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JIMMA UNIVERSITY SCHOOL OF GRADUATE STUDIES JIMMA INSTITUTE OF TECHNOLOGY FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING HIGHWAY ENGINEERING STREAM

AN EXPERIMENTAL INVESTIGATION ON THE CAUSES OF FLEXIBLE PAVEMENT FAILURES: A CASE STUDY ON TARCHA – YALO ROAD SECTION.

A Thesis is submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Highway engineering.

By

Hailemichael Debalke Damota

May, 2023

Jimma, Ethiopia

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Main Advisor: Anteneh Geremew (Assi.Prof.)

Co-advisor: Engr. Abel Tesfaye (Msc)

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DECLARATION

I, the undersigned declare that this research entitled "AN EXPERIMENTAL INVESTIGATION ON THE CAUSES OF FLEXIBLE PAVEMENT FAILURES: A CASE STUDY ON TARCHA-YALO ROAD SECTION**"** is my original work and has not been presented by any other person on an award of degree in this or other university and all sources of materials used for this thesis have been duly acknowledged.

Candidate: Hailemichael Debalke Damota ________________ 30-07-2023

Signature Date

As masters research advisors, we hear by certifying that we have read and evaluated this MSc research prepare under our guidance, by Hailemichael Debalke Damota entitled "AN EXPERIMENTAL INVESTIGATION ON THE CAUSES OF FLEXIBLE PAVEMENT FAILURES: A CASE STUDY ON TARCHA-YALO ROAD SECTION**".** We recommend that it can be submitted as fulfilling the MSc research proposal requirement.

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Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental

EngineeringHighway Engineering Stream

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

By

Hailemichael Debalke Damota

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ABSTRACT

In Ethiopia, recently constructed roads are reported to deteriorate rapidly after being opened to traffic. This may include excessive loads, climatic changes, poor drainage, and inferior pavement materials. 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. In order to meet the objective a systematic methodology is used to investigate field survey and laboratory tests were carried out. The soil samples were collected using purposive techniques of sampling from three severely damaged and two non-damaged sections. The severely damaged section distresses were corrugation, block cracking, ravelling and stripping. Based on the type failures, 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 performance condition and 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.

The 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. From laboratory test result, the soil classification according to AASHTO and Unified Soil Classification of Subgrade A-7 and SC, sub base A-2-4 and GP and base course A-1-a and GW respectively. An average liquid limit (LL), plastic limit and plasticity index(PI) of failed sections of base course are (5%,0%,5%), sub-base(33.33%,25%,8.33%) and subgrade(52.5%,31.33%,21.33%) respectively whereas an average liquid limit (LL), plastic limit and plasticity index(PI) of the non-failed sections are (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 base course of failed section are (1.73g/cc,10.92%),sub base(1.67g/cc,12.23%) and sub-grade(1.58g/cc,20.33% whereas the non-failed sections were (1.76g/cc,9.95%), (1.74g/cc,11.1% , (1.65g/cc,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. 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.

Based on the laboratory test result and condition survey the pavement failure is due to insufficient thickness design, improper compaction and absence of shoulder. Finally it is recommended that the preventive maintenance is to be applied for failed section in Tarcha-Yalo road section.

Key words: - Pavement distress, distress type, laboratory tests, ERA 2013, condition survey

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ACRONYMS AND ABREVIATIONS

AASHTO	American Association of State High way and Transportation Officials
ASTM	America Association for Test and Material
CBR	California Bearing Ratio Hot-Mix Asphalt
ECDSWC	Ethiopian Construction Design & Supervision Works Corporation
EP.LLC	Envestro proeket.LLC
ERA	Ethiopian Road Authority
KM	Kilo Meter
KN	Kilo Newton
MDD	Maximum Dry Density
MM	Millimeter
MR	Modulus Resilient
OMC	Optimum Moisture Content
D60	The percentage of pass in 60mm diameter size of sieve
SNNPRS	Southern Nations, Nationalities and People Regional state
CM	Centimeters
LL	Liquid limit

PI	Plasticity index
PL	Plasticity limit
Cu	Uniformity coefficient
Cc	Coefficient of Curvature
BH	Bore hole of test pits
CESAL	Cumulative equivalent standard axle load
EF	Equivalent factor
D30	The percentage of pass in 30mm diameter size of sieve
D10	The percentage of pass in 10mm diameter size of sieve
D60	The percentage of pass in 60mm diameter size of sieve
GDP	Gross Domestic Product
LOS	Level of Service

CHAPTER ONE

1. INTRODUCTION

1.1 Background

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(1).

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. (2)

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(3). 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 (4). 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 (5). The effect of poor drainage on pavement condition increases moisture content and decreases pavement strength. Therefore, poor drainage leads to premature pavement failure (5). Similarly, under the combined effect of traffic, environment and climatic conditions, road pavements tend to crack eventually (6).

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 (7). 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. (2)

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 (2). 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(2). 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 (9). 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 (9).

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.

1.2. 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.

- 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.
- 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.
- 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.

1.3. Research Questions

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

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

1.4. Objective

1.4.1 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.

1.4.2 Specific Objectives

- To identify the locations of serious damage to flexible pavements and the factors that cause this damage
- To determine the existing pavement layers and compare them with standard specifications.
- To Propose remedial measures to improve the existing condition of the flexible pavement

1.5 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:

- ✓ The causes of pavement failure on the Tarcha - Yalo road section will be investigated.
- ✓ All of the above research questions will be answered.
- ✓ The results of the study will be used by relevant government agencies, especially ERA, as well as other researchers.

- ✓ The report of this study will be used as a supporting document for other related roads when they are engaged in similar projects.
- ✓ 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.

1.6. 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 47.4 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.

CHAPTER- TWO

2. LITERATURE REVIEW

2.1. Review on Flexible Pavement Performance

The performance of flexible pavement implies the serviceability and functionality of the road for traffic. Serviceability describes durability and quality of service, and functionality means safety and comfort for road users. The condition of flexible pavements changes with time and traffic applications. During the time a newly constructed road is in service, the pavement is usually in good condition. As a result of constant traffic loads and seasonal variations in environmental factors, the condition of the pavement gradually deteriorates and the condition of the pavement deteriorates. The change in pavement condition with time or traffic is defined as performance (12). When the pavement condition reaches a certain unacceptable level, the pavement has reached the end of its service life. Performance prediction is important to ensure that the pavement reaches the unacceptable condition at the end of its service life. Currently, there is no fully mechanistic (or theoretical) method for predicting pavement performance (12). Empirical or mechanistic-empirical methods are currently used to predict performance. Pavement degradation is a very serious problem that unnecessarily delays traffic flow, affects pavement esthetics, damages vehicles, and most importantly, causes traffic accidents in which lives and property are lost. Pavement deformation affects safety and ride quality on the roadway because it can lead to premature failures. Pavement deformation depends on several factors, including the type of construction material, type of subgrade, drainage system, climate, and traffic volume(13).

The second type of failure is functional failure. It occurs when the pavement, due to its roughness, is unable to perform its intended function without causing discomfort to drivers or passengers or placing a heavy load on vehicles. These failure conditions can be caused by inadequate maintenance, excessive loads, climatic and environmental conditions, poor drainage resulting in a poor base, and deterioration of component materials. The integration of both definitions leads to a new understanding of performance, which can be interpreted as the integration of serviceability over time (14)

Flexible pavements are considered here as pavements consisting of an asphalt surface layer on top of a bound or unbound base layer, which in turn rests on a subgrade. In pavement design, the main focus is usually on structural design. This means that layer thicknesses and materials are selected so that the pavement can withstand heavy axle loads without causing severe cracking in the bound layers and excessive deformation of the subgrade. However, in addition to these aspects, pavements should also be designed so that excessive permanent deformation does not occur in the individual pavement layers, as this deformation is visible on the surface as ruts. In addition, the pavement should not deteriorate excessively due to environmental factors. Finally, the pavement surface should have adequate durability. Any structure will fail if the induced stresses are greater than the strength of the material from which the structure is constructed. There are three basic external design parameters to consider when designing pavements, both in the design of the mix and the design of the structure:

1. The properties of the subgrade on which the pavement is placed have a major influence on structural design. The stiffness and drainage characteristics of the subgrade help determine the thickness of the pavement layers, the number of layers, seasonal loading limitations, and potential improvements to the stiffness and drainage of the subgrade itself(15).

2. The anticipated traffic load is one of the most important design considerations for both mix design and construction design. The traffic load is used to determine the composition of the pavement, the type of layer, and the thickness of the layer, all of which affect the life of the pavement(15).

3. The environment has a major impact on the performance of pavement materials. Environmental factors such as temperature, humidity, and ice formation can affect pavement durability, binder rheology, structural support, and ultimately pavement life and failure(4)

The performance of a pavement is composed of functional and structural performance. The structural performance of a pavement refers to its physical condition, i.e., the occurrence of cracks, distortions, or other conditions that would negatively affect the pavement's bearing capacity. The functional performance of the pavement refers to how well the pavement serves users, such as ride comfort or ride quality and safety(13). The performance of road pavements depends on the quality of the subgrade and base. A stable subgrade and well-draining base contribute to a long-lasting pavement. A high degree of spatial uniformity of the subgrade and base course in terms of key engineering parameters such as shear strength, stiffness, volumetric stability, and permeability is critical to the effective performance of the pavement system. The subgrade and base form the foundation for the upper layers of the pavement system and are critical in resisting the deleterious effects of climate and the static and dynamic loads imposed by traffic(16).

2.1.1. Flexible Pavement and Its Construction Materials

A true flexible pavement yields "elastically" to traffic loads. It is constructed with a bituminous surface treatment or a relatively thin surface of hot mix asphalt (HMA) over one or more unbound base layers on a subgrade. Its strength results from the load-distributing properties of a layer system designed to protect any underlying layer, including the subgrade, from compressive shear failure(17).

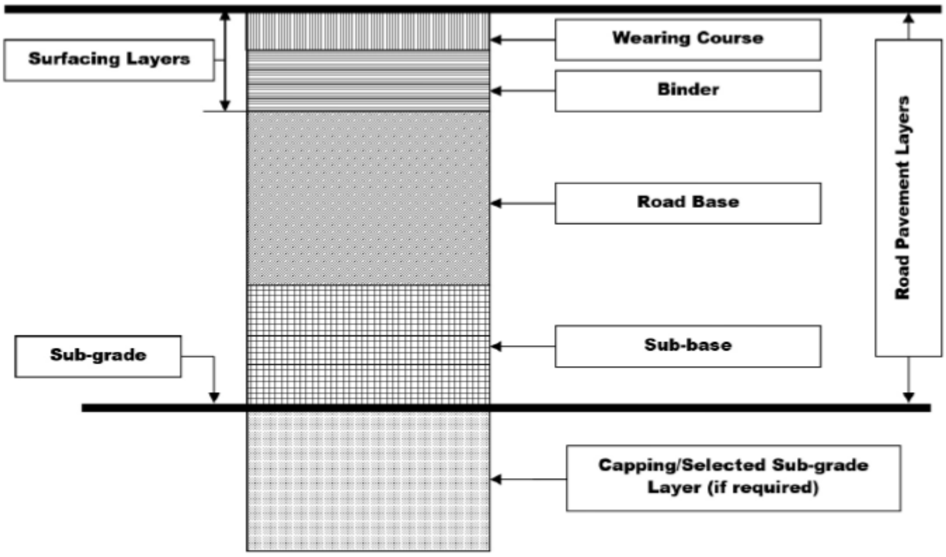

Figure 2-1.Flexible pavement profile (18)

Better and better materials are being used for the upper structure to withstand the higher near-surface loads from traffic wheel loads. These materials include an all-weather surface that is resistant to erosion from the environment and traffic. The bituminous/ HMA surface course must also be resistant to fatigue damage and remain stable under traffic loads when surface temperatures exceed 150ºF. The surface course of a flexible pavement protects the underlying base course from traffic and water while providing adequate friction for tires, generates minimal noise in urban areas, and provides suitable light reflection for nighttime travel. Such surfaces are produced either by a bituminous film coated with stones (the so-called spray and chip seal) or by a thin asphalt layer. Spray and chip seal is used for light to moderate traffic or to rehabilitate existing asphalt surfaces over McAdam-style base courses. It is relatively inexpensive, effective and impervious, and lasts about 10 years. Its major drawback is high noise generation. Maintenance usually involves another spray coat of bituminous surface treatment(19). Asphalt pavements are used for higher traffic volumes or in urban areas. Asphalt pavement usually contains smaller and more wear-resistant stones than the base course and contains relatively high amounts of bitumen. It is better able to withstand horizontal forces and generates less noise than a spray-split seal(20). According to various literatures, an ideal pavement should meet the following requirements:

- ❖ Sufficient thickness to distribute wheel load stresses to a safe value in the subgrade,
- ❖ Structural strength to be able to withstand all types of stresses,
- ❖ Adequate coefficient of friction to prevent vehicle skidding,
- ❖ Smooth surface to provide comfort to road users even at high speeds,
- ❖ Lowest noise generated by moving vehicles,
- ❖ Dust-proof surface, so that road safety is not affected by a reduction in visibility,
- ❖ Impermeable surface so that the subgrade is well protected, and
- ❖ Long service life with low maintenance costs.

Flexible pavements are made of bituminous or unbound material. The load is transferred to the subgrade by the lateral distribution of the applied load with depth. Flexible pavements consist of a bituminous surface layer and underlying base and sub-base layers. The bituminous material is usually asphalt, whose viscous nature allows considerable plastic deformation. Most asphalt pavements are built on a gravel base course, although some 'full-depth' asphalt pavements are built directly on the subgrade. Depending on the temperature at which it is placed, asphalt is categorized as hot mix asphalt (HMA), warm mix asphalt, or cold mix asphalt (21)

Flexible pavement is so called because the surface of the pavement reflects the total deformation of all subsequent layers due to the traffic load applied to them. Flexible pavement is based on the load-distributing properties of a layered system. It transfers the load to the subgrade through a combination of layers. Flexible pavement distributes the load over a relatively small area of the underlying subgrade. The initial cost of installing flexible pavement is quite low, which is why this type of pavement is usually found everywhere. However, flexible pavement requires maintenance and routine repairs every few years. In addition, flexible pavement deteriorates quickly; cracks and potholes are likely due to poor drainage and heavy vehicular traffic(15) . A. Surface course: the surface course is, of course, the layer that comes into contact with the traffic load and usually contains the highest quality materials. The surface course plays an important role in friction, smoothness, noise reduction, rutting and shear resistance, and drainage. In addition, the surface course serves to prevent excessive amounts of surface water from infiltrating the underlying base course, subgrade and subgrade. The top structural layer of the material is sometimes divided into two layers(22) .

I. Surface course: this is the top layer of the road structure that is in direct contact with traffic loads. A well-designed maintenance program should be able to detect damage to the pavement surface while it is still confined to the surface course.

II. Binder Course: The purpose of this course is to distribute the load of the surface course. This layer forms the main part of the HMA structure.

B. Base Course: The base course is a layer of a specific material and thickness that supports the base course and distributes traffic loads to the subgrade or subgrade. It provides additional load distribution and contributes to drainage and frost resistance. A variety of materials can be used as an unbound base course, including crushed rock, crushed and screened, mechanically stabilized, modified or naturally occurring 'as dug' gravels. Their suitability for use depends primarily on the proposed traffic load of the pavement and the climate.

C. Subgrade: The subgrade is constructed between the base course and the subgrade. The subgrade is generally made of inferior materials to the base course, but better than the subgrade. The subgrade consists of granular material - gravel, crushed stone, reclaimed material, or a combination of these materials. It allows traffic stresses in the subgrade to be reduced to acceptable levels, it serves as a working platform for construction of the upper pavement layers, and it acts as a separation layer between the subgrade and the base course. In special circumstances, it may also serve as a filter or drainage layer. For a pavement constructed on a high quality, rigid subgrade, the additional features of a base course may not be necessary.

D. Subgrade: The subgrade is characterized by the modulus of elasticity (E) of the subgrade. The modulus of elasticity (E) is a measure of the stiffness of the road base (16).

According to (Adlinge and Gupta, 2009), the main functions of a pavement are to:

- To provide a reasonably smooth road surface: A smooth road surface (low roughness) is essential for driving comfort and over the years has become the benchmark for how road users perceive a road. Roughness can have a variety of causes, but most commonly it is due to pavement damage caused by structural deformation.
- Provide adequate surface friction (skid resistance): In addition to ride comfort, the other requirement of road users is safety. Safety, especially in wet conditions, can be related to a loss of surface friction between the tire and the road surface. Therefore, a road surface must have sufficient surface friction and structure to ensure the safety of road users in all conditions.

Protect the subgrade: The supporting soil beneath the roadway is commonly referred to as the subgrade. If over-stressed by the applied axle loads, the subgrade will deform and lose its ability to properly support these axle loads. Therefore, the pavement must have sufficient structural capacity (strength and thickness) to adequately reduce the actual stresses so that they do not exceed the strength of the subgrade. The strength and thickness requirements of a pavement can vary greatly depending on the combination of subgrade type and loading condition (magnitude and number of axle loads).

Provide waterproofing: The pavement surfacing acts as a waterproofing surface that prevents the under laying support layers including the subgrade from becoming saturated through moisture ingress. When saturated, soil loses its ability to adequately support the applied axle loads, which will lead to premature failure of the pavement

2.2. Distresses of Flexible pavement

Pavement distresses are the irregularity of pavement surface that have negative effect on the performance of roads. Distresses are visible defects on the surface of pavement which indicates problems of pavement deterioration(23).

The deteriorated road is hard and risk for road users .Therefore the problems are studied in detailed and solution is needed to improve the performance of flexible road.(24)

2.2.1 Types of flexible pavement Distresses

According to professor T.F.Fwa, published text book flexible pavement distresses are categorized into four. These are:-Cracking, surface deformation, disintegration and surface defects.

I. Cracking

It is the fractured pavement condition resulting from numbers of causes and is found in variety of patterns ranging from single to interconnected patterns(12). The common cracks in flexible pavement are:-

- ✓ Crocodile cracks
- ✓ Longitudinal cracks
- ✓ Transverse cracks
- ✓ Block cracks
- ✓ Diagonal cracks
- ✓ Meandering cracks
- ✓ Crescent shaped cracks

II. Surface deformation

Surface deformation is the change in pavement surface profile and it can affect the roughness condition and skid resistance when water ponding occurs(12). The common surface deformations are:-

- ✓ Corrugation
- ✓ Rutting
- ✓ shoving

III. Surface defects

Surface defects are distresses on the surface of pavement(12). The common surface defects on flexible pavement surface are:-

- ✓ Delamination
- ✓ Potholes
- ✓ Patching
- ✓ Stripping
- ✓ Polishing
- ✓ Raveling
- ✓ Flushing

IV. Edge defects

Edge defects are the defects that can occur along the joint of the pavement edge and shoulder(12). The common edge defects are

- ✓ Edge break
- ✓ Edge drop-off

2.2.2. Meaning of Distresses in asphalt pavement

2.2.2.1. Alligator cracking (Fatigue)

A. Description

Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. Cracking begins at the bottom of the asphalt surface, or stabilized base, where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are generally less than 0.5 m (1.5 ft) on the longest side. Alligator cracking occurs only in areas subjected to repeated traffic loading, such as wheel paths. Pattern-type cracking that occurs over an entire area not subjected to loading is called –block cracking, which is not a load- associated distress (25)(22).

B. Severity Levels:

- **Low level of severity (L):-**Fine, longitudinal hairline cracks running parallel to each other with no, or only a few interconnecting cracks. The cracks are not spalled(22).
- **Moderate level of severity (M):-**Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled(22).
- **Higher level of severity (H):-** Network or pattern cracking has progressed so that the pieces are well defined and spelled at the edges. Some of the pieces may rock under traffic(25).

Figure 2-2 Fatigue Cracking (22)(25)

C. How to Measure

Alligator cracking is measured in square meters (square feet) of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately; however, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity present. If alligator cracking and rutting occur in the same area, each is recorded separately as its respective severity level(22)(25) .

2.2.2.2. Bleeding

A. Description

Bleeding is a film of bituminous material on the pavement surface that creates a shiny, glasslike, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphaltic cement or tars in the mix, excess application of a bituminous sealant, or low air void content, or a combination thereof. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the pavement surface. Since the bleeding process in not reversible during cold weather, asphalt or tar will accumulate on the surface(22)(25).

B. Severity Levels:

- **Low level of severity (L):-**Bleeding only has occurred to a very slight degree and is noticeable only during a few days of the year. Asphalt does not stick to shoes or vehicles(25).
- **Moderate level of severity (M):-**Bleeding has occurred to the extent that asphalt sticks to shoes and vehicles during only a few weeks of the year(25).
- **Higher level of severity (H):-** Bleeding has occurred extensively and considerable asphalt sticks to shoes and vehicles during at least several weeks of the year(22)(25).

C. How to Measure

Bleeding is measured in square meters (square feet) of surface area. If bleeding is counted, polished aggregate should not be counted(22)(25).

2.2.2.3. Block cracking

A. Description

Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 0.3 by 0.3 m (1 by 1 ft) to 3 by 3 m (10 by 10 ft.). Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling, which results in daily stress/strain cycling. It is not load-associated. Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large portion of the pavement area, but sometimes will occur only in non-traffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many-sided pieces with sharp angles. Also, unlike block, alligator cracks are caused by repeated traffic loadings, and therefore, are found only in traffic areas, that is, wheel paths (22)(25).

B. Severity Levels:

- **Low level of severity (L):-**Blocks are defined by low-severity cracks
- **Moderate level of severity (M):-**Blocks are defined by medium-severity cracks
- **Higher level of severity (H):-** Blocks are defined by high-severity cracks.

C. How to Measure

Block cracking is measured in m^2 given pavement section; however, if areas of different severity levels can be distinguished easily from one another, they should be measured and recorded separately (22)(25).

Figure 2-3 Block Cracking(22)(25)

2.2.2.4. Corrugation

A. Description

Corrugation, also known as ―wash-boarding‖, is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals, usually less than 3 m (10ft) along the pavement. The ridges are perpendicular to the traffic direction. This type of distress usually is caused by traffic action combined with an unstable pavement surface or base (22)(25).

B. Severity Levels:

- **Low level of severity (L):-**Corrugation produces low-severity ride quality.
- **Moderate level of severity (M):-**Corrugation produces medium-severity ride quality
- **Higher level of severity (H):-** Corrugation produces high-severity ride quality

C. How to Measure

Corrugation is measured in square meters (square feet) of surface area (22).

2.2.2.5. Depression

A. Description

Depressions are localized pavement surface areas with elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are not noticeable until after a rain, when ponding water creates a ―birdbath‖ area; on dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of improper construction. Depressions cause some roughness, and when deep enough or filled with water, can cause hydroplaning (22)(25).

B. Severity Levels (Maximum Depth of Depression):

- **Low level of severity (L):-**13 to 25 mm (1⁄2 to 1 in.)
- **Moderate level of severity (M):-**25 to 50 mm (1 to 2 in.)
- **Higher level of severity (H):-** More than 50 mm (2 in.)(25).

C.How to Measure

Depressions are measured in square meters (square feet) of surface area

2.2.2.6. Edge cracking

A. Description

Edge cracks are parallel to and usually within 0.3 to 0.5 m (1 to 1.5 ft) of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or subgrade near the edge of the pavement. The area between the crack and pavement edge is classified as raveled if it is broken up (sometimes to the extent that pieces are removed) (26)(25)

B. Severity Levels:

- **Low level of severity (L):-**Low or medium cracking with no breakup or raveling
- **Moderate level of severity (M):-**Medium cracks with some breakup and raveling
- **Higher level of severity (H):-** Considerable breakup or raveling along the edge (27)

C. How to Measure

Edge cracking is measure in linear meters (feet) (22).

Figure 2-4 Edge Cracking(22)

2.2.2.7. Lane shoulder drop

A. Description

Lane/shoulder drop-off is a difference in elevation between the pavement edge and the shoulder. This distress is caused by shoulder erosion, shoulder settlement, or by building up the roadway without adjusting the shoulder level (22) (28).

B. Severity Levels:

- **Low level of severity (L):-**The difference in elevation between the pavement edge and shoulder is > 25 mm (1 in.) and< 50 mm (2 in.)
- **Moderate level of severity (M):-**The difference in elevation is > 50 mm (2in) and

< 100 mm (4 in)

- **Higher level of severity (H):-** The difference in elevation is > 100 mm (4in)

C. How to Measure

Lane/shoulder drop-off is measured in linear meters (feet) (22).

Figure 2-5 Lane-to-Shoulder Drop-Off(22)(28)

2.2.2.8. Longitudinal & Transverse

A. Description

Longitudinal cracks are parallel to the pavement‘s centerline or laydown direction. They may be caused by:

- A poorly constructed paving lane joint.
- Shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or daily temperature cycling, or both.
- A reflective crack caused by cracking beneath the surface course, including cracks in PCC slabs, but not PCC joints.
- Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of laydown. These types of cracks are not usually load-associated (22)(28).

B. Severity Levels:

- **Low level of severity (L):-**One of the following conditions exists: non-filled crack width is less than 10 mm (3⁄8 in.), or filled crack of any width (filler in satisfactory condition)(28).

- **Moderate level of severity (M):-**One of the following conditions exists: non-filled crack width is greater than or equal to 10 mm and less than 75 mm (3⁄8 to 3 in.); non-filled crack is less than or equal to 75 mm (3 in.) surrounded by light and random cracking; or, filled crack is of any width surrounded by light random cracking(28).

- **Higher level of severity (H):-** One of the following conditions exists: any crack filled or non-filled surrounded by medium- or high-severity random cracking; non-filled crack greater than 75m (3 in.); or, a crack of any width where approximately 100mm (4 in.) of pavement around the crack is severely broken (22)(28).

C. How to Measure

Longitudinal and transverse cracks are measured in linear meters (feet). The length and severity of each crack should be recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately (22).

Figure 2-6 Longitudinal Cracking(22)(28)

2.2.2.9. Polished Aggregate

A. Description

This distress is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small, or there are no rough or angular aggregate particles to provide good skid resistance. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examination reveals that the aggregate extending above the asphalt is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from a previous rating (22).

B. Severity Levels

No degrees of severity are defined; however, the degree of polishing should be clearly evident in the sample unit in that the aggregate surface should be smoothto the touch

C. How to Measure

Polished aggregate is measured in square meters (square feet) of surface area. If bleeding is counted, polished aggregate should not be counted (22).

2.2.2.10. Potholes

A. Description

Potholes are small usually less than 750 mm (30 in.) in diameter bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. When holes are created by high-severity alligator cracking, they should be identified as potholes, not as weathering (22).

B. Severity Levels:

- The levels of severity for potholes less than 750mm (30 in.) in diameter are based on both the diameter and the depth of the pothole, according to Table1
- If the pothole is more than 750 mm (30 in.) in diameter, the area should be determined in square feet and divided by 0.5 m2 (5.5 ft2) find the equivalent number of holes. If the depth is 25 mm (1 in.) or less, the holes are considered medium-severity. If the depth is more than 25 mm (1 in.), they are considered high-severity(22) .

Table 2-1 . Levels of severity for potholes (15)**.**

Maximum depth of pothole	Average diameter (mm)(in.)		
	100 to 200mm (4 to 8in.)	200 to 450mm (8 to 18in.)	450 to 750mm (18 to 30in.)
13 to ≤25mm (1/2 to 1in.)	L	L	M
>25 and ≤50mm (1 to 2in.)	L	M	H
>50mm (2in.)	M	M	H

C. How to Measure

Potholes are measured by counting the number that are low-, medium-, and high- severity and recording them separately (15).

Figure .2-7 potholes (22)

2.2.2.11. Rutting

A. Description

A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut, but, in many instances, ruts are noticeable only after a rainfall when the paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrades; usually caused by consolidated or lateral movement of the materials due to traffic load (22)

B. Severity Levels (Mean Rut Depth):

- **Low level of severity (L):-**6 to 13 mm (1⁄4 to 1⁄2 in.)
- **Moderate level of severity (M) :-**> 13 to 25 mm (>1⁄2 to 1 in.)
- **Higher level of severity (H):-** >25 mm (>1 in.)

C. How to Measure

Rutting is measured in square meters (square feet) of surface area, and its severity is determined by the mean depth of the rut. The mean rut depth is calculated by laying a straight edge across the rut, measuring its depth, then using measurements taken along the length of the rut to compute its mean depth in millimeters (22).

Figure 2-8.Rutting (22)

2.2.2.12. Shoving

A. Description:

Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements. Shoves also occur where asphalt pavements abut PCC pavements. The PCC pavements increase in length and push the asphalt pavement, causing the shoving (22).

B. Severity Levels:

- **Low level of severity (L):-**Shove causes low-severity ride quality.
- **Moderate level of severity (M):-** Shove causes medium-severity ride quality.
- **Higher level of severity (H):-** Shove causes high-severity ride quality (22).

C. How to Measure

Shoves are measured in square meters (feet) of surface area. Shoves occurring in patches are considered in rating the patch, not as a separate distress (22).

Figure 2-9.Shoving (22)

2.2.2.13. Raveling &Weathering

A. Description

Weathering and raveling are the wearing away of the pavement surface due to a loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicate that either the asphalt binder has hardened appreciably or that a poor- quality mixture is present. In addition, raveling may be caused by certain types of traffic, for example, tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage also are included under raveling (30).

B. Severity Levels:

- **Low level of severity (L):-**Aggregate or binder has started to wear away. In some areas, the surface is starting to pit. In the case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.(30)

- **Moderate level of severity (M):-** Aggregate or binder has worn away. The surface texture is moderately rough and pitted. In the case of oil spillage, the surface is soft and can be penetrated with a coin(30).

- **Higher level of severity (H):-** Aggregate or binder has been worn away considerably. The surface texture is very rough and severely pitted. The pitted areas are less than 10 mm (4 in.) in diameter and less than 13 mm (1⁄2 in.) deep; pitted areas larger than this are counted as potholes. In the case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose(31)(30)

C. How to Measure

Weathering and raveling are measured in square meters (square feet) of surface area (2)(22).

2.3 Causes of distresses in flexible pavement

The causes of distresses in flexible pavement are traffic loading associated factors, construction, structural composition and material associated factors and environment associated factors(14)..According to (32)and (2) causes of flexible pavement is associated with the following factors.

- Sudden increase in traffic loading especially on new roads where the design is based on lesser traffic is a major cause of cracking. After construction of good road, traffic of other roads also shifts to that road. This accelerates the fatigue failure (Alligator Cracking).
- Temperature variation ranging from 50º C to below zero conditions in the plain areas leads to bleeding and cracking.
- Provision of poor shoulders leads to edge failures.
- Provision of poor clayey subgrade results in corrugation at the surface and increase in unevenness.
- Poor drainage conditions especially during rainy seasons, force the water to enter the pavement from the sides as well as from the top surface. In case of open graded

bituminous layer, this phenomenon becomes more dangerous and the top layer gets detached from the lower layers

- .If the temperature of bitumen/bituminous mixes is not maintained properly, and then it also leads to pavement failure. Overheating of bitumen reduces the binding property of bitumen.

A. Traffic load associated factors

These include factors associated with traffic namely, traffic volumes, axle loads, number of Equivalent Single Axle Loads (ESAL's), tire pressure, type of axles and their configuration, load application time and mechanism of load application.(33)

B. Construction, Structural Composition and Material Properties Associated Factors

These include the main engineering properties of the materials used in pavement construction such as strength or bearing capacity of soil subgrade layer, gradation of soil and aggregates, physical properties of aggregates, aggregate mix properties, elastic and resilience modulus of layers and Poisson ratio.(33)(9).

C. Environmental Associated Factors:

Factors like, moisture in soil, temperature of soil, pavement layers and surroundings, freeze and thaw cycles, humidity and precipitation, and movement of ground water, capillary water or surface water becomes the part of environmental associated factors (4).

2.4. Method of performance evaluation of flexible pavement

Pavement performance evaluation is important activity for pavement maintenance and rehabilitation works. It includes evaluation of existing distresses, road roughness, structural adequacy, traffic analysis, material testing and study of drainage condition. This section deals with the types and causes of flexible pavement distresses(4).

There are two categories of flexible pavement performance evaluation. These are destructive survey and non-destructive survey methods. The destructive survey includes DCP survey and test pit excavations. Also the non-destructive survey includes pavement condition survey, roughness survey and deflection survey (23).

From all of these methods of evaluations only pavement condition survey and test pit excavation method were performed in this research and the remained methods were not performed because of lack of resource and instruments. The details of two methods (pavement condition survey and test pit excavation methods) are discussed below on review(23) .

2.4.1. Pavement condition survey

Distresses survey can be performed manually, or automated equipment may be used. In this study of research the manually survey method was performed .But in either case ,the surface of pavement is observed and evaluation is made to determine the type of distresses, severity and the extent (quantity of distresses)present on the surface of flexible pavement(34).

The type of distresses tell us what type of damage has developed; the severity tells us how bad the damage is ;and the extent of the distresses tells us the quantity of the damaged observed on the surface of flexible pavement.(35)(34)

All above three factors are required to get full picture of the damage that has developed on flexible pavement surface for the performance evaluation and the causes of poor performance in serviceability and functionality modes. Various type and degree of distresses are measured during the condition survey and are used to determine type and timing of maintenance and rehabilitation ;and reconstruction(23).

The key for maintenance program is priority developing pavement distresses information in detailed manner. Therefore ,pavement engineers have long recognized the importance distresses information in quantifying the quality of pavement in order to obtain an overall assessment of pavement conditions for road networks ,it is often necessary to combine individual distresses data to form the composite index called the pavement condition index (PCI).PCI summarizes the condition of each segments(36) .

A complete survey of the selected site is performed using pavement condition index (PCI) method .PCI values range from very poor (0) to excellent (100) and which assesses the present pavement surface condition based on specific criteria. In this procedure the deduct values are assigned to certain observed distress types according to their density and severity and then subtracted from perfect score to give the pavement condition index (PCI) value and the pavement rating .The procedure consists of six steps which are summarized as follows. 1. The inspection unit inspects target highways using distress identification guide, and the approximate amount of each distress type /severity combination is recorded as percentage by dividing the distress type/severity combination quantities by the total area of the segment and multiplying by 100(15). 2. The deduction values for each distress type/severity combination are determined from special deduct value curves. The PCI procedure uses a set of ‘’deduct curves’’ to calculate the numerical impact of each distress type/severity combination on the overall PCI(15).

Table 2-2 ***Location selected road sections for condition survey***

SN	Start location name	station	Distance from Addis Ababa in KM		End location	Location		
			By Jimma	By Sodo		Latitude	Longitude	Altitude
1	Tarcha	63+900	501	477	Turi	7º09’14.8’’N	37º10’07.8’’E	1324m
2	Turi	70+900	508	470	-	7º06’53.07’’N	37º11’23.07’’E	1696m
3	Waka	80+800	518	460	Tulema	7º03’30.15’’N	37º11’30.20’’E	2415m
4	Tulema	89+800	527	451	Gesa	7º00’45.09’’N	37º14’16.14’’E	2364m
5	Gesa	97+000	534.2	443.7	Elabacho	7º01’06.71’’N	37º16’50.22’’E	2201m
6	Elabacho	103+300	540.5	437.4	Yalo	6º58’48.15’’N	37º18’02.22’’E	1764m
7	Yalo	111+300	548.5	429.4	-	6º56’50.30’’E	37º20’09.83’’E	1246m

3. The number of distress type/severity combination with deduct s value larger than 2 are counted .The obtained q-value is used later in the calculations to correct the curves because research found that if occurrence of small deduct values are included, the final value would be too small, or overestimated(15).4.The total deduct value is computed by swimming all the deduct value for distress type/severity combination(15). 5. When multiple distress type /severity combinations are present, the deduct units must be corrected as more distress type/severity combinations occur in the same inspection unit, they have less and less impact. To account for this nonlinearity, the total deduction and the q-values are used with correction curve to determine the corrected deduct value(15). 6. The corrected deduct value is subtracted from 100 to determine the inspection unit PCI in percentage(15). Condition survey is the indication of the serviceability and functionality of flexible pavement condition and also the physical condition of the assets. It is the way of collection of data to determine the serviceability and functional performance (riding quality and structural integrity of road segments). Data are based on observation s and measurements of flexible pavement distress ,surface deformation, surface defects, disintegration and crack (37). In this study the flexible pavement condition survey is used to determine the extent, severity and type of distresses on the section of road Tarcha-Yalo road segment. During the data collection the method is used is to conduct and collect the distress using standards and visual observation on field and measuring the distress with hand roller meter measurement. The segment is delineated into five sections. These are =- 1. Tarcha-Waka Section 2. Waka-Tulema 3.Tulema-Gesa 4.Gesa –Elabacho 5. Elabacho –Yalo sections.

2.4.1.1. Assessment of Pavement Condition

Pavement condition assessment includes collecting and analyzing pavement performance data (i.e., cracking, rutting, faulting, structural capacity, surface characteristics) for determining individual or overall indicators of pavement condition. The inspection method is designed to allow the calculation of a composite rating index called the pavement condition index. The PCI scale is shown in (Table 3). The distress types, severity levels, and methods of estimating quantities are keyed to the deduct curves presented in the area(24).

The key to a useful evaluation is identifying different types of pavement distress and linking them to a cause. Understanding the cause for current conditions is important in selecting an appropriate maintenance or rehabilitation technique.

2.4.1.1.1. Pavement Condition Index (PCI)

The detailed field inspections categorize and quantify the pavement distresses and deterioration that are mentioned above section. These deficiencies are entered into the PMS program that calculates a Pavement Condition index (PCI) for each road section. PCI values range from zero (very poor) to 100 (excellent).

2.4.1.1.2. Pavement Condition Rating

The pavement condition rating is a description of pavement condition through rating scale ranges as a function of the PCI value that varies from 100 (excellent condition) to 0 (failed) as shown in Table 2.Most pavements will deteriorate through the phases listed in the rating scale. The time it takes to go from excellent condition (100) to complete failure (0) depends largely on the quality of the original construction and the amount of heavy traffic loading(15).

Table 2-3.Pavement condition ratings and pavement condition index ranges(12)

Pavement condition	Pavement rating
Excellent	100-86
Very good	71-85
Good	56-70
Fair	41-55
Poor	26-40
Very poor	11-25
Failed	0-11

The PCI is a quick method of comparing the overall condition of pavement and magnitude of rehabilitation needs. The following figure shows how pavement condition typically deteriorates over time. The new pavement holds its good condition for a long period, but once it begins to fail; its condition drops rapidly (38).

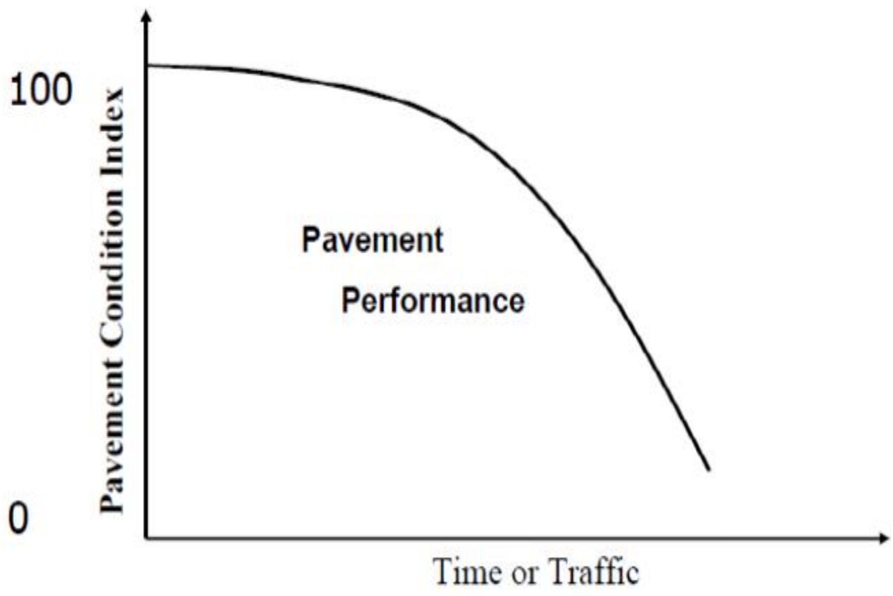

Figure 2-10. Relationship between pavement condition and time(23)

2.4.1.1.3 Definition of Pavement Condition

A. Excellent: Pavement is new construction. Nothing would improve the roadway at this time (30).

B. Very Good: Pavement structure is stable, with no cracking, no patching, and no deformation evident. Roadways in this category are usually fairly new. Riding qualities are excellent. Nothing would improve the roadway at this time(30).

C. Good: Pavement structure is stable, little cracking and no deformation evident. Little maintenance would improve the roadway at this time(30).

D. Fair: Pavement structure is generally stable with minor areas of structural weakness evident. Cracking is easier to detect. The pavement may be patched but not excessively. Although riding qualities are good, deformation is more pronounced and easily noticed.

E. Poor: Areas of instability, marked evidence of structural deficiency, large crack patterns (alligator) heavy and numerous patches, deformation very noticeable. Riding qualities are range from acceptable to poor(30).

F. Very Poor: Pavement is in extremely deteriorated condition. Numerous areas of instability, Majority of section is showing structural deficiency. Riding quality is unacceptable (probably should slow down)(30).

G. Failed: Pavement structure is failed, with cracking and deformation evident. Roadways in this category are usually failed and reconstruction at this time(30).

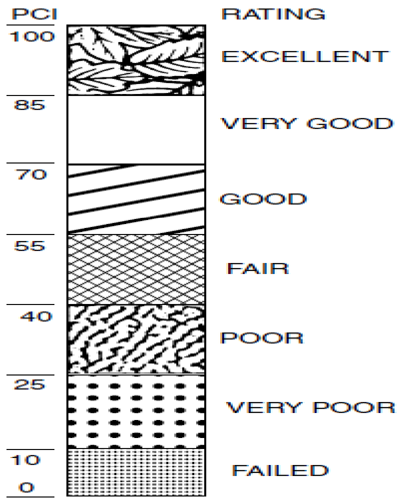

Figure 2-11 Pavement Condition Index (PCI), Rating scale and suggested color **((12))**

In addition to indicating the surface condition of a road, a given rating also includes a recommendation for needed maintenance or repair. This feature of the rating system facilitates its use and enhances its value as a tool in ongoing road maintenance (39)

2.4.2 Laboratory tests

Laboratory tests are useful in providing reliable data for calculating ultimate bearing capacity of soil, stability and settlement behavior of foundation and for determining physical characteristics of soils. Most of the engineering properties of soil and granular materials are determined by laboratory testing. The laboratory tests are conducted on selected samples extracted from the field. The following tests were conducted in China Railway seventh group and Jimma University Institute of Technology Laboratory. They are moisture content, free swell test Atterberg limits, Grain size Analysis, Compaction Tests, California Bearing Ratio (CBR) and Los Angeles Abrasion Test (LAA) were made to evaluate the causes of deterioration. Test procedures are not used for lateritic soil as recommended in the literature, even though soil in the study area may be lateritic as indicated by ERA site investigation 2013 standards.

A. Grain size distribution

The mechanical analysis consists of the determination of the amount and proportion of coarse material by the use of sieves; and the analysis for the fine grained fraction by sedimentation method. For the materials passing 75 microns, hydrometer method was used. The combined grading of the material shall be a smooth continuous curve falling within the grading limits. When determined in accordance with the requirements of AASHTO T-27. The mass of material passing the 0.075 mm sieve shall be determined in accordance with the requirements of AASHTO T-11(7).Sedimentation method. For the materials passing 75 microns hydrometer method was used. The shapes of the curves indicate the nature of the soil tested. On the basis of the shapes we can classify soils as:-

1. Uniformly graded or poorly graded.

2. Well graded.

3. Gap graded.

A sample of dry soil (of about 500 g) is mechanically shaken through a series of Sieves and the percentage retained or passing through each sieve is weighted. The results are then plotted as a cumulative curve against the sieve size and because the range of possible particles is of the order of 106 (from over 100mm to less than 0.001 mm), the grain size distribution is usually represented versus the logarithm of the average grain diameter. Fine sand ranges from 0.06 to 0.2mm and coarse sand from 0.6 to 2 mm (7).

B. Soil compaction

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified comp active effort. The comp active effort is the amount of mechanical energy that is applied to the soil mass.

The Compaction tests are designed to simulate the density of soils compacted by field methods. Modified Proctor Test was used for this study area. The soil tested was thoroughly mixed with measured quantity of water and, it was then filled in the mold in five layers of approximately equal thickness. Each layer was subjected to 25 numbers of blows using modified hammer weighing 44.5 N, which was allowed to drop freely from a height of 46 cm. After compaction of five layers, the soil was trimmed at the top of the mold. The mold with its content was removed from the base plate and weighed. Moisture content determination was undertaken on a sample of soil and the dry density was then calculated. This procedure was repeated with addition of water content and a compaction curve was drawn(40)(25). The co-ordinates of the curve that represents peak gave the maximum dry density and the optimum moisture content.

$$\rho_d \frac{\rho}{1+w} \dots\dots\dots\dots\dots\dots\dots\dots\dots..(2.1)$$

Where: w= moisture content in percent divided by 100, and

ρ = wet density in grams per centimeter cubic.

