JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

PERFORMANCE EVALUATION OF GRAVEL ROAD: CASE STUDY ALONG SHAMBU TO AMURU ROAD SEGMENT, HORO GUDURU WOLLEGA

A Research Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering)

By:

Bona Ayele

FEBRUARY, 2018

JIMMA, ETHIOPIA

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Advisor: Prof. Emer T. Quezon

Co-Advisor: Eng. Besha Fayissa, MSc.

FEBRUARY, 2018

JIMMA, ETHIOPIA

DECLARATION

I, the undersigned, declare that this thesis entitled: "**performance evaluation of gravel road, a case study along shambu to Amuru**." is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for these have been duly acknowledged.

Candidate:

Bona Ayele

Signature______________________________

As Master's Research Advisors, we at this moment certify that we have read and evaluated this MSc research prepared under our guidance, by Bona entitled: "**performance evaluation of gravel road, a case study along shambu to Amuru**."We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Prof. Emer T. Quezon	_____________	25/03/2018
Advisor	Signature	Date
Engr. Basha Feyissa	_________	25/03/2018
Co- Advisor	Signature	Date

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ABSTRACT

In Ethiopia Gravel roads are serving majority of the nations in major rural areas for agricultural, commercial and other social mobility purposes. Due to lack of maintenance, movement of traffic, and climatic changes over a period of time, the issues with gravel are numerous and inaccessibility of roads during rainy season, which are possible factors which affect performance of the gravel road .the road along the shambu to Amuru is one of the segment which was severely deteriorated due to the above factors.

The objective of the study was to evaluate the performance of existing gravel road by taking the possible factors which can affect the performance of the road in the study area. Sampling for material laboratory(6 samples for sub grade soil and 6 for surface wearing gravel), for each sample laboratory test was done for CBR test, gradation test; Atterberg's limits test, compaction test, specific gravity and hydrometer test. The field measurement of side drainage factor, and distress type along the study road were divided in sections. From the collected data were processed and analyzed on excel spreadsheet. The analyzed data generates the indication of the performance of the road.

The results of sub grade soils were Clay and silty clay with low CBR and under S3 class and the surfacing gravel was on lower boundary condition as per ERA. This leads easily deteriorates under normal traffic. The rating of distress by type, degree and extent were determined to know the performance of the road. Erosion, rutting and potholes were the types of distress observed with high degree and extent at different section which reduces the general performance of the road. The approach recommended in this research advocates first understanding the materials, which requires inexpensive testing and simple interpretation of the test results, and then Considering the material properties, traffic, and climate; Selecting an optional maintenance strategy for distress types or decision to improve the performance this road. Thus the study recommend to immediate actions to be taken to this road to perform its function.

Keywords: Factors affecting gravel roads, Gravel road, Material tests for gravel road, Performance of a gravel road.

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ABBRREVATIONS AND ACRONYMS

AASHTO	American Association of State of Highway andTransportation Officials
AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
ASTM	American Society for Testing Materials
CBR	California Bearing Ratio
DF	Drainage Factor
ERA	Ethiopian Roads Authority
FHWA	Federal Highway Administration
frqncy	Frequency
LL	Liquid Limit
LTVR	Low Traffic Volume Roads
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PCI	Pavement Condition Index
PI	Plastic Index
PL	Plastic Limit
SG	Sub grade soil

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Pavement performance is a function of its relative ability to serve traffic over a period of time. Originally, pavements relative ability to serve traffic was determined quite subjectively by visual inspection and experience. Typically, a system of objective measurements is used to quantify pavement’s condition and performance. These systems are used to aid in making the following types of decisions [1]

Gravel roads are a critical and substantial part of most of the entire rural road networks in both the developed and developing countries. The majority of road networks, whether part of a municipal or national network, are made up of low volume gravel roads. For example, in some developed countries, up to 60 per cent of the network can be unsealed. The percentage is usually higher in developing and emerging economies. The maintenance of unsealed roads is an essential function, particularly where these roads form the backbone of the local land transportation system. As unsealed roads are typically maintained locally, the use of materials and technologies can vary widely [2].There were 1,370,000 miles of unpaved road in the U.S. This number makes up 35% of the total road mileage of 3,981,000 shows historic mileage data of both paved and unpaved roads [3].

From the total road network in the country which was 56,100 km of both gravel and asphalt road asset, federal road authority (ERA) had 24,550 km and the regional road authorities had 31,550km. Considering gravel roads network that was managed by both authorities, it was 82% of the country’s road network [4].

After implementation of the program in 2015G.C, the total classified road network of the country is expected to reach 136,044 km from the existing 48,793 km in 2010G.C. The proportion of area further than 5 km from an all-weather road will have been reduced to 29% from 64.2 % (2010G.C). Allvillages will be connected by all-weather roads and the proportion of rural population within 2 km from an all-weather road will increase from the current 27% to 67% [5].

In the context of Ethiopia’s geography, pattern of settlement and economic activity, transport plays a vital role in facilitating economic development. In particular, it is road transport that provides the means for the movement of people, utilization of land and natural resources, improved agricultural production and marketing, access to social services, and opportunities for sustainable growth. Low volume roads in ethiopia typicallycarry less than 300 vehicles per day and provide important links from homes, villages and farms to markets and offer the public access to health,education and other essesntial services.these roads also provide impportant links between wereda centers and the federal road nnetwork[6].

Studying the performance of these gravel pavement structure under traffic, climatic condition which they undergo after construction is essential. Even though the cause for the deterioration of this low volume road is too many, studying the material loss on the environmental and structural strength of the material with the traffic influence causes is desirable.

- The Principal Concerns that should be care for gravel roads are:
- Natural gravel usually occurs in limited natural deposits of variable quality.
- Gravel materials are often difficult to meet standard grading and plasticity specifications.
- Gravel surfaces waste; typically 10-50mm/year/100MVPD). It is essential to have a sustained maintenance programme and regular re-gravelling to replace gravel loss.
- Traffic, climatic and longitudinal gradient (<6%) constraints on use relating to rate of gravel loss, High maintenance costs; regular surface reshaping & re-gravelling.
- Unlikely to be practical to maintain economically in high rainfall areas (>2,000mm/year).
- Possible dust pollution in dry weather.
- Health & Environmental concerns.
- Not suitable for soaked or overtopping/flooding situations.
- Quality Assurance; particularly regarding testing, quality compliance and thickness control [7].

Gravel roads are heavily affected by their environment. Road environment can be classified in to two. Man–made environment includes traffic, historical events, political decision, and economics and natural environment includes; topography, climate, and geology. Topography to which the gravel road constructed on, can be related to alignment of the roads, drainage and gravel loss.

The effects of topography on gravel roads alignment therefore are higher. Topography also affects the drainage capability of the roads. If the roads have flat terrain water may be accumulated on the road and facilitate the deterioration of the road. If the roads have mountainous terrain, since it increases the flow of water, the consequence become erosion and gravel loss of the surfacing material. Traffic in terms of composition, volume and axle load, should be considered to identify the defects on gravel roads. Traffic, climate, quality of surfacing material and geometric design of the roads etc., are the major variables that should be considered to investigate the kind of deterioration on gravel roads [8].

The study area is located along the road from Shambu town to Amuru town, Horro Guduru Wollega zone, a part of Oromia region, located in the western part of Ethiopia. The total length of the road segment was 68km. The road connects three woredas; Horro woreda-Jardega Jarte woreda-Amuru woreda, which were selected for the study of performance evaluation of existing gravel road. The road is under the jurisdiction and mandated by Ethiopian Road Authority. The Climatic condition of the case study site fall under Wiena Dega to Dega, and it is summarized in table below.

Table 1.1: Annual rainfall, temperature and altitude of the study area.

Name of Districts	Average annual Rainfall data in (mm)			Temperature (^{o}C)		Altitude (m)	
	Min.	Mid.	Max.	Min.	Max.	Min.	Max.
Amuru	1200	1350	1500	18	25	1100	2500
J/ Jarte	1200	1700	2000	20	26	1600	2380
Horro	1200	1516	1788	18	27	1450	2844

Source: [9]

Based on the statistics, the traffic is increasing rapidly from year to year as the report Annual Average daily traffic by road section shows from 188AADT in 2011, 198AADT in 2012,221 AADT in 2013,269 AADT in 2014 and 487AADT in 2015 [10].

1.2. Statement of the Problem

Road transport facilities play a vital role in both the production and consumption decisions of every household in their day-to-day a-activities. Likewise, roads serve as key infrastructural units, which provide linkages to other modes of transportation like railways, shipping, and airways [11].

The community of the study area is predominantly agricultural based, even though the rural road has high importance for agricultural and industry, there are many challenges regarding the performance due to the fact these roads are unpaved and other related factors. The society's economic growth and changes from time to time and there is high need for mobility of goods and passengers which leads to high transportation demand. Due to the movement of traffic and climatic changes over a period of time, the issues with gravel are numerous like dust generation, gravel loss, safety hazard, health hazard, discomfort and nuisance, air pollution, and inaccessibility of roads during rainy season. This leads to the increased maintenance cost in terms of re-graveling [53].

The road failures along shambu to Amuru section call the attention for concerns to users of the road because several hours are spent before getting to their destinations, while affecting the businesses of society along this segment. In addition, spending long time, the travelling public tends to pay additional cost on each journey day to day. This can negatively affect the socio-economic activities especially in districts of Horro, Jardega Jarte, and Amuru which mainly serves of this road link. Hence, this study tried to evaluate the material properties of the road including the causes of road failures or distresses in order to know its performance level.

1.3. Research questions

The research questions are based on the realistic situation on gravel road performance in Horo-Guduru-Wollega, and Shambu-Amuru segment. The research is sought to answer the following specific questions besides many other relevant issues to be addressed to help evaluating the performance level of the gravel road. These questions are:

1. What are the engineering properties of materials affecting the performance of gravel road?
2. What are the distresses types reducing the performance of gravel road in the study area?

3. Which parameters of the road side drainage affect the performance of the road?
4. What are the possible remedial measures to be taken to overcome the problems reducing the performance of gravel roads in the study area?

1.4. Research Objectives

1.4.1. General objective

The general objective of this study was to evaluate the performance of gravel road at Horo-Guduru Wollega, Shambu to Amuru segment.

1.4.2. Specific objectives

The specific objectives of the research are:

1. To determine the engineering properties of gravels affecting the performance gravel road and comparing with standard specifications.

2. To analyze the attributes of distress along the study segment in relation with the properties of sub grade and surfacing materials on the performance of gravel road in the study area.

3. To rank the adequacy of drainage provision by using drainage factor of the pavement.

4. To recommend the possible remedial measures on performance of gravel road.

1.5. Significance of the Study

The study evaluates the performance of gravel road in Horro Guduru Wallaga zone which provide helpful information for road governing agencies and for contractors. The study prediction can be used for many purposes. It can help road agencies in:-, in determining maintenance and rehabilitation requirement, inquality material requirements as per specifications and for properly provision of adequate gravelling and gravel materials characteristics and specification.

On the other hand, studying the factors that affect the performance of existing gravel road helps in revising the design practices as per local condition is an important and economic activity for provision of continue access of road usage. It is also believed to encourage the road and transportation authorities to have to consider to the situations along the study in upgrading of the road to asphalt concrete.

1.6. Scope and limitation of the Study

The study is mainly aimed to determine to evaluation of gravel road performance in Horo Guduru Wollega, on the road from Shambu town to Amuru town. The study was limited on the gravel materials property that can affect the performance of gravel road and only the most critical factors that affect the gravel road was included. This means the research was consider and focus on limited on the basis of the sampled subgrade soil and subbase materials used as the wearing course of gravel surface of the road, measured deteriorated result along the segment and use it as performance rating assessment to evaluate how the road is performing. The data was recorded, from six places for sub grade and surface wearing material laboratory, investigated and analyzed with standard specifications. The adequacy of side drainage and attributes of distress along the study at the time of data collection was analyzed. The study did not include Gravel loss calculation, the effect heavy vehicles on gravel roads, effect of maintenance practices and regravelling frequency depending on the AADT and material quality, so it was recommended for further researches.

However, due to the number of variables contributing to the performance of gravel roads, each road organization has to record the characteristics of the distress on the gravel roads in their locality. This is due to the fact that variables behind distress formulation are not readily transferable from one geographical location to the other. This is the case, particularly if the locations in question differ in climatic condition, gravel material characteristics, quality of construction and maintenance, terrain, traffic characteristics and driver behaviors.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1. General and Definition

2.1.1. General

Performance is a term used in everyday life, in engineering and particularly for roads; performance should be a measurable entity. This is in fact essential for assessing the current and future state of road infrastructure, as well as agency (institutional efficiency in service and safety provision to users, productivity, cost-effectiveness, environmental protection, preservation of investment and other functions. Due to the movement of traffic and climatic changes over a period of time, the issues with gravel are numerous like dust generation, gravel loss, safety hazard, health hazard, discomfort and nuisance, air pollution, and inaccessibility of roads during rainy season. This leads to increased maintenance cost in terms of re-gravelling. Maintenance of gravel roads is expensive, especially periodic re-gravelling. In order to eliminate these effects and to improve the performance of the gravel roads, the best alternate is to identify the factors that affect the performance of gravel roads and recommend remedial measures to overcome the problems [12].

2.1.2. Definition

The term gravel road is generally used to refer to all unpaved roadways. A true gravel road is a roadway whose surface layer is constructed of mineral aggregate materials (such as sand, gravel, pebbles or crushed stone) that are generally obtained from gravel pits and quarries [13].In line to the above definition, unsealed roads as a road that has no permanent surface proofing of water in contrast of sealed road [14].

Gravel roads are built and designed to certain engineering principles, including the supply, where warranted, of gravel wearing surface. Construction of these roads also involves a defined cross section, drainage and structures (bridges, culverts). Good gravel road is constructed of three different layers. The subgrade or roadbed is the bottom layer made up of the native material (clay, silt or sand) found along the roadway alignment or fill to level a depression. The aggregate base is placed on top of the subgrade and is ideally 45cm to 60cm depth. It should be constructed from free draining and easily compactable aggregate material (gravel or crushed stone) that produces a strong and stable layer. Finally, the surface layer (uniformly graded gravel or crushed stone) is placed on top of the aggregate base and it is at least 20cm in depth. Gravel roads can also be known as unpaved roads. Great care should be taken in using gravel as a road surface in some circumstances. It is unlikely that it will be suitable due to high costs of replacing the surface material that will be lost due to rainfall or traffic, or dust nuisance in the locations[15]; where

- Traffic is more than 200 motor vehicles per day
- Annual Rainfall is greater than 2,000mm
- Longitudinal slope of road surface is more than 6%
- Through community settlements
- The haul distance from the quarry/pit to the road site is more than 10km
- The road section experiences flooding
- The gravel is of poor quality.

2.2. Engineering characteristics of highway materials

The selection of pavement materials is a critical element in the design, construction and maintenance of pavements if performance is to be optimized. Construction materials have their own characteristics suited to a specific design and construction use. There are three basic types of soil materials used for building camp roads: gravel, sand, and fines (listed in order from largest to smallest particle size). Gravel and sand particles, coarse material, are readily distinguishable to the naked eye.

Fines (silts and clays) are generally comprised of particles too small for the eye to see. Each soil material has specific properties that make it useful for different aspects of road building. Coarse material provides strength and has large voids between the particles that provide good drainage. Fines fill the voids between the coarse material particles holding them together, and on the road surface, decrease infiltration of water into the road. When selecting road bed material, it is important to have a range of different size gravel and sand so that the particles "lock" together.

This is called well-graded. If they are all the same size, they are more apt to move around, causing rutting. This is called poorly graded [16].

The performance of the gravel surface mainly depends on material quality, the location of the road, and the volume of traffic using the road. Gravel roads passing through populated areas in particular require materials that do not generate excessive dust in dry weather. Steep gradients place particular demands on gravel wearing course materials, which must not become slippery in wet weather or erode easily. Consideration should therefore be given to the type of gravel wearing course material to be used in particular locations such as towns or steep sections. Performance characteristics that will assist in identifying suitable material are shown in figure below.

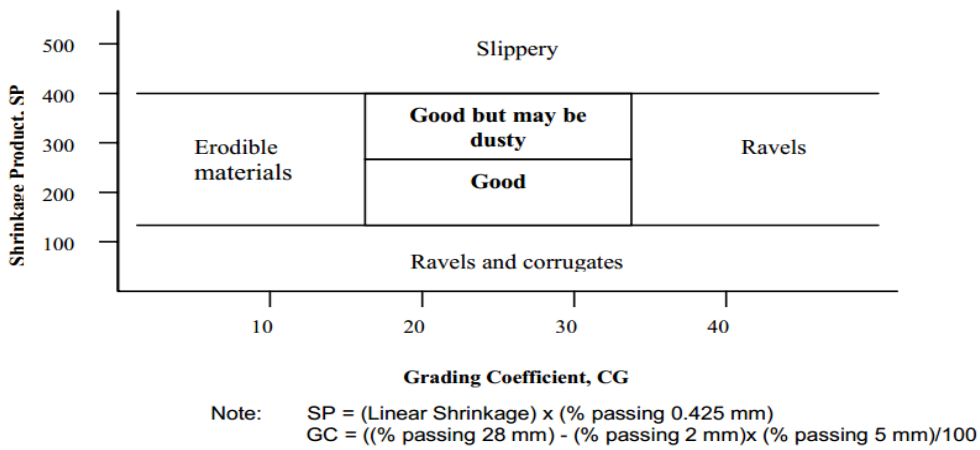


Figure 2.1: Expected Performance of Gravel Wearing Course Materials

Source: ERA [17].

2.2.1 Material Requirements for Gravel Wearing Course

The wearing course material should be durable and of consistent quality to ensure it wears evenly. The desirable characteristics of such a material are: - Good skid resistance, Smooth riding characteristics, cohesive properties, Resistance to raveling and scouring, Wet and dry stability, Low permeability, Load spreading ability. The structural failure of a pavement is associated with the strength characteristics of the constituent materials and the thickness of each layer. Major failure types are surface rutting and crack formation either at the top surface or bottom layers. The required thickness of each layer of the flexible pavement varies widely depending on the materials used, magnitude and number of traffic repetitions, environmental conditions, and the desired service life of the pavement. The primary function of surface course is to provide a safe, smooth, stable riding carriageway for traffic and to contribute to the structural stability of the pavement and protect it from the natural elements perform well with in the design period of the pavement[18].

Surface gravel should meet a specification for its purpose which is to carry traffic and remain reasonably stable in wet or dry conditions. Many States do not have surface gravel (aggregate) specifications. The agency needs to work with suppliers to get suitable material for surfacing. It must be acknowledged that gravel surfaces will never perform like pavements. Some loose aggregate, rutting and some corrugation may form in the best gravel when exposed to heavy traffic and prolonged wet or dry conditions. Use the best material that can be obtained to improve gravel road performance [19].

good base material needs a good percentage of larger stone for strength to carry the loads on the pavement above it. And the some needs a good percentage of fracture to help get aggregate interlock. the overall gradation is important also needs to be a good blend of sand sized particles and some fines along with the stone to get good density.but a highly plastic base material is never good. this will cause the base to hold moisture and it will loose its strength, especially during the spring thaw season.”Heaving” problems will become much worse as well.but the biggest problem will be early failure of the pavement surface because of weak base.good base needs to drain well. In general different uses require different types of material and only by testing ca you realy determine if it’s suitable for specific purpose. Testing prior to use solves many problems that can show up later even on common gravel road. And it pays to increase your knowledge of materials and testing[20].

Low-volume road surfaces and structural sections are typically built from native materials that must support light vehicles and may have to support heavy commercial truck traffic. In addition, low-volume roads should have a surface that, when wet, will not rut and will provide adequate traction for vehicles [21].Roadway materials, and particularly roadway surfacing materials, such as aggregate or paving, can be half the cost of a road. Selection of materials directly affects the function, structural support, rider comfort, environmental impact and safety of the road user.

Gravel surfacing material should contain the appropriate blend of material. Coarse aggregate, sand and fine aggregate parts of the surfacing material should be to their intended mix. The proper blend of different size aggregate on the road produces a surface that can be used in all types of weather [22] from the perspective of gravel surfacing material; the material should satisfy some important criteria. The surfacing material should have sufficient cohesion to prevent raveling and corrugating (especially in dry conditions) and the amount of fines (particularly plastic fines) should be limited to avoid a slippery surface under wet conditions [23].

2.2.2. Material Requirements for specifying Sub grade class

Pavement performance is a function of volume stability, which depends on the properties of subgrades and other related variables. It is therefore, obvious that pavement design should be rationally and scientifically related to all the variables that may be expected in the design under service condition from economic point of view [24].

Subgrades are classified on the bases of the laboratory soaked CBR tests on samples compacted at 97% AASHTO T180 compaction. Samples are soaked for four days or until zero swell is recorded. For the design of earth and gravel roads if no suitable laboratory is available. The sub grade strength for design is assigned to one of six strength classes reflecting the sensitivity of thickness design to sub grade strength. The classes are defined in table below**.** The CBR results obtained from the sub grade soils testing are used to determine which subgrade class should be specified for design purposes in accordance with traffic classes. [25]

Table 2.1: The CBR and ranges of sub grade classes

	Sub grade class				
Design CBR	S2	S3	S4	S5	S6
Range %	3-4	5-8	9-14	15-29	30+

Source: [25].

2.3. Laboratory Tests

2.3.1. Grain size distribution analysis

A particle size distribution analysis is a necessary classification test for soils, especially coarse soils, in that it presents the relative portions of different sizes of particles. From this it is possible to determine whether the soil consists of predominantly gravel, sand, silt, or clay sizes and, to a limited extent, which of these size ranges is likely to control the engineering properties of the soil [26].

The grain size distribution is found by mechanical analysis. The components of soils which are coarse grained were analyzed by sieve analysis and the soil fines by sedimentation analysis. The grain size analysis or the mechanical analysis is hence carried out to determine the percentage of individual grain size present in a soil sample. This test is aim at the determination of the size of the particles of the soil consists. The test result is illustrated by the grain size distribution curve. In case of the particles with size larger than 75 μm (retained on sieve no. 200), the particle sizes are determined by “Sieve Analyses”. While for the particles of the sizes smaller than 75 μm (passed through sieve no.200), the particle sizes are determined by “Hydrometer Analyses”.

Depending on what the material is to be used for, the ideal blend of stone, sand and fine material varies. For example, good surface material for a gravel road would need more material passing a #200 sieve (true fines) than a good base material. There is also a difference in the need for a plastic or binding characteristic in the fine material. Surface gravel needs some natural clay which gives a “binding characteristic.” The adjacent chart is an example of one State’s base and gravel surfacing specifications. The characteristics of the material and uniform quality will have a major impact on the performance of the roadway surface.

Notice the major differences in the specification in the top-sized material and the smallest sized material. The base course requires 100 percent of the material to pass a 1-inch sieve, but allows up to 20 percent of the stone to be retained on the 3/4 inch sieve.

While this could make excellent base gravel, it will likely perform poorly if used as gravel surfacing. There would be too much large stone resulting in very difficult blade maintenance.

Also, the high percentage of coarse material would make a rough driving surface. A higher percentage of large stone is needed for strength in the base course, but will be detrimental to surface gravel. Good surface gravel that goes into a tightly bound state will provide a good driving surface. The grading of the gravel after placing and compaction shall be a smooth continuous curve within and approximately parallel to the envelopes or the grading limits in table2.2 below. When determined in accordance with the requirements of AASHTO T-27.

Table 2.2: Grading Requirements for Gravel Wearing Course and Gravel Shoulder

Test sieve size(mm)	Percent (%) by mass of total aggregate passing test sieve					
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
50	_	_	_	100	_	_
37.5	100	_	100	85_100	_	_
28	_	100	95_100	_	_	_
20	80_100	95_100	85_100	60_80	100	100
14	_	80_100	65_100	_	_	_
10	55_100	65_100	55_100	45_65	80_100	100
5	40_60	45_85	35_95	30_50	60_85	80_100
2.36	30_50	_	_	20_40	45_70	50_80
2	_	30_65	22_65	_	_	_
1	_	25_55	18_60	_	_	_
0.425	15_30	18_45	15_50	10_25	25_45	25_45
0.075	5_15	12_32	10_40	5_15	10_25	10_25

Source: ERA standard technical specification [27]

2.3.2. Specific gravity Test

The specific gravity of soils is required for the determination of voids ratio, degree of saturation which is a very important for compaction point of view. This lab is performed to determine the specific gravity of soil by using a pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature as method of ASTM D854-00 [28].

2.3.3. Plasticity Index

The Atterberg limit is most frequently used as a measure of control and includes liquid limit (LL), plastic limit (PL), plasticity index (PI), and linear shrinkage (LS). LL and PL are determined in accordance with AASHTO T-89 and T-90, respectively, and are performed on the fraction finer than the No. 40 (0.425 mm) sieve. Liquid limit represents the moisture content, in percent, at which the transition from the liquid to the plastic state of the material is reached, whereas the plastic limit represents the moisture content at which the transition from plastic to a semi-solid state is reached. The moisture content at which the transition from a semi-solid to solid state takes place is defined as the shrinkage limit. PI is simply the difference between LL and PL.

The difference in the fine material and the plasticity index (PI) sometimes referred to as Atterberg Limits. While gravel surfacing allows as little as 4 percent and up to 15 percent (and sometimes modified to 8 to 15 percent) of the material to pass a #200 sieve, base course can have as little as 3 percent, but not more than 12 percent passing the same sieve. More importantly, the PI can be no less than 4 or as high as 12 in surface gravel. The same index can fall to 0 in base course and rise to no more than 6. There is good reason for this. Good surface gravel needs a percentage of plastic material, usually natural clays, which will give the gravel a “binding” characteristic and hence a smooth driving surface. This is critical during dry weather.

During wet weather, the surface may rut a bit, but will quickly dry and harden in sunny and windy weather. The same material used as base would lose its strength and stability if it became wet and cause rutting or even failure of the pavement. Too often the same gravel is used for both base works. And surface gravel. Generally, it will be good for one purpose or the other, but will not work for both applications.

The classification systems for gravels used in road construction are generally depends on some measure of grading, maximum particle size, plasticity and bearing capacity [29] AASHTO M 145, Classification of Soil-Aggregate Mixtures for Highway Construction Purposes, divides soils into the two major groups, namely granular and silt-clay materials. The granular materials are those soils with 35% or less passing the 0.075 mm (No. 200) sieve. ASTM D 2487, divides soils into three major groups of coarse-grained soils (sands and gravels), fine-grained soils (silts and clays), and highly organic soils (peat and other highly organic soils).

2.3.4. Compaction of sub grade soil and gravel surface wearing material

The process of compaction, a form of mechanical stabilization resulting in densification of the material, is key to ensure the best possible performance of a soil or gravel material. Compaction of soils and gravels is measured relative to the MDD (maximum dry density) determined in the laboratory. The intention should always be to aim for the highest practical densification achieved with an effort commensurate with the type of equipment being used and the intended usage of the road [30].

Good compaction produces tightly bound gravel with optimum particle interlock, minimum permeability and porosity and significantly increased strength. A poor degree of compaction results in a low density, permeable material which ravels easily and is highly moisture sensitive. Deep rutting, compaction under traffic, potholing, corrugations and passability problems under soaked conditions are common problems with poorly compacted material. The initial traffic-induced compaction and increased gravel loss again interfere with the maintenance management strategy for the road [31].

2.3.5. California bearing ratio

California bearing capacity (CBR) is one of the most widely used tests for evaluating the strength of sub grade, sub base and base course support value that is the bearing capacity of the pavement. The strength of the subgrade is assessed in terms of CBR. The CBR depends on the nature of the soil, its density and its moisture content. Based on ERA manual, for the sub-base material the minimum soaked California Bearing Ratio (CBR) shall be 30% when determined in accordance with the requirements of AASHTO T-193. The California Bearing Ratio (CBR) shall be determined at a density of 95% of the maximum dry density when determined in accordance with the requirements of AASHTO T-180 method D [32].

Design of the various pavement layers is very much dependent on the strength of the sub grade soil over which they are going to be laid for the thickness of the gravel wearing course. The CBR is deterministic strength factor for the sub grade and the top wearing sub base material. Sub grade strength is mostly expressed in terms of CBR (California Bearing Ratio).

Weaker sub grade essentially requires thicker layers whereas stronger sub grade goes well with thinner pavement layers. The pavement of the gravel bearing capacity and the sub grade bearing capacity mutually must sustain the traffic volume. A minimum CBR of 30 per cent is required at the highest anticipated moisture content when compacted to the specified field density, usually a minimum of 95 per cent of the maximum dry density achieved in the ASTM Test Method D 1557 (Heavy Compaction) for gravel surface wearing course material used according to ERA 2002 manual. In these circumstances, the bearing capacity should be determined on samples soaked in water for a period of four days.

The California bearing ratio, abbreviated as CBR is defined as the ratio of the test load to the standard load, expressed as percentage for a given penetration of the plunger.

CBR = (Test load/Standard load) ×100.

In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the design CBR. In some case, the ratio at 5.08 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5.08 mm should be used.

2.4. Field evaluation of the performance of unpaved roads

The visual evaluation and field measurement is one of the most important aspects of the pavement evaluation process. This usually involves a comprehensive survey of the road while a variety of parameters is visually evaluated in detail. Visual evaluation generally requires a rating of degree and extent of the various distress parameters by an experienced person or preferably a team of two or more. It is essential that all raters use a standard rating system. The raters must also be calibrated against each other periodically for consistency [33]. The verbal descriptions illustrated with photographs that let the evaluator rate a road describing its overall quality. They also describe various distresses, as well as other factors to consider when rating a road, such as the appropriate maintenance activity for the rated road. [34]

2.5 Attributes of gravel road surface distress

The appearance of gravel road distress is varied and often extremely complex. the task of describing this distress was achieved by recording its main characteristics which is called attributes of distress. The attributes referred to are: a) type b) degree c) extent. These attributes are described as follows:

2.5.1 Type of distress

Common type of distress encountered on gravel roads under study are: gravel loss, potholes, rutting, erosion, corrugation, loose materials, stoniness, and dust. These were assessed together with material properties, road profiles, riding quality, and drainage. The following is a brief description of each type of distress assessed with the emphasis of its contribution to gravel loss.

1. Potholes: are bowl shaped distresses. Once potholes formation has been initiated (irrespective of the cause) drainage deteriorates and water ponds in the depressions. Enlargements of potholes by traffic occur through compaction and remolding of the weakened material (in the wet state) and removal of the material from the hole by vehicle wheels and splashing. Materials with a low soaked strength are thus likely to develop larger and deeper potholes in shorter periods and accelerate gravel loss [35].

Table 2.3: Degree of potholing

Degree	Description
1	depressions just visible, cannot be felt in the vehicle
2	<20mm deep
3	larger potholes affecting safety 20mm-50mm deep
4	50mm-75mm deep
5	larger ,dangerous potholes requiring evasive action>75mm deep

Source: [35]

2. Rutting: these generally form as a result of gravel loss from the wearing course by traffic abrasion and by deformation of sub grade compaction of the wearing course [35]. Ruts are assessed in terms of their capacity their capacity to retain water using a visual estimate of their average depth. The higher the severity degree of rutting is, the higher the effects of directional instability of a vehicle.

Table 2.4: Degree of rutting

Degree	Description
1	rutting is just visible
2	<20mm deep
3	rutting between 20mm-40mm deep
4	40mm-60mm deep
5	rutting>60mm deep affecting directional stability of a vehicle

Source: [35]

3. Erosion: is the loss of gravel wearing course caused by the flow of water over the gravel road. The ability of a gravel material to resist erosion depends on its shear strength under the conditions in which the water flow occurs. Much of eroded gravel is deposited in the drains and culverts. Erosion of the wearing course also results in a change in the properties of the material as various fractions of the material are selectively removed[35].Earth and gravel surfaces usually suffer from excessive erosion with longitudinal gradients of more than 6% in modest rainfall locations. In areas with rainfall of more than 500mm/year erosion may be excessive on gradient above 4%.Another factor that causes erosion on roadway including paved and unpaved road is poor construction activity. Road drainages are constructed without taken anticipated runoff into consideration and this often leads to the design of drains that cannot hold and channel runoff into the nearby stream. Similarly, culvert inlets are designed improperly. Also improper construction of drainages and culvert were also found to cause road erosion [2].

Table 2.5: Degrees of transverse or diagonal erosion and longitudinal erosion.

a) Degrees of transverse or diagonal erosion	
Degree	Description
1	evidence of water damage
2	channels <20mm deep
3	channels 20mm-40mm deep
4	channels 40mm-60mm deep
5	channels>60 mm deep
b)Degrees of longitudinal erosion	
Degree	Description
1	minor evidence of water damage
2	seen, but not felt or heard(channels 10mm x 50mmwide)
3	can be felt and heard- speed reduction necessary (30mmx 75mm)
4	significant speed reduction necessary(50mmx150mm)
5	vehicles drive very slowly and attempt to avoid them(>60mm x250mm)

Source [35]

The factors affecting surface erosion from roads include rainfall intensity and duration, snowfall, the characteristics of surface materials, the hydraulic characteristics of the road surface, road slope, traffic, construction and maintenance, and the contributing road area [36].

4. Stoniness-loose and embedded:

Stoniness is the relative percentage of material in the road that is larger than the recommended maximum size of 37.5mm [35].stoniness was assessed by estimating the extent and severity. The variation of stones sizes in a gravel wearing course and it reveals a lacks of control at the source of gravel materials before being delivered to the site.

5. Dustiness

Dust is the fine material released from the road under the wheels of moving vehicles and turbulence caused by vehicles and wind dust is one of the major sources of gravel loss. The gradation of the gravel, weather conditions, and traffic volumes will determine the extent and severity of dust: since heavy conditions remove necessary fines from the roadway, this defect can be an indicator of future maintenance problems. Thick dust that obscures traffic can create obvious safety problems. A dust palliative is useful especially near populated areas [37]. For assessment purpose, dust was rated in terms three degrees, namely1which signifies 0 no loss of visibility, 3 signifying some loss of visibility and 5 which is the dangerous loss of visibility. The higher the traffic volume the heaver the dust generated [35].

6. Loose material: this is formed by the raveling of the wearing course material under traffic. It is mainly caused a deficiency of fine material due to lack of cohesion, a poor particle size distribution (e.g. gap grading) in the wearing course materials; and inadequate compaction [35] loose material was assessed by estimating its thickness variation across carriageway.

7. Corrugation: Corrugated gravel roads generate more complaints than any other condition. Even a shallow "washboard" creates a bumpy ride. More severe corrugations can reduce driver control of vehicles.Washboarding occurs when the surface gravel has too few “fines.”These tiny particles will pass through a screen with 200 openings per square inch. They bind the larger particles together to distribute and support vehicle loads. With too few fines, vehicle tires easily move the larger particles into the washboard pattern shown here.

Corrugated roads occur due to four factors

1. Vehicle speed and related driving habits.

2. Vehicle volume.
3. Poor gravel quality.
4. Lack of moisture.

Vehicle speed, acceleration, and braking are the greatest causes. Of course, changing the public's driving habits is unrealistic. However, cities and towns can minimize the effects of vehicle volume, gravel quality, and moisture. This article will describe ways to control these factors.

8. Slipperiness and skid resistance: slipperiness is the loss of traction caused by an accumulation of excessively fine or plastic material on the surface of the wearing course in wet conditions, while skid resistance is affected by the excess of loose, fine gravel (between 2 and 7mm in diameter) that accumulates on the road surface through raveling under traffic or poor grading practices during dry conditions9pearson).slipperiness can often be evaluated by observing wheel tracks formed during wet weather. Wheel tracks retained in the road after drying. Skid resistance is evaluated in terms of the effect of loose material on vehicle stability, and the general impression gained while driving and breaking on the dry road. Slipperiness and skid resistance were rated as either acceptable or an acceptable. The impression of wheel tracks reflected on gravel roads, indicate the quantity of gravel material lost on that particular road section.

9. Trafficaility: The mechanism affecting trafficability is the loss of traction between the tyres and the road resulting from the low shear strength of the material. This results in chuming of the material and sinking of the vehicles into the weak layer. Sandy materials are more prone to impassability when dry, while clayey materials become impassible when wet.For assessment purposes, trafficability was rated as either acceptable or unacceptable. The chuming of the materials signify the loss of gravelling materials.

10. Riding quality and influencing factors: defects influencing riding quality are; corrugation, loose materials, stoniness, is ruts, and erosion. Riding quality is easily rated as a function of the estimated comfortable and safe driving speed 9 unaffected by geometric constraints or road width) and was interpreted as indicated in table below.

Table 2.6:Assessment of riding quality on unpaved roads, as recommended by the study

rating	Descriptor	Description
1	Very good	Estimated safe speed between 60 and 70km/h
2	Good	Estimated safe speed between 50 and 60km/h
3	Average	Estimated safe speed between 30 and 50km/h
4	Poor	Estimated safe speed between 20 and 30km/h
5	Very poor	Estimated safe speed 20km/h

Source: [35].

2.5.2 Extent and degree of surface distress

The degree of particular type of distress is measured of its severity. The degree recorded gave the predominant severity of a particular type of distress. The most important degrees are 1, 3, and 5; the defect may be marked as 2 or 4 respectively purposes.

The extent of distress is a measure of how wide spread the distress is over the length of the road segment. The extent is also indicated on a five- point scale in which the length of road affected by the distress is estimated as a percentage point out that the extent of the distress should be recorded only for that width of the road affecting the traffic [38]. This is particularly relevant for research purposes.

Table 2.7: General description of extent classifications

Extent	Description	Estimate (%)
1	Isolated occurrence, not representative of the segment length being evaluated. They are usually associated with localized changes in the material, subgrade or drainage conditions. Intersections, steep grades or sharp curves may also result in isolated occurrences.	<5
2		5 – 20
3	Intermittent occurrence, over most of the segment length, or extensive occurrence over a limited portion of the segment length.	20-60

	When occurring over most of the segment length, problems are usually associated with the material quality or maintenance procedures. When occurring over limited portions, the problem is usually a result of local material variations or drainage problems.	
4		60-80
5	Extensive occurrence. This is usually a result of poor quality or insufficient wearing course material, or inadequate maintenance.	80-100

Source: [35]

2.6. Rating for surface gravel roads

Rating and evaluating gravel-surfaced roads differs from rating paved surfaces. Gravel road surface conditions change quickly. Heavy rains, heavy local traffic, or recent maintenance activities can significantly change many of the gravel road surface characteristics.

Gravel road rating should be based primarily on three major factors. A gravel road is best given an overall rating through observation of individual defects. These defects can be combined to provide the information necessary to make an overall assessment of road conditions. Records on the extent and severity of these types of defects, when monitored from year to year, can show how well roadways are performing. The rate of change and development of surface defects can be helpful in selecting between routine maintenance and major rehabilitation

In evaluating and rating the characteristic, signs of distress related to inadequate pavement strength should be sought. Failures from heavy loads take the form of rutting and potholes. Minor surface rutting (less than 1 in.) can occur from traffic dislodgement of gravel. Deeper rutting (over 1 in.) is a better indicator of actual strength limitations related to the gravel layer. Isolated potholes may indicate isolated conditions. More extensive potholes and breakdown of the surface are an indication that an adequate layer does not exist.

Understanding the maintenance record of a road also improves the ability to rate and evaluate conditions. If frequent regrading is necessary to prevent rutting and repair potholes, an adequate gravel layer may not exist. Obviously,roadway strength is related to drainage and subgrade support as well as gravel thickness. A gravel layer that would normally be adequate may not perform well if the roadway is frequently flooded or in an area of a very high water table. If surface distress such as rutting and potholing is not sufficient to evaluate the adequacy of a gravel layer with confidence, more field investigation is recommended. Several test holes can provide information on the thickness of the gravel layer. A visual inspection of the aggregate may indicate poor gradation. Laboratory testing of aggregate properties is even more useful.

Records on the extent and severity of these types of defects, when monitored from year to year, can show how well roadways are performing. The rate of change and development of surface defects can be helpful in selecting between routine maintenance and major rehabilitation [50].For each distress measured, there are deduct values depending upon the nature of the distress, its severity and quantity. The deduct values are summed, adjusted to take into account the total number of distresses identified, then can be used to compare sections with one another, to monitor road performance over time for that section, and to show a picture of the entire network condition by examining the number of sections. The PASER ranges are described as table below.

Table 2.8: Description of Rating system of condition gravel roads.

Scale	Surface condition	Distress condition description	General condition and treatment measures.
5	Excellent	No distress, Dust controlled. Excellent surface condition end ride.	New construction - or total reconstruction, Excellent drainage. Little or no maintenance required.
4	Good	Dust under dry conditions, Moderate loose aggregate, Slight washboarding.	Recently regarded, Good crown and drainage throughout, Adequate gravel for traffic,Routine maintenance needed.

