHTO-T_27 or ASTM-C-136
1.6	Los Angeles abrasion test	AASHTO-T_96 or ASTM-C-535-89

3. Result and Discussions

3.1. Condition Survey

The condition survey of the selected road segment was subdivided into five sections of road segments. The sections of segments Tarcha-Turi (19%), Waka-Tulema (24%), Tulema-Gesa (19%), Gesa-Ellabacho (16%) and Ellabacho-Yalo (22%). The survey was carried along the five subdivided sections and different types of flexible pavement distresses were viewed and observed. Distresses observed along the sections were alligator cracking, block cracking, depression, shoving, corrugation, polishing, edge cracking, edge drop off, rutting, raveling, transverse and longitudinal cracking, potholes and bleeding. Among the observed distresses Alligator cracking, potholes, bleeding, edge cracking, rutting and raveling were majorly dominant whereas depression, block cracking, shoving and polishing were moderately dominant and transvers and longitudinal cracking, edge drop off and corrugation were the least dominant.

3.1.1. Pavement Condition Index Evaluation

The average value of PCI of Tarcha-Turi section (79.71%), Waka-Tulema section (65.33%), Tulema-Gesa section (84.14%), Gesa-Ellabacho section (62%) and Ellabacho-Yalo section (69.9%) and these values were under rating of pavement condition was good and very good in which the 60% was good and 40% was under very good. The PCI value indicates the pavement performance condition of the total road length (47.4 km) is under category of good (60%) and very good (40%), that is the average result of the five sections were fall in good and very good condition of pavement condition rating.

According the findings of the results from pavement distresses the dominant failures were structural and material failures. The structural failures were subjected to traffic load because the thickness of the pavement structures obtained in the field are not enough to withstand the traffic loads and the material factors were subjected to constructions condition and laboratory result influences because the compaction and material quality of sub grade and base course in failed section are not satisfied the ERA and AASHTO specifications. The construction was in progress of construction and the distresses were premature which implies the structural and environmental related problems should be the best concern and are the causes for failures.

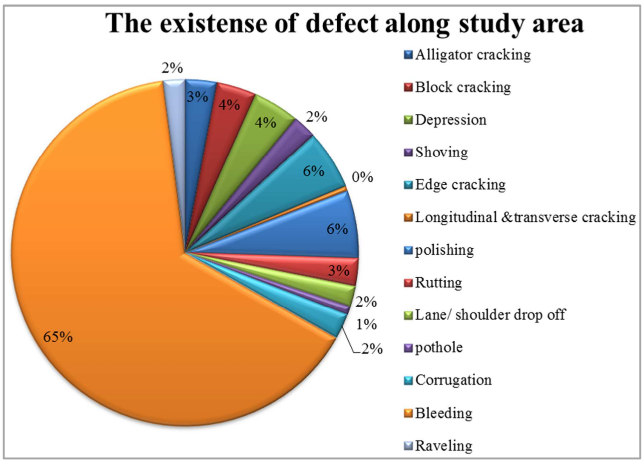

Figure 3. *Pavement distresses distribution percentage.*

3.1.2. Drainage and Shoulder

From condition survey observation the road has sever drainage problem in Tarch Town-Turi and Gesa Town-Ellabacho and the whole road missed proper shoulder and drainage. Ditches and shoulder are important drainage structure for pavement performance. In the study area the field survey result shows the consideration construction of drainage and shoulder is in bad condition.

According to ERA manual shoulder provides the structural function of road pavement; providing lateral support for pavement layers. It is also helps the removal of surface water from road surface and facilitates the internal drainage of the pavement structures. Shoulder is especially important when unbound materials are used in pavement structures. From functional point of view the minimum width of the shoulder is 1m but in the study area there were no shoulder even in town area. So the drainage problem in Tarcha-Yalo road segment may be because of miss of shoulder and ditches.

The design of pavement is mainly depends on traffic load. From the traffic analysis made, the cumulative standard axle loads of traffic in the study area is 9.55 million. From ERA 2013 pavement design manual the traffic class is ranged in 6-10 million which is T6. The thickness of the embankment of subgrade layer and subgrade strength are based on the T6. From the CBR test result CBR of sub grade is 8 and in ERA pavement design manual the strength of subgrade is ranged in between 8-14% which is S4.