The moisture content of each compacted soil specimen was calculated using the average of the two water contents. To compute the wet density in grams per cubic centimeter of the compacted soil sample was divided the wet mass by the volume of the mold used, then the dry density computed using the wet density and the water content(41).

C. Atterberge limits

Most of the methods for soil identification and classification are based on certain physical properties of the soils. The commonly used properties for the classification are the grain size distribution, liquid limit and plasticity index. These properties have also been used in empirical design methods for flexible pavements, and in deciding the suitability of subgrade soils. Tests were undertaken on base course, sub-base, subgrade and Capping layer or selected subgrade fill materials at selected test pits of the three sections(42). The testing procedure was done according to ASTM D 4318

D. California Bearing Ratio (CBR)

California Bearing Ratio is a measure of shearing resistance of the material under controlled density and moisture conditions. The test consisted of causing a cylindrical plunger of 50 mm diameter to penetrate a pavement component material at 1.25 mm/minute. The loads for 2.54 mm and 5.08 mm were recorded. This load is expressed as a percentage of standard load value at a respective deformation level to obtain CBR value. The equation to be computing the CBR vale is as follows(37).

CBR (%) = 100 *(x/y)--------------------------------(2.2)

Where: X = material resistance or the unit load on the piston (pressure) for 2.54mm or

5.08 mm of penetration.

y = standard unit load (pressure) for well graded crushed stone. For 2.54mm

Penetration = 6.9mpa and for 5.08mm penetration = 10.3mpa

The standard load values were obtained from the average of a large number of tests on different crushed stones. Three point CBR Test were made for all samples. California bearing ratio test results (CBR test) for four days soaked samples at their maximum dry density were compared with the standard specifications. The density versus CBR was plotted and the required CBR "for the 56 blows" had computed from the graph for the maximum dry density(37).

E. Los Angeles Abrasion Value (LAAV) ASTM C 131-9

The Los Angeles test is a measure of degradation of mineral aggregates of standard grading resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres, the number depending upon the grading of the test sample. As the drum rotates a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, creating an impact crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate impacts and the cycle is repeated. After the prescribed number of revolutions, the content is removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss(1).The sample preparation criteria for the sample for test are given in the following table.

Table 2-4 Los Angeles Abrasion Value (LAAV) Test sample preparation requirements

Grading of test Sample	Fraction and Mass		Numbers of spheres (steel Balls)
	Sieve size (mm)	Mass (g)	
A	37.5 to 25	1250	12
	25 to 19	1250	
	19 to12.5	1250	
	12.5 to 9.5	1250	
B	19 to 12.5	2500	11
	12.5 to 9.5	2500	
C	9.5 to 6.3	2500	8
	6.3 to 4.75	2500	
D	4.75 to 2.36	5000	6

2.4.3 Traffic analysis

The deterioration of paved roads caused by traffic as a result of the magnitude of the individual wheel loads and the number of times these loads are applied. It is necessary to Consider not only the total number of vehicles that will use the road but also the wheel loads (or, for convenience, the axle loads) of these vehicles. Equivalency factors are used to convert traffic volumes into cumulative standard axle loads. Classes are defined for paved roads, for pavement design purposes, by ranges of cumulative traffic number of equivalent standard axles load(43).

A. Determination of cumulative traffic volumes

In order to determine the cumulative number of vehicles over the design period of the road, the following procedure should be followed,(43). Determine the initial traffic volume (AADT0) using the results of the traffic survey and any other recent traffic count information that is available. For paved roads, detail the AADT in terms of car, bus, truck, and truck-trailer.

2. Estimate the annual growth rate “i” expressed as a decimal fraction, and the anticipated number of years “x” between the traffic survey and the opening of the road.

3. Determine AADT1 the traffic volume in both directions on the year of the road opening by:

AADT1 = AADT0 (1+i) x…………………………………………………. (2.3)

4. The cumulative number of vehicles, T over the chosen design period N (in years) is obtained

T = 365 AADT1 [(1+i) N– 1] / (i)…………………..……………………….. (2.4)

B. Axle Load

The damage that vehicles do to a paved road is highly dependent on the axle loads of the vehicles. For pavement design purposes the damaging power of axles is related to a “standard” axle of 8.16 metric tons using empirical equivalency factors. In order to determine the cumulative axle load damage that a pavement will sustain during its design life, it is necessary to express the total number of heavy vehicles that will use the road over this period in terms of the cumulative number of equivalent standard axles (ESAs),(43).

Axle loads can be converted and compared using standard factors to determine the damaging power of different vehicle types. A vehicle’s damaging power, or Equivalency Factor (EF), can be expressed as the number of equivalent standard axles (ESAs), in units of 80 kN. Finally, the cumulative ESAs over the design period (N) are calculated as the products of the cumulative one-directional traffic volume (T) for each class of vehicle by the mean equivalency factor for that class and added together for each direction. The relationship between a vehicle's EF and its axle loading is normally considered in terms of the axle mass measured in kilograms. The relationship takes the form(43).

$$\text{Equivalency factor} = \left(\frac{\text{Axle Load i}}{8160}\right)^{n} \qquad \text{.......................................} \ (2.5)$$

Where; axle i= mass of axle load i, n = a power factor that varies depending on the pavement construction type and subgrade but which can be assumed to have a value of 4.5 and the standard axle load is taken as 8 160kg with the summation taken over the number of axles on the vehicle in question.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

The selected highway segment Tarcha– Yalo is section of Sodo-Chida which is a link road described in Ethiopia road map as B52 that connects Dawuro zone with its neighboring zones and regions. This road has been upgraded to asphalt few years and some kilometers are up today under construction. The road is found in southwestern Ethiopia Peoples Regional state Dawuro zone. It has economic value in integrating Southwestern Ethiopia people regional state zones with Wolaita Zones, SNNPRS and also with central government. It is the back bone in integrating south western Ethiopia people's regional state and southeast Zones of SNNPRS and Oromia region with Wolaita Zone for trade and other economic activities. The length of highway segment selected for this study is 47.4.km that is from Tarcha Town – Yalo village (rural town)(4) . Dawuro Zone is located in 7º00'00"N latitude and 37º09'60" E. And also it is about 492 km far from Addis Ababa by Jimma and 482 km far from Addis Ababa by Wolaita Sodo. The study was conducted in section of selected highway section that crosses Loma and Mareka districts in Dawuro Zone of Southern Western Ethiopia Peoples Regional State (SWEPRS) Ethiopia. Figure 3.1 shows the location of selected highway for study. The section of study section at the beginning point of location is 7º 09'19.54''N" and 37 º10'23.68''E to the end point of location 6º 57'07.98''N and 37 º 20'39.59''E. The study area was sectioned in to five. The first section is from Tarcha Town to Turi Village, Waka town-Tulema village, Tulema-Gesa town, Gesa town-Ellabacho village and the last section extends from Ellabacho Village to Yalo Municipality. First the road has been constructed us unpaved gravel road from the year 1994 to 1999 G.C as B52 link road from Jimma - Chida - Soddo. The road has upgraded from gravel to DS4 road class/ERA/'s geometric design manual 2002. The upgraded road has a cross section width of 7 m in rural section with 0.5 m shoulder on each side and 19link road described in Ethiopia road map as B52 that connects Dawuro zone and Wolaita Zone with its neighboring zones and regions(4). This road has been upgraded to asphalt few years and some kilometers are up today under construction.

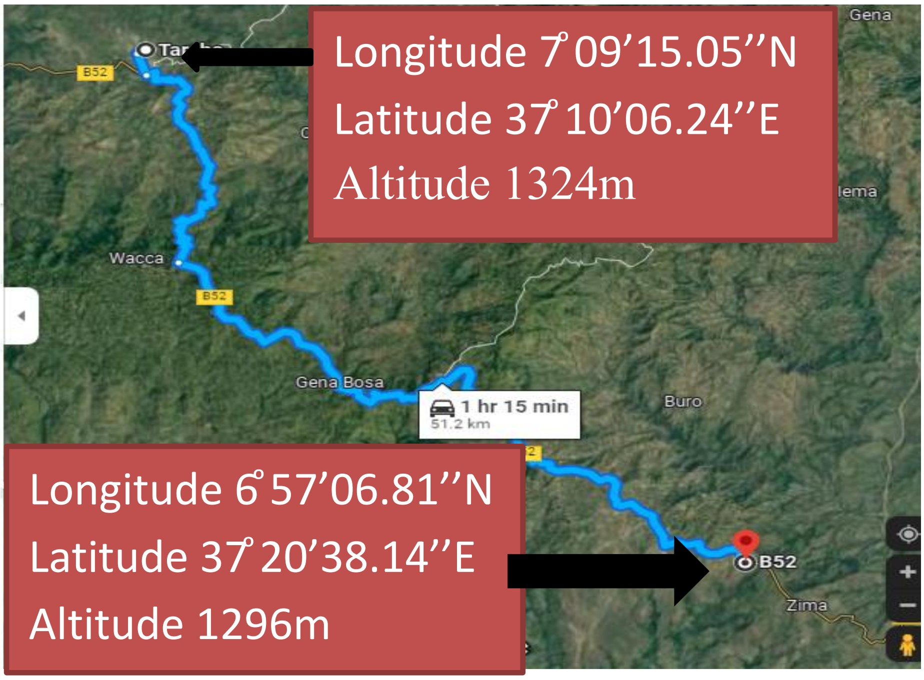

Figure .3-1. Location of selected Highway (source: www.google)

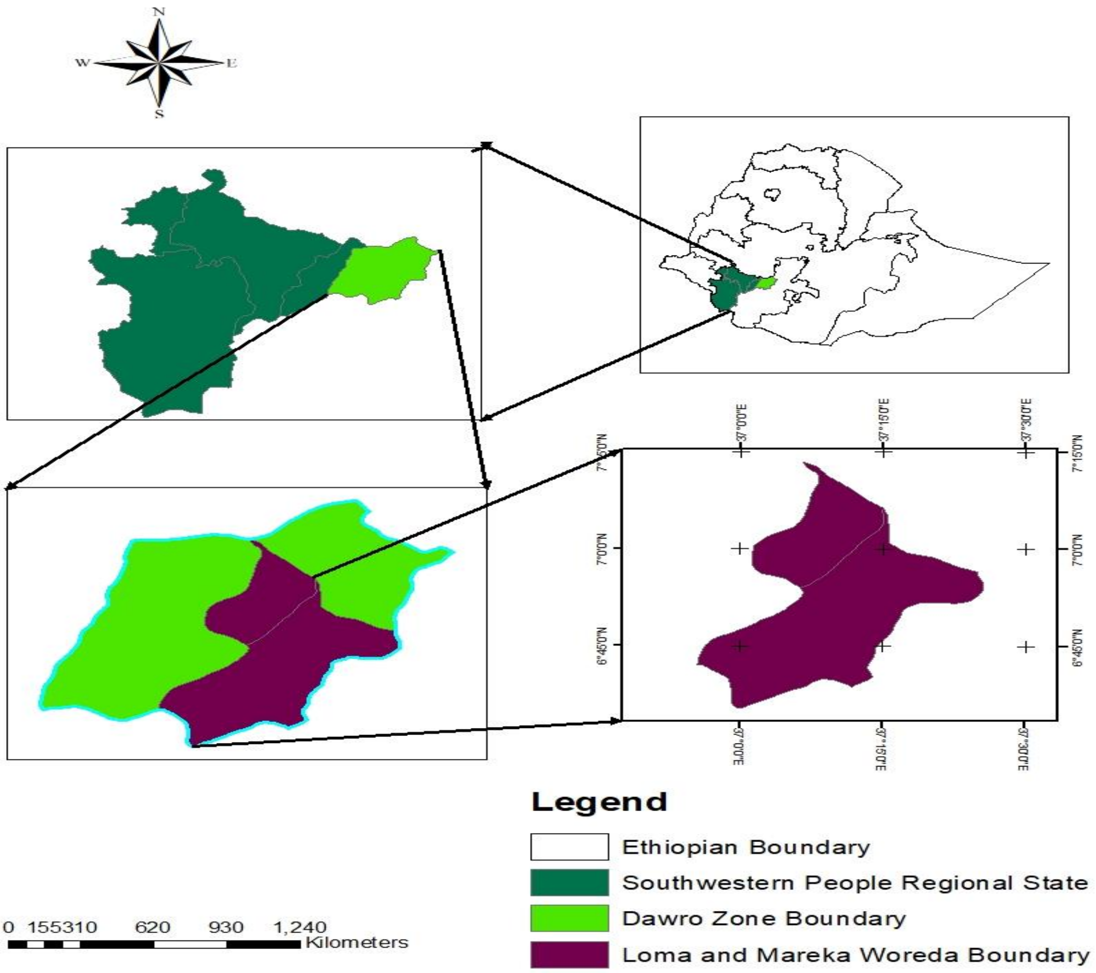

Figure 3-2 Location of administrative area map Arch GIS shape file 2018

3.1.1. Climate Data of the Study Area

Location, climate and topography of the study area Tarcha –Yalo Road Section is in Southwest Ethiopia Peoples Regional State Region Dawro Zone (Tarcha City administration, Tarcha Zuriya Woreda Mareka Woreda and Loma Bosa Woreda). It is located at an elevation of 1364 meters and 492 km southwest Region of Addis Ababa.

Table .3-1.*Location and climate data*

s.no	Attributes	Indicatorsh	Tarcha Town start point	Yalo Municipality End point
1	Locations	Longitude	7º09'15.05''N	6º57'06.81''N
		Latitude	37º10'06.24''E	37º20'38.14''E
		Altitude	1324m	1296m
2	Distance	from Addis Ababa by Sodo	482km	436km
		from Addis Ababa by Jimma	492km	537km
3	Climate	Rainfall(MM)	1672.09	1612.594
		Temperature (ºC)	20.336	20.15

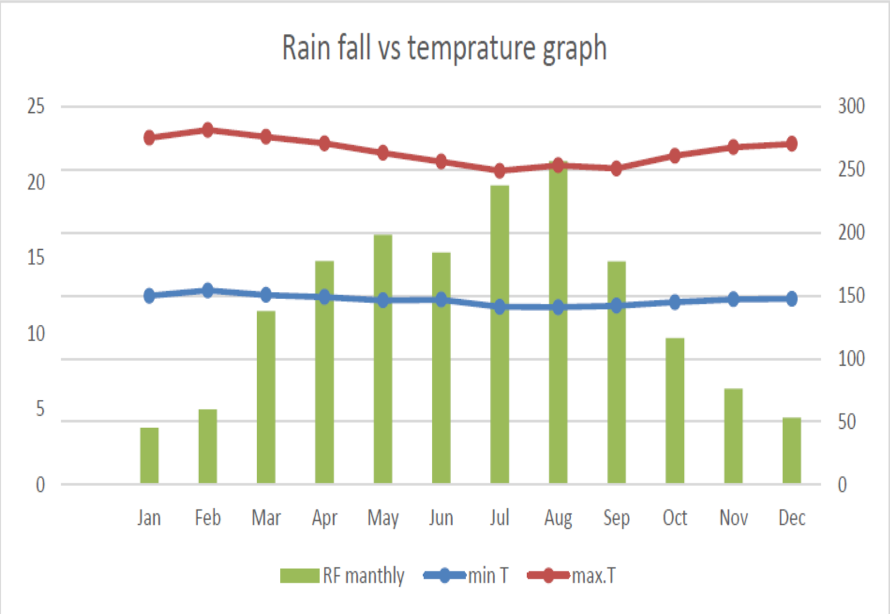

Figure 3-3 Mean monthly minimum and maximum temperatures (ºC) and mean monthly total rainfall (mm) of the first of section study area recorded for the year from 1999-2010 Source: (National Meteorological Agency; Tarcha District)(4)

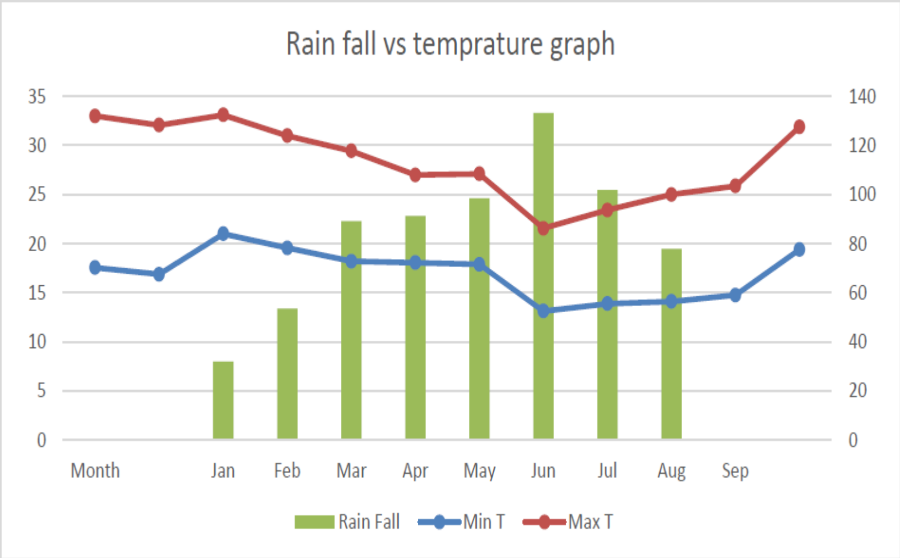

Figure .3-4. Mean monthly minimum and maximum temperatures (°C) and mean monthly rainfall (mm) of the second section of study area recorded for 2016-2020 (Source CRSG and ECDSWC, TDSWS)(4)

3.2. Study Period

The studies for this research will be six months from April 1/2022 up to September 30/2022 including the time for collecting of all important data of study.

3.3. Study Procedures

The procedure followed throughout the conduction of this study were: Review of related literatures on an experimental investigation of causes of flexible pavement failure on flexible pavement performance, flexible pavement failures, factors that affects the performance of flexible pavement related causes of flexible pavement failure, condition survey of flexible pavement, pavement condition index, pavement condition rating and engineering properties of subgrade, sub base and base course materials and characteristics of materials for flexible pavement from journal articles, reference books, previous researches and standards ERA and AASHTO. The research design was conducted in two design procedures. These are the Pavement condition evaluation and experimental works. The pavement condition evaluation has qualitative and quantitative data to evaluate the research work .The qualitative data is the visual observation and judgment on physical condition of pavement (severity, type and extent) in the field survey .And the quantitative data was the measurement of distresses of the study area during field survey.

The second research design was on experimental work. This was followed by collection of soil sample from severely damaged section of asphalt and laboratory tests were conducted using ERA,ASTM and AASHTO manuals .Necessary data collection, laboratory test, organization, comparison, and analysis were obtained, and then subsequently compared the results with preexisting literature and standard specifications. Conclusion and recommendation drew based on the observations and investigation results

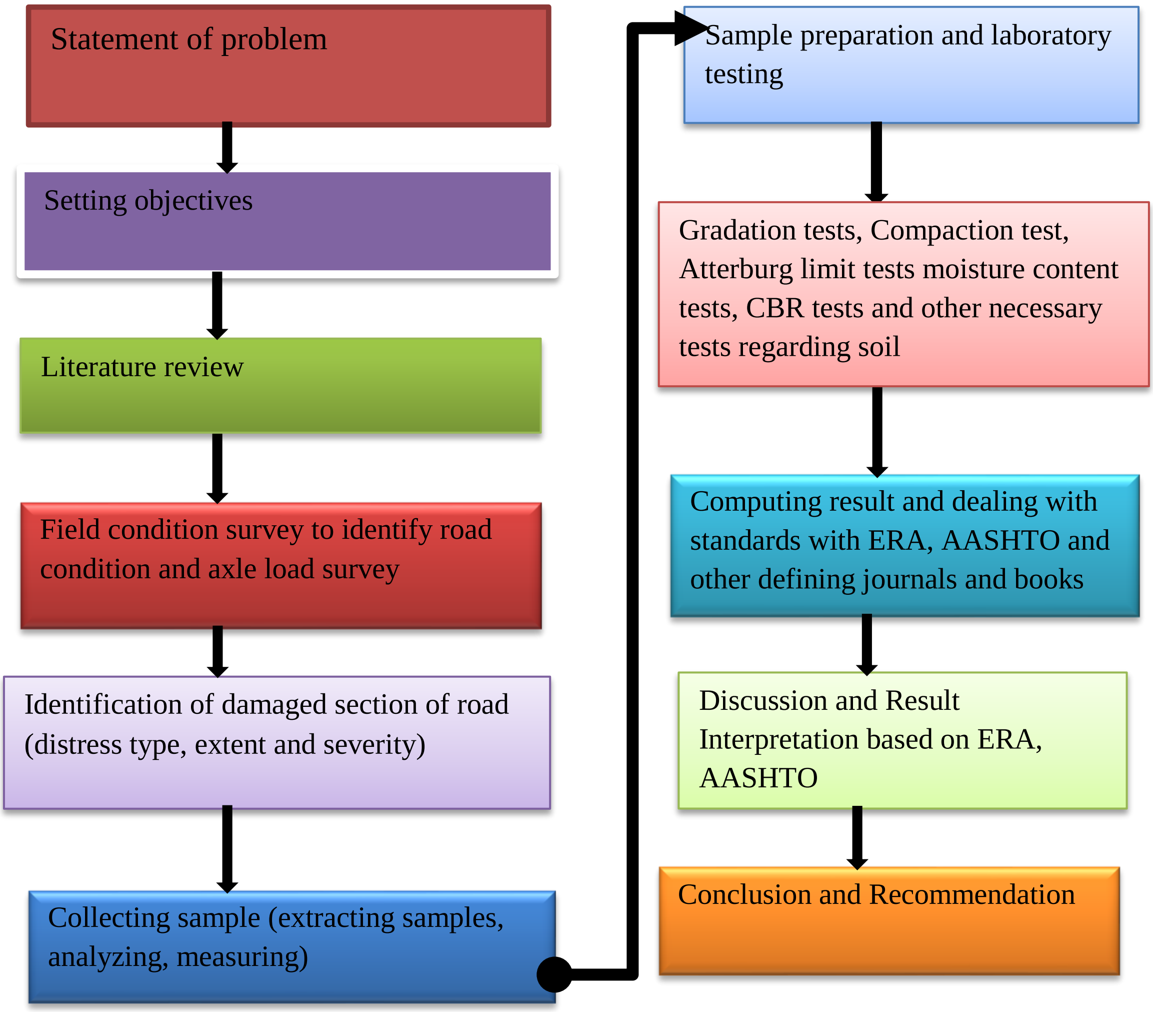

Figure .3-5. Flow chart of research design

3.4. Data Collection

I. Primary Data

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 .The condition survey was conducted on 5 sections of divisions. The section divisions were illustrated in the following table

Table 3-2.*Condition surveying sections description*

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

II. Secondary Data

The secondary data were obtained from: different manuals document (ERA, ASTM and AASHTO), different books and related research journals.

III. Sample Size, Selection and sampling techniques

The sample size selection and technique was designed for two parameters or variables of study. The selected study area was investigated pavement condition evaluation and experimental study of materials engineering properties .Therefore, sample selection and technique design were designed for experimental study and condition survey of pavement.

A. Sample size selection and techniques of experimental study

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

B. Sample size selection and techniques of pavement condition evaluation

In order to achieve the objectives of this research, primarily the pavement was divided into sections that were divided into sample units due to preliminary site visit with visual observations of a pavement section for study. 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 quantity of the distress was measured as described in Appendix A. 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 3. 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.The locality branch of section name were:- (Tarcha-Turi, Waka-Tulema, Tulema-Gesa,

Gesa-Elabacho and Elabacho-Yalo) were selected for detail study by considering the following major criteria's:

- Because of preliminary site visit, the three selected sections were identified as more distressed than other sections and the one was selected for comparison.
- By consideration of current pavement condition, travel distance and available time, resource, money, and manpower, the decision was made to conduct condition survey only within the five sections of road stretch. These selected sections also having greater length than others, and so that more representing the whole road than others

The number of these divided sample units or homogeneous test blocks of the all divide up sections were shown in Table 3 with value 1000m length.

Table 3-3 ***sample identified to be surveyed for study area***

S.NO	Road section division of Survey	Length in km	Section area	Sample unit area	N	n	Spacing (km)	No. of sample inspected
1	Tarcha-Turi	7	45260	7200	7	7	1	7
2	Waka-Tulema	9	64970	7200	9	9	1	9
3	Tulema -Gesa	7.2	42340	7200	7.2	7	1	7
4	Gesa -Elabacho	6.3	53290	7200	6.3	6	1	6
5	Elabacho-Yalo	8	51100	7200	8	8	1	8

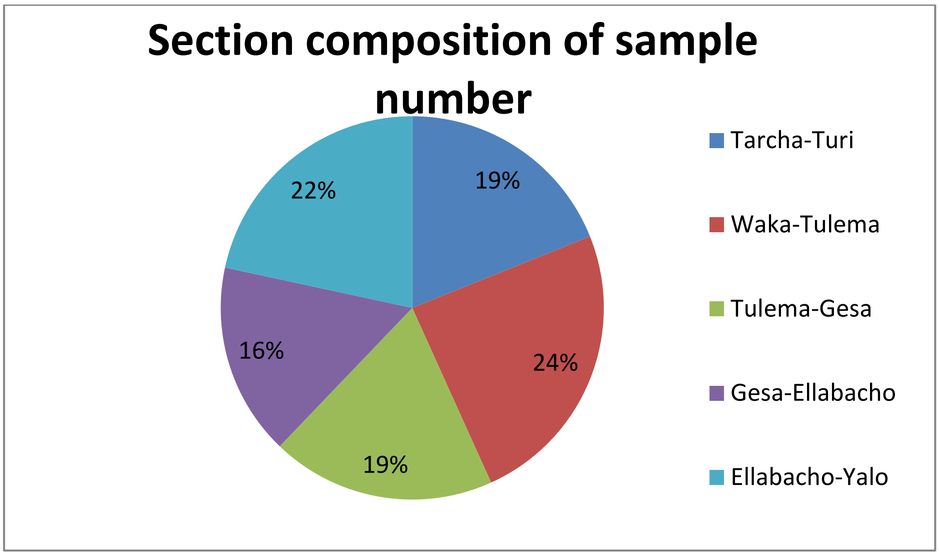

Figure .3-6 .Sample number composition of sections of road segments of study area

Notice:

I =stands for interval of sample units of selected sections of sampling area

N=Stands for total number of sample units of selected sections of sampling area

n=the number of sample units to be surveyed within selected sections of sampling area

IV. Data Processing

Data processing would be conducted through different laboratory tests to determine consecutive results in order to compare with the material property during construction and standards specification with constructed specifications and also adequacy of underlain material to serve as;

- ✓ Subgrade
- ✓ Sub base and
- ✓ Base course material based on project specification and Ethiopian Roads Authority (ERA) standard specifications.

The laboratory tests on representative samples would be extracted from the site to determine the engineering properties of soil, and aggregate materials to compare the test results with the standard specification and the material property during construction as well as with the existing condition of the pavement.

V. Population

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.

3.4.1 Condition Survey

Condition survey is an attempt to provide a comprehensive assessment of the reliability or acceptability of highway pavement sections and it is very valuable when determining priorities for maintenance funding within a major road system(38). Pavement Condition Measurement involves Pavement Condition Survey and Calculation of PCI. PCI is a mathematical index, with values ranging from 0 ~ 100, where 0 is denoted for failed pavement and 100 designates faultless (new) condition. Evaluation of PCI is established on the result of visual survey, which recognizes types, quantity and severity of distress. It was established to deliver an index for structural integrity of the pavement and its surface serviceability(34).

3.5. Study Variables

A. Independent Variable

They are related to specific objectives and to be measured, manipulated to determine its relationships to observed phenomenon. They are:

- ✓ Moisture content
- ✓ Sieve analysis
- ✓ Atterberg limit
- ✓ Moisture density relation
- ✓ CBR value
- ✓ Aggregate tests
- ✓ Axle load
- ✓ Thickness of layers
- ✓ locations of severely damaged pavement damage

B. Dependent Variables

The out puts and factors observed in the study and measured to determine the effects of independent variable laboratory investigations on the construction materials to obtain the causes of flexible pavement failures along Tarcha to Yalo Road section

3.6. Data Analysis

After collection of all core information through site observation and laboratory the results are analyzed by using excel spread sheet and Microsoft word in the forms of table, graphs and equations. The laboratory tests conducted were Natural Moisture content (NMC), Atterberg limit, proctor, gradation and CBR. NMC is conducted to determine the Natural water content of the material through which the amount of water for the CBR is determined. Liquid limit and plastic limit were conducted to determine the index properties of sampled materials from each station. That is, important to determine the engineering properties and requirement of materials. The modified proctor test which is used in the laboratory to show the relationship of moisture content and density of materials (compacted mass of materials in a unit volume through a range of moisture contents) was conducted for each sample from different stations. The gradation test was conducted to determine the degree of inhabitance of different size of materials. The current laboratory test result of CBR values have done and took the mean values of each tables. Samples collected from deteriorated place the CBR tests were carried out and comparisons were made between the CBR value of existing document and current CBR values. The data collected from repetitive observation, and secondary document analysis was analyzed to meet the specific objectives. Statistical Microsoft Excel 2007 software was employed to analyze the data. The analyzed data were presented using tables, graphs and charts. Using laboratory results the engineering properties of soil materials were determined as per specifications, and then classified as AASHTO Classifications. Defects on the pavement were surveyed and were analyzed from the results measured in the field and careful observation taken at different section of the road section during different time.

3.6.1. Performance Evaluation of Flexible Pavement Data Analysis

3.6.1.1 Condition Survey of Selected Segment

Condition survey was done to determine the performance of pavement. The serviceability and functionality of the road is defined as pavement performance. Condition survey is the indication of the serviceability and functionality of flexible pavement condition and also the physical condition of the assets. It is the way of collection of data to determine the serviceability and functional performance (riding quality and structural integrity of road segments). Data are based on observation s and measurements of flexible pavement distress ,surface deformation, surface defects, disintegration and crack (44). In this study the flexible pavement condition survey was used to determine the extent, severity and type of distresses on the section of road Tarcha-Yalo road segment. During the data collection the method was used was to justify the distress using visual observation on field and measuring the distress with hand roller meter measurement. The segment was delineated into three sections. These were =-

A. Tarcha-Waka Section
B. Waka-Tulema
C. Tulema-Gesa
D. Gesa –Elabacho
E. Elabacho–Yalo

Table 3-4 Location of the segments that condition survey has been taken

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+900-70+900	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

1. **Tarcha-Turi Road segment section (63+900-70+900):-**The road section is the section of study area with paved section. The paved section was seven kilometers. In this section the road has rutting, raveling, bleeding, polishing, edge cracking, potholes and drainage problems.

Figure 3-7 Distresses along Tarcha-Turi segment

2. Waka-Tulema Segment Section (80+800-89+800): It is the paved section and it has more types of failures. The types of flexible pavement failures were observed in this section were potholes, bleeding, raveling, longitudinal and transverse cracking, rutting, corrugation, shoving, edge cracking, block cracking and depression.

Figure 3-8 Distresses in Waka-Tulema road segment

3. Tulema-Gesa Segment Section (89+800-97+000):-

This section was section of severely damaged section. The distresses observed in this section were corrugation, potholes, raveling, rutting, block cracking, depression, and shoving, bleeding, edge cracking and polishing. This section was severely damaged section.

Figure 3-9 Distresses observed in Tulema-Gesa section

4. **Gesa-Elabacho(97+000-103+300):**

The fourth section was Gesa town to Elabacho .There were high and more medium level of failure of pavement in this section. Distresses were observed in this section were corrugation, rutting, block cracking, raveling, bleeding, edge cracking, polishing, depression, shoving, bleeding and alligator cracking

Figure 3-10 Distresses in Gesa-Elabqacho road segment

5. **Elabacho-Yalo (103+300-111+300):**

The last section divided for condition survey was Elabacho-Yalo road section. In this section I have also observed medium level of distresses severity. Distresses observed in this section were block cracks, rutting, raveling, bleeding, alligator cracking, edge cracking, shoving, depressions and potholes

Figure 3-11 Distresses in Elabacho-Yalo road segment

3.6.1.2. Pavement condition evaluation

A. Calculation of sample units

The study area has 37.5 km length of segment to be surveyed. In order to manage time and budget the road segment is surveyed using 1 km length for standard area according to ERA manual 2013. The road width is 7.2m and the standard sample unit area was $7200m^2$. To determine the sample units and number of sample units to be surveyed; there were 5 sections of road segments were subdivided according to the location ,length and time in order to adjust for suitability of field survey. The sections were Tarcha-Turi which was 7.0km, Waka-Tulema which was 9.0km, Tulema-Gesa which was 7.2 km, Gesa-Elabacho which was 6.3 km and Elabacho-Yalo which was 8.0 km. The sample unit and number of sample were calculated as follows.

Table 3-5 Sample unit Data

S.NO	Road section division of Survey	Length in km	Section area	Sample unit area	N	n	Spacing (km)	No. of sample inspected
1	Tarcha-Turi	7	45260	7200	7	5.09	1	2
2	Waka-Tulema	9	64970	7200	9	6.00	1	4
3	Tulema -Gesa	7.2	42340	7200	7.2	5.19	1	2
4	Gesa -Elabacho	6.3	53290	7200	6.3	4.73	1	2
5	Elabacho-Yalo	8	51100	7200	8	5.57	1	3

1. Tarcha-Turi

Length of road =7.0 km

Standard length=1.0 km

The width of road=7.2m

Standard area=7.2*1000=$7200m^2$

Sample area of section=7.2m*1000*7.0m=50,400m^2

$$N = \frac{sample\ area\ of\ section}{Standard\ area}$$

$$N = \frac{50,400}{7200} = 7$$

$$n = \frac{N * \sigma^2}{\frac{e^2}{4}(N-1) + \sigma^2}$$

$e = 5 \quad \sigma = 10\ for\ flexible\ pavement$

$$n = \frac{7 * 10^2}{\frac{5^2}{4}(7-1) + 10^2} = 5.09$$

$$i = \frac{N}{n} = \frac{7}{5} = 1.4$$

Using the spacing 1km for all section with applying the same method; the following table shows the number of samples to be surveyed and sample unit's area of the sections. For each section number of sample units and spacing was calculated using above methods of calculation and tabulated as follows

Table 3-6 ***Sample units' area and number of sample to be surveyed***

SNO	Start Section name	End section name	Length	Section area	Sample unit area m^2	N	n	i	No.of sample to
1	Tarcha	Turi	7.0	50400	7200	7	5	1.4	7
2	Waka	Tulema	9.0	64800	7200	9	6	1.5	9
3	Tulema	Gesa	7.2	51840	7200	7.2	5	1.4	7
4	Gesa	Ellabacho	6.3	45360	7200	6.3	4	1.5	6
5	Ellabacho	Yalo	8.0	57600	7200	8	5	1.6	8

3.6.1.3. Determination of Extent of Distresses

The condition survey of the selected road segment is in maintenance requirement condition. The survey investigation along the study road segment shows the different types of flexible pavement distresses such as surface deformation, surface defects, Disintegration, cracks and problems related to flexible pavement failures are identified. There were about twelve flexible pavement distresses were identified during field survey. These were illustrated below table.3-7

Table 3-7 ***the extent of distresses***

S.NO	Type of distress	Measuring units	Extent and severity		
			low	medium	high
1	Alligator cracking	m^2	413.75	431.22	75.8
2	Block cracking	m^2	189.58	394.33	565.03
3	Depression	m^2	433.04	271.25	632.86
4	Shoving	m^2	163.12	211.72	314.35
5	Edge cracking	m	327.95	1327.75	72.24
6	Longitudinal &transverse cracking	m	119.27	31.88	
7	polishing	m^2	1946.48		
8	Rutting	m^2	529.16	178.26	85.22
9	Lane/ shoulder drop off	m		237.88	362.64
10	pothole	number	80	122	50
11	Corrugation	m^2	66.63	239.87	427.1
12	Bleeding	m^2	6623.90	12756.62	738.22
13	Raveling	m^2	319.44	129.5	174.47

3.6.1.4. Determination of density of distresses

The densities of the distresses were calculated width the extent or quantity of the distresses divided by standard sample unit area and multiplied by 100.In the field there were about 13 types of distresses were identified and surveyed with their severities and extents.

$$Density = \frac{distresses\ in\ meter}{sample\ unit\ area\ in\ square\ meter} * 100\%$$

$$Density = \frac{distresses\ in\ square\ meter}{sample\ unit\ area\ in\ square\ meter} * 100\%$$

$$Density = \frac{Distreses\ in\ number}{sample\ unit\ area\ in\ square\ meter} * 100\%$$

Table 3-8 ***densities of distresses***

S.NO	Type of distress	Extent and severity			Sample unit Area	Density%		
		low	medium	high		Low	Medium	High
1	Alligator cracking	413.75	431.22	75.8	115200	0.36	0.37	0.07
2	Block cracking	189.58	394.33	565.03	108000	0.18	0.37	0.52
3	Depression	433.04	271.25	632.86	136800	0.32	0.2	0.46
4	Shoving	163.12	211.72	314.35	86400	0.22	0.29	0.44
5	Edge cracking	327.95	1327.75	72.24	108000	0.3	1.27	0.07
6	Long.&trans.cracking	119.27	31.88		14400	0.83	0.22	0
7	polishing	1946.48			57600	3.38		
8	Rutting	529.16	178.26	85.22	144000	0.37	0.12	0.06
9	Lane/shoulder drop		237.88	362.64	14400	0	1.65	2.52
10	pothole	80	122	50	158400	0.1	0.1	0.03
11	Corrugation	66.63	239.87	427.1	72000	0.1	0.33	0.59
12	Bleeding	6623.9	12756.62	738.22	172800	3.83	7.38	0.43
13	Raveling	319.44	129.5	174.47	93600	0.34	0.14	0.19

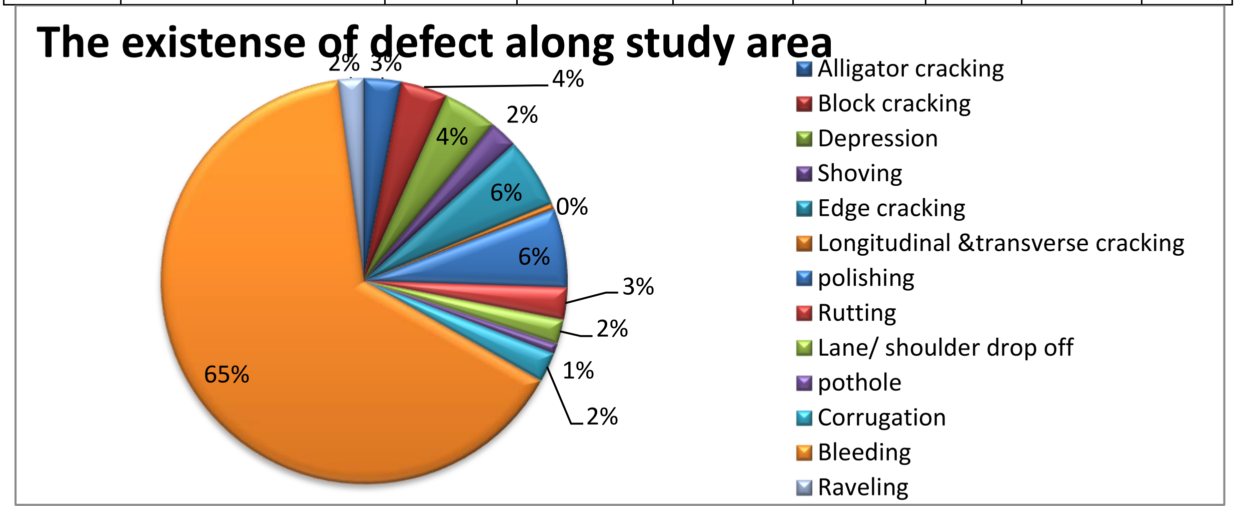

Figure 3-12 Pavement distresses distribution percentage

3.6.1.5. Determination of pavement condition index

In this study of research, the pavement condition data were analyzed using the method of (ASTM D6433, 2007): To calculate PCI of the sample unit the following steps were adopted.

1) Add up the total quantity of each distress type at each severity level, and record them in the "Total Severities" section. The units for the quantities may either be in square feet (square meters), linear feet (meters), or several occurrences, depending on the distress type.

2) Divide the total quantity of each distress type/severity level of the total area of the sample unit and multiply by 100 to obtain the percent density of each distress type and severity.

3) Determine the deduct value (DV) for each distress type and severity level combination of the distress deduct value curves.

4) Determine the maximum corrected deduct value (CDV). The following procedure was used to determine the maximum CDV.

a) If none or only one individual deduct value is greater than two, the total value is used in place of the maximum CDV in determining the PCI; otherwise, maximum CDV must be determined using the procedure described below.
b) List the individual deducts values in descending order.
c) Determine the allowable number of deducts value (m), using equation
d) $m = 1 + (9/98)(100 - HDV) \leq 10$

Where:

m = allowable number of deducts including fractions (must be less than or equal to 10).

HDV = highest individual deducts value.

d) The number of individual deduct values are reduced to the m largest deduct values, including the fractional part.
e) Determine maximum CDV iteratively
   i. Determine total deduct value by summing individual deduct values. The total deduct value is obtained by adding the individual deduct values in d,
   ii. Determine q as the number of deducts with a value greater than 2.0.
   iii. Determine the CDV from total deduct value and q by looking up the appropriate correction curve for AC pavements in appendix l.

iv. Reduce the smallest individual deduct value greater than 2.0 to 2.0 and repeat i-iii until q = 1.

v. Maximum CDV is the largest of the CDVs.

5) Calculate PCI by subtracting the maximum CDV from 100: PCI = 100-max CDV.

The detailed calculation procedures are in appendix A. The following table shows the summary of PCI of the road segment of study area. Detail calculations are shown in appendix A

Table 3-9 Pavement condition rating of average PCI value of five sections of study area

Sectional routes Name	Station	Length(km)	PCI	PCR
Tarcha-Turi	63+900-70+900	7	79	Very good
Waka-Tulema	80+800-89+800	9	65	good
Tulema-Gesa	89+800-97+000	7.2	55	poor
Gesa-Ellabacho	97+000-103+300	6.3	62	good
Ellabacho-Yalo	103+300-111+300	8	69	good

3.6.1.6. Determination of pavement condition rating

Table 3-10 ***PCR and its percentage for the total length of study area***

Pavement condition Rating(PCR)	Total number of PCR	% of PCR
Excellent	5	13.9
Very good	16	44.4
Good	10	27.8
Fair	3	8.3
Poor	2	5.6

A verbal description of pavement condition is described as a function of the PCI value that varies from failed (0) to good (100) (ASTM D6433, 2007).

Based on the field condition survey, except very poor and failed rating; all types of pavement condition rating were exist in the study area along the road section from Tarcha to Yalo. The following table show the result of pavement condition rating along the selected road section from Tarcha to Yalo road segment and the calculation of these values is shown in Appendix A

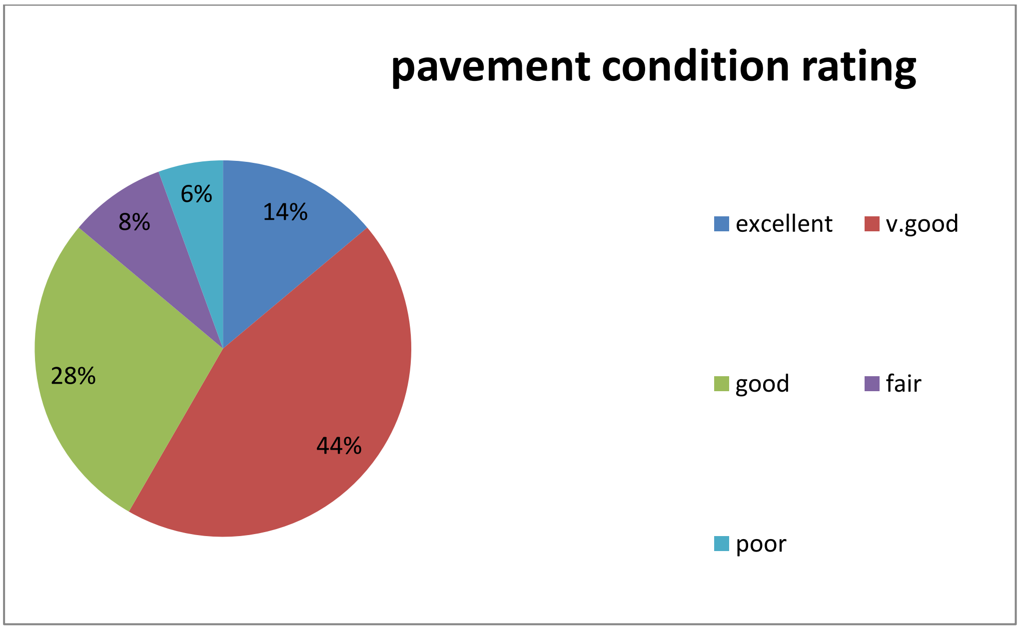

Figure 3-13 Percentage distribution of PCR

3.6.2. Laboratory Tests Data Analysis

To determine the engineering properties of the base course, sub-base and subgrade materials different tests has conducted. They were gradation test; Atterbergs limit test, Los Angeles Abrasion tests, Compaction test and California Bearing Ratio Test (CBR). The laboratory investigation was based on AASHTO, ASTM, BS and ERA manuals specification and standards.