3	Fair	Ditches present on more than50% of roadway. None or slight rutting (less than 1" deep). An occasional small pothole (less than 2"deep	Shows traffic effects. Regarding is necessary, Some areas may need additional gravel, additional aggregate may be needed at a few locations to correct isolated potholes, ruts and erosion. See note *
2	poor	Adequate ditches on less than 50% of roadway. Portions of the ditches may be failed.	Needs additional aggregate, Major ditch construction and culvert maintenance also required.
1	Failed	Severe rutting (over 3"deep) Severe potholes (over 4"deep), for over 25% of area.	Travel is difficult and road may be closed at times, Needs complete rebuilding*see note

Source [50]

Note: Individual roadway may not have all of the distress types listed for any particular rating. They may have one or two types. *

2.7. Adequacy of Side drainage

Drainage should be rated to identify sections with significant problems, particularly those related to maintenance, and to provide insights as to why a given road may be performing poorly. It should assist maintainers with identifying areas where better or additional maintenance is needed. Drainage inspection should also take place after an exceptional runoff event, because it is easier to see how drainage performs during or just after these events and because these events may reveal problems that either weren't apparent or didn't exist before the flooding event. Side drainage is one of the most important factors affecting pavement performance. Such drainage may be quantified in terms of a "drainage factor" which is the product of the height of the crown of the road above the bottom of the ditch (h) and the horizontal distance, d, from the centerline of the road to the bottom of the ditch as shown on figure 6.1 below. The minimum desirable value of h is 0.75m (derived [39].

Whilst the horizontal distance d is related to the width of the paved carriageway plus shoulder (d3), the horizontal component of the side slope (d2) (side slope typically 1:3) and the half width of the trapezoidal drain (d)

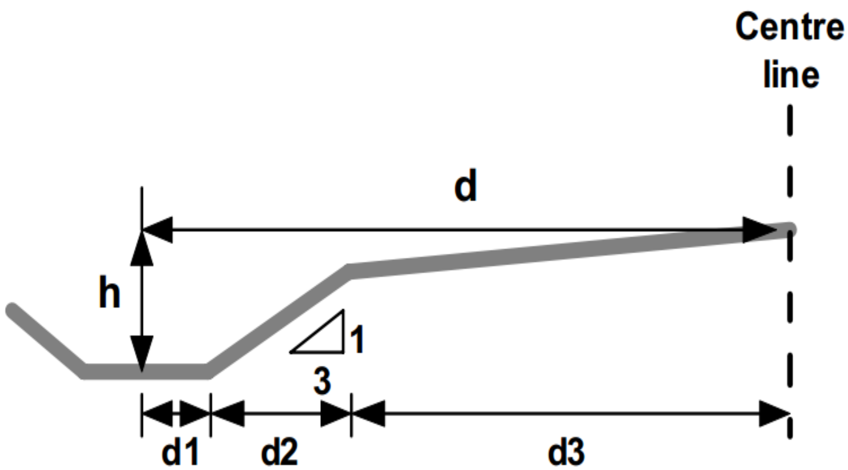


Figure 2.2: Drainage parameters for classifying side drainage.

Source: [40]

Based on a range of values of d and a minimum value of h of 0.75m, the classification of road drainage for LVSRs in terms of their drainage factor is presented in Table 2.8 below.

Table 2.9:Road drainage classification by drainage factor

Drainage parameters		Drainage classification by drainage factor DF(=dxh)			
d(m)	h(m)	Good	Moderate	poor	Very poor
10.00	0.75	≥7.5 or free drainage	5.1_7.5	2.6_5.0	≤2.5
9.5	0.75	≥7.1	4.8_7.1	2.5_2.7	≤2.4
9.00	0.75	≥6.8	4.6_6.8	2.4_4.5	≤2.3
8.50	0.75	≥6.4	4.4_6.4	2.2_4.3	≤2.1
8.00	0.75	≥6.0	4.2_6.0	2.1_4.1	≤2.0

Source : [40]

2.8. Factors affecting the performance of gravel roads

2.8.1. Maintenance of existing gravel roads

The material requirements for the gravel wearing course include provision of a gravel surface that is effectively maintainable. Adherence to the limits on oversize particles in the material is of particular importance in this regard and will normally necessitate the use of crushing or screening equipment during material production activities [41].

The principal operation in maintaining earth and gravel roads is grading. Dragging or brushing May also is carried out with the objective of controlling the development of corrugations and light or routine grading is also carried out for this reason. Heavy grading is used to reshape the road surface and to restore it to its correct camber or crossfall and to provide a smooth running surface. Heavy grading can be combined with regravelling to restore the thickness of the gravel surface. Filling or patching are labour-intensive operations to deal with the worst defects on low-volume roads for which the expense of grading or other machine activities. Maintenance of existing gravel road surfaces shall be classified as one or more of the following operation.

a) Shaping existing gravel roads

b) Ripping and processing existing gravel roads

c) Regravelling existing gravel

a. Shaping existing gravel road

- Shaping existing gravel roads comprises the following operation carried out to the satisfaction of the Engineer:
- Bringing loose material back to the road from the slopes and ditches if instructed by the Engineer.
- Shaping by motor grader, or equivalent equipment approved by the Engineer.

b. Ripping and processing existing gravel roads

Ripping and processing existing gravel roads comprises the following operations:

- Ripping of the existing road to a depth of minimum 100 mm as required by the Engineer.
- Bringing loose material back to the road from the slopes and ditches if instructed by the Engineer.
- Mixing, breaking of lumps, removal of oversize particles and watering as required to make a homogenous material having suitable moisture content at or around the optimum moisture content of BS-Heavy density.
- Shaping and finishing to the correct grade and crossfall and compaction to the requirements.

c. Re-gravelling existing gravel roads

Re-gravelling comprises the following operation:

- Addition of gravel wearing course material to an existing road.
- Gravel wearing material by mixing, breaking of lumps, removal of oversize particles and watering as required to make a homogenous material having suitable moisture content at or around the optimum moisture content of BS-Heavy density.
- Shaping and finishing to the correct grade and crossfall and compaction to the requirements.

2.8.2. Traffic volume

The mechanism of deterioration of gravel roads differs from that of paved roads and is directly related to the number of vehicles using the road rather than the number of equivalent standard axles. The traffic volume is therefore used in the design of unpaved roads, as opposed to the paved roads which require the conversion of traffic volumes into the appropriate cumulative number of equivalent standard axles [42].

- There are types of traffic-related deterioration that may be differentiated on unpaved roads during wet season. These are:-
    1. Deterioration such as roughness, which occurs primarily as a surface phenomenon in the dry seasons.

2. Surface deterioration (corrugations and roughness) in the wet season even though good drainage exists and the surfacing and roadbed materials possess sufficient shear strength to withstand the imparted traffic load stresses.
3. Surface deterioration of a material that possesses low shear strength at moisture contents that are found during the wet seasons
4. Deformation of the roadbed during the wet season, which occurs where the roadbed material has a low shear strength or California bearing ratio (CBR) and the surfacing thickness is insufficient to reduce the deformations in the subgrade to within limits that the material can accommodate.

❖ The most prominent deterioration mechanisms in dry weather are:

1. Wear and abrasion of the surface, which generate loose material and develop ruts
2. Loss of the surfacing material by whip-off and dusts.
3. Movement of loose material into corrugations under traffic actions and
4. Raveling of the surface in cases where there is insufficient binding power of the material to keep the surface intact, which often results in depressions that cause a rough ride.

At this time there are no theoretical models that can predict these deterioration mechanisms. Consequently, the viable method of predicting performance is developing empirical model [43].

2.8.3. Materials and Method Compaction requirement

The gravel wearing course material, and respectively the combination of imported and scarified material, shall meet the requirements for material class GW as given in table below

Table 2.10: Requirements for layers of gravel wearing course GW, materials

Material properties CML Tests	Material class
CBR:CML1.11	
CBR(%) wet or moderate climate zones	Minimum 25 after 4 days soaking
CBR(%)dry climatic zones	Minimum at OMC
Grading and Atterberg limits	
Shrinkage product, SP	Minimum 120, maximum 400

Grading coefficient, GC	Minimum 16, maximum 34

Source: [standard specifications for road networks Tanzania, 2000]

2.8.4. Geometric design of gravel roads /Absolute Gradient

Geometric design is the process whereby the layout of the road through the terrain is designed to meet the needs of all the road users. It covers road width, cross-fall, horizontal and vertical alignments, sight distance and transverse profile or cross-section. The geometric features influencing gravel loss are horizontal and vertical curvature, the cross section elements and longitudinal grades. Geometric cross-sectional characteristics particularly crown, camber, side drains and run-off points have pronounced effects on drainage and gravel road deterioration during high rainfall.

The crossfall of carriageway and shoulders for gravel roads shall be "4%" as indicated in ERA's Geometric Design Manual - 2002. This is to ensure that potholes do not develop by rapidly removing surface water and to ensure that excessive crossfall does not cause erosion of the surface. Provision of drainage is extremely important for the performance of gravel roads [44].

Normal crossfall (or camber, crown) should be sufficient to provide adequate surface drainage whilst not being so great as to make steering difficult. The ability of a surface to shed water varies with its smoothness and integrity. On unpaved roads, the minimum acceptable value of crossfall should be related to the need to carry surface water away from the pavement structure effectively, with a maximum value above which erosion of material starts to become a problem. The normal crossfall should be 2.5 percent on paved roads and 4 percent on unpaved roads. Shoulders having the same surface as the roadway should have the same normal crossfall. Unpaved shoulders on a paved road should be 1.5 percent steeper than the crossfall of the roadway. The precise choice of normal crossfall on unpaved roads will vary with construction type and material rather than any geometric design requirement. In most circumstances, crossfalls of 4 percent should be used, although the value will change throughout the maintenance cycle. The recommended applications of normal crossfall and for shoulder cross fall are given in Table below.

Table 2.11: Geometric design standard parameter for design standard DS5 (unpaved)

Design Elements	Unit	Flat	Rolling	Mountainous	Escarpment	Urban /per-Urban
Design Speed	Km/h	70	60	50	40	50
Min. stopping sight distance	M	110	85	55	45	55
Min. passing sight distance	M	275	225	175	125	175
%passing opportunity	%	25	25	15	0	20
Min. horizontal curve radius	M	175	125	85	50	85
Transition curves required		No	No	No	No	No
Max. gradient(desirable)	%	4	5	7	7	7
Max. gradient(absolute)	%	6	7	9	9	9
Minimum gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum super elevation	%	8	8	8	8	4
Crest vertical curve	K	31	18	10	5	10
Sag vertical curve	K	25	18	12	8	12
Normal cross fall(paved)	%	2.5	2.5	2.5	2.5	2.5
Shoulder cross fall (paved)	%	4	4	4	4	4
Normal and shoulder Cross fall(unpaved)	%	4	4	4	4	4
Right of way	M	50	50	50	50	50

Source: Geometric Design Manual-2002 Cross Section Elements ERA

2.8.5 Climate/Precipitation

Climate also has a strong influence on the pavement performance, and may be accounted for in the design to some extent. This is particularly true for Ethiopia where a wide range of climatic zones are encountered; from desert in the north-east triangle around Djibouti, to temperate and mountainous (sub-alpine) over a significant part of the country, with annual rainfall up to 1500 mm. The climate influences the subgrade moisture content and strength and requires precautions to ensure adequate drainage. The rainfall also influences the selection of adequate pavement materials, such as the allowable limits of materials properties and is a potential incentive to use stabilized materials Suitable material should posessess properties similar to those of a good surfacing material for unpaved roads.the should be well graded and have a plasticity index at the lower end of the appropriate for and ideal unpaved road wearing course under the prevailing conditions.The materials meeting the requirements for severe conditions will usually be of higher quality than the standard sub-base or natural gravel for surfacing gravel road the recommended plasticity characteristics for granular sub-bases [45]. The table 2.10 below is the recommended values as per ERA.

Table 2.12: Recommended Plasticity Characteristics for Granular Sub-Bases (GS)

Climate	Typical annual rainfall(mm)	Liquid Limit	Plasticity Index	Linear Shrinkage
Moist tropical and wet tropical	>500	<35	<6	<3
Seasonally wet tropical	>500	<45	<12	<6
Arid and semi-arid	<500	<55	<20	<10

Source [45]

Precipitation plays a significant role in eroding the surfacing material. A gravel road is susceptible to variations in climatic condition of the area to which the road located. In rainy season, the moisture content in the road become higher and due to this bearing capacity of the gravel road in general reduces and this leads the roads to rutting. In dry season the moisture content of the gravel roads reduces and this leads the roads to be corrugated and dusty. Never underestimate the force of a drop of rainwater. It is that water drop exploding when it impacts bare soil that starts the erosion process. If water passes through a road and fills the native soil, the road, whatever may be its thickness, loses its support and goes to pieces [46].

The deterioration of gravel road is governed by the behavior of the road material, the drainage capacity under the combined action of traffic and climate and the absence of maintenance activities [47]. These combination leads to dust, rutting, potholes, corrugations, loose gravel, frost damages, erosion channels, and other distresses. The above discussed points were summarized and each factor contributes to the other factor as cause which in general affect the performance of gravel road, as figure below

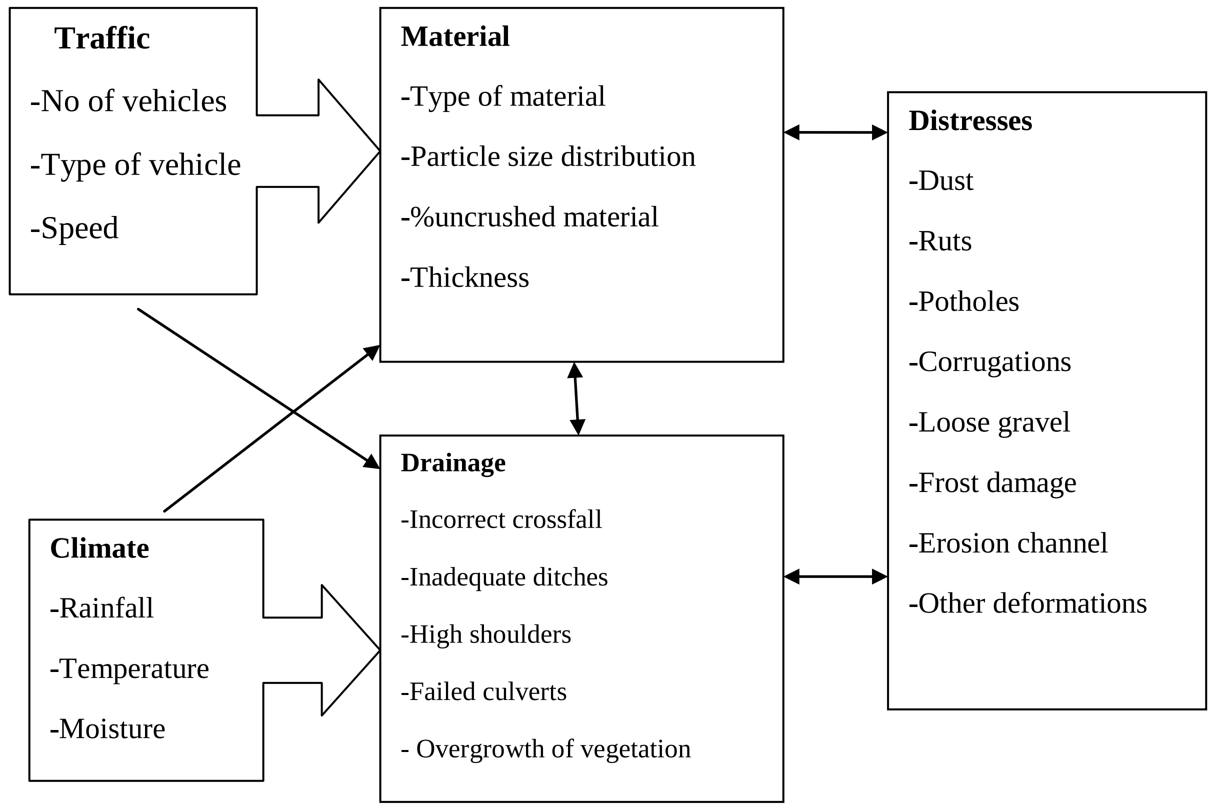


Figure 2.3: Schematic of deterioration process on gravel roads

Source: [47]

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

3.1. General

This chapter contents are the study area of the research, the research design, sample size and sampling process, study variables, data collection and how to analysis the data collected were explained. Generally, in this chapter the materials used and the methodology used to conduct this research was described in each sub topic as below.

3.2. Study area

The study was conducted at Horo Guduru Wollega zone, Oromia regional state, western Ethiopia which starts at shambu town with 314km by road west of Addis Ababa and its end point at Amuru town, a 382km from Addis Ababa. The road segment is found in an altitude of about 2844m at Shambu, 2380m at Jarte and 2500m at Amuru, above sea level. It lies in the climatic zone locally known Woyna Dega and Dega which have a temperature of 25degrees CelciusAmuru and 26degrees Celciusc, at Jarte and 27degrees Celcius at Shambu. The average annual rainfall of the districts were1350mm, 1700mm and 1516mm for Horro, J/Jarte and Amuru respectively. The population 0f the study area was 100938 in Horro, 66450 in Jardega Jarte and 72942 in Amuru district[48].

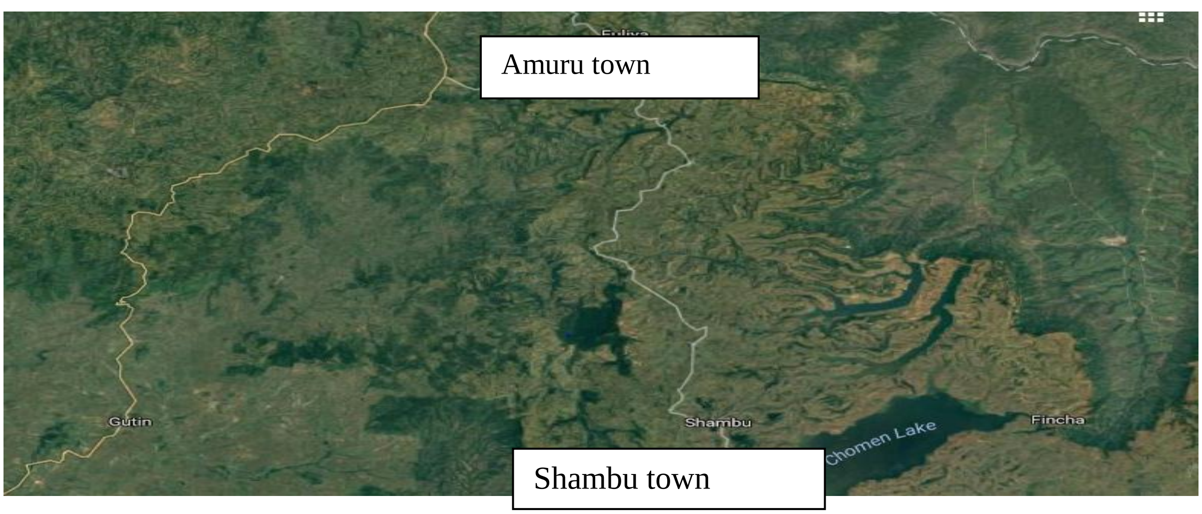


Figure 3.1: Map of the study area (Source: www.googlemap.com)

3.3. Research Design

To achieve the objectives of the study, it was designed that experimental investigation, and field measurement as well as visual observation would have conducted. The research was undertaken by using both descriptive and analytical methods. Which mean that the methodology used in the research is laboratory analysis of samples extracted from the road segment was the subgrade soil strength properties, Construction materials for road surfacing, were evaluated/tested in laboratory, a purposive approach was followed, and the data could be used to evaluate the performance of gravel road along the study segment, and distress types measurement from samples collected from the site, including the adequacy of side drainage, and drainage condition of the road was evaluated by measurements of drainage condition factors, road width, shoulder width and depth of the drainages. Types of distress with their attributes were analyzed in detail with measurements and detail visual observation methods.

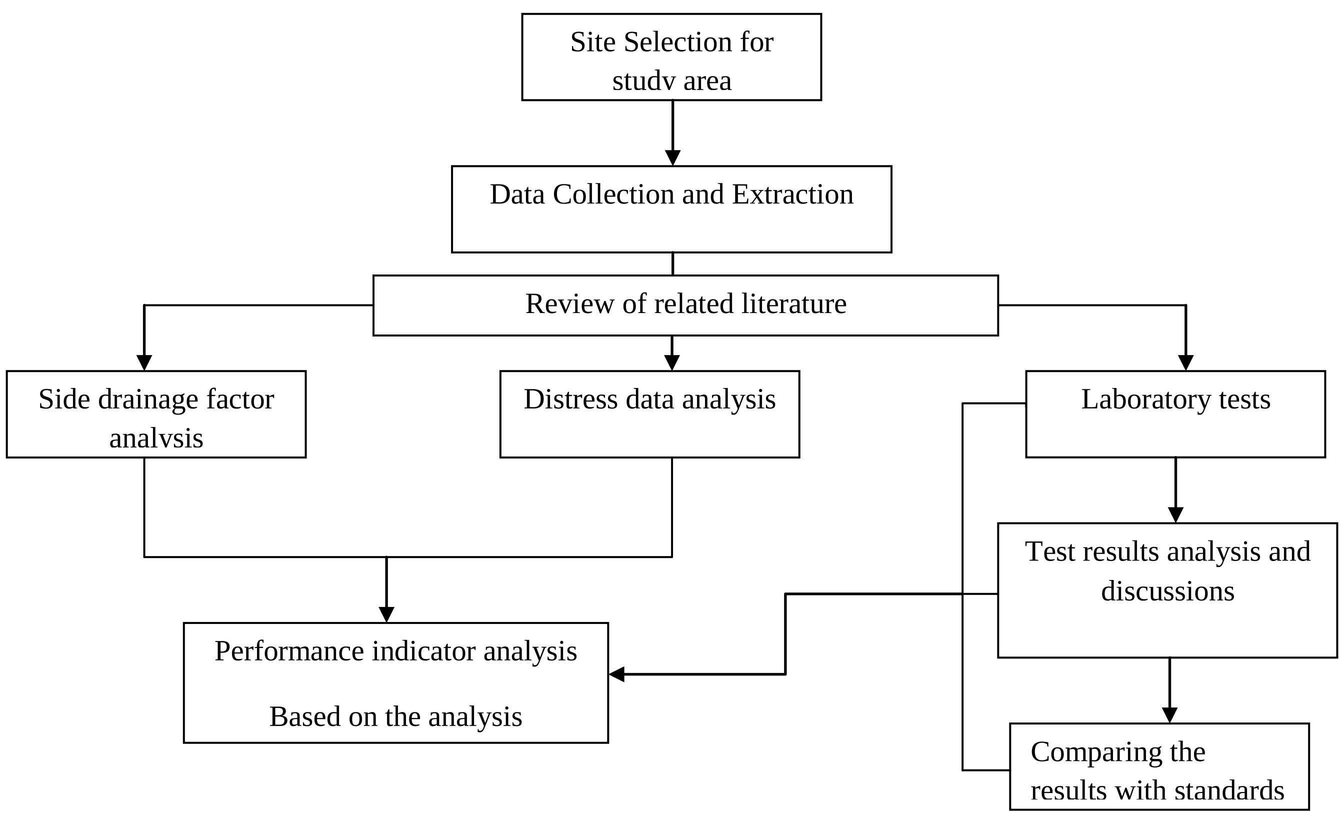


Figure 3.2: The Research Design and process

After having all the necessary data and laboratory analysis obtained, the evaluation of the performance of unpaved road through interpretation of results.

3.4. Data collection Method

The following subtopics were discusses the data collection methods for the study.

3.4.1. Laboratory test of the Engineering property of subgrade and surfacing gravel

The objective of the laboratory test design was to ensure that suitable data were collected. A purposive approach was followed, and the data could be used to evaluate the performance of gravel road along the study segment. The material properties tested include particle size distribution, Atterberg limits comprising of liquid limit and plastic limit tests, compaction tests and California bearing ratio (CBR), specific gravity test and hydrometer test. These tests were conducted to test likely the occurrence of failure due to the changing geotechnical properties along road under the study. Finally, the results were analyzed to determine the engineering properties of the soil and the road conditions of the site in order the performance of the road evaluated in detail, which leading to the comparison with the standard specifications (ERA, AASHTO).

a)  b)  c) 

Figure 3.3: a) sieve analysis b) LL and PL test, c) compaction and CBR soaking d) specific gravity test and hydrometer test pictures of laboratory test activities
[photo was taken by Barasa Ayele]

3.5.1. Field measurements and visual observation

The data regarding the side drainage factors of the road was obtained by the help of measuring the depth of side drainage below the surface of road, shoulder width, and total width of the carriageway. The samples were taken at different places depending on material sources and grades (at steep grade, at normal grade and flat grades) and taken at interval of 40m for 200m at each place. Then the recorded measurements were analyzed using drainage factor method in this study transverse and longitudinal erosions were quantified by its depth and width using tape measure. The drainage factor was calculated by using the empirical formula.

Estimate in % of degree = [(frequency of each degree x average of sampling)/ (total sample length)] x 100%

The surface gravel thickness was measured at right side, left side and center of each section of the road, by carefully digging using hand tools and measured with meter tape. Then it was used to describe which material is suitable or not, at what portion of the road is more loose (at center or at sides) and make description for the materials with result of laboratory results. For all sections, measurements were done for rutting, potholes, erosions both (longitudinal and transverse). Dustiness, Corrugations, loose materials, slipperiness, sub grade exposure, landslide of the road at embankment places, trafficability and the like, isolated problems were assessed in detail by visual observation and supported by photograph taken at each section of the study segment.

a)  b)  c) 

d)   

Figure 3.4:A) rutting B) longitudinal erosion, C) and transverse erosion) potholes, distress measurement at different section of the study segment.

[Taken by Motuma Bayana]

3.6. Sample size and sampling method

Purposive sampling was used for this study. During the site visits, the conditions of the pavement on the selected roads were visually assessed and pictures of the pavement were taken. In addition, the conditions of the drainages of selected roads were also assessed. The road segments have 6 sources of materials at different sections. Twelve samples were collected from six places, two samples from each section, one for surface wearing course and one for sub grade soil. The samples were collected at a depth ranging from 1.0m to 1.5m for sub grade soil, and at 60mm to 150mm depth for surface wearing course. Sample for subgrade strength test have been taken at least from three places along the road segments at both normal road section. While sections severely damaged for CBR test, gradation test; Atterberg's limits test, compaction test, moisture content test, specific gravity and hydrometer test.

For subgrade soil and sub-base or surfacing material laboratory test would be conducted for material property tests and finally compared with standards to check the quality of materials. The output of the test results were used to compare the material properties used with the standard specification of gravel roads under low volume traffic. The sample size tests were determined based on the material sources of surfacing gravel and for sub grade soils 3 from severely damaged section and 3 from normal section as a purposive representative.

Performance indicators, distress types and their attributes were assessed at each segment where relatively uniform in terms of its material type and general performance was taken about 10 % of section length at 40m interval In order to avoid the collection of excessive and repetitive data, unless the segment was used a variety of different materials sources. For ease of use and application, the start and end-points of each segment was related to fixed datum points (e.g. town sections, boundary of districts, forests on rural areas). Direction of measuring was in both direction to get side drainage factor from left and right.the measurement where it starts from Shambu town to the end point Amuru.

Generally, sampling for material laboratory, side drainage factor and distress type along the study road was divided in sections (Shambu to Sakala, Sakala to Abuna, Abuna to Shuluke, Shuluke to Jarmat, Jarmat to Jarte, and Jarte to Amuru).The representative data were measured according to the visual assessment manual [35] to validate the sampling data represent all the section length. (I.e. 10% to 15% of total section length was taken).

3.7. Study variables

3.7.1. Independent variable

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

- Material quality of subgrade and surfacing material.

- Deterioration revealed on the roads.
- Side drainage condition of the road.
- Environmental factors and location of the road.

3.7.2. Dependent variables

The out puts and factors observed in the study and measured to determine the effects of independent variable.

- ✓ Performance of the rural gravel road

3.8. Data collection and process

The performance data collection like the distress types rating scores were taken individually and the distress scores then combined to create a performance of overall with combination with the laboratory results of materials.

The maintenance data were taken from construction or consultant firms, and road administrative agencies. Review of Relevant literatures on current pavement material performance and serviceability approach on various modes of failure and damage propagations were conducted.

Data collection process was carried out by obtaining necessary data from the field observation and measurements, data from laboratory test results and any other Performance indicators measurement and laboratory test was collected in the site for the analysis of the performance level. The sample data that were collected for the purpose of: CBR test, gradation test, Atterberg limits test, compaction test/ moisture content test, specific gravity and hydrometer test:

- CBR test: Sample data for CBR test was collected on site at both for gravel surface wearing course and sub grade soil at normal section and severely damaged section of road for strength test.
- Compaction test: Procter test (density, moisture content.) was collected for purpose of testing compaction requirement of the materials.
- Gradation test, hydrometer test, specific gravity test and, Atterberg limits test Sample data for surfacing course material and subgrade was collected from site for tests for the comparison and classification purposes.

- Performance indicator (measurable parameters like longitudinal and transverse erosions, potholes, and rutting, cracking, corrugations, road width, and thickness measurement were taken.
- The visual evaluation is one of the most important aspects of the pavement evaluation process. This usually involves a comprehensive survey of the road while a variety of parameters was visually evaluated in detail. They provide verbal descriptions illustrated with photographs that let the evaluator rate a road describing its overall quality. They also describe various distresses, as well as other factors to consider when rating a road, such as the appropriate maintenance activity for the rated road.

3.9. Data analysis

In order to describe the performance of the road all the necessary data were analyzed quantitatively as well as qualitatively. Parameters such as Laboratory tests, potholes, rutting, erosion, thickness and road width, and side drainage factors were analyzed quantitatively and the qualitative parameters include ridding quality, corrugation, sub grade exposures, dustiness, loose material, slipperiness and skid resistance.

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 and USCS Classifications.

Attributes of distress were analyzed from the results measured in the field and careful observation taken at different section of the road section during different time. Then, it is put in degrees and extent as per visual assessment for low volume unsealed roads. The side drainage factor was analyzed from the measurement taken like road carriage width, shoulder width, and depth of side drainage from bottom of the drainage to surface of the road. Using the results of the measurements, the drainage factor obtained and the adequacy of the drainage was analyzed.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. General

In this chapter the results of laboratory tests for Gradation analysis tests, specific gravity tests, Atterberg's limit tests, proctor tests and CBR tests were analyzed. The engineering properties of subgrade soil and surface wearing material were discussed and compared with the standard specifications. The attribute of distress along the road were presented by their type, extent and degree as per Standard Visual Assessment Manual for Unsealed Roads. The adequacy of side drainage along the road was analyzed using side drainage factor. From the analyzed data possible remedial measures were recommended.

4.2. Determinations of Engineering Properties of Gravel material along the study

One of the objectives of this study was to determine the engineering property of gravel and comparing their results with ERA and other some standard specification. Based on the samples retrieved from the sites, laboratory tests on the twelve samples were undertaken for each test required to achieve objective of the study. The necessary laboratory tests which are important to evaluate the performance of gravel roads were done using the AASHTO and ASTM methods. Accordingly, the following different kinds of tests have been performed:

- Grain size Analysis Test (ASTM D 422-63)
- Specific gravity test(ASTM D 854-00)
- Liquid Limit Test (ASTM D 4318)
- Plastic Limit Test (ASTM D4318-III)
- Modified Proctor Test (AASHTO T 180)
- CBR Test (AASHTO T 193)

4.2.1. Grain size Analysis Test

This test was performed to determine the percentage of different grain sizes contained within a soil. The sieve analysis was performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.

4.2.1.1. Sieve Analysis Test

In this test the sieve size test analysis of AASHTO T89 for the grading and used to check for the correct mix of course, intermediate and fine particles and also for soil classifications.

a) Sieve analysis of surface wearing gravel material.

AASHTO M 145, Classification of Soil-Aggregate Mixtures for Highway Construction Purposes divides soils into the two major groups, namely granular and silt-clay materials. The granular materials are those soils with 35% or less passing the 75 µm (No. 200) sieve. ASTM D 2487, divides soils into three major groups of coarse-grained soils (sands and gravels), fine-grained soils (silts and clays), and highly organic soils (peat and other highly organic soils). The results of sieve analysis for gravel surfacing shows that at all sections there is not well graded material but, there are not more excessive fines passing sieve 0.075mm, which shows the values were as allowed percent passing recommended of AASHTO and ASTM classifications, because it shows less than 35%. The percent passing sieve of 0.075mm from sieve analysis for 6 samples were summarized as below. Even though percent passing particles were allowed, for the purpose of classifying into soil group, the hydrometer test was done in next section below.

Table 4.1:Summary of sieve analysis percent passing by mass of Surface wearing gravel.

sieve opening (mm)	percentage of pass by mass of SW of each sample					
	1.shambu	2.Abuna	3.Shuluke	4.Jarmat	5.Irro	6.Hangar
50	100	100	100	100	100	100
37.5	100	100	100	100	100	100
28	100	98.49	100	100	96.93	100
20	97.77	95.93	98.72	96.88	91.18	97.10
14	92.16	91.40	95.46	92.27	84.98	93.14
10	85.47	85.79	91.22	87.78	78.33	87.35
5	77.74	79.68	84.09	73.94	71.03	80.53
2.36	69.65	71.84	75.31	61.21	62.33	73.29
2	60.25	63.12	65.81	55.85	52.76	65.87
1	50.67	54.15	54.38	48.05	41.94	54.20
0.425	40.44	39.37	40.76	40.54	30.44	34.68
0.075	20.96	22.27	28.10	25.86	20.16	16.76

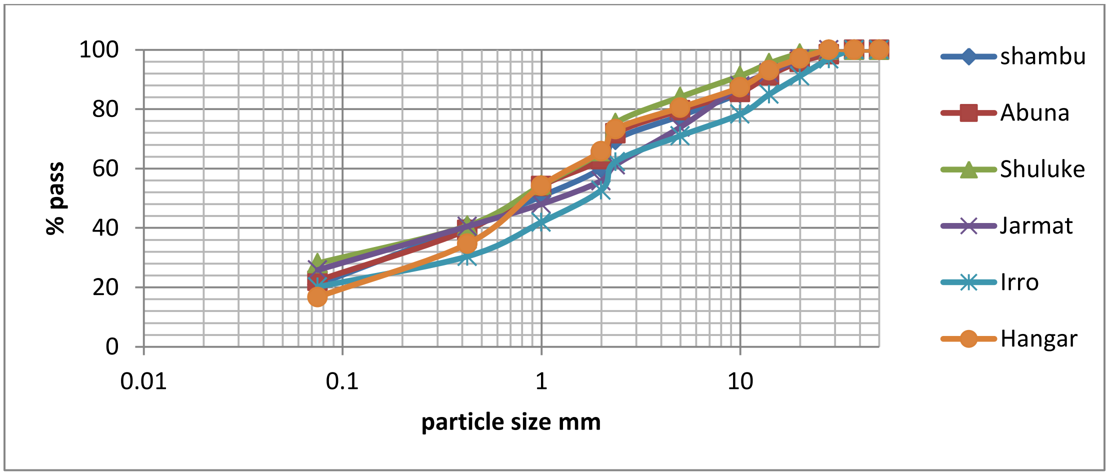


Figure 4.1: graph of sieve analysis of summary of percent pass by mass of SW

The Slipperiness of the surface of gravel road is a significant safety problem in wet weather, which was caused by excessively fine in the wearing course. Even materials with adequate coarse aggregate may become slippery if the fine silt and clay fraction becomes concentrated near the surface.

In dry weather, the gravel roads were dusty due to an excess of loose, fine gravel (between 2mm to 0.075 mm in diameter) accumulates on the road surface through raveling under traffic or poor blading practices. This layer behaves like a layer of ball bearings and the skid resistance is reduced practically to zero. This is especially a problem on the road along shambu to Amuru were too fine and too thin to lead to significant slipperiness during wet season and dusty during dry season as the result of test indicates. This problem occurs due to increment of traffic volumes from time to time as traffic data, Ethiopian roads Authority (ERA) annual average daily traffic by road section 2016 shows. The grading coefficient of natural gravel were determined from the sieve analysis results to find out where was the materials performance location as per ERA expected Performance of Gravel Wearing Course Materials as follow

Table 4. 2Grading coefficient of surface wearing gravel course

parameter	1.shambu	2.Abuna	3.Shuluke	4.Jarmat	5.Irro	6.Hangar
% p	40.44	39.37	40.76	40.54	30.44	34.68

0.425						
% P28	100	98.49	100	100	96.93	100
% P 5	77.74	79.68	84.09	73.94	71.03	80.53
% P 2	60.25	63.12	65.81	55.85	52.76	65.87
GC	53.16	48.19	44.66	58.70	59.46	46.96

The results of grading coefficient for the samples of gravel wearing materials were greater than 40 at all the sections of samples taken. This result shows that the materials had the properties of raveling, which is very poor performance of the gravel.

b) Sieve analysis of Sub grade soil.

Different soil class under AASHTO classification generally rated for subgrade suitability from excellent to good for coarse graded material and good to poor for fine graded soil [52].This parameter used as a general guide to the load bearing capacity of a soil.

Sieve analysis for sub grade soil was used to classify the sub grade soils depending on the percent passing of particles through sieves 2mm, 0.425mm and 0.075mm. The purpose of classifying this was for identifying the properties of the soil under the study. Knowing the classification of soil help us what type of additional layer require improving if it were weak or use it as original depending on soil type. The results of six samples of sub grade soil were summarized as table 4.2 below.

Table 4.3: Summary of sieve analysis percent passing by mass of sub grade soil

sieve opening (mm)	percentage of pass by mass of SG of each sample					
	1.shambu	2.Abuna	3.Shuluke	4.Jarmat	5.Irro	6.Hangar
75	100	100	100	100	100	100
63.5	100	100	100	100	100	100
50	100	100	100	100	100	100
37.5	100	100	100	100	100	100
25	100	100	100	100	100	100
19	100	100	100	100	100	100
9.5	100	100	100	100	100	100
4.75	100	100	98.18	100	100	100
2.36	99.44	100	94.49	98.87	99.48	100
1.18	97.43	99.28	90.21	96.47	97.12	99.19

0.60	92.05	95.85	84.01	92.60	94.85	96.64
0.425	84.16	91.96	73.56	87.14	89.83	92.15
0.30	73.08	84.31	64.69	80.28	86.77	86.79
0.15	57.90	74.89	55.53	68.26	76.93	77.32
0.075	48.78	58.59	45.15	45.59	66.62	69.97

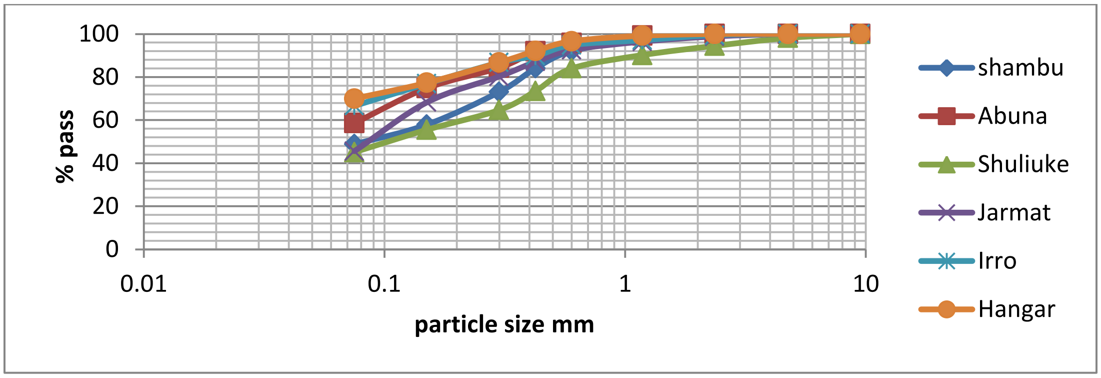


Figure 4.2: graph of sieve analysis of summary of percent pass by mass of SG soil

4.2.1.2. Hydrometer Test

The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles. This test is aim at the determination of the size of the particles of the soil consists. The Hydrometer Analyses test result is illustrated by the grain size distribution curve, for the particles of the sizes smaller than 75 µm (passed through sieve no.200).

The hydrometer analysis determines the relative proportions of fine sand, silt and clay contained in a given soil sample. Knowledge of the range of moisture content over which a soil will exhibit a certain consistency is beneficial to the understanding of how a soil might behave when used as a construction material.