3.2. Laboratory Tests

The laboratory investigation was carried on five stations of severely damaged and non-failed stations. The geotechnical properties of sub grade, sub base and base course materials were tested. The tests were sieve analysis, compaction tests, atterberg limits, and CBR and Los Angeles abrasion tests.

3.2.1. Gradation Analysis

Comparing the laboratory test results for gradation with that of the specification for Base, and sub base materials and to determine the percentage of gravel and sand from grain size curve depending on percentage of fines (fraction smaller than 75micron sieve size) coarse grained soils are classified as follows: less than 5%: GW, GP, SW and SP. And more than 12%: GM, GC, SM, and SC. 5%-12% border line case required use of dual symbols. According to Unified soil classification system:-

1) In case of base course materials Cu =55.1, which is greater than 4 shows a wide variation of size particles. Cc =5.60, indicates well graded sand particles, According to USCS, base material is classified as well graded sand with gravel.
2) For the sub-base materials Cu =50.78, which is greater than 4 shows a wide variation of size particles, Cc =2.04, indicates well graded gravel particles. According to USCS, the sub base material is well graded gravel with sand.
3) The subgrade materials are classified as A-2-7, A-4 and A-5 according to AASHTO soil classification system.

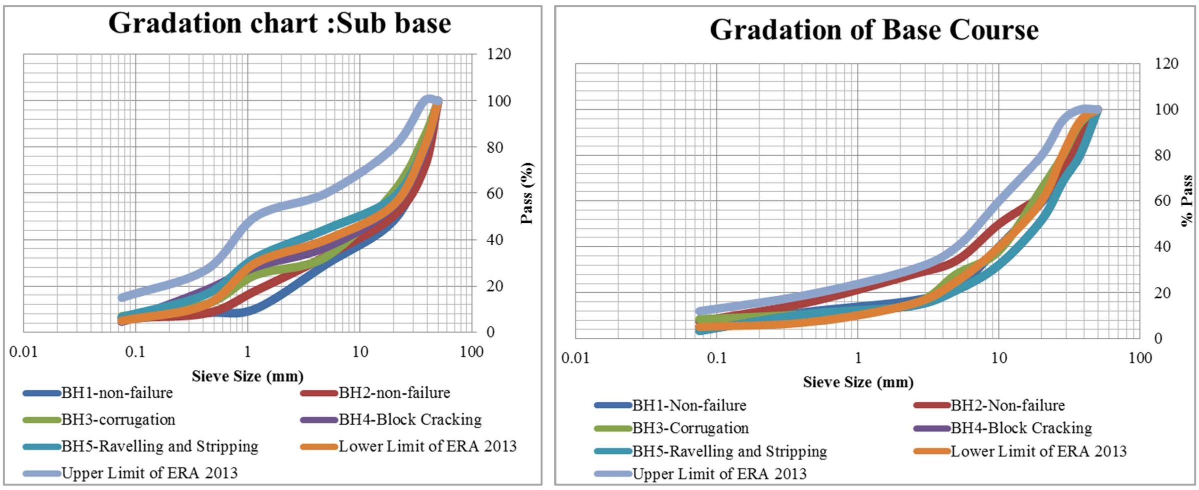

Figure 4. *Gradation curve of Sub Grade, Sub Base and Base Course.*

Based on to Ethiopian road authority manual 2013, pavement design manual conventional aggregate was classified as graded crushed stone (GB1) and the grading limit of this material for 37.5mm nominal maximum aggregate size was used. As it was observed from the result Figure 3 above, RAPA contains a higher courser than that of a crushed natural aggregate compared to GB1 base course material standard depending on the milling and stockpiling operation. The result recorded above also above shows the ceramic waste aggregates fall within the limit. Generally, the Table 2 and Figure 3 reveal that the gradation results of CSA, RAPA and CWA were between upper and lower limits and recommended to use as GB1 according to ERA specification. So, the gradation was accepted and suitable for the pavement construction materials.

3.2.2. Atterberg Limit Test Discussion

The laboratory result shows as the average results of liquid limit, plastic limit and plasticity index of sub grade, sub base and base course.

1) The average liquid limit of sub grade soil is 55%, the plastic limit is 32% and plasticity index is 23%. According to AASHTO system the percentage passing No. 200 (39.36%)>35%, LL>41 minimum and PI>11

minimum satisfies the A-7-6 and USCS system the sub grade soil is classified as clay sand with gravel (SC).