3.6.2.1. Gradation Test (Grain Size Distribution Tests)

According to ERA 2013 and AASHTO manuals the gradation of sub base and base course materials is justified and standardize with required specifications. The distribution of particles of different size in the soil mass is called Grading and the grading of soil can be obtained from the particle size distribution curve. The mechanical analysis consists of determination of the amount and portion of coarse material by the use of sieve. The grain size analysis results are plotted below with layers of pavement and the data is given in Appendix -D

A.Sub Grade

According to ERA manuals and specification the laboratory result of the size distribution of all test pits of sub grade materials are presented under the following table 3.11

Table 3-11 Percentage passes of subgrade soil

Grain size distribution of pavement construction materials					
Material Type:Sub Grade			Date of sampled:30/11/2022		
Failure Type:All Failures type			Date of test:21/12/2022		
Type of sieve :Wahed		Sampled by:Hailemichael Debalke Damota			
Types of Failure	Non failure	Non-failure	Corrugation	Block Cracking	Ravelling and stripping
Test Pit No.	BH1	BH2	BH3	BH4	BH5
Sieve Size(mm)	Pass %	Pass %	Pass %	Pass %	Pass %
5	100	100	100	100	100
4.75	97.1	94.18	90.5	96.2	94.44
2.36	82.19	93.1	89	90.8	91.25
1.18	70.85	85.42	75.5	88.12	80.5
0.425	61.24	70.13	67.52	78	72.3
0.3	52.4	62.24	54.19	70.68	67.62
0.075	48.3	34.31	24.9	28.53	59.45
pan	0	0	0	0	0

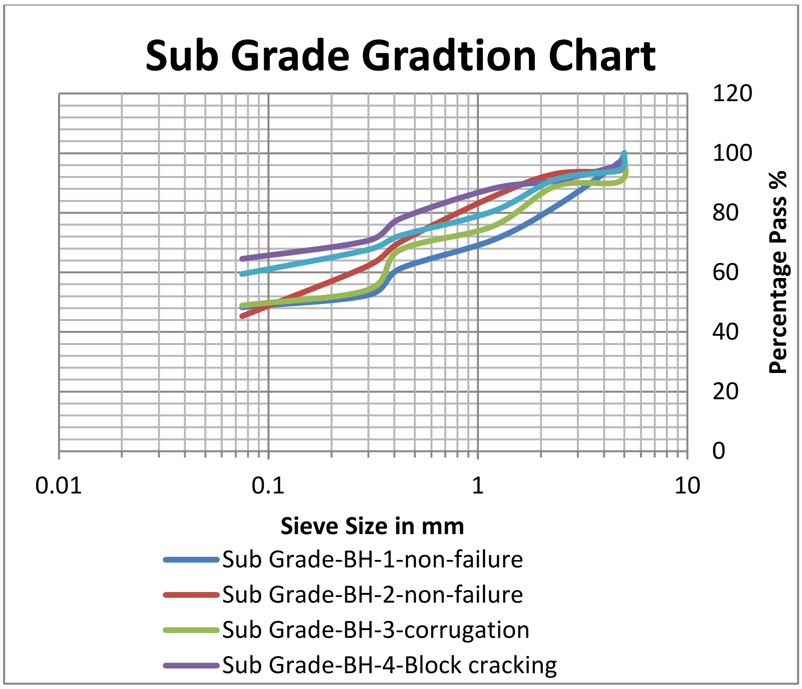

Figure 3-14 the distribution chart of percentage pass of subgrade soil

Table 3-12 Subgrade soil classification using AASHTO soil classification

Test pits	Station	LL	PL	PI	Pass in 0.075mm	Soil class
BH1	63+900	50	32	18	48.3	A-7-5
BH2	83+400	52	27	25	34.31	A-2-7
BH3	89+800	68	34	34	24.9	A-2-7
BH4	97+000	57	34	23	28.53	A-2-7
BH5	103+300	48	33	15	59.45	A-7-5

B. Gradation or grain size distribution of sub base materials

According to ERA manuals and specification the laboratory result of the size distribution of all test pits of sub base materials are presented under the following table 3.13

Table 3-13 Wash gradation results with ERA specification of Sub-base

Grain size distribution of pavement construction materials						ERA 2013 Grading Lower Limmit	ERA 2013 Grading upper Limmit
Material Type:Sub Base			Date of sampled:30/11/2022				
Failure type:All failures			Date of test:21/12/2022				
Type of sieve :Wahed	Sampled by:Hailemichael Debalke Damota						
Types of Failure	Non-failure	Non-failure	Corrugation	Block Cracking			
Test Pit No.	BH1	BH2	BH3	BH4	BH5		
Sieve Size(mm)	Pass %	Pass %	Pass %	Pass %	Pass %	Pass %	Pass %
50	100	100	100	100	100	100	100
37.5	75.32	70.85	84.42	78.36	80.37	80	100
20	48.12	50.24	60.62	54.45	58.12	55	80
5	29.41	33	32.64	36.75	44.52	40	60
1.18	10.25	18	24.8	28.34	32.25	30	50
0.425	8.4	8.24	12.22	18.28	16.43	12	27
0.075	5.68	6.32	7	4.45	6.62	5	15
pan	0	0	0	0	0	0	0

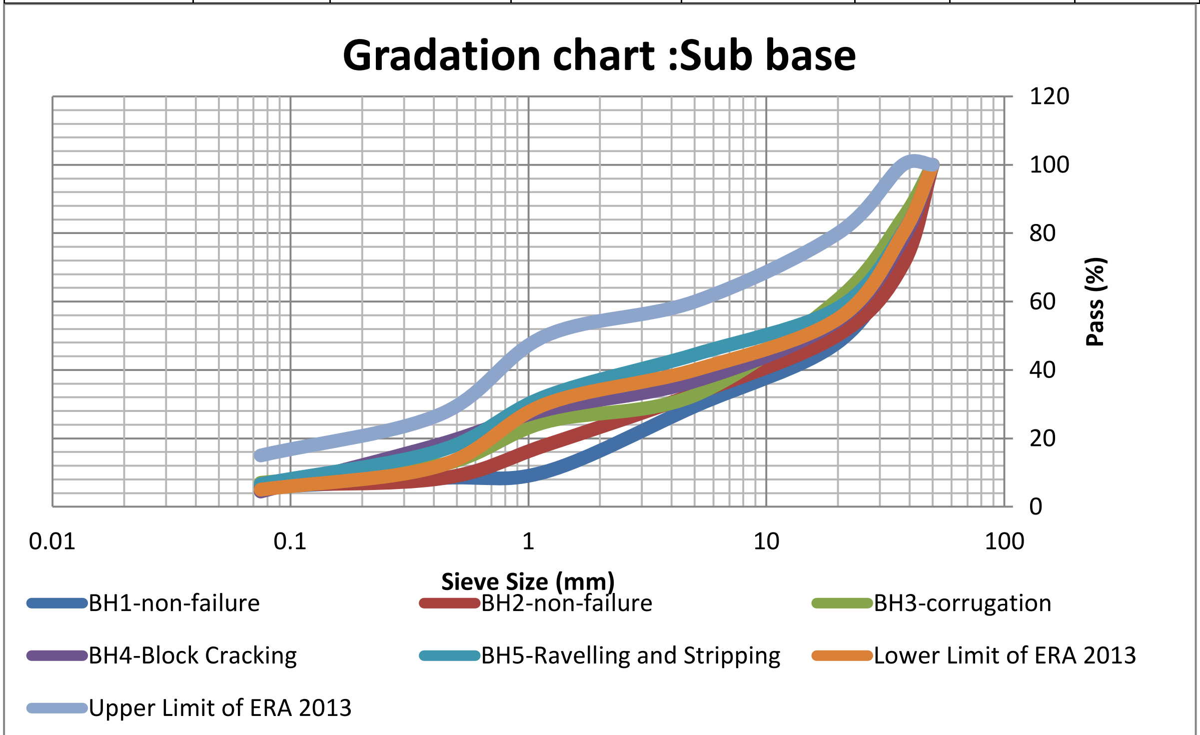

Figure 3-15 the gradation curve chart of sub base

Table 3-14 ***Parameters from sub base sieve analysis curve***

Test pits	Gravel %	Sand %	Fines %	D10 inmm	D30 in mm	D60 in mm	Cu	CC
BH1	75.67	18.65	5.68	3	5	16.7	5.57	0.5
BH2	67.44	26.24	6.32	0.7	3.9	19	27.14	1.14
BH3	55.98	37.02	7	0.3	4.7	20.3	67.67	3.63
BH4	48.93	46.62	4.45	0.17	3.8	20	117.65	4.25
BH5	44.7	48.68	6.62	0.15	2.3	13	86.67	2.71

Note the average cu=50.78 and average cc=2.04

The average uniformity coefficient of sub base is 50.78 which is greater than 4 and the average coefficient curvature of sub base is 2.04 which is between 1 and 3 .Hence the subgrade soil is well graded gravel(GW).

C. Gradation or grain size distribution of base course materials

According to ERA manuals and specification the laboratory result of the size distribution of all test pits of base course materials are presented under the following table 3.15

Table 3-15 ***Wash gradation results with ERA specification of base course***

Grain size distribution of pavement construction materials						ERA 2013 Grading Lower Limmit	ERA 2013 Grading upper Limmit
Material Type:Base Course			Date of sampled:30/11/2022				
Failure Type:All Failures type			Date of test:21/12/2022				
Type of sieve :Wahed		Sampled by:Hailemichael Debalke Damota					
Types of Failure	Non-failure	Non-failure	Corrugation	Block Cracking	Raveling and Stripping		
Test Pit No.	BH1	BH2	BH3	BH4	BH5		
Sieve Size(mm)	Pass %	Pass %	Pass %	Pass %	Pass %	Pass %	Pass %
50	100	100	100	100	100	100	100
37.5	85.6	89	94.18	90.08	80.37	95	100
28	70.72	72.2	79.57	88.54	68.12	80	95
20	59.4	62.18	65.32	68.21	51.74	60	80

10	40.21	50.03	38.4	50.23	32.25	40	60
5	22.3	34.12	28.22	42	21.22	25	40
2.36	16.5	27.77	14.77	25.14	14.25	15	30
0.425	11.62	15.62	10.68	19.24	10.72	7	19
0.075	4.88	7.6	8.49	12.04	3.25	5	12
pan	0	0	0	0	0	0	0

Table 3-16 *Parameters from base course sieve analysis curve*

Test pits	Gravel %	Sand %	Fines %	D10 inmm	D30 in mm	D60 in mm	Cu	CC
BH1	67	28.12	4.88	0.27	7	20.3	75.19	8.94
BH2	49.01	43.39	7.6	0.18	5	20	111.11	6.94
BH3	66.06	25.45	8.49	0.35	6	19	54.29	5.41
BH4	43.58	44.38	12.04	0	2.9	18	0	0
BH5	71.78	24.97	3.25	0.3	9.9	27	90	12.1

Note the average cu=55.10 and average cc=5.6

The average uniformity coefficient of base course is 55.1 which is greater than 4 and the coefficient of curvature is 5.6 which is greater 1 and 3 .Hence the soil is well graded sand.

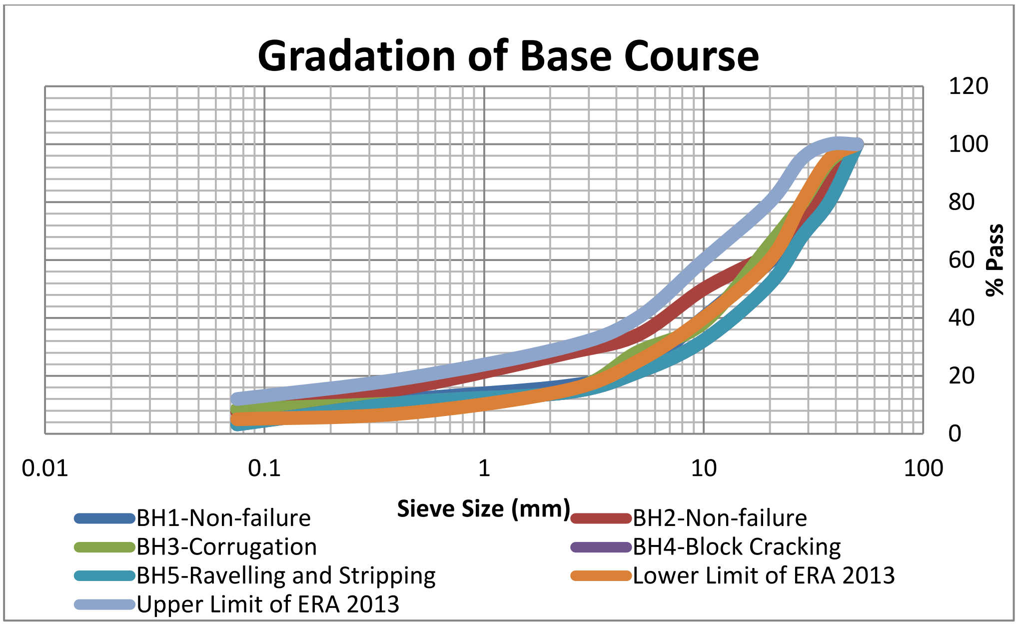

Figure 3-16 Wash gradation results of base course materials

3.6.2.2 .Compaction Test

The purposes for this test are to determine the maximum dry density attainable under specified nominal compaction energy for a given material and the (optimum) moisture content corresponding to this density. Material or soil compaction tests were conducted in the laboratory according to AASHTO T-99 (Standard Proctor Test) for subgrade and AASHTO T-180 (Modified Proctor Test) for sub grade, sub base and base course material by using disturbed samples which taken from the existing road. The detail of compaction test is presented in appendix-E. The following table shows summary results.

Table 3-17 ***Summarized Compaction Tests Results***

		subgrade		sub base		basecourse	
Test pits	stations	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

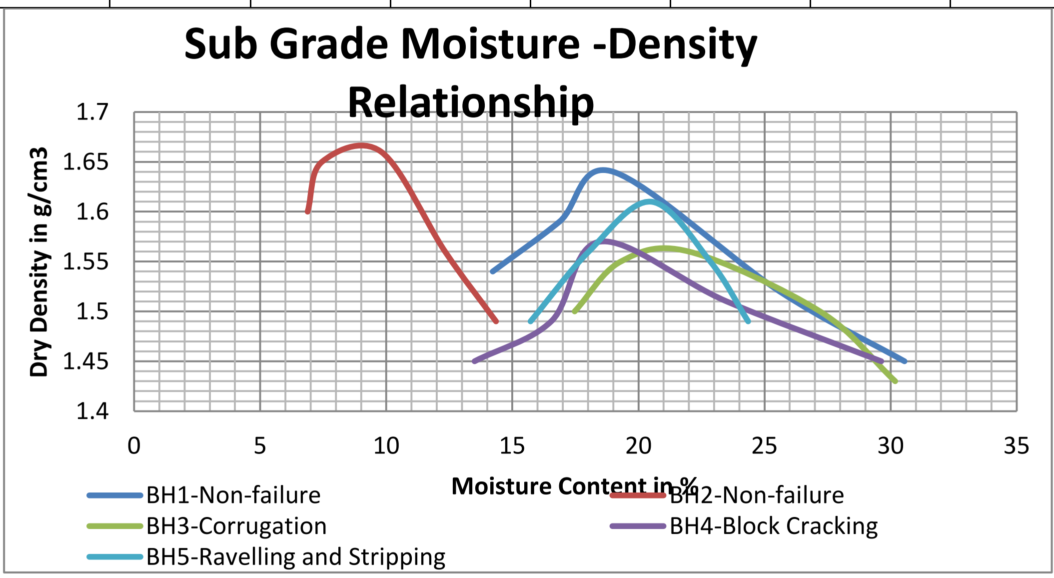

Figure 3-17 The Laboratory Test Result for OMC & MDD of Subgrade soil.

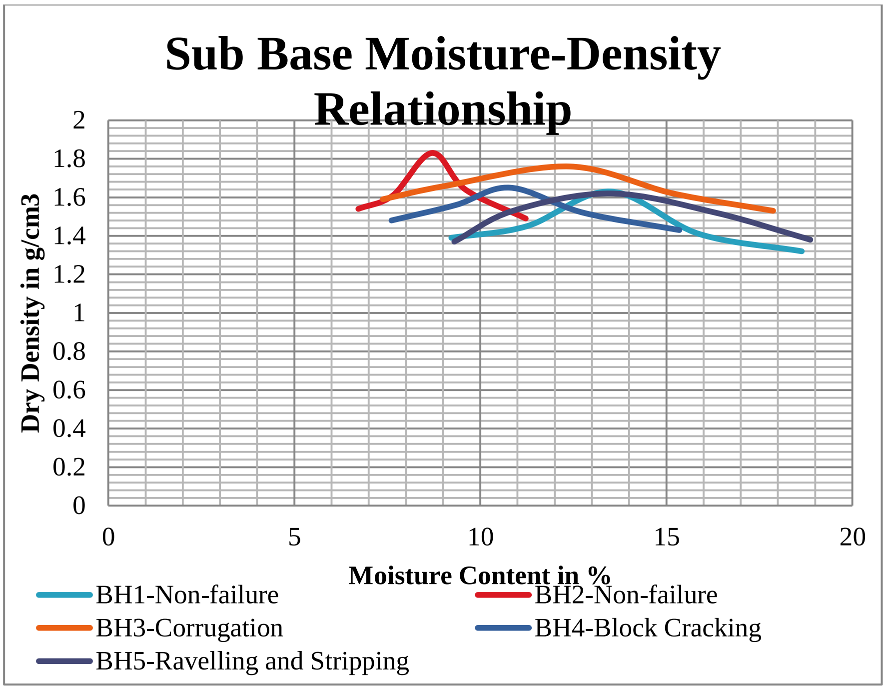

Figure 3-18 The Laboratory Test Result for OMC & MDD of Sub-base Layer

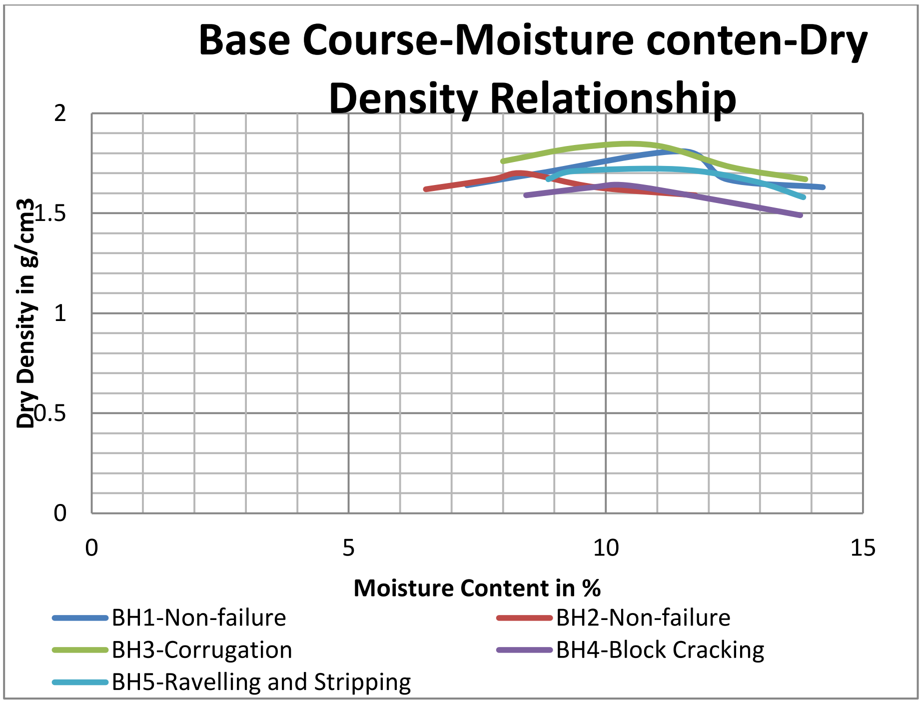

Figure 3-19 The Laboratory Test Result for OMC and MDD of Base course Layer

3.6.2.3. Atterberg Limit Test

This lab test is performed to determine the plastic and liquid limits of a fine-grained material and then determine the value of plasticity of the material and which are based on the moisture content of the material. The water contents corresponding to the transition from one state to another are termed as Atterberg's Limits are recorded. The three Atterberg's limits, which are liquid limit, plastic limit, and shrinkage limits are the boundary between each of the two consecutive states of the soil-water phases. The liquid limit and plastic limit test are performed only on that portion of sampled materials, which passes the 0.425 mm (No. 40) Sieve. Atterberg limit test was made on Base course, Sub base and Sub grade on each boreholes. The testing procedure was done according to AASHTO T89, T90 and M145(45). The plastic limits, liquid limits and plastic index are summarized and tabulated below and the individual atterberg limit was shown in Appendix-F

Table 3-18 ***Summary of Atterberg limits of all pits***

Test pits	stations	subgrade			sub base			basecourse		
		LL	PL	PI	LL	PL	PI	LL	PL	PI
BH1	63+900	50	32	18	35	26	9	4.4	0	4.4
BH2	83+400	52	27	25	38	25	13	4.5	0	4.5
BH3	89+800	68	34	34	37	29	8	5	0	5
BH4	97+000	57	34	23	31	26	5	4	0	4
BH5	103+300	48	33	15	32	20	12	6	0	6

3.6.2.4. California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) was used for evaluating the suitability of sub-grade and the materials used in sub-base and base course. The CBR number is obtained as the ratio of the unit load (in KN/m2) required to effect a certain depth of penetration of the penetration piston in to a compacted specimen of soil at some water content and density to the standard unit load required to obtain the same depth of penetration on a standard sample of crushed stone(46). The result of the CBR is shown in the table below and the analysis is attached in Appendix-G

Table 3-19 *Summary of CBR of all test pits*

Reading on 2.54 mm penetration of 65 blows						
Test pits	Sub grade		Sub base		Base course	
	CBR	SWELL	CBR	SWELL	CBR	SWELL
BH-1	10	1.105	39	0.7	90	0.57
BH-2	15	1.265	73	0.7	86	0.44
BH-3	7	1.128	91	0.53	92	0.59
BH-4	13	1.145	60	0.61	59	0.536
BH-5	7	1.074	77	0.72	74	0.558

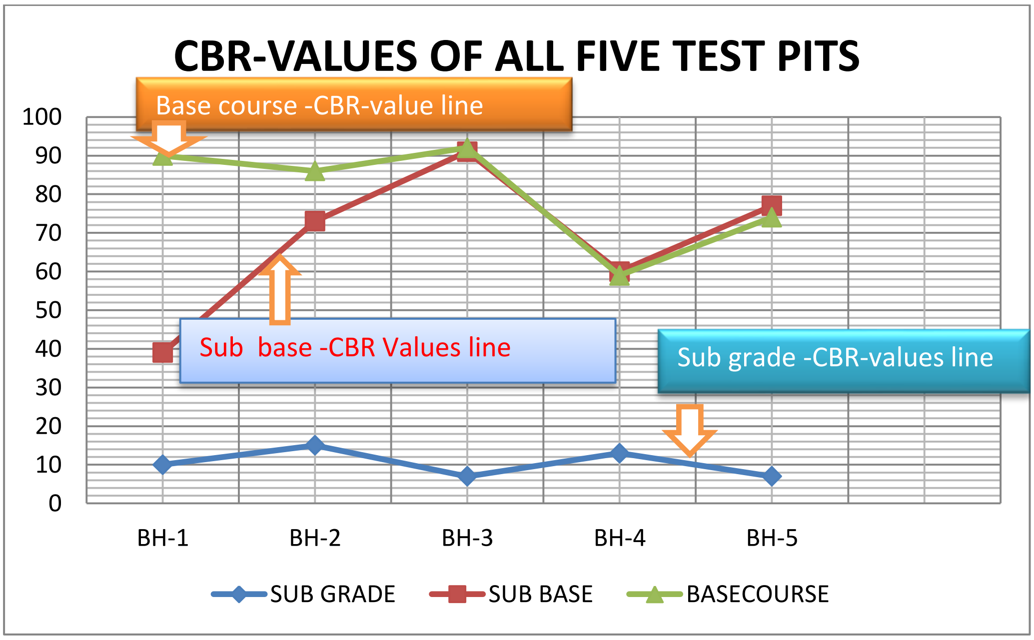

Figure 3-20.The CBR Values variation chart of all layers of all pits

3.6.2.5. Los Angeles Abrasion Test (ASTM C131 And ASTM C535-89)

Abrasion test is the test used to know how the aggregate is sufficiently hard to resist the abrasive effect of traffic over its service life. The most widely used abrasion test is the Los Angeles Abrasion Test which involves the use of a steel drum, revolving on horizontal axis, into which the test sample of chippings is loaded together with steel balls of 46.8 mm diameter. The Los Angeles Abrasion Value (LAV) is the percentage of fines passing the 1.7 mm sieve after a specified number of revolutions of the drum at specified speed. The drum is fitted with internal baffles causing the aggregate and the steel balls to be lifted and then fall as the drum revolves.

Table 3-20.Los Angeles Abrasion test results of Base course

Base course Trial 1					
Test pits No.	Weight of sample for test	weight of retained on sieve 1.7mm	weight of passing on sieve 1.7mm	Weight loss	Percent loss
BH1	5000	1453	3547	1453	29.06
BH2	5000	1308	3692	1308	26.16
BH3	5000	1210.42	3789.58	1210.42	24.2084
BH4	5000	1992	3008	1992	39.84
BH5	5000	1103	3897	1103	22.06
Base course Trial 2					
Test pits No.	Weight of sample for test	weight of retained on sieve 1.7mm	weight of passing on sieve 1.7mm	Weight loss	Percent loss
BH1	5000	1525.65	3724.35	1525.65	30.513
BH2	5000	1373.4	3876.6	1373.4	27.468
BH3	5000	1270.941	3979.059	1270.941	25.41882
BH4	5000	2091.6	3158.4	2091.6	41.832
BH5	5000	1158.15	4091.85	1158.15	23.163

The test therefore gives an indication of the impact strength in combination with the abrasion resistance of the aggregate. For bituminous surface dressings, chippings with an ACV less than 30 are desirable and the stronger they are the more durable will be the dressings. With premixed bituminous materials and with crushed stone bases, high mechanical strength, though useful, is not always of paramount importance. The repeatability and reproducibility of this test are satisfactory and appropriate for use in contract specifications.(44)

Table 3-21 .*Los Angeles Abrasion test results of Sub base*

Sub base Trial 1					
Test pits No.	Weight of sample for test	weight of retained on sieve 1.7mm	weight of passing on sieve 1.7mm	Weight loss	Percent loss
BH1	5000	1512	3488	1512	30.24
BH2	5000	1781	3219	1781	35.62
BH3	5000	1236	3764	1236	24.72
BH4	5000	1148	3852	1148	22.96
BH5	5000	1878	3122	1878	37.56
Sub base Trial 2					
Test pits No.	Weight of sample for test	weight of retained on sieve 1.7mm	weight of passing on sieve 1.7mm	Weight loss	Percent loss
BH1	5000	1587.6	3662.4	1587.6	31.752
BH2	5000	1870.05	3379.95	1870.05	37.401
BH3	5000	1297.8	3952.2	1297.8	25.956
BH4	5000	1205.4	4044.6	1205.4	24.108
BH5	5000	1971.9	3278.1	1971.9	39.438

In this test (ASTM, 1996) an aggregate sample is subjected to attrition and impact by steel balls whilst rotating within a steel cylindrical drum at a prescribed rate for a set number of revolutions. On completion of the test, the sample is screened on a 1.70mm sieve. The coarser fraction is washed, oven dried and weighed. The loss in weight expressed as a percentage of the original sample weight is the Los Angeles Abrasion Value(47)

Los Angeles Abrasion test were made on pavement material Base course and Sub base to evaluate the strength properties of aggregate. The mass of sample passed sieve size 1.7mm helps to determine the amount of Abrasion (friction) by vehicle. Aggregates are subjected to crushing and abrasive wear during the manufacture, placing and compaction of asphalt paving mixes. They are also subjected to abrasion under traffic loads. There does not appear to be a really satisfactory test for measuring aggregates' resistance to abrasion but the Los Angeles Test is one of those most commonly applied. This test is both an abrasion and impact test and appears to be more suitable for aggregates used in the wearing course / surface dressing than for asphalt concrete in other layers. Resistance to abrasion is necessary for maintaining surface macro-texture but (unfortunately) the tougher an aggregate is, the more likely it is to polish under the action of vehicle tyres. To assess the resistance to crushing and abrasive wear of an aggregate by means of the Los Angeles Abrasion Machine(48)The results are illustrated in Table 3.20 and Table 3.21

3.6.3. Subgrade Soil Classification

Soil classification is based on Atterberg limit tests results of liquid limit and plasticity index of soils and the uniformity coefficient and curvature coefficients into different group in order that the soils in a particular group would have similar behavior. The method of classification used in this study was the AASHTO System. The AASHTO Classification system is useful for classifying soils for highways. The particle size analysis and the plasticity characteristics are required to classify a soil. The soils with the lowest number, A-1, is the most suitable as a highway material or sub grade. Thus according to the AASHTO Classification system the sub-grade material is classified as A-2-7 and A-7-5 .The average value of liquid limit (55%) and plasticity index (23%) and passing of particles in sieve size 0.075mm is 39.1%. Hence the soil classification of the study area is A-7-5.The table below shows the soil classification according to AASHTO standard and unified soil classification system.

Table 3-22 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		
BH1	Base course	4.5		4.5	A-1-a	GP
	Sub base	33	26	7	A-2-4	GW-GS
	Sub grade	45	32	13	A-7-5	MC-SC
BH2	Base course	4.5	0	4.5	A-1-a	GP
	Sub base	38	25	13	A-2-6	GW
	Sub grade	48	34	14	A-2-7	CG-GS
BH3	Base course	5.0	0	5.0	A-1-a	GP
	Sub base	37	29	8	A-2-4	GP-GM
	Sub grade	53	27	26	A-2-7	CG-GS
BH4	Base course	4.0	0	4.0	A-1-a	GW
	Sub base	31	26	5	A-1-b	GP-GS
	Sub grade	57	34	23	A-2-7	CG-GS
BH5	Base course	6.0	0	6.0	A-1-a	GP
	Sub base	32	20	12	A-2-6	SW-GC
	Sub grade	48	33	15	A-7-5	MC-CS

Table 3-23.Summary of laboratory test results of soil samples of distress type's boreholes with base, sub-base and sub-grade layers

Test pit No	Pavement layers	Thickness of layers during	Atterberg limit			Compaction		AASHTO classification	Unified soil system	CBR
			LL	PL	PI	OMC	MDD			2.54 mm
BH1	Base course	8cm	4.5		4.5	11.5	1.81	A-1-a	GP	90
	Sub base	12cm	33	26	7	13.5	1.64	A-2-4	GW-GS	39
	Sub grade	-	45	32	13	19	1.64	A-7-5	MC-SC	10
BH2	Base course	10cm	4.5	0	4.5	8.4	1.71	A-1-a	GP	86
	Sub base	13cm	38	25	13	8.7	1.84	A-2-6	GW	73
	Sub grade	-	48	34	14	9.8	1.67	A-2-7	CG-GS	15
BH3	Base course	9.5cm	5.0	0	5.0	10.95	1.84	A-1-a	GP	92
	Sub base	11cm	37	29	8	12.4	1.76	A-2-4	GP-GM	91
	Sub grade		53	27	26	22	1.56	A-2-7	CG-GS	7
BH4	Base course	12cm	4.0	0	4.0	10.4	1.64	A-1-a	GW	59
	Sub base	10cm	31	26	5	10.8	1.65	A-1-b	GP-GS	60
	Sub grade		57	34	23	18.5	1.57	A-2-7	CG-GS	13
BH5	Base course	10cm	6.0	0	6.0	11.4	1.72	A-1-a	GP	74
	Sub base	14cm	32	20	12	13.5	1.6	A-2-6	SW-GC	77
	Sub grade		48	33	15	20.5	1.62	A-7-5	MS-CS	7

Table 3-24 Summary of the Geotechnical properties of Laboratory results of subgrade soil

Laboratory tests parameters	Types of failures				
	non	non	Corrugation	Block cracking	Raveling and stripping
Natural moisture content	11.5	6.4	16.4	10.5	13.8
Liquid Limit (LL %)	50	52	68	57	48
Plastic Limit (PL %)	32	27	34	34	33
Plasticity Index (PI %)	13	14	14	23	15
% passing 0.075mm	48.3	34.31	24.9	28.53	59.45
MDD(g/cm3)	1.64	1.67	1.56	1.57	1.62
OMC %	19	9.8	22	18.5	20.5
CBR %	10	15	7	13	7
AASHTO Classification	A-7-5	A-2-7	A-2-7	A-2-7	A-7-5
USCS classification	MC-SC	CG-GS	CG-GS	CG-GS	MC-SC

Table 3-25.Summary of Laboratory results of sub base material

Laboratory tests parameters	Types of failures				
	non	non	Corrugation	Block cracking	Raveling and stripping
Natural moisture content	7.6	3.4	8.8	7.4	6.4
Liquid Limit (LL %)	35	38	37	31	32
Plastic Limit (PL %)	26	25	29	26	20
Plasticity Index (PI %)	9	13	8	5	12
% passing 0.075mm	4.88	7.6	8.49	12.04	3.25
MDD(g/cm3)	1.64	1.84	1.76	1.65	1.6
OMC %	13.5	8.7	12.4	10.8	13.5
CBR %	39	73	91	60	77
AASHTO Classification	A-2-4	A-2-6	A-2-4	A-1-b	A-2-6
USCS classification	GW-GS	GW	GP-GM	GP-GS	SW-GC

Table 3-26.Summary of properties of Laboratory results of base courses

Laboratory tests parameters	Types of failures				
	non	non	Corrugation	Block cracking	Raveling and stripping
Natural moisture content	3.5	2.6	3.4	3.8	2.8
Liquid Limit (LL %)	4.5	4.5	5	4	6
Plastic Limit (PL %)	0	0	0	0	0
Plasticity Index (PI %)	4.5	4.5	5	4	6
% passing 0.075mm	5.68	6.32	7	4.45	6.62
MDD(g/cm3)	1.81	1.71	1.84	1.64	1.72
OMC %	11.5	8.4	10.95	10.4	11.4
CBR %	90	86	92	59	74
AASHTO Classification	A-1-a	A-1-a	A-1-a	A-1-a	A-1-a
USCS classification	GP	GP	GP	GW	GP

3.6.4. Traffic Analysis

The study area road segment was a part of link road and it links the southwestern people's regional state and Oromia regions with SNNPRS. The flow of traffic condition was medium and has accelerating growth of traffic volume. Traffic count was taken for this study case because of traffic data count absence. The following table shows the traffic volume of count.

Table 3-27. ***Traffic count data (Tarcha-Sodo exit and entrance)***

Day	Car	Wagon & pick up	Mini bus & Vans	Small bus	Medium bus	Large bus	Light truck	Medium truck	Heavy truck	Articulate Truck
1	116	119	104	82	75	2	22	12	2	0
2	114	119	88	88	66	1	12	20	7	3
3	76	113	79	85	76	1	14	22	4	4
4	90	123	78	96	57	1	30	13	5	3
5	113	138	76	84	60	2	40	14	6	0
6D	76	106	78	85	43	1	18	18	5	3
6N	59	83	32	49	30	0	0	0	1	1
7D	66	92	79	77	42	1	34	17	2	0
7N	45	66	30	41	22	1	0	0	3	1

Table 3-28 AADT summary

Car	Wagon & pick up	Mini bus & Vans	Small bus	Medium bus	Large bus	Light truck	Medium truck	Heavy truck	Articulate Truck	Total
272	356	236	258	164	4	61	41	13	6	1410

Determination of AADT1for each Vehicles: AADT1=AADTo (1+i) n, n=is a years

Traffic survey (AADT0 in 2022 and investigation of traffic 2032) =10year i= growth rates for each vehicles types.

Table .3-29. Cumulative volume of traffic

Vehicle	AADT	$T = \frac{365 * AADT((1+3.6\%)^{10} - 1)}{3.6\%}$	$T(10^6)$
Car	272	2836633	2.836633
Wagon & pick up	356	3712652	3.712652
Mini bus & Vans	236	2461197	2.461197
Small bus	258	2690630	2.69063
Medium bus	164	1710323	1.710323
Large bus	4	41715.2	0.041715
Light truck	61	636156.7	0.636157
Medium truck	41	427580.8	0.427581
Heavy truck	13	135574.4	0.135574
Articulate Truck	6	62572.79	0.062573
Total	1411	14715035	14.71504

Determination of One directional traffic flow, T over the design period for each Class of Vehicles

Investigation period for research(x) =10 years up to now

i= growth rates for each vehicles types=3.6% (from GDP World Bank 2021)

Lane distribution factor =1

T = 365 *1*AADT1 [(1+i) x – 1] / (i)

Compute vehicles Damage factors for each types of vehicles: - DF= (Axle Load/8160)4.5

Table 3-30.Average equivalent axle load factor(47)

vehicles	Car	Wagon & pick up	Mini bus & Vans	Small bus	Medium bus	Large bus	Light truck	Medium truck	Heavy truck	Articulate Truck
EF	0	0	0.3	1.5	1.5	2	5	12	17	17
EF(one direction)	0	0	0.15	0.75	0.75	1	2.5	6	8.5	8.5

Table 3-31 Cumulative total Equivalent Standard Axle Load (CESAL)

Vehicle	AADT	$T(10^6)$	EF	$\mathrm{CESAL}(10^6)$
Car	272	2.836633	0	0
Wagon & pick up	356	3.712652	0	0
Mini bus & Vans	236	2.461197	0.15	0.369179
Small bus	258	2.69063	0.75	2.017973
Medium bus	164	1.710323	0.75	1.282742
Large bus	4	0.041715	1	0.041715
Light truck	61	0.636157	2.5	1.590392
Medium truck	41	0.427581	6	2.565485
Heavy truck	13	0.135574	8.5	1.152382
Articulate Truck	6	0.062573	8.5	0.531869
Total	1411	14.71504		9.55173694

Cumulative Equivalent Standard Axil load (CESAL) total

CESAL=Design traffic*EF

According to ERA 2013 b; Traffic Classes for Flexible Pavement Design the traffic class is categorized as T6

3.8. Ethical Considerations

The permission of Jimma Institute of Technology was acquired in order to conduct this research study.

- Ensuring the confidentiality of the data obtained.
- The research has to be approved by an ethics review committee to make sure the study is not violating any of the above considerations.
- Do not taking advantage of easy-to-access groups of people.
- When reporting the results, be sure that it accurately represent on what is observed or told.

3.9. Data Quality Assurance

To maintain data quality the replicated measure will be carried out at Laboratory test and fieldwork in order to avoid the error of data. The training is given for data collectors to handle the data carefully. The reliability and accuracy of the data will be checked. Laboratory instruments are calibrated; at least three samples and two experiments are done for one laboratory test in order to avoid the error of data and results.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. PAVEMENT 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. The detailed PCI calculations are shown in Appendix A, B and C

The result of the selected road segment performance was evaluated and results of PCI were fall in (40-97%). From pavement condition survey data was collected and rated as 13.9% excellent, 44.4% very good, 27.8% good, 8.3% fair, 5.6 % poor, 0% very poor and 0% failed. The dominant ratings were good and very good which were 27.8% and 44.4% respectively.

The average value of PCI of Tarcha-Turi section (79%), Waka-Tulema section (65%), Tulema-Gesa section (55%), Gesa-Ellabacho section (60%) and Ellabacho-Yalo section (66%) 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.

4.3. 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

Table 4-1.The alternatives for pavement structures thickness according ERA 2013 pavement design manual.(47)

Pavement structures	Alternative 1 CHART 3	Alternative 2 CHART 4	Alternative 3 CHART 5	Alternative 4 CHART 7	Observed average thickness
Asphalt layer thickness	5cm	5cm	5cm	10cm	2.62cm
Base course thickness	17.5cm	15cm	15cm	20cm	12.5cm
Sub base thickness	25cm	25cm	20cm	17.5cm	13.8cm

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. According to ERA the following alternatives are chosen and compared with average existing pavement structures observed and measured from test pits are shown in table

If one of the alternatives in the above table is chosen the designed and constructed pavement structures are less than the standard specifications are given in the ERA flexible pavement design manual.

4.4. LABORATORY TEST RESULT DISCUSSION

The laboratory tests are carried to examine the engineering properties of pavement construction materials. The construction materials are commonly known in three layers.

Table 4-2 Selected pits for experimental study

sn	Test pits	station	coordinates		Altitude	Types of distresses
			latitude	longitude		
1	BH1	63+900	7º09’14.8’’N	37º10’07.8’’E	1324	non
2	BH2	83+400	7º02’17.73’’N	37º11’59.09’’E	2400	non
3	BH3	89+800	7º00’45.09’’N	37º14’16.14’’E	2364	corrugation
4	BH4	97+00	7º01’06.71’’N	37º16’50.22’’E	2201	Block cracking
5	BH5	103+300	6º58’48.15’’N	37º18’02.22’’E	1764	Rutting

The main objective of laboratory tests are to determine the engineering properties of flexible pavement construction materials such as subgrade, sub base and base course material samples for selected highway segment of study highway section for representative samples extracted . These are subgrade, sub base and base course and the top finishing and traffic subject layer is asphalt. Laboratory tests are focused on gradation tests, Atterberg limit tests, moisture-density tests, CBR, moisture contents, aggregate crushing value, Los Angeles abrasion tests and aggregate impact value. The road inventory from the visual inspection would become reliable, proper identification was made along the road sections and identify the common distress types compares with non-distress test pits along study area.

Table 4-3 The thickness of pavement layers of test-pits

Test pits	Sub base thickness	Base course thickness	Asphalt thickness	Tests pits locality name	Far from Addis Ababa by Jimma
BH1	12cm	8cm	3.5cm	Tarcha Town	498km
BH2	13cm	10cm	3.2	Orobi	519km
BH3	11cm	9.5cm	1.8	Tulema	525.5km
BH4	10cm	12cm	2.5	Gesa Town	532.7km
BH5	14cm	10cm	2.1	Ellabacho	539km

4.4.1. 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:-

- 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.
- 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.
- The subgrade materials are classified as A-2-7, A-4 and A-5 according to AASHTO soil classification system.

4.4.2. 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.

- 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).
- 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).
- 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).

4.4.3. 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.

- The sub grade soil material MDD is 1.64 g/cm3 and OMC 17.95% which do not meet standard specification (MDD>1.76g/cm3)
- The average MDD and OMC of sub base is 1.67g/cm3 and 11.75% respectively
- 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)

4.4.4. 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 24, 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 -- the CBR value ranges 59%-92%.therefore the two selected station BH4 and BH5 are failed to satisfy the requirements stated in ERA 213.

4.4.5. 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.

Table 4-4 Summary of relationship obtained between soil properties and road failures and suggested maintenance

Test pits	station	Dominant failures type	Possible Causes of failure obtained	Suggested maintenance options
BH3	89+800	Corrugation	Low in service stability of bituminous Road	Corrugated layers removed by cold milling and resurfacing with modified materials
BH4	97+000	Block cracking	• Old and dried out mix • Mix was placed too dry • Fine aggregate mix with low penetration asphalt & absorptive aggregate	• Crack Seal/Fill • Fog Seal • Scrub Seal • Slurry Seal • Thin Cold Mix Overlay
BH5	103+300	Raveling and Stripping	• Poor mixture quality • Insufficient asphalt content • Improper construction methods • loss of asphalt binder • Separation of bituminous film from aggregates • Disintegration of aggregates	• surface dressing or thin overlay • Cold mill and resurfacing. • Square patching

CHAPTER-FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

According to laboratory and condition survey of pavement performance evaluation results the following conclusions were made.

- The pavement condition survey along the Tarcha-Yalo Road section affected by different failures types such as surface defects, structural and material failures(cracking) and disintegrations of pavement surface and problems related to road failures was identified during field investigation; this shows indicates that lack of routine and periodic maintenance along on a road section.
- 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.
- 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.
- 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%

- The insufficient thickness of sub base and base course material influence the proper distribution of stresses and direct stresses application to sub grade.
- Lack of shoulder and proper management of drainage concern is also the cause of failure.
- 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.
- 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.
- 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.
- 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.

5.2. RECOMMENDATION

Based on the finding of the study are the following suggestions and recommendation are drawn

- The majority of distresses were raveling and stripping, corrugation, block cracks, polishing, potholes and shoving. So that the routine and periodic maintenance is needed to sustain the performance of pavement.
- The sub grade soils of the failed sections should be treated by geotechnical justification
- The existing road thickness of pavement structures (sub base, base course and asphalt) should modified because of subgrade strength identified and traffic load.