Fines can also be washed out if flooding occurs due to poor road drainage design or failure to clear blocked ditches and culverts. Dissolvable dust suppressants will also be leached out of roads that are subject to flooding or rainwater pooling. Poor ditch drainage can lead to poor road performance.[49]

Table 4.4: Typical Hydrometer Test Results for Surface wearing at Hangar forest

actual time	elapsed time(min.)	Temp.(oc)	Actual hydr. Rdg	hdr.corr,for	effective depth,	K Value	particle size D(mm)	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted finer,Pa
5:30: AM	1	21	45	46	8.8	0.01340	0.03975	0.20	1.00	39.20	78.4	13.1398
5:32	2	21	42	43	9.2	0.01340	0.02874	0.20	1.00	36.20	72.4	12.1342
:35	5	21	42	43	9.2	0.01340	0.01818	0.20	1.00	36.20	72.4	12.1342
5:40	10	21	40	41	9.6	0.01340	0.01313	0.20	1.00	34.20	68.4	11.4638
5:45	15	21	39	40	9.7	0.01340	0.01078	0.20	1.00	33.20	66.4	11.1286
6:00	30	21	37	38	10.1	0.01340	0.00778	0.20	1.00	31.20	62.4	10.4582
6:30	60	21	35	36	10.4	0.01340	0.00558	0.20	1.00	29.20	58.4	9.78784
7:30	120	22	32	33	10.9	0.01324	0.00399	0.40	1.00	26.40	52.8	8.84928
9:30	240	22	30	31	11.2	0.01324	0.00286	0.40	1.00	24.40	48.8	8.17888
1:30	480	22	26	27	11.9	0.01324	0.00208	0.40	1.00	20.40	40.8	6.83808
6:30	960	21	25	26	12.0	0.01340	0.00150	0.20	1.00	19.20	38.4	6.43584
5:30: AM	1440	20	24	25	12.2	0.01357	0.00125	0.00	1.00	18.00	36	6.0336

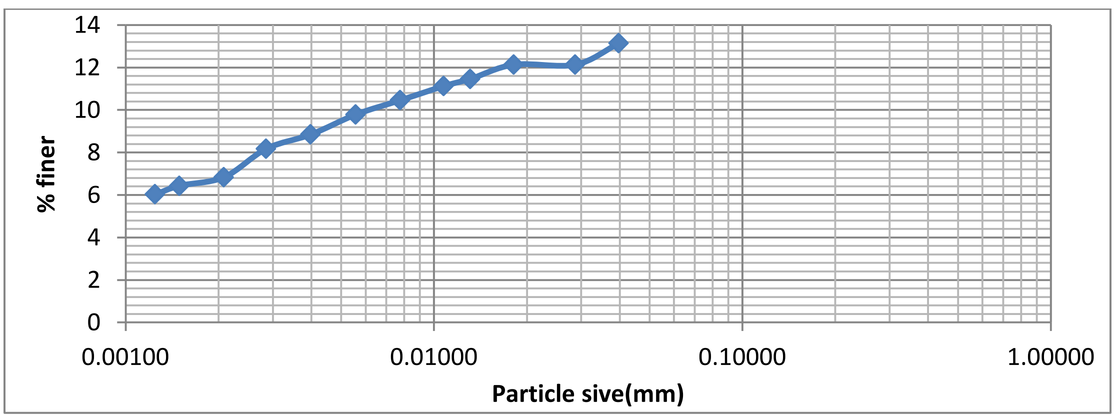


Figure 4.3: Typical graph of Hydrometer Test Results for Surface wearing at Hangar

Hydrometer analysis gives results from which the percent of soil finer than 0.002 mm in diameter can be estimated. This shows that the percent finer than 0.002 mm in size is clay or clay-size fractions. Most clay particles are smaller than 0.001 mm, and 0.002 mm is the upper limit. The presence of clay in a soil contributes to its plasticity. Generally the particles less than 0.002mm were less than 15%.

Generally, the test result of gravel soil the Samples was 15%% below at 0.08mm sieve size and more percentages above the ERA Standard Specification at the rest sieve sizes. From the gradation test result, the sample revealed that, the fine and coarse materials were not uniformity. Therefore, the soil needs an improvement.

4.2.2. Specific gravity test

The specific gravity test was performed to determine the specific gravity of soil by using a pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The determination of specific gravity was determined to classify the soils by the specific gravity values which can help us to identify the soil type. A systematic study of the specific gravity of soils is required for the determination of voids ratio, degree of saturation which is a very important for compaction point of view. The results of specific gravity for both sub grade soils and surface wearing gravel are tabulated in Table 4.3 with their class of the soil type

Table 4.5: Specific Gravity Test Result for SG and SW through all sections

No.	sample section location	specific gravity of material type	
		SG	SW
1	Shambu	2.69	2.67
2	Abuna	2.68	2.65
3	Shuluke	2.66	2.68
4	Jarmat	2.7	2.67
5	Irro	2.69	2.68
6	Hangar	2.63	2.67

From the above results of specific gravity values of sub grade soils and surface wearing gravel the soil type can be grouped depending on their values the classification is as per [52]. Thus, the surface wearing natural gravel were gravel type with values varies between (2.65 – 2.68) and the sub grade soils silty sands and silts with values between (2.66 to 2.70).and it is used in knowing the type of soils and used in determination of void ratio and particle size. Here in this thesis it determined only to help in classifying into their type. Thus, per ERA standard specification the specific gravity of subbase material is greater or equal to 2.63.Therefore, it is ok as the result of laboratory shows.

4.2.3. Atterberg's Test

The Atterberg's limits, which include the liquid limit and plastic limit, are readily accepted in the engineering community as an objective measure of consistency. When coarse soil particles (sand and gravel) are used as a construction material, their suitability and behavior is influenced by the amount of clay fines that may be present after processing. When clay minerals are present in fine grained soil, the soil can be remolded in the presence of some moisture without crumbling. The atterberg tests are done for both sub grade and surface wearing materials and using the results the soil is classified as AASHTO and USCS classification system**.**

Table 4.6: Typical Results of liquid limit and plastic limit Surface wearing at Hangar forest

Determination	Liquid Limit				Plastic Limit		plastic index
Number of blows	No	31	25	17			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	MB1	E1	N4	T	K	
Wt. of container + wet soil	(g)	54.05	48.96	53.47	19.44	19.96	
Wt. of container + dry soil	(g)	46.88	42.44	45.11	17.58	17.74	
Wt. of container	(g)	17.33	17.47	17.42	6.147	6.09	
Wt. of water	(g)	7.17	6.52	8.37	1.86	2.21	
Wt. of dry soil	(g)	29.55	24.97	27.68	11.43	11.65	
Moisture container	(%)	24.25	26.13	30.22	16.28	19.00	
Average	(%)	26.87			17.6		9.2

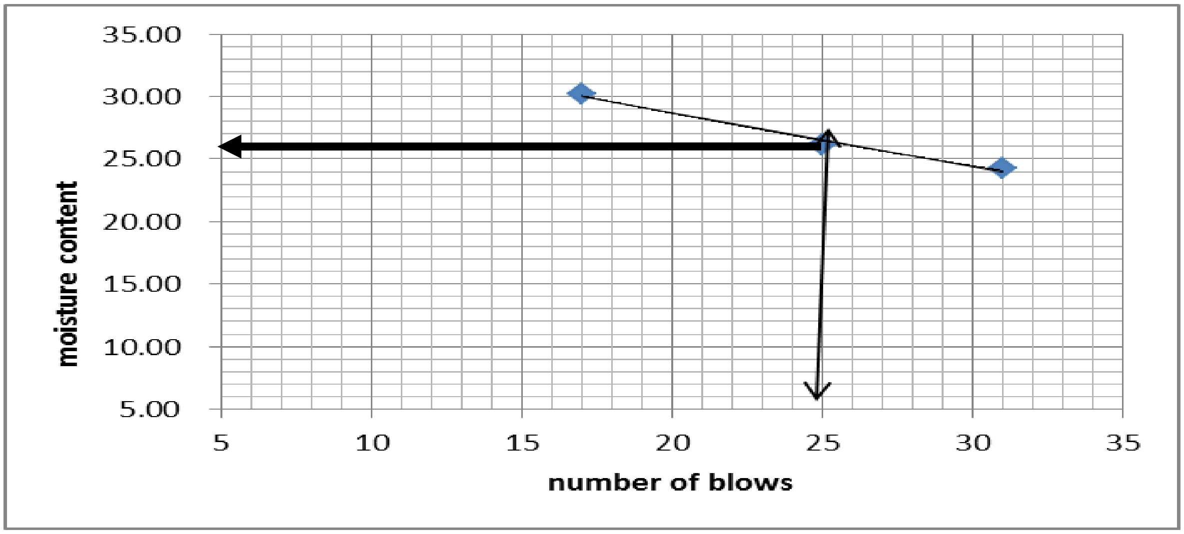


Figure 4.4: Typical Results of LL and PL graph of Subgrade Soils at Hangar

Good surface gravel needs a percentage of plastic material, usually natural clays, which will give the gravel a "binding" characteristic and hence a smooth driving surface. This is critical during dry weather. The results of liquid limit and plastic limits were used in determination of soil classification systems for both sub grade and surface wearing gravel material. The all values were summarized in tabular form in table 4.10 in next section.

4.2.4. Proctor Test

One of the critical aspects of using natural gravels is to maximize their strength and increase their stiffness and bearing capacity through effective compaction. This can be achieved, not necessarily by compacting to a pre-determined relative compaction level, as is traditionally done, but by compacting to the highest uniform level of density possible without significant degradation of the particles.

Effective compaction is one of the most cost-effective means of improving the structural capacity of pavements. A well compacted sub grade possesses enhanced strength, stiffness and bearing capacity; is more resistant to moisture penetration; and less susceptible to differential settlement. Thus, there is every benefit to achieving as high a density and related strength as economically possible in the subgrade. The study has carried out the compaction test by AASHTO 189 method D as a typical test result given on table 4.5 below.

Compacting granular soils increases the ability to bear weight and will make unpaved roads hold together much longer. Density of soil will increase as water content is increased until all of the voids are filled with water. Granular soils are improved with compactive effort and large amount of water (Fundamentals of geotechnical analysis 314-315).

The density of the compacted sub grade soil will remain approximately the same except for some residual compaction under traffic and possible volume variations of certain moisture sensitive soils. However the moisture content of the subgrade will change, depending on climate, soil properties, depth of water table, rainfall and drainage. As the moisture content increases at constant density (moving to the right) the CBR decreases quite quickly. If the soil becomes saturated, i.e. the air voids become filled with water and decrease to zero, the soil becomes very weak indeed [45].

Table 4.7: Typical Moisture Density Relationship of SG Soil

	trial number	unit	1	2	3	4
DENSITY	weight of sample	g	6000	6000	6000	6000
	water added	litre	250%	500%	750%	1000%
	weight of soil + mold	g	10205	10690	10802	10768
	weight of mold	g	6590	6590	6590	6590
	weight of soil	g	3615	4100	4212	4178
	volume of mold	cc	2105	2105	2105	2105
	wet density of soil	g/cc	1.717	1.948	2.001	1.985
MOISTURE	container number		X	AT1	B	AU
	wet soil + container	g	167.08	173.86	176.1	183.42
	dry soil + container	g	151.34	144.3	140.8	145.19
	weight of water	g	15.74	29.56	35.30	38.23
	weight of container	g	25.700	25.200	25.800	27.200
	weight of dry soil	g	125.64	119.10	115.00	117.99
	moisture content	%	12.53	24.82	30.70	32.40
	dry density of soil	g/cc	1.53	1.56	1.53	1.50
	MDD (gm/cc)	g/cc	1.56			
	OMC (%)	%	24.82			

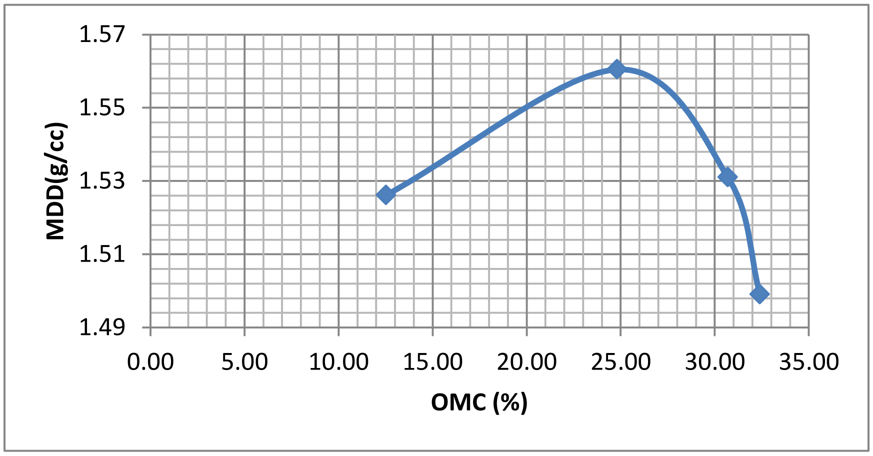


Figure 4.5: Typical Moisture Density Relationship of SG Soil at Hangar Station

Likewise Table 4.6 above for all samples the compaction test was done for both sub grade and gravel course material in laboratory. It shows that, the maximum dry density of the samples of sub grade soils was less than that of the natural gravel and crushed. And the optimum moisture content of sub grade soils was greater than that of surface wearing gravel. The compaction value of surface wearing at Hangar sample was high from all samples taken and the sample at Shuluke was the least as the result indicates. The detail of all the result for subgrade soil for optimum moisture content and maximum dry density is explained in table 4.10 in summary of procter and CBR test results for sub grade soils.

4.2.5. CBR Test

The California Bearing Ratio (CBR) performed on material in the laboratory is the most commonly used bearing capacity test. The test was done as AASHTO T-193 test method.

Surface deterioration of a material that possesses low shear strength at moisture contents that are found during the wet season and Deformation of the roadbed during the wet season, which occurs where the roadbed material has a low shear strength [or California bearing ratio (CBR)] and the surfacing thickness is insufficient to reduce the deformations in the subgrade to within limits that the material can accommodate. The interaction of these modes is has high in affecting the performance the gravel roads.

Table 4.8: typical result of CBR load penetration for SG soil at hangar

penetration	10 Blows				30 Blows				65 Blows			
(mm)	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	8.0	0.097			26.0	0.317			74	0.901		
1.27	17.0	0.207			48.0	0.585			108	1.315		
1.96	25.0	0.305			66.0	0.804			122	1.486		
2.54	45.0	0.548	0.55	4.1	96.0	1.169	1.17	8.8	145	1.766	1.77	13.2
3.18	48.0	0.585			107.0	1.303			154	1.876		
3.81	56.0	0.682			113.0	1.376			157	1.912		
4.45	61.0	0.743			128.0	1.559			178	2.168		
5.08	64.0	0.780	0.78	3.9	127.0	1.547	1.55	7.7	186	2.265	2.27	11.3
7.62	75.0	0.914			135.0	1.644			198	2.412		
10.16	79.0	0.962			142.0	1.730			200	2.436		
12.7	81.0	0.987			145.0	1.766			206	2.509		

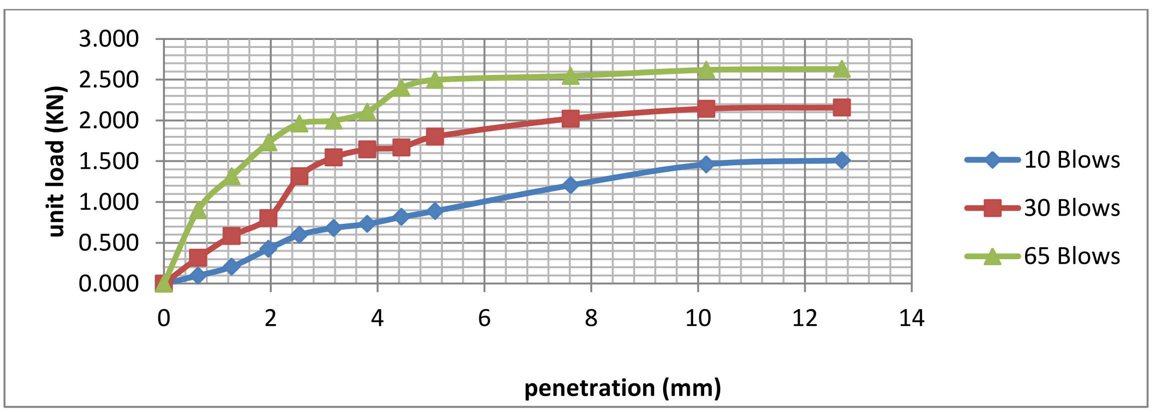


Figure 4.6: Typical CBR load penetration graph for SG soil at hangar

Table 4.9: typical result of CBR load penetration for SG soil at hangar

No.of blows	LOAD (KN)		CBR(%)		SWELL	DRY DENSITY Vs SOCKED C.B.R.			
	2.54mm	5.08mm	2.54mm	5.08mm	%				
10	0.55	0.78	4.11	3.90	2.21	No of blows	10	30	65
30	1.17	1.55	8.76	7.73	1.60	Dry density	1.38	1.65	1.97
65	1.77	2.27	13.23	11.33	0.68	Socked C.B.R.	4.11	8.76	13.23

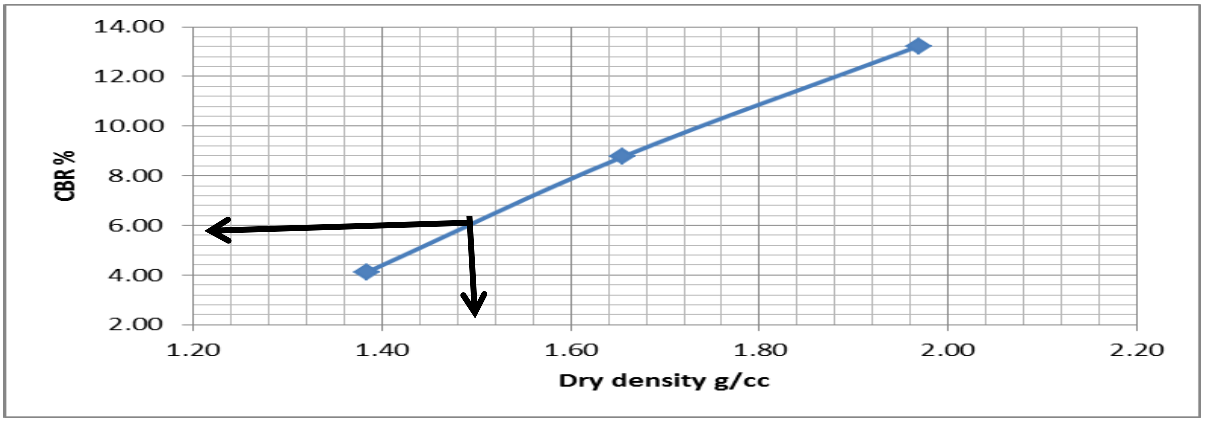


Figure 4.7: typical graph of CBR vs. dry density for SG soil at hangar forest

4.2.6. Test results and Discussions for sub grade soil

As the result of test for sub grade soil show the soil was silty clay and clayey soil which have not enough strength. Generally, classification of general rating of sub grade is fair to poor because the soil classes were A-6 to A-7-6,which show the significant constituent of the materials are silty soils and clayey soils. The results of all the tests taken were summarized in table below with Soil classification systems according to AASHTO and USCS.

Table 4.10: Summary of sieve analysis and Atterberg test and soil classifications for SG soil

It. No.	sample Station	sieve analysis % pass									atterberg limit			soil classfn.	
		9.5	4.75	2.00	1.18	0.6	0.425	0.3	0.15	0.075	LL %	PL%	PI%	AASHTO	USCS
1	shambu	100	100	99.4	98.4	92.9	84.9	73.8	58.4	49.2	40.32	20.69	19.62	A-7-6	CL
2	Abuna	100	100	100	99.3	95.9	91.96	84.31	74.9	58.6	36.3	18.7	17.60	A-6	CL
3	Shuluke	100	100	100	96.4	89.9	80.76	68.19	54.9	44.6	40.5	20.8	19.70	A-7-6	CL
4	Jarmat	100	100	98.9	96.5	92.6	87.1	80.3	68.3	45.6	38.32	18.2	20.1	A-6	CL
5	Irroo	100	100	99.5	97.1	94.9	89.83	86.77	76.9	66.6	39.21	22.38	16.84	A-6	CL
6	Hangar	100	100	100	99.2	96.6	92.15	86.79	77.3	70	40.05	19.8	20.3	A-7-6	CL

Subgrades are classified on the base of laboratory soaked CBR tests on samples compacted to 95% of AASHTO T180 compaction. The sub grade strength for design is assigned to one of six strength classes reflecting the sensitivity of thickness design to sub grade strength. The CBR results obtained from the sub grade soils testing are used to determine which sub grade class should be specified for design purposes.

Table 4.11: summary of Procter and CBR test results for sub grade soils

Procter		CBR					class
MDD g/cc	OMC %	Blows	ϱ(g/cc)	load at	load at 5.08mm	CBR at 95% MDD	ERA
1.56	20.07	10	1.45	4.38	4.14	5.5	S3
		30	1.55	6.48	5.36		
		65	1.71	9.21	7.31		
1.59	22.24	10	0.98	0.69	0.95	9.0	S4
		30	1.48	1.14	1.47		
		65	1.77	1.44	1.89		
1.57	25.72	10	1.33	0.71	0.85	6.1	S3
		30	1.46	0.85	1.05		
		65	1.54	1.1	1.39		
1.75	21.8	10	1.39	1.01	1.4	9.8	S4
		30	1.73	1.43	2.02		
		65	2.12	2.17	2.76		
1.48	23.2	10	0.39	0.89	1.22	7.0	S3
		30	0.86	1.34	1.94		
		65	0.94	1.67	2.48		
1.56	24.82	10	1.38	0.55	0.78	5.4	S3
		30	1.65	1.17	1.55		
		65	1.97	1.77	2.27		

For the stronger sub grades especially class S4 and higher CBR 9% to 14% and more, there is no need to improve on the basis of sub grade which can affect the performance of the road .Based on the results of laboratory summarized on table below, it is recommended that the sub grade layers should be improved to a minimum of 15% in order to reduce or use as it is the surface wearing course, and this helps in saving the expensive material of gravel wearing when the sub grade strength is improved. The samples of tests were show that the CBR Strength for sub grade soils were classified under S3 (CBR ranges from 5% to 8%) in most of the test section. when surface course were affected or loss under traffic, the sub grade cannot withstand to bear the load and this is one factor which contributes to reduce the performance of the road along Shambu to Amuru segment.

4.2.7. Summary of all test results for surface wearing gravel

After individual test for each sample were done it was summarized as table and its discussion were done in next sections depending on the results and classification according to AASHTO and USCS classification system. The below is the summary result of sieve analysis, liquid limit, plastic limit, and plastic index of surface wearing gravel material.

Table 4.12: Summary of test result for sieve analysis and Atterberg test for surfacing material

It. No.	sample Station	sieve analysis % pass												atterberg limit			classifn.	
		50	37.5	28	20	14	10	5	2.36	2	1	0.425	0.075	LL %	PL%	PI%	AASHTO	USCS
1	shambu	100	100	100	97.8	92.2	85.5	77.7	69.65	60.25	50.7	40.44	20.96	26	17	8	A-2-4	GM
2	Abuna	100	100	98.5	95.9	91.4	85.8	79.7	71.84	63.12	54.2	39.37	22.27	28	19	9	A-2-4	GM
3	Shuluke	100	100	100	98.7	95.5	91.2	84.1	75.31	65.81	54.4	40.76	28.10	28	18	10	A-2-6	GC
4	Jarmat	100	100	100	96.6	91.7	86.8	71.9	65.69	59.77	51.3	43.18	27.26	26	16	10	A-2-6	GC
5	Irroo	100	100	96.9	91.2	85	78.3	71	62.33	52.76	41.9	30.44	20.16	27	19	8	A-2-4	GM
6	Hangar	100	100	100	97.1	93.1	87.4	80.5	73.29	65.87	54.2	34.68	16.76	27	18	9	A-2-4	GM

The properties of all marginal gravel materials used to surface gravel roads change over time with use and exposure to environmental condition. These changes can be noted during routine visual assessment of the condition and performance of gravel roads. Thus, the need to study the behavioral changes of marginal gravel materials under the impact of traffic and climatic elements for the sake of evaluating the performance of the road, it can be deduced that the economical use of gravel surfaced materials should to be advocated through deployment of marginal gravel materials. This can be achieved through studying and incorporating into unsealed road performance prediction models the impact of climatic elements and traffic volumes on marginal gravel materials. Study has to be extended to visual assessment of the condition and performance of gravel roads surfaced with marginal materials. Such studies will aid in optimum structural design, construction and maintenance of gravel road network in question.

This study is focused on the performance of gravel road, materials deployed to surface unsealed roads in shambu to Amuru. For the sake of protecting performance, it can be deduced that the gravel surfaced materials should to be improved from the of marginal gravel materials in order to perform well. This can be achieved through studying and incorporating into unsealed road performance predictions to the impact of climatic elements and traffic volumes on marginal gravel materials on performance of the road.

Table 4.13: Summary of all Procter and CBR test results for surfacing material

It. No.	Sample location	Procter test result		CBR test result	Acceptable Class>=30
		MDD g/cc	OMC %	CBR at 95%MDD	ERA
1	Shambu	2.18	16.90	38.00	Ok
2	Abuna	1.872	14.01	30.00	Ok
3	Shuluke	1.87	14.48	28.00	Not ok
4	Jarmat	2.27	20.36	31	Ok
5	Irroo	2.00	18.60	31	Ok
6	Hangar	2.31	14.19	34	Ok

From the above result it is observed that the CBR values of selected gravel material used for the wearing course has been on the under boundary .thus, the can be lost the initial strength after it has been open to traffic.

The reduction in the CBR value is due to the gravel material used for the wearing course is corrugated at certain station or crushed too fine in certain sections as it is visualized during condition survey time sampling the project route this may due to increase in traffic [10], weather and environment condition that the material suffering after it has been open to traffic. The analysis of laboratory test result can show that the material performance is low which can be loss in material strength and leads loss in riding quality or comfort to drive, when the material strength is reduced Because, the material is sensitive to be affected under traffic within short period of time. Such materials requires short period of time maintenance which indirectly increases the cost of maintenance and can cause problematic on environment by depleting natural gravel and can be exposed to different type of distress become higher. Then, distresses are developed to high degree the road is failed to perform well under the conditions.

4.3. Attributes of Distress Results along study segment

According to the research objectives, the distress data have been collected through six sections along the segment. The results of the data were used to build for pavement condition performance.

The task of describing distress was achieved by recording its main characteristics which is called attributes of distress. The attributes of distresses discussed in this study are identified by degree and by extent. The visual evaluation and field measurement are one of the most important aspects of the pavement evaluation process. This usually involves a comprehensive survey of the road while a variety of parameters is visually evaluated in detail. Visual evaluation generally requires a rating of degree and extent of the various distress parameters by an experienced person. The attributes were described as follows:

4.3.1 Type and degree of distress

The degree of a particular type of distress is a measure of its severity. Since the degree of distress can vary over the pavement section, the degree was recorded in connection with the extent of occurrence, give the best average assessment of the seriousness of a particular type of distress. The degree is indicated by a number where Degree 1 indicates the first evidence of a particular type of distress ("slight"), Degree 3 indicates a warning (requires attention) and Degree 5 indicates the worst degree ("severe").

The common type distresses encountered on gravel roads under study are: potholes, rutting, erosion, corrugation, loose materials, stoniness, and dust. These were assessed together with field measurement and detail visual observation of the road at different time. The results were analyzed according to visual assessment of gravel roads manual. Degree 1 generally indicates that no attention is required; degree 3 indicates that maintenance/improvement might be required in the near future, whereas degree 5 indicates that immediate maintenance/improvement is required. Then from a field measured data and description of each type of distress its degree was assessed with the emphasis of its contribution to road performance.

All of the distress degree rating scores were translated into individual distress index scores and then combined to create a single average. Due to the fact that there is no roughness data associated with these sections, the Pavement Condition Rating (PCR) is equivalent to the average of the degree score at the intervals of sample taken; the summary results were presented as table4.13 below. The other distress measured data and its results in degree for all sections were depicted in distress Appendix G part.

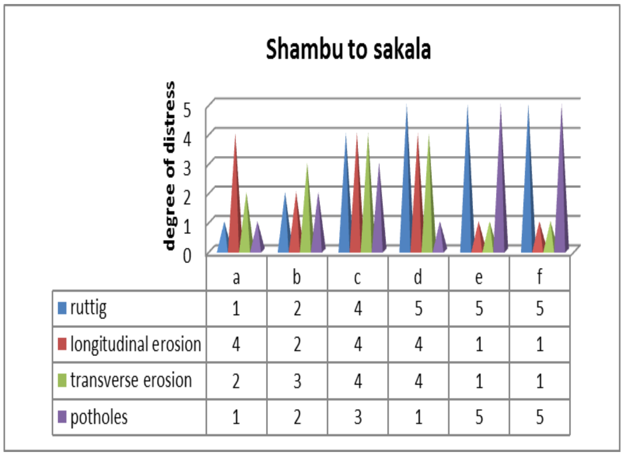
The analysis was carried out for all of sections, and then for each section the average of the degree was determined by using excels spreadsheet. For each section out of total sampled length the measured distress was taken as average, and then the degree is given for average value. The raw data was analyzed and summarized as shown in table below.

Table 4.14: summary of Average Degree of Distress type

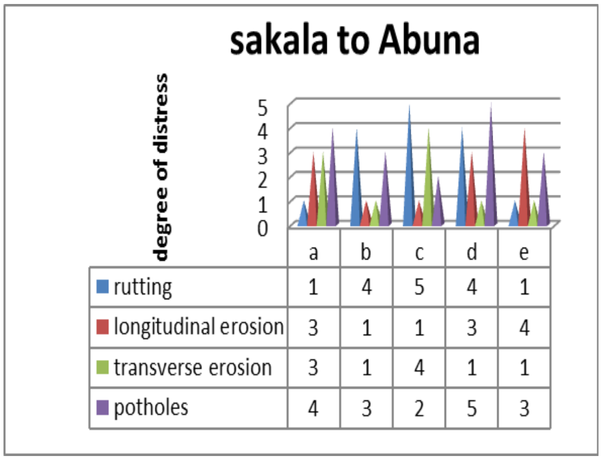
Secton	sample code	Average degree of each distress type			
		rutting	longitudinal erosion	transverse erosion	potholes
shambu-sakala	A	1	4	2	1
	B	2	2	3	2
	C	4	4	4	3
	D	5	4	4	1
	E	5	1	1	5
	F	5	1	1	5
Sakala-Abuna	A	1	3	3	4
	B	4	1	1	3
	C	5	1	4	2
	D	4	3	1	5
	E	1	4	1	3
Abuna-Shuluke	A	1	4	5	5
	B	1	1	4	4
	C	1	4	5	3
	D	5	2	4	1
	E	5	5	1	5
	F	5	3	1	2
Shuluke-Jarmat	A	5	5	3	5
	B	3	5	1	5
	C	5	4	5	1
	D	5	5	5	3
	E	3	1	1	3
rm at- Ja	A	3	5	1	5

	B	4	1	5	5
	C	5	5	3	1
	D	5	5	5	3
	E	1	5	1	1
	F	3	3	5	1
Jarte-Amuru	A	2	5	1	1
	B	3	1	2	3
	C	5	3	5	1
	D	5	3	1	5
	E	5	5	3	5
	F	1	1	1	2

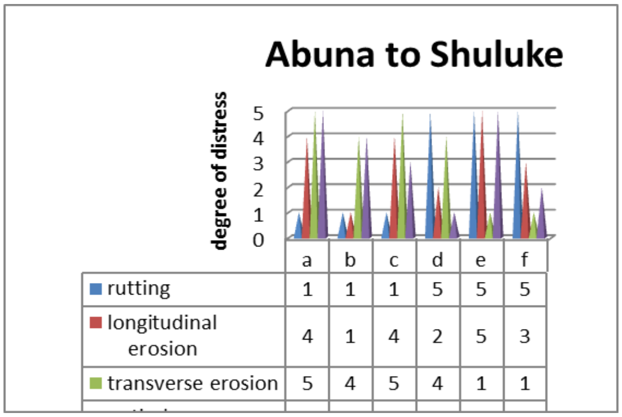
Where sample codes a, b, c, d, e, f, are represents the average value of the measurement at samples taken in each section of the segment and the numbers 1, 2, 3, 4, and 5 are represents for average degrees of distress. The summary of distress summarized in table above were analyzed and interpreted by graph as below for each section of the road along the study segment.



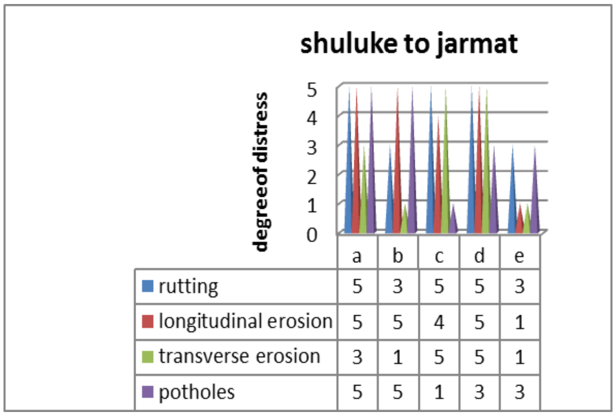
	a	b	c	d	e	f
ruttig	1	2	4	5	5	5
longitudinal erosion	4	2	4	4	1	1
transverse erosion	2	3	4	4	1	1
potholes	1	2	3	1	5	5



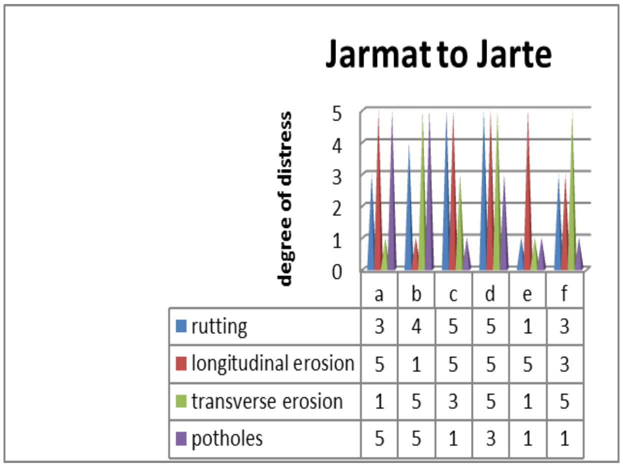
	a	b	c	d	e
rutting	1	4	5	4	1
longitudinal erosion	3	1	1	3	4
transverse erosion	3	1	4	1	1
potholes	4	3	2	5	3



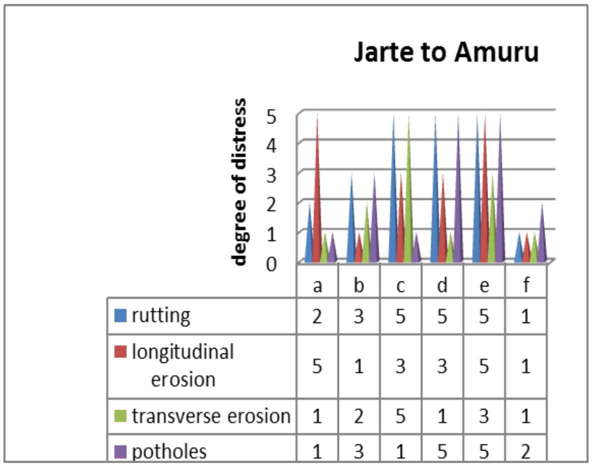
	a	b	c	d	e	f
rutting	1	1	1	5	5	5
longitudinal erosion	4	1	4	2	5	3
transverse erosion	5	4	5	4	1	1



	a	b	c	d	e
rutting	5	3	5	5	3
longitudinal erosion	5	5	4	5	1
transverse erosion	3	1	5	5	1
potholes	5	5	1	3	3



	a	b	c	d	e	f
rutting	3	4	5	5	1	3
longitudinal erosion	5	1	5	5	5	3
transverse erosion	1	5	3	5	1	5
potholes	5	5	1	3	1	1



	a	b	c	d	e	f
rutting	2	3	5	5	5	1
longitudinal erosion	5	1	3	3	5	1
transverse erosion	1	2	5	1	3	1
potholes	1	3	1	5	5	2

Figure 4.8: degree of distress along the study sections

Roadways will not have all types of distress at any particular time. They may only have one or two of the individual distresses.

During the data collection detail observation was taken and the following points were discussed

- ✓ At steep grades and curves there is high degree of surface erosion both longitudinal and transverse erosion.

  This is due to high this result highly reduces the speed of vehicles up to impassibility during high rainfall season, after exposure to sub grade layer.
- ✓ At flat grades Rutting and potholes with high degree were observed which requires immediate attention because larger, dangerous potholes requiring evasive action. And they are the most distress types which reduces the performance of the road.

  The rutting was developed due high heavy vehicles during May to June when heavy Vehicles are hauling fertilizers for farmers. And potholes were developed when the rutted areas cumulates water during rainfall time.

Most of the sections of the road segment was with different degree of distresses from degree 1 to degree5, which means a fared badly on erosion, rutting, and potholes are the severely damaged section and the minimum severity with degree 1, which is not significantly visible distress.

- ❖ The following is the general state of distressed conditions on test sections for all distress types observed during the study time. These were:
  - The distress conditions with degree 1 was very small in percent, which was less than 15% in all sections and the degree 2 and degree 3 conditions were between 5% to 20%.the high degree distresses, degree4 and degree 5 were ranges from 20% to 60% of in most sections of the study. Thus, this result shows the road along the study segment is in poor condition due to the high degree severity of distress.
  - Most of the sections were under poor and very poor condition by more than 60% as the analysis of distress shows.
- ❖ Depending on the severity of the distress on the road the following remedial measures were recommended

Potholes were exist at bottom of the grades and at flat areas though out each section. In most sections it occurs as an isolated defect and these require spot-patching or maintenance from a safety standpoint. Extensive (over 25 percent of the area) and deep (over 4 in.) potholes are an indication of lack of strength and the need for more major rehabilitation and the addition of gravel. Potholes trap water and can speed surface deterioration if routine maintenance is not provided. Thus, regravelling on the areas of the road which was damaged by potholes is necessary to efficiently perform its function.

Rutting is another important defect to consider. Minor (less than degree 2 rutting in the wheel path may be simply an indication of a heavy traffic volume. By Routine regrading and maintaining it can be corrected as a good surface and keeping the drainage can remedy this defect. Deeper rutting (degree3 and above) may indicate lack of gravel thickness or subgrade support. This defect is very serious and usually indicates that major reconstruction is required.

The authors of this study believe the excessive erosions, and potholes and rutting observed during the study can be directly attributed to the weakening of the subgrade and consequent under design of the sections that resulted in contributing as the main factors in affecting the gravel road maintenance. These primary factors have to be inadequate design due to weakening of the subgrade via increased moisture content and reduced shear strength.

Erosion is one of the defect available on the road, especially longitudinal erosions mostly occurs on steep grades and transverse erosions on high grades and mostly on curves and this erosions on high grades and curves were with high degrees. These defects can be corrected by regravelling with qualified and non erodible material with proper construction method

Generally, the materials for surface wearing gravel were weak as the results of the test shows it was low CBR strength and high percentage of fine particles which could be easily eroded under normal traffic. On the other hand, at high gradients there is erosion even if it is strong enough, so correcting the gradient as per standard for gravel road can reduce the amount of such distress.

4.3.2. The extent of distress types along the study

The extent of distress is a measure of how widespread the distress is over the length of the road segment. The extent is also indicated on a five-point scale in which the length of road affected by the distress is estimated as a percentage. The extent of the distress is recorded from the type of distresses measured and detail observational assessment. The general description of the extent classifications for isolated occurrence (1), scattered occurrence over most of length or extensive occurrence over a limited portion of the length (3), and by extensive occurrence (5) as per Standard visual assessment manual for unsealed roads [35].

The percentage of each degree of distress type is found by multiplying the frequency of each degree by average of sampling interval and divided it by total sampling length.

Estimate in % of degree = [(frequency of each degree x average of sampling)/(total sample length)] x 100%

Then using this formula the percentage of degree and from the results of each percent the extent of each degree of distress was found by using excel spreadsheet. The general description of extent classification was as per standard manual assessment for unpaved roads. The result was presented as function of percentage of degree of distress, and summarized as shown below.

From the results of the distress, three distress types namely rutting, longitudinal erosion and transverse erosion are the most abundantly appear on the road along the study segment and Its effect on performance of that road. The extent to which erosion occurs depends on soil types, slope, climate, and vegetation.