2) The average liquid limit of sub base is 34%, plastic limit is 25% and plasticity index is 9%. According to AASHTO system the percentage passing No. 200<35%, LL<40%, and PI<10% satisfies the A-2-4 and USCS system the sub base soil is classified as poorly graded gravel with sand silt (GP).
3) The average liquid limit of base course is 5%, plastic limit is 0 and plasticity index is 5%. According to AASHTO system the Sieve analysis percent passing No. 10 < 50% max, No. 40 <30% max, No. 200<15% max and PI <6%) satisfies the A-1-a and USCS system the base course soil is classified as poorly graded gravel with sand silt (GP).

Table 3. *Soil classifications according to AASHTO and Unified soil classification system.*

Test pit No	Pavement layers	Atterberg limit			AASHTO classification	Unified system soil classification
		LL	PL	PI		
	Base course	4.5		4.5	A-1-a	GP
BH1	Sub base	33	26	7	A-2-4	GW-GS
	Sub grade	45	32	13	A-7-5	MC-SC
	Base course	4.5	0	4.5	A-1-a	GP
BH2	Sub base	38	25	13	A-2-6	GW
	Sub grade	48	34	14	A-2-7	CG-GS
	Base course	5.0	0	5.0	A-1-a	GP
BH3	Sub base	37	29	8	A-2-4	GP-GM
	Sub grade	53	27	26	A-2-7	CG-GS
	Base course	4.0	0	4.0	A-1-a	GW
BH4	Sub base	31	26	5	A-1-b	GP-GS
	Sub grade	57	34	23	A-2-7	CG-GS
	Base course	6.0	0	6.0	A-1-a	GP
BH5	Sub base	32	20	12	A-2-6	SW-GC
	Sub grade	48	33	15	A-7-5	MC-CS

3.2.3. Compaction Test Results

The laboratory test result showed in the table----the average MDD and OMC of sub grade, sub base and base course to be compared with standard specifications.

1) The sub grade soil material MDD is 1.64 g/cm^3 and OMC 17.95% which do not meet standard specification (MDD>1.76g/cm^3)
2) The average MDD and OMC of sub base is 1.67g/cm^3 and 11.75% respectively
3) The average MDD and OMC of base course is 1.76 g/cm3 and 10.45% respectively which do not meet the standard specification. (MDD>2g/cm3)

Table 4. *The compaction data.*

Test pits	stations	subgrade		sub base		basecourse	
		MDD g/cm3	OMC in %	MDD g/cm3	OMC in %	MDD in g/cm3	OMC in %
BH1	63+900	1.64	19	1.63	13.5	1.81	11.5
BH2	83+400	1.66	9.8	1.83	8.7	1.71	8.4
BH3	89+800	1.56	22	1.76	12.4	1.84	10.95
BH4	97+000	1.57	18.5	1.65	10.8	1.64	10.4
BH5	103+300	1.61	20.5	1.62	13.5	1.72	11.4

3.2.4. California Bearing Ratio (CBR) Test

ERA Pavement Design Manual volume I, the recommended soaked CBR value subgrade materials is greater than 5%, for sub base is greater than 30% and for base course is greater than 80%. The laboratory test results given in Table, the CBR of the sub grade material use ranges from 8%-15% the subgrade strength class for CBR range on average 8%-16%. Since most of the laboratory results lay on the range 8%-16% it can be classified as S4. The CBR value sub base materials presented in table the CBR value ranges 39%-91%. Therefore the result satisfies the requirements stated in ERA 213. And the base course materials presented in table 4 the CBR value ranges 59%-92%. Therefore the two selected station BH4 and BH5 are failed to satisfy the requirements stated in ERA 213.

Table 5. *Laboratory CBR Result Data.*

Test pits	Blows	Sub grade			Subbase			Base cours		
		2.54mm	5.08mm	Ave.CBR	2.54mm	5.08mm	Ave.CBR	2.54mm	5.08mm	Aver.CBR
BH1	10	6	7	6.5	14	25	20	23	20	21.5
	30	7	10	8.5	23	25	24	38	45	41.5
	65	10	14	12	39	45	42	90	95	92.5
	Aver.CBR			9	Aver.CBR		29	Aver.CBR		51.8