- The pavement layer material should be compacted with required and suitable depth until well enough to support the pavement structures and attainable compressive strength value based on standard specification limit
- ERA and concerning body of federal and local government should follow the construction progress during construction time.
- ERA should follow proper pavement maintenance and management practice in order to reduce pavement failure.

5.3 Proposed for future research

For future research, it is recommended that detailed in-depth investigation should be carried out on related project; compliance with soil classification and construction methods in accordance with ERA Standard Specifications in order to avoid future failure of the study area.

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APPENDIX-A: PAVEMENT PERFORMANCE EVALUATION TABLE

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Tarcha-Turi **SECTION**: 063+900-064+900 **SAMPLE UNIT**:1
SURVEYED By:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

SKETCH

1.Alligator Cracking
2.Long.&trans.cracking
3.Block cracking
4.Depression
5.Slippage cracking
6.Bumps and sag
7.Patching and utility patching
8.Lane/shoulder drop off
9.Corrugation
10.Polished Aggregate
11.Potholes
12.Rutting
13.Edge Cracking
14.Swell
15.Shoving
16.Joint reflection cracking
17.Bleeding
18.Raveling
19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
8H				100	85				45		230	3.19	8.2
11M	4	2	2		3			3	1		15	0.21	10
12M	4.89*1.2	5.33*2.21	20.21*1.3	7.22*2	6.55*2.1						72.11	1.00	19.2
13M	100	100	85	100	30	15		100	24	100	654	9.08	13.3
17M	18.5*2.5	19.33*2.7	18.14*1.8	15.89*2.1	13.55*2.24				14*2		222.81	3..1	6.7

$m = 1 + \frac{9}{98} x(100 - HDV) = 1 + \frac{9}{98} x(100 - 12.7) = 9.76 > 4$ OK

#	Deduct Values										Total	q	CDV
1	19.2	13.3	10	8.2	6.7						57.4	5	27
2	19.2	13.3	10	8.2	2						52.7	4	28
3	19.2	13.3	10	2	2						46.5	3	29
4	19.2	13.3	2	2	2						38.5	2	30
5	19.2	2	2	2	2						27.2	1	29

Max CDV=19, PCI=100-Max CDV=100-30=70 and PCR=good

PAVEMENT PERFORMANCE EVALUATION TABLE

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Tarcha-Turi **SECTION**: 064+900-065+900 **SAMPLE UNIT**:2

SURVEYED By:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2

Hailemichael Debalke

SKETCH 1000m 7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
10	25.63*1.3	35.84*2.14	89*2.1	18.23*1.77	20.22*2.1						371.65	5.17	2.3
12L	5.89*1.2	8.76*2	10.11*1.23	9.5*2.3	12.33*2.3						87.23	1.21	9.6
18L	4.55*2.5	10.89*2.3	2.3*1.12	2.2*1.8							42.96	0.6	8.7
17M	33.3*1.22	44.89*1.8	48.3*1.89	32*2.3	36.33*2.15			22*1	9.55*1.2		397.89	5.53	10

$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 8.2) = 9.76 > 4$ OK

#	Deduct Values										Total	q	CDV
1	10	9.6	8.7	2.3							30.6	4	12
2	10	9.6	8.7	2							30.3	3	17
3	10	9.6	2	2							23.6	2	18
4	10	2	2	2							16	1	18

Max CDV=12, PCI=100-Max CDV=100-18=82and PCR=Very good

PAVEMENT PERFORMANCE EVALUATION TABLE

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m 7.2m
BRANCH: Tarcha-Turi **SECTION**: 065+900-066+900 **SAMPLE UNIT**:3 **SURVEYED By**:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	8.78*2.2		12.3*1.8	10.25*2.13	9.6*1.5						77.69	1.08	10
8M	38.99	33.22	42.13	30.21	44.63			38.25			237.88	3.31	3.8
13M	20	14.7	11.2	2.33	8.97				8.5		65.7	0.92	6.2
18L	14.2*1.23	2.89*1.17									20.85	0.29	5.3

$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 5.3) = 9.76 > 2$ OK

#	Deduct Values										Total	q	CDV
1	10	6.2	5.3	3.8							25.3	4	-
2	10	6.2	5.3	2							23.5	3	11
3	10	6.2	2	2							20.2	2	14
4	10	2	2	2							16	1	17

Max CDV=8, PCI=100-Max CDV=100-17=83 and PCR=Very good

PAVEMENT PERFORMANCE EVALUATION TABLE

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m, 7.2m
BRANCH: Tarcha-Turi **SECTION**: 066+900-067+900 **SAMPLE UNIT**:4 **SURVEYED By**:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	3.56*1.4	8.96*1.32	5.69*1.1	4.55*1.3	7.8*1.3						39.13	0.54	7.6
12L	18.4*1.3	22*1.1									35.46	0.49	5.0
13L	5.89	24	11.88	4.55	15.66				4.5		66.48	0.92	2.1

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 8.2) = 9.76 > 4 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	7.6	5	2.1								14.7	3	-
2	7.6	5	2								14.6	2	10
3	7.6	2	2								11.6	1	10

Max CDV=5, PCI=100-Max CDV=100-10=90 and PCR=excellent

PAVEMENT PERFORMANCE EVALUATION TABLE

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Tarcha-Turi **SECTION**: 067+900-068+900 **SAMPLE UNIT**:5 **SURVEYED By:DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
12L	1.1*2.3	2.55*1.12	2.89*2.33								12.12	0.17	1.8
13M	80	45	12.5	20.25							157.75	2.19	7
17L	100*2.24	80*3	2.5*200								964	13.39	10

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 10) = 9.26 > 4 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	10	7	1.8								18.8	3	-
2	10	7	2								19	2	12
3	10	2	2								14	1	14

Max CDV=14, PCI=100-Max CDV=100-14=86 and PCR=excellent

PAVEMENT PERFORMANCE EVALUATION TABLE

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Tarcha-Turi **SECTION**: 068+900-069+900 **SAMPLE UNIT**:6
SURVEYED By:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
12L	6.35*2.3	2.55*1.12	2.89*2.33		8.71*1.25						35.08	0.49	3.7
13M	80	45	12.5	20.25	8.89				3.55		170.19	2.36	8.4
17M	100*2.24	80*3	2.5*200	20.12*1.12	12*2.1						1011.73	14.05	16.5

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 10) = 9.26 > 4$ OK

#	Deduct Values										Total	q	CDV
1	16.5	8.4	3.7								28.6	3	15
2	16.5	8.4	2								26.9	2	18
3	16.5	2	2								20.5	1	20

Max CDV=20, PCI=100-Max CDV=100-20=80 and PCR=Very good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m 7.2m
BRANCH: Tarcha-Turi **SECTION**: 069+900-070+900 **SAMPLE UNIT**:7 **SURVEYED By**:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M			10.36*1.3	13.5*2.1	8.96*1.89			6.2*2			71.15	0.99	20
12M	8.1*2.3	7.55*1.12	9.89*2.33								50.13	0.70	15.3
13M	80	45	12.5	20.25	18.22			6.77			182.74	2.54	8.8
17M	100*2.24	80*3	2.5*200	60*2.14	35*2.3						1172.9	16.29	17.4

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 10) = 9.26 > 4 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	20	17.4	15.3	8.8							61.5	4	33
2	20	17.4	15.3	2							54.7	3	33
3	20	17.4	2	2							41.4	2	30
4	20	2	2	2							26	1	29

Max CDV=33, PCI=100-Max CDV=100-33=67 and PCR=good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Tarcha-Turi **SECTION**: 080+800-081+800 **SAMPLE** ~~**UNIT**:8~~ **SURVEYED By**:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

Alligator Cracking	Bumps and sag	Polished Aggregate	Shoving
Long.&trans.cracking	Patching and utility patching	Potholes	Joint reflection cracking
Block cracking	Lane/shoulder drop off	Rutting	Bleeding
Depression	Corrugation	Edge Cracking	Raveling
Slippage cracking		Swell	Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	5.62*1.3	8.36*2.1	4.1*1.1	2.85*1.45	6.3*1.33						41.89	0.58	18.6
11M	5	2	3	4	1	1		2	1		19	0.26	11.4
12L	3.1*2.3	4.55*1.12	6.89*2.33								28.28	0.39	3.2
13L	60	25	12.5	20.25	18.33				6.33		142.41	2.0	2.4
17M	100*3.5	80*3	90*3.5	100*3.5	100*7.2						1975	27.43	20.8

#	Deduct Values										Total	q	CDV
1	20.8	18.6	11.4	3.2	2.4						56.4	5	28
2	20.8	18.6	11.4	3.2	2						56	4	32
3	20.8	18.6	11.4	2	2						54.8	3	33
4	20.8	18.6	2	2	2						45.4	2	35
5	20.8	2	2	2	2						28.8	1	29

Max CDV=35, PCI=100-Max CDV=100-35=65 and PCR=good

PAVEMENT PERFORMANCE EVALUATIONWORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH *1000*m — 7.2m

BRANCH: Tarcha-Turi **SECTION**: 081+800-082+800 **SAMPLE UNIT**:9

SURVEYED By:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2

Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	3.84*1.25	2.39*2.3	10.85*1.8	8.65*2	5.88*1.89						58.24	0.81	9.8
10L	14.78*2.1	10.47*2.3	3.89*2.14		7.38*1.78						76.58	1.06	-
11M	1	3	2	2	2			3			13	0.18	10
12L	11.73*2.3	2.64*3	6.97*2.12								49.68	0.69	6.4
13M	18.50	21.00	7.96								47.46	0.66	5.7
17M	13.19*2.24	12.94*2.51	11.68*2.46	16.02*2.53	14.23*2.24						164.75	2.29	6.2

#	Deduct Values										Total	q	CDV
1	10	9.8	6.4	6.2	5.7						38	5	17
2	10	9.8	6.4	6.2	2						34.4	4	17
3	10	9.8	6.4	2	2						30.2	3	17
4	10	9.8	2	2	2						22.4	2	18
5	10	2	2	2	2						18	1	20

Max CDV=12, PCI=100-Max CDV=100-20=80 and PCR=very good

PAVEMENT PERFORMANCE EVALUATION WORKSHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Waka-Tulema **SECTION**: 082+800-083+800 **SAMPLE UNIT**:10

SURVEYED By:DATE: 20/10/2022 **SAMPLE AREA**: 7200m^2

Hailemichael Debalke

SKETCH 1000m

7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

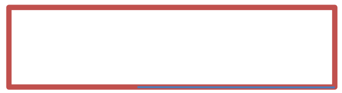
DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
10L	20*2.89	40*2.64	18*1.77	18*2.3	20*1.88	80*2.1		30*2.2		38*2.2	591.86	8.22	3.0
11M	3	5	1	3	1	1	1	1	1	1	18	0.25	13
17M	100*3.5	100*3.5	100*3.5	100*3.5	100*3.5	100*7.2	100*7.2	100*3.5	100*3.5	100*3.5	4240	58.89	30
18L	8.9*2.2	20*1.89	14*1.16	15.36*1.6							98.196	1.36	2.2

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 10) = 9.26 > 4 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	30	13	3	2.2							48.2	4	24
2	30	13	3	2							48	3	30
3	30	13	2	2							47	2	33
4	30	2	2	2							36	1	37

Max CDV=37, PCI=100-Max CDV=100-37=63 and PCR=good

PAVEMENT PERFORMANCE EVALUATIONWORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Waka-Tulema **SECTION**: 083+800-084+800 **SAMPLE UNIT**:11 **SURVEYED By**:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	 7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
10L	100*3.5	40*2.54	22.89*2.45	18.9*2.22	18*2.2				8.9*2.14		608.29	8.5	3.4
11H	4	3	3	2	2	2		2	3		21	0.29	30
17L	100*3.5	100*7.2	100*7.2	100*3.5	100*3.5						2490	34.58	10
18L	11.18*2.3	8.9*2.64	6.97*2.14								64.13	0.89	4.5

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 10) = 9.26 > 4 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	30	10	4.5	3.4							47.9	4	23
2	30	10	4.5	2							46.5	3	28
3	30	10	2	2							44	2	34
4	30	2	2	2							36	1	36

Max CDV=36, PCI=100-Max CDV=100-36=64 and PCR=good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Waka-Tulema **SECTION**: 084+800-085+800 **SAMPLE UNIT**:12 **SURVEYED By**:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
10L	13.19*2.24	8.94*2.51	7.68*2.46	10.02*2.53	14.23*2.24						128.11	1.78	-
11L	2	1	3	4	2	1		1	1		14	0.19	3.7
12L	8.14*2.58	1.89*2.36	14.72*1.12	20.11*1.38							69.70	0.97	8.2
17L	85.50*3.5	100*3.5	55*2.85	100*3.5	100*3.5						1506	20.92	7.3
18M	5.89*2.3	8.69*1.85	2.38*1.1								32.24	0.45	8.6

Table 4.4 Calculation of corrected PCI value for Satisfactory PCR

#	Deduct Values										Total	q	CDV
1	8.6	8.2	7.3	3.7							27.8	4	10
2	8.6	8.2	7.3	2							26.1	3	14
3	8.6	8.2	2	2							20.8	2	26
4	8.6	2	2	2							14.6	1	17

Max CDV=26, PCI=100-Max CDV=100-26=74 and PCR=very good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH

BRANCH: Waka-Tulema **SECTION**: 085+800-086+800 **SAMPLE UNIT**:13
SURVEYED By:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
2L	24.63	3.5	18.22								48.35	0.67	-
11M	6	4	1	5	3			5			24	0.33	15.4
12L	15.50*2.1	11.00*1.25	8.96*2.3								66.91	0.93	9
13L	18.22	3.85	16.33	13.65	15.23						67.28	0.93	7.2
17M	89*3.5	75*2.3	85*2.8	50*3.5	45*3.5						1054.5	14.65	15.6
18H	6.89*2.14	18.22*1.36	20.78*2.3								87.32	1.22	18.4

#	Deduct Values										Total	q	CDV
1	18.4	15.6	15.4	9	7.2						65.6	5	34
2	18.4	15.6	15.4	9	2						60.4	4	32
3	18.4	15.6	15.4	2	2						53.4	3	33
4	18.4	15.6	2	2	2						40	2	29
5	18.4	2	2	2	2						26.4	1	27

Max CDV=34, PCI=100-Max CDV=100-34=66 and PCR=good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Waka-Tulema **SECTION**: 086+800-087+800 **SAMPLE UNIT**:14
SURVEYED By:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m²
Hailemichael Debalke

1.Alligator Cracking
2.Long.&trans.cracking
3.Block cracking
4.Depression
5.Slippage cracking
6.Bumps and sag
7.Patching and utility patching
8.Lane/shoulder drop off
9.Corrugation
10.Polished Aggregate
11.Potholes
12.Rutting
13.Edge Cracking
14.Swell
15.Shoving
16.Joint reflection cracking
17.Bleeding
18.Raveling
19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	4.19*2.34	3.94*2.51	2.68*1.46	8.02*1.53	6.23*1.24						43.61	0.6	8.6
4L	15.50*2.3	12.3*1.12	8.96*2.31								70.12	0.97	5.2
10L	11.73*1.18	2.64*1.36	6.97*1.28	2.89*3.1							35.31	0.49	-
11L	1	8	4		1						14	0.19	4.7
17M	89.23*3.5	100*3.5	56*3.5	66.89*3.5							1092.42	15.17	16
18M	8.96*2.1	2.38*1.12		3.96*2.3							30.59	0.42	7.2

#	Deduct Values										Total	q	CDV
1	16	8.6	7.2	5.2	4.7						41.7	5	17
2	16	8.6	7.2	5.2	2						39	4	19
3	16	8.6	7.2	2	2						35.8	3	22
4	16	8.6	2	2	2						30.6	2	22
5	16	2	2	2	2						24	1	25

Max CDV=25, PCI=100-Max CDV=100-25=75 and PCR=very good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Waka-Tulema **SECTION**: 087+800-088+800 **SAMPLE UNIT**:15 **SURVEYED By**:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

1.Alligator Cracking 2.Long.&trans.cracking 3.Block cracking 4.Depression 5.Slippage cracking	6.Bumps and sag 7.Patching and utility patching 8.Lane/shoulder drop off 9.Corrugation	10.Polished Aggregate 11.Potholes 12.Rutting 13.Edge Cracking 14.Swell	15.Shoving 16.Joint reflection cracking 17.Bleeding 18.Raveling 19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	3.5*2.1	8.96*3.2									36.022	0.50	17.4
3M	5.89*1.8				15.36*2.2						44.394	0.62	0
4M	4.5*2.3				3.5*2.3						18.4	0.26	9.5
11M	1	3	1	2	1			2		3	13	0.18	13.2
12M	8.6*2.3	2.58*1.58			10.25*1.65						40.77	0.57	15.4
15M	4.55*1.11	3.19*2.54		7.36*1.55							24.51	0.34	5.3
17H	45*2.8	30*3.2	22.5*2.89	18.9*3.5							353.18	4.91	9.6
18H	12.5*2			6.89*1.28	5.8*1.3						41.36	0.57	13.5

#	Deduct Values										Total	q	CDV
1	17.4	15.4	13.5	13.2	9.6	9.5	5.3				83.9	7	-
2	17.4	15.4	13.5	13.2	9.6	9.5	2				80.6	6	39
3	17.4	15.4	13.5	13.2	9.6	2	2				73.1	5	36
4	17.4	15.4	13.5	13.2	2	2	2				65.5	4	36
5	17.4	15.4	13.5	2	2	2	2				54.3	3	35
6	17.4	15.4	2	2	2	2	2				42.8	2	32

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m 7.2m

BRANCH: Waka-Tulema **SECTION**: 088+800-089+800 **SAMPLE UNIT**:16
SURVEYED By:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking
2.Long.&trans.cracking
3.Block cracking
4.Depression
5.Slippage cracking
6.Bumps and sag
7.Patching and utility patching
8.Lane/shoulder drop off
9.Corrugation
10.Polished Aggregate
11.Potholes
12.Rutting
13.Edge Cracking
14.Swell
15.Shoving
16.Joint reflection cracking
17.Bleeding
18.Raveling
19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3H	2.89*2.1	3.56*1.14	3.25*1.36	15.2*3.2							63.19	0.88	8.4
4H	3.5*2.3	8.96*2.1		8.63*1.89							43.18	0.60	18.5
9H	8.63*3.5	12.22*3.5									72.98	1.01	34.8
11H	1		1		4			3			9	0.13	20
12H	2.89*2.13	18.6*1.14	14.33*2.3								60.32	0.84	27.3
15H	5.44*2.55	10*2.11									34.97	0.49	11.4

#	Deduct Values										Total	q	CDV
1	34.8	27.3	20	18.5	11.4	8.4					120.4	6	60
2	34.8	27.3	20	18.5	11.4	2					114	5	60
3	34.8	27.3	20	18.5	2	2					104.6	4	60
4	34.8	27.3	20	2	2	2					88.1	3	55
5	34.8	27.3	2	2	2	2					70.1	2	50
6	34.8	2	2	2	2	2					44.8	1	48

Max CDV=60, PCI=100-Max CDV=100-60=40 and PCR=poor

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Tulema-Gesa **SECTION**: 089+800-090+800 **SAMPLE UNIT**:17
SURVEYED By:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3H	30*2.1		40*2.3	10.23*2.6							181.60	2.52	13.3
4H	100*2.3		50*1.45		33*2.2						375.1	5.21	30.8
9H	8.96*3.2	33*2.2		15.22*1.55							124.86	1.73	40
15H	4.89*2.1		50*1.8		3.89*2.45						106.61	1.48	22.5

#	Deduct Values										Total	q	CDV
1	40	30.8	22.5	13.3							106.6	4	60
2	40	30.8	22.5	2							95.3	3	60
3	40	30.8	2	2							74.8	2	55
4	40	2	2	2							46	1	47

Max CDV=60, PCI=100-Max CDV=100-60=40 and PCR=poor

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Tulema-Gesa **SECTION**: 090+800-091+800 **SAMPLE UNIT**:18 **SURVEYED By**:**DATE**: 20/10/2022 **SAMPLE AREA**: 7200m² Hailemichael Debalke	7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	13.88*2.1			6.89*2.33	8.77*1.14						55.20	0.77	20
4L	4.74*1.45	2.47*1.32	12.3*1.1								23.66	0.33	4.6
11L	1			1		1				1	4	0.06	-
12 L	13.8*2.3			5.2*1.4	3.5*2.1						46.37	0.64	7.8
17L	25.8*2.8		78*2.1		45*2.38						343.14	4.76	8.7
18M	1.47*2.5	8.57*2.14		3.8*2.1							29.99	0.42	7.5

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

#	Deduct Values										Total	q	CDV
1	20	8.7	7.8	7.5	4.6						48.6	5	21
2	20	8.7	7.8	7.5	2						46	4	22
3	20	8.7	7.8	2	2						40.5	3	24
4	20	8.7	2	2	2						34.7	2	24
5	20	2	2	2	2						26	1	26

Max CDV=26, PCI=100-Max CDV=100-26=74 and PCR=very good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Tulema-Gesa **SECTION**: 091+800-092+800 **SAMPLE UNIT**:19
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	4.19*1.24	1.94*1.51	2.68*1.46	4.02*2.53	3.23*2.24						29.44	0.41	4.2
2L	15.50	11.00	8.96								35.46	0.49	-
4L	11.73*2.3	2.64*1.23	6.97*2.3								46.26	0.64	4.6
11L	1	3			4						8	0.11	3.3
17L	24.8*3.5		38.2*3.5		40*3.5						360.5	5.00	8

Table 4.4 Calculation of corrected PCI value for Satisfactory PCR

#	Deduct Values										Total	q	CDV
1	8	4.6	4.2	3.3							20.1	4	-
2	8	4.6	4.2	2							18.8	3	-
3	8	4.6	2	2							16.6	2	10
4	8	2	2	2							14	1	15

Max CDV=15, PCI=100-Max CDV=100-15=85 and PCR=very good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m 7.2m

BRANCH: Tulema-Gesa **SECTION**: 092+800-093+800 **SAMPLE UNIT**:20
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking
2.Long.&trans.cracking
3.Block cracking
4.Depression
5.Slippage cracking
6.Bumps and sag
7.Patching and utility patching
8.Lane/shoulder drop off
9.Corrugation
10.Polished Aggregate
11.Potholes
12.Rutting
13.Edge Cracking
14.Swell
15.Shoving
16.Joint reflection cracking
17.Bleeding
18.Raveling
19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3L	4.19*2.08	3.58*1.78	5.67*2.32								28.24	0.39	2.3
11L	2			4		1					7	0.1	2.1
12M	2.45*1.89		5.28*1.7	4.17*2.3							23.20	0.32	9.8
17L	25.66*2.17		18.45*1.5		18.89*1.14						104.89	1.46	0
18L	4.17*1.45	2.5*1.1	3.66*2.32								17.29	0.24	0

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

#	Deduct Values										Total	q	CDV
1	9.8	2.3	2.1								14.2	3	-
2	9.8	2.3	2								14.1	2	8
3	8.8	2	2								12.8	1	13

Max CDV=13, PCI=100-Max CDV=100-13=87 and PCR=excellent

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Tulema-Gesa **SECTION**: 093+800-094+800 **SAMPLE UNIT**:21
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	4.55*2.31	8.69*1.25	10.55*1.89	4.68*1.44	1.2*2.3						50.81	0.71	8.8
3M	25*3.1	10.2*2.3		8.9*1.56							114.84	1.60	4.7
4M	5.23*2.17	10.2*1.16									23.18	0.32	9.8
9L	7.8*3.1	5.89*1.4		12*2.85							66.63	0.93	12.7
11M	3		3	2	1	1					10	0.14	5.4
17M	2.1*1.11		6.5*2.89	8.7*1.9	3.25*1.47						42.42	0.59	2.8

#	Deduct Values										Total	q	CDV
1	12.7	9.8	8.8	5.4	4.7	2.8					44.2	6	17
2	12.7	9.8	8.8	5.4	4.7	2					43.4	5	19
3	12.7	9.8	8.8	5.4	2	2					40.7	4	19
4	12.7	9.8	8.8	2	2	2					37.3	3	23
5	12.7	9.8	2	2	2	2					30.5	2	22
6	12.7	2	2	2	2	2					22.7	1	23

Max CDV=23, PCI=100-Max CDV=100-23=78 and PCR=very good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Tulema-Gesa **SECTION**: 094+800-095+800 **SAMPLE UNIT**:22
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: $7200m^2$
Hailemichael Debalke

SKETCH

1000m

7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1H	4.77*1.18		3.58*2.12	2.54*2.4	10.88*1.14						31.72	0.44	20.5
3H		12.33*2.15	2.89*2.54	3.54*2.36	1.89*2.36						44.75	0.62	6.1
4H	14*2.1	4.66*1.38		2.8*1.11	8.56*1.66						53.12	0.74	17.8
9H					14.52*2.41						34.99	0.49	29.5
12 L	5.33*1.57	1.22*3.2	4*2.8		8.98*2.3						44.13	0.61	5.4
13M	4.58		12.55		13.22						30.35	0.42	4.6
18M		3.55*2.34		6.8*1.44	8.69*2.16						36.68	0.51	8.9

#	Deduct Values										Total	q	CDV
1	29.5	20.5	17.8	8.9	6.1	5.4	4.6				92.8	7	
2	29.5	20.5	17.8	8.9	6.1	5.4	2				90.2	6	
3	29.5	20.5	17.8	8.9	6.1	2	2				86.8	5	
4	29.5	20.5	17.8	8.9	2	2	2				82.7	4	
5	29.5	20.5	17.8	2	2	2	2				75.8	3	
6	29.5	20.5	2	2	2	2	2				60	2	
7	29.5	2	2	2	2	2	2				41.5	1	

Max CDV=14, PCI=100-Max CDV=100-14=86 and PCR=excellent

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Tulema-Gesa **SECTION**: 095+800-096+800 **SAMPLE UNIT**:23
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1. Alligator Cracking
2. Long.&trans.cracking
3. Block cracking
4. Depression
5. Slippage cracking
6. Bumps and sag
7. Patching and utility patching
8. Lane/shoulder drop off
9. Corrugation
10. Polished Aggregate
11. Potholes
12. Rutting
13. Edge Cracking
14. Swell

a.

15. Shoving
16. Joint reflectioncracking
17. Bleeding
18. Raveling
19. Railroad cross cracking

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
1M	2.32*1.25	3.25*2.14	8.96*2.3	7.34*1.58	11.23*1.11					54.53	0.76	20.8
3M	15.3*2.14		8.96*1.98		11.12*1.69					69.09	0.96	2.1
4M			15.3*1.47		5.68*2.1					34.42	0.48	9.7
11H	3		1		3			2		9	0.13	20
12M	2.36*1.1		4.68*1.41	1.89*3.2						15.25	0.21	11.5
13L	15.3	3.22		20.33				12.33		51.18	0.71	0
15L	7.36*1.8			6.55*1.77				12*1.98		48.60	0.68	3.6

#	Deduct Values										Total	q	CDV
1	20.8	20	11.5	9.7	3.6	2.1					67.7	6	30
2	20.8	20	11.5	9.7	3.6	2					67.6	5	32
3	20.8	20	11.5	9.7	2	2					66	4	35
4	20.8	20	11.5	2	2	2					58.3	3	37
5	20.8	20	2	2	2	2					48.8	2	37
6	20.8	2	2	2	2	2					30.8	1	30

Max CDV=37, PCI=100-Max CDV=100-37=63 and PCR=good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Tulema-Gesa **SECTION**: 096+800-097+800 **SAMPLE UNIT**:24
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3M	3.54*1.44			8.57*1.12		4.55*1.1					19.7	0.27	0
4M	8.99*1.89		3.89*2.2		8.63*1.5						38.49	0.53	11
9M	7.33*2.1			5.89*1.77		3.85*2.3					34.67	0.48	12
11M	3		3		1		1		1	1	10	0.14	6.8
13M	12.11			15.36			10.22				37.69	0.52	7.7
15M	5.41*2.2				2.36*1.5			8.9*2.4			36.8	0.51	7.3
17M	45*2.1		32*1.2		60*2.3						270.90	3.76	8.5

#	Deduct Values										Total	q	CDV
1	12	11	8.5	7.3	7.7	6.8					53.3	6	22
2	12	11	8.5	7.3	7.7	2					48.5	5	22
3	12	11	8.5	7.3	2	2					42.8	4	21
4	12	11	8.5	2	2	2					37.5	3	25
5	12	11	2	2	2	2					31	2	24
6	12	2	2	2	2	2					22	1	24

Max CDV=16, PCI=100-Max CDV=100-25=75 and PCR=very good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Gesa-Elabacho **SECTION**: 097+800-098+800 **SAMPLE UNIT**:25 **SURVEYED By**:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	18.5*2.4			14.11*1.4			5.89*1.58				73.46	1.02	2.3
3M		4.68*2.14	12.3*2.1		3.52*1.68						42.18	0.59	9.6
4M	3.21*1.87		4.85*1.2			5.47*1.9					22.22	0.31	9.4
9M					20.22*3.6					25*3.8	167.79	2.33	18.3
12L	12*1.8		18*2.2				16*1.22				80.72	1.12	0
15L		4.85*2.5		8.77*2.3		5.66*2.3					45.31	0.63	0

#	Deduct Values										Total	q	CDV
1	18.3	9.6	9.4	2.3							39.6	4	18
2	18.3	9.6	9.4	2							39.3	3	23
3	18.3	9.6	2	2							31.9	2	23
4	18.3	2	2	2							24.3	1	25

Max CDV=25, PCI=100-Max CDV=100-25=75 and PCR=very good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Gesa-Elabacho **SECTION**: 098+800-099+800 **SAMPLE UNIT**:25
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

SKETCH 1000m

7.2m

1.Alligator Cracking
2.Long.&trans.cracking
3.Block cracking
4.Depression
5.Slippage cracking
6.Bumps and sag
7.Patching and utility patching
8.Lane/shoulder drop off
9.Corrugation
10.Polished Aggregate
11.Potholes
12.Rutting
13.Edge Cracking
14.Swell
15.Shoving
16.Joint reflection cracking
17.Bleeding
18.Raveling
19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3H	20.85*3.6				30*2.2		16.22*2				173.5	2.41	12.5
4H	19.63*2.8		15.3*2.55			5.89*2.14					106.58	1.48	20
9H	18*2.8			8.55*2.13		8.9*2.54					91.22	1.27	36.8
11L	1		3		2	1		1		1	9	0.13	3.2
15H	22*2.14		3.89*2.4			20*2.2					100.42	1.39	11
17M	55*2.3			38.55*2.3		44*2.1	100*2.3				537.57	7.47	10

#	Deduct Values										Total	q	CDV
1	36.8	20	12.5	11	10	3.2					93.5	6	45
2	36.8	20	12.5	11	10	2					92.3	5	48
3	36.8	20	12.5	11	2	2					84.3	4	48
4	36.8	20	12.5	2	2	2					75.3	3	48
5	36.8	20	2	2	2	2					64.8	2	48
6	36.8	2	2	2	2	2					46.8	1	48

Max CDV=48, PCI=100-Max CDV=100-48=52 and PCR=Fair

PAVEMENT PERFORMANCE EVALUATIONWORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Gesa-Elabacho **SECTION**: 099+800-100+800 **SAMPLE UNIT**:26 **SURVEYED By**:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
4L	3.12*1.87	4.22*1.14	8.77*1.56	5.2*1.47	5.44*1.3	5.6*2.1	8.94*2.1		6.55*1.8		81.37	1.13	5.1
8H	5.33	15.88			20.55		65.22		25.66		132.64	1.84	7.8
11L	1		1	1	1		1	1	1		7	0.1	2.4
13M	14.32		17.35		20.55						52.22	0.73	5.3
17M	45*2.85		62*2.14		18.22*1.8	23*1.47	25*2.1		25*1.8		425.04	5.90	10
18L	5.66*2			2.48*1.5			5.78*1.8		4.77*1.1		30.69	0.43	-

#	Deduct Values										Total	q	CDV
1	10	7.8	5.3	5.1	2.4						30.6	5	10
2	10	7.8	5.3	5.1	2						30.2	4	12
3	10	7.8	5.3	2	2						27.1	3	16
4	10	7.8	2	2	2						23.8	2	18
5	10	2	2	2	2						18	1	20

Max CDV=16, PCI=100-Max CDV=100-20=80 and PCR=very good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Gesa-Elabacho **SECTION**: 100+800-101+800 **SAMPLE UNIT**:27
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	4.5*2.14			5.6*1.87		1.68*1.1					21.95	0.31	4.4
4M	8.41*1.5	4.89*1.4		6.12*1.9				12.3*2.3			59.38	0.82	9.8
11L	1		1		1		1	1	1		6	0.08	-
10H	5.2*2.4			7.12*1.3			2.3*1.89				26.08	0.36	18.6
13M	5.66		12.33		8.66			13.55			40.2	0.56	5.7
17L	56*1.2		36*2.1		52*1.3			23.33*1.1			236.06	3.29	0

#	Deduct Values										Total	q	CDV
1	18.6	9.8	5.7	4.4							38.5	4	17
2	18.6	9.8	5.7	2							36.1	3	20
3	18.6	9.8	2	2							32.4	2	22
4	18.6	2	2	2							24.6	1	25

Max CDV=25, PCI=100-Max CDV=100-25=75 and PCR=very good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Gesa-Elabacho **SECTION**: 101+800-102+800 **SAMPLE UNIT**:28 **SURVEYED By**:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3M	2.55*2.4	8.96*2.13		12.5*1.99							50.08	0.70	5.2
4M	12.12*2.66		5.88*2.3		14*2.1						75.16	1.04	10.3
11M	1		1	1	3		1		1		8	0.11	20
13H	3.17		8.6	10.36							22.13	0.31	9.9
15M	20.22*1.98				8.96*2.22						59.93	0.83	9.6
17H	45*2.3			35*1.14							143.4	1.99	9.7

#	Deduct Values										Total	q	CDV
1	20	10.3	9.9	9.7	9.6	5.2					64.7	4	32
2	20	10.3	9.9	9.7	9.6	2					61.5	3	30
3	20	10.3	9.9	9.7	2	2					53.9	2	29
4	20	10.3	9.9	2	2	2					46.2	1	29
5	20	10.3	2	2	2	2					38.3		29
6	20	2	2	2	2	2					30		30

Max CDV=32, PCI=100-Max CDV=100-32=68 and PCR=good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Elabacho-Yalo **SECTION**: 102+800-103+800 **SAMPLE UNIT**:29 **SURVEYED By**:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1H	14.22*3.1										44.082	0.61	23.6
2M			13.55		18.33						31.88	0.44	4.3
4H		17.33*2.65		3.89*2.3							54.88	0.76	17.5
9H	5.69*2.55				6.87*1.85						27.22	0.38	22.4
15H	3.18*2.1		4.6*1.45	8.95*2.3	1.89*1.11						36.03	0.5	20
18H	8.11*1.4		4.58*1.88		12.3*2.1						45.79	0.64	13.7

#	Deduct Values										Total	q	CDV
1	23.6	22.4	20	17.5	13.7	4.3					101.5	6	50
2	23.6	22.4	20	17.5	13.7	2					99.2	5	50
3	23.6	22.4	20	17.5	2	2					87.5	4	50
4	23.6	22.4	20	2	2	2					72	3	47
5	23.6	22.4	2	2	2	2					54	2	40
6	23.6	2	2	2	2	2					33.6	1	37

Max CDV=50, PCI=100-Max CDV=100-50=50 and PCR=fair

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Elacho-Yalo **SECTION**: 103+800-104+800 **SAMPLE UNIT**:30 **SURVEYED By**:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3H	14.3*2.58			8.45*1.55	3.89*2.22						58.63	0.81	9.3
9H		22.3*1.56			10.11*2.54						60.47	0.84	30.3
11H	2	2		1		3	1	1	1		11	0.15	20.8
12H		2.25*2.17		14*1.11				3.89*1.15			24.90	0.35	18.1
17H	40*2.14				20*1.8						121.6	1.69	8.7
18M	2.38*2.14			3.89*2.4		8.9*2.1		3.55*3.1			44.12	0.61	9.5

#	Deduct Values										Total	q	CDV
1	30.3	20.8	18.1	9.5	9.3	8.7					96.7	6	47
2	30.3	20.8	18.1	9.5	9.3	2					90	5	45
3	30.3	20.8	18.1	9.5	2	2					82.7	4	45
4	30.3	20.8	18.1	2	2	2					75.2	3	48
5	30.3	20.8	2	2	2	2					59.1	2	43
6	30.3	2	2	2	2	2					40.3	1	40

Max CDV=48, PCI=100-Max CDV=100-48=52 and PCR=Fair

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Elacho-Yalo **SECTION**: 104+800-105+800 **SAMPLE UNIT**:31
SURVEYED By:Hailemichael Debalke **DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2

SKETCH 1000m

7.2m

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	3.19*2.24	2.94*2.51	1.68*2.46	6.02*2.53	4.23*2.24						43.37	0.60	19.2
4L	15.50*1.5	11.00*2.1	8.96*1.18								56.92	0.79	6.7
9M	11.73*1.4	2.64*2.22	6.97*2.17								37.41	0.52	12.8
13H	24.63	11.69		10.14	3.65						50.11	0.69	9.8
15M	12.45*3.5		10.55*2.3		14.33*1.58						90.48	1.26	10
17H		22.45*2.14		30*2.4							120.043	1.67	19.7

#	Deduct Values										Total	q	CDV
1	19.7	19.2	12.8	10	9.8	6.7					78.2	6	37
2	19.7	19.2	12.8	10	9.8	2					73.5	5	38
3	19.7	19.2	12.8	10	2	2					65.7	4	36
4	19.7	19.2	12.8	2	2	2					57.7	3	37
5	19.7	19.2	2	2	2	2					46.9	2	35
6	19.7	2	2	2	2	2					29.7	1	29

Max CDV=38, PCI=100-Max CDV=100-38=62 and PCR=good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m 7.2m
BRANCH: Elacho-Yalo **SECTION**: 105+800-106+800 **SAMPLE UNIT**:32 **SURVEYED By**:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3H	3.19*2.24	2.94*2.51	1.68*2.46	6.02*2.53	4.23*2.24						43.36	0.6	4.8
4L	25.50*2	11.00*1.18	8.96*1.28								75.45	1.05	-
10M	11.73*3.2	2.64*2.04	6.97*1.74								55.05	0.76	8.6
15H	24.63*1.35	11.69*1.58	2.35*1.12								36.32	0.51	12

#	Deduct Values										Total	q	CDV
1	12	8.6	4.8								25.4	3	15
2	12	8.6	2								22.6	2	17
3	12	2	2								16	1	8

Max CDV=17, PCI=100-Max CDV=100-17=83 and PCR=very good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Elacho-Yalo **SECTION**: 106+800-107+800 **SAMPLE UNIT**:33

SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2

Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	3.89*2.4	3.69*2.56	3.68*2.46	7.23*2.53	4.23*2.24						55.60	0.77	19.8
10L	15.50*1.3	11.00*2.14	8.96*1.1								53.55	0.74	-
12L	11.73*3	2.6*0.75	6.97*3.19								59.37	0.82	17.2

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 19.8) = 8.36 > 3 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	19.8	17.2									37	2	29
2	19.8	2									21.8	1	21
3													

Max CDV=29, PCI=100-Max CDV=100-29=71 and PCR=very good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m, 7.2m
BRANCH: Elacho-Yalo **SECTION**: 107+800-108+800 **SAMPLE UNIT**:34 **SURVEYED By**:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2 Hailemichael Debalke	

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3L	2.36*1.98	5.89*1.54	17.5*2	6.78*2.35	4.87*2.14						75.10	1.04	3.5
4L	3*1.1	17*0.89	1.88*2								22.19	0.31	3
17M	30*3.2	18.23*2.89									148.69	2.07	10

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 10) = 9.26 > 3 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	10	3.5	3								16.5	3	9
2	10	3.5	2								15.5	2	12
3	10	2	2								14	1	17

Max CDV=17, PCI=100-Max CDV=100-17=83 and PCR=very good

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH 1000m
BRANCH: Elacho-Yalo **SECTION**: 108+800-109+800 **SAMPLE UNIT**:35 **SURVEYED By**:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m² Hailemichael Debalke	7.2m

1.Alligator Cracking 2.Long.&trans.cracking 3.Block cracking 4.Depression 5.Slippage cracking	6.Bumps and sag 7.Patching and utility patching 8.Lane/shoulder drop off 9.Corrugation	10.Polished Aggregate 11.Potholes 12.Rutting 13.Edge Cracking 14.Swell	15.Shoving 16.Joint reflection cracking 17.Bleeding 18.Raveling 19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3M	3.10*2.25	2.96*2.3	1.98*2.46	7.22*2.3							35.26	0.49	2.8
12L	12.32*1.4	11.00*0.96									27.81	0.39	-
15L	11.87*2	20.1*1.25	18*1.13								69.21	0.96	-
17L	24.63*1.1	8.96*1.3									38.27	0.53	0

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 10) = 9.26 > 3 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	18.2	2.4	2.1	1.3							24	3	14
2	18.2	2.4	2	1.3							23.9	2	18
3	18.2	2	2	1.3							23.5	1	22

Max CDV=2.8, PCI=100-Max CDV=100-2.8=97.2 and PCR=excellent

PAVEMENT PERFORMANCE EVALUATION WORK SHEET

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH 1000m

7.2m

BRANCH: Elacho-Yalo **SECTION**: 109+800-111+300 **SAMPLE UNIT**:36
SURVEYED By:**DATE**: 21/10/2022 **SAMPLE AREA**: 7200m^2
Hailemichael Debalke

1.Alligator Cracking	6.Bumps and sag	10.Polished Aggregate	15.Shoving
2.Long.&trans.cracking	7.Patching and utility patching	11.Potholes	16.Joint reflection cracking
3.Block cracking	8.Lane/shoulder drop off	12.Rutting	17.Bleeding
4.Depression	9.Corrugation	13.Edge Cracking	18.Raveling
5.Slippage cracking		14.Swell	19.Railroad cross cracking

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	10.19*2.3	4.94*2.7	1.8*2.5	7.3*2.53	4.23*2.24						69.22	0.96	10
3L	15.5*3	11.00*1.87	8.96*2.14								86.24	1.20	-
4L	31.73*1.12	2.64*1.82	6.97*2.4								57.07	0.79	2.4
11L	4	2	1	1	3						11	0.15	4

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

$$m = 1 + \frac{9}{98}x(100 - HDV) = 1 + \frac{9}{98}x(100 - 10) = 9.26 > 3 \text{ OK}$$

#	Deduct Values										Total	q	CDV
1	10	4	2.4								16.4	3	-
2	10	4	2								16	2	13
3	10	2	2								14	1	17

Max CDV=17, PCI=100-Max CDV=100-17=83 and PCR=very good

APPENDIX-B-PCI VALUES OF TOTAL LENGTH OF 47.4KM

Station	Pavement condition index	Pavement condition rating	Station	Pavement condition index	Pavement condition rating
63+900-64+900	70	Good	82+800-83+800	63	Good
64+900-65+900	82	Very good	82+800-84+800	64	Good
65+900-66+900	83	Very good	84+800-85+800	74	Very good
66+900-67+900	90	Excellent	85+800-86+800	66	Good
67+900-68+900	86	Excellent	86+800-87+800	75	Very good
68+900-69+900	80	Very good	87+800-88+800	61	Good
69+900-70+900	67	Good	88+800-89+800	40	poor
80+800-81+800	65	Good	89+800-90+800	41	Poor
81+800-82+800	80	Very good	90+800-91+800	74	Very good
92+800-93+800	87	Excellent	103+800-104+800	62	Good
93+800-94+800	78	Very good	104+800-	83	Very good

			105+800		
94+800-95+800	86	Excellent	105+800-106+800	71	Very good
95+800-96+800	63	Good	106+800-107+800	83	Very good
96+800-97+800	75	Very good	107+800-108+800	80	Very good
97+800-98+800	75	Fair	108+800-109+800	97.2	excellent
98+800-99+800	52	Very good	109+800-111+300	83	Very good
99+800-100+800	75	Very good			
100+800-101+800	68	Good			
101+800-102+800	50	Fair			