Table 4.15: Summary of extent and degree analysis result of distress types

segnt sec.		degree 1		degree 2		degree 3		degree 4		degree 5	
	type of distress	frqcy	(%)	frqcy	(%)	Frqcy	(%)	frqcy	(%)	Frqcy	(%)
shambu-sakala	Rutting	1	16.67	1	16.67	0	0.00	1	16.67	3	50.00
	Extent	2		2		1		2		3	
	L/erosion	2	33.33	1	16.67	0	0.00	3	50.00	0	0.00

	Extent	3		2		1		3		1	
	t/erosion	1	16.67	0	0.00	2	33.33	2	33.33	0	0.00
	Extent	2		1		3		3		1	
	Potholes	2	33.33	1	16.67	1	16.67	0	0.00	2	33.33
	Extent	3		2		2		1		3	
Sakala-Abuna	Rutting	2	40.00	0	0.00	0	0.00	2	40.00	1	20.00
	Extent	2		2		1		2		3	
	L/erosion	2	40.00	0	0.00	2	40.00	1	20.00	0	0.00
	Extent	3		2		1		3		1	
	t/erosion	3	60.00	0	0.00	1	20.00	1	20.00	0	0.00
	Extent	2		1		3		3		1	
	Potholes	0	0.00	1	20.00	2	40.00	1	20.00	1	20.00
	Extent	3		2		2		1		3	
Abuna-Shuluke	Rutting	3	50.00	0	0.00	0	0.00	0	0.00	3	50.00
	Extent	2		2		1		2		3	
	L/erosion	1	16.67	1	16.67	1	16.67	2	33.33	1	16.67
	Extent	3		2		1		3		1	
	t/erosion	2	33.33	0	0.00	0	0.00	2	33.33	2	33.33
	Extent	2		1		3		3		1	
	Potholes	1	16.67	1	16.67	1	16.67	1	16.67	2	33.33
	Extent	3		2		2		1		3	
Shuluke-Jarmat	Rutting	0	0.00	0	0.00	2	40.00	0	0.00	3	60.00
	Extent	2		2		1		2		3	
	L/erosion	1	20.00	0	0.00	0	0.00	1	20.00	3	60.00
	Extent	3		2		1		3		1	
	t/erosion	2	40.00	0	0.00	1	20.00	0	0.00	2	40.00
	Extent	2		1		3		3		1	
	Potholes	1	20.00	0	0.00	2	40.00	0	0.00	2	40.00
	Extent	3		2		2		1		3	
Jarmat-Jarte	Rutting	1	16.67	0	0.00	2	33.33	1	16.67	2	33.33
	Extent	2		2		1		2		3	
	L/erosion	1	16.67	0	0.00	1	16.67	0	0.00	4	66.67

	Extent	3		2		1		3		1	
	t/erosion	2	33.33	0	0.00	1	16.67	0	0.00	3	50.00
	Extent	2		1		3		3		1	
	Potholes	3	50.00	0	0.00	1	16.67	0	0.00	2	33.33
	Extent	3		2		2		1		3	
Jarte-Amuru	Rutting	1	16.67	1	16.67	1	16.67	0	0.00	3	50.00
	Extent	2		2		1		2		3	
	L/erosion	2	33.33	0	0.00	2	33.33	0	0.00	2	33.33
	Extent	3		2		1		3		1	
	t/erosion	3	50.00	1	16.67	1	16.67	0	0.00	1	16.67
	Extent	2		1		3		3		1	
	Potholes	2	33.33	1	16.67	1	16.67	0	0.00	2	33.33
	Extent	3		2		2		1		3	

4.4. Adequacy of side drainage

Side drainage is one of the most significant factors among the factors affecting pavement performance, and can be quantified in terms of the ‘drainage factor (DF).This is the product of the height of the crown of the road above the bottom of the ditch (h) and the horizontal distance from the centre-line of the road to the bottom of the ditch (d).The side drainage data were attached on the appendix part. From the collected data is analyzed and the results were summarized.

Identifying the distress types to its degree and extent is very important for planning for the maintenance type required depending on its extent and degree. The analysis of performance of gravel road, in case of drainage factors were very poor drainage quality increases with increase in the saturation time. If the saturation time is more and drainage quality is the worst, then the performance of low volume roads is the worst [51].

4.4.1. Side drainage results and discussion

Provision of adequate drainage is an important factor in the location and geometric design of highways. Drainage facilities on any highway or street should adequately provide for the flow of water away from the surface and subsurface of the pavement to properly designed channels and then discharge to the natural waterways. Inadequate drainage will eventually result in: Serious damage to road structure, Traffic operation problems by Slow traffic movement by accumulated water on the pavement Cause traffic accidents as a result of loss of visibility[highway engineering handout].Thus, drainage is one of the most important components which affect the performance of the roads. So it is important to evaluate is adequacy. Here in this case the study used the side drainage factor method. The results of the data was then analyzed and classified as good, moderate, poor and very poor depending on the value of DF and summarized as table below

Table 4.16: Summary of the average side drainage results classifications (shambu to Shuluke)

Sample place /sections	NO.	drainage parameters				Side drainage factor, DF= d*h		classification of the drainage	
		d(m)		h(m)					
		L	R	L	R	L	R	L	R
avg. of shambu to sakala at each sample	1	5.81	5.79	0.44	0.69	2.53	3.98	Poor	Poor
	2	2.99	3.49	0.79	0.00	2.34	0.00	very poor	free drainage/good
	3	4.59	4.72	0.71	1.04	3.27	4.92	Poor	Moderate
	3	5.40	5.40	0.54	0.58	2.92	3.13	Poor	Poor
	5	5.20	5.15	0.79	0.78	4.09	4.02	moderate	Moderate
	6	5.97	5.85	0.64	0.57	3.82	3.32	Poor	Poor
avg. value of sakala to Abuna	1	5.32	3.96	0.52	0.69	2.78	2.71	Poor	Poor
	2	3.49	3.84	1.21	0.00	4.11	0.00	moderate	free drainage/good
	3	4.64	4.27	0.70	0.54	3.21	2.30	Poor	very poor
	4	5.40	5.49	0.78	0.70	4.25	3.87	moderate	Moderate
	5	3.50	4.00	1.42	0.00	4.98	0.00	moderate	free drainage/good
avg. Valve of AbunaShuluke	1	4.72	4.00	0.72	0.00	3.40	0.00	Poor	free drainage/good
	2	5.20	4.53	1.27	0.16	6.59	0.86	Good	very poor
	3	5.56	5.58	0.30	0.39	1.67	2.18	Poor	very poor
	4	5.42	5.49	0.64	0.25	3.49	1.37	Poor	very poor

	5	3.22	3.39	0.79	0.70	2.54	2.41	Poor	very poor
	6	3.18	3.36	1.33	0.50	4.22	1.67	moderate	very poor

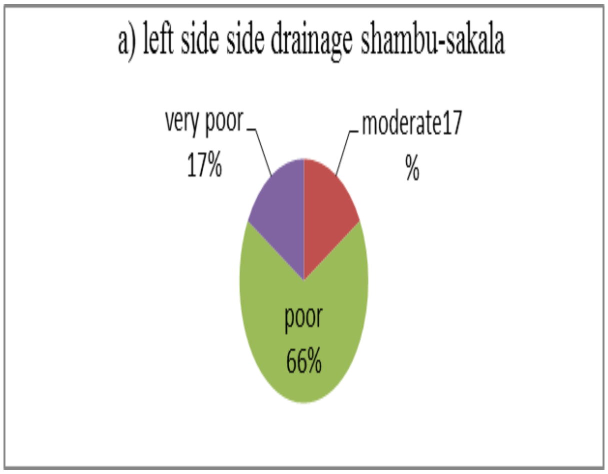
Table 4.17: Summary of the average side drainage results classifications (Shuluke to Amuru)

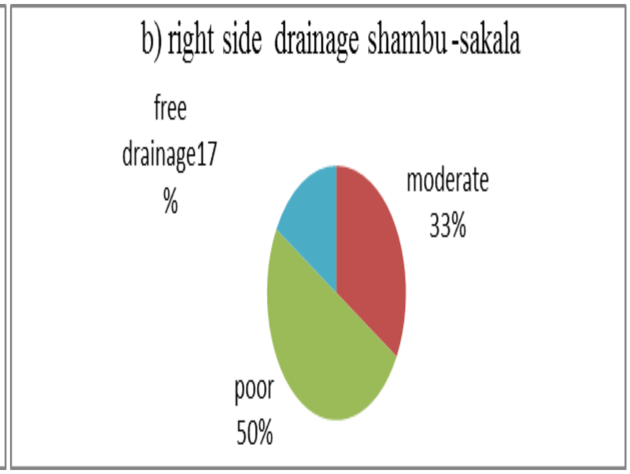
Sample	NO.	drainage parameters				drainage factor, DF= d*h		classification of the drainage	
		d(m)		h(m)					
		L	R	L	R	L	R	L	R
Shuluke to Jarmat	1	4.00	3.50	0.00	1.55	0.00	5.42	free drainage/good	Moderate
	2	5.40	4.58	0.17	0.44	0.93	1.95	very poor	very poor
	3	4.09	3.89	0.54	0.53	2.22	2.06	very poor	very poor
	4	5.81	5.97	0.61	0.59	3.57	3.53	Poor	Poor
	5	6.12	6.11	1.64	1.54	10.01	9.42	Good	Good
Jarmat to Jarte	1	5.48	5.81	1.23	1.24	3.35	4.48	Good	good
	2	5.06	5.20	1.00	0.92	4.02	4.29	Moderate	Moderate
	3	3.64	3.84	0.39	0.00	4.63	4.76	Poor	free /good
	4	5.82	3.53	0.00	0.67	5.11	5.29	Free drainage/good	Poor
	5	6.38	6.08	1.64	0.00	5.42	5.65	Free drainage/good	Poor
	6	6.38	6.08	1.64	0.00	4.51	4.89	Good	Moderate
Jarte to Amuru	1	3.03	2.63	0.00	0.94	0.00	2.50	free drainage/good	very poor
	2	5.32	5.21	0.67	1.27	3.55	6.62	Poor	Good
	3	3.50	2.90	0.70	0.00	2.40	0.00	Poor	free drainage/good
	4	5.40	5.49	0.78	0.70	4.25	3.87	Moderate	Moderate
	5	5.23	4.90	0.55	0.52	2.87	2.50	Poor	very poor
	6	6.01	6.03	1.64	1.47	9.89	8.85	Good	Good

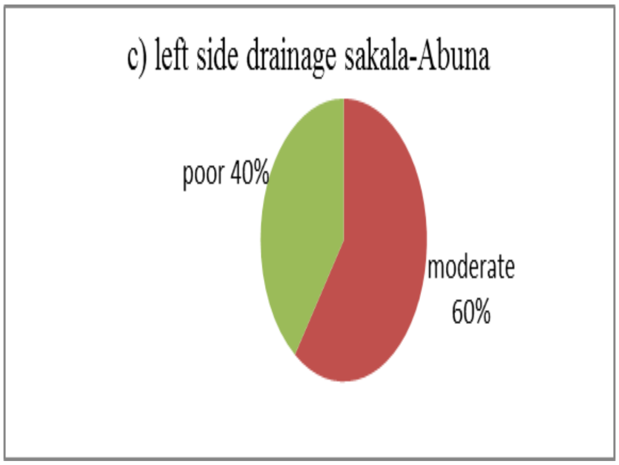
Table 4.18: Summary of the average side drainage classification in percentage

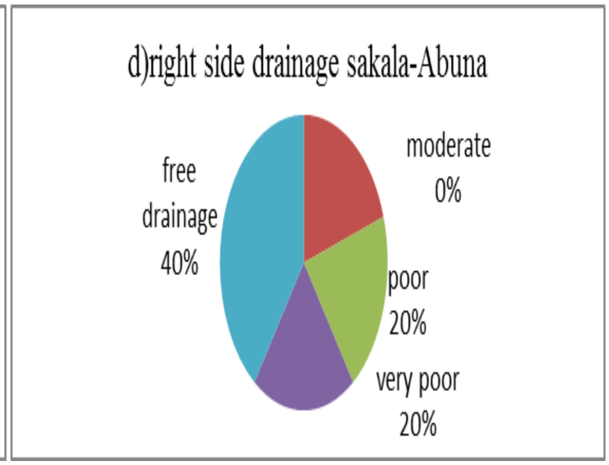
Sample place	adequacy of drainage classification description	from avrg.total sample taken		estimation in (%)	
		L	R	L	R
shambu - sakala	good	0	0	0	0
	moderate	1	2	17	33
	poor	4	3	67	50
	very poor	1	0	17	0
	free drainage	0	1	0	17
sakala - Abuna	good	0	0	0	0
	moderate	3	1	60	20
	poor	2	1	40	20
	very poor	0	1	0	20
	free drainage	0	2	0	40
Abuna- Shuluke	good	1	0	17	0
	moderate	1	0	17	0
	poor	4	0	67	0
	very poor	0	5	0	83
	free drainage	0	1	0	17
shuluke - Jarmat	good	1	1	20	20
	moderate	0	1	0	20
	poor	1	1	20	20
	very poor	2	2	40	40
	free drainage	1	0	20	0
Jarmat - Jarte	good	2	1	33	17
	moderate	1	2	17	33
	poor	1	2	17	33
	very poor	0	0	0	0
	free drainage	2	1	33	17
Jarte-Amuru	good	1	2	17	33
	moderate	1	1	17	17
	poor	3	0	50	0
	very poor	0	2	0	33
	free drainage	1	1	17	17

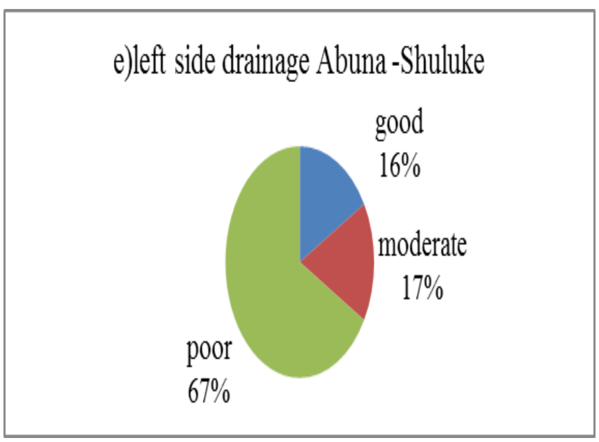
From the results analyzed in percentage which is summarized on the table above then it was put in bar chart as figure below.

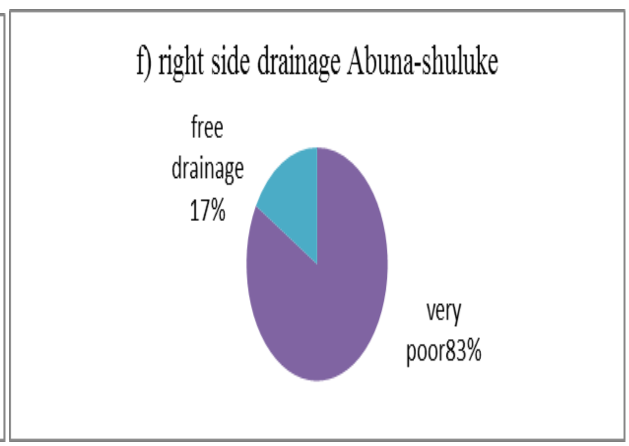

a) left side side drainage shambu-sakala
very poor 17%
moderate17 %
poor 66%


b) right side drainage shambu -sakala
free drainage17 %
moderate 33%
poor 50%


c) left side drainage sakala-Abuna
poor 40%
moderate 60%


d)right side drainage sakala-Abuna
free drainage 40%
moderate 0%
poor 20%
very poor 20%


e)left side drainage Abuna -Shuluke
good 16%
moderate 17%
poor 67%


f) right side drainage Abuna-shuluke
free drainage 17%
very poor83%

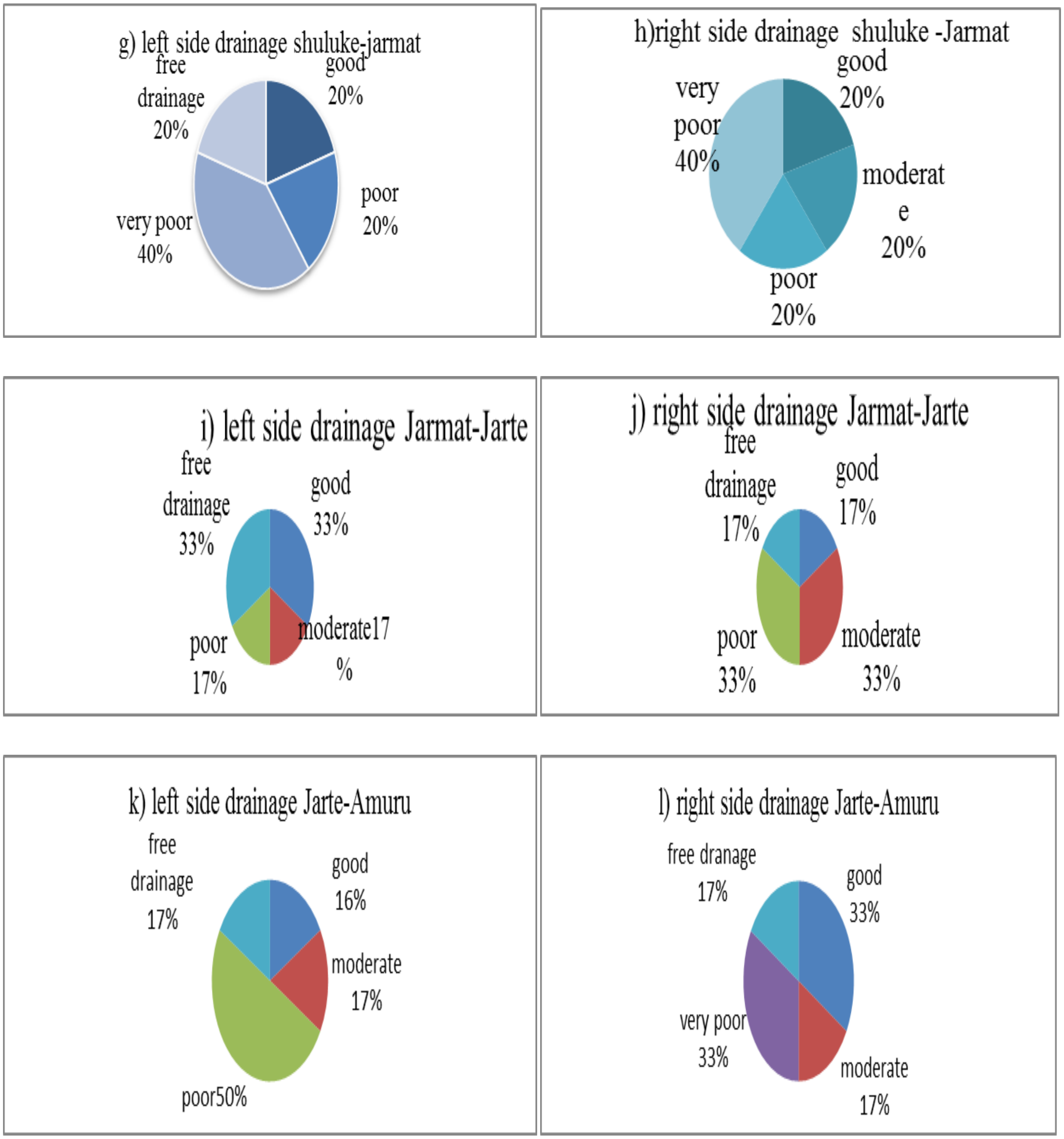


Figure 4.9: Side drainage factor classification in the pie char

Continues flow of suface water over shoulder, side slopes and unlined channels often results in soil erosion which can lead to conditions that are detrimental to the road structure, embankments and cut sections. From the analysis result of side drainage factor the following points were discussed as below.

- ✓ At steep grade High percentage of the side drainage was poor, due to scour and highly damaged by erosions.
- ✓ At flat areas at major sections the adequacy is poor; this is due to sedimentation of soil particles at bottom of the grades.
- ✓ The free drainage and at minor section the side drainage is good.

4.4. Recommendation and Remedial Measures

4.4.1. Recommendation Remedial Measures on material properties

The performance of unsealed road depends primarily on the quality sub grade and the gravel used to construct the wearing course**.** On the other hand, the location and topography of the road and the volume of traffic using the road has big influence on performance of gravel road. Gravel roads passing through populated areas in particular require materials that do not generate excessive dust in dry weather. Steep gradients place particular demands on gravel wearing course materials, which must not become slippery in wet weather or erode easily. Consideration should therefore be given to the type of gravel wearing course material to be used in particular locations such as towns or steep sections.

Key material properties influencing unpaved road performance include the grading or particle size distribution, the fines content, the clay content, and the material shear strength. These are determined from basic material indicator tests including a grading analysis, a plasticity test (Atterberg, test) and a strength test for California Bearing Ratio CBR. Depending on the results of material properties grading various particle size fractions, plastic limit, moisture content and dry density, and California bearing ratio) and standard material as per specification the following recommendation are given as below.

- **Recommended material properties of sub grade soils**

The results of the test shows that the sub grade soils are vary from silt sand to silty clay soils. And have low CBR less than S4 as ERA classification. But the road along the segment Shambu to Amuru has high volume traffic so it is recommended that to improve the sub grade soil to increase the CBR to some extent. This can be achieved by adding selective material as capping layer**.**

- **Recommended material properties of surface Wearing materials**

The properties contributing to good gravel are particle size distribution and cohesion. The gravel should have a range of particle sizes ranging from very fine up to courser in order to provide a strong framework of stones interlocked by a tight matrix of fines. An excessive number of large stones results in poor riding quality and difficulties with maintenance. The fines need to have some plasticity to provide cohesion when dry. However, plasticity should not be so high that the road becomes slippery and impassable when wet. Here, in this study there were:

- High percent of particles passing sieve 0.075
- high plasticity values greater than 6
- weak or low CBR surface wearing

Therefore the following points are recommended to improve the material properties

- ✓ Find other source of local materials available and take all tests which can meet for gravel road specifications.
- ✓ Blending the existing material with other materials like crushed stone with natural gravel or a soil that can improve its strength is the best option.
- ✓ Showering the roadway in village during dry season to reduce the amount of dust that pollute the environment or Use the dust controlling chemical in order to reduce high volume dust.

- **Recommended remedial measures to be taken on distress types**

During the data collection period from the end month of may 2017 to end of august 2017 the high degree of distress exist on the segment was erosions both longitudinal and transverse, potholes and rutting, on the surface of the road. The extent of each distress is different from each segment section. Depending on the detail visual observation and field measurement results the following remedial measures are recommended.

The distress types with high degree need immediate action because it causes dangerous driving. Therefore the following measures are recommended:

- Potholes of the damaged sections where distress is shows more roughness (degree30 and extreme (degree5) of distress requires immediate attention shallow or deep blading or re-gravelling must be performed to keep the pavement safe. Leaving the potholes unmaintained cause deficiency in the layers and exposed to sub grade which in turn causes traffic impassability.
- Ruts are longitudinal depressions in the wheel paths caused by high moisture content in the subsurface soil or base, inadequate surface course thickness, and /or heavy traffic loads. Rutting can be corrected by adding suitable material, grading, crowning, and rolling the road surface. Do not simply fill ruts with stone or soil. Filing ruts with stone can lead to new ruts being generated beside the original ones and thus would be an expensive and temporary “fix” which can also interfere with grading. The surface must be re-mixed and properly bladed or graded in more severe cases.
- Erosions both longitudinal and transverse on surface of roads can also cause excessive wear and tear on vehicles and contribute to high levels of road dust, a significant issue in many rural areas and they are expensive to maintain, requiring continual grading to smooth out the effects of concentrated drainage flowing across the road surface
- ✓ The sections where Distress is distinct with severity of(degree 3),Start of secondary defects and Distress notable with respect to possible consequences, Maintenance might be required in near future e.g. potholes can be removed by blading)

❖ Generally, Crossfall on gravel and earth roads should be 4-6 per cent as per ERA standard specification. It is very important to ensure correct camber on steep alignments. ‘Flat’ cambers are frequently the cause of the longitudinal gullying commonly found on such alignments.

4.4.2. Recommended remedial measure on side drainage of the road

Side drainage adequacy is one of the most important factors in contribution for evaluating performance of roads. Because it greatly affects the whole structure of the road layer unless otherwise we properly put and give appropriate maintenance for side drainage.

The side drainage adequacy was very poor as the result of drainage factor shows and as shown on the figure given in appendix H.

The remedial measures to be taken depending on the results are:

- ✓ The side drainages at steep grades should be constructed of selected material which can resist erosion. Intercepting drains at the top of a cut to collect and transport runoff to spillways that are placed at strategic locations on the side cuts and then to the longitudinal ditches alongside the roadway.
- ✓ Check dams should be provided with locally available material to prevent erosion of side drainage.
- ✓ Regularly cleaning the side drainage when it is sediment and closed.
- ✓ Turf (grass) cover on unpaved shoulders, ditches, embankments to prevent erosion should be developed by sowing suitable grasses immediately after grading.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

To evaluate the performance of gravel road titled as, at performance evaluation of gravel road shambu to Amuru segment, Horo Guduru Wollega; the major factors that affect gravel roads were selected as objective of the study. The selected factors were evaluating the material property of sub grade soil and surface wearing course, the attributes of distress along the segment and side drainage adequacy. From observation result, the Sub grade soil silty clay soils and weak with CBR values less than 10 at six samples. The natural gravel surface wearing material were excessive fines, high PI values and low CBR strength which can easily deformed during wet season when heavy vehicles use the road.

The major defects on the gravel roads that lead to low performance of the road were identified. From observation of the sample roads, the major significant defects on the observed roads were rutting, erosion (longitudinal and transverse) and potholes. Although other factors such corrugation, dustiness and slipperiness could affect the gravel road performance, on the selected roads they were not observed.

During this study detail observation and measurements were conducted on samples of segment divided sections. In several of the sections, ist was determined that the primarily distress types were coming from high degree to low degree at all sections through the segment. Major defects identified are poor at high grades which are highly damaged by surface longitudinal erosion. And excessive potholes at flat grades, poor drainage elements (improper drainage and erosion damaged side drainage were found. The majority of the extent of the distress were longitudinal erosion by following the path of vehicle tires at steep grades and at flat areas it was observed highly damaged by potholes and when amount of rainfall increases during June and July it could be difficult for trafficability. More than 60% of the road sections were under poor condition as the analysis of distress shows by degree and extent.

This research experience has shown that it is essential to select a uniform and site specific data set of gravel road performance evaluation and use consistent methods to collect and record gravel road condition survey data. This is to ensure the compatibility and quality of data sets and make greater use of available data for improved statistical reliability in developing performance prediction models to evaluate relevant data to be used in the performance models.

5.2. Recommendations

From the findings of this research it is found that materials for gravel wearing course are marginal to use as surface wearing material. Therefore mixing, the locally available natural gravel with crushed rocks were recommended to Ethiopian Roads Authority, Nekemte district to use in maintenance and rebuild of Shambu to Amuru road segment the more improved material to upgrade the bearing capacity and to reduce the amount of fineness, high plasticity amounts which is causative for slipperiness during wet and dustive during dry season. The sub grade soil were **S3** and **S4** the CBR between **5** to **10** as ERA specification, thickness of gravelling material should be added than the recommended to keep on the performance of gravel roads well.

This study has certain limitations like the data for distress types is taken from only one wet season so that it is uncertain to generalize for all type of distresses appear on the road in all seasons during the year, Because every road project has its own unique condition in different time of environmental situation. Thus, field evaluation plan has been suggested to further validate the performance-related of identified distress types at dry season, wet season. This provide for monitoring of the road construction and performance as well as testing the adaptability of the highway department methods of field measurement evaluation and comparing the results with current procedure. As the result of distress types by their degree and extent analysis shows the current condition of the road was under poor condition, which requires immediate actions to be taken to perform its function.

There is a need for political will to be ready to allocate funds and sincerely implement the budget for this damaged road to become an effective and safety of user in the future condition needs and there is a need to study the interaction between the local climatic condition, the traffic characteristics, construction and maintenance standards which are specific to individual localities and effect of poor performance of gravel roads on the socio economic development of the community and as a whole on the county.

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Appendix A-Specific Gravity

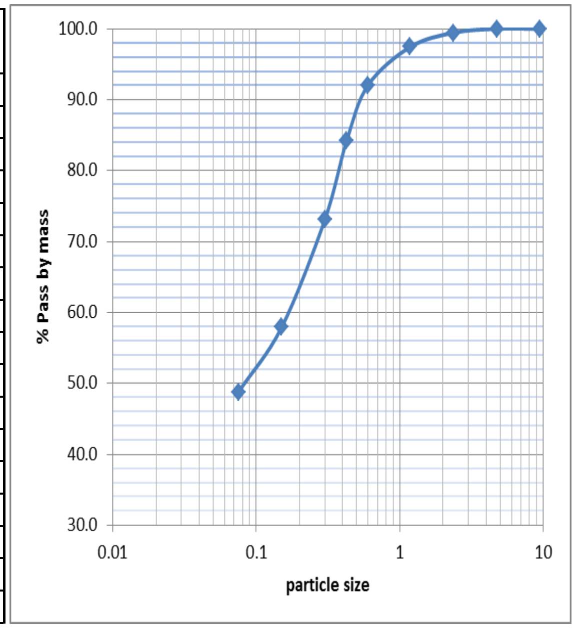
Specific Gravity Test result for sub grade and surface wearing gravel

sample type	No.	Mb	mbs	Mbws	mbw	Ms	Gs	Gs avg.	Temp. (o C)
Shambu SG Soil	1	28.853	38.718	85.661	79.223	9.865	2.879		
	2	28.749	38.689	85.771	79.466	9.940	2.735		
	3	28.09	38.015	85.874	79.997	9.925	2.452	2.69	23.00
Shambu SW	1	27.814	37.894	85.196	78.968	10.080	2.617		
	2	28.096	38.174	86.214	79.892	10.078	2.683		
	3	28.979	38.928	86.258	79.990	9.949	2.703	2.67	23.00
Abuna SG soil	1	28.864	38.780	85.665	79.023	9.916	3.029		
	2	27.613	37.555	84.596	78.466	9.942	2.608		
	3	28.024	38.105	85.768	79.897	10.081	2.395	2.68	21
Abuna SW course	1	27.926	37.994	85.197	78.968	10.068	2.623		
	2	28.139	38.274	86.206	79.892	10.135	2.652		
	3	28.919	38.928	86.246	79.990	10.009	2.667	2.65	24
Shuluke SG soil	1	27.864	37.780	84.875	78.723	9.916	2.634		
	2	27.613	37.425	84.446	78.066	9.812	2.859		
	3	28.024	38.205	85.963	79.897	10.181	2.474	2.66	22
shuluke SW	1	28.527	38.814	86.897	79.806	10.287	3.219		
	2	27.929	37.464	85.126	79.792	9.535	2.270		
	3	28.647	38.622	86.046	79.992	9.975	2.544	2.68	24
Jarmat SG SOIL	1	27.865	37.783	84.885	78.723	9.918	2.641		
	2	27.6121	37.414	84.4360	78.066	9.802	2.856		
	3	28.013	38.162	85.943	79.697	10.149	2.600	2.70	22.00
Jarmat SW	1	27.926	37.914	85.097	78.908	9.988	2.629		
	2	28.129	38.164	86.106	79.792	10.035	2.697		
	3	28.919	38.912	86.046	79.790	9.993	2.674	2.67	22.00
Irro SG Soli	1	27.923	37.741	84.861	78.721	9.818	2.669		
	2	28.104	38.389	85.992	79.717	10.285	2.565		
	3	27.579	37.209	84.368	78.138	9.630	2.832	2.69	22
Irro SW	1	27.869	37.978	85.119	78.992	10.109	2.539		
	2	28.078	38.069	86.142	79.972	9.991	2.615		
	3	27.529	37.711	85.661	78.994	10.182	2.897	2.68	22
hangar SG soil	1	27.887	37.793	84.645	78.823	9.906	2.426		
	2	27.711	37.814	84.803	78.187	10.103	2.897		
	3	28.129	38.282	85.913	79.697	10.153	2.579	2.63	20.00
hangar SW	1	27.869	37.668	84.685	78.473	9.799	2.732		
	2	28.078	38.034	84.436	78.266	9.956	2.630		
	3	27.529	37.201	85.913	79.897	9.672	2.646	2.67	21.00

Appendix B-Sieve Analysis

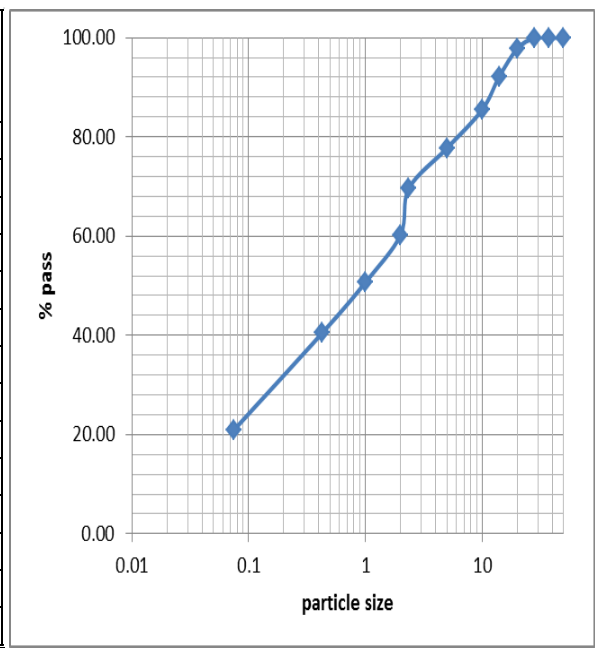
1. Sieve Analysis for Sub grade soil at Shambu Section

sieve size(mm)	mass retained(g	%retained	%passed
75	0	0.0	100.0
63.5	0	0.0	100.0
50	0	0.0	100.0
37.5	0	0.0	100.0
25	0	0.0	100.0
19	0	0.0	100.0
9.5	0	0.0	100.0
4.75	0	0.0	100.0
2.36	6	0.6	99.4
1.18	21.56	2.0	97.4
0.60	57.8	5.4	92.1
0.425	84.82	7.9	84.2
0.30	119	11.1	73.1
0.15	163	15.2	57.9
0.075	98	9.1	48.8
pan	524	48.8	0.0
Total weight before wash		=	1074.18



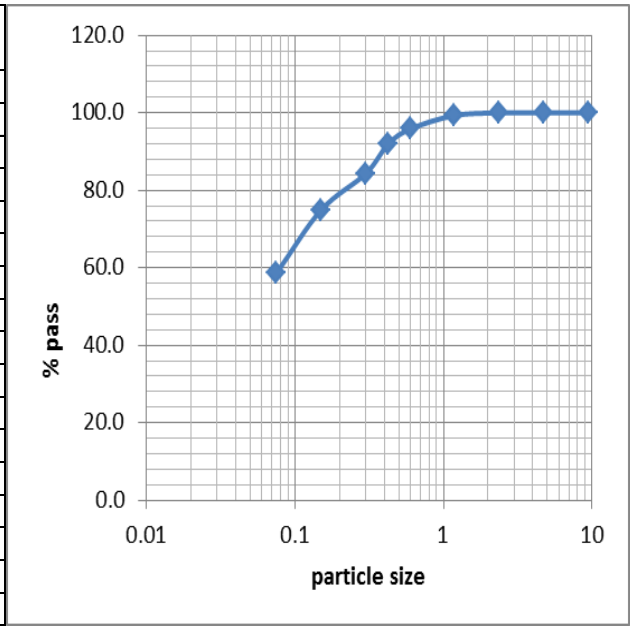
2.Sieve Analysis for Surface Wearing gravel at Shambu Section

sieve opening (mm)	mass of retained soil(g)	%retained by mass	% passed by mass
50	0	0.00	100.00
37.5	0	0.00	100.00
28	0	0.00	100.00
20	27	2.23	97.77
14	68	5.61	92.16
10	81	6.68	85.47
5	93.7	7.73	77.74
2.36	98	8.09	69.65
2	114	9.41	60.25
1	116	9.57	50.67
0.425	124	10.23	40.44
0.075	236	19.48	20.96
pan	254	20.96	0.00
Total wt.of dry soil before wash=			1211.7



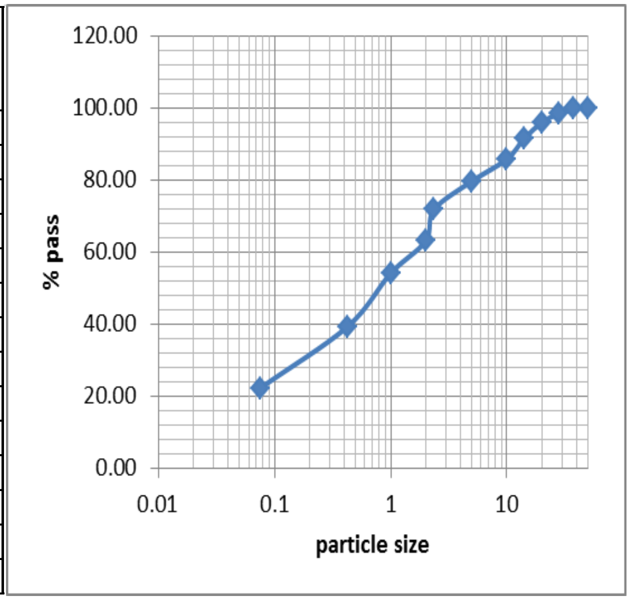
3. Sieve Analysis for Sub grade soil at Abuna Section

sieve size(mm)	mass retained(g	%retained	%passed
75	0	0.0	100.0
63.5	0	0.0	100.0
50	0	0.0	100.0
37.5	0	0.0	100.0
25	0	0.0	100.0
19	0	0.0	100.0
9.5	0	0.0	100.0
4.75	0	0.0	100.0
2.36	0	0.0	100.0
1.18	5.67	0.7	99.3
0.60	27.2	3.4	95.8
0.425	30.8	3.9	92.0
0.30	60.5	7.6	84.3
0.15	74.6	9.4	74.9
0.075	129	16.3	58.6
pan	464	58.6	_
Total weight before wash		=	791.51



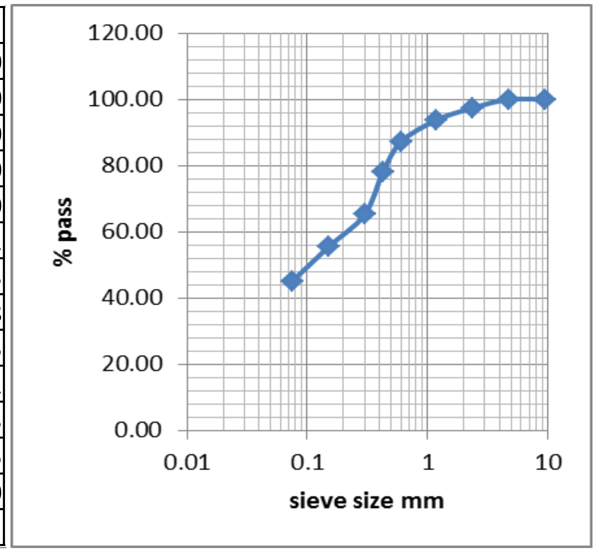
4. Sieve Analysis for Surface Wearing gravel at Abuna Section

sieve opening (mm)	mass of retained soil(g)	%retained by mass	% passed by mass
50	0.00	0.00	100.00
37.5	0.00	0.00	100.00
28	15.34	1.51	98.49
20	26.00	2.56	95.93
14	46.00	4.53	91.40
10	57.00	5.61	85.79
5	62.00	6.11	79.68
2.36	79.63	7.84	71.84
2	88.52	8.72	63.12
1	91.12	8.97	54.15
0.425	150.12	14.78	39.37
0.075	173.61	17.10	22.27
pan	226.15	22.27	_
Total wt.of dry soil before wash=			1015.52



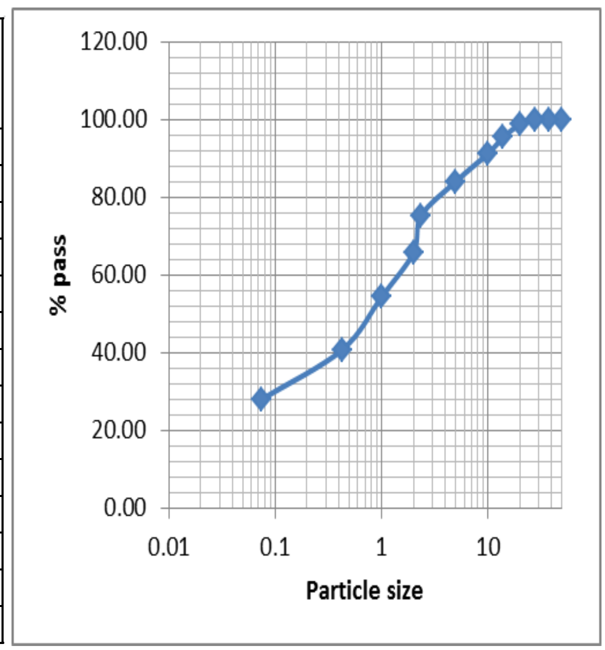
5.Sieve Analysis for Subgrade soil at Shuluke Section

ieve Size(mm	Wt.ret	% retaind	%passing
75	0	0.00	100.00
37.5	0	0.00	100.00
19	0	0.00	100.00
9.5	0	0.00	100.00
4.75	0	0.00	100.00
2.36	34	2.58	97.42
1.18	48.8	3.70	93.73
0.6	86.49	6.55	87.18
0.425	121.76	9.22	77.95
0.3	168	12.73	65.22
0.15	128	9.70	55.53
0.075	137	10.38	45.15
Pan	596	45.15	0.00
Total wt.	1320.05		