Test pits	Blows	Sub grade			Subbase			Base cours		
		2.54mm	5.08mm	Ave.CBR	2.54mm	5.08mm	Ave.CBR	2.54mm	5.08mm	Aver.CBR
BH2	10	7	7	7	17	26	22	20	23	21.5
	30	9	9	9	60	62	61	49	67	58
	65	15	15	15	73	90	82	86	95	90.5
	Aver.CBR			10.3	Aver.CBR		55	Aver.CBR		56.7
BH3	10	4.7	5	4.85	13	17	15	22	24	23
	30	5.5	6	5.75	61	64	63	40	46	43
	65	7	7.5	7.25	91	95	93	92	95	93.5
	Aver.CBR			5.95	Aver.CBR		57	Aver.CBR		53.2
BH4	10	8	9	8.5	22	26	24	23	26	24.5
	30	10	12	11	47	66	57	46	66	56
	65	13	13	13	60	83	72	59	84	71.5
	Aver.CBR			10.8	Aver.CBR		51	Aver.CBR		50.7
BH5	10	4.6	4.6	4.6	18	21	20	18	23	20.5
	30	5.5	6.6	6.05	58	63	61	56	64	60
	65	7	7	7	77	95	86	74	91	82.5
	Aver.CBR			5.88	Aver.CBR		55	Aver.CBR		54.3

3.2.5. Los Angeles Abrasion Test

The laboratory test results of sub base and base course were sampled with two trials of tests for each. The result of sub base abrasion resistance loss is 30.97%which is less than 40% that is the standard specification in ERA 2013. Hence it fulfills the requirement. And the result of base course is 28.97% which is less than 35% that is standard specification in ERA 2013. Hence it satisfies the requirements.

4. Conclusions

From the test results as well as the analysis and discussion the following conclusions were drawn:

1) The laboratory results of sub grade materials of LL varies from 48%-68%, PI varies 15%-34%, the CBR value varies 9-15% and according AASHTO soil classification system the soil classification underlined in A-2-7 and A-7-5. And also according to USCS system of soil classification it is silty clay with clay sand. From ERA manual 2013 the liquid limit of subgrade does not exceed 50%. The failed sections of the study area does not meet the specification. Hence the sub grade would cause the failure.
2) The laboratory result of sub base materials of LL varies 31%-38%, PI varies from 20%-29% and the CBR varies from 39%-91%. According to ERA 2013 the sub base material should fulfill the seasonally wet tropical climate area specification requirements. In seasonally wet tropical climate region area the liquid limit of sub base material should be less than 45% and the plastic index should be less than 12%. Hence the sub base material failed of the requirement specification recommended ERA 2013 pavement design manual.
3) The laboratory result of base course materials of LL varies 4.4%-6%, PI varies from 4.4%-6% and the CBR varies from 69%-91%. The CBR value of BH-4 (69%) and BH-5 (74%) failed the ERA recommendation that the CBR value of base course materials should be greater than 80%
4) The insufficient thickness of sub base and base course material influence the proper distribution of stresses and direct stresses application to sub grade.
5) Lack of shoulder and proper management of drainage concern is also the cause of failure.
6) The high liquid limit and moisture content of sub grade influence the bondage of materials of pavement structures and causes failure because it results in reduction of material strength, increase in deformation, facilitate degradation of materials quality.
7) The gradation of sub base and base course materials shows below the specification of ERA standard that the material binding and bondage problem is also the cause of failure.
8) The compaction tests of all layers were below the specification in ERA and it is also the cause. This is because the improper compaction results voids between particles of pavement structures and when the heavy traffic load applied it results in deformation and cracking.
9) The laboratory test results of sub base and base course were sampled with two trials of tests for each. The result of sub base abrasion resistance loss is 30.97%which is less than 40% that is the standard specification in ERA 2013. Hence it fulfills the requirement. And the result of base course is 28.97% which is less than 35% that is standard specification in ERA 2013. Hence it satisfies the requirements.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

Firstly and for all, my thanks favors to Almighty God, with his endless mercy and for giving me Peace and power to execute my research work. Secondly, I would like to express my sincere gratitude to my Advisor Ass. prof. Anteneh Geremew and my co advisor Eng. Abel Tesfaye for his valuable guidance throughout the proposal work and their unlimited support.

I also have grateful concern to thank my lovely wife Mihret Manjore for her great support and motivation for me to succeed my work and finally I have thanks to my friends Eferem Aysa, Afras Abera, Kenfesha Kebede, Mengistu Mengesha, Mekonnen Tadese, Dr. Andualem Tonamo and Eshetu Omoshe for their support of my data collection works and all other my colleagues and friends and families.

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