APPENDIX-C: GRAPHS OF DISTRESSES DEDUCT VALUE READING

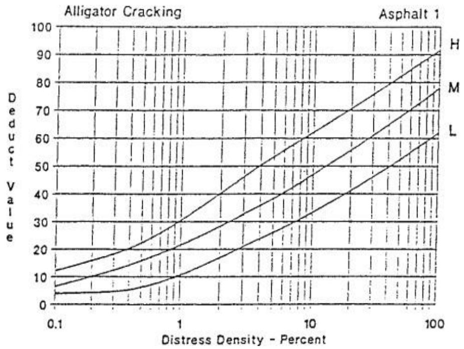


Fig: Alligator Cracking

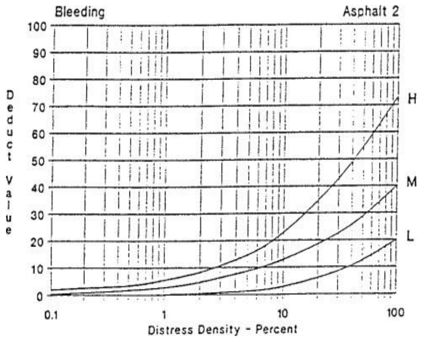


Fig: Bleeding

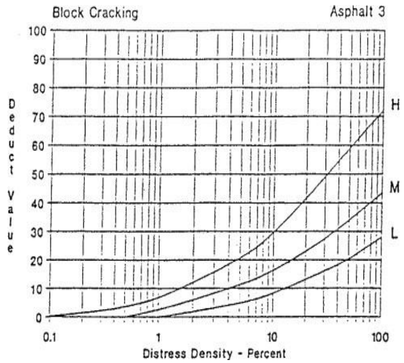


Fig: Block Cracking

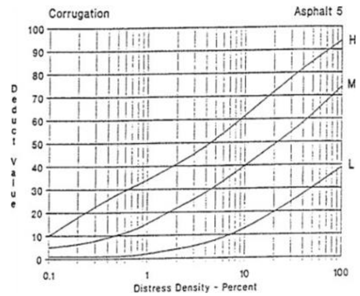


Fig: Corrugation

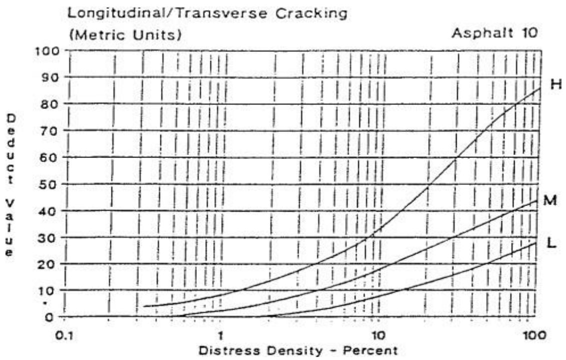


Fig: Longitudinal/Transverse Cracking

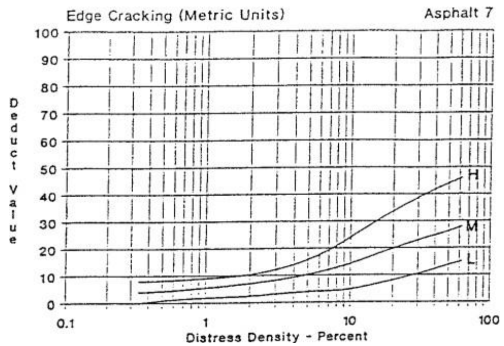


Fig: Edge Cracking (metric units)

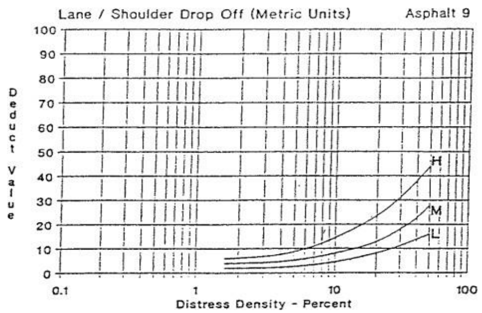
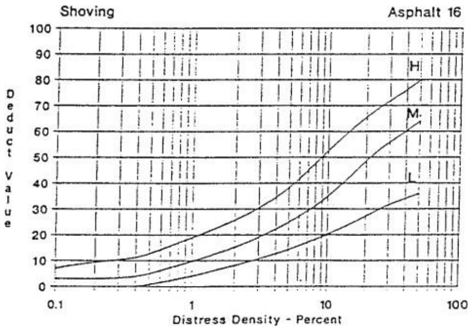


Fig: Lane/Shoulder Drop-Off (metric units)



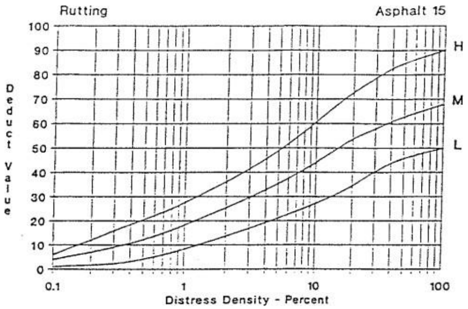


Fig: Rutting

Fig: Shoving

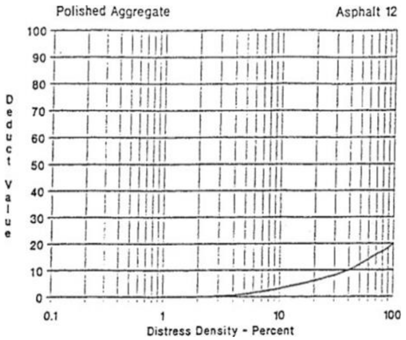


Fig: Polished Aggregate

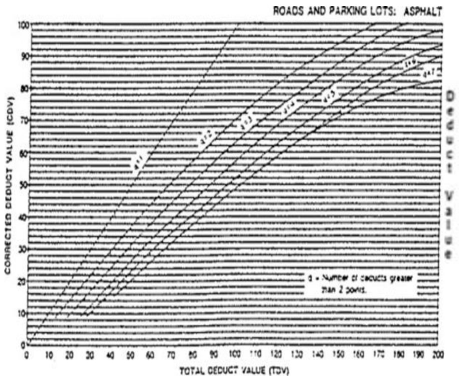


Fig: Total Deduct Value

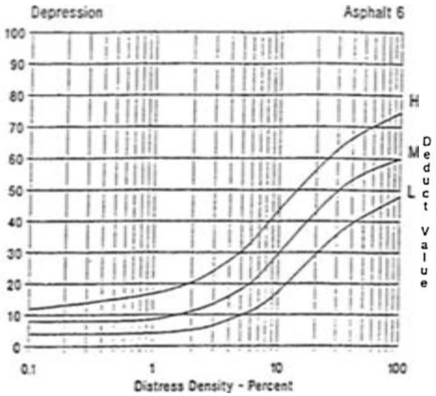


Fig: Depression

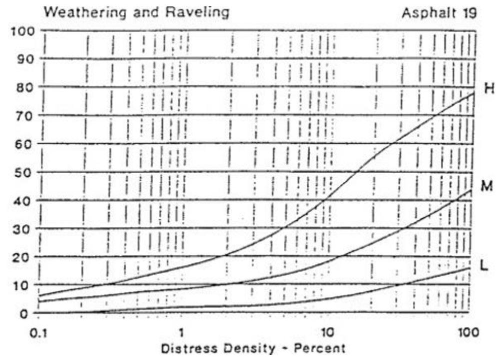


Fig: Weathering and Raveling

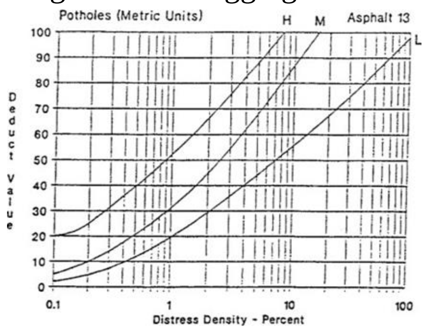
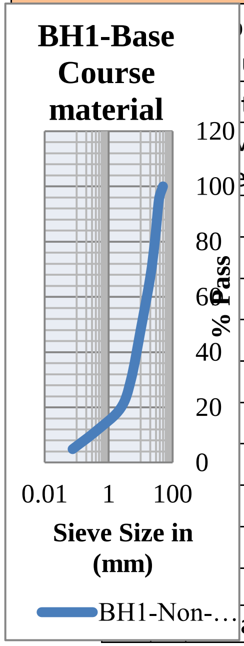


Fig: Potholes (metric units)

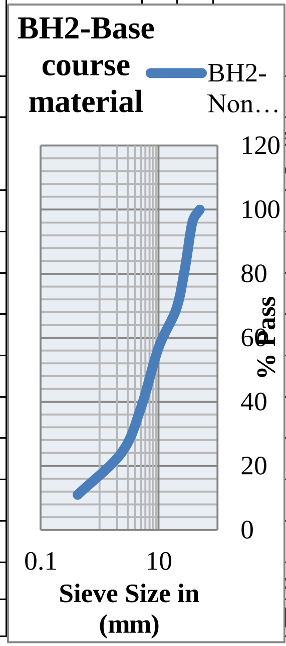
Appendix-D-Sieve Analysis Results

Gradation of Base course of test pit-1

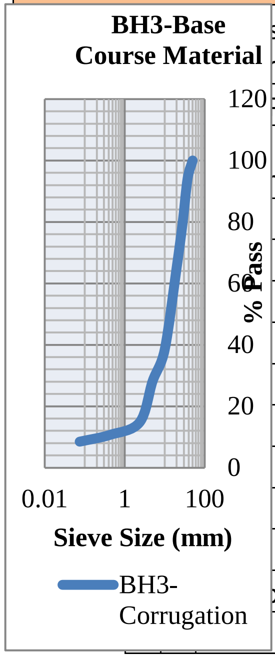
Material Type:Base Course	Sampled Date:30/11/2022			
	Completed Date:21/12/2022			
Source:BH1	Sampled By:Hailemichael Debalke			
Sieve Type: Washed	Nominal Sieve Size:37.5mm			
...es of ...ure	non			
...t Pit No.	BH1			
...ve ...(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
50	0	0	0	100
37.5	256.5	4.75	4.75	95
28	803.52	14.9	19.63	80
20	716.04	13.3	32.89	67
10	1036.26	19.2	52.08	48
5	967.14	17.9	69.99	30
2.36	558.9	10.4	80.34	20
0.425	435.24	8.06	88.4	12
0.075	362.88	6.72	95.12	4.9
pan	263.52	4.88	100	0
...alTotal	5400g			



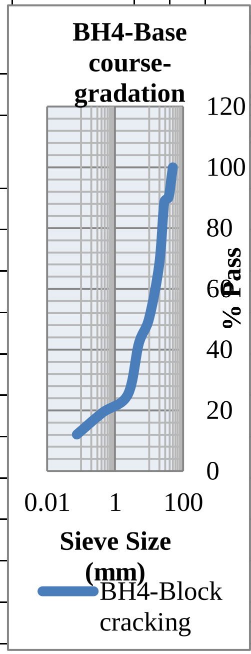
Material Type:Base Course	Sampled Date:30/11/2022			
	Completed Date:21/12/2022			
Source:BH1	Sampled By:Hailemichael Debalke			
Sieve Type: Washed	Nominal Sieve Size:37.5mm			
...s of Failure	Non			
...Pit No.	BH2			
...veSize(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
50	0	0	0	100
37.5	225.62	3.89	3.89	96.11
28	838.1	14.45	18.34	81.66
20	733.12	12.64	30.98	69.02
10	704.7	12.15	43.13	56.87
5	1096.78	18.91	62.04	37.96
2.36	803.88	13.86	75.9	24.1
0.425	762.7	13.15	89.05	10.95
0.075	359.6	6.2	95.25	4.75
...pan	275.5	4.75	100	0
...Total	5800g			



Material Type:Base Course	Sampled Date:30/11/2022			
	Completed Date:21/12/2022			
Source:BH3	Sampled By:Hailemichael Debalke			
Sieve Type: Washed	Nominal Sieve Size:37.5mm			
s of e		corrugation		
Pit No.	BH3			
mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
50	0	0	0	100
37.5	349.2	5.82	5.82	94
28	876.6	14.6	20.43	80
20	855	14.3	34.68	65
10	1615.2	26.9	61.6	38
5	610.8	10.2	71.78	28
2.36	807	13.5	85.23	15
0.425	245.4	4.09	89.32	11
0.075	131.4	2.19	91.51	8.5
pan	509.4	8.49	100	0
Total	6000g			

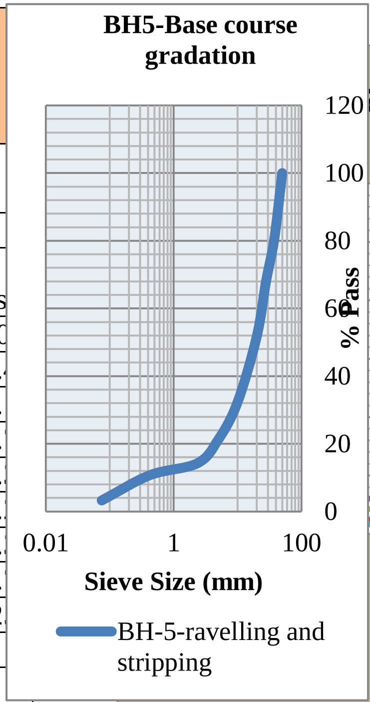


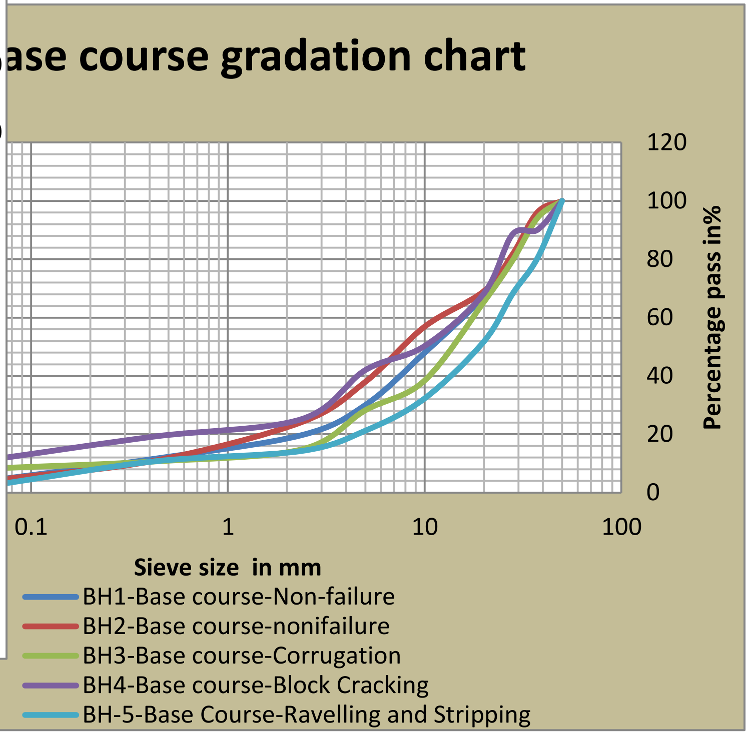
Material Type:Base Course	SampledDate:30/11/2022			
	Completed Date:21/12/2022			
Source:BH1	Sampled By:Hailemichael Debalke			
Sieve Type: Washed	Nominal Sieve Size:37.5mm			
pes of ilure		Block Cracking		
st Pit No.	BH4			
ve e(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
50	0	0	0	100
37.5	535.7	10	9.9	90
28	83.16	2	11	89
20	1098	20	32	68
10	970.9	18	50	50
5	444.4	8	58	42
2.36	910.4	17	75	25
0.425	318.6	6	81	19
0.075	388.8	7	88	12
pan	650.2	12	100	0
tal	5400g			



Gradation of Base course of test pit-5 and summary of all base course layers (BH1, BH2, BH3, BH4 andBH5)

Material Type:Base Course		Completed Date:21/12/2022		
Source:BH5	Sampled By:Hailemichael Debalke			
Sieve Type: Washed		Nominal Sieve Size:37.5mm		
Types of Failure		Ravelling and stripping		
Test Pit No.	BH5			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pas
50	0	0	0	100
37.5	1177.8	19.63	19.63	80.
28	735	12.25	31.88	68.
20	982.8	16.38	48.26	51.
10	1169.4	19.49	67.75	32.
5	661.8	11.03	78.78	21.
2.36	418.2	6.97	85.75	14.
0.425	211.8	3.53	89.28	10.
0.075	448.2	7.47	96.75	3.2
pan	195	3.25	100	0
Total	6000g			



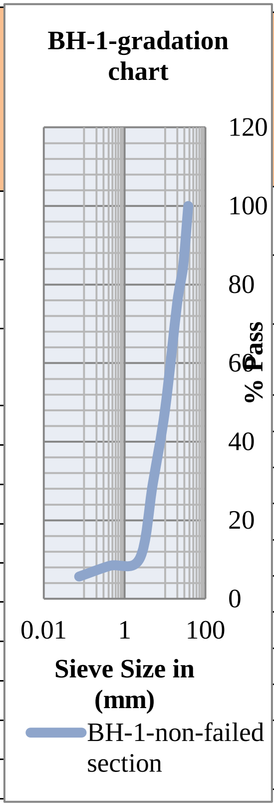


Base course materials Uniformity coefficient and coefficient of curvature

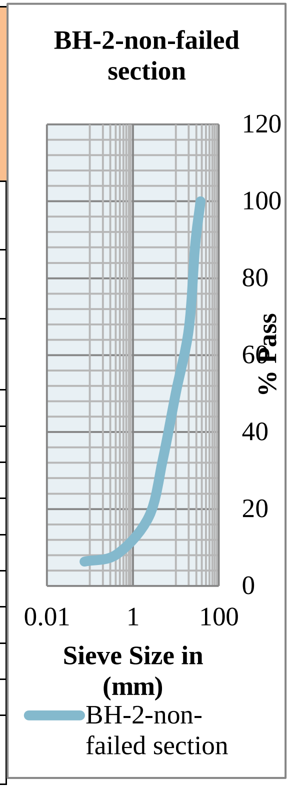
Test pits	Gravel %	Sand %	Fines %	D10 inmm	D30 in mm	D60 in mm	Cu	CC
BH1	75.67	18.65	5.68	3	5	16.7	5.57	0.5
BH2	67.44	26.24	6.32	0.7	3.9	19	27.14	1.14
BH3	55.98	37.02	7	0.3	4.7	20.3	67.67	3.63
BH4	48.93	46.62	4.45	0.17	3.8	20	117.65	4.25
BH5	44.7	48.68	6.62	0.15	2.3	13	86.67	2.71

Gradation of Sub Base of test pit-1and Gradation of Sub Base of test pit-2

Material Type:Sub Base Source:BH1 Sieve Type:		Sampled Date:30/11/2022 Completed Date:21/12/2022 Sampled By:Hailemichael Debalke Nominal Sieve Size:37.5mm		
Types of Failure		non		
Test Pit No.	BH1			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
37.5	0	0	0	100
28	862.4	15.4	15.4	84.6
20	519.68	9.28	24.68	75.3
10	1523.2	27.2	51.88	48.1
5	1047.76	18.71	70.59	29.4
2.36	1072.96	19.16	89.75	10.3
0.425	103.6	1.85	91.6	8.4
0.075	152.32	2.72	94.32	5.68
pan	318.08	5.68	100	0
Total	5600	100		

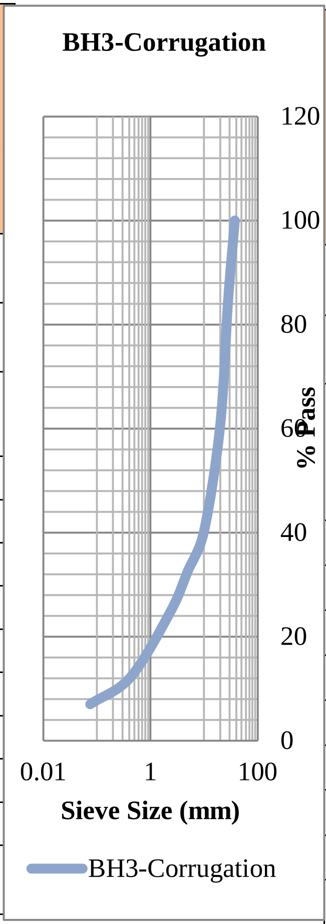


Material Type:Sub Base Source:BH2 Sieve Type:		Sampled Date:30/11/2022 Completed Date:21/12/2022 Sampled By:Hailemichael Debalke Nominal Sieve Size:37.5mm		
Types of Failure		Non		
Test Pit No.	BH2			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
37.5	0	0	0	100
28	626.4	11.6	11.6	88.4
20	1166.4	21.6	33.2	66.8
10	894.24	16.56	49.76	50.2
5	930.96	17.24	67	33
2.36	810	15	82	18
0.425	527.04	9.76	91.76	8.24
0.075	103.68	1.92	93.68	6.32
pan	341.28	6.32	100	0
Total weight	5400g	100		

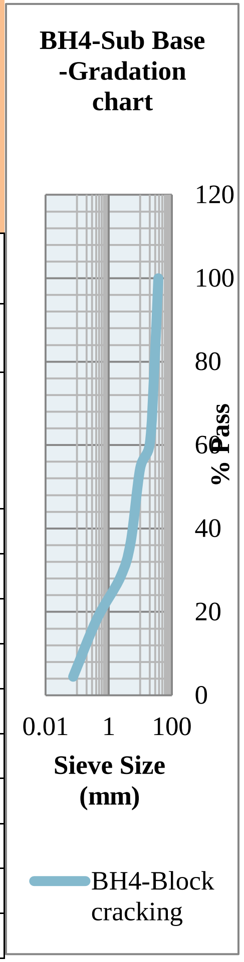


Gradation of Sub Base of test pit-3 and Gradation of Sub Base of test pit-4

Material Type:Sub Base		Sampled Date:30/11/2022 Completed Date:21/12/2022		
Source:BH3		Sampled By:Hailemichael Debalke		
Sieve Type:		Nominal Sieve Size:37.5mm		
Types of Failure		Corrugation		
Test Pit No.	BH3			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
37.5	0	0	0	100
28	934.8	15.58	15.58	84.4
20	1428	23.8	39.38	60.6
10	1218.6	20.31	59.69	40.3
5	460.2	7.67	67.36	32.6
2.36	470.4	7.84	75.2	24.8
0.425	754.8	12.58	87.78	12.2
0.075	313.2	5.22	93	7
pan	420	7	100	0
Total weight	6000 g	100		

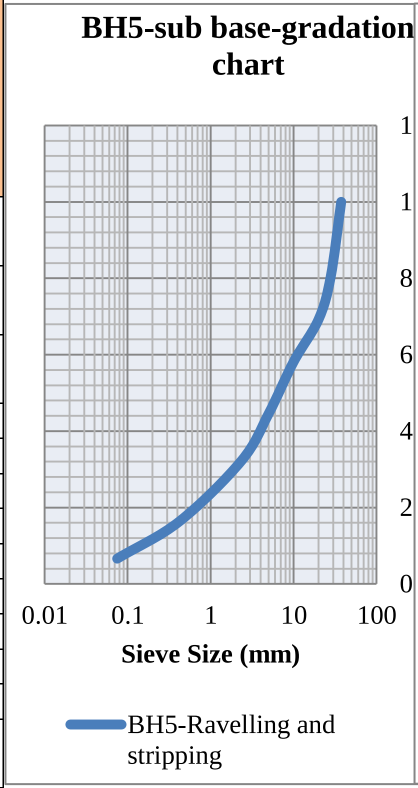


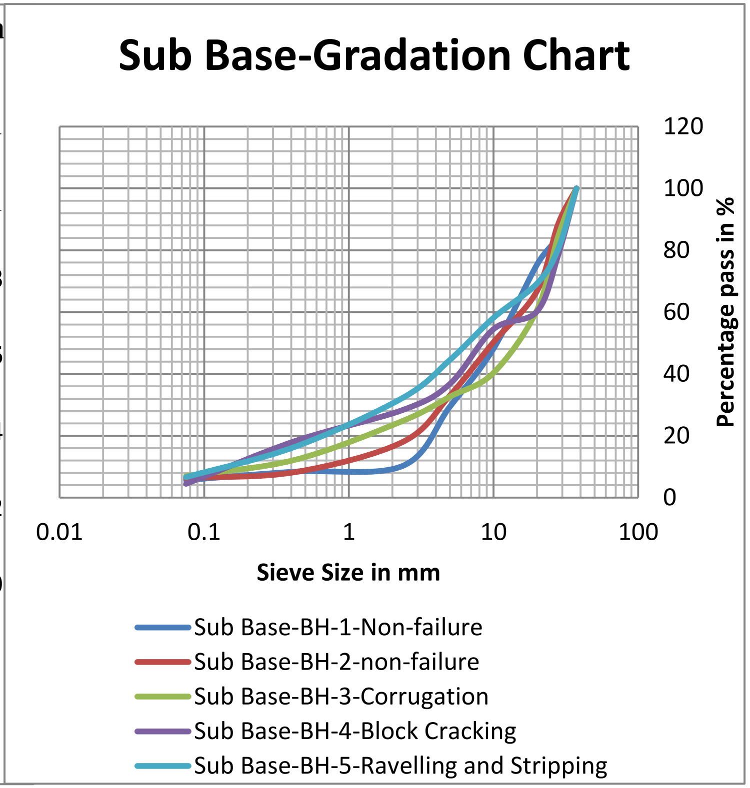
Material Type:Sub Base		Sampled Date:30/11/2022 Completed Date:21/12/2022		
Source:BH4		Sampled By:Hailemichael Debalke		
Sieve Type:		Nominal Sieve Size:37.5mm		
Types of Failure	Block Cracking			
Test Pit No.	BH4			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
37.5	0	0	0	100
28	1125.28	21.64	21.64	78.4
20	943.8	18.15	39.79	60.2
10	299.52	5.76	45.55	54.5
5	920.4	17.7	63.25	36.8
2.36	437.32	8.41	71.66	28.3
0.425	523.12	10.06	81.72	18.3
0.075	719.16	13.83	95.55	4.45
pan	231.4	4.45	100	0
	5200g	100		



Gradation of Sub Base of test pit-5 and all test pits sub base layers

Material Type:Sub Base Failure Type: Source: Sieve Type:		Sampled Date: Completed Date: Sampled By:Hailemichael Debalke Nominal Sieve Size:37.5mm		
Types of Failure		Ravelling and stripping		
Test Pit No.	BH5			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
37.5	0	0	0	100
28	1177.8	19.63	19.63	80.4
20	669	11.15	30.78	69.2
10	666	11.1	41.88	58.1
5	816	13.6	55.48	44.5
2.36	736.2	12.27	67.75	32.3
0.425	949.2	15.82	83.57	16.4
0.075	588.6	9.81	93.38	6.62
pan	397.2	6.62	100	0
Total weight	6000	100		



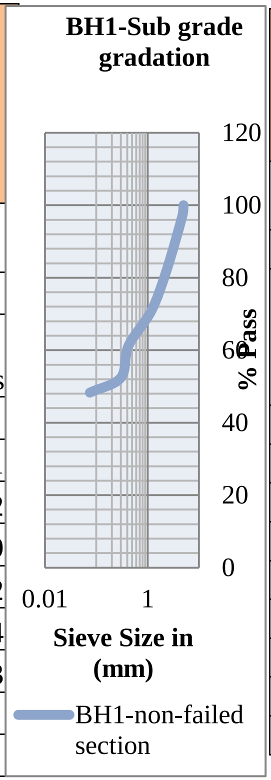


Sub Base materials Uniformity coefficient and coefficient of curvature

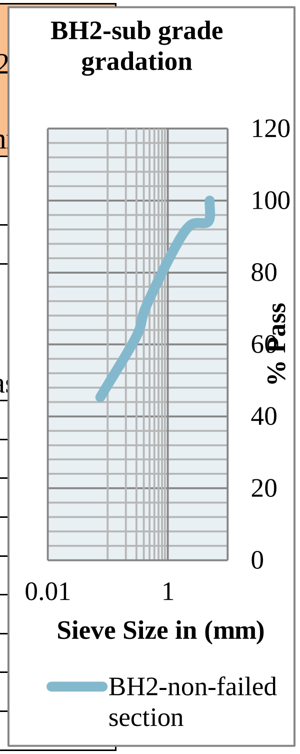
Test pits	Gravel %	Sand %	Fines %	D10 inmm	D30 in mm	D60 in mm	Cu	CC
BH1	67	28.12	4.88	0.27	7	20.3	75.19	8.94
BH2	49.01	43.39	7.6	0.18	5	20	111.11	6.94
BH3	66.06	25.45	8.49	0.35	6	19	54.29	5.41
BH4	43.58	44.38	12.04	0	2.9	18	0	0
BH5	71.78	24.97	3.25	0.3	9.9	27	90	12.1

Gradation of Sub grade of test pit-1and Gradation of Sub grade of test pit-2

Material grade	Type:Sub	Sampled Date:30/11/2022 Completed Date:21/12/2022		
Source:BH1	Sampled By:Hailemichael Debalke			
Sieve Type:Washed		Nominal Sieve Size:4.75mm		
Types of Failure		non-failed section		
Test Pit No.	BH1			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
5	0	0	0	100
4.75	174	2.9	2.9	97.1
2.36	894.6	14.91	17.81	82.2
1.18	680.4	11.34	29.15	70.9
0.425	576.6	9.61	38.76	61.2
0.3	530.4	8.84	47.6	52.4
0.075	246	4.1	51.7	48.3
pan	2898	48.3	100	0
Total	6000	100		

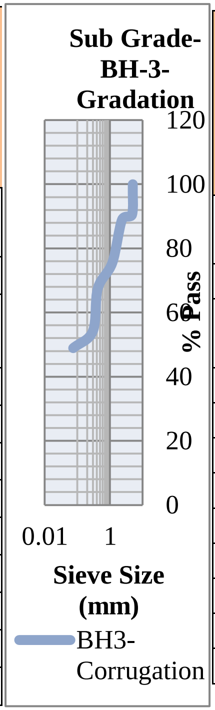


Material grade	Type:Sub	Sampled Date:30/11/2022 Completed Date:21/12/202		
Source:BH2	Sampled By:Hailemichael Debalke			
Sieve Type:Washed		Nominal Sieve Size:4.75m		
Types of Failure		non-failed section		
Test Pit No.	BH2			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pa
5	0	0	0	100
4.75	232.8	5.82	5.82	94.2
2.36	43.2	1.08	6.9	93.1
1.18	307.2	7.68	14.58	85.4
0.425	611.6	15.29	29.87	70.1
0.3	315.6	7.89	37.76	62.2
0.075	677.2	16.93	54.69	45.3
pan	1812.4	45.31	100	0
Total	4000g	100		

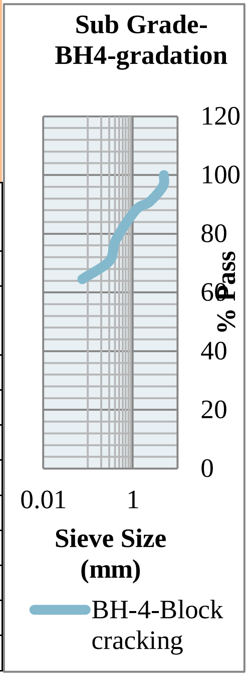


Gradation of Sub grade of test pit-3 and Gradation of Sub grade of test pit-4

Material grade	Type:Sub	Sampled Date:30/11/2022 Completed Date:21/12/2022		
Source:BH3	Sampled By:Hailemichael Debalke			
Sieve Type:Wahed		Nominal Sieve Size:4.75mm		
Types of Failure		Corrugation		
Test Pit No.	BH3			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
5	0	0	0	100
4.75	475	9.5	9.5	90.5
2.36	75	1.5	11	89
1.18	675	13.5	24.5	75.5
0.425	399	7.98	32.48	67.5
0.3	666.5	13.33	45.81	54.2
0.075	264.5	5.29	51.1	48.9
pan	2445	48.9	100	0
Total	5000g	100		

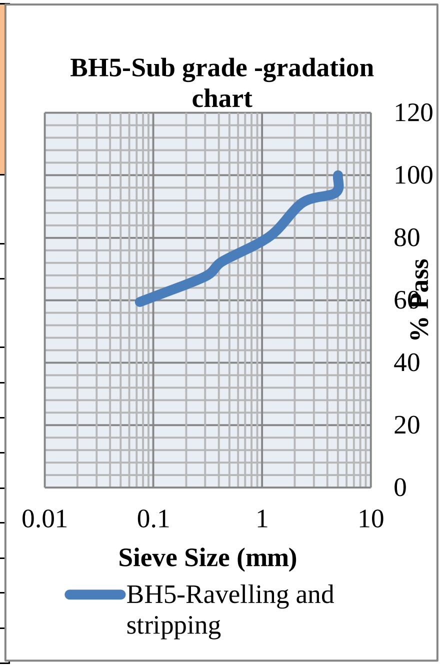


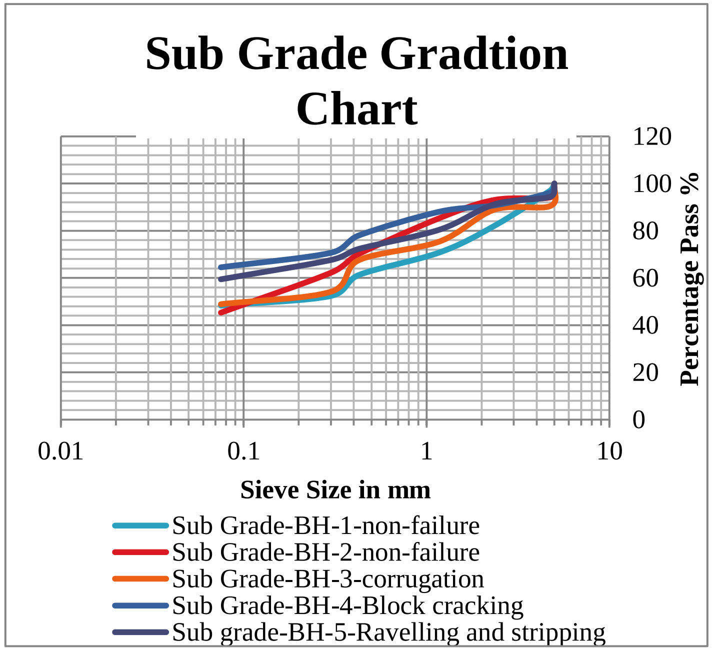
Material grade	Type:Sub	Sampled Date:30/11/2022 Completed Date:21/12/2022		
Source:BH4	Sampled By:Hailemichael Debalke			
Sieve Type:washed		Nominal Sieve Size:4.75mm		
Types of Failure		Block cracking		
Test Pit No.	BH4			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
5	0	0	0	100
4.75	174.8	3.8	3.8	96.2
2.36	248.4	5.4	9.2	90.8
1.18	123.28	2.68	11.88	88.1
0.425	465.52	10.12	22	78
0.3	336.72	7.32	29.32	70.7
0.075	282.9	6.15	35.47	64.5
pan	2968.38	64.53	100	0
Total	4600g	100		



Gradation of Sub grade of test pit-5 and all tests pits summary of subgrade layyers

Material grade	Type:Sub	Sampled Date:30/11/2022 Completed Date:21/12/2022		
Source:BH5	sampled by:Hailemichael Debalke			
Sieve Type:washed		Nominal Sieve Size:4.755mm		
Types of Failure		Ravelling and stripping		
Test Pit No.	BH5			
Sieve Size(mm)	Mass Retain(g)	% Retained	Cumalative Retained(%)	% Pass
5	0	0	0	100
4.75	300.24	5.56	5.56	94.4
2.36	172.26	3.19	8.75	91.3
1.18	580.5	10.75	19.5	80.5
0.425	442.8	8.2	27.7	72.3
0.3	252.72	4.68	32.38	67.6
0.075	441.18	8.17	40.55	59.5
pan	3210.3	59.45	100	0
Total	5400g	100		





Appendix-E-Los Angeles Abrasion Test-All test pits samples of sub base and base course

A.Sub base material test data

Sub base Trial 1					
Test pits No.	Weight of sample for test	weight of retained on sieve 1.7mm	weight of passing on sieve 1.7mm	Weight loss	Percent loss
BH1	5000	1512	3488	1512	30.24
BH2	5000	1781	3219	1781	35.62
BH3	5000	1236	3764	1236	24.72
BH4	5000	1148	3852	1148	22.96
BH5	5000	1878	3122	1878	37.56
Sub base Trial 2					
Test pits No.	Weight of sample for test	weight of retained on sieve 1.7mm	weight of passing on sieve 1.7mm	Weight loss	Percent loss
BH1	5000	1587.6	3662.4	1587.6	31.752
BH2	5000	1870.05	3379.95	1870.05	37.401
BH3	5000	1297.8	3952.2	1297.8	25.956
BH4	5000	1205.4	4044.6	1205.4	24.108
BH5	5000	1971.9	3278.1	1971.9	39.438

B. Base course material test data

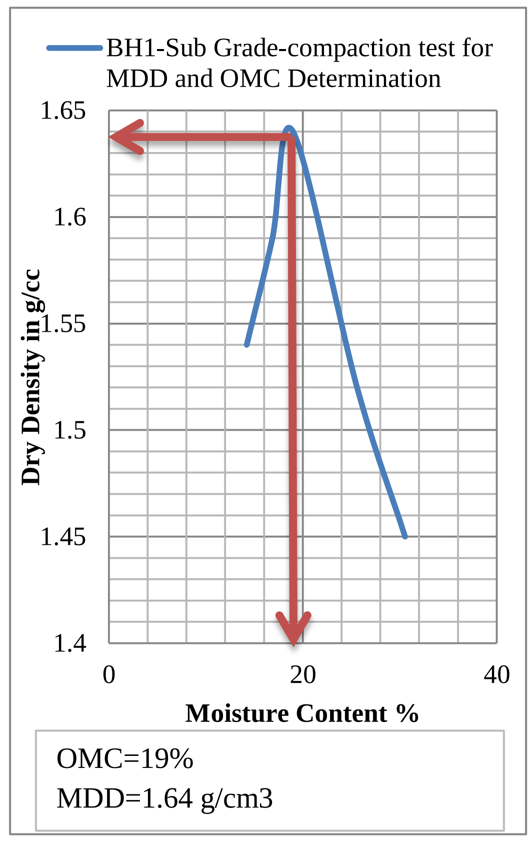
Base course Trial 1					
Test pits No.	Weight of sample for test	weight of retained on sieve 1.7mm	weight of passing on sieve 1.7mm	Weight loss	Percent loss
BH1	5000	1453	3547	1453	29.06
BH2	5000	1308	3692	1308	26.16
BH3	5000	1210.42	3789.58	1210.42	24.2084
BH4	5000	1992	3008	1992	39.84
BH5	5000	1103	3897	1103	22.06
Base course Trial 2					
Test pits No.	Weight of sample for test	weight of retained on sieve 1.7mm	weight of passing on sieve 1.7mm	Weight loss	Percent loss
BH1	5000	1525.65	3724.35	1525.65	30.513
BH2	5000	1373.4	3876.6	1373.4	27.468
BH3	5000	1270.941	3979.059	1270.941	25.41882
BH4	5000	2091.6	3158.4	2091.6	41.832
BH5	5000	1158.15	4091.85	1158.15	23.163

B. **Base course material test data**

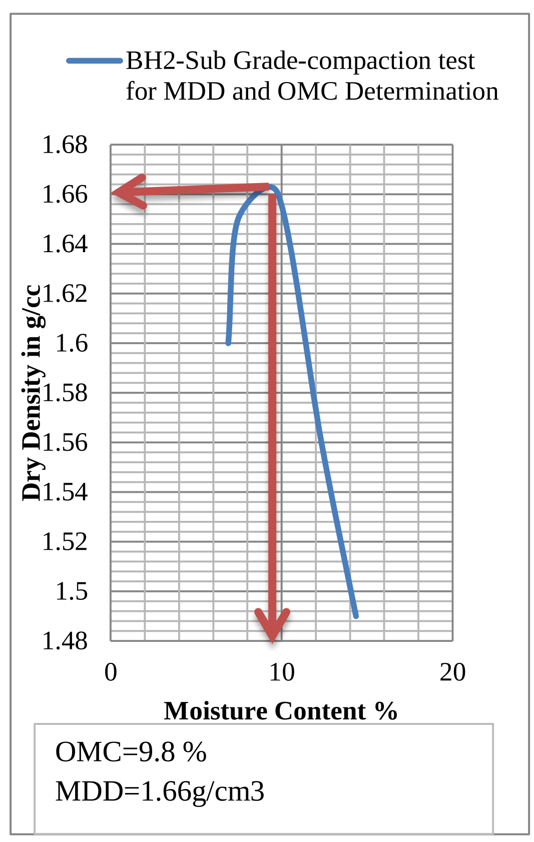
Appendix –F-Laboratory Test Results of Atterberg Limit

A. Moisture-Density Relationship of Sub grade for test pit-1,pit-2 and pit-3

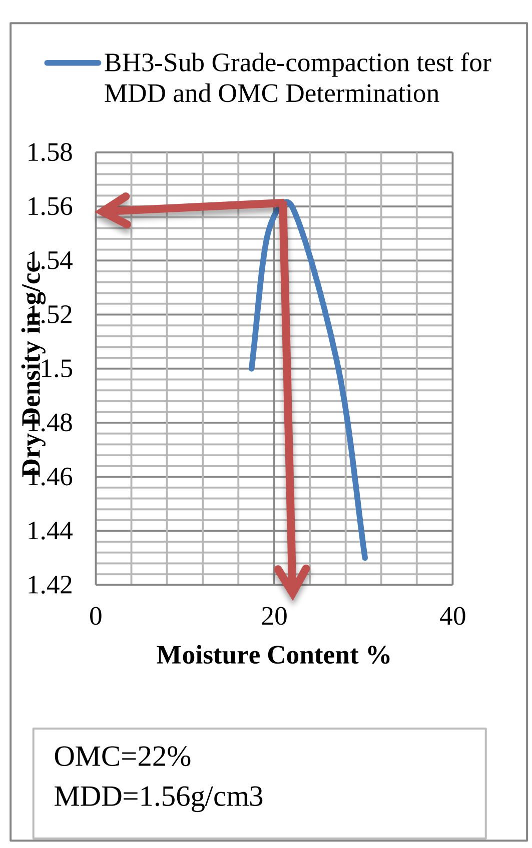
Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10517	10687	11019	10859	10727.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3570	3740	3986	3826	3765
Volume of mold	2155	2155	2180	2180	2160
wet density	1.66	1.74	1.83	1.76	1.74
Mosture content and Dry Density Determination					
Container NO.	N16	Y-7	M-3	S-30	D-12
Weight of wet soil+Container	197.02	199.7	203.8	183.5	228.84
Weight of dry soil+Container	184.86	185.7	185.6	163.3	205.12
weight of container	32.86	34.58	30.94	33.72	34.5
weight of moisture	12.16	14.08	18.2	20.22	23.72
weight of dry soil	152	151.1	154.6	129.5	170.62
mosture content	14.22	16.87	19	25.6	30.55
dry density	1.54	1.59	1.64	1.52	1.45



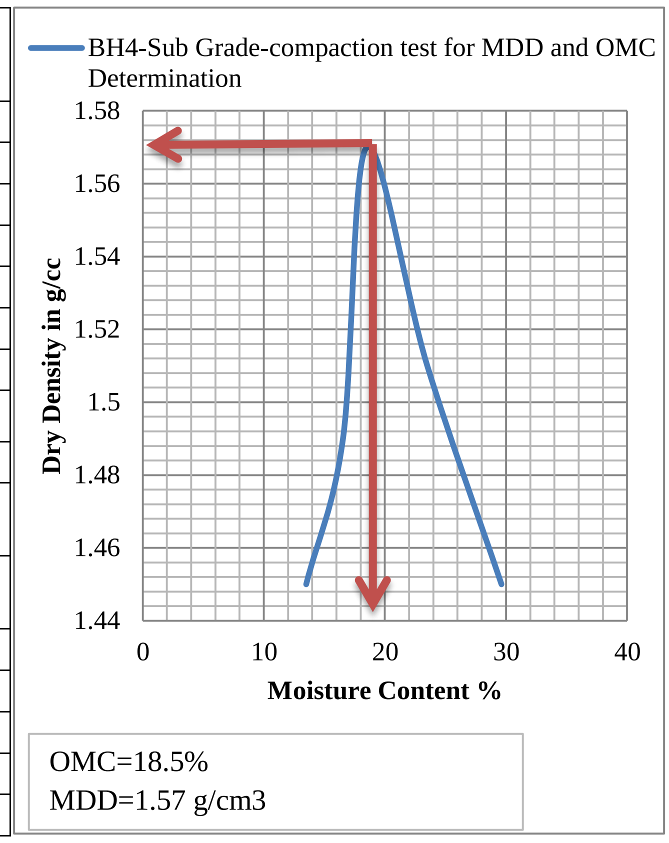
Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10627	10787	11022	10918	10752.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3680	3840	3989	3885	3790
Volume of mold	2155	2155	2180	2180	2160
wet density	1.71	1.78	1.83	1.78	1.75
Mosture content and Dry Density Determination					
Container NO.	D-3	O-16	B-1	A-12	K-34
Weight of wet soil+Container	290.66	269.2	254.8	272.1	285.31
Weight of dry soil+Container	279.9	255.8	240.6	253.6	265.06
weight of container	31.72	32.8	34.76	35.2	33.64
weight of moisture	10.76	13.44	14.22	18.55	20.25
weight of dry soil	248.18	223	205.8	218.4	231.42
mosture content	6.88	7.45	9.8	12.33	14.35
dry density	1.6	1.65	1.66	1.56	1.49