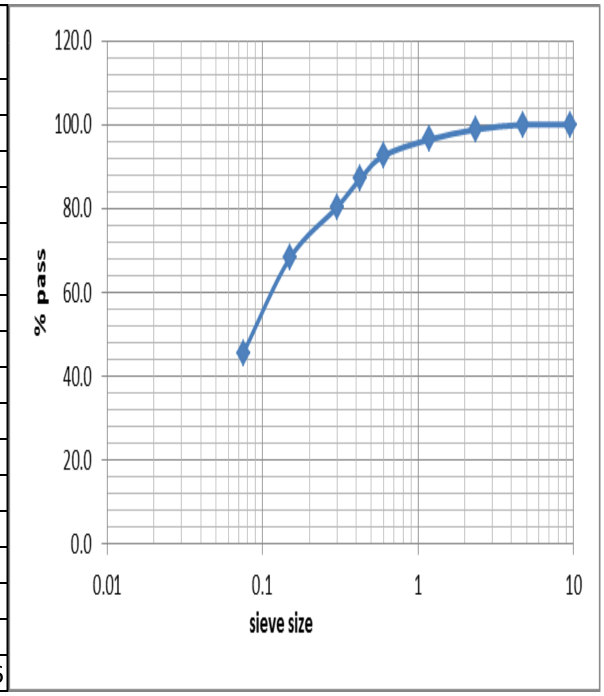
6.Sieve Analysis for Surface Wearing gravel at Shuluke Section

sieve opening (mm)	mass of retained soil(g)	%retained by mass	% passed by mass
50	0	0.00	100.00
37.5	0	0.00	100.00
28	0	0.00	100.00
20	14	1.28	98.72
14	35.67	3.26	95.46
10	46.5	4.25	91.22
5	78	7.12	84.09
2.36	96.2	8.79	75.31
2	104	9.50	65.81
1	125.1	11.43	54.38
0.425	149.1	13.62	40.76
0.075	138.59	12.66	28.10
pan	307.68	28.10	0.00
Total weight of dry soil before washing= 1094.84			



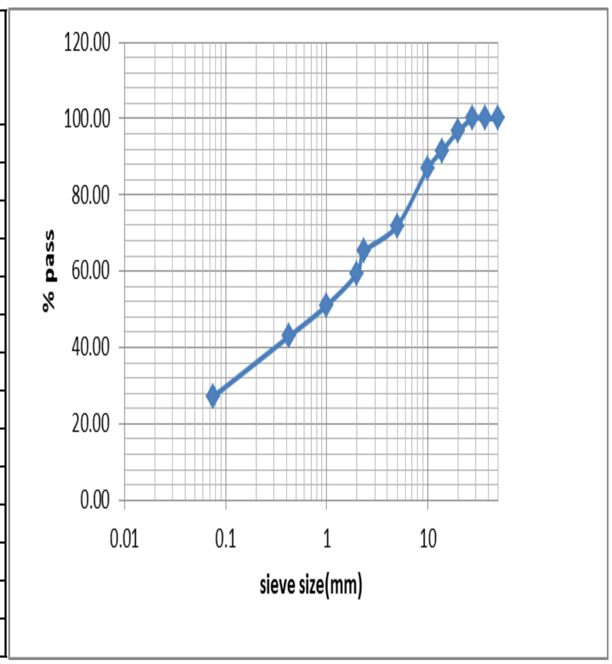
7. Sieve Analysis for Subgrade soil at Jarmat Section

sieve size(mm)	mass retained(gm	%retained	%passed
75	0	0.0	100.0
63.5	0	0.0	100.0
50	0	0.0	100.0
37.5	0	0.0	100.0
25	0	0.0	100.0
19	0	0.0	100.0
9.5	0	0.0	100.0
4.75	0	0.0	100.0
2.36	9.58	1.1	98.9
1.18	20.4	2.4	96.5
0.60	32.8	3.9	92.6
0.425	46.36	5.5	87.1
0.30	58.27	6.9	80.3
0.15	102	12.0	68.3
0.075	192.45	22.7	45.6
pan	387	45.6	_
Total weight before wash		=	848.86



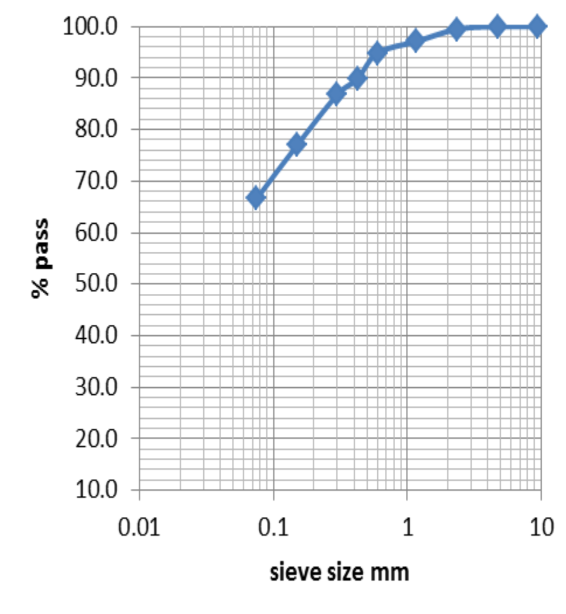
8. Sieve Analysis for Surface Wearinggravel at Jarmat Section

sieve opening (mm)	mass of retained soil(g)	%retained by mass	% passed by mass
50	0	0.00	100.00
37.5	0	0.00	100.00
28	0	0.00	100.00
20	48	3.36	96.64
14	71	4.97	91.67
10	69	4.83	86.84
5	213	14.92	71.92
2.36	96	6.72	65.20
2	82.53	5.78	59.42
1	120	8.40	51.02
0.425	115.52	8.09	42.93
0.075	226	15.83	27.10
pan	387	27.10	0.00
Total weight of dry soil before washing= 1428.05			



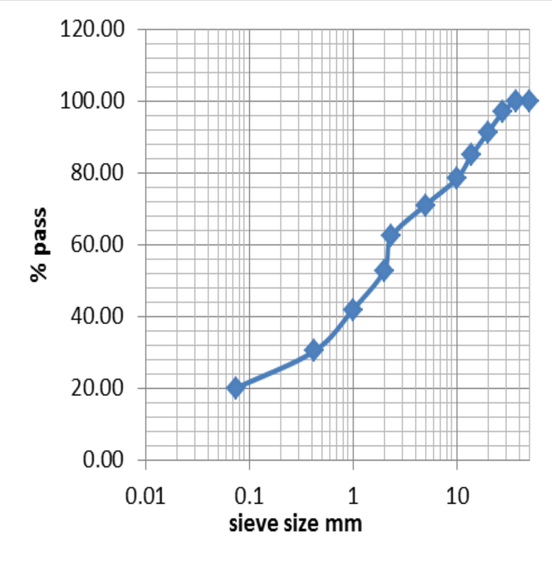
9. Sieve Analysis for Subgrade soil at Irro Section

sieve size(mm)	mass retained(g	%retained	%passed
75	0	0.0	100.0
63.5	0	0.0	100.0
50	0	0.0	100.0
37.5	0	0.0	100.0
25	0	0.0	100.0
19	0	0.0	100.0
9.5	0	0.0	100.0
4.75	0	0.0	100.0
2.36	6.7	0.5	99.5
1.18	30.2	2.4	97.1
0.60	29	2.3	94.9
0.425	64.4	5.0	89.8
0.30	39.16	3.1	86.8
0.15	126	9.8	76.9
0.075	132	10.3	66.6
pan	853.3	66.6	_
Total weight before wash		=	1280.76



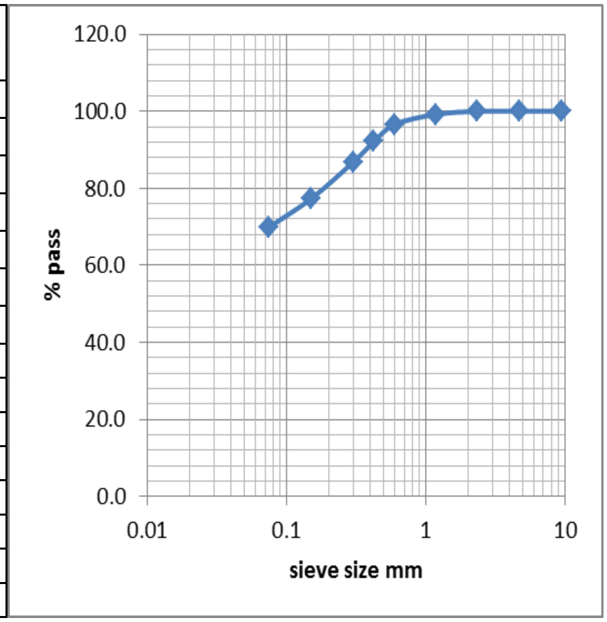
10. Sieve Analysis for Surface Wearing gravel at Irro Section

sieve opening (mm)	mass of retained soil(g)	%retained by mass	% passed by mass
50	0	0.00	100.00
37.5	0	0.00	100.00
28	52.6	3.07	96.93
20	98.4	5.75	91.18
14	106.22	6.20	84.98
10	114	6.66	78.33
5	125	7.30	71.03
2.36	148.9	8.69	62.33
2	164	9.58	52.76
1	185.26	10.82	41.94
0.425	197	11.50	30.44
0.075	176	10.28	20.16
pan	345.3	20.16	0.00
Total weight of dry soil before washing= 1712.68			



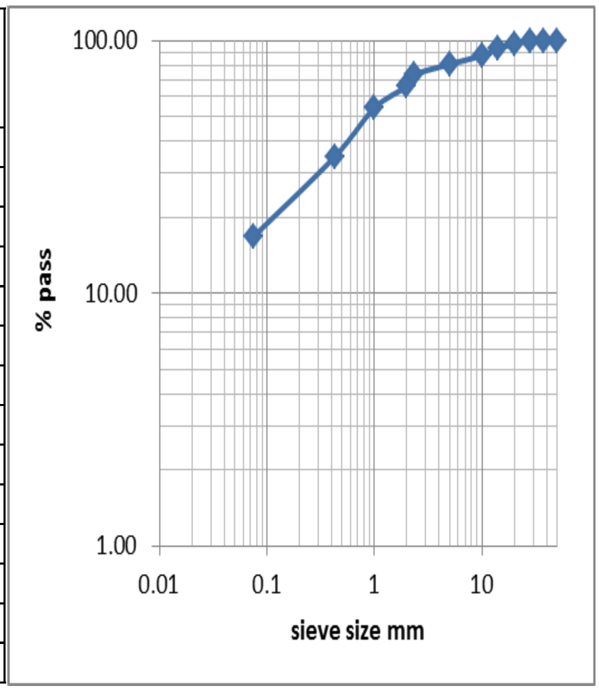
11. Sieve Analysis for Subgradesoil at Hangar Section

sieve size(mm)	mass retained(gm)	%retained	%passed
75	0	0.0	100.0
63.5	0	0.0	100.0
50	0	0.0	100.0
37.5	0	0.0	100.0
25	0	0.0	100.0
19	0	0.0	100.0
9.5	0	0.0	100.0
4.75	0	0.0	100.0
2.36	0	0.0	100.0
1.18	13	0.8	99.2
0.60	41	2.6	96.6
0.425	72	4.5	92.1
0.30	86	5.4	86.8
0.15	152	9.5	77.3
0.075	118	7.4	70.0



12. Sieve Analysis for Surface Wearing gravel at Hangar Section

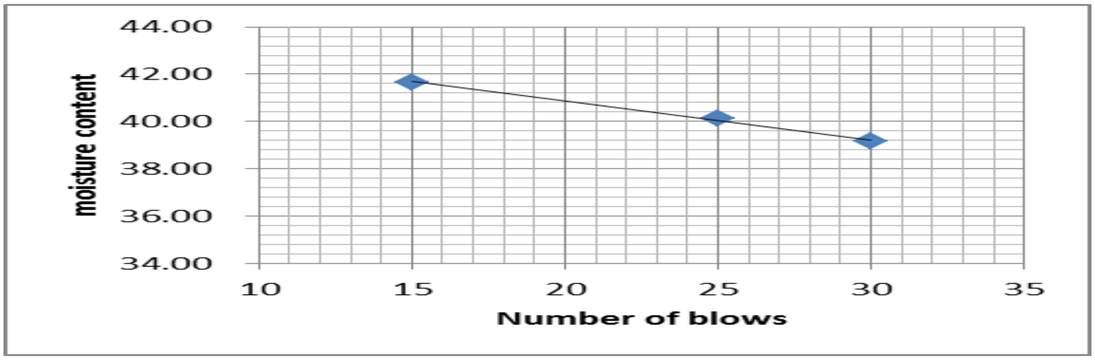
sieve opening (mm)	mass of retained soil(g)	%retained by mass	% passed by mass
50	0	0.00	100.00
37.5	0	0.00	100.00
28	0	0.00	100.00
20	46	2.90	97.10
14	62.8	3.96	93.14
10	91.86	5.79	87.35
5	108.12	6.82	80.53
2.36	114.78	7.24	73.29
2	117.8	7.43	65.87
1	185.1	11.67	54.20
0.425	309.6	19.52	34.68
0.075	284.19	17.92	16.76
pan	265.8	16.76	0.00
Total weight of dry soil before washing= 1586.05			



Appendix C- Determination of Liquid Limit & Plastic Limit and Plastic index

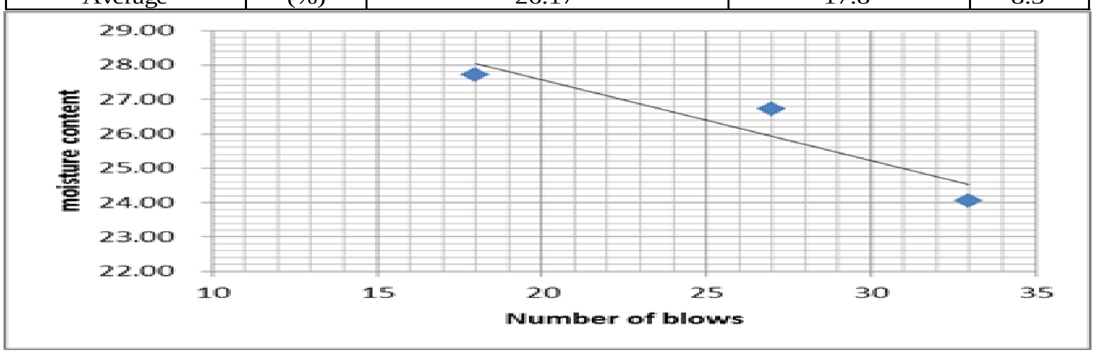
1. Determination of Liquid Limit & Plastic Limit at Shambu Subgrade Soil

Determination		Liquid Limit			Plastic Limit		plastic index
Number of blows		30	25.00	15.00			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	1A	FG	SH	AZ	A4	
Wt. of container + wet soil,	(g)	61.11	58.76	60.04	31.22	32.43	
Wt. of container + dry soil,	(g)	48.29	46.54	47.62	28.71	29.89	
Wt. of container,	(g)	15.53	16.1	17.82	17.20	16.90	
Wt. of water,	(g)	12.83	12.22	12.41	2.52	2.54	
Wt. of dry soil,	(g)	32.76	30.44	29.80	11.51	12.99	
Moisture container,	(%)	39.15	40.15	41.65	21.88	19.51	
Average	%	40.32			20.7	20.70	19.62



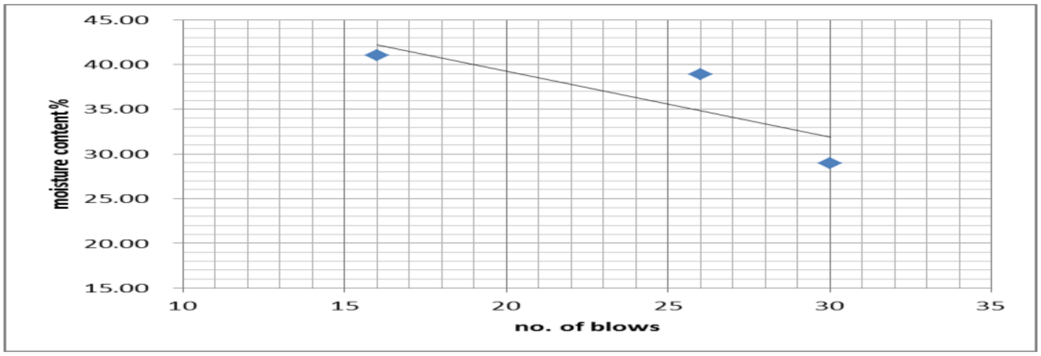
2. Determination of Liquid Limit & Plastic Limit at Shambu Surface Wearinggravel

Determination		Liquid Limit			Plastic Limit		plastic index
Number of blows		33	27	18			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	AE	B23	G	E	Dc	
/t. of container + wet so	(g)	55.36	48.57	54.87	19.44	19.76	
/t. of container + dry so	(g)	47.99	42.01	46.74	17.58	17.49	
Wt. of container,	(g)	17.33	17.47	17.42	6.147	5.79	
Wt. of water,	(g)	7.38	6.56	8.13	1.86	2.28	
Wt. of dry soil,	(g)	30.65	24.54	29.32	11.43	11.69	
Moisture container,	(%)	24.06	26.72	27.72	16.23	19.45	
Average	(%)	26.17			17.8		8.3



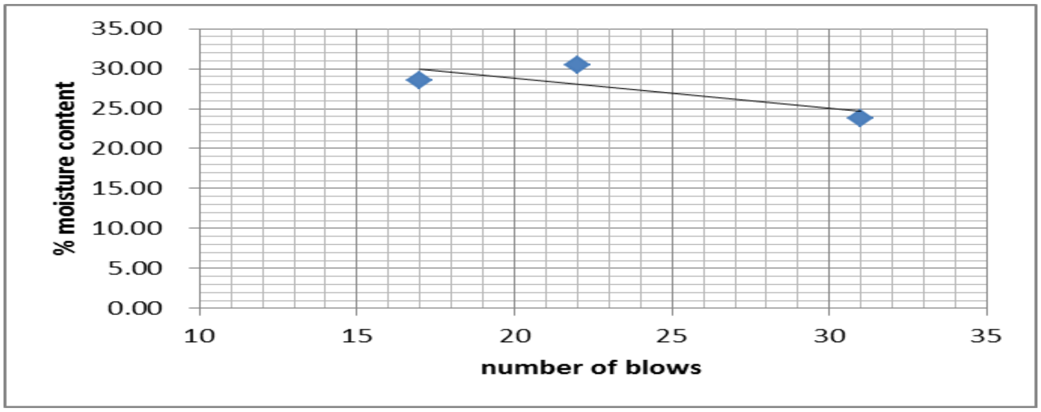
3.Determination of Liquid Limit & Plastic Limit at Abuna Subgrade Soil

Determination		Liquid Limit			Plastic Limit		plastic index
Number of blows		30	26	16			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	b	a	c1	c2	b4	
Wt. of container + wet soil	(g)	38.44	45.24	47.82	22.10	22.28	
Wt. of container + dry soil	(g)	33.54	37.13	39.12	21.06	21.23	
Wt. of container	(g)	16.60	16.28	17.90	15.69	15.38	
Wt. of water,	(g)	4.90	8.11	8.70	1.04	1.05	
Wt. of dry soil,	(g)	16.94	20.85	21.22	5.37	5.85	
Moisture content	(%)	28.93	38.90	41.00	19.37	17.95	
Average	(%)	36.27			18.7		17.6



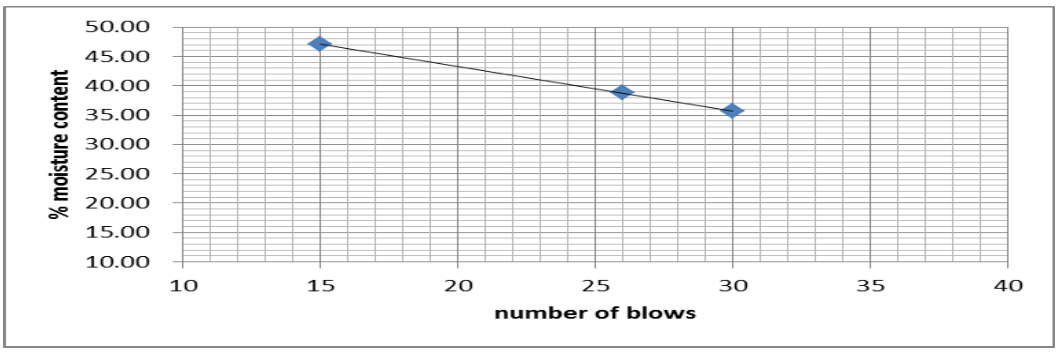
4.Determination of Liquid Limit & Plastic Limit at AbunaSurface Wearinggravel

Determination					Plastic Limit		plastic index
Number of blows		31	22.00	17.00			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	C	B4	A	Cc	d1	
Wt. of container + wet soil,	(g)	38.40	40.85	40.47	21.98	21.94	
Wt. of container + dry soil,	(g)	33.90	35.23	35.10	21.08	21.04	
Wt. of container,	(g)	15.00	16.75	16.24	16.00	16.04	
Wt. of water,	(g)	4.50	5.62	5.37	0.90	0.90	
Wt. of dry soil,	(g)	18.90	18.48	18.86	5.08	5.00	
Moisture container,	(%)	23.81	30.41	28.47	17.72	18.00	
Average	(%)	27.56			17.9	17.86	9.71



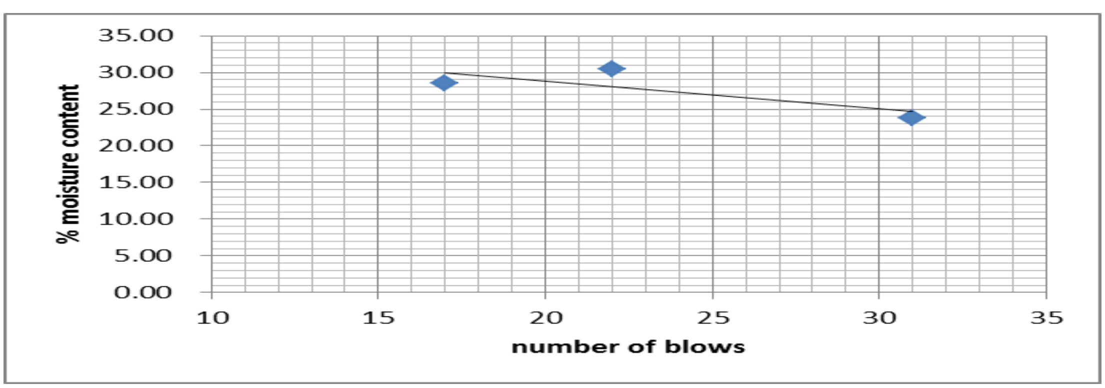
5.Determination of Liquid Limit & Plastic Limit at Shuluke Subgrade Soil

Determination		Liquid Limit			Plastic Limit		plastic index
Number of blows		30	26.00	15.00			
Test	No	1	2	3	1	2	
Container	No	B	A1	C3	E	J	
Wt. of container + wet soil,	(g)	38.31	43.67	48.02	21.73	22.22	
Wt. of container + dry soil,	(g)	32.67	35.99	38.12	20.91	21.13	PI=LL-PL
Wt. of container,	(g)	16.86	16.2	17.10	16.62	16.28	
Wt. of water,	(g)	5.64	7.68	9.90	0.82	1.09	
Wt. of dry soil,	(g)	15.81	19.79	21.02	4.29	4.85	
Moisture content	(%)	35.67	38.81	47.10	19.11	22.47	
Average	(%)	40.53			20.8	20.79	19.73



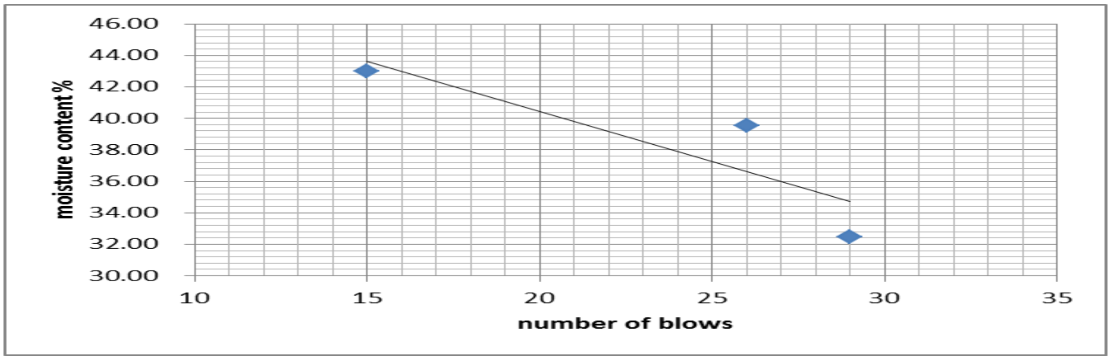
6.Determination of Liquid Limit & Plastic Limit at Shuluke Surface Wearinggravel

Determination					Plastic Limit		plastic index
Number of blows		31	22.00	17.00			
Test	No	1	2	3	1	2	
Container	No	C	B4	A	Cc	d1	
Wt. of container + wet soi	(g)	38.40	40.85	40.47	21.98	21.94	
Wt. of container + dry soi	(g)	33.90	35.23	35.10	21.08	21.04	PI=LL-PI
Wt. of container,	(g)	15.00	16.75	16.24	16.00	16.04	
Wt. of water,	(g)	4.50	5.62	5.37	0.90	0.90	
Wt. of dry soil,	(g)	18.90	18.48	18.86	5.08	5.00	
Moisture container,	(%)	23.81	30.41	28.47	17.72	18.00	
Average	(%)	27.56			17.9	17.86	9.71



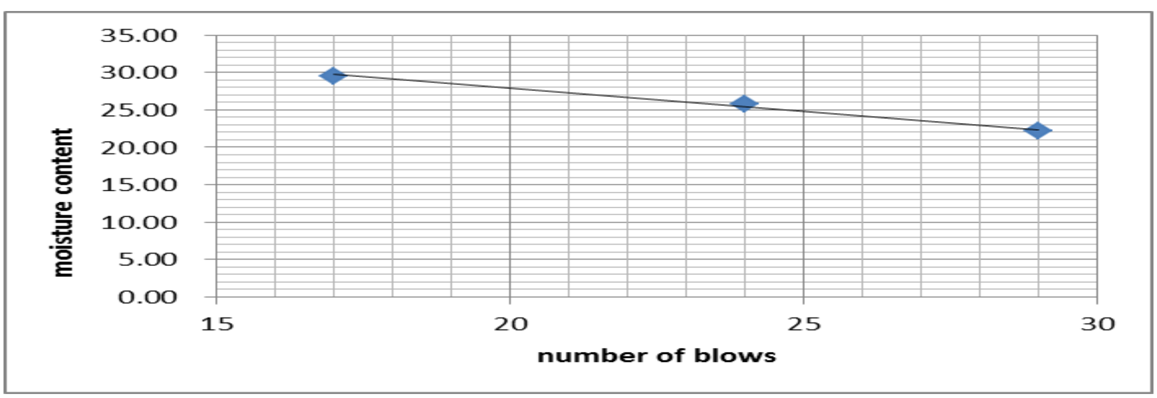
7.Determination of Liquid Limit & Plastic Limit at JarmatSubgrade Soil

Determination	Liquid Limit				Plastic Limit		plastic index
Number of blows		29	26	15			
Test	No	1	2	17	1	2	PI=LL-PL
Container	No	A4	BP1	LC1	B2	II	
Wt. of container + wet soi	(g)	41.92	44.10	53.12	17.57	17.48	
Wt. of container + dry soi	(g)	35.97	36.26	42.30	15.87	15.69	
Wt. of container,	(g)	17.63	16.41	17.12	6.581	5.83	
Wt. of water,	(g)	5.95	7.84	10.82	1.70	1.79	
Wt. of dry soil,	(g)	18.34	19.85	25.18	9.29	9.86	
Moisture container,	(%)	32.44	39.51	42.99	18.30	18.16	
Average	(%)	38.32			18.2		20.1



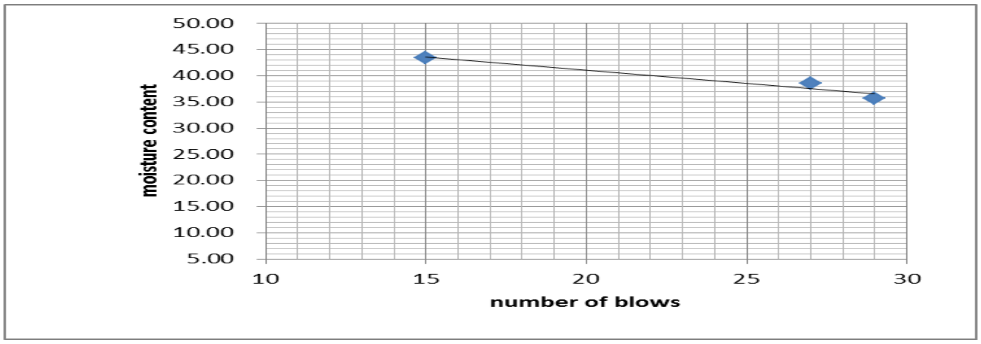
8.Determination of Liquid Limit & Plastic Limit at JarmatSurface Wearinggravel

Determination	Liquid Limit				Plastic Limit		plastic index
Number of blows		29	24	17			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	A3	B	D2	B2	H	
. of container + wet s	(g)	42.08	39.82	41.99	18.89	18.79	
. of container + dry s	(g)	37.58	34.78	35.94	17.10	17.18	
Wt. of container,	(g)	17.29	15.23	15.48	6.588	6.88	
Wt. of water,	(g)	4.50	5.04	6.05	1.79	1.61	
Wt. of dry soil,	(g)	20.29	19.55	20.47	10.51	10.31	
Moisture container,	(%)	22.15	25.78	29.56	17.02	15.62	
Average	(%)	25.83			16.3		9.5



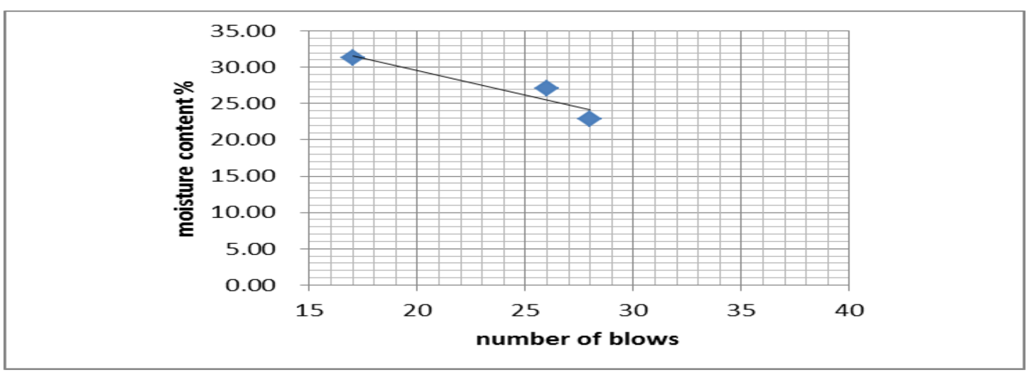
9.Determination of Liquid Limit & Plastic Limit at Irro SubgradeSoil

Determination	Liquid Limit				Plastic Limit		plastic index
Number of blows		29	27.00	15.00			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	bb1	D2	H	ab	A1	
Wt. of container + wet so	(g)	61.25	53.43	54.45	27.13	28.20	
Wt. of container + dry so	(g)	49.77	43.41	43.05	25.87	26.01	
Wt. of container,	(g)	17.60	17.4	16.80	17.45	17.60	
Wt. of water,	(g)	11.48	10.02	11.40	1.26	2.19	
Wt. of dry soil,	(g)	32.17	26.01	26.25	8.42	8.41	
Moisture container,	(%)	35.69	38.52	43.43	14.90	26.04	
Average	(%)	39.21			20.5	20.47	18.74



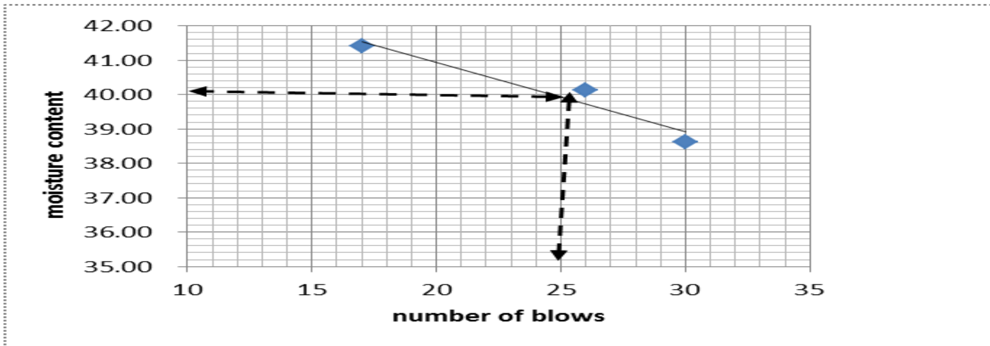
10. Determination of Liquid Limit & Plastic Limit at IrroSurface Wearinggravel

Determination	Liquid Limit				Plastic Limit		plastic index
Number of blows		28	26.00	17.00			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	NC23	N4	F58	M	B	
Wt. of can + wet soil	(g)	55.85	48.67	54.77	19.45	19.46	
Wt. of can + dry soil	(g)	48.69	42.01	45.87	17.28	17.39	
Wt. of can	(g)	17.33	17.473	17.42	6.147	5.79	
Wt. of water	(g)	7.16	6.66	8.89	2.17	2.08	
Wt. of dry soil	(g)	31.36	24.54	28.45	11.13	11.59	
Moisture content	(%)	22.83	27.13	31.26	19.45	17.90	
Average	(%)	27.07			18.7	18.67	8.40



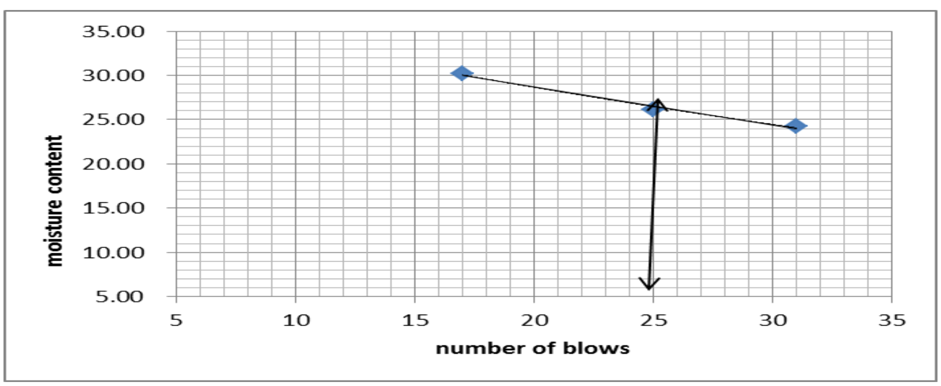
11.Determination of Liquid Limit & Plastic Limit at HangarSubgradeSoil

Determination	Liquid Limit				Plastic Limit		plastic index
Number of blows	No	30	26	17			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	MB1	E1	N4	T	K	
Wt. of container + wet	(g)	61.31	57.18	56.31	19.90	20.00	
Wt. of container + dry	(g)	49.10	45.81	44.85	17.36	18.00	
Wt. of container,	(g)	17.49	17.47	17.19	6.194	6.09	
Wt. of water,	(g)	12.21	11.37	11.46	2.54	2.00	
Wt. of dry soil,	(g)	31.62	28.34	27.66	11.17	11.91	
Moisture content	(%)	38.62	40.13	41.42	22.70	16.83	
Average	(%)	40.05			19.8		20.3



12. Determination of Liquid Limit & Plastic Limit at Hangar Surface Wearinggravel

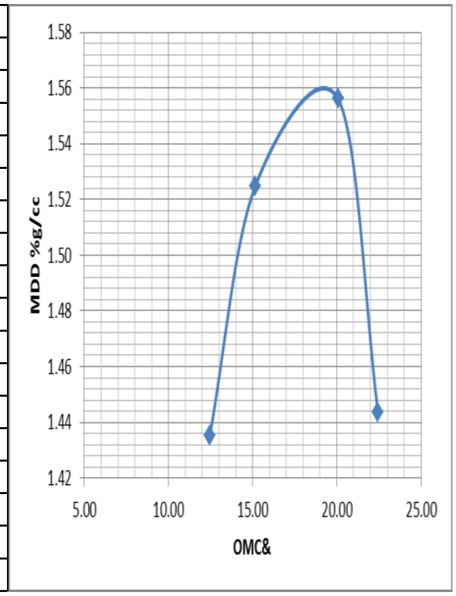
Determination	Liquid Limit				Plastic Limit		plastic index
Number of blows	No	31	25	17			
Test	No	1	2	3	1	2	PI=LL-PL
Container	No	MB1	E1	N4	T	K	
Wt. of container + wet soil	(g)	54.05	48.96	53.47	19.44	19.96	
Wt. of container + dry soil	(g)	46.88	42.44	45.11	17.58	17.74	
Wt. of container	(g)	17.33	17.47	17.42	6.147	6.09	
Wt. of water	(g)	7.17	6.52	8.37	1.86	2.21	
Wt. of dry soil	(g)	29.55	24.97	27.68	11.43	11.65	
Moisture container	(%)	24.25	26.13	30.22	16.28	19.00	
Average	(%)	26.87			17.6		9.2



Appendix D- MOISTURE DENSITY RELATIONSHIP OF SOIL

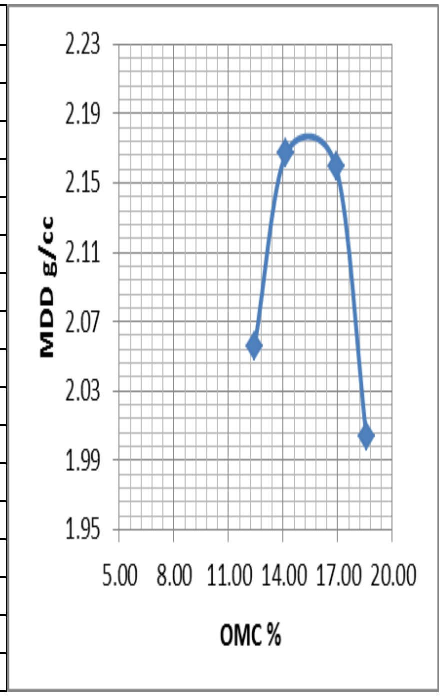
1. Compaction of Subgrade Soil at Shambu Station

		unit	1	2	3	4
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	l	300%	600%	900%	1200%
	WEIGHT OF SOIL + MOLD	g	9987	10286	10523	10311
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	3397	3696	3933	3721
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	1.614	1.756	1.868	1.768
MOISTURE	CONTAINER NUMBER		AA	D	CB	E
	WET SOIL + CONTAINER	g	143.23	147.2	141.44	148.82
	DRY SOIL + CONTAINER	g	130.1	131.16	122.06	126.08
	WEIGHT OF WATER	g	13.13	16.04	19.38	22.74
	WEIGHT OF CONTAINER	g	24.610	25.300	25.500	24.750
	WEIGHT OF DRY SOIL	g	105.49	105.86	96.56	101.33
	MOISTURE CONTENT	%	12.45	15.15	20.07	22.44
	DRY DENSITY OF SOIL	g/cc	1.44	1.52	1.56	1.44
	MDD (gm/cc)	g/cc	1.56			
	OMC (%)	%	20.07			



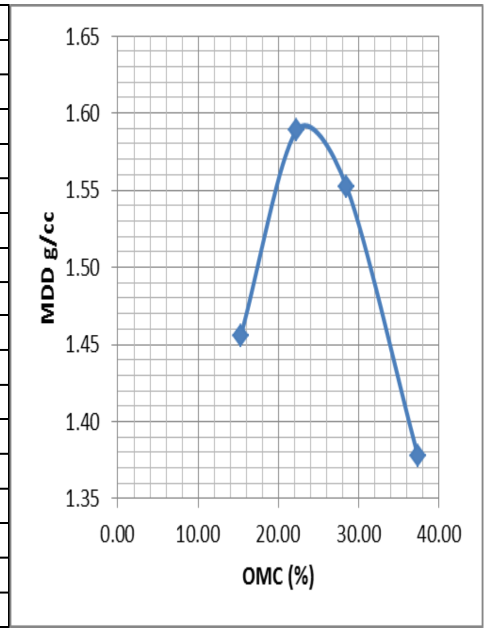
2.Compaction of Surface Wearing gravel at Shambu Station

		unit	1	2	3	4
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	l	300%	600%	900%	1200%
	WEIGHT OF SOIL + MOLD	g	11456	11797	11903	11592
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	4866	5207	5313	5002
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	2.312	2.474	2.524	2.376
MOISTURE	CONTAINER NUMBER		I	T	E	M
	WET SOIL + CONTAINER	g	136.71	143.55	147.34	139.48
	DRY SOIL + CONTAINER	g	124.32	129	129.83	121.9
	WEIGHT OF WATER	g	12.39	14.55	17.51	17.58
	WEIGHT OF CONTAINER	g	24.600	26.200	26.200	27.200
	WEIGHT OF DRY SOIL	g	99.72	102.80	103.63	94.70
	MOISTURE CONTENT	%	12.42	14.15	16.90	18.56
	DRY DENSITY OF SOIL	g/cc	2.06	2.17	2.16	2.00
	MDD (gm/cc) :	2.17	2.17			
	OMC (%) :	16.90	14.15			