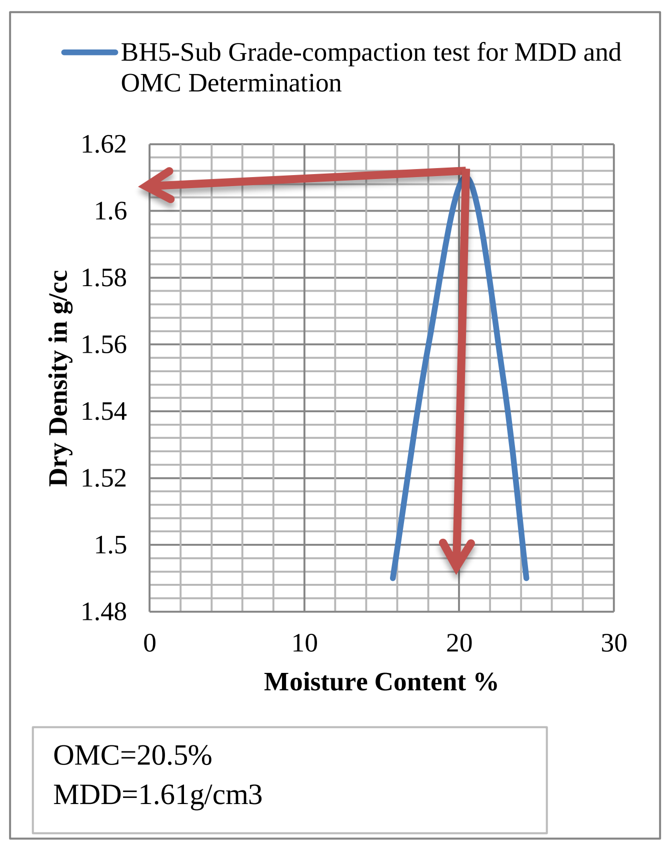
Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10417	10627	10845	10823	10652.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3470	3680	3812	3790	3690
Volume of mold	2155	2155	2180	2180	2160
wet density	1.61	1.71	1.75	1.74	1.71
Mosture content and Dry Density Determination					
Container NO.	W-10	Q-13	Y-6	U-17	V-0
Weight of wet soil+Container	237.38	208.1	190.4	174.6	176.61
Weight of dry soil+Container	223.75	191.9	173.1	155.3	153.69
weight of container	32.86	34.58	30.94	33.72	34.5
weight of moisture	13.63	16.2	17.22	19.3	22.92
weight of dry soil	190.89	157.3	142.2	121.6	119.19
mosture content	17.47	19.3	22	27.2	30.18
dry density	1.5	1.55	1.56	1.5	1.43

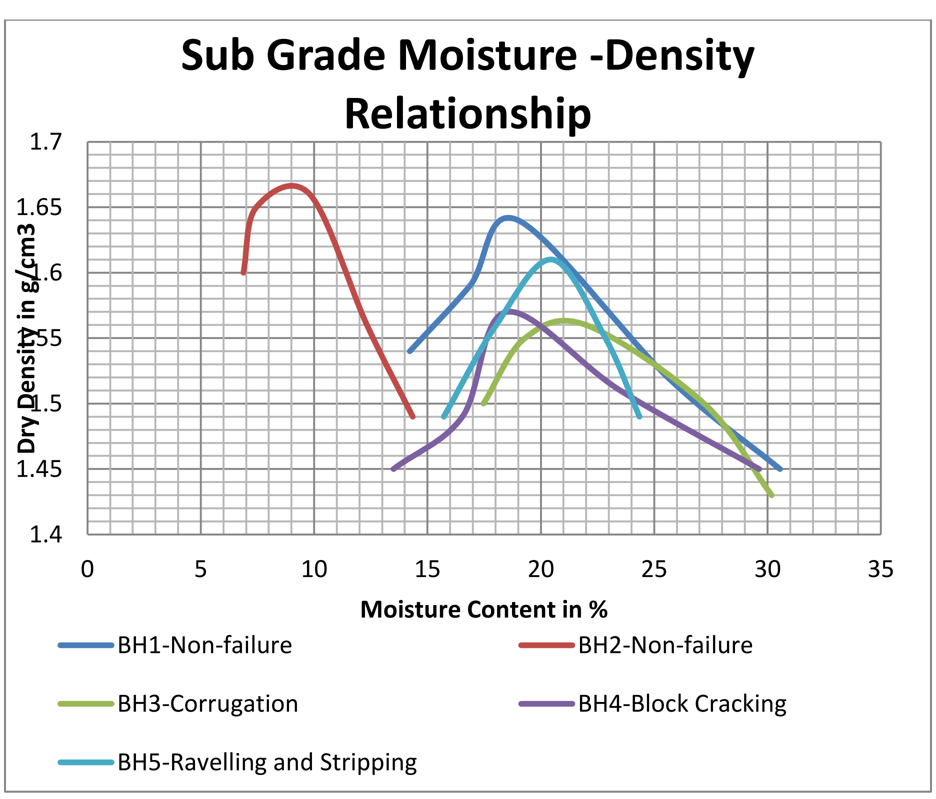


Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10337	10523	10953	10843	10704.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3390	3576	3920	3810	3742
Volume of mold	2155	2155	2180	2180	2160
wet density	1.57	1.66	1.8	1.75	1.73
Mosture content and Dry Density Determination					
Container NO.	D-45	Y-7	M-3	S-30	D-12
Weight of wet soil+Container	186.87	174	160.2	172.5	166.12
Weight of dry soil+Container	174.99	159.8	144	153.1	144.79
weight of container	34.4	33.4	32.6	32.7	34.5
weight of moisture	11.88	14.18	16.21	19.4	21.33
weight of dry soil	140.59	126.4	111.4	120.4	110.29
mosture content	13.5	16.54	18.5	23.5	29.63
dry density	1.45	1.49	1.57	1.51	1.45



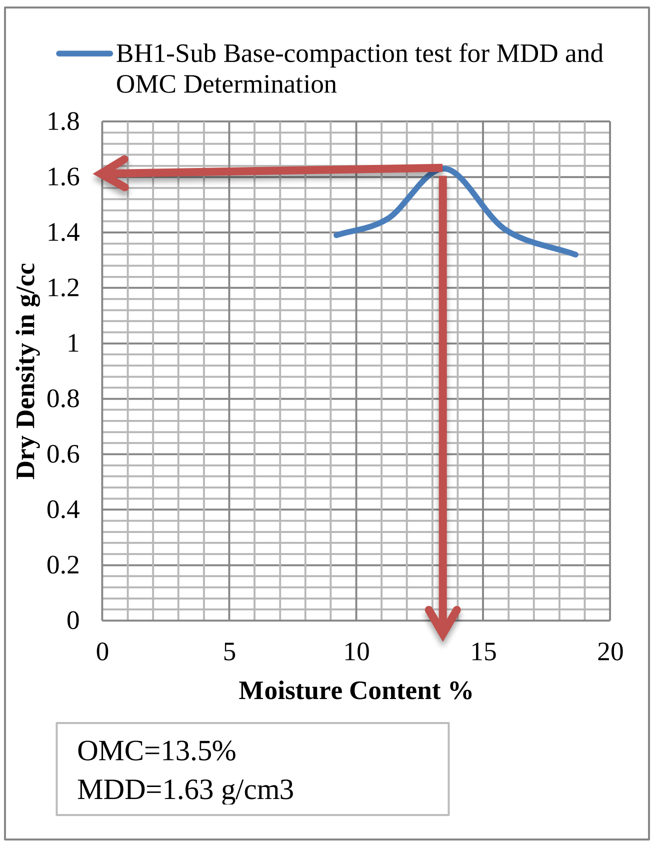
Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10347	10566	10856	10765	10616.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3400	3619	3823	3732	3654
Volume of mold	2155	2155	2180	2180	2160
wet density	1.58	1.68	1.75	1.71	1.69
Mosture content and Dry Density Determination					
Container NO.	D-3	Y-4	M-10	S-20	D-2
Weight of wet soil+Container	269.14	243.2	257.7	262.4	239.78
Weight of dry soil+Container	256.42	227.7	239.2	240.9	215.86
weight of container	34.1	34.8	34.2	35.4	36.2
weight of moisture	12.72	15.5	18.45	21.52	23.92
weight of dry soil	222.32	192.9	205	205.5	179.66
mosture content	15.72	18.03	20.5	22.85	24.35
dry density	1.49	1.56	1.61	1.55	1.49



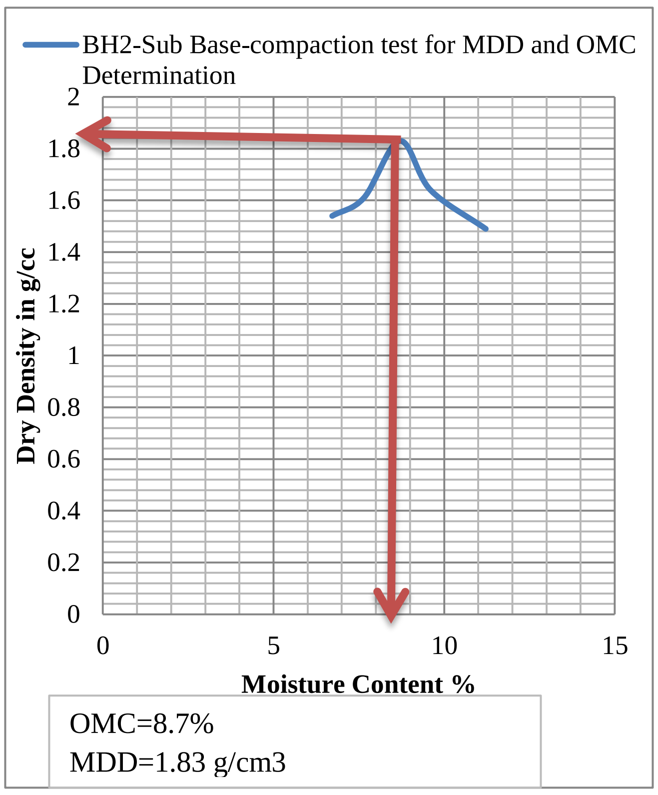


B. Moisture-Density Relationship of Sub base for test pit-1,pit-2 and pit-3

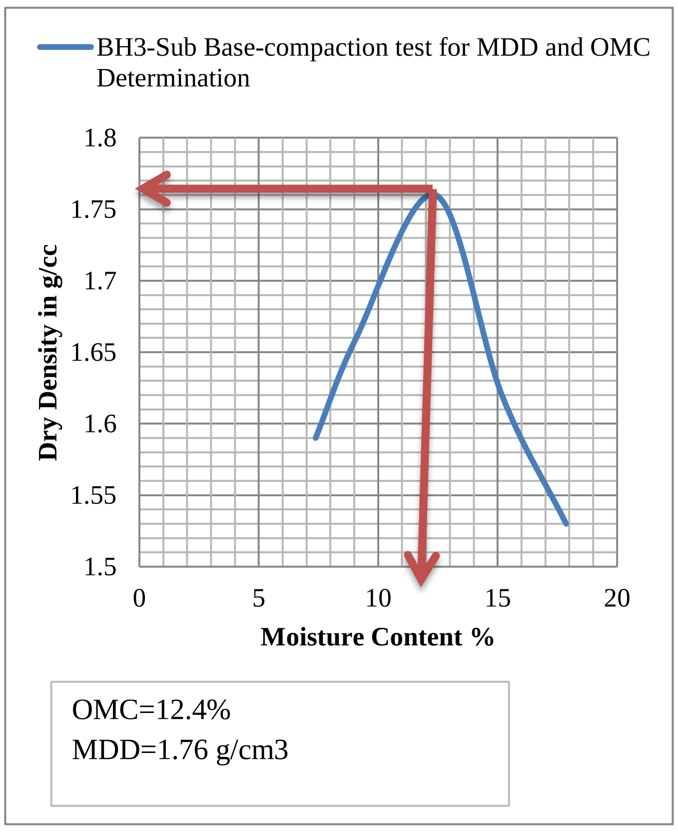
Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10178	10399	10978	10565	10350.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3231	3452	3945	3532	3388
Volume of mold	2155	2155	2180	2180	2160
wet density	1.5	1.6	1.81	1.62	1.57
Mosture content and Dry Density Determination					
Container NO.	B-10	D-6	C-4	H-2	K-1
Weight of wet soil+Container	244.29	241.5	281.9	239.1	211.27
Weight of dry soil+Container	228.6	222	256.8	212	182.94
weight of container	32.86	34.58	30.94	33.72	34.5
weight of moisture	15.69	19.41	25.11	27.14	28.33
weight of dry soil	195.74	187.5	225.8	178.3	148.44
mosture content	9.22	11.25	13.5	15.88	18.64
dry density	1.39	1.45	1.63	1.41	1.32



Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10156	10462	11113	10723	10320.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3209	3515	4080	3690	3358
Volume of mold	2155	2155	2180	2180	2160
wet density	1.49	1.63	1.87	1.69	1.55
Mosture content and Dry Density Determination					
Container NO.	N16	Y-7	M-3	S-30	D-12
Weight of wet soil+Container	264.85	217.6	238.7	258.7	258.13
Weight of dry soil+Container	250.17	199.1	216	232.8	229.9
weight of container	31.72	32.8	34.76	35.2	33.64
weight of moisture	14.68	18.47	22.73	25.88	28.23
weight of dry soil	218.45	166.3	181.3	197.6	196.26
mosture content	6.72	7.65	8.7	9.6	11.22
dry density	1.54	1.61	1.83	1.64	1.49

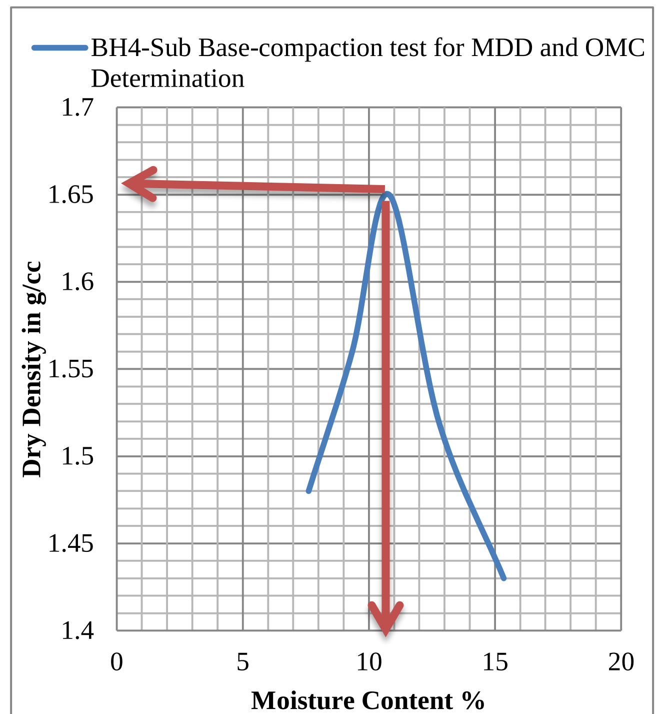


Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10631	10847	11261	11053	10840.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3684	3900	4228	4020	3878
Volume of mold	2155	2155	2180	2180	2160
wet density	1.71	1.81	1.94	1.84	1.8
Mosture content and Dry Density Determination					
Container NO.	D-20	Y-2	M-4	S-20	D-6
Weight of wet soil+Container	238.41	218.5	268.4	237.2	222.89
Weight of dry soil+Container	224.29	203.1	246.4	212.4	194.56
weight of container	32.86	34.58	30.94	33.72	34.5
weight of moisture	14.12	15.31	21.96	24.77	28.33
weight of dry soil	191.43	168.6	215.5	178.7	160.06
mosture content	7.38	9.08	12.4	15.18	17.87
dry density	1.59	1.66	1.76	1.62	1.53



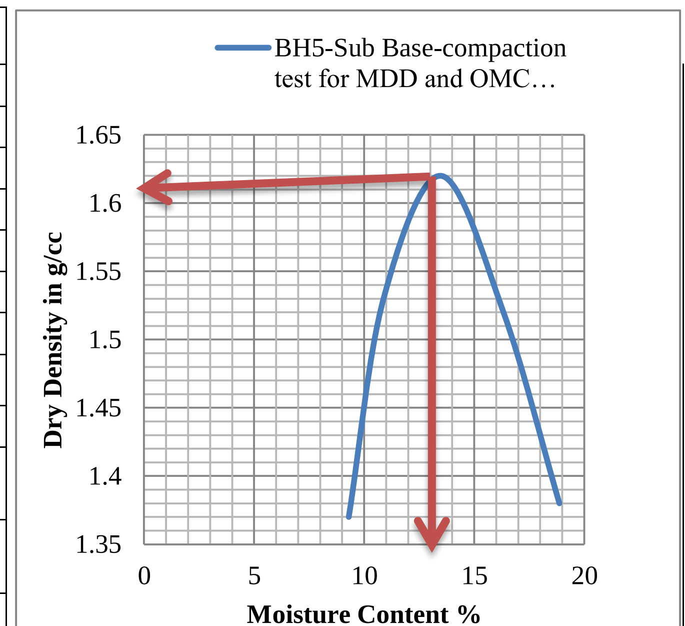
C. Moisture-Density Relationship of Sub grade for test pit-4and pit-5

Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10371	10618	11020	10785	10503.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3424	3671	3987	3752	3541
Volume of mold	2155	2155	2180	2180	2160
wet density	1.59	1.71	1.83	1.72	1.64
Mosture content and Dry Density Determination					
Container NO.	B-33	C-0	M-0	H-1	D-10
Weight of wet soil+Container	244.82	223.5	233.9	221.9	232.17
Weight of dry soil+Container	229.94	207.2	214.4	199.4	206.39
weight of container	34.4	33.4	32.6	32.7	34.5
weight of moisture	14.88	16.23	19.44	22.47	25.78
weight of dry soil	195.54	173.8	181.8	166.7	171.89
mosture content	7.61	9.34	10.8	12.77	15.35
dry density	1.48	1.56	1.65	1.52	1.43

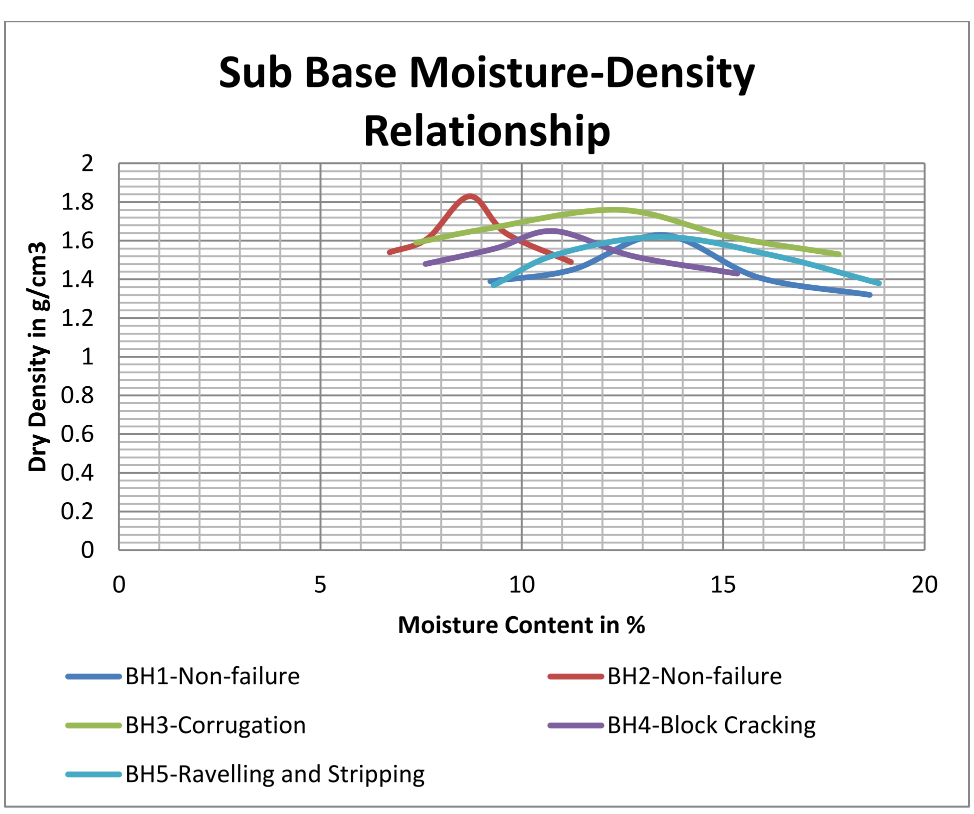


OMC=10.8%
MDD=1.65g/cm3

Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10176	10561	10954	10777	10506.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3229	3614	3921	3744	3544
Volume of mold	2155	2155	2180	2180	2160
wet density	1.5	1.68	1.8	1.71	1.64
Mosture content and Dry Density Determination					
Container NO.	W-0	V-5	U-2	T-10	R-12
Weight of wet soil+Container	214.21	237.1	245.1	256.1	214.87
Weight of dry soil+Container	198.88	218.9	223.8	231	186.46
weight of container	34.1	34.8	34.2	35.4	36.2
weight of moisture	15.33	18.21	21.38	25.13	28.41
weight of dry soil	164.78	184.1	189.6	195.6	150.26
mosture content	9.3	10.88	13.5	16.33	18.87
dry density	1.37	1.53	1.62	1.52	1.38

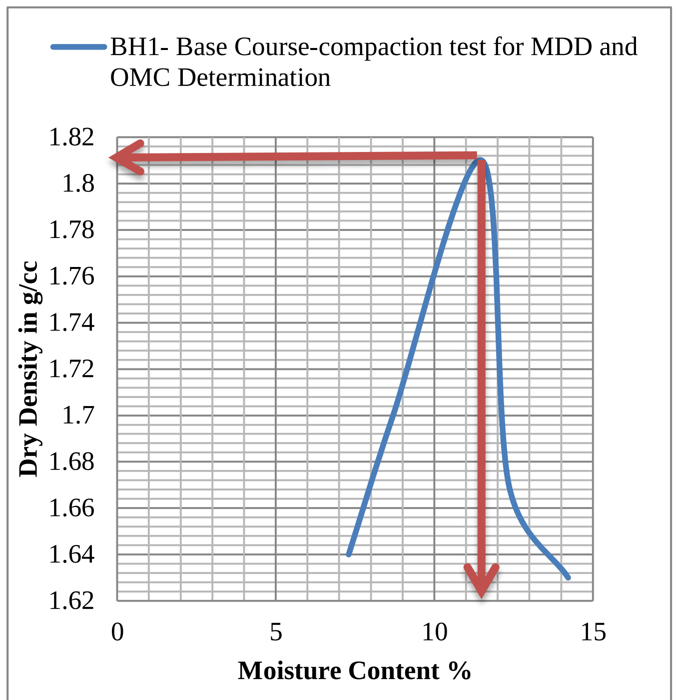


OMC=13.5%
MDD=1.62 g/cm3



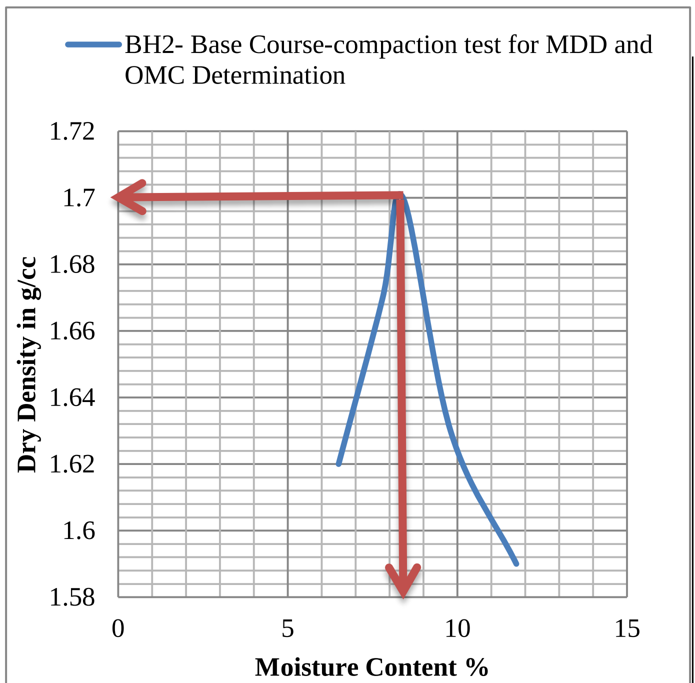
D. Moisture-Density Relationship of Sub grade for test pit-1,pit-2and pit-3

Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10622	10767	11219	10993	10826.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3675	3820	4186	3960	3864
Volume of mold	2155	2155	2180	2180	2160
wet density	1.71	1.77	1.92	1.81	1.79
Mosture content and Dry Density Determination					
Container NO.	N16	Y-7	M-3	S-30	D-12
Weight of wet soil+Container	271.21	280.1	260.3	274.8	255.66
Weight of dry soil+Container	261.76	269.9	247.7	256.4	235.55
weight of container	33.9	34.6	32.5	32.7	34.8
weight of moisture	9.45	10.23	12.66	18.34	20.11
weight of dry soil	227.86	235.3	215.2	223.7	200.75
mosture content	7.3	8.7	11.5	12.35	14.22
dry density	1.64	1.7	1.81	1.67	1.63



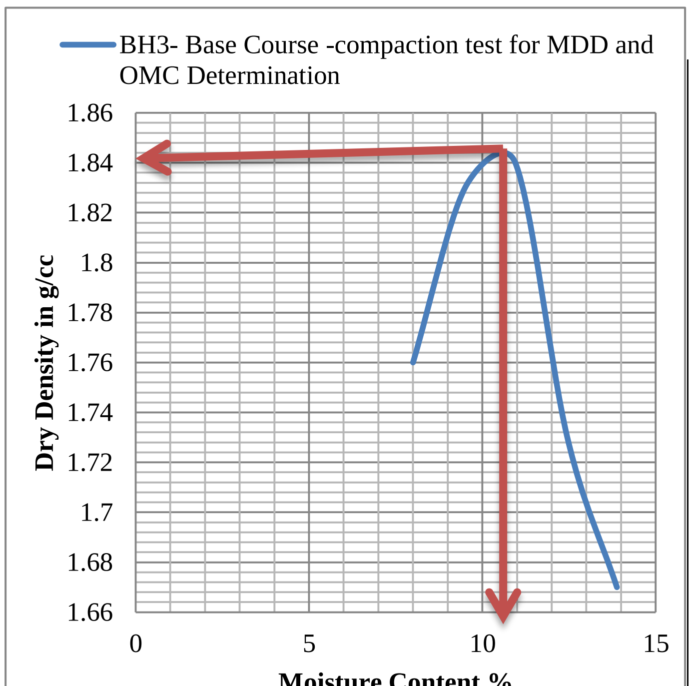
OMC=11.5
MDD=1.81

Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10567	10715	10949	10907	10772.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3620	3768	3916	3874	3810
Volume of mold	2155	2155	2180	2180	2160
wet density	1.68	1.75	1.8	1.78	1.76
Mosture content and Dry Density Determination					
Container NO.	W-0	V-5	U-2	T-10	R-12
Weight of wet soil+Container	287.1	263.5	241.8	235.6	256.44
Weight of dry soil+Container	278.24	253.1	229.6	218.1	235.19
weight of container	34.1	34.9	34.4	33.8	33.7
weight of moisture	8.86	10.39	12.15	17.48	21.25
weight of dry soil	244.14	218.2	195.2	184.3	201.49
mosture content	6.5	7.8	8.4	9.8	11.74
dry density	1.62	1.67	1.7	1.63	1.59



OMC=8.4% MDD=1.7g/cm3

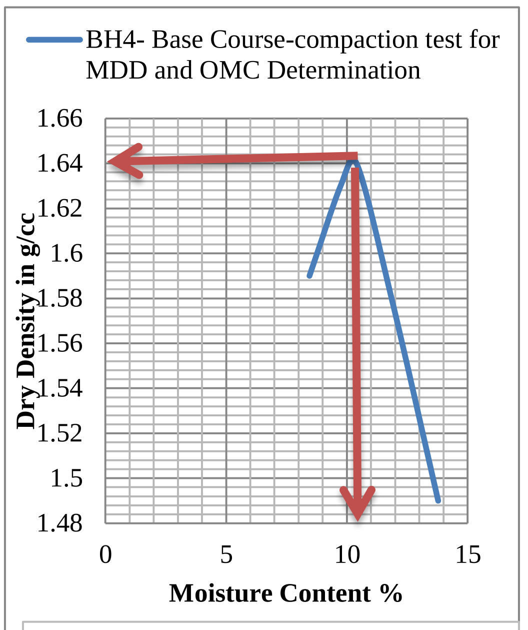
Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10873	11077	11303	11133	10951.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3926	4130	4270	4100	3989
Volume of mold	2155	2155	2180	2180	2160
wet density	1.82	1.92	1.96	1.88	1.85
Mosture content and Dry Density Determination					
Container NO.	B-33	C-0	M-0	H-1	D-10
Weight of wet soil+Container	266.41	253.3	245.1	250.3	247.18
Weight of dry soil+Container	258.75	243.5	232.4	233.2	226.87
weight of container	34.6	32.5	33.9	32.7	34.8
weight of moisture	7.66	9.8	12.76	17.12	20.31
weight of dry soil	224.15	211	198.5	200.5	192.07
mosture content	8	9.5	10.95	12.45	13.88
dry density	1.76	1.83	1.84	1.73	1.67



OMC=10.95%
MDD=1.84g/cm3

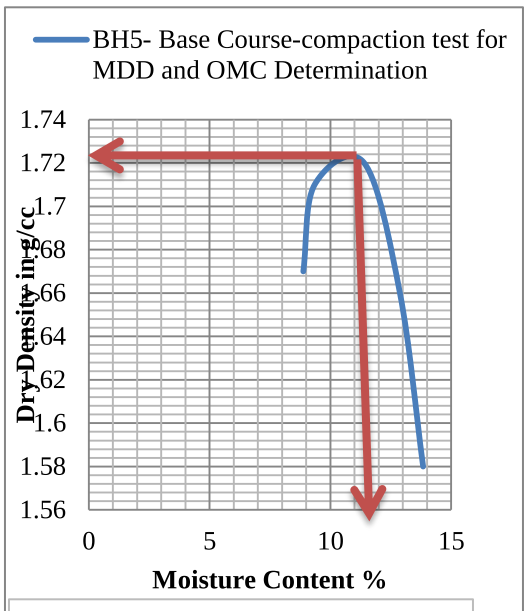
E. Moisture-Density Relationship of Sub grade for test pit-4 and pit-5

Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10537	10708	10927	10815	10653.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3590	3761	3894	3782	3691
Volume of mold	2155	2155	2180	2180	2160
wet density	1.67	1.74	1.79	1.74	1.71
Mosture content and Dry Density Determination					
Container NO.	D-20	Y-2	M-4	S-20	D-6
Weight of wet soil+Container	274.22	265.1	249.3	273.1	223.37
Weight of dry soil+Container	263.34	251.2	231.2	251.4	199.96
weight of container	34.9	34.1	33.8	33.7	34.5
weight of moisture	10.88	13.9	18.12	21.7	23.41
weight of dry soil	228.44	217.1	197.4	217.7	165.46
mosture content	8.45	9.74	10.4	11.85	13.78
dry density	1.59	1.63	1.64	1.58	1.49

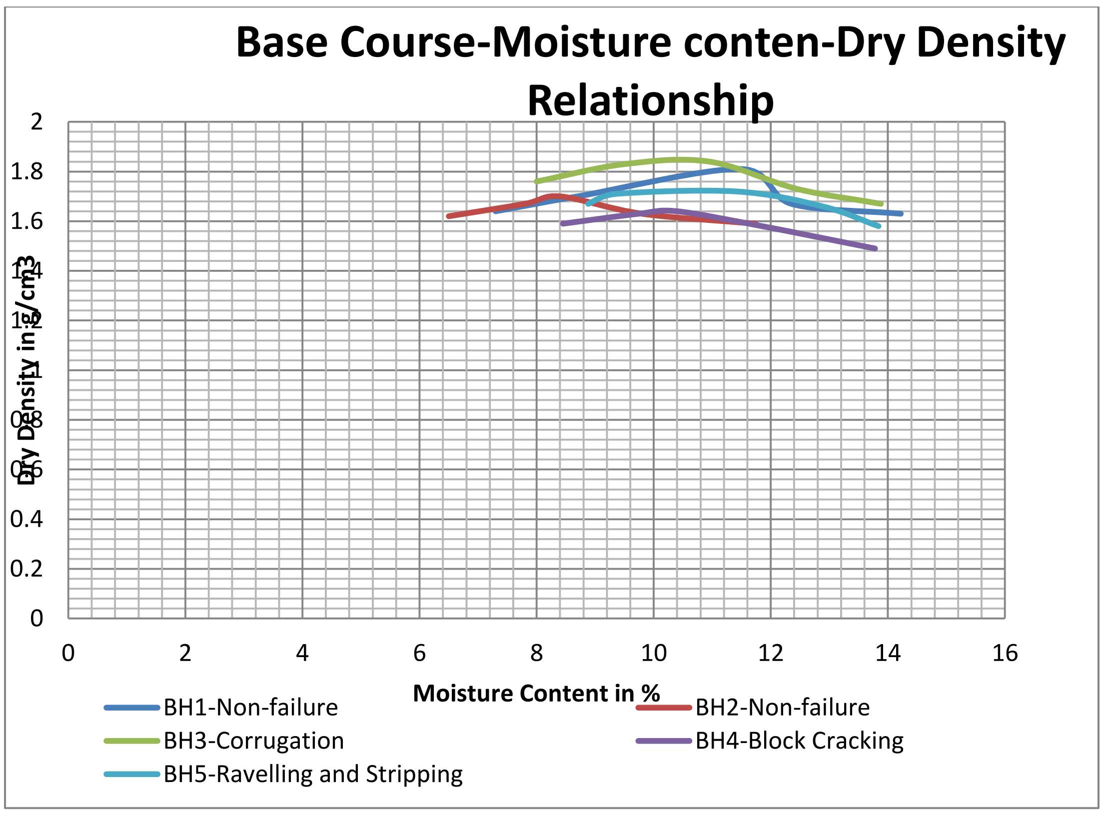


OMC=10.4
MDD=1.64

Wet Density Determination					
Trial number	1	2	3	4	5
Water to be added %	2	4	6	8	10
Weight of wet soil +mold	10697	10817	11033	10941	10772.2
weight of mold	6946.5	6947	7033	7033	6962.2
weight of wet soil	3750	3870	4000	3908	3810
Volume of mold	2155	2155	2180	2180	2160
wet density	1.74	1.796	1.835	1.793	1.764
Mosture content and Dry Density Determination					
Container NO.	B-10	D-6	C-4	H-2	K-1
Weight of wet soil+Container	269.14	243.2	257.7	262.4	239.78
Weight of dry soil+Container	260.24	233.1	243.4	245.2	219.12
weight of container	33.2	34.1	35.8	35.2	36.2
weight of moisture	8.9	10.1	14.3	17.15	20.66
weight of dry soil	227.04	199	207.6	210	182.92
mosture content	8.88	9.35	11.4	12.88	13.84
dry density	1.67	1.71	1.72	1.66	1.58

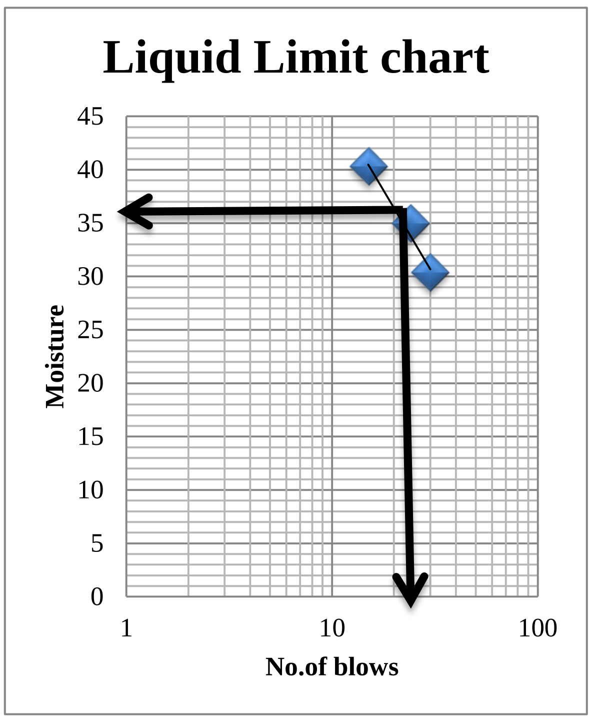


OMC=11.4%
MDD=1.72g/cm3

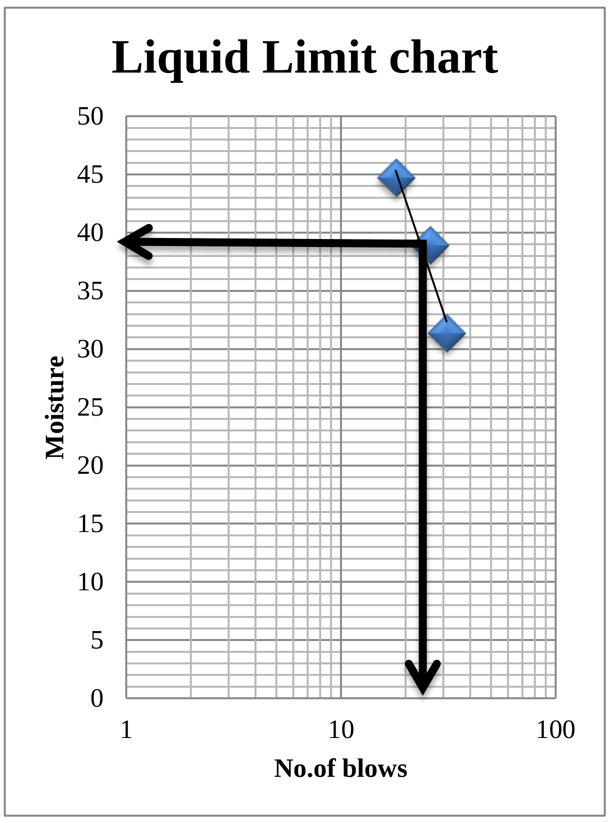


Appendix –D-Laboratory Test Results of Atterberg Limit
Atterberg Limit of Sub base materials for test pit-1 ,pit-2and pit-3

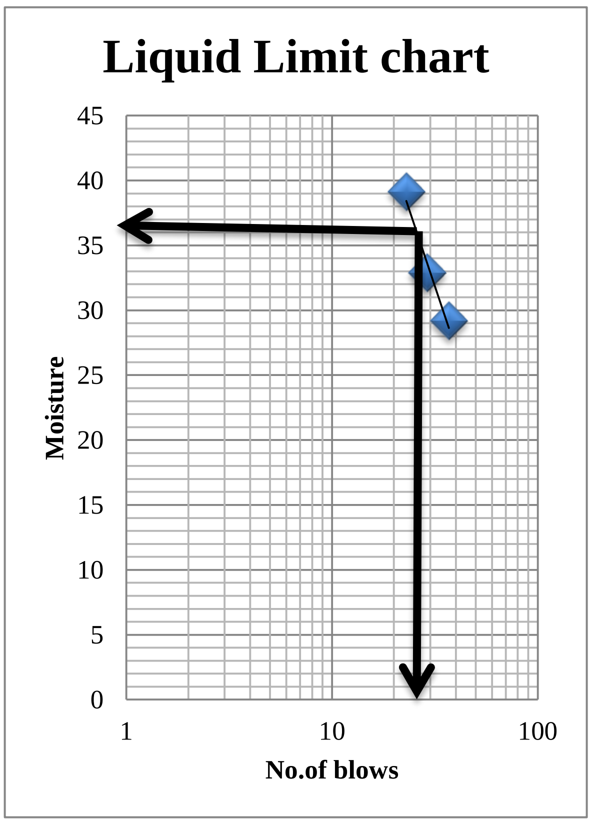
Material Type :Sub Base Source:BH1	Date of sampled :30/11/2022 Date of tested:25/12/2022				
Sampled by Hailemichael Debalke Damota					
Liquid Limit				Plastic Limit	
Container NO.	N16	Y-7	M-3	C-30	D-23
No.of blows	30	24	15		
Weight of wet soil+Container	80.15	86.78	86.44	14.52	13.29
Weight of dry soil+Container	70.86	73.59	71.2	13.69	12.37
weight of container	33.62	35.9	33.4	10.47	9
weight of moisture	11.33	13.19	15.24	0.83	0.92
weight of dry soil	37.24	37.69	37.8	3.22	3.37
mosture content	30.4242749 7	34.9960 2	40.3174 6	25.776 4	27.2997
	Average LL=35.24			Average PL=26.54	
Liquid Limit	35				
Plastic Limit	26				
Plastic Index	9				



Atterberg limit test Work sheet					
Material Type :Sub Base Source:BH2	Date of sampled :30/11/2022 Date of tested:25/12/2022				
Sampled by Hailemichael Debalke					
Container NO.	M-22	D-0	A	S	R
No.of blows	31	26	18		
Weight of wet soil+Container	76.36	79.61	82.13	14.92	18.46
Weight of dry soil+Container	67.67	69.16	69.25	14.06	17.22
weight of container	31.94	32.72	33.2	10.4	12.68
weight of moisture	11.21	14.18	16.12	0.86	1.24
weight of dry soil	35.73	36.44	36.05	3.65	4.54
mosture content	31.3741953 5	38.9132 8	44.7156 7	23.56	27.3127 8
	Average LL=38.33			Average PL=25.44	
Liquid Limit	38				
Plastic Limit	25				
Plastic Index	13				

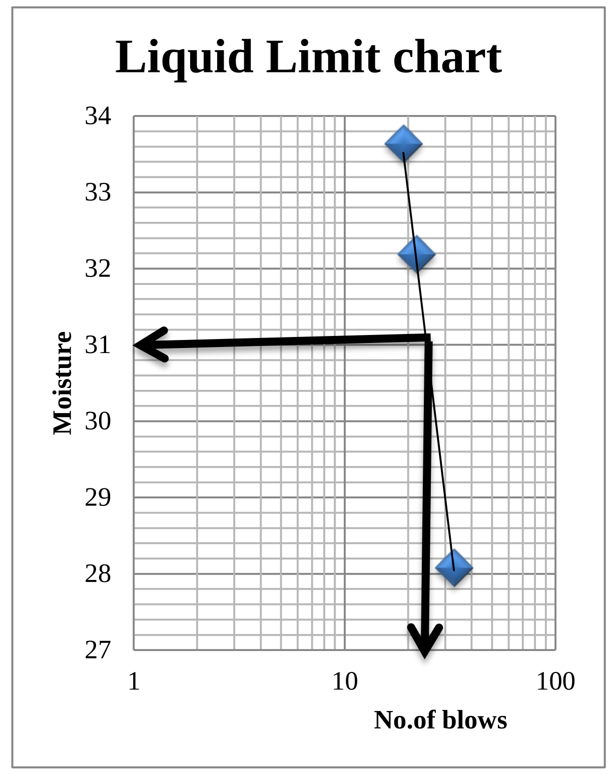


Atterberg Limit test Work sheet					
Material Type :Sub Base Source:BH3	Date of sampled :30/11/2022 Date of tested:25/12/2022				
Sampled by Hailemichael Debalke Damota					
Liquid Limit				plastic limit	
Container NO.	B-0	C-2	R-12	F	X
No.of blows	37	29	23		
Weight of wet soil+Container	77.76	81.66	79.89	18.4	21.16
Weight of dry soil+Container	67.62	69.86	66.64	17.26	19.64
weight of container	32.9	33.46	32.82	12.94	14.72
weight of moisture	10.14	11.98	13.25	1.14	1.52
weight of dry soil	34.72	36.4	33.82	4.58	4.92
mosture content	29.2050691 2	32.9120 9	39.178	26.92	30.89
	Average LL=33.77			Average PL=28.91	
Liquid Limit	37				
Plastic Limit	29				
Plastic Index	8				