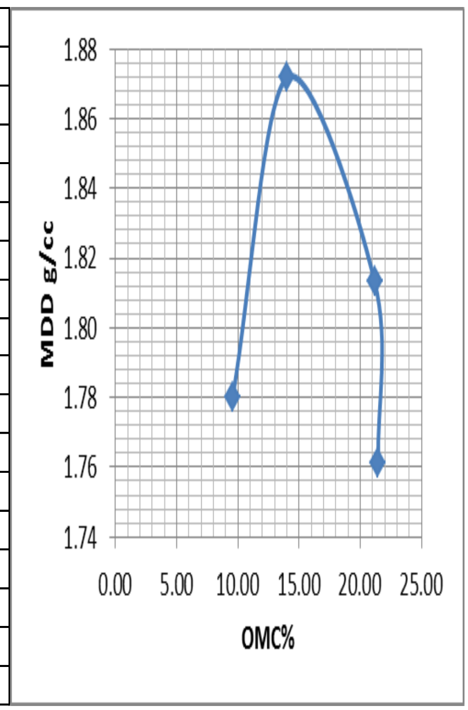
3.Compaction ofSubgrade Soil at Abuna Station

		unit				
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	litre	300%	600%	900%	1200%
	WEIGHT OF SOIL + MOLD	g	10121	10678	10788	10574
	WEIGHT OF MOLD (g)	g	6590	6590	6590	6590
	WEIGHT OF SOIL (g)	g	3531	4088	4198	3984
	VOLUME OF MOLD (cc)	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL (g/	g/cc	1.677	1.942	1.994	1.893
MOISTURE	CONTAINER NUMBER		Y	M2	C	Bo
	WET SOIL + CONTAINER	g	132.19	138.48	149.37	126.74
	DRY SOIL + CONTAINER	g	118.15	118	122.08	99.74
	WEIGHT OF WATER	g	14.04	20.48	27.29	27.00
	WEIGHT OF CONTAINER	g	26.240	25.930	26.210	27.420
	WEIGHT OF DRY SOIL	g	91.91	92.07	95.87	72.32
	MOISTURE CONTENT (%)	%	15.28	22.24	28.47	37.33
	DRY DENSITY OF SOIL	g/cc	1.46	1.59	1.55	1.38
	MDD	g/cc	1.59			
	OMC	cc	22.24			



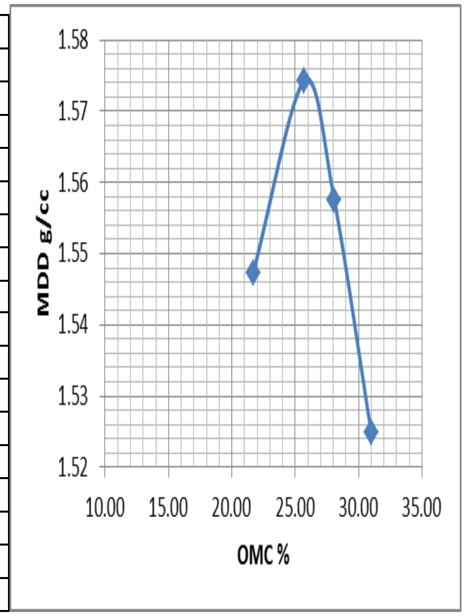
4.Compaction of Surface Wearing gravelat Abuna Station

		unit				
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	litre	280%	480%	680%	880%
	WEIGHT OF SOIL + MOLD	g	10695	11082	11215	11093
	WEIGHT OF MOLD (g)	g	6590	6590	6590	6590
	WEIGHT OF SOIL (g)	g	4105	4492	4625	4503
	VOLUME OF MOLD (cc)	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL (g/	g/cc	1.950	2.134	2.197	2.139
MOISTURE	CONTAINER NUMBER		AA	L1	O	D
	WET SOIL + CONTAINER	g	133.14	132.24	146.16	134.16
	DRY SOIL + CONTAINER	g	123.64	119.22	125.24	115.28
	WEIGHT OF WATER	g	9.50	13.02	20.92	18.88
	WEIGHT OF CONTAINER	g	24.260	26.300	26.430	27.300
	WEIGHT OF DRY SOIL	g	99.38	92.92	98.81	87.98
	MOISTURE CONTENT (%)	%	9.56	14.01	21.17	21.46
	DRY DENSITY OF SOIL	g/cc	1.78	1.87	1.81	1.76
	MDD		1.87			
	OMC		14.01			



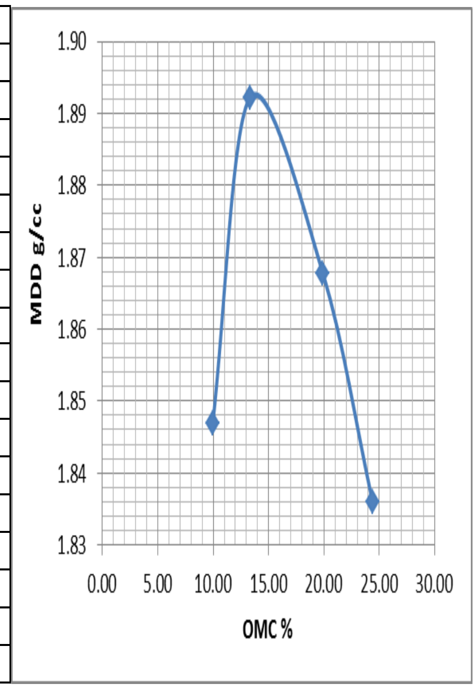
5.Compaction of atSubgrade SoilShuluke Station

		unit	1	2	3	4
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	litre	350%	550%	750%	950%
	WEIGHT OF SOIL + MOLD	g	9263	9416	9663	9247
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	2673	2826	3073	2657
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	1.270	1.343	1.460	1.262
MOISTURE	CONTAINER NUMBER		C2	A4	E	G
	WET SOIL + CONTAINER	g	125.12	131.74	143.514	133.76
	DRY SOIL + CONTAINER	g	107.34	109.81	117.2	108.1
	WEIGHT OF WATER	g	17.78	21.93	26.31	25.66
	WEIGHT OF CONTAINER	g	25.270	24.530	23.470	25.320
	WEIGHT OF DRY SOIL	g	82.07	85.28	93.73	82.78
	MOISTURE CONTENT	%	21.66	25.72	28.07	31.00
	DRY DENSITY OF SOIL	g/cc	1.55	1.57	1.56	1.52
	MDD (gm/cc)	g/cc	1.57			
	OMC (%)	%	25.72			



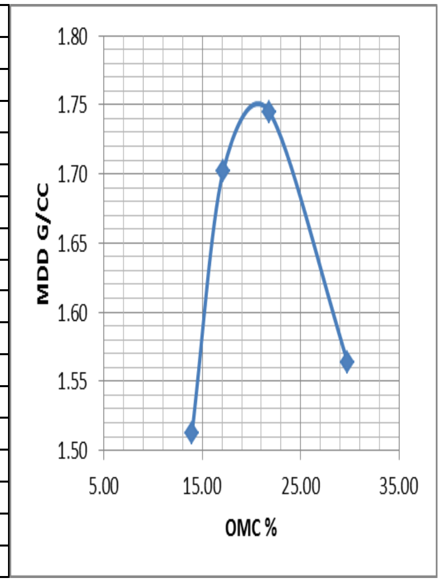
6.Compaction ofSurface Wearing gravel at Shuluke Station

		unit	1	2	3	4
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	litre	300%	550%	800%	1050%
	WEIGHT OF SOIL + MOLD	g	10156	10358	10526	9968
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	3566	3768	3936	3378
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	1.694	1.790	1.870	1.605
MOISTURE	CONTAINER NUMBER		C2	A4	E	G
	WET SOIL + CONTAINER	g	125.12	131.74	143.1	133.76
	DRY SOIL + CONTAINER	g	116	119.13	123.18	112.43
	WEIGHT OF WATER	g	9.12	12.61	19.92	21.33
	WEIGHT OF CONTAINER	g	24.270	24.530	23.070	25.020
	WEIGHT OF DRY SOIL	g	91.73	94.60	100.11	87.41
	MOISTURE CONTENT	%	9.94	13.33	19.90	24.40
	DRY DENSITY OF SOIL	g/cc	1.85	1.89	1.87	1.84
	MDD (gm/cc)	g/cc	1.89			
	OMC (%)	%	13.33			



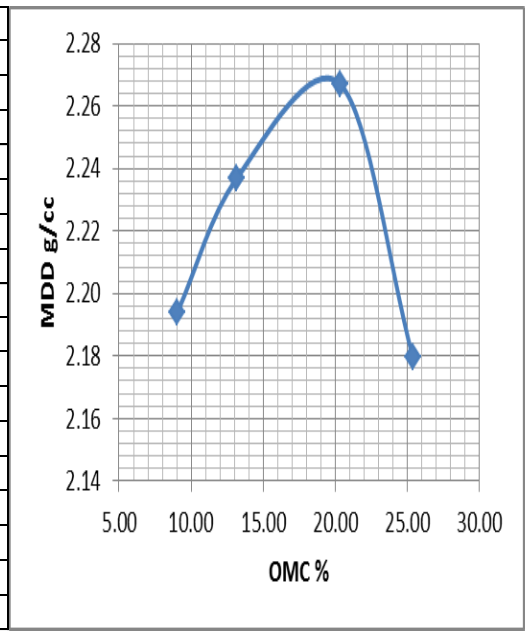
7.Compaction of Subgrade Soil at Jarmat Station

		unit	1	2	3	4
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	l	400%	600%	800%	1000%
	WEIGHT OF SOIL + MOLD	g	9541	9956	10144	9412
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	2951	3366	3554	2822
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	1.402	1.599	1.688	1.341
MOISTURE	CONTAINER NUMBER		C2	A4	E	G
	WET SOIL + CONTAINER	g	129.85	134.55	140.89	136.27
	DRY SOIL + CONTAINER	g	116.94	118.47	119.82	110.74
	WEIGHT OF WATER	g	12.91	16.08	21.07	25.53
	WEIGHT OF CONTAINER	g	24.270	24.530	23.070	25.020
	WEIGHT OF DRY SOIL	g	92.67	93.94	96.75	85.72
	MOISTURE CONTENT	%	13.93	17.12	21.78	29.78
	DRY DENSITY OF SOIL	g/cc	1.51	1.70	1.75	1.56
	MDD (gm/cc)	g/cc	1.75			
	OMC (%)	%	21.78			



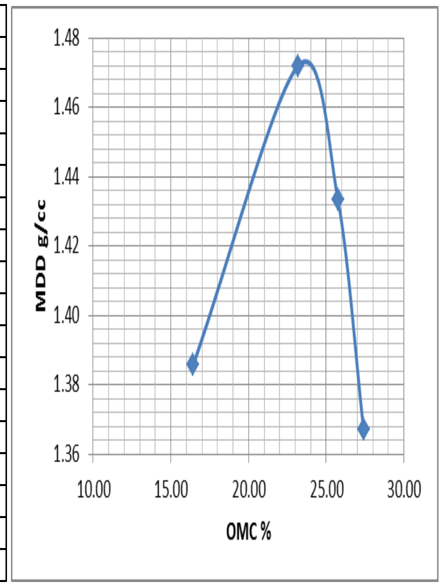
8. Compaction of Surface Wearing gravel at Jarmat Station

		unit	1	2	3	4
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	l	330%	530%	730%	930%
	WEIGHT OF SOIL + MOLD	g	10693	10842	10984	10343
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	4103	4252	4394	3753
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	1.949	2.020	2.087	1.783
MOISTURE	CONTAINER NUMBER		E	NB	J	L
	WET SOIL + CONTAINER	g	121.14	126.73	134.9	127.6
	DRY SOIL + CONTAINER	g	113.12	114.83	116.15	106.82
	WEIGHT OF WATER	g	8.02	11.90	18.75	20.78
	WEIGHT OF CONTAINER	g	24.270	24.530	24.070	25.020
	WEIGHT OF DRY SOIL	g	88.85	90.30	92.08	81.80
	MOISTURE CONTENT	%	9.03	13.18	20.36	25.40
	DRY DENSITY OF SOIL	g/cc	2.19	2.24	2.27	2.18
	MDD (gm/cc)	g/cc	2.27			
	OMC (%)	%	20.36			



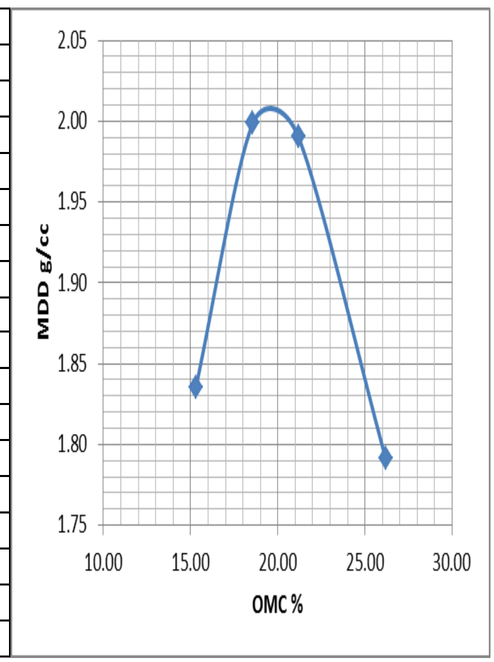
9.Compaction of atSubgrade SoilIrro Station

	TRIAL NUMBER	unit	1	2	3	4
DENSITY	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	litre	300%	500%	700%	900%
	WEIGHT OF SOIL + MOLD	g	9986	10406	10384	10256
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	3396	3816	3794	3666
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	1.613	1.813	1.802	1.742
MOISTURE	CONTAINER NUMBER		B2	A	D	A4
	WET SOIL + CONTAINER	g	114.26	119.86	104.12	107.92
	DRY SOIL + CONTAINER	g	100.45	100.45	86.34	88.41
	WEIGHT OF WATER	g	13.81	19.41	17.78	19.51
	WEIGHT OF CONTAINER	g	16.400	16.670	17.300	17.200
	WEIGHT OF DRY SOIL	g	84.05	83.78	69.04	71.21
	MOISTURE CONTENT	%	16.43	23.17	25.75	27.40
	DRY DENSITY OF SOIL	g/cc	1.39	1.47	1.43	1.37
	MDD (gm/cc)	g/cc	1.47			
	OMC (%)	%	23.17			



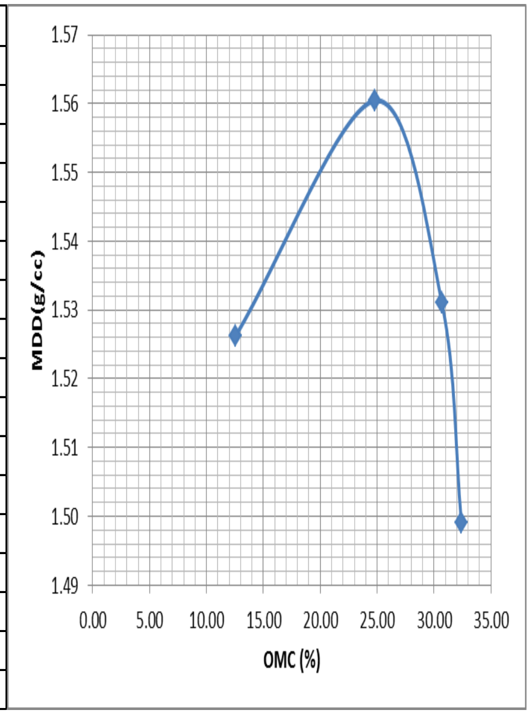
10. Compaction of Surface Wearing gravel at Irro Station

	TRIAL NUMBER	unit	1	2	3	4
DENSITY	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	litre	350%	550%	750%	950%
	WEIGHT OF SOIL + MOLD	g	11045	11578	11667	11348
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	4455	4988	5077	4758
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	2.116	2.370	2.412	2.260
MOISTURE	CONTAINER NUMBER		A4	CH	A2	a2
	WET SOIL + CONTAINER	g	121.66	116.74	119.57	113.56
	DRY SOIL + CONTAINER	g	109.02	102.27	103.25	95.72
	WEIGHT OF WATER	g	12.64	14.47	16.32	17.84
	WEIGHT OF CONTAINER	g	26.400	24.300	26.200	27.600
	WEIGHT OF DRY SOIL	g	82.62	77.97	77.05	68.12
	MOISTURE CONTENT	%	15.30	18.56	21.18	26.19
	DRY DENSITY OF SOIL	g/cc	1.84	2.00	1.99	1.79
	MDD	g/cc	2.00			
	OMC	%	18.56			



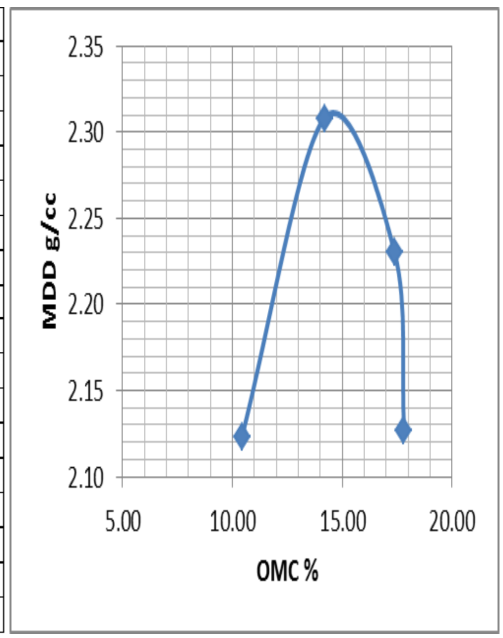
11. Compaction of Subgrade Soil at Hangar Station

DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	litre	250%	500%	750%	1000%
	WEIGHT OF SOIL + MOLD	g	10205	10690	10802	10768
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	3615	4100	4212	4178
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	1.717	1.948	2.001	1.985
MOISTURE	CONTAINER NUMBER		X	AT1	B	AU
	WET SOIL + CONTAINER	g	167.08	173.86	176.1	183.42
	DRY SOIL + CONTAINER	g	151.34	144.3	140.8	145.19
	WEIGHT OF WATER	g	15.74	29.56	35.30	38.23
	WEIGHT OF CONTAINER	g	25.700	25.200	25.800	27.200
	WEIGHT OF DRY SOIL	g	125.64	119.10	115.00	117.99
	MOISTURE CONTENT	%	12.53	24.82	30.70	32.40
	DRY DENSITY OF SOIL	g/cc	1.53	1.56	1.53	1.50
	MDD (gm/cc)	g/cc	1.56			
	OMC (%)	%	24.82			



12. Compaction ofSurface Wearing gravel at Hangar Station

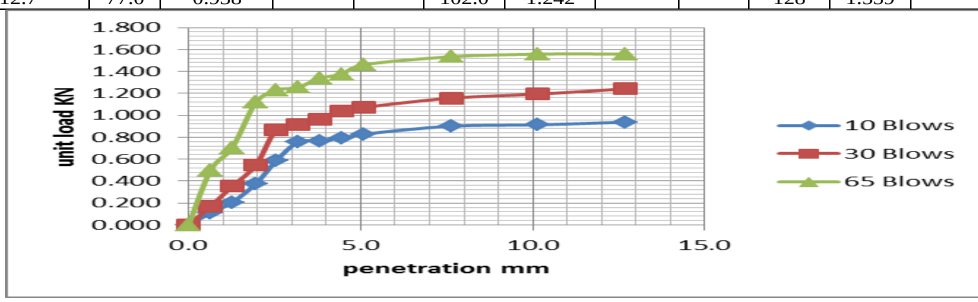
DENSITY	TRIAL NUMBER	unit	1	2	3	4
	WEIGHT OF SAMPLE	g	6000	6000	6000	6000
	WATER ADDED	litre	300%	500%	700%	900%
	WEIGHT OF SOIL + MOLD	g	11525	12138	12100	11864
	WEIGHT OF MOLD	g	6590	6590	6590	6590
	WEIGHT OF SOIL	g	4935	5548	5510	5274
	VOLUME OF MOLD	cc	2105	2105	2105	2105
	Wet DENSITY OF SOIL	g/cc	2.344	2.636	2.618	2.505
MOISTURE	CONTAINER NUMBER		B	T1	C	A2
	WET SOIL + CONTAINER	g	197.6	190.65	189.7	195.54
	DRY SOIL + CONTAINER	g	181.4	170.1	165.3	169.86
	WEIGHT OF WATER	g	16.20	20.55	24.40	25.68
	WEIGHT OF CONTAINER	g	26.000	25.300	25.000	25.740
	WEIGHT OF DRY SOIL	g	155.40	144.80	140.30	144.12
	MOISTURE CONTENT	%	10.42	14.19	17.39	17.82
	DRY DENSITY OF SOIL	g/cc	2.12	2.31	2.23	2.13
	MDD (gm/cc)	g/cc	2.31			
	OMC (%	%	14.19			



Appendix E- California Bearing Ratio Test

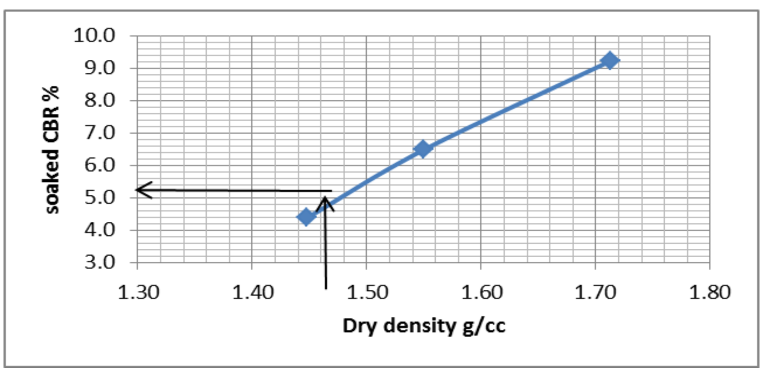
1. Penetration Test Data for Subgrade Soil at Shambu Station

penetration (mm)	10 Blows				30 Blows				65 Blows			
	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	9.0	0.110			14.0	0.171			41	0.499		
1.27	17.0	0.207			29.0	0.353			58	0.706		
1.96	31.0	0.378			45.0	0.548			92	1.121		
2.54	48.0	0.585	0.58	4.4	71.0	0.865	0.86	6.5	101	1.230	1.23	9.2
3.18	62.0	0.755			75.0	0.914			103	1.255		
3.81	63.0	0.767			79.0	0.962			110	1.340		
4.45	65.0	0.792			85.0	1.035			113	1.376		
5.08	68.0	0.828	0.83	4.1	88.0	1.072	1.07	5.4	120	1.462	1.46	7.3
7.62	74.0	0.901			95.0	1.157			126	1.535		
10.16	75.0	0.914			98.0	1.194			128	1.559		
12.7	77.0	0.938			102.0	1.242			128	1.559		



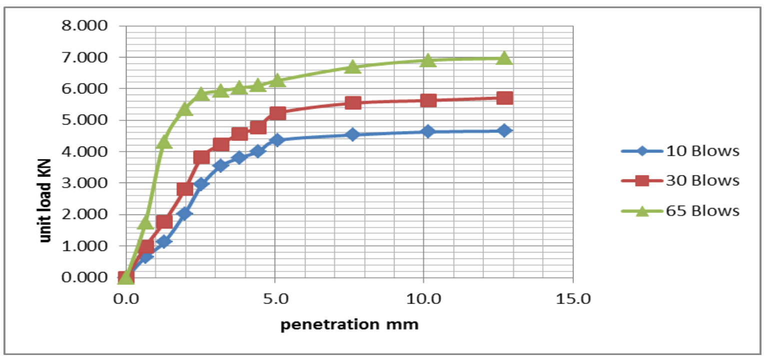
CBR versus Dry Density for Subgrade Soil at Shambu Station

blows	load (KN)		CBR(%)		swell %	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	0.58	0.83	4.4	4.1	1.39	No.of blows	10	30	65
30	0.86	1.07	6.5	5.4	1.58	dry density	1.45	1.55	1.71
65	1.23	1.46	9.2	7.3	0.58	soaked CBR	4.4	6.5	9.2



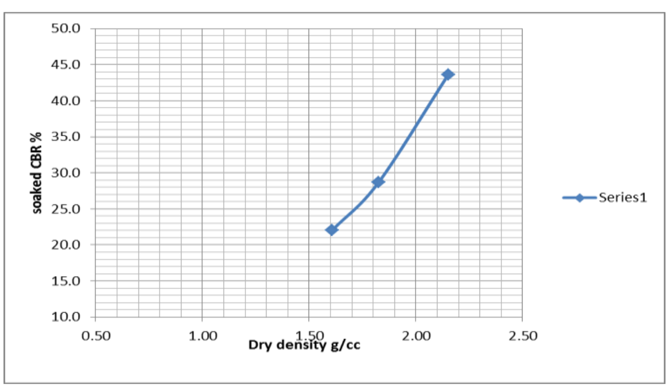
2.Penetration Test Data for Surface Wearing gravel at Shambu Station

penetration	10 Blows				30 Blows				65 Blows			
(mm)	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	ɔad (KN	Cor. Load (kN)	CBR %	dial RDG	load (KN	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	53.0	0.646			80.0	0.974			143	1.742		
1.27	92.0	1.121			145.0	1.766			354	4.312		
1.96	166.0	2.022			230.0	2.801			439	5.347		
2.54	242.0	2.948	2.95	22.1	314.0	3.825	3.82	28.6	478	5.822	5.82	43.6
3.18	291.0	3.544			348.0	4.239			487	5.932		
3.81	312.0	3.800			375.0	4.568			495	6.029		
4.45	329.0	4.007			392.0	4.775			501	6.102		
5.08	358.0	4.360	4.36	21.8	429.0	5.225	5.23	26.1	514	6.261	6.26	31.3
7.62	372.0	4.531			455.0	5.542			549	6.687		
10.16	380.0	4.628			462.0	5.627			567	6.906		
12.7	382.0	4.653			469.0	5.712			572	6.967		



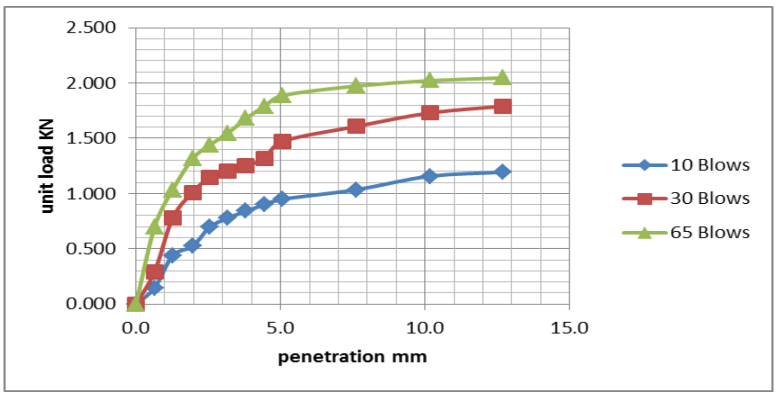
CBR versus Dry Density for Surface wearing gravel at Shambu Station

blows	load (KN)		CBR(%)		swell %	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	2.95	4.36	22.1	21.8	1.07	No.of blows	10	30	65
30	3.82	5.23	28.6	26.1	0.74	dry density	1.61	1.82	2.15
65	5.82	6.26	43.6	31.3	0.52	soaked CBR	22.1	28.6	43.6



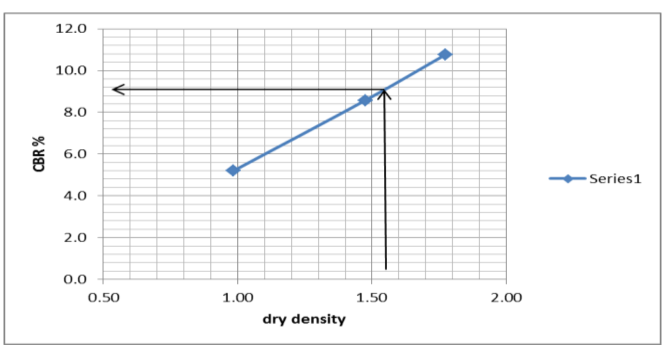
3. Penetration Test Data for for Subgrade Soil at Abuna Station

penetration (mm)	10 Blows				30 Blows				65 Blows			
	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	12.0	0.146			24.0	0.292			57	0.694		
1.27	36.0	0.438			64.0	0.780			85	1.035		
1.96	43.0	0.524			83.0	1.011			108	1.315		
2.54	57.0	0.694	0.69	5.2	94.0	1.145	1.14	8.6	118	1.437	1.44	10.8
3.18	64.0	0.780			99.0	1.206			127	1.547		
3.81	69.0	0.840			103.0	1.255			138	1.681		
4.45	74.0	0.901			108.0	1.315			147	1.790		
5.08	78.0	0.950	0.95	4.8	121.0	1.474	1.47	7.4	155	1.888	1.89	9.4
7.62	85.0	1.035			132.0	1.608			162	1.973		
10.16	95.0	1.157			142.0	1.730			166	2.022		



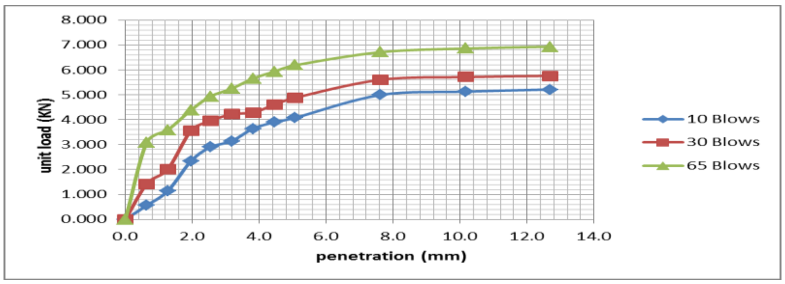
CBR versus Dry Density for Subgrdae Soil at Abuna Station

blows	load (KN)		CBR(%)		swell %	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	0.69	0.95	5.2	4.8	2.24	No.of blows	10	30	65
30	1.14	1.47	8.6	7.4	1.52	dry density	0.98	1.48	1.77
65	1.44	1.89	10.8	9.4	0.42	soaked CBR	5.2	8.6	10.8



4.Penetration Test Data for Surface Wearing gravel at Abuna Station

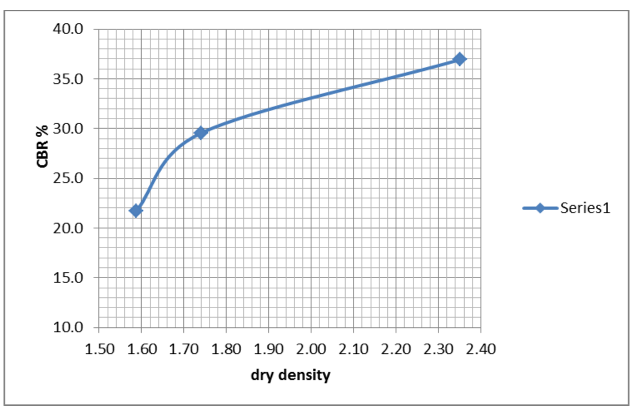
penetration (mm)	10 Blows				30 Blows				65 Blows			
	dial RDG	Load (kN)	Cor. Load(kN)	CBR %	dial RDG	load (KN)	cor.load (KN)	CBR %	dial RDG	load (KN)	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	46.0	0.560			117.0	1.425			254	3.094		
1.27	94.0	1.145			166.0	2.022			295	3.593		
1.96	192.0	2.339			292.0	3.557			360	4.385		
2.54	238.0	2.899	2.90	21.7	324.0	3.946	3.95	29.6	405	4.933	4.93	37.0
3.18	258.0	3.142			347.0	4.226			431	5.250		
3.81	299.0	3.642			352.0	4.287			464	5.652		
4.45	320.0	3.898			378.0	4.604			487	5.932		
5.08	335.0	4.080	4.08	20.4	401.0	4.884	4.88	24.4	508	6.187	6.19	30.9
7.62	410.0	4.994			460.0	5.603			551	6.711		
10.16	421.0	5.128			469.0	5.712			563	6.857		
12.7	428.0	5.213			473.0	5.761			569	6.930		



CBR versus Dry Density for Surface Wearing at Abuna Station

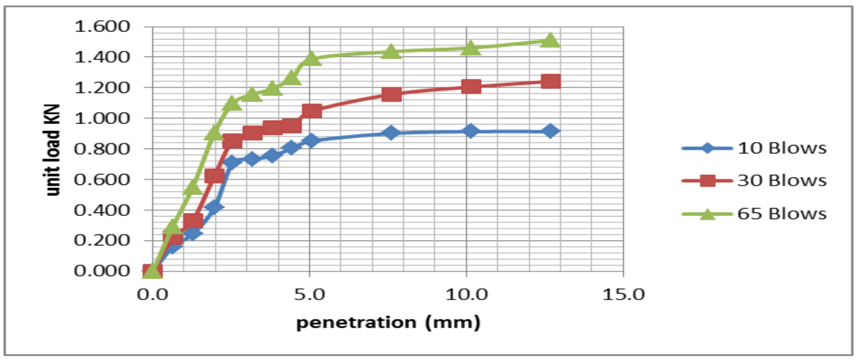
BLOWS	LOAD (KN)		CBR(%)		SWELL
	2.54mm	5.08mm	2.54mm	5.08mm	%
10	2.90	4.08	21.7	20.4	1.85
30	3.95	4.88	29.6	24.4	1.23
65	4.93	6.19	37.0	30.9	0.64

DRY DENSITY Vs SOCKED C.B.R.			
No # OF BLOWS	10	30	65
DRY DENSITY	1.59	1.74	2.35
SOCKED C.B.R.	21.7	29.6	37.0



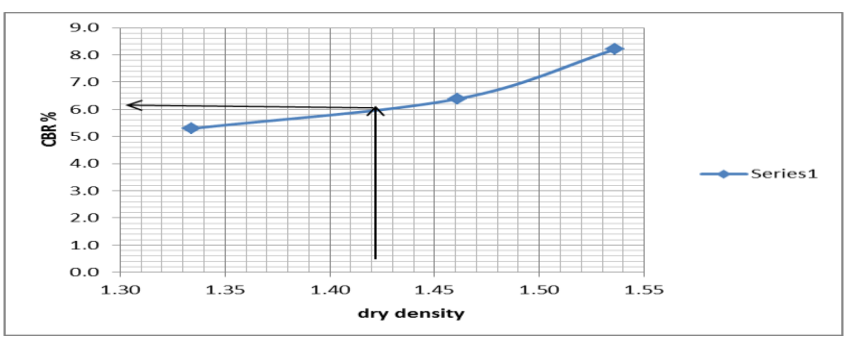
5.Penetration Test Data forSubgrade Soil at Shuluke Station

penetration (mm)	10 Blows				30 Blows				65 Blows			
	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	13.0	0.158			18.0	0.219			24	0.292		
1.27	20.0	0.244			27.0	0.329			45	0.548		
1.96	34.0	0.414			51.0	0.621			74	0.901		
2.54	58.0	0.706	0.71	5.3	70.0	0.853	0.85	6.4	90	1.096	1.10	8.2
3.18	60.0	0.731			74.0	0.901			95	1.157		
3.81	62.0	0.755			77.0	0.938			98	1.194		
4.45	66.0	0.804			78.0	0.950			104	1.267		
5.08	70.0	0.853	0.85	4.3	86.0	1.047	1.05	5.2	114	1.389	1.39	6.9
7.62	74.0	0.901			95.0	1.157			118	1.437		
10.16	75.0	0.914			99.0	1.206			120	1.462		
12.7	75.0	0.914			102.0	1.242			124	1.510		



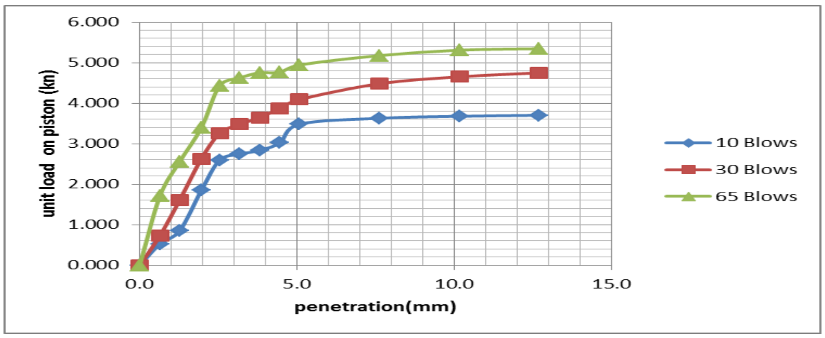
CBR versus Dry Density for Subgrade Soil atShuluke Station

blows	load (KN)		CBR(%)		swell %	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	0.71	0.85	5.3	4.3	2.28	No.of blows	10	30	65
30	0.85	1.05	6.4	5.2	1.54	dry density	1.33	1.46	1.54
65	1.10	1.39	8.2	6.9	0.76	soaked CBR	5.3	6.4	8.2



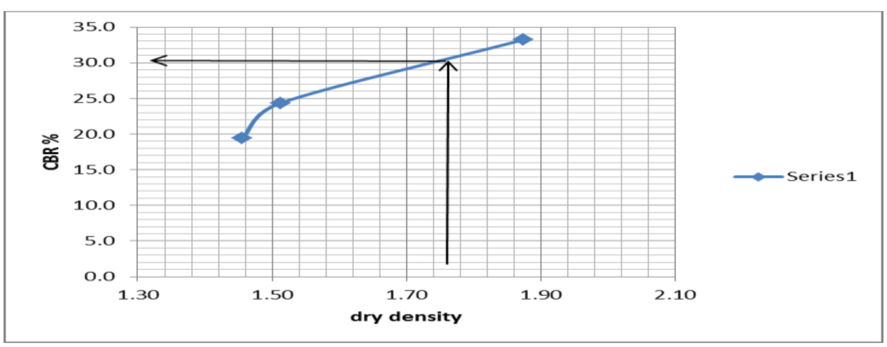
6.Penetration Test Data for Surface Wearing at Shuluke Station

penetration (mm)	10 Blows				30 Blows				65 Blows			
	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	43.0	0.524			60.0	0.731			140	1.705		
1.27	70.0	0.853			132.0	1.608			210	2.558		
1.96	152.0	1.851			216.0	2.631			279	3.398		
2.54	213.0	2.594	2.59	19.4	267.0	3.252	3.25	24.4	364	4.434	4.43	33.2
3.18	225.0	2.741			286.0	3.483			380	4.628		
3.81	233.0	2.838			299.0	3.642			390	4.750		
4.45	248.0	3.021			318.0	3.873			391	4.762		
5.08	286.0	3.483	3.48	17.4	336.0	4.092	4.09	20.5	406	4.945	4.95	24.7
7.62	298.0	3.630			368.0	4.482			425	5.177		
10.16	302.0	3.678			382.0	4.653			436	5.310		



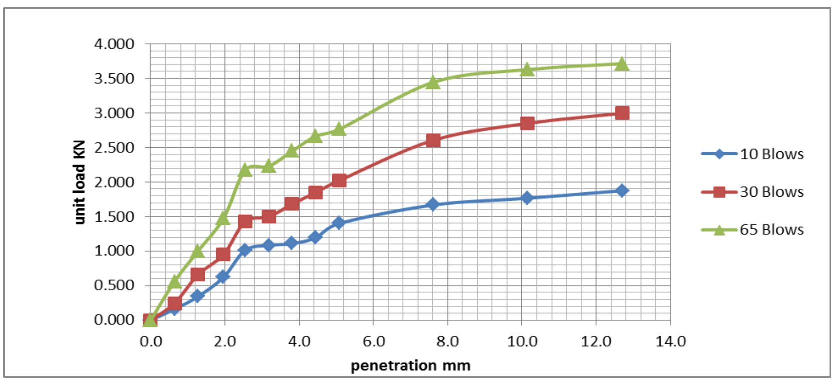
CBR versus Dry Density for Surface Wearing at Shuluke Station

blows	load (KN)		CBR(%)		swell %	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	2.59	3.48	19.4	17.4	2.05	No.of blows	10	30	65
30	3.25	4.09	24.4	20.5	1.41	dry density	1.46	1.51	1.87
65	4.43	4.95	33.2	24.7	0.49	soaked CBR	19.4	24.4	33.2



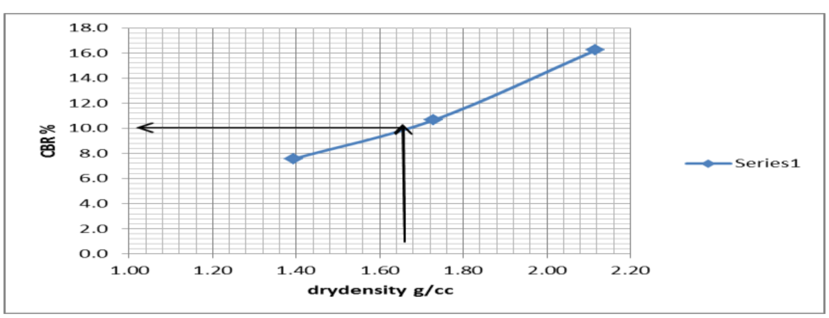
7.Penetration Test Data for Subgrade Soil at Jarmat Station

penetration(mm)	10 Blows				30 Blows				65 Blows			
	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	13.0	0.158			20.0	0.244			46	0.560		
1.27	28.0	0.341			54.0	0.658			82	0.999		
1.96	51.0	0.621			78.0	0.950			121	1.474		
2.54	83.0	1.011	1.01	7.6	117.0	1.425	1.43	10.7	178	2.168	2.17	16.2
3.18	89.0	1.084			123.0	1.498			183	2.229		
3.81	91.0	1.108			138.0	1.681			201	2.448		
4.45	98.0	1.194			152.0	1.851			219	2.667		
5.08	115.0	1.401	1.40	7.0	166.0	2.022	2.02	10.1	227	2.765	2.76	13.8
7.62	137.0	1.669			214.0	2.607			283	3.447		
10.16	145.0	1.766			234.0	2.850			298	3.630		
12.7	154.0	1.876			246.0	2.996			305	3.715		



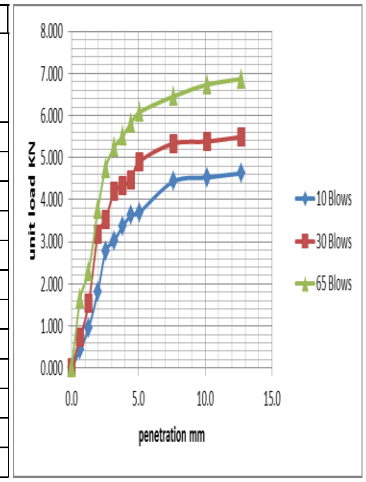
CBR versus Dry Density for Subgrade Soilat Jarmat Station

blows	load (KN)		CBR(%)		swell %	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	1.01	1.40	7.6	7.0	2.30	No.of blows	10	30	65
30	1.43	2.02	10.7	10.1	1.61	dry density	1.39	1.73	2.12
65	2.17	2.76	16.2	13.8	0.55	soaked CBR	7.6	10.7	16.2



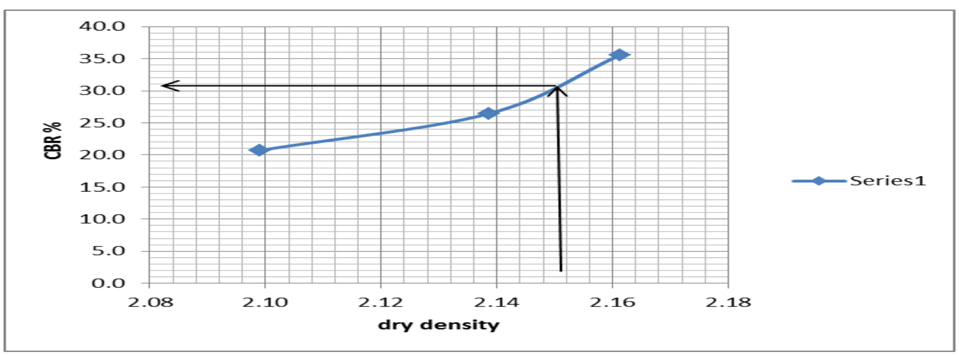
8.Penetration Test Data for Surface Wearing at Jarmat Station

penetration(mm)	10 Blows				30 Blows				65 Blows			
	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	36.0	0.438			60.0	0.731			135	1.644		
1.27	78.0	0.950			126.0	1.535			189	2.302		
1.96	149.0	1.815			260.0	3.167			309	3.764		
2.54	227.0	2.765	2.76	20.7	290.0	3.532	3.53	26.5	390	4.750	4.75	35.6
3.18	248.0	3.021			344.0	4.190			430	5.237		
3.81	276.0	3.362			355.0	4.324			452	5.505		
4.45	298.0	3.630			368.0	4.482			478	5.822		
5.08	304.0	3.703	3.70	18.5	403.0	4.909	4.91	24.5	499	6.078	6.08	30.4
7.62	364.0	4.434			438.0	5.335			530	6.455		
10.16	372.0	4.531			442.0	5.384			553	6.736		
12.7	380.0	4.628			451.0	5.493			564	6.870		



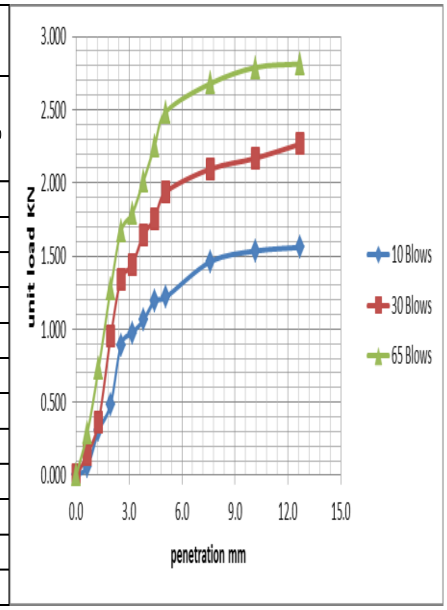
CBR versus Dry Density for Surface Wearing at Jarmat Station

blows	load (KN)		CBR(%)		swell %	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	2.76	3.70	20.7	18.5	2.07	No.of blows	10	30	65
30	3.53	4.91	26.5	24.5	1.49	dry density	2.10	2.14	2.16
65	4.75	6.08	35.6	30.4	0.74	soaked CBR	20.7	26.5	35.6



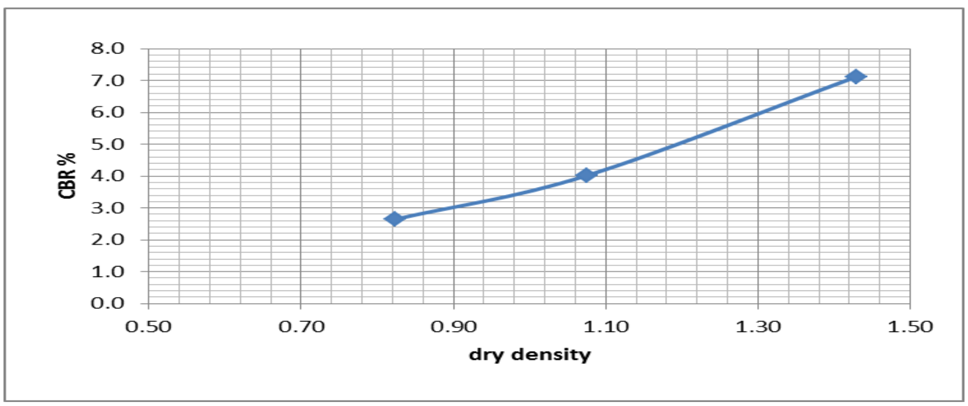
9.Penetration Test Data for Surface Wearing at Irro Station

penetration	10 Blows				30 Blows				65 Blows			
(mm)	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	5.0	0.061			12.0	0.146			24	0.292		
1.27	25.0	0.305			30.0	0.365			60	0.731		
1.96	40.0	0.487			78.0	0.950			105	1.279		
2.54	73.0	0.889	0.89	6.7	110.0	1.340	1.34	10.0	137	1.669	1.67	12.5
3.18	80.0	0.974			118.0	1.437			147	1.790		
3.81	87.0	1.060			135.0	1.644			165	2.010		
4.45	98.0	1.194			144.0	1.754			185	2.253		
5.08	100.0	1.218	1.22	6.1	159.0	1.937	1.94	9.7	204	2.485	2.48	12.4
7.62	120.0	1.462			172.0	2.095			220	2.680		
10.16	126.0	1.535			178.0	2.168			229	2.789		
12.7	128.0	1.559			186.0	2.265			231	2.814		



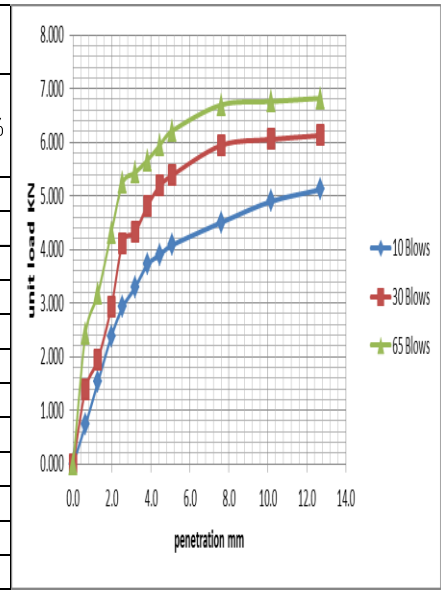
CBR versus Dry Density for Sub grade at Irro Station

blows	load (KN)		CBR(%)		swell %	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	0.89	1.22	6.7	6.1	1.36	No.of blows	10	30	65
30	1.34	1.94	10.0	9.7	1.43	dry density	0.39	0.86	0.94
65	1.67	2.48	12.5	12.4	0.76	soaked CBR	6.7	10.0	12.5



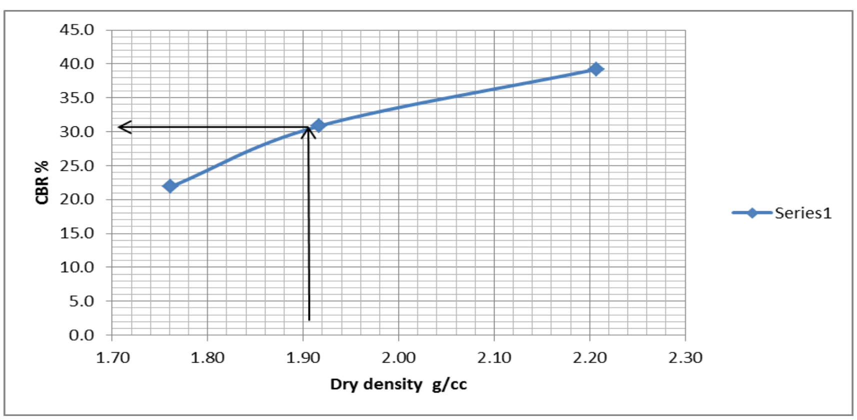
10.Penetration Test Data for Surface Wearing at Irro Station

penetration	10 Blows				30 Blows				65 Blows			
(mm)	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	60.0	0.731			115.0	1.401			200	2.436		
1.27	125.0	1.523			160.0	1.949			260	3.167		
1.96	195.0	2.375			240.0	2.923			354	4.312		
2.54	240.0	2.923	2.92	21.9	338.0	4.117	4.12	30.8	430	5.237	5.24	39.2
3.18	270.0	3.289			355.0	4.324			446	5.432		
3.81	305.0	3.715			395.0	4.811			465	5.664		
4.45	320.0	3.898			426.0	5.189			488	5.944		
5.08	335.0	4.080	4.08	20.4	442.0	5.384	5.38	26.9	510	6.212	6.21	31.1
7.62	370.0	4.507			488.0	5.944			550	6.699		
10.16	402.0	4.896			497.0	6.053			555	6.760		
12.7	420.0	5.116			503.0	6.127			560	6.821		



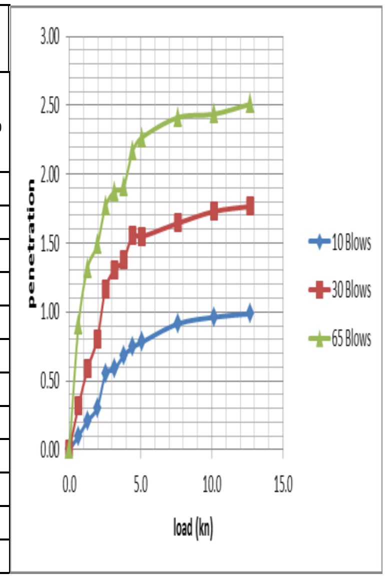
CBR versus Dry Density for Surface Wearing at Irro Station

blows	load (KN)		CBR(%)		swell	dry density vs CBR			
	2.54mm	5.08mm	2.54mm	5.08mm	%				
10	2.92	4.08	21.9	20.4	2.04	No.of blows	10	30	65
30	4.12	5.38	30.8	26.9	1.37	dry density	1.76	1.92	2.21
65	5.24	6.21	39.2	31.1	0.74	soaked CBR	21.9	30.8	39.2



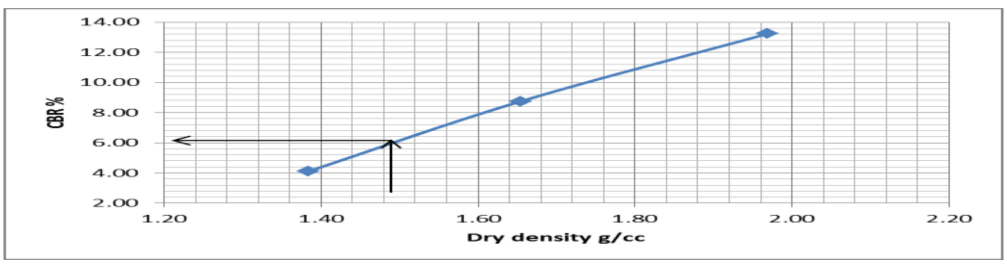
11.Penetration Test Data for Subgrade at Hangar Station

penetration	10 Blows				30 Blows				65 Blows			
(mm)	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	8.0	0.097			26.0	0.317			74	0.901		
1.27	17.0	0.207			48.0	0.585			108	1.315		
1.96	25.0	0.305			66.0	0.804			122	1.486		
2.54	45.0	0.548	0.55	4.1	96.0	1.169	1.17	8.8	145	1.766	1.77	13.2
3.18	48.0	0.585			107.0	1.303			154	1.876		
3.81	56.0	0.682			113.0	1.376			157	1.912		
4.45	61.0	0.743			128.0	1.559			178	2.168		
5.08	64.0	0.780	0.78	3.9	127.0	1.547	1.55	7.7	186	2.265	2.27	11.3
7.62	75.0	0.914			135.0	1.644			198	2.412		
10.16	79.0	0.962			142.0	1.730			200	2.436		
12.7	81.0	0.987			145.0	1.766			206	2.509		



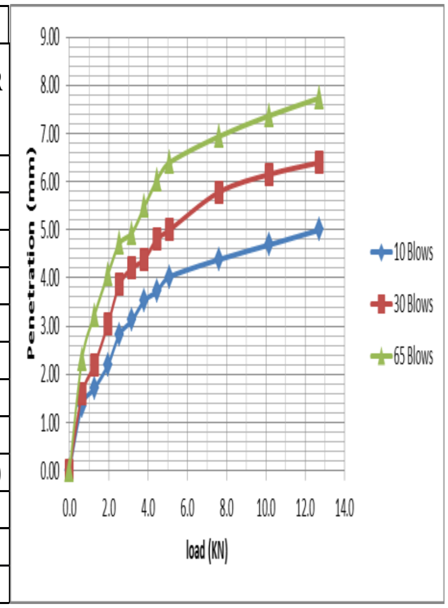
CBR versus Dry Density for Sub grade at Hangar Station

No.of blows	LOAD (KN)		CBR(%)		SWELL	DRY DENSITY Vs SOCKED C.B.R.			
	2.54mm	5.08mm	2.54mm	5.08mm	%				
10	0.55	0.78	4.11	3.90	2.21	No of blows	10	30	65
30	1.17	1.55	8.76	7.73	1.60	Dry density	1.38	1.65	1.97
65	1.77	2.27	13.23	11.33	0.68	Socked C.B.R.	4.11	8.76	13.23



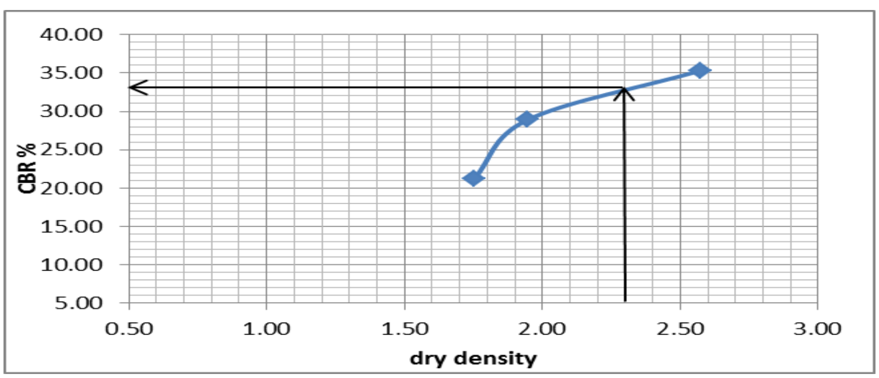
12.Penetration Test Data for Surface Wearing at Hangar Station

penetration	10 Blows				30 Blows				65 Blows			
(mm)	dial RDG	Load (kN)	Cor. Load (kN)	CBR %	dial RDG	load (KN)	Cor. Load (kN)	CBR %	dial RDG	load (KN	cor.load (KN)	CBR %
0.0	0.0	0.000			0.0	0.000			0	0.000		
0.64	110.0	1.340			130.0	1.583			190	2.314		
1.27	140.0	1.705			180.0	2.192			265	3.228		
1.96	180.0	2.192			250.0	3.045			335	4.080		
2.54	232.0	2.826	2.83	21.2	317.0	3.861	3.86	28.9	387	4.714	4.71	35.3
3.18	256.0	3.118			345.0	4.202			405	4.933		
3.81	290.0	3.532			360.0	4.385			450	5.481		
4.45	305.0	3.715			395.0	4.811			495	6.029		
5.08	330.0	4.019	4.02	20.1	410.0	4.994	4.99	25.0	525	6.395	6.39	32.0
7.62	360.0	4.385			475.0	5.786			570	6.943		
10.16	385.0	4.689			505.0	6.151			605	7.369		
12.7	410.0	4.994			525.0	6.395			635	7.734		



CBR versus Dry Density for Surface Wearing at Hangar Station

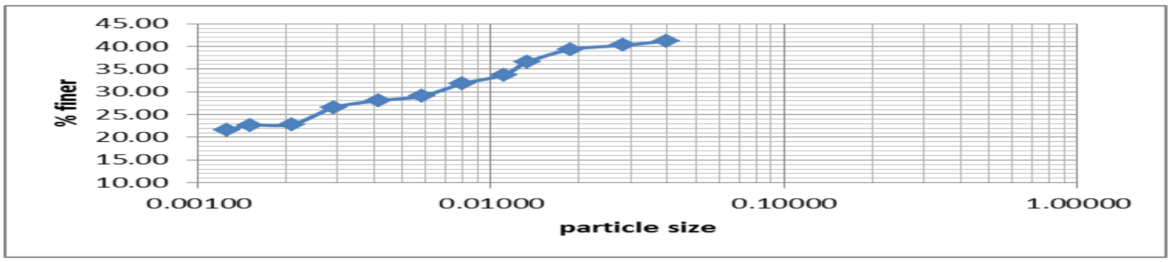
No.of blows	LOAD (KN)		CBR(%)		SWELL %	DRY DENSITY Vs SOCKED C.B.R.			
	2.54mm	5.08mm	2.54mm	5.08mm					
10	2.83	4.02	21.17	20.10	1.98	No # OF BLOWS	10	30	65
30	3.86	4.99	28.92	24.97	1.43	DRY DENSITY	1.75	1.95	2.57
65	4.71	6.39	35.31	31.97	0.51	SOCKED C.B.R.	21.17	28.92	35.31



Appendix F- Hydrometer Test

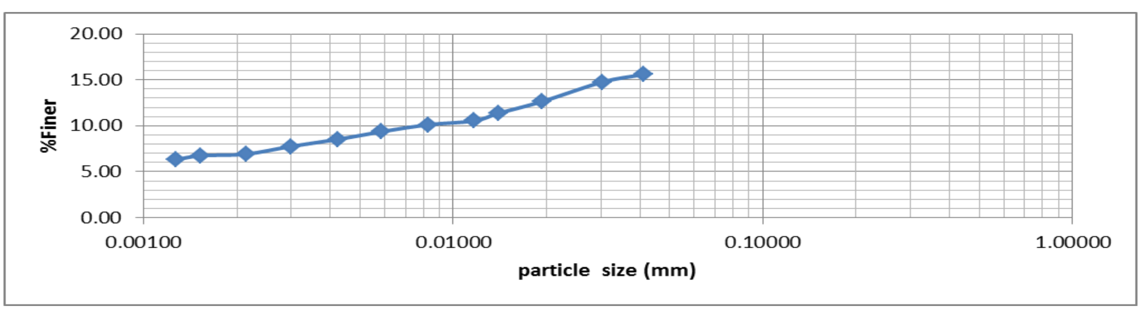
1. Hydrometer Test Results for Sub grade soil at Shambu Station

actual time	elapsed time(min	Temp. (oc)	Actual	hdr.corr, for (Cm)	effective depth,L	K Value	particle size	temp. corr.(Ct)	a value	corr. Hydr.(R	% finer P	% Adjusted finer,Pa
5:30: AM	1	20	50	51	8.6	0.01348	0.03953	0.00	0.99	44.00	87.12	41.21
5:32	2	20	49	50	8.9	0.01348	0.02844	0.00	0.99	43.00	85.14	40.27
:35	5	20	48	49	9.6	0.01348	0.01868	0.00	0.99	42.00	83.16	39.33
5:40	10	20	45	46	9.7	0.01348	0.01328	0.00	0.99	39.00	77.22	36.53
5:45	15	20	42	43	10.1	0.01348	0.01106	0.00	0.99	36.00	71.28	33.72
6:00	30	20	40	41	10.6	0.01348	0.00801	0.00	0.99	34.00	67.32	31.84
6:30	60	20	37	38	11.1	0.01348	0.00580	0.00	0.99	31.00	61.38	29.03
7:30	120	20	36	37	11.4	0.0135	0.00415	0.00	0.99	30.00	59.4	28.10
9:30	240	22	34	35	11.9	0.0132	0.00293	0.40	0.99	28.40	56.232	26.60
1:30	480	22	30	31	12.2	0.0132	0.00210	0.40	0.99	24.40	48.312	22.85
6:30	960	21	30	31	12.4	0.01332	0.00151	0.20	0.99	24.20	47.916	22.66
5:30: AM	1440	20	29	30	12.5	0.0135	0.00126	0.00	0.99	23.00	45.54	21.54



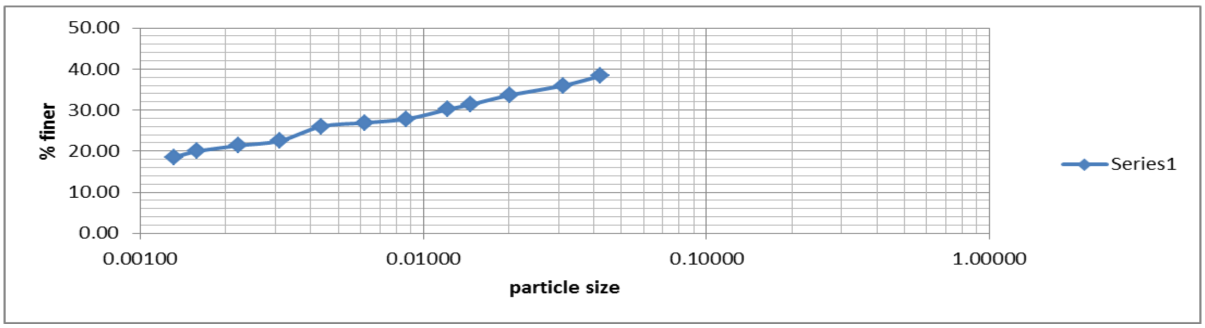
2.Hydrometer Test Results for Surface Wearingat Shambu Station

actual time	elapsed time(min	Temp. (oc)	Actual	hdr.corr, for (Cm)	effective depth,L	K Value	particle size	temp. corr.(Ct)	a value	corr. Hydr.(R	% finer P	% Adjusted finer,Pa
5:30: AM	1	20	43	44	9.2	0.01357	0.04116	0.00	1.00	37.00	74	15.60
5:32	2	20	41	42	9.9	0.01357	0.03019	0.00	1.00	35.00	70	14.76
:35	5	20	36	37	10.2	0.01357	0.01938	0.00	1.00	30.00	60	12.65
5:40	10	20	33	34	10.7	0.01357	0.01404	0.00	1.00	27.00	54	11.38
5:45	15	20	31	32	11.1	0.01357	0.01167	0.00	1.00	25.00	50	10.54
6:00	30	20	30	31	11.2	0.01357	0.00829	0.00	1.00	24.00	48	10.12
6:30	60	21	28	29	11.5	0.01340	0.00587	0.20	1.00	22.20	44.4	9.36
7:30	120	21	26	27	11.9	0.0134	0.00422	0.20	1.00	20.20	40.4	8.52
9:30	240	22	24	25	12.2	0.0132	0.00299	0.40	1.00	18.40	36.8	7.76
1:30	480	22	22	23	12.5	0.0132	0.00214	0.40	1.00	16.40	32.8	6.91
6:30	960	21	22	23	12.5	0.01340	0.00153	0.00	1.00	16.00	32	6.75
5:30: AM	1440	20	21	22	12.7	0.0136	0.00127	0.00	1.00	15.00	30	6.32



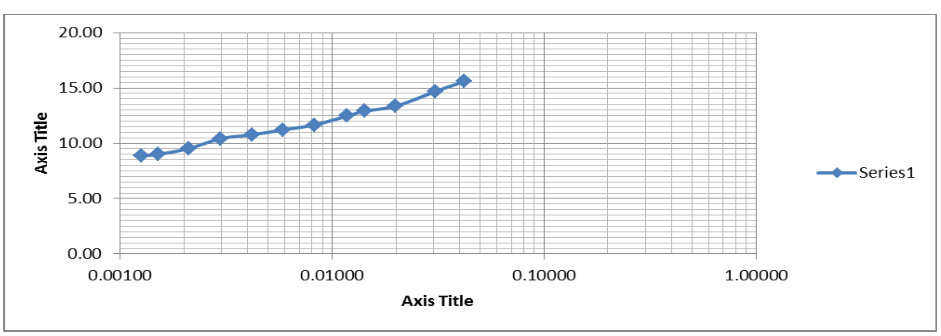
3.Hydrometer Test Results forSub grade soilat Abuna Station

actual time	elapsed	Temp. (oc)	Actual hydr.R	hdr.corr, for (Cm)	effective depth L	K Value	particle size	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted finer,Pa
5:30: AM	1	20	39	40	9.7	0.01352	0.04211	0.00	0.99	33.00	65.34	38.29
5:32	2	20	37	38	10.6	0.01352	0.03113	0.00	0.99	31.00	61.38	35.97
:35	5	20	35	36	11.2	0.01352	0.02023	0.00	0.99	29.00	57.42	33.65
5:40	10	20	33	34	11.7	0.01352	0.01462	0.00	0.99	27.00	53.46	31.33
5:45	15	20	32	33	12.2	0.01352	0.01219	0.00	0.99	26.00	51.48	30.17
6:00	30	20	30	31	12.5	0.01352	0.00873	0.00	0.99	24.00	47.52	27.85
6:30	60	21	29	30	12.9	0.01336	0.00619	0.20	0.99	23.20	45.936	26.92
7:30	120	22	28	29	13	0.0132	0.00434	0.40	0.99	22.40	44.352	25.99
9:30	240	22	25	26	13.3	0.0132	0.00311	0.40	0.99	19.40	38.412	22.51
1:30	480	22	24	25	13.5	0.0132	0.00221	0.40	0.99	18.40	36.432	21.35
6:30	960	21	23	24	13.5	0.01336	0.00158	0.20	0.99	17.20	34.056	19.96
5:30: AM	1440	20	22	23	13.7	0.01352	0.00132	0.00	0.99	16.00	31.68	18.56



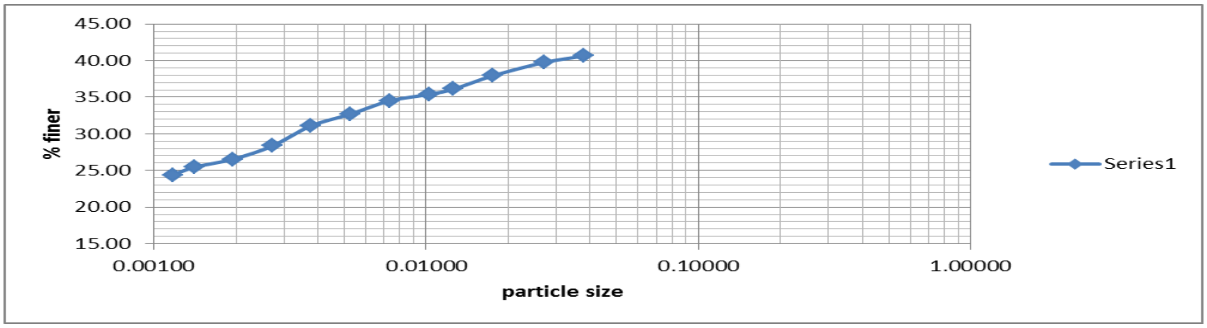
4.Hydrometer Test Results for Surface Wearingat Abuna Station

actual time	elapsed	Temp. (oc)	Actual hydr.R	hdr.corr, for (Cm)	effective depth L	K Value	particle size	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted finer,Pa
5:30: AM	1	20	41	42	9.4	0.01365	0.04185	0.00	1.00	35.00	70	15.59
5:32	2	20	39	40	10.2	0.01365	0.03083	0.00	1.00	33.00	66	14.70
:35	5	20	36	37	10.7	0.01365	0.01997	0.00	1.00	30.00	60	13.36
5:40	10	20	35	36	10.9	0.01365	0.01425	0.00	1.00	29.00	58	12.92
5:45	15	20	34	35	11.2	0.01365	0.01179	0.00	1.00	28.00	56	12.47
6:00	30	21	32	33	11.2	0.01348	0.00824	0.20	1.00	26.20	52.4	11.67
6:30	60	21	31	32	11.4	0.01348	0.00588	0.20	1.00	25.20	50.4	11.22
7:30	120	21	30	31	11.7	0.01348	0.00421	0.20	1.00	24.20	48.4	10.78
9:30	240	22	29	30	12	0.01332	0.00298	0.40	1.00	23.40	46.8	10.42
1:30	480	22	27	28	12	0.01332	0.00211	0.40	1.00	21.40	42.8	9.53
6:30	960	21	26	27	12.0	0.01348	0.00151	0.20	1.00	20.20	40.4	9.00
5:30: AM	1440	20	26	27	12.2	0.01365	0.00126	0.00	1.00	20.00	40	8.91



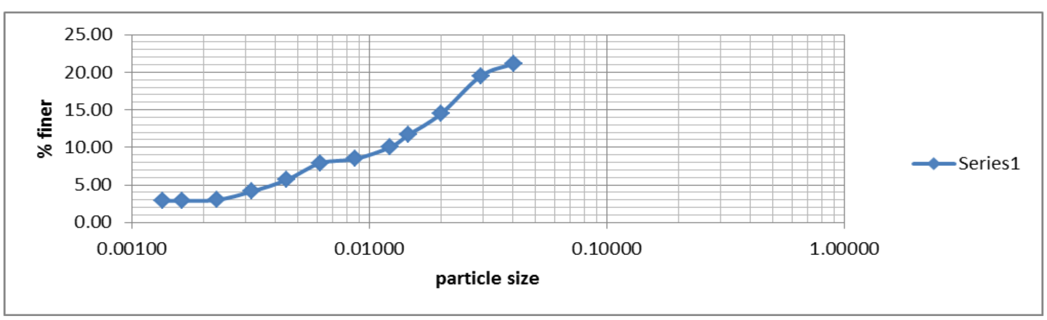
5.Hydrometer Test Results for Sub grade soil at Shuluke Station

actual time	elapsed time(min	Temp.(oc)	Actual hydr.Rd	hdr.corr,f or (Cm)	effective depth,L	K Value	particle size	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted
5:30: AM	1	20	51	52	7.8	0.01361	0.03801	0.00	1.00	45.00	90	40.64
5:32	2	20	50	51	7.9	0.01361	0.02705	0.00	1.00	44.00	88	39.73
:35	5	20	48	49	8.3	0.01361	0.01754	0.00	1.00	42.00	84	37.93
5:40	10	20	46	47	8.6	0.01361	0.01262	0.00	1.00	40.00	80	36.12
5:45	15	21	45	46	8.8	0.01344	0.01029	0.20	1.00	39.20	78.4	35.40
6:00	30	21	44	45	8.9	0.01344	0.00732	0.20	1.00	38.20	76.4	34.49
6:30	60	21	42	43	9.2	0.01344	0.00526	0.20	1.00	36.20	72.4	32.69
7:30	120	22	40	41	9.6	0.01328	0.00376	0.40	1.00	34.40	68.8	31.06
9:30	240	22	37	38	10.1	0.01328	0.00272	0.40	1.00	31.40	62.8	28.35
1:30	480	22	35	36	10.4	0.01328	0.00195	0.40	1.00	29.40	58.8	26.55
6:30	960	21	34	35	10.6	0.01344	0.00141	0.20	1.00	28.20	56.4	25.46
5:30: AM	1440	20	33	34	10.7	0.01361	0.00117	0.00	1.00	27.00	54	24.38



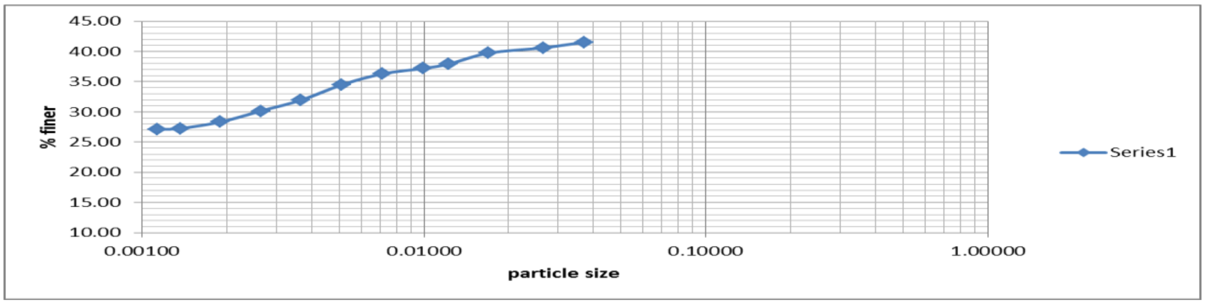
6.Hydrometer Test Results for Surface Wearingat Shuluke Station

actual time	elapsed time(min	Temp.(oc)	Actual hydr.Rd	hdr.corr,f or (Cm)	effective depth,L	K Value	particle size	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted
5:30: AM	1	20	44	45	8.9	0.01352	0.04033	0.00	0.99	38.00	75.24	21.14
5:32	2	20	41	42	9.4	0.01352	0.02931	0.00	0.99	35.00	69.3	19.47
:35	5	20	32	33	10.9	0.01352	0.01996	0.00	0.99	26.00	51.48	14.47
5:40	10	20	27	28	11.7	0.01352	0.01462	0.00	0.99	21.00	41.58	11.68
5:45	15	20	24	25	12.2	0.01352	0.01219	0.00	0.99	18.00	35.64	10.01
6:00	30	21	21	22	12.7	0.01336	0.00869	0.20	0.99	15.20	30.096	8.46
6:30	60	21	20	21	12.9	0.01336	0.00619	0.20	0.99	14.20	28.116	7.90
7:30	120	21	16	17	13.5	0.01336	0.00448	0.20	0.99	10.20	20.196	5.68
9:30	240	22	13	14	14	0.0132	0.00319	0.40	0.99	7.40	14.652	4.12
1:30	480	22	11	12	14.3	0.0132	0.00228	0.40	0.99	5.40	10.692	3.00
6:30	960	21	11	12	14.3	0.01336	0.00163	0.20	0.99	5.20	10.296	2.89
5:30: AM	1440	20	11	12	14.3	0.01352	0.00135	0.20	0.99	5.20	10.296	2.89



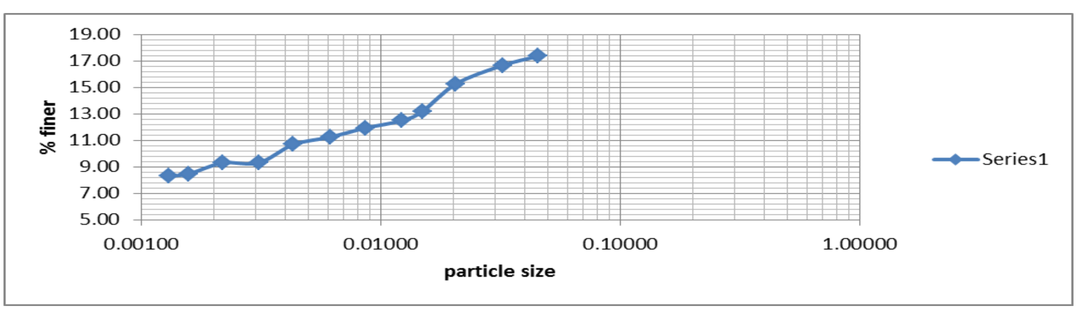
7.Hydrometer Test Results forSub grade soilat Jarmat Station

actual time	elapsed time(min.	Temp.(oc)	Actual hydr.Rdg	hdr.corr,for (Cm)	effective depth,L	K Value	particle size	temp. corr.(Ct	a value	corr. Hydr.(Rc)	% finer P	% Adjusted
5:30: AM	1	20	52	53	7.6	0.01344	0.03705	0.00	0.99	46.00	91.08	41.53
5:32	2	20	51	52	7.8	0.01344	0.02654	0.00	0.99	45.00	89.1	40.63
:35	5	20	50	51	7.9	0.01344	0.01689	0.00	0.99	44.00	87.12	39.73
5:40	10	20	48	49	8.3	0.01344	0.01224	0.00	0.99	42.00	83.16	37.92
5:45	15	21	47	48	8.4	0.01328	0.00994	0.20	0.99	41.20	81.576	37.20
6:00	30	21	46	47	8.6	0.01328	0.00711	0.20	0.99	40.20	79.596	36.30
6:30	60	21	44	45	8.9	0.01328	0.00511	0.20	0.99	38.20	75.636	34.49
7:30	120	22	41	42	9.4	0.01312	0.00367	0.40	0.99	35.40	70.092	31.96
9:30	240	22	39	40	9.7	0.01312	0.00264	0.40	0.99	33.40	66.132	30.16
1:30	480	22	37	38	10.1	0.01312	0.00190	0.40	0.99	31.40	62.172	28.35
6:30	960	21	36	37	10.2	0.01328	0.00137	0.20	0.99	30.20	59.796	27.27
5:30: AM	1440	20	36	37	10.2	0.01344	0.00113	0.00	0.99	30.00	59.4	27.09



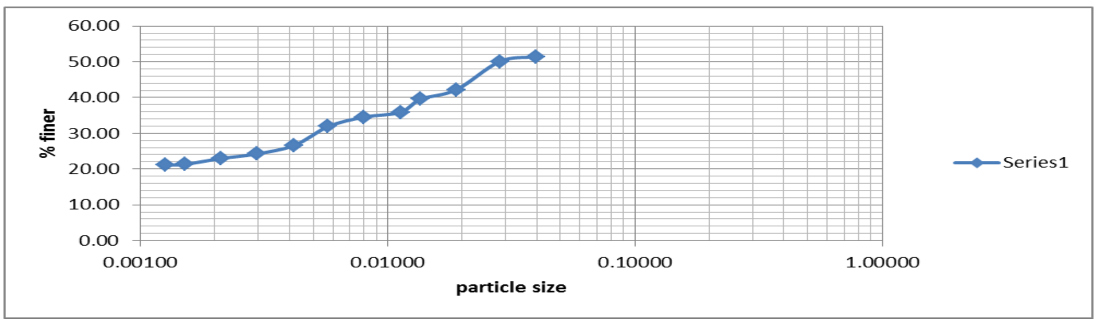
8.Hydrometer Test Results for Surface Wearing at Jarmat Station

actual time	elapsed time(mi	Temp.(oc)	Actual hydr.Rdg	hdr.corr,for (Cm)	effective depth,L	K Value	particle size	temp. corr.(Ct	a value	corr. Hydr.(Rc)	% finer P	% Adjusted
5:30: AM	1	20	31	32	11.1	0.01357	0.04521	0.00	1.00	25.00	62.5	17.35
5:32	2	20	30	31	11.2	0.01357	0.03211	0.00	1.00	24.00	60	16.66
:35	5	20	28	29	11.5	0.01357	0.02058	0.00	1.00	22.00	55	15.27
5:40	10	20	25	26	12	0.01357	0.01487	0.00	1.00	19.00	47.5	13.19
5:45	15	20	24	25	12.2	0.01357	0.01224	0.00	1.00	18.00	45	12.49
6:00	30	21	23	24	12.4	0.01340	0.00861	0.20	1.00	17.20	43	11.94
6:30	60	21	22	23	12.5	0.01340	0.00612	0.20	1.00	16.20	40.5	11.24
7:30	120	22	21	22	12.7	0.01324	0.00431	0.40	1.00	15.40	38.5	10.69
9:30	240	22	19	20	13	0.01324	0.00308	0.40	1.00	13.40	33.5	9.30
1:30	480	22	19	20	13	0.01324	0.00218	0.40	1.00	13.40	33.5	9.30
6:30	960	21	18	19	13.2	0.01340	0.00157	0.20	1.00	12.20	30.5	8.47
5:30: AM	1440	20	18	19	13.2	0.01357	0.00130	0.00	1.00	12.00	30	8.33