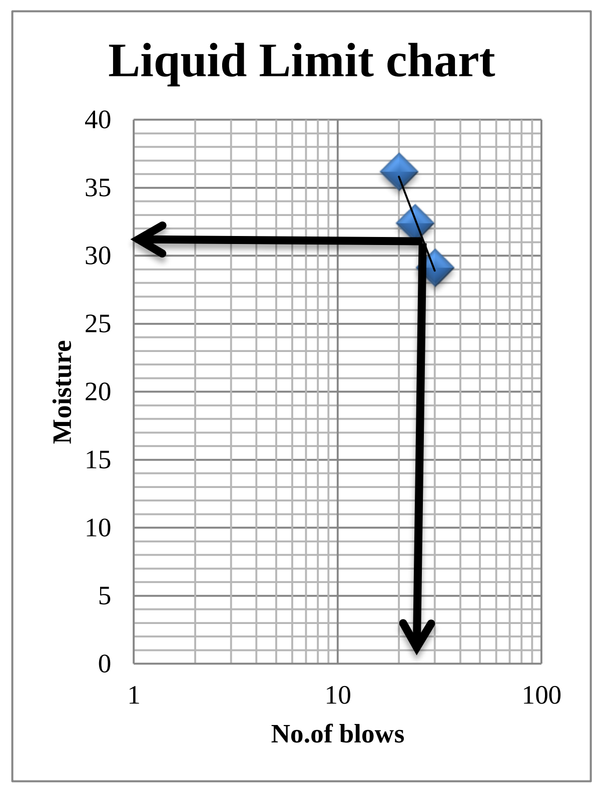


Atterberg Limit of Sub base materials for test pit-4 and pit-5

Atterberg limit test work sheet					
Material Type :Sub Base			Date of sampled :30/11/2022		
Source:BH4			Date of tested:25/12/2022		
Sampled by Hailemichael Debalke Damota					
liquid Limit				plastic limit	
Container NO.	D-1	B-3	E	K-0	K-3
No.of blows	33	22	19		
Weight of wet soil+Container	77.76	82.96	80.98	18.4	15.87
Weight of dry soil+Container	67.82	70.97	68.62	17.26	15.09
weight of container	32.42	33.72	31.88	14.72	12.27
weight of moisture	9.94	11.99	12.36	0.63	0.78
weight of dry soil	35.4	37.25	36.74	2.6	2.82
mosture content	28.08	32.19	33.64	24.16	27.78
	Average LL=31.30			Average PL=25.97	
Liquid Limit	31				
Plastic Limit	26				
Plastic Index	5				

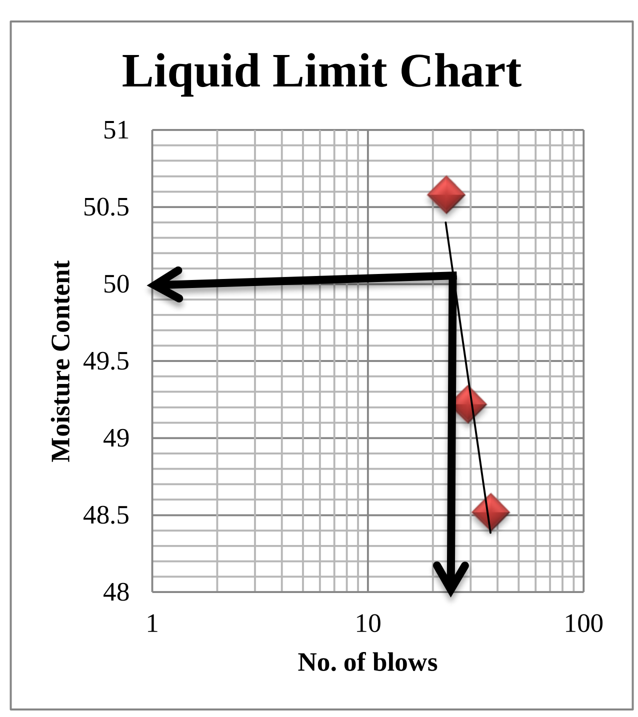


Atterberg limit test work sheet					
Material Type :Sub Base			Date of sampled :30/11/2022		
Source:BH5			Date of tested:25/12/2022		
Sampled by Hailemichael Debalke Damota					
Liquid Limit				Plastic Limit	
Container NO.	X	B-0	D-0	D-3	B-22
No.of blows	30	24	20		
Weight of wet soil+Container	81.2	86.92	76.45	24.51	21.58
Weight of dry soil+Container	72.64	69.48	66.93	23.2	20.48
weight of container	35.42	31.45	30.44	16.4	15.28
weight of moisture	10.85	12.33	13.21	1.31	1.1
weight of dry soil	37.22	38.03	36.49	6.8	5.2
mosture content	29.15099409	32.42177	36.2017	19.22	21.23
	Average LL=32.59			Average PL=20.23	
Liquid Limit	32				
Plastic Limit	20				
Plastic Index	12				



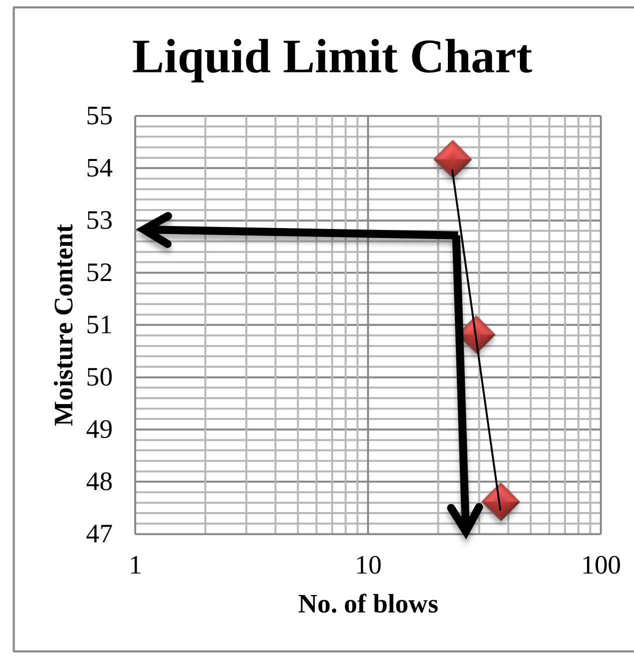
Atterberg Limit of Sub grade materials for test pit-1

Material Type :Sub grade			Date of sampled :30/11/2022		
Source:BH1			Date of tested:25/12/2022		
Sampled by Hailemichael Debalke Damota					
Liquid Limit				plastic Limit	
Container NO.	N16	Y-7	M-3	K-0	K-3
No.of blows	37	29	23		
Weight of wet soil+Container	55.83	60.75	66.04	21.25	23.72
Weight of dry soil+Container	44.44	47.28	50.6	19.72	21.96
weight of container	17.62	17.12	17.62	14.82	16.68
weight of moisture	11.39	13.47	15.44	1.53	1.76
weight of dry soil	26.82	30.16	32.98	4.9	5.28
mosture content	48.52	49.22	50.58	31.19	33.28
	Average LL=50			Average PL=32.24	
Liquid Limit	50				
Plastic Limit	32				
Plastic Index	18				

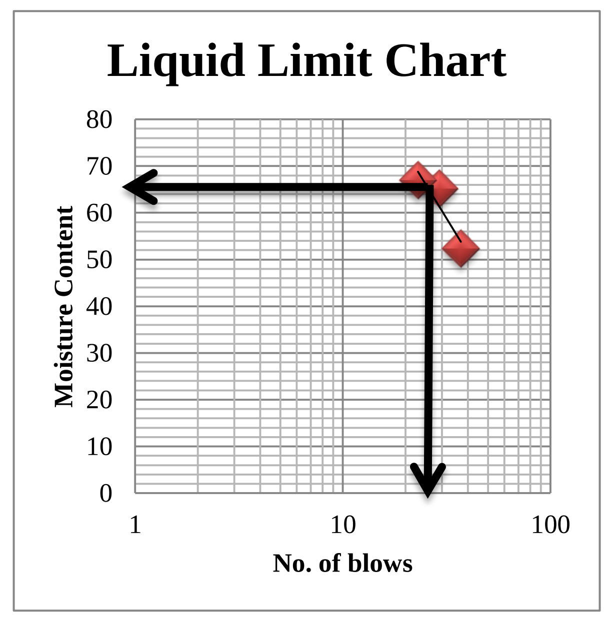


Atterberg Limit of Sub grade materials for test pit-2, pit-3, pit-4 and pit-5

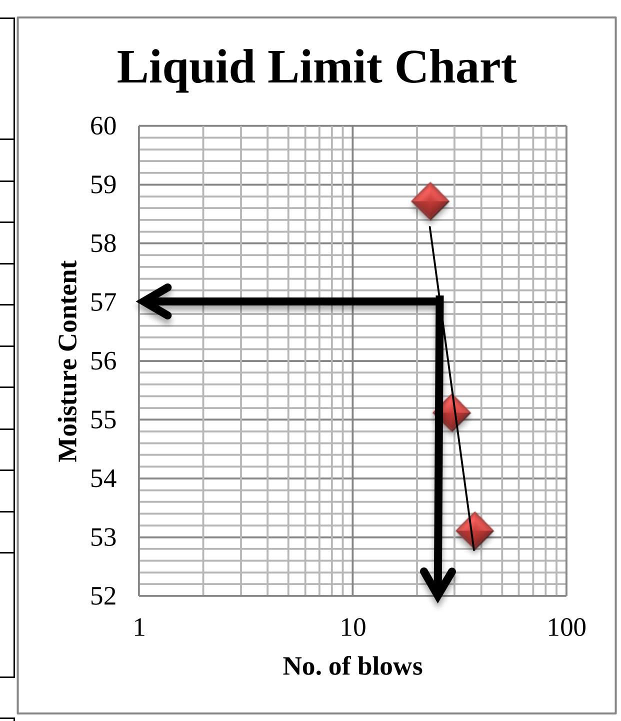
Material Type :Sub grade			Date of sampled :30/11/2022		
Source:BH2			Date of tested:25/12/2022		
Sampled by Hailemichael Debalke Damota					
Liquid Limit				Plastic limit	
Container NO.	D	B	A	E	C
No.of blows	37	29	23		
Weight of wet soil+Container	48.43	54.13	65.11	23.53	25.79
Weight of dry soil+Container	38.44	42.2	49.12	22.3	
weight of container	17.46	18.72	19.6	18	18.7
weight of moisture	9.99	11.93	15.99	1.23	1.49
weight of dry soil	20.98	23.48	29.52	4.3	5.6
mosture content	47.62	50.82	54.17	28.68	26.52
	Average LL=50.87			Average PL=27.60	
Liquid Limit	52				
Plastic Limit	27				
Plastic Index	25				



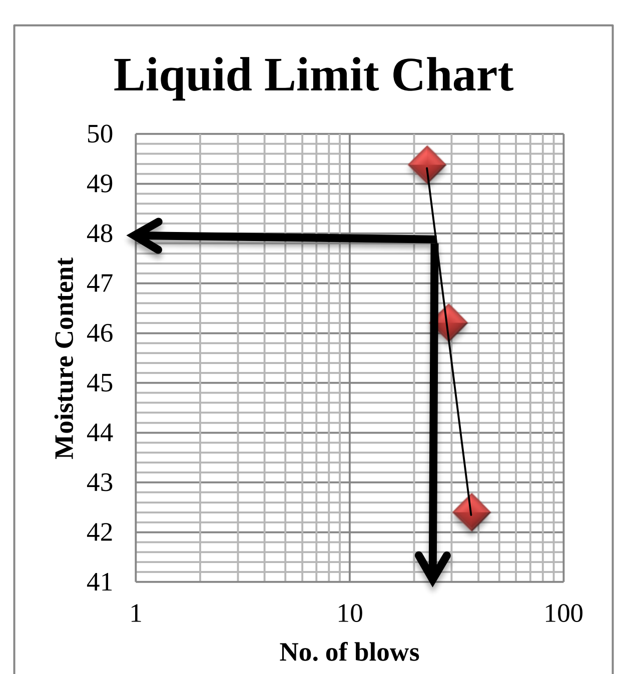
Material Type :Sub grade			Date of sampled :30/11/2022		
Source:BH3			Date of tested:22/12/2022		
Sampled by Hailemichael Debalke Damota					
Container NO.	N-0	M-0	F	E	K
No.of blows	37	29	23		
Weight of wet soil+Container	51.63	62.69	66.76	23.04	25.32
Weight of dry soil+Container	41.1	48.5	50.7	21.7	23.1
weight of container	17.6	18.12	17	17.7	16.9
weight of moisture	10.53	14.19	16.06	1.34	2.22
weight of dry soil	23.5	30.38	33.7	4	6.2
mosture content	52.5	65.35	67.12	33.38	35.73
	Average LL=68.56			Average PL=34.56	
Liquid Limit	68				
Plastic Limit	34				
Plastic Index	34				



Material Type :Sub grade			Date of sampled :30/11/2022		
Source:BH4			Date of tested:25/12/2022		
Sampled by Hailemichael Debalke Damota					
			Sampled by		
Container NO.	N16	Y-7	M-3	F	X
No.of blows	37	29	23		
Weight of wet soil+Container	52.59	65.73	62.29	23.66	27.11
Weight of dry soil+Container	40.31	49.44	45.72	21.9	24.5
weight of container	17.2	19.9	17.5	16.6	17.3
weight of moisture	12.28	16.29	16.57	1.76	2.61
weight of dry soil	23.11	29.54	28.22	5.3	7.2
mosture content	53.12	55.13	58.73	33.15	36.18
	Average LL=55.66			Average PL=34.67	
Liquid Limit	57				
Plastic Limit	34				
Plastic Index	23				



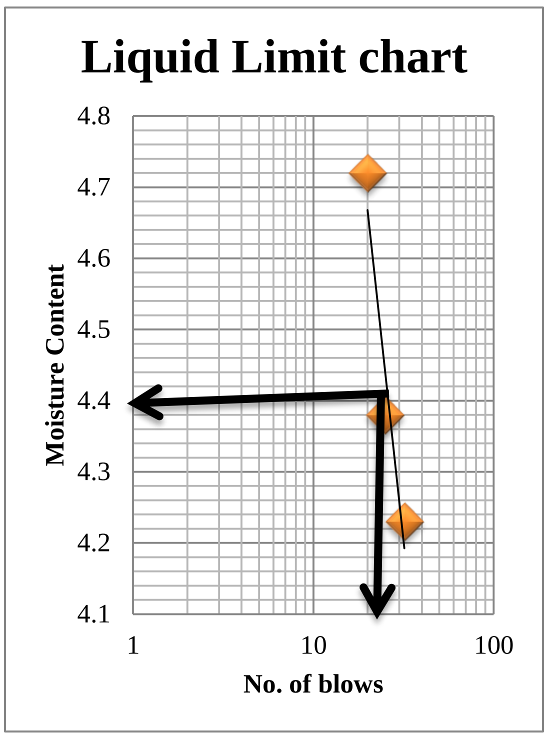
Material Type :Sub grade			Date of sampled :30/11/2022		
Source:BH5			Date of tested:25/12/2022		
Sampled by Hailemichael Debalke Damota					
			Sampled by		
Container NO.	D-22	C-0	B-2	K-0	F
No.of blows	37	29	23		
Weight of wet soil+Container	55.65	58.39	61.51	21.85	22.78
Weight of dry soil+Container	44.32	45.37	46.5	20.5	21.3
weight of container	17.6	17.2	16.1	16.7	16.4
weight of moisture	11.33	13.02	15.01	1.35	1.48
weight of dry soil	26.72	28.17	30.4	3.8	4.9
mosture content	42.4	46.21	49.38	35.6	30.24
	Average LL=45.99			Average PL=32.92	
Liquid Limit	48				
Plastic Limit	33				
Plastic Index	15				



Atterberg Limit of Base Course materials for test pit-1, pit-2, pit-3 and pit-4

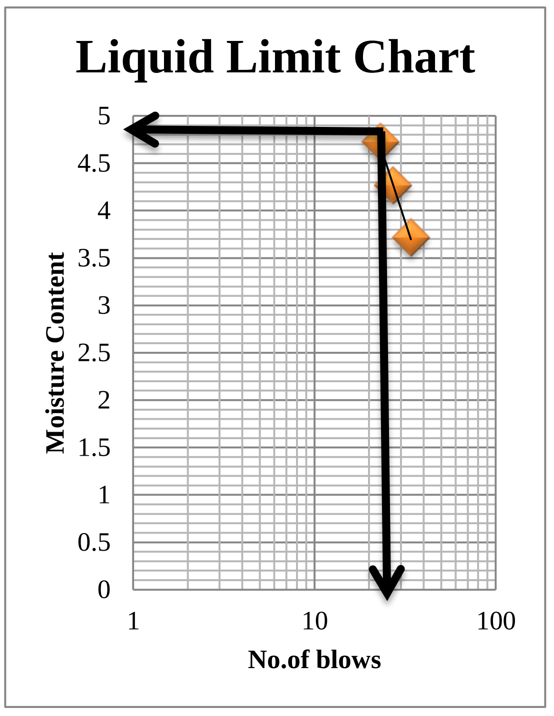
Material Type :Bae course — Date of sampled :30/11/2022
Source:BH1 — Date of tested:25/12/2022
Sampled by Hailemichael Debalke Damota

	liquid Limit			platic limit	
Container NO.	N16	Y-7	M-3		
No.of blows	32	25	20		
Weight of wet soil+Container	54.65	62.42	59.8		
Weight of dry soil+Container	53	60.66	57.9		
weight of container	14	13.91	13089		
weight of moisture	1.65	1.76	1.9		
weight of dry soil	39	46.75	44.01		
mosture content	4.23	4.38	4.72		
	Average LL=4.1				
Liquid Limit	4.4				
Plastic Limit	0				
Plastic Index	4.4				



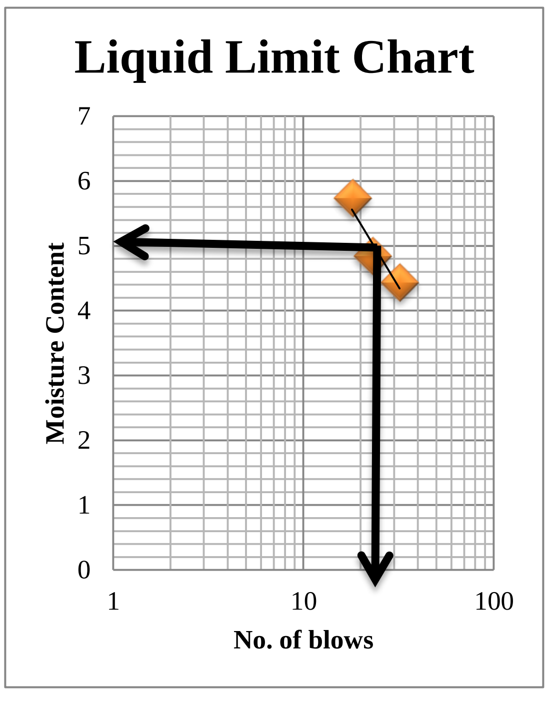
Material Type :Base course — Date of sampled :30/11/2022
Source:BH2 — Date of tested:25/12/2022
Sampled by Hailemichael Debalke Damota

	liquid Limit			plastic limit	
Container NO.	C	K	E		
No.of blows	34	27	23		
Weight of wet soil+Container	50.5	56.54	54.85		
Weight of dry soil+Container	49	55.02	53		
weight of container	13.85	14.12	13.95		
weight of moisture	1.5	1.52	1.85		
weight of dry soil	35.15	40.9	39.15		
mosture content	3.72	4.27	4.73		
	Average LL=4.24				
Liquid Limit	5				
Plastic Limit	0				
Plastic Index	5				



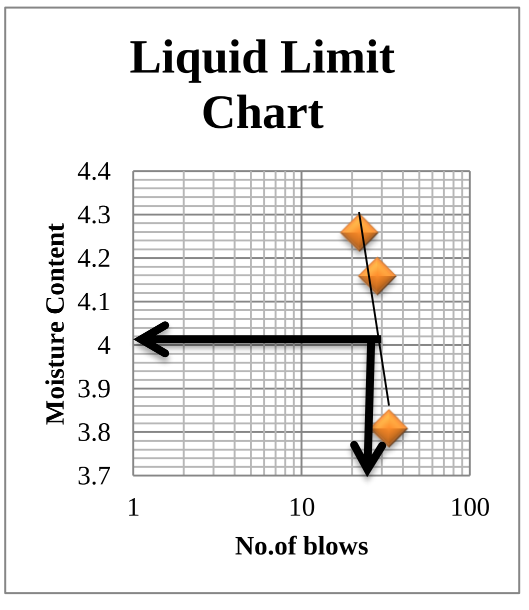
Material Type :base course — Date of sampled :30/11/2022
Source:BH3 — Date of tested:25/12/2022
Sampled by Hailemichael Debalke Damota

	Liquid Limit			plastic limit	
Container NO.	1	8	3		
No.of blows	32	23	18		
Weight of wet soil+Container	54.56	53.48	56.8		
Weight of dry soil+Container	52.8	51.65	54.92		
weight of container	13.85	13.6	14		
weight of moisture	1.76	1.83	2.35		
weight of dry soil	39.6	37.75	40.92		
mosture content	4.44	4.85	5.74		
	Average LL=5.01				
Liquid Limit	5				
Plastic Limit	0				
Plastic Index	5				



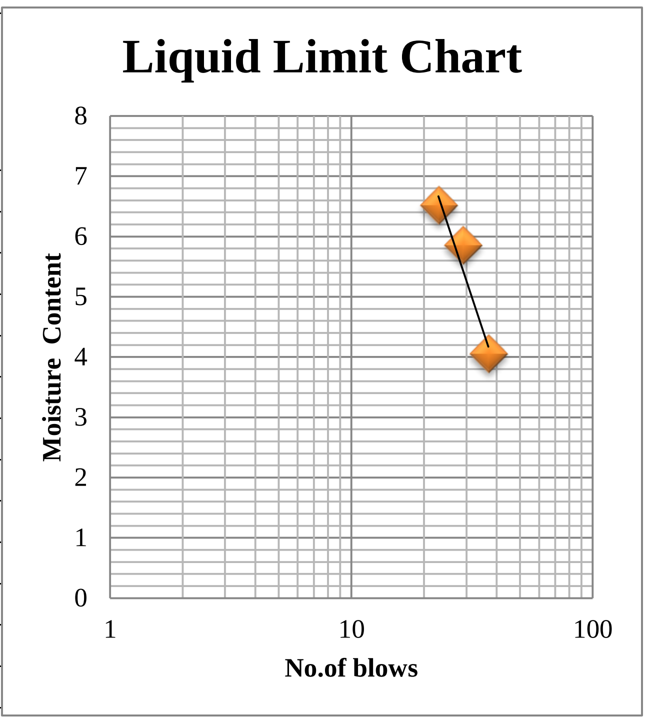
Material Type :base course — Date of sampled :30/11/2022
Source:BH4 — Date of tested:25/12/2022
Sampled by Hailemichael Debalke Damota

Container NO.	R	S-0	U		
No.of blows	33	28	22		
Weight of wet soil+Container	55.65	58.45	59.2		
Weight of dry soil+Container	54.1	56.68	57.35		
weight of container	13.45	14.12	13.92		
weight of moisture	1.55	1.77	1.85		
weight of dry soil	40.65	42.56	43.43		
mosture content	3.81	4.16	4.26		
	Average LL=4.08				
Liquid Limit	4				
Plastic Limit	0				
Plastic Index	4				



Atterberg Limit of Base course materials for test pit-5

Material Type :base course		Date of sampled :30/11/2022			
Source:BH5		Date of tested:25/12/2022			
Sampled by Hailemichael Debalke Damota					
		Sampled by			
Container NO.	B	S	M-3		
No.of blows	37	29	23		
Weight of wet soil+Container	59.15	60.45	61.22		
Weight of dry soil+Container	57.35	57.85	58.3		
weight of container	12.96	13.48	13.52		
weight of moisture	1.8	2.6	2.92		
weight of dry soil	44.39	44.37	44.78		
mosture content	4.06	5.86	6.52		
	Average LL=5.48				
Liquid Limit	6.1				
Plastic Limit	0				
Plastic Index	6.1				

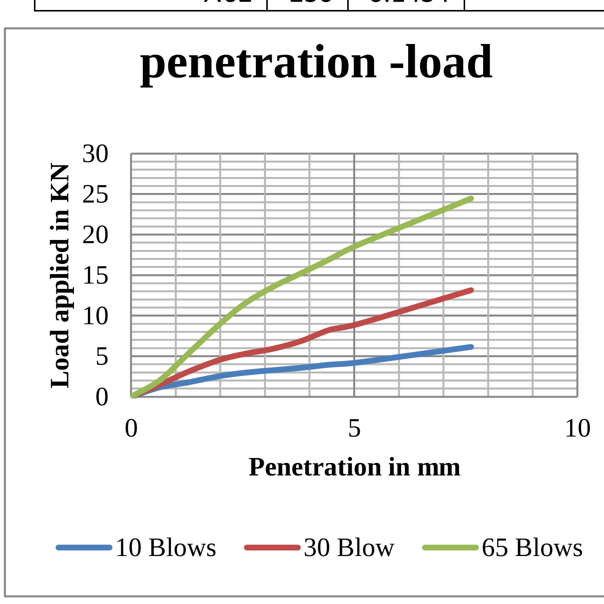


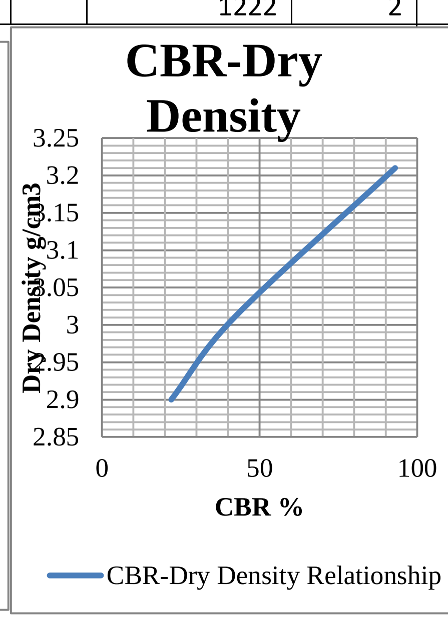
Appendix-C- Laboratory Result Details Of Subgrade, Sub Base and Base Course Materials

F. CBR Test-Result WORK SH-Base Course-BH-1

Base Course -BH-1-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	13522.5	13698.5	13978	14408.5	14246.2	14427.2
wt of mold,g	6946.5	6946.5	7032.6	7032.5	6962.2	6962.2
mass of soil,g	6576	6752	6945	7376	7284	7465
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	3.05	3.13	3.19	3.38	3.37	3.46
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	235.7	247.81	264.1	239.4	229.6	243.7
wt of dry sample+con,g	224.2	233.1	248.7	219.56	218.7	229.6
wt of moisture content	11.5	14.71	15.4	19.84	10.9	14.1
wt of cont,g	33.05	37.67	34.65	34.99	25.37	33.11
wt of dry soil	191.15	195.43	214.05	184.57	193.33	196.49
water content	6.02	7.53	7.19	10.75	5.64	7.18
dry density	2.88	2.91	2.97	3.06	3.19	3.22
Average Dry Density	2.90		3.01		3.21	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial RDG	load applied	Corrected Load	CBR	Dial RDG	Applied load	c.load	CBR	Dial RDG	Applied load	c.load	CBR
0	0	0			0	0			0	0		
0.64	45	1.1557			80	1.4815			97	2.017		
1.27	70	1.764			110	3.0629			265	5.253		
1.96	101	2.5182			218	4.4984			421	8.829		
2.54	**119**	**2.9561**	3	23	**380**	**5.2826**	5	38	594	**11.46**	12	90
3.18	132	3.2724			470	5.9152			742	13.55		
3.81	144	3.5644			550	6.8641			800	15.23		
4.45	160	3.9536			842	8.2509			850	16.96		
5.08	**171**	**4.2213**	4	20	971	**8.9564**	9	45	1240	**18.71**	19	95
7.62	250	6.1434			1222	13.1412			1422	24.45		



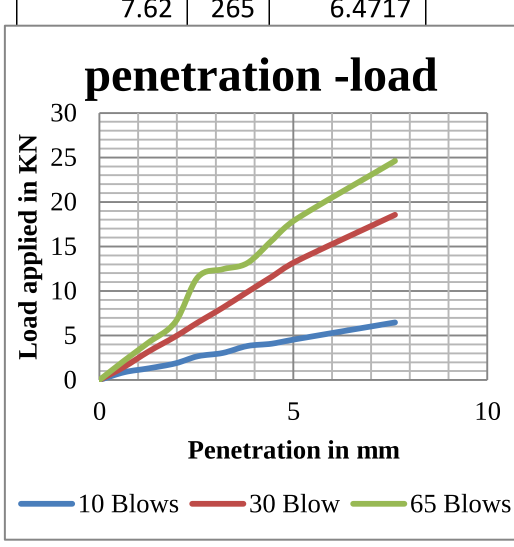


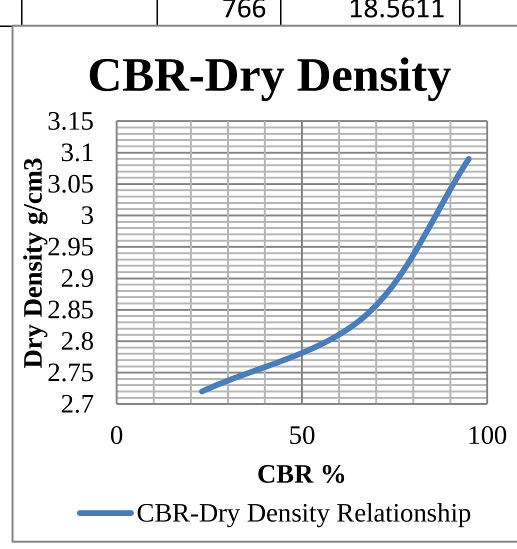
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.1	0.56	0.33
Percent swell	0.945	0.48	0.283
Average percent Swell	**0.57**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	20	45	95
Dry Density	2.9	3.01	3.21

G. CBR Test-Result WORK SH-Base Course-BH-2

Base Course -BH-2-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	10665.7	11204.7	10314	11156.1	10604.1	10968
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	6344	6548	6710	6823	6908	7407
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.94	3.04	3.08	3.13	3.20	3.43
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	252.3	230.9	246.7	222.6	229.1	233.6
wt of dry sample+con,g	236.7	209.6	231.9	203.88	218.9	217.33
wt of moisture content	15.6	21.3	14.8	18.72	10.2	16.27
wt of cont,g	34.9	35.3	35.2	35.1	35.6	35.4
wt of dry soil	201.8	174.3	196.7	168.78	183.3	181.93
water content	7.73	12.22	7.52	11.09	5.56	8.94
dry density	2.73	2.71	2.86	2.82	3.03	3.15
Average dry density	2.72		2.84		3.09	

	10 Blows				30 blows				65 blows			
Penetration in mm	Dial RDG	load applied	C.Load	CBR	Dial RDG	Applied Load	C.load	CBR	Dial RDG	applied load	c.load	CBR
0	0	0			0	0			0	0		
0.64	35	0.8758			61	1.4815			80	2.18		
1.27	53	1.3137			135	3.2089			164	4.223		
1.96	76	1.8733			204	4.8877			259	6.535		
2.54	**109**	**2.6762**	3	20	**269**	**6.4691**	6	49	341	**11.56**	12	87.58
3.18	124	3.0412			337	8.1235			439	12.45		
3.81	156	3.8197			409	9.8753			530	13.13		
4.45	167	4.0873			481	11.627			635	15.68		
5.08	**188**	**4.5983**	4	23	552	**13.3545**	13	67	734	**18.09**	18	95
7.62	265	6.4717			766	18.5611			856	24.61		





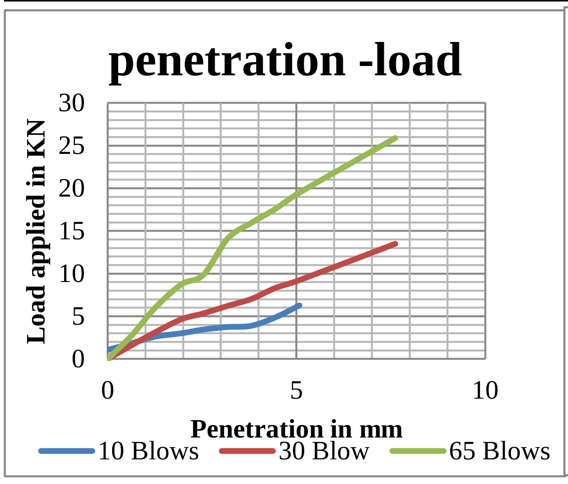
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.06	0.32	0.18
Percent swell	0.91	0.27	0.15
Average percent Swell	**0.44**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	23	67	95
Dry Density	2.72	2.84	3.09

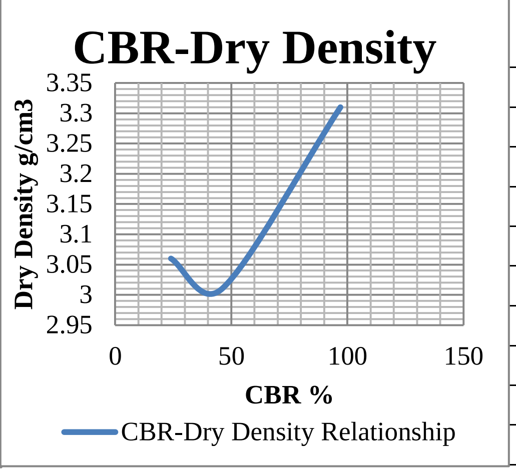
H. CBR Test-Result WORK SH-Base Course-BH-3

Base Course-BH-3-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	10665.7	11204.7	10314	11156.1	10604.1	10968
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	7030	7107	7213	7293	7818	7998
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	3.26	3.30	3.31	3.35	3.62	3.70

Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	267.36	259.43	244.9	235.27	247.8	260.5
wt of dry sample+con,g	255.82	240.25	227.6	213.51	231.14	235.66
Wt of moisture content	11.54	19.18	17.22	21.76	16.66	24.84
wt of cont,g	35.5	35	35.1	34.8	35	35.6
wt of dry soil	220.32	205.25	192.5	178.71	196.14	200.06
water content	5.24	9.34	8.94	12.18	8.49	12.42
dry density	3.10	3.02	3.04	2.98	3.34	3.29
Average Dry Density	3.06		3.01		3.31	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial RDG	load applied	C.Load	CBR	Dial RDG	Applied Load	C.Load	CBR	Dial RDG	Applied Load	C.Load	CBR
0	0	0			0	0			0	0		
0.64	38	1.0678			66	1.6201			120	2.768		
1.27	70	1.8464			129	3.1529			155	6.053		
1.96	102	2.6249			191	4.6614			407	8.751		
2.54	**118**	**3.0142**	3	22	**219**	**5.3426**	5	40	506	**9.87**	10	74.77
3.18	136	3.4522			255	6.2185			586	14.11		
3.81	148	3.7441			288	7.0304			662	15.96		
4.45	154	3.8901			342	8.3352			729	17.59		
5.08	**195**	**4.8877**	5	24	379	**9.2354**	9	46	807	**19.48**	19	97
7.62	252	6.2745			554	13.4932			863	25.88		



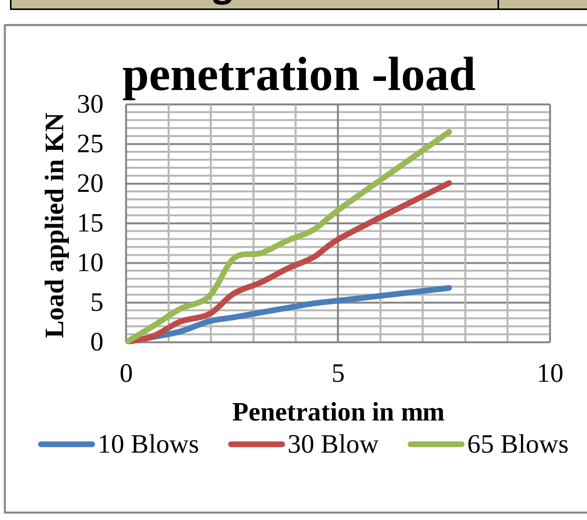


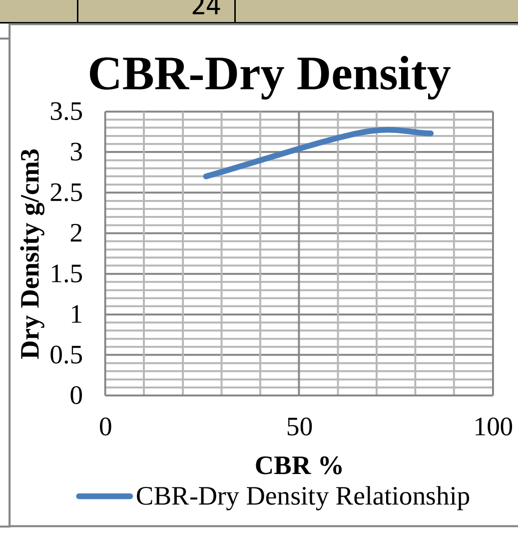
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.04	0.62	0.4
Percent swell	0.893	0.53	0.344
Average percent Swell	**0.59**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	24	46	97
Dry Density	3.06	3.01	3.31

I. CBR Test-Result WORK SH-Base Course-BH-4

Base Course-BH-4-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	10665.7	11204.7	10314	11156.1	10604.1	10968
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	6040	6410	7427	7879	7100	8004
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.80	2.97	3.41	3.61	3.29	3.71
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	258.42	273.6	263.2	284.15	260.46	263.7
wt of dry sample+con,g	245.64	256.23	246.3	263.54	243.72	244.9
wt of moisture content	12.78	17.37	16.83	20.61	16.74	18.8
wt of cont,g	33.05	37.67	34.65	34.99	25.37	33.11
wt of dry soil	212.59	218.56	211.7	228.55	218.35	211.79
water content	6.01	7.95	7.95	9.02	7.67	8.88
dry density	2.64	2.76	3.16	3.32	3.05	3.40
Average Dry Density	2.70		3.24		3.23	

	10 Blows				30 blows				65 blows			
Penetration in mm	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	30	0.6542			38	0.7732			90	2.038		
1.27	58	1.3355			112	2.5736			178	4.179		
1.96	111	2.625			152	3.5468			244	5.795		
2.54	**132**	**3.1359**	3	23	**258**	**6.1258**	6	46	330	**10.56**	10	80
3.18	157	3.7442			316	7.5369			396	11.24		
3.81	181	4.3281			388	9.2887			451	12.82		
4.45	205	4.9119			450	10.7972			588	14.25		
5.08	**220**	**5.2769**	5	26	549	**13.2058**	13	66	695	**16.96**	17	84
7.62	284	6.8341			831	20.066			732	26.51		
Average CBR=50				24				56				71



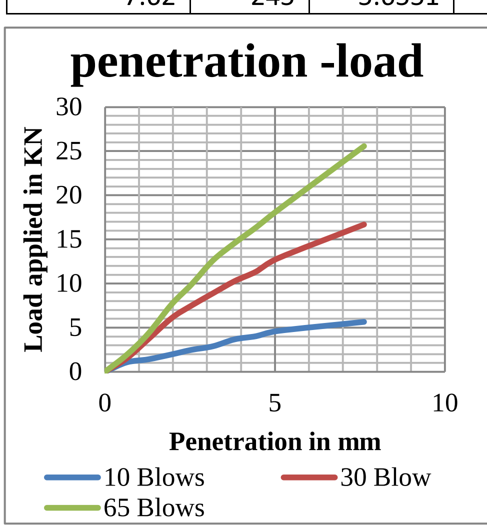


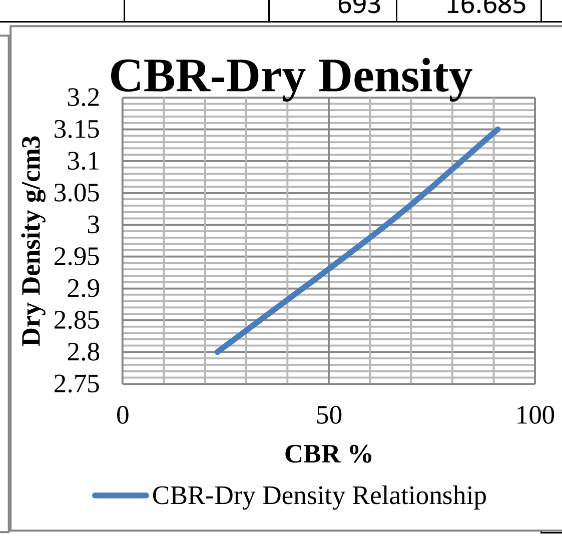
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1	0.52	0.35
Percent swell	0.859	0.45	0.301
Average percent Swell		**0.536**	
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	26	66	84
Dry Density	2.7	3.24	3.23

J. CBR Test-Result WORK SH-Base Course-BH-5

Base Course-BH-5-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	13244.5	13539.5	13843	14182.5	14047.2	14478.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	6298	6593	6810	7150	7085	7516
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.92	3.06	3.12	3.28	3.28	3.48
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	252.6	287.34	261.1	249.5	277.93	265.44
wt of dry sample+con,g	239.88	269.32	251.8	231.88	263.19	247.7
wt of moisture	12.72	18.02	9.34	17.62	14.74	17.74
wt of cont,g	35.3	34.5	35.7	34.5	35.5	33.11
wt of dry soil	204.58	234.82	216.1	197.38	227.69	214.59
water content	6.22	7.67	4.32	8.93	6.47	8.27
dry density	2.75	2.84	2.99	3.01	3.08	3.21
Average Dry Density	2.80		3.00		3.15	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	46	1.0678			70	1.5274			82	1.919		
1.27	60	1.4085			158	3.6685			180	4.304		
1.96	83	1.9681			257	6.0772			317	7.637		
2.54	**104**	**2.4789**	2	18	**315**	**7.4883**	5	56	409	**9.875**	10	74
3.18	121	2.8926			373	8.8994			522	12.62		
3.81	153	3.6712			429	10.2619			602	14.57		
4.45	168	4.0361			474	11.3568			676	16.37		
5.08	**192**	**4.62**	4	23	535	**12.8409**	13	64	755	**18.29**	18	91
7.62	245	5.6551			693	16.685			850	25.57		



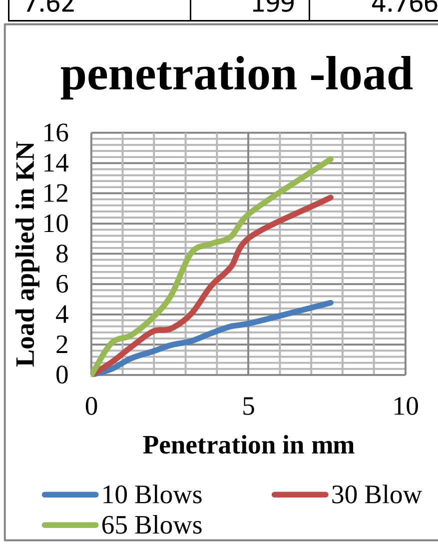


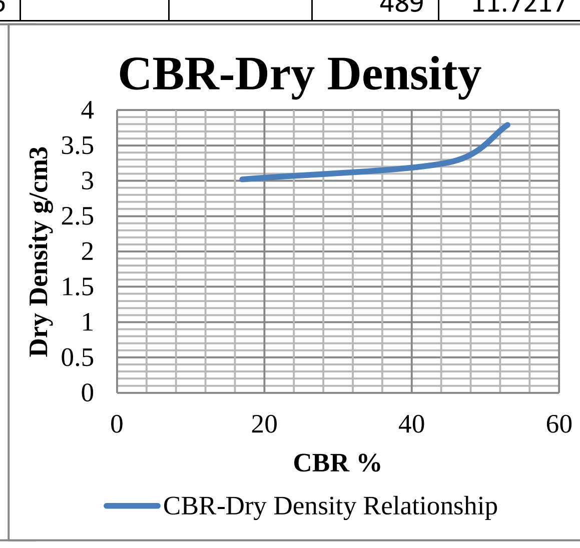
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.02	0.53	0.4
Percent swell	0.876	0.46	0.344
Average percent Swell	**0.558**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	23	64	91
Dry Density	2.8	3	3.15

K. CBR Test-Result WORK SH-Sub Base -BH-1

Sub Base-BH-1-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	13631.5	14348.5	14679	14790.5	15591.2	15801.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	6685	7402	7646	7758	8629	8839
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	3.10	3.43	3.51	3.56	3.99	4.09
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	286.4	277.9	233.9	386.5	308.1	300.3
wt of dry sample+con,g	270.5	256.6	217.6	360.4	292.7	281.6
wt of cont,g	33.9	32.7	34.9	33.9	34.4	33.8
wt of water content	15.90	21.30	16.30	26.10	15.40	18.70
Wt of dry sample	236.60	223.90	#####	326.50	258.30	247.80
Moisture Content	6.72	9.51	8.92	7.99	5.96	7.55
dry density	2.91	3.14	3.22	3.30	3.77	3.80
Average Dry Density	**3.02**		**3.26**		**3.79**	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	19	0.3866			37	0.8245			89	2.09		
1.27	48	1.0921			79	1.8464			111	2.625		
1.96	67	1.5544			121	2.8683			159	3.793		
2.54	**84**	**1.9681**	3	14	**129**	**3.0629**	5	23	219	**5.253**	6	39
3.18	95	2.2356			169	4.0361			334	8.051		
3.81	116	2.7466			244	5.8609			359	8.659		
4.45	135	3.2089			297	7.1503			379	9.145		
5.08	**148**	**3.4252**	5	17	379	**9.1454**	9	45	449	**10.75**	11	53
7.62	199	4.766			489	11.7217			589	14.25		



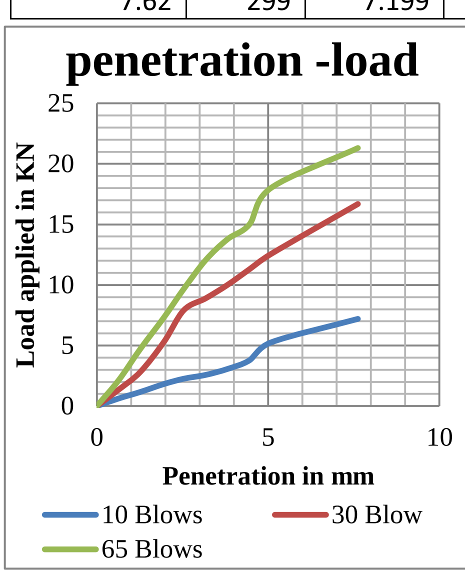


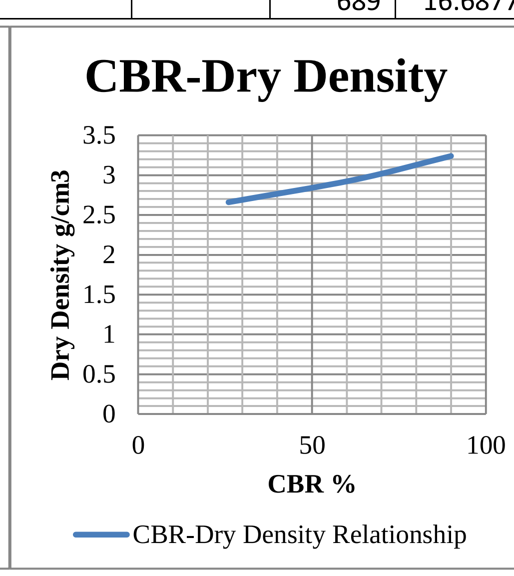
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.53	0.77	0.15
Percent swell	1.314	0.66	0.129
Average percent Swell	**0.701**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	17	45	53
Dry Density	3.02	3.26	3.79

L. CBR Test-Result WORK SH-Sub Base -BH-2

Sub Base-BH-2-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	13161.5	13378.5	13899	14396.5	14614.2	14803.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	6215	6432	6866	7364	7652	7841
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.88	2.98	3.15	3.38	3.54	3.63
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	264.2	298.5	279.8	286.7	238.4	260.1
wt of dry sample+con,g	246.3	269.3	257.1	259.5	219.8	236.7
wt of cont,g	33.3	35.2	33.9	33.1	33.6	34.1
wt of water content	17.90	29.20	22.70	27.20	18.60	23.40
wt of dry soil	213.00	234.10	#####	226.40	186.20	202.60
moisture content	8.40	12.47	10.17	12.01	9.99	11.55
dry density	2.66	2.65	2.86	3.02	3.22	3.25
Average Dry Density	**2.66**		**2.94**		**3.24**	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	29	0.6299			59	1.3598			91	2.138		
1.27	51	1.1652			119	2.8196			197	4.717		
1.96	78	1.8221			221	5.3013			304	7.321		
2.54	**96**	**2.2601**	2	17	**329**	**7.9209**	8	60	401	**9.681**	10	73
3.18	109	2.5763			369	8.9021			499	12.07		
3.81	129	3.0629			414	9.997			569	13.77		
4.45	158	3.7685			467	11.2864			619	14.98		
5.08	**219**	**5.2526**	5	26	519	**12.5516**	13	62	743	**18**	18	90
7.62	299	7.199			689	16.6877			879	21.31		



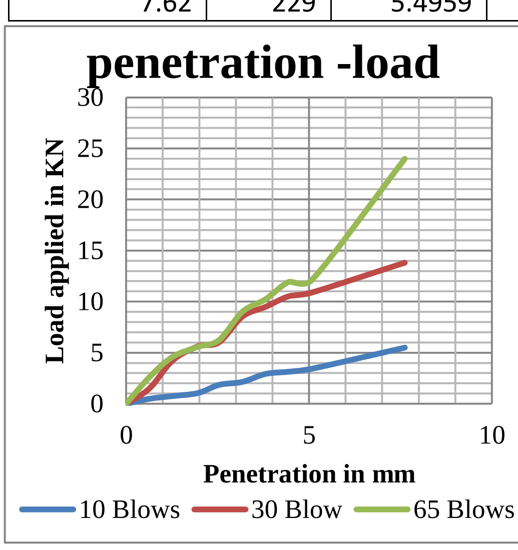


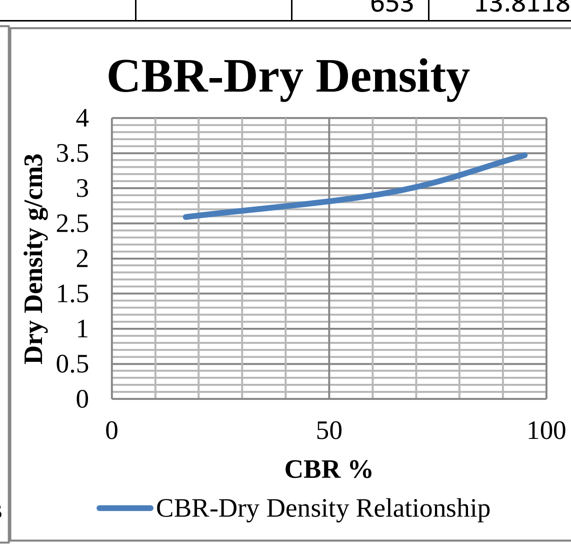
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.61	0.55	0.28
Percent swell	1.383	0.47	0.241
Average percent Swell	**0.699**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	26	62	90
Dry Density	2.66	2.94	3.24

M. CBR Test-Result WORK SH-Sub Base -BH-3

Sub Base-BH-3-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	13031.5	13374.5	13715	14862.5	15052.2	16048.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	6085	6428	6682	7830	8090	9086
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.82	2.98	3.07	3.59	3.75	4.21
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	258.9	269.4	229.7	270.1	259.6	383.3
wt of dry sample+con,g	236.8	242.11	209.3	240.23	237.6	328.85
wt of cont,g	36	35.1	34.2	33.8	33.6	33.9
weight moisture content	22.1	27.29	20.4	29.87	22	54.45
weight Dry soil	200.80	207.01	#####	206.43	204.00	294.95
Moisture Content	11.01	13.18	11.65	14.47	10.78	18.46
dry density	2.54	2.64	2.75	3.14	3.38	3.55
Average Dry Density	2.59		2.94		3.47	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	23	0.4839			65	1.5058			111	2.625		
1.27	34	0.7515			177	4.2307			253	4.589		
1.96	46	1.0435			284	5.6238			389	5.568		
2.54	**79**	**1.8464**	2	13	**337**	**6.0128**	6	45.6	497	**6.231**	6	47.2
3.18	91	2.1384			395	8.5347			589	9.011		
3.81	123	2.9169			434	9.4836			629	10.23		
4.45	132	3.1359			477	10.5297			799	11.93		
5.08	**144**	**3.4279**	3	17	533	**10.8922**	10	54.5	889	**12.12**	12	60.6
7.62	229	5.4959			653	13.8118			989	23.99		





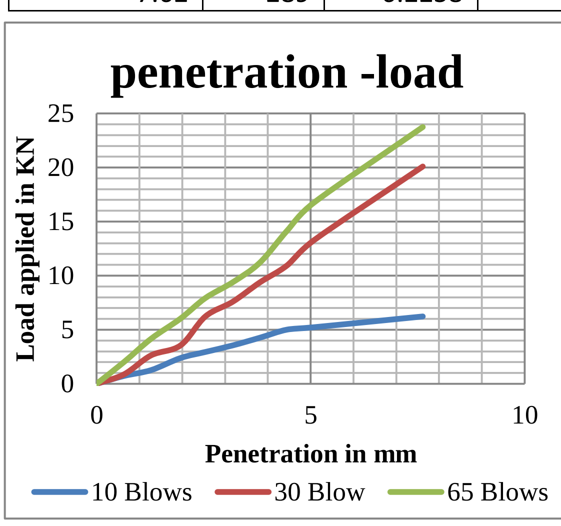
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.28	0.54	0.32
Percent swell	1.099	0.46	0.275
Average percent Swell	**0.613**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	17	54.5	60.6
Dry Density	2.59	2.94	3.47

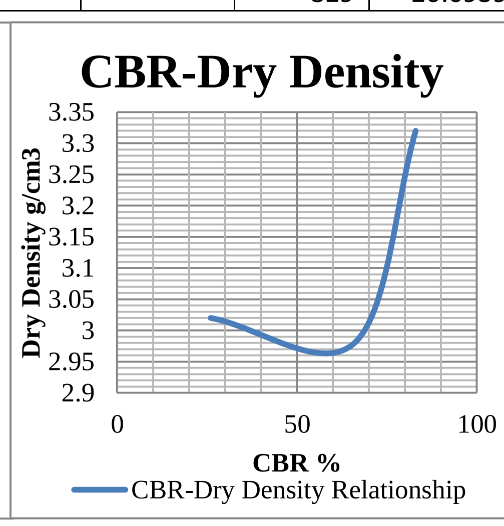
N. CBR Test-Result WORK SH-Sub Base -BH-4

Sub Bsae-BH-4-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	13708.5	14327.5	13615	14836.5	14904.2	14945.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	6762	7381	6582	7804	7942	7983
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	3.14	3.43	3.02	3.58	3.68	3.70

Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	278.2	278.2	255.5	286.9	274.7	278.1
wt of dry sample+con,g	263.4	254.8	236.8	260.22	253.3	250.9
wt of cont,g	35.1	35	34.2	34	35.3	33.11
Weight of water content	14.80	23.40	18.70	26.68	21.40	27.20
weight of dry soil	228.30	219.80	#####	226.22	218.00	217.79
moisture Content	6.48	10.65	9.23	11.79	9.82	12.49
dry density	2.95	3.10	2.76	3.20	3.35	3.29
Average Dry Density	3.02		2.98		3.32	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	33	0.7272			39	0.8732			86	2.017		
1.27	55	1.2625			112	2.6249			174	4.158		
1.96	101	2.3817			149	3.5495			252	6.031		
2.54	**124**	**2.9413**	3	22	**289**	**6.2258**	5	47	330	**7.929**	11	60
3.18	149	3.5495			315	7.5883			389	9.389		
3.81	178	4.2551			388	9.3644			464	11.19		
4.45	209	5.0093			453	10.9458			585	14.16		
5.08	**225**	**5.22956**	4	26	549	**13.2815**	9	66	692	**16.76**	19	83
7.62	289	6.2258			829	20.0939			980	23.74		



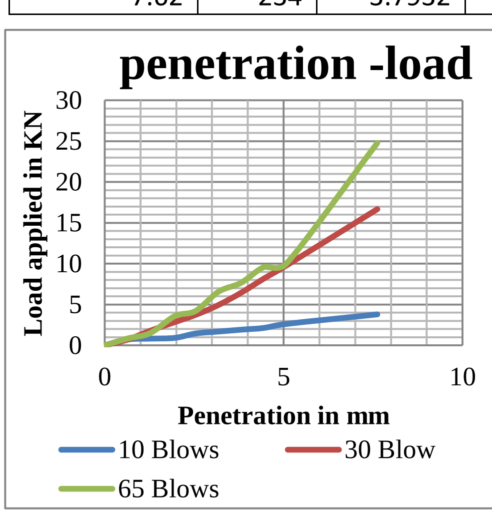


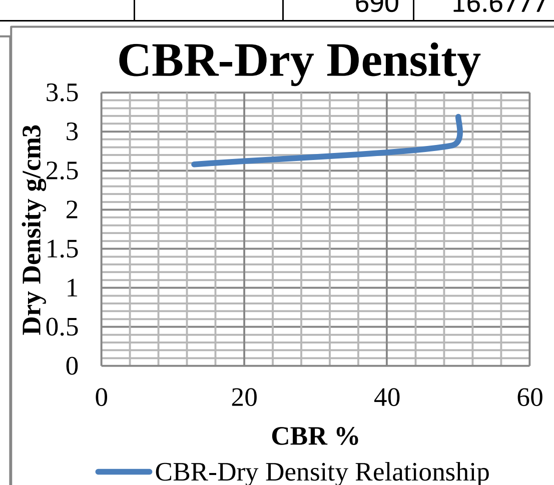
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.33	0.46	0.22
Percent swell	1.142	0.4	0.189
Average percent Swell	**0.575**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	26	66	83
Dry Density	3.02	2.98	3.32

O. CBR Test-Result WORK SH-Sub Base -BH-5

Sub Base-BH-5-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	13060.5	13353.5	13901	14099.5	14663.2	15367.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	6114	6407	6868	7067	7701	8405
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.84	2.97	3.15	3.24	3.57	3.89
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	255.5	280.2	294.5	296.9	240.8	255.4
wt of dry sample+con,g	233.1	250.12	268.6	260.78	215.4	219.88
wt of cont,g	35.3	34.2	34.5	34	35.6	35.2
weight ofwater content	22.40	30.08	25.95	36.12	25.40	35.52
weight of dry soil	197.80	215.92	#####	226.78	179.80	184.68
moisture Content	11.32	13.93	11.09	15.93	14.13	19.23
dry density	2.55	2.61	2.84	2.80	3.12	3.26
Average Dry Density	2.58		2.82		3.19	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	38	0.7245			65	0.7059			80	0.846		
1.27	54	0.82382			156	1.7855			188	1.498		
1.96	90	0.91897			244	2.8509			316	3.588		
2.54	**104**	**1.4546**	1	11.02	**322**	**3.7333**	4	28.3	419	**4.209**	4	31.88
3.18	123	1.6926			371	4.9407			521	6.568		
3.81	156	1.9198			433	6.4349			606	7.658		
4.45	170	2.1362			464	8.179			685	9.59		
5.08	**181**	**2.6283**	3	13.14	529	**9.7849**	10	48.9	786	**10.02**	10	50.12
7.62	234	3.7932			690	16.6777			1022	24.78		



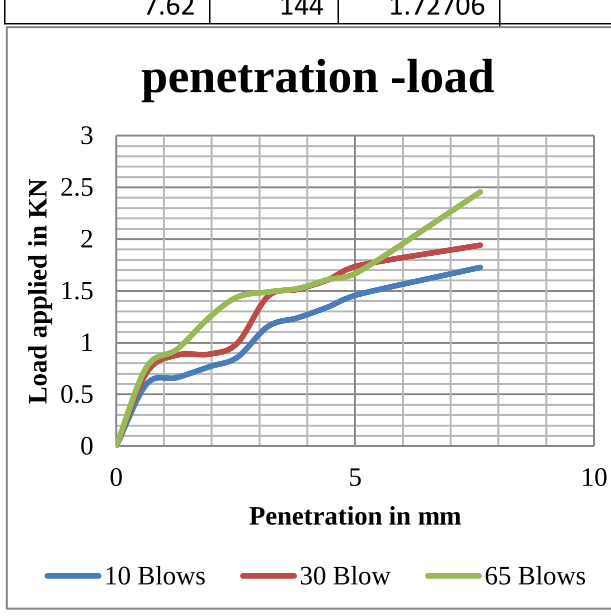


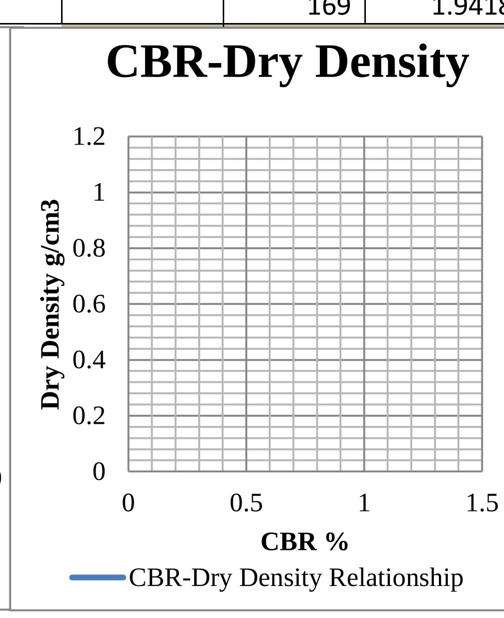
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.66	0.57	0.28
Percent swell	1.426	0.49	0.241
Average percent Swell	**0.719**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	13	49	50
Dry Density	2.58	2.82	3.19

P. CBR Test-Result WORK SH-Sub Grade -BH-1

Sub Grade-BH-1-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	11906.5	12046.5	12213	12502.5	12082.2	12972.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	4960	5100	5180	5470	5120	6010
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.30	2.37	2.38	2.51	2.37	2.78
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	174.2	185.88	176.3	204.2	196	206.78
wt of dry sample+con,g	139.3	138.88	148.5	160.2	163	158.78
wt of cont,g	25.2	25	26.3	25.9	25.7	26
weight of water content	34.90	47.00	27.83	44.00	33.00	48.00
Weight of dry soil	114.10	113.88	#####	134.30	137.30	132.78
Moisture Content	30.59	41.27	22.78	32.76	24.03	36.15
dry density	1.76	1.68	1.94	1.89	1.91	2.04
Average Dry Density	1.72		1.91		1.98	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	58	0.6005			96	0.7123			75	0.766		
1.27	63	0.66247			81	0.87972			92	0.935		
1.96	98	0.7689			100	0.88966			118	1.248		
2.54	**99**	**0.86**	1	6	**117**	**0.9963**	1	7	134	**1.442**	1	10
3.18	105	1.15724			120	1.4484			138	1.49		
3.81	111	1.24182			134	1.51634			148	1.524		
4.45	120	1.3474			149	1.60985			162	1.612		
5.08	**129**	**1.46709**	1	7	161	**1.74523**	2	8	198	**1.686**	2	8
7.62	144	1.72706			169	1.9418			218	2.455		





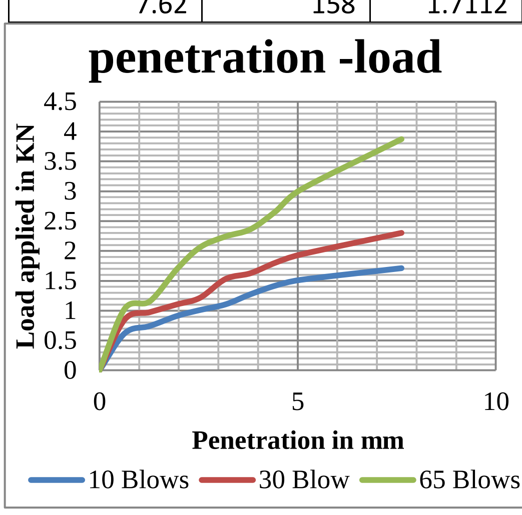
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	2.18	1.01	0.67
Percent swell	1.872	0.87	0.575
Average percent Swell	**1.105**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	7	8	8
Dry Density	1.72	1.91	1.98

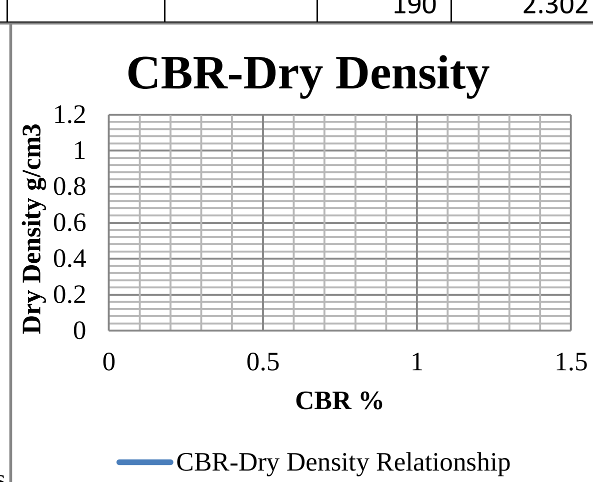
Q. CBR Test-Result WORK SH-Sub Grade -BH-2

Sub Grade-BH-2-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	11776.5	12836.5	12263	13182.5	12262.2	13182.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	4830	5890	5230	6150	5300	6220
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.24	2.73	2.40	2.82	2.45	2.88

Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	198.4	203.4	183.3	224.14	207.8	198.4
wt of dry sample+con,g	174.9	166.5	156.8	184.5	189	166.82
wt of cont,g	25.3	25.1	25.3	25.2	27.3	27
weight water content	23.50	36.90	26.50	39.64	18.80	31.58
wet of dry soil	149.60	141.40	#####	159.30	161.70	139.82
moisture Content	15.71	26.10	20.15	24.88	11.63	22.59
dry density	1.94	2.17	2.00	2.26	2.20	2.35
Average Dry Density	2.05		2.13		2.27	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	68	0.6229			70	0.8545			94	1.036		
1.27	78	0.7434			80	0.9752			104	1.156		
1.96	92	0.9124			90	1.106			149	1.7		
2.54	**100**	**1.0111**	1	7	**100**	**1.2166**	1	9	179	**2.062**	2	15
3.18	108	1.1055			126	1.5304			194	2.243		
3.81	122	1.2745			134	1.627			204	2.363		
4.45	134	1.4214			148	1.806			229	2.665		
5.08	**142**	**1.5161**	2	7	160	**1.9408**	2	9	259	**3.027**	3	15
7.62	158	1.7112			190	2.302			329	3.872		



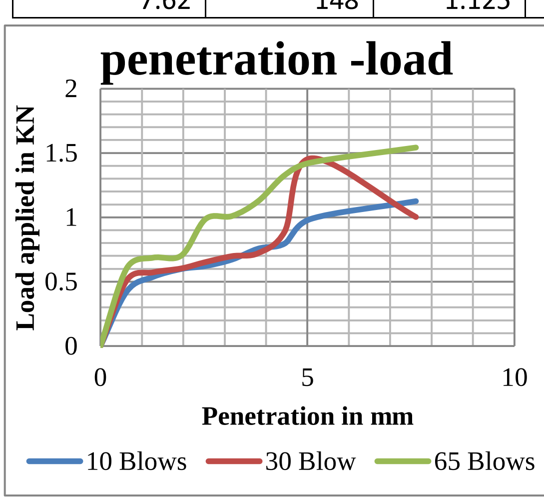


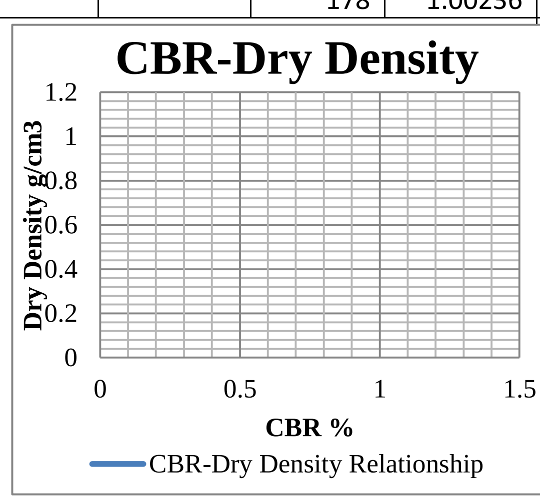
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	2.25	1.42	0.75
Percent swell	1.932	1.22	0.644
Average percent Swell	**1.265**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	7	9	15
Dry Density	2.05	2.15	2.27

R. CBR Test-Result WORK SH-Sub Grade -BH-3

Sub Grade -BH-3-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	10907.5	11048.5	11116	11507.5	11888.2	12060.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	3961	4102	4083	4475	4926	5098
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	1.84	1.90	1.87	2.05	2.28	2.36
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	177.6	143.7	186.3	209.8	206.6	136
wt of dry sample+con,g	144.5	114.55	154.1	166.87	170	111.22
wt of cont,g	25.4	25.6	26.2	25.7	25.5	25.4
weight of water content	33.10	29.15	32.20	42.93	36.60	24.78
weight of dry soil	119.10	88.95	#####	141.17	144.50	85.82
moisture Content	27.79	32.77	25.18	30.41	25.33	28.87
dry density	1.44	1.43	1.50	1.57	1.82	1.83
Average Dry Density	1.44		1.54		1.83	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	59	0.42563			73	0.51234			85	0.606		
1.27	68	0.5369			87	0.57231			97	0.686		
1.96	90	0.59876			110	0.60314			125	0.704		
2.54	**100**	**0.62178**	1	4.7	**122**	**0.65234**	1	4.94	138	**0.987**	1	7.477
3.18	110	0.67216			132	0.698213			147	1.01		
3.81	115	0.75631			140	0.7213			156	1.125		
4.45	125	0.79638			152	0.88923			165	1.327		
5.08	**143**	**0.987**	1	4.935	164	**1.458**	1	7.29	208	**1.425**	1	7.125
7.62	148	1.125			178	1.00236			229	1.542		



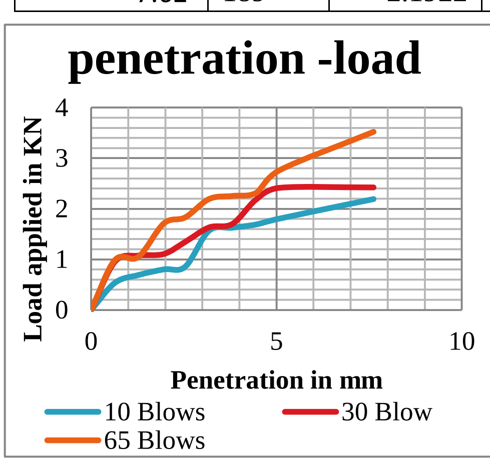


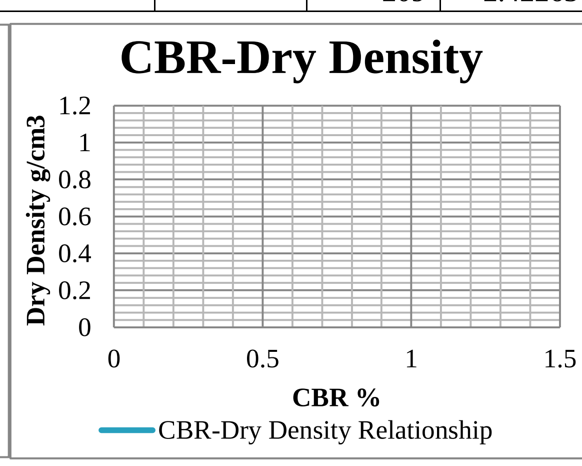
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	2.2	1.13	0.67
Percent swell	1.89	0.97	0.575
Average percent Swell		**1.145**	
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	4.5	4.8	5.3
Dry Density	1.44	1.54	1.83

S. CBR Test-Result WORK SH-Sub Grade -BH-4

Sub Grade-BH-4-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	11647.5	12161.5	11779	12520.5	12786.2	13193.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	4701	5215	4746	5488	5824	6231
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.18	2.42	2.18	2.52	2.70	2.88
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	199.9	245	194.1	228.6	187.9	260.7
wt of dry sample+con,g	167.1	192	162.6	177.7	155	200.2
wt of cont,g	33.5	33.6	34.8	34.3	36.3	34.7
Weight of water content	32.80	53.00	31.50	50.90	32.90	60.50
weight of dry soil	133.60	158.40	#####	143.40	118.70	165.50
moisture Content	24.55	33.46	24.65	35.50	27.72	36.56
dry density	1.75	1.81	1.75	1.86	2.11	2.11
Average Dry Density	1.78		1.80		2.11	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	60	0.5362			80	0.9545			90	0.986		
1.27	88	0.6897			90	1.0753			95	1.047		
1.96	89	0.80236			100	1.106			140	1.711		
2.54	**104**	**0.85693**	1	8	**120**	**1.3473**	1	10	150	**1.831**	2	13
3.18	138	1.5663			136	1.63142			160	2.193		
3.81	142	1.626			150	1.7004			180	2.254		
4.45	150	1.6898			190	2.1833			195	2.314		
5.08	**157**	**1.80605**	2	9	200	**2.414**	2	12	200	**2.761**	3	13
7.62	189	2.1922			209	2.42263			230	3.521		



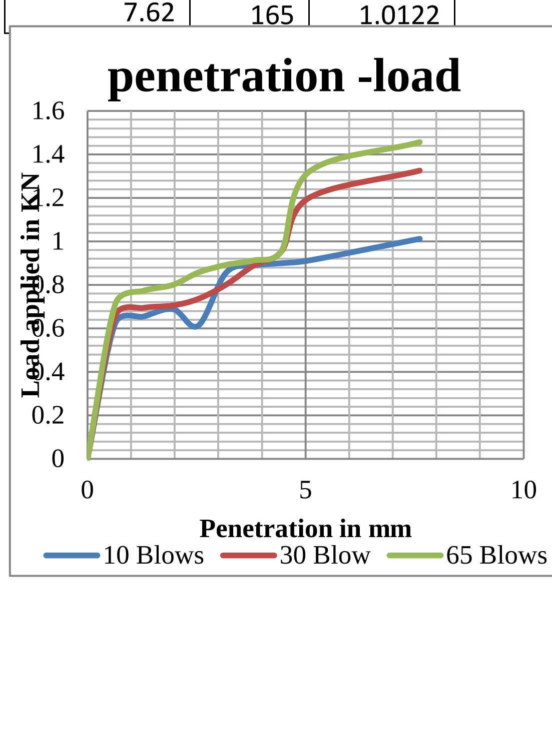


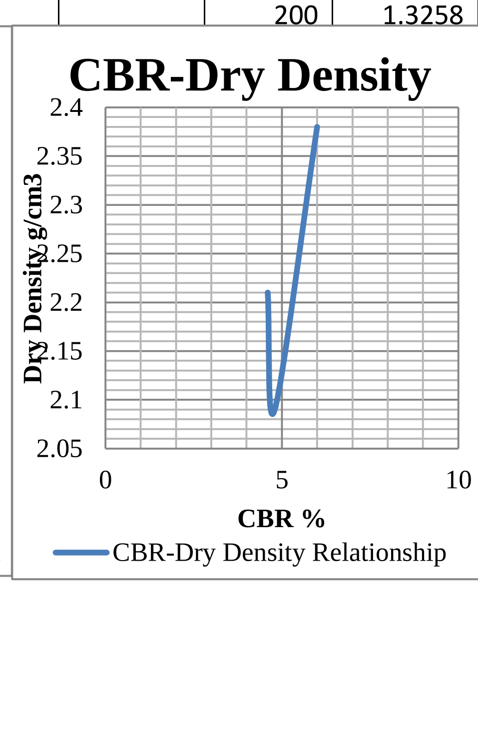
Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.55	1.33	1.06
Percent swell	1.331	1.14	0.91
Average percent Swell		**1.128**	
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	9	12	13
Dry Density	1.78	1.8	2.11

T. CBR Test-Result WORK SH-Sub Grade -BH-5

Sub Grade-BH-5-Density Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
mold number						
wt of wet sample+mould,g	12127.5	13174.5	12274	13292.5	13223.2	13454.2
wt of mold,g	6946.5	6946.5	7033	7032.5	6962.2	6962.2
mass of soil,g	5181	6228	5241	6260	6261	6492
volume of mould,cc	2155	2155	2180	2180	2160	2160
density	2.40	2.89	2.40	2.87	2.90	3.01
Moisture Content Determination						
Soaking Condition	10		30		65	
	before soaking	after soaking	before soaking	after soaking	before soaking	after soaking
Mold number						
wet of wet sample+con ,g	208.3	200.6	193.7	234.78	207.5	195.6
wt of dry sample+con,g	184.3	166.7	167.9	182.55	179.2	156.88
wt of cont,g	25.2	25.4	26	25.5	27.7	27.1
weight of water content	24.00	33.90	25.80	52.23	28.30	38.72
weight of dry soil	159.10	141.30	#####	157.05	151.50	129.78
moisture Content	15.08	23.99	18.18	33.26	18.68	29.84
dry density	2.09	2.33	2.03	2.15	2.44	2.31
Average Dry Density	2.21		2.09		2.38	

Penetration in mm	10 Blows				30 blows				65 blows			
	dial reading	load applied	Corrected Load	CBR				CBR				CBR
0	0	0			0	0			0	0		
0.64	60	0.6242			74	0.6584			78	0.712		
1.27	70	0.65389			80	0.6941			88	0.772		
1.96	84	0.6891			100	0.70563			98	0.8		
2.54	**92**	**0.61233**	1	4.6	**110**	**0.73561**	1	5.6	148	**0.857**	1	6.492
3.18	100	0.85632			130	0.80125			178	0.892		
3.81	120	0.88963			145	0.8893			193	0.913		
4.45	132	0.90012			160	0.95461			198	0.957		
5.08	**140**	**0.91236**	1	4.6	180	**1.2001**	1	6	258	**1.32**	1	6.6
7.62	165	1.0122			200	1.3258			318	1.457		





Swell Data			
Hieght of specimen (mm)=116.43			
No.of blows	10	30	65
RDG (before soaking)	0	0	0
RDG (After soaking)	1.99	1.21	0.55
Percent swell	1.709	1.04	0.472
Average percent Swell	**1.073606459**		
CBR Data			
No. of Layers	5	5	5
Soaked CBR in %	4.6	4.8	6
Dry Density	2.21	2.09	2.38

Appendix-H-Tests Pits Photos

TEST-PIT-BH-1

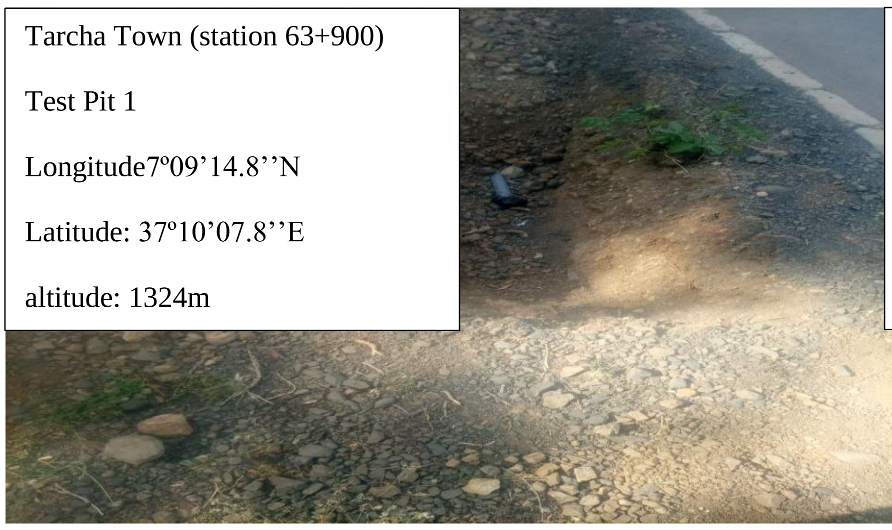
Tarcha Town (station 63+900)

Test Pit 1

Longitude7º09’14.8’’N

Latitude: 37º10’07.8’’E

altitude: 1324m



TEST-PIT-2-BH-2

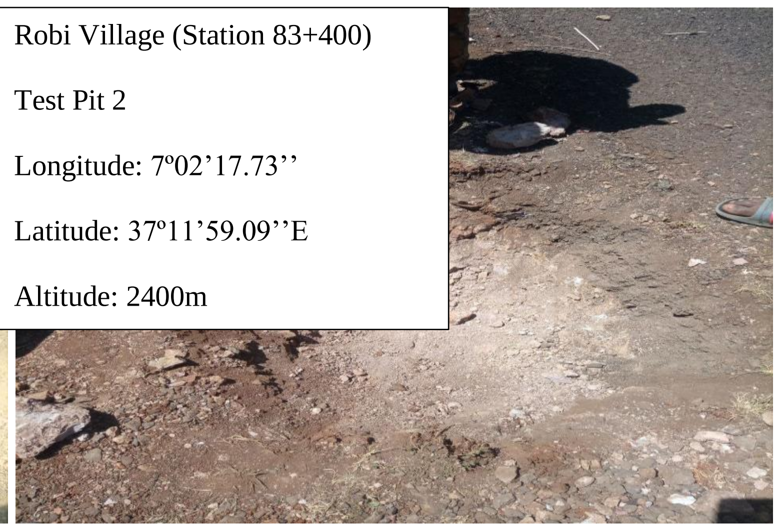
Robi Village (Station 83+400)

Test Pit 2

Longitude: 7º02’17.73’’

Latitude: 37º11’59.09’’E

Altitude: 2400m



TEST-PIT-BH3

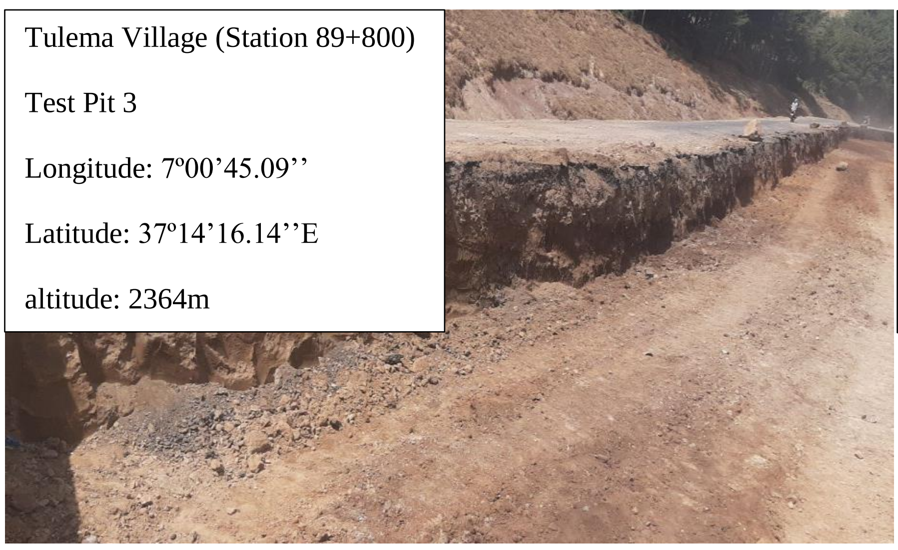
Tulema Village (Station 89+800)

Test Pit 3

Longitude: 7º00’45.09’’

Latitude: 37º14’16.14’’E

altitude: 2364m



TEST-PIT-4-BH-4

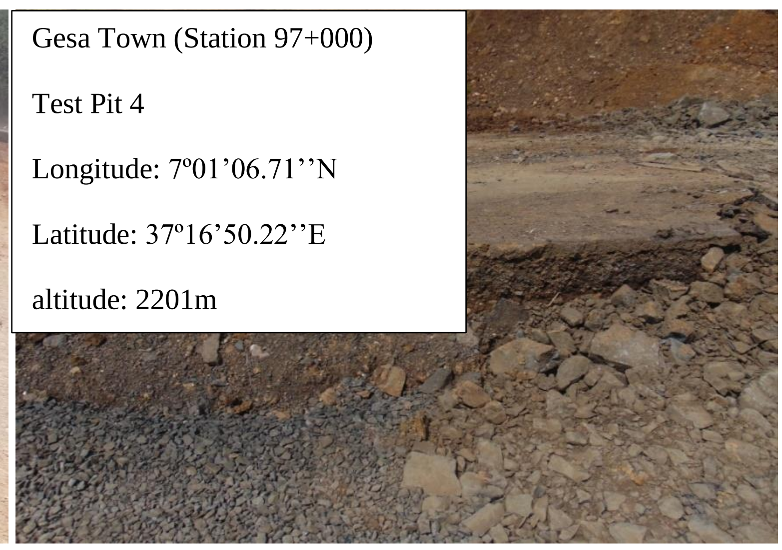
Gesa Town (Station 97+000)

Test Pit 4

Longitude: 7º01’06.71’’N

Latitude: 37º16’50.22’’E

altitude: 2201m



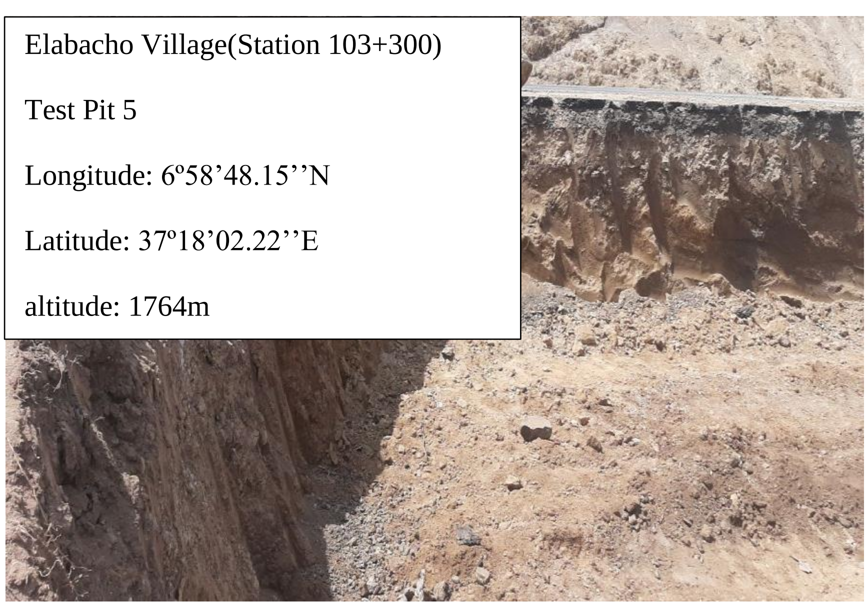
Elabacho Village(Station 103+300)

Test Pit 5

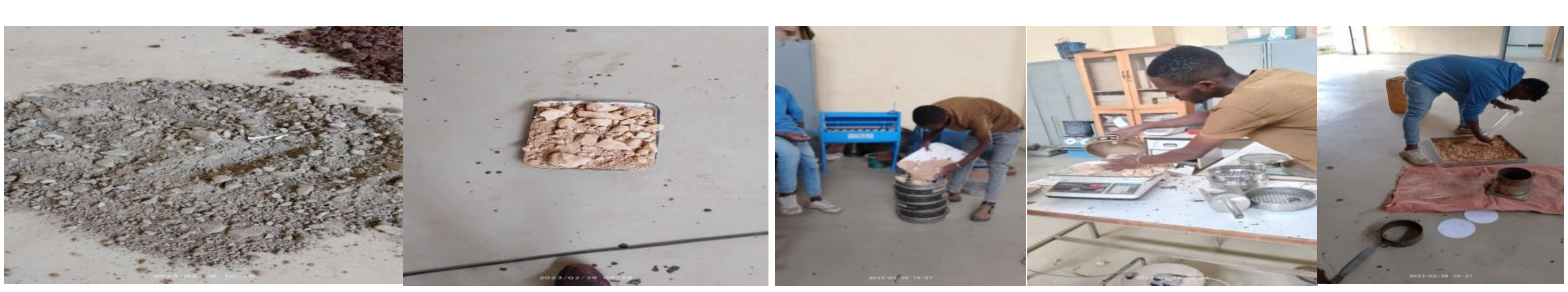
Longitude: 6º58’48.15’’N

Latitude: 37º18’02.22’’E

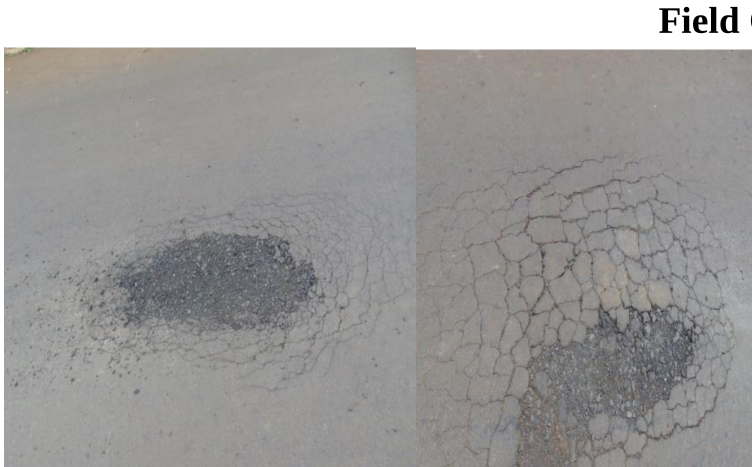
altitude: 1764m



Sampling and Laboratory Tests photos highlights



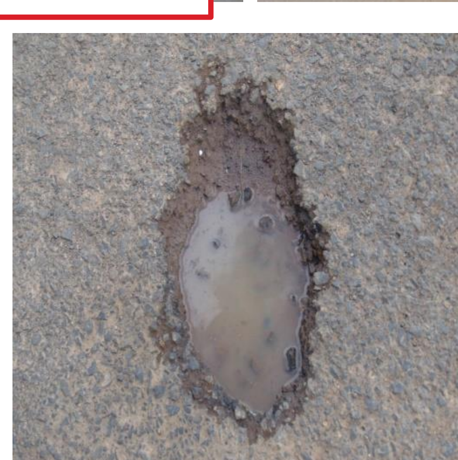
Field Observations Photos



BLOCK CRACKS (98+800-97+000)

CORRUGATION (97+000-103+300)

RUTTING (103+300-111+300)



POTHOLE (81+8000-89+800)

STRIPPING AND RAVELINGING 80+800-89+80)