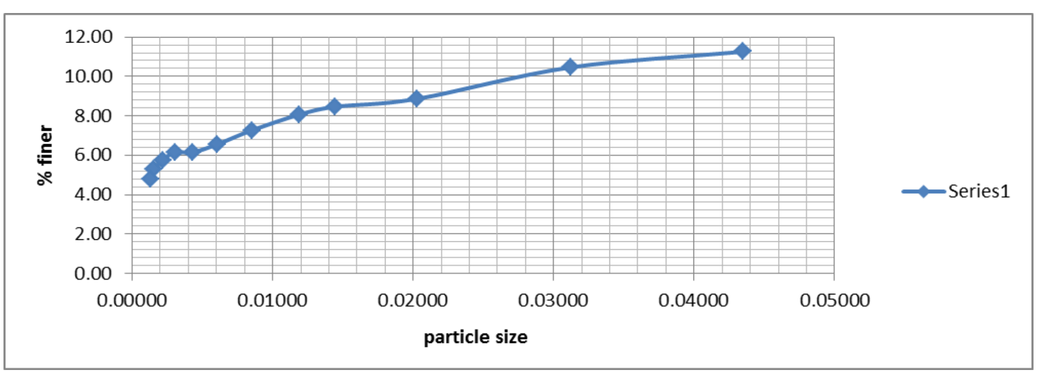
9. Hydrometer Test Results for Sub grade soilat Irro Station

actual time	elapsed time(mi	Temp.(oc)	Actual hydr.Rd	hdr.corr, for (Cm)	effective depth,L	K Value	particle size	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted
5:30: AM	1	20	45	46	8.8	0.01348	0.03999	0.00000	0.99	39.00	77.22	51.43
5:32	2	20	44	45	8.9	0.01348	0.02844	0.00000	0.99	38.00	75.24	50.11
:35	5	20	38	39	9.9	0.01348	0.01897	0.00000	0.99	32.00	63.36	42.20
5:40	10	20	36	37	10.2	0.01348	0.01361	0.00000	0.99	30.00	59.40	39.56
5:45	15	21	33	34	10.7	0.01332	0.01125	0.20000	0.99	27.20	53.86	35.87
6:00	30	21	32	33	10.9	0.01332	0.00803	0.20000	0.99	26.20	51.88	34.55
6:30	60	21	30	31	11.2	0.01332	0.00575	0.20000	0.99	24.20	47.92	31.91
7:30	120	21	26	27	11.9	0.01332	0.004195	0.20000	0.99	20.20	40.00	26.64
9:30	240	22	24	25	12.2	0.01316	0.002967	0.40000	0.99	18.40	36.43	24.26
1:30	480	22	23	24	12.4	0.01316	0.002115	0.40000	0.99	17.40	34.45	22.95
6:30	960	21	22	23	12.5	0.0	0.00152	0.20000	0.99	16.20	32.08	21.36
5:30: AM	1440	20	22	23	12.5	0.01348	0.001256	0.00000	0.99	16.00	31.68	21.10



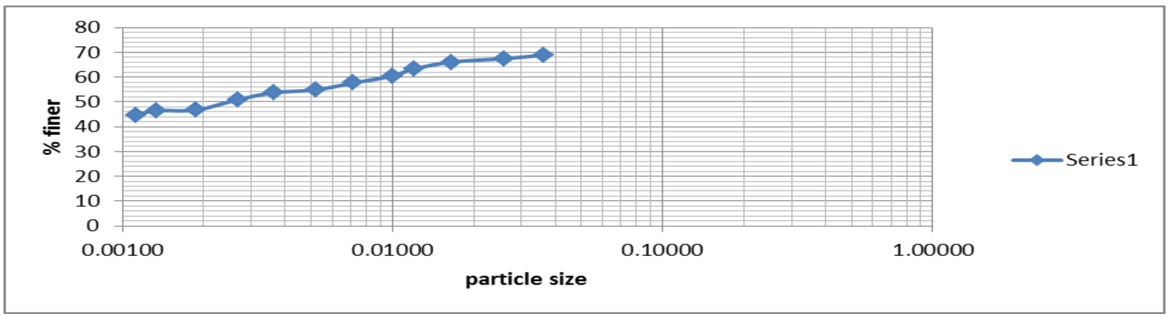
10.Hydrometer Test Results for Surface Wearingat Irro Station

actual time	elapsed time(mi	Temp.(oc)	Actual hydr.Rd	hdr.corr, for (Cm)	effective depth,L	K Value	particle size	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted
5:30: AM	1	21	34	35	10.6	0.01336	0.04350	0.20000	0.99	28.20	55.84	11.26
5:32	2	21	32	33	10.9	0.01336	0.03119	0.20000	0.99	26.20	51.88	10.46
:35	5	21	28	29	11.5	0.01336	0.02026	0.20000	0.99	22.20	43.96	8.86
5:40	10	21	27	28	11.7	0.01336	0.01445	0.20000	0.99	21.20	41.98	8.46
5:45	15	21	26	27	11.9	0.01336	0.01190	0.20000	0.99	20.20	40.00	8.06
6:00	30	21	24	25	12.2	0.01336	0.00852	0.20000	0.99	18.20	36.04	7.26
6:30	60	22	22	23	12.5	0.0132	0.00602	0.40000	0.99	16.40	32.47	6.55
7:30	120	22	21	22	12.7	0.0132	0.004294	0.40000	0.99	15.40	30.49	6.15
9:30	240	22	21	22	12.7	0.0132	0.003036	0.40000	0.99	15.40	30.49	6.15
1:30	480	22	20	21	12.9	0.0132	0.002164	0.40000	0.99	14.40	28.51	5.75
6:30	960	21	19	20	13	0.0	0.00155	0.20000	0.99	13.20	26.14	5.27
5:30: AM	1440	20	18	19	13.2	0.01352	0.001294	0.00000	0.99	12.00	23.76	4.79



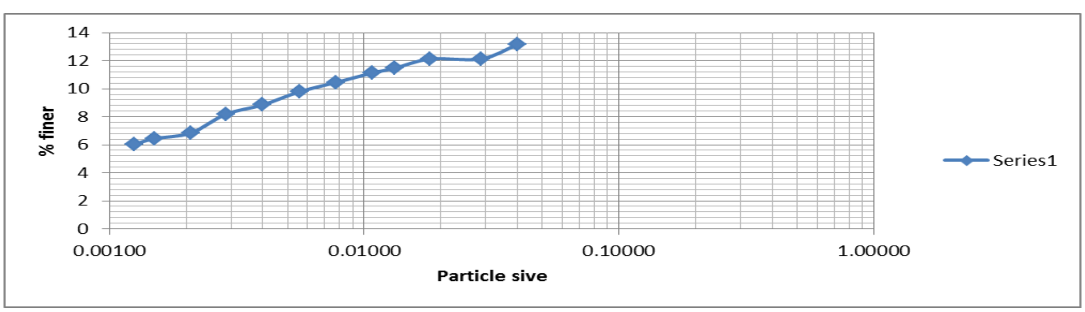
11. Hydrometer Test Results forSub grade soilat Hangar Station

actual time	elapsed time(	Temp .(oc)	Actual hydr.	hdr.corr,for	effective depth,	K Value	particle size D(mm)	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted finer,Pa
4:34	1	21	55	56	7.1	0.01356	0.03613	0.20	1.00	49.20	98.4	68.88
4:36	2	21	54	55	7.3	0.01356	0.02591	0.20	1.00	48.20	96.4	67.48
0.20069	5	21	53	54	7.4	0.01356	0.01650	0.20	1.00	47.20	94.4	66.08
4:44	10	21	51	52	7.8	0.01356	0.01198	0.20	1.00	45.20	90.4	63.28
4:49	15	21	49	50	8.1	0.01356	0.00996	0.20	1.00	43.20	86.4	60.48
5:04	30	21	47	48	8.4	0.01356	0.00718	0.20	1.00	41.20	82.4	57.68
5:34	60	21	45	46	8.8	0.01356	0.00519	0.20	1.00	39.20	78.4	54.88
6:34	120	22	44	45	8.9	0.0134	0.00365	0.40	1.00	38.40	76.8	53.76
8:34	240	22	42	43	9.6	0.0134	0.00268	0.40	1.00	36.40	72.8	50.96
12:34	480	22	39	40	9.4	0.0134	0.00188	0.40	1.00	33.40	66.8	46.76
8:34	960	21	39	40	9.4	0.01356	0.00134	0.20	1.00	33.20	66.4	46.48
4:34	1440	20	38	39	9.6	0.01374	0.00112	0.00	1.00	32.00	64	44.8



12.Hydrometer Test Results for Surface Wearing at Hangar Station

actual time	elapsed time(min.)	Temp .(oc)	Actual hydr. Rdg	hdr.corr,for	effective depth,	K Value	particle size D(mm)	temp. corr.(Ct)	a value	corr. Hydr.(Rc)	% finer P	% Adjusted finer,Pa
5:30: AM	1	21	45	46	8.8	0.01340	0.03975	0.20	1.00	39.20	78.4	13.1398
5:32	2	21	42	43	9.2	0.01340	0.02874	0.20	1.00	36.20	72.4	12.1342
:35	5	21	42	43	9.2	0.01340	0.01818	0.20	1.00	36.20	72.4	12.1342
5:40	10	21	40	41	9.6	0.01340	0.01313	0.20	1.00	34.20	68.4	11.4638
5:45	15	21	39	40	9.7	0.01340	0.01078	0.20	1.00	33.20	66.4	11.1286
6:00	30	21	37	38	10.1	0.01340	0.00778	0.20	1.00	31.20	62.4	10.4582
6:30	60	21	35	36	10.4	0.01340	0.00558	0.20	1.00	29.20	58.4	9.78784
7:30	120	22	32	33	10.9	0.01324	0.00399	0.40	1.00	26.40	52.8	8.84928
9:30	240	22	30	31	11.2	0.01324	0.00286	0.40	1.00	24.40	48.8	8.17888
1:30	480	22	26	27	11.9	0.01324	0.00208	0.40	1.00	20.40	40.8	6.83808
6:30	960	21	25	26	12.0	0.01340	0.00150	0.20	1.00	19.20	38.4	6.43584
5:30: AM	1440	20	24	25	12.2	0.01357	0.00125	0.00	1.00	18.00	36	6.0336



Appendix- G: Distress Data

1.Distress data at shambu to sekela section

sample location	No.of samples taken at 20m interval	Types of distress							
		1.rutting		2.a.Surface erosion/longitudinal		2.b.Surface erosion/transverse		3.potholes	
		w (mm	d (mm	w(mm)	d (mm)	w(mm)	d (mm)	w(mm)	d(mm)
at norma grade of exit shambu town down to	1	0	0	59	51	0	0	0	0
	2	0	0	78	31	23	18	0	0
	3	0	0	106	52	38	35	0	0
	4	0	0	133	64	41	64	0	0
	5	0	0	125	75	94	44	0	0
	avg.	0	0	100.2	54.6	39.2	32.2	0	0
degree	A	1		4		2		1	
at rolling and curves around Laku village	1	54	68	0	0	0	0	0	0
	2	85	72	84	68	57	40	0	0
	3	213	66	93	31	73	62	46	41
	4	118	79	52	74	99	61	38	35
	5	35	56	0	0	45	33	119	30
	avg.	101	68.2	45.8	34.6	54.8	39.2	40.6	21.2
degree	B	5		3		3		3	
at chabir rolling and high grade	1	65	69	145	73	28	41	34	15
	2	57	25	740	65	82	37	65	17
	3	47	50	32	16	220	140	75	35
	4	0	0	58	55	60	32	96	22
	5	144	117	45	24	29	77	86	49
	avg.	62.6	52.2	204	46.6	83.8	65.4	71.2	27.6
degree	C	4		4		4		3	
at chabir flat grade	1	0	0	363	43	32	30	0	0
	2	0	0	145	38	70	24	0	0
	3	0	0	524	20	59	55	0	0
	4	0	0	610	39	34	27	0	0
	5	175	413	69	66	86	92	0	0
	avg.	35	82.6	342.2	41.2	56.2	45.6	0	0
degree	D	5		4		4		1	
at oda buluk flat grade	1	144	38	0	0	0	0	14	94
	2	253	46	0	0	0	0	58	60
	3	90	29	0	0	0	0	45	69
	4	65	51	0	0	0	0	175	52
	5	1090	173	0	0	0	0	90	87
	avg.	328	67.4	0	0	0	0	76.4	72.4
degree	E	5		1		1		5	
at entrance of sakala town flat grade	1	85	39	0	0	0	0	74	74
	2	55	67	0	0	0	0	182	95
	3	92	25	0	0	0	0	236	78
	4	0	0	0	0	0	0	982	125
	5	765	689	0	0	0	0	46	23
	avg.	199	164	0	0	0	0	304	79
degree	F	5		1		1		5	

2.Distress data at sekela to Abuna section

sample location code	No.of samples taken at 40m	1.rutting		2.a.Surface erosion/longitudinal		2.b.Surface erosion/transverse		3.potholes	
		w (mm)	d (mm)	w(mm)	d (mm)	w(mm)	d (mm)	w(mm)	d(mm)
at noral grade of exit sakal town, slight curve	1	0	0	0	0	41	54	0	0
	2	0	0	0	0	62	85	147	80
	3	0	0	0	0	128	35	90	29
	4	0	0	0	0	38	125	88	34
	5	0	0	251	216	10	67	76	108
	avg.	0	0	50.2	43.2	55.8	73.2	80.2	50.2
degree	A	1		3		3		4	
flat area around haro,	1	0	0	0	0	0	0	241	27
	2	320	45	0	0	0	0	342	64
	3	150	68	0	0	0	0	514	90
	4	54	60	0	0	0	0	0	0
	5	74	35	0	0	0	0	0	0
	avg.	119.6	41.6	0	0	0	0	219.4	36.2
degree	B	4		1		1		3	
at rolling in plato areas	1	53	67	0	0	164	89	0	0
	2	54	85	0	0	164	33	0	0
	3	27	33	0	0	210	146	0	0
	4	500	85	0	0	171	82	468	78
	5	0	0	0	0	133	125	0	0
	avg.	126.8	54	0	0	168.4	95	93.6	15.6
degree	C	5		1		4		2	
around entrance to abuna villages slight grade	1	0	0	328	22	0	0	621	452
	2	0	0	230	44	0	0	0	0
	3	0	0	63	19	0	0	0	0
	4	16	61	0	0	0	0	0	0
	5	90	147	58	36	0	0	0	0
		21.2	41.6	135.8	24.2	0	0	124.2	90.4
degree	D	4		3		1		5	
around Abuna river at slight grade	1	0	0	51	114	0	0	201	32
	2	0	0	62	55	0	0	44	45
	3	0	0	122	50	0	0	0	0
	4	0	0	0	0	0	0	92	87
	5	0	0	76	42	0	0	0	0
	avg.	0	0	62.2	52.2	0	0	67.4	32.8
degree	E	1		4		1		3	

3.Distress data at Abuna to Shuluke section

sample location code	No.of samples taken at 40m	1.rutting		2.a.Surface erosion/longitudinal		2.b.Surface erosion/transverse		3.potholes	
		w (mm)	d (mm)	w(mm)	d (mm)	w(mm)	d (mm)	w(mm)	d(mm)
at slight grade of Abuna	1	0	0	95	34	213	96	50	85
	2	0	0	87	42	64	274	47	66
	3	0	0	126	59	325	253	35	51
	4	0	0	263	64	83	162	55	72
	5	0	0	251	61	462	190	74	148
	avg.	0	0	164.4	52	229.4	195	52.2	84.4
degree	A	1		4		5		5	
at abuna flat grade	1	0		0	0	0	0	0	0
	2	237	157	0	0	64	74	47	66
	3	205	68	0	0	55	53	35	51
	4	0	0	0	0	83	62	55	72
	5	0	0	0	0	462	90	74	48
	avg.	88.4	45	0	0	132.8	55.8	42.2	47.4
degree	B	1		1		4		4	
at rolling grade	1	0	0	46	58	186	417	28	23
	2	0	0	61	100	269	84	24	42
	3	0	0	78	87	243	95	62	17
	4	0	0	0	0	326	52	16	30
	5	0	0	21	38	234	63	65	31
	avg.	0	0	41.2	56.6	251.6	142.2	39	28.6
degree	C	1		4		5		3	
at flat grade	1	0	0	87	39	35	241	0	0
	2	56	80	0	0	146	366	0	0
	3	27	69	0	0	420	296	0	0
	4	276	158	0	0	0	0	0	0
	5	105	64	90	28	0	0	0	0
	avg.	92.8	74.2	35.4	13.4	120.2	180.6	0	0
degree	D	5		2		4		1	
at slight grade in village.	1	161	90	47	52	0	0	0	0
	2	82	67	56	62	0	0	0	0
	3	44	70	63	114	0	0	74	164
	4	40	69	78	100	0	0	0	0
	5	89	49	53	35	0	0	1062	513
	avg.	83.2	69	59.4	72.6	0	0	227.2	135.4
degree	E	5		5		1		5	
at around shuluke curves	1	50	85	0	0	0	0	0	0
	2	83	69	84	68	0	0	0	0
	3	102	62	93	31	0	0	0	0
	4	99	107	52	74	0	0	38	35
	5	0	0	0	0	0	0	119	30
	avg.	66.8	64.6	45.8	34.6	0	0	31.4	13
degree	F	5		3		1		2	

4.Distress data at ShuluketoJarmat section

sample location	No.of samples taken at 40m	1.rutting		2.a.Surface erosion/longitudinal		2.b.Surface erosion/transverse		3.potholes	
	No.	w (mm)	d (mm)	w(mm)	d (mm)	w(mm)	d (mm)	w(mm)	d(mm)
at rollingand curves of shuluke	1	0	0	186	462	0	0	357	514
	2	721	234	817	410	0	0	0	0
	3	140	179	1500	298	79	246	0	0
	4	0	0	172	60	238	76	0	0
	5	365	965	56	1080	0	0	142	106
	avg.	245.2	275.6	546.2	462	63.4	64.4	99.8	124
degree	A	5		5		3		5	
at shuluke near forest	1	0	0	0	0	0	0	416	178
	2	346	159	0	0	0	0	286	270
	3	0	0	68	195	0	0	104	162
	4	0	0	242	264	0	0	1009	354
	5	0	0	158	63	0	0	625	149
	avg.	69.2	31.8	93.6	104.4	0	0	488	222.6
degree	B	3		5		1		5	
at curves section in villages	1	0	0	132	174	105	240	0	0
	2	0	0	0	0	461	60	0	0
	3	634	415	0	0	250	169	0	0
	4	130	256	210	351	111	200	0	0
	5	0	0	96	207	96	1000	0	0
	avg.	152.8	134.2	87.6	146.4	204.6	333.8	0	0
degree	C	5		4		5		1	
jardega flat rolling grade	1	97	110	0	0	470	578	0	0
	2	430	100	0	0	0	0	0	0
	3	37	80	2451	126	51	90	450	54
	4	55	62	179	153	0	0	125	63
	5	863	60	0	0	93	345	0	0
	avg.	296.4	82.4	526	55.8	122.8	202.6	115	23.4
degree	D	5		5		5		3	
at entrance to jardega flat grade	1	0	0	0	0	0	0	0	0
	2	82	82	0	0	0	0	1200	146
	3	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0
	5	32	175	0	0	0	0	148	39
	avg.	22.8	51.4	0	0	0	0	269.6	37
degree	E	3		1		1		3	

5.Distress data at Jarmat to Jarte section

sample location code	No.of samples taken at 40m interval	1.rutting		2.a.Surface erosion/longitudinal		2.b.Surface erosion/transverse		3.potholes	
		w (mm)	d (mm)	w(mm)	d (mm)	w(mm)	d (mm)	w(mm)	d(mm)
at rolling to flat of jarmat exit	1	0	0	0	0	0	0	82	141
	2	0	0	178	300	0	0	164	223
	3	0	0	1622	95	0	0	0	0
	4	116	168	0	0	0	0	0	0
	5	0	0	0	0	0	0	246	421
	avg.	23.2	33.6	360	79	0	0	98.4	157
degree	A	3		5		1		5	
rolling around wandi school	1	439	136	0	0	0	0	0	0
	2	346	159	0	0	320	525	0	0
	3	0	0	0	0	0	0	510	74
	4	0	0	0	0	71	146	651	468
	5	0	0	0	0	0	0	0	0
	avg.	157	59	0	0	78.2	134.2	232.2	108.4
degree	B	4		1		5		5	
at Aga Alabe slight grade	1	0	0	178	340	0	0	0	0
	2	0	0	746	0	0	0	0	0
	3	0	0	413	0	250	169	0	0
	4	0	0	124	81	0	0	0	0
	5	283	328	190	48	143	196	0	0
	avg.	56.6	65.6	330.2	93.8	78.6	73	0	0
degree	C	5		5		3		1	
at kattaa ali grade section	1	2480	1600	0	0	176	800	1200	241
	2	0	0	90	55	126	468	0	0
	3	0	0	410	730	0	0	0	0
	4	0	0	675	1042	0	0	0	0
	5	0	0	9100	324	0	0	0	0
	avg.	496	320	2055	430.2	60.4	253.6	240	48.2
degree	D	5		5		5		3	
at ula sogida steep grade	1	0	0	235	83	0	0	0	0
	2	0	0	146	35	0	0	0	0
	3	0	0	77	52	0	0	0	0
	4	0	0	89	61	0	0	0	0
	5	0	0	60	93	0	0	0	0
	avg.	0	0	121.4	64.8	0	0	0	0
degree	E	1		5		1		1	
at entrance to Jarte town	1	0	0	0	0	53	170	0	0
	2	124	97	0	0	0	0	0	0
	3	0	0	0	0	250	169	0	0
	4	72	33	124	81	111	200	0	0
	5	0	0	190	48	1000	96	0	0
	avg.	39.2	26	62.8	25.8	282.8	127	0	0
degree	F	3		3		5		1	

6.Distress data at Jarte to Amuru section

sample location	No.of samples taken	1.rutting		2.a.Surface erosion/longitudinal		2.b.Surface erosion/transverse		3.potholes	
		w (mm	d (mm	w(mm	d (mm	w(mm	d (mm	w(mm	d(mm)
at steep grade of exit jarte town top to down	1	0	0	95	34	0	0	0	0
	2	0	0	87	42	0	0	0	0
	3	0	0	126	59	0	0	0	0
	4	0	0	263	64	0	0	0	0
	5	26	46	251	115	0	0	0	0
	avg.	5.2	9.2	164	62.8	0	0	0	0
degree	A	2		5		1		1	
flat area around irro school	1	0	0	64	70	224	130	0	0
	2	934	63	0	0	0	0	0	0
	3	426	72	0	0	0	0	215	170
	4	0	0	0	0	0	0	156	81
	5	0	0	0	0	0	0	0	0
	avg.	272	27	0	0	44.8	26	74.2	50.2
degree	B	3		1		2		3	
at hangar forest with curves/ grades,	1	80	96	87	93	35	41	0	0
	2	65	52	0	0	346	256	0	0
	3	72	84	0	0	420	296	0	0
	4	1000	79	29	42	0	0	0	0
	5	0	0	90	48	0	0	0	0
	avg.	243	62.2	41.2	36.6	160	118.6	0	0
degree	C	5		3		5		1	
at gura goromti flat area/rolling	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	325	120	0	0	0	0	74	164
	4	516	85	0	0	0	0	0	0
	5	98	174	69	123	0	0	1062	513
	avg.	188	75.8	13.8	24.6	0	0	227	135.4
degree	D	5		3		1		5	
at Ejere village rolling grade	1	124	145	47	52	241	220	0	0
	2	128	236	56	62	0	0	0	0
	3	21	80	63	114	0	0	74	164
	4	134	96	78	100	187	147	0	0
	5	236	43	53	35	65	95	1062	513
	avg.	129	120	59.4	72.6	98.6	92.4	227	135.4
degree	E	5		5		3		5	
at entrance to amuru town	1	0	0	0	0	0	0	65	46
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	12	24
	5	0	0	0	0	0	0	0	0
	avg.	0	0	0	0	0	0	15.4	14
degree	F	1		1		1		2	

Appendix-H: Side Drainage Factor Data

1.Side Drainage Factot at Shambu –Sekela Section

Sample place	sample NO.	shoulder width (m)		carriage width, w (m)	total width, D (m)	half width, d3		from edge of shoulder to start pt of bottom drng. d2(m)		c/c of drainage at bottom d1(m)		sum of d3+d2+d1=d(m)		h,bottom of drng to top of surface h		drainage factor, DF= d*h	
		L	R			L	R	L	R	L	R	L	R	L	R	L	R
at exit of shambu town	1	1.00	1.00	7.00	9.00	4.50	4.50	1.35	1.28	0.00	0.00	5.85	5.78	0.42	0.52	2.46	3.01
	2	1.00	1.00	7.00	9.00	4.50	4.50	1.30	1.26	0.00	0.00	5.80	5.76	0.50	0.56	2.90	3.23
	3	1.00	1.00	7.00	9.00	4.50	4.50	1.27	1.34	0.00	0.00	5.77	5.84	0.48	0.74	2.77	4.32
	4	1.00	1.00	7.00	9.00	4.50	4.50	1.32	1.33	0.00	0.00	5.82	5.83	0.39	0.81	2.27	4.72
	5	1.00	1.00	7.00	9.00	4.50	4.50	1.30	1.25	0.00	0.00	5.80	5.75	0.39	0.80	2.26	4.60
	avg.	1.00	1.00	7.00	9.00	4.50	4.50	1.31	1.29	0.00	0.00	5.81	5.79	0.44	0.69	2.53	3.98
at laku flat grade	1	0.00	0.50	6.20	6.70	3.10	3.60	0.00	0.00	0.00	0.00	3.10	3.60	0.76	0.00	2.36	0.00
	2	0.00	0.50	5.90	6.40	2.95	3.45	0.00	0.00	0.00	0.00	2.95	3.45	0.81	0.00	2.39	0.00
	3	0.00	0.50	5.50	6.00	2.75	3.25	0.00	0.00	0.00	0.00	2.75	3.25	0.98	0.00	2.70	0.00
	4	0.00	0.50	6.00	6.50	3.00	3.50	0.00	0.00	0.00	0.00	3.00	3.50	0.96	0.00	2.88	0.00
	5	0.00	0.50	6.30	6.80	3.15	3.65	0.00	0.00	0.00	0.00	3.15	3.65	0.43	0.00	1.35	0.00
	avg.	0.00	0.50	5.98	6.48	2.99	3.49	0.00	0.00	0.00	0.00	2.99	3.49	0.79	0.00	2.34	0.00
	1	0.50	0.50	7.00	8.00	4.00	4.00	0.64	0.53	0.00	0.00	4.64	4.53	0.69	0.85	3.20	3.85
at chabir steep grade	2	0.48	0.50	7.00	7.98	3.98	4.00	0.70	0.65	0.00	0.00	4.68	4.65	0.64	1.02	3.00	4.74
	3	0.40	0.49	7.00	7.89	3.90	3.99	0.67	0.80	0.00	0.00	4.57	4.79	0.90	0.96	4.11	4.60
	4	0.44	0.50	7.00	7.94	3.94	4.00	0.51	0.82	0.00	0.00	4.45	4.82	0.76	1.15	3.38	5.54
	5	0.45	0.50	7.00	7.95	3.95	4.00	0.64	0.79	0.00	0.00	4.59	4.79	0.58	1.22	2.66	5.84
	avg.	0.45	0.50	7.00	7.95	3.95	4.00	0.63	0.72	0.00	0.00	4.59	4.72	0.71	1.04	3.27	4.92
	1	0.50	0.50	7.00	8.00	4.00	4.00	1.25	1.30	0.00	0.00	5.25	5.30	0.46	0.62	2.42	3.29
at exit of chair rolling grade	2	0.50	0.50	7.00	8.00	4.00	4.00	1.45	1.58	0.00	0.00	5.45	5.58	0.63	0.57	3.43	3.18
	3	0.50	0.50	7.00	8.00	4.00	4.00	1.48	1.32	0.00	0.00	5.48	5.32	0.51	0.60	2.79	3.19
	4	0.50	0.50	7.00	8.00	4.00	4.00	1.28	1.54	0.00	0.00	5.28	5.54	0.58	0.56	3.06	3.10
	5	0.50	0.50	7.00	8.00	4.00	4.00	1.54	1.28	0.00	0.00	5.54	5.28	0.52	0.55	2.88	2.90
	avg.	0.50	0.50	7.00	8.00	4.00	4.00	1.40	1.40	0.00	0.00	5.40	5.40	0.54	0.58	2.92	3.13
	1	1.00	1.00	7.00	9.00	4.50	4.50	0.74	0.65	0.00	0.00	5.24	5.15	0.90	0.82	4.72	4.22
at oda buluk flat grade	2	1.00	1.00	7.00	9.00	4.50	4.50	0.75	0.60	0.00	0.00	5.25	5.10	0.76	0.72	3.99	3.67
	3	1.00	1.00	7.00	9.00	4.50	4.50	0.70	0.69	0.00	0.00	5.20	5.19	0.86	0.84	4.47	4.36
	4	1.00	1.00	7.00	9.00	4.50	4.50	0.68	0.70	0.00	0.00	5.18	5.20	0.71	0.76	3.68	3.95
	5	1.00	1.00	7.00	9.00	4.50	4.50	0.64	0.62	0.00	0.00	5.14	5.12	0.70	0.76	3.60	3.89
	avg.	1.00	1.00	7.00	9.00	4.50	4.50	0.70	0.65	0.00	0.00	5.20	5.15	0.79	0.78	4.09	4.02
at entrance of sakala town	1	1.00	1.00	6.70	8.70	4.35	4.35	1.53	1.24	0.00	0.00	5.88	5.59	0.51	0.43	3.00	2.40
	2	1.00	1.00	6.50	8.50	4.25	4.25	1.62	1.62	0.00	0.00	5.87	5.87	0.65	0.62	3.82	3.64
	3	1.00	1.00	7.00	9.00	4.50	4.50	1.71	1.43	0.00	0.00	6.21	5.93	0.70	0.47	4.35	2.79
	4	1.00	1.00	7.00	9.00	4.50	4.50	1.60	1.44	0.00	0.00	6.10	5.94	0.75	0.84	4.58	4.99
	5	1.00	1.00	6.80	8.80	4.40	4.40	1.40	1.52	0.00	0.00	5.80	5.92	0.58	0.81	3.36	4.80
	avg.	1.00	1.00	6.80	8.80	4.40	4.40	1.75	1.45	0.00	0.00	5.97	5.85	0.64	0.63	3.82	3.72

2.Side Drainage Factot at Sekela – Abuna Section

Sample place	sample NO.	shoulder width (m)		carraige width, w (m)	total width, D (m)	half width, d3		from edge of shoulder to start pt of bottom drng. d2(m)		c/c of drainage at bottom d1(m)		sum of d3+d2+d1=d(m)		h,bottom of drng to top of surface h		drainage factor, DF= d*h	
		L	R			L	R	L	R	L	R	L	R	L	R	L	R
at exit of sakala	1	0.50	0.50	7.00	8.00	4.00	4.00	1.35	0.00	0.00	0.00	5.35	4.00	0.39	0.60	2.09	2.40
	2	0.50	0.45	7.00	7.95	4.00	3.95	1.30	0.00	0.00	0.00	5.30	3.95	0.52	0.75	2.76	2.96
	3	0.50	0.44	7.00	7.94	4.00	3.94	1.34	0.00	0.00	0.00	5.34	3.94	0.56	0.70	2.99	2.76
	4	0.50	0.44	7.00	7.94	4.00	3.94	1.34	0.00	0.00	0.00	5.34	3.94	0.60	0.67	3.20	2.64
	5	0.50	0.45	7.00	7.95	4.00	3.95	1.28	0.00	0.00	0.00	5.28	3.95	0.54	0.71	2.85	2.80
	avg.	0.50	0.46	7.00	7.96	4.00	3.96	1.32	0.00	0.00	0.00	5.32	3.96	0.52	0.69	2.78	2.71
at flat grade of dimbe	1	0.00	0.50	6.80	7.30	3.40	3.90	0.00	0.00	0.00	0.00	3.40	3.90	1.60	0.00	5.44	0.00
	2	0.00	0.50	6.60	7.10	3.30	3.80	0.00	0.00	0.00	0.00	3.30	3.80	1.43	0.00	4.72	0.00
	3	0.00	0.45	6.50	6.95	3.25	3.70	0.00	0.00	0.00	0.00	3.25	3.70	1.49	0.00	4.84	0.00
	4	0.00	0.38	7.00	7.38	3.50	3.88	0.00	0.00	0.00	0.00	3.50	3.88	1.20	0.00	4.20	0.00
	5	0.50	0.40	7.00	7.90	4.00	3.90	0.00	0.00	0.00	0.00	4.00	3.90	0.34	0.00	1.36	0.00
	avg.	0.10	0.45	6.78	7.33	3.49	3.84	0.00	0.00	0.00	0.00	3.49	3.84	1.21	0.00	4.11	0.00
	1	0.50	0.50	6.00	7.00	3.50	3.50	1.00	0.98	0.00	0.00	4.50	4.48	0.84	0.53	3.78	2.37
at flat grade tulu boshi	2	0.50	0.50	4.60	5.60	2.80	2.80	1.30	0.95	0.00	0.00	4.10	3.75	0.93	0.50	3.81	1.88
	3	0.50	0.50	5.80	6.80	3.40	3.40	1.35	0.90	0.00	0.00	4.75	4.30	0.90	0.41	4.28	1.76
	4	0.50	0.50	6.40	7.40	3.70	3.70	1.26	0.87	0.00	0.00	4.96	4.57	0.40	0.60	1.98	2.74
	5	0.50	0.50	6.20	7.20	3.60	3.60	1.30	0.65	0.00	0.00	4.90	4.25	0.45	0.65	2.21	2.76
	avg.	0.50	0.50	5.80	6.80	3.40	3.40	1.24	0.87	0.00	0.00	4.64	4.27	0.70	0.54	3.21	2.30
	1	0.47	0.36	7.00	7.83	3.97	3.86	1.32	1.29	0.00	0.00	5.29	5.15	0.64	0.71	3.39	3.66
at grade laga abuna	2	0.32	0.35	7.00	7.67	3.82	3.85	1.25	1.85	0.00	0.00	5.07	5.70	0.68	0.65	3.45	3.71
	3	0.41	0.38	7.00	7.79	3.91	3.88	1.54	1.76	0.00	0.00	5.45	5.64	0.92	0.76	5.01	4.29
	4	0.45	0.42	7.00	7.87	3.95	3.92	1.82	1.54	0.00	0.00	5.77	5.46	0.85	0.74	4.90	4.04
	5	0.47	0.44	7.00	7.91	3.97	3.94	1.45	1.58	0.00	0.00	5.42	5.52	0.83	0.66	4.50	3.64
	avg.	0.42	0.39	7.00	7.81	3.92	3.89	1.48	1.60	0.00	0.00	5.40	5.49	0.78	0.70	4.25	3.87
	1	0.00	0.50	7.00	7.50	3.50	4.00	0.00	0.00	0.00	0.00	3.50	4.00	1.53	0.00	5.36	0.00
at high grade of laga abuna	2	0.00	0.50	7.00	7.50	3.50	4.00	0.00	0.00	0.00	0.00	3.50	4.00	1.27	0.00	4.45	0.00
	3	0.00	0.50	7.00	7.50	3.50	4.00	0.00	0.00	0.00	0.00	3.50	4.00	1.58	0.00	5.53	0.00
	4	0.00	0.50	7.00	7.50	3.50	4.00	0.00	0.00	0.00	0.00	3.50	4.00	1.07	0.00	3.75	0.00
	5	0.00	0.50	7.00	7.50	3.50	4.00	0.00	0.00	0.00	0.00	3.50	4.00	1.67	0.00	5.85	0.00
	avg.	0.00	0.50	7.00	7.50	3.50	4.00	0.00	0.00	0.00	0.00	3.50	4.00	1.42	0.00	4.98	0.00

3.Side Drainage Factot at Abuna - Shuluke Section

Sample place	sample NO.	shoulder width (m)		carriage width,w (m)	total width, D (m)	half width, d3		from edge of shoulder to edge of drng. d2(m)		c/c of drainage d1(m) at bottom		sum of d3+d2+d1=d (m)		h,bottom of drng to top of surface h		drainage factor, DF= d*h	
		L	R			L	R	L	R	L	R	L	R	L	R	L	R
at abuna river	1	0.50	0.50	7.00	8.00	4.00	4.00	0.59	0.00	0.00	0.00	4.59	4.00	0.64	0.00	2.94	0.00
	2	0.50	0.50	7.00	8.00	4.00	4.00	0.78	0.00	0.00	0.00	4.78	4.00	0.68	0.00	3.25	0.00
	3	0.50	0.50	7.00	8.00	4.00	4.00	0.75	0.00	0.00	0.00	4.75	4.00	0.70	0.00	3.33	0.00
	4	0.50	0.50	7.00	8.00	4.00	4.00	0.76	0.00	0.00	0.00	4.76	4.00	0.83	0.00	3.95	0.00
	5	0.50	0.50	7.00	8.00	4.00	4.00	0.71	0.00	0.00	0.00	4.71	4.00	0.75	0.00	3.53	0.00
	avg.	0.50	0.50	7.00	8.00	4.00	4.00	0.72	0.00	0.00	0.00	4.72	4.00	0.72	0.00	3.40	0.00
at bone village	1	0.50	0.50	7.00	8.00	4.00	4.00	1.50	1.35	0.00	0.00	5.50	5.35	1.25	0.47	6.88	2.51
	2	0.50	0.50	7.00	8.00	4.00	4.00	1.46	1.30	0.00	0.00	5.46	5.30	1.29	0.34	7.04	1.80
	3	0.50	0.50	7.00	8.00	4.00	4.00	1.20	0.00	0.00	0.00	5.20	4.00	1.24	0.00	6.45	0.00
	4	0.50	0.50	7.00	8.00	4.00	4.00	0.98	0.00	0.00	0.00	4.98	4.00	1.20	0.00	5.98	0.00
	5	0.50	0.50	7.00	8.00	4.00	4.00	0.88	0.00	0.00	0.00	4.88	4.00	1.35	0.00	6.59	0.00
	avg.	0.50	0.50	7.00	8.00	4.00	4.00	1.20	0.53	0.00	0.00	5.20	4.53	1.27	0.16	6.59	0.86
	1	0.48	0.40	7.00	7.88	3.98	3.90	1.62	1.68	0.00	0.00	5.60	5.58	0.46	0.53	2.58	2.96
chato at grade	2	0.46	0.38	7.00	7.84	3.96	3.88	1.54	1.52	0.00	0.00	5.50	5.40	0.65	0.50	3.58	2.70
	3	0.45	0.40	7.00	7.85	3.95	3.90	1.65	1.68	0.00	0.00	5.60	5.58	0.25	0.38	1.40	2.12
	4	0.40	0.46	7.00	7.86	3.90	3.96	1.69	1.97	0.00	0.00	5.59	5.93	0.40	0.30	2.24	1.78
	5	0.42	0.45	7.00	7.87	3.92	3.95	1.57	1.45	0.00	0.00	5.49	5.40	0.62	0.25	3.40	1.35
	avg.	0.44	0.42	7.00	7.86	3.94	3.92	1.61	1.66	0.00	0.00	5.56	5.58	0.48	0.39	2.64	2.18
	1	0.42	0.38	7.00	7.80	3.92	3.88	1.32	1.29	0.00	0.00	5.24	5.17	0.45	0.33	2.36	1.71
at harbu charana	2	0.40	0.35	7.00	7.75	3.90	3.85	1.25	1.85	0.00	0.00	5.15	5.70	0.52	0.30	2.68	1.71
	3	0.47	0.38	7.00	7.85	3.97	3.88	1.54	1.76	0.00	0.00	5.51	5.64	0.65	0.26	3.58	1.47
	4	0.44	0.38	7.00	7.82	3.94	3.88	1.82	1.54	0.00	0.00	5.76	5.42	0.75	0.20	4.32	1.08
	5	0.47	0.44	7.00	7.91	3.97	3.94	1.45	1.58	0.00	0.00	5.42	5.52	0.83	0.16	4.50	0.88
	avg.	0.44	0.39	7.00	7.83	3.94	3.89	1.48	1.60	0.00	0.00	5.42	5.49	0.64	0.25	3.49	1.37
	1	0.00	0.38	7.00	7.38	3.50	3.88	0.00	0.00	0.00	0.00	3.50	3.88	0.75	0.67	2.63	2.60
at laga farso	2	0.00	0.50	7.00	7.50	3.50	4.00	0.00	0.00	0.00	0.00	3.50	4.00	0.85	0.90	2.98	3.60
	3	0.00	0.00	6.35	6.35	3.18	3.18	0.00	0.00	0.00	0.00	3.18	3.18	0.97	0.51	3.08	1.62
	4	0.00	0.00	6.10	6.10	3.05	3.05	0.00	0.00	0.00	0.00	3.05	3.05	0.80	0.58	2.44	1.77
	5	0.00	0.00	5.70	5.70	2.85	2.85	0.00	0.00	0.00	0.00	2.85	2.85	0.56	0.86	1.60	2.45
	avg.	0.00	0.18	6.43	6.61	3.22	3.39	0.00	0.00	0.00	0.00	3.22	3.39	0.79	0.70	2.54	2.41
at shuluke steep grade	1	0.00	0.38	6.00	6.38	3.00	3.38	0.00	0.00	0.00	0.00	3.00	3.38	1.20	0.34	3.60	1.15
	2	0.00	0.50	6.50	7.00	3.25	3.75	0.00	0.00	0.00	0.00	3.25	3.75	1.56	0.40	5.07	1.50
	3	0.00	0.00	6.40	6.40	3.20	3.20	0.00	0.00	0.00	0.00	3.20	3.20	1.67	0.53	5.34	1.70
	4	0.00	0.00	6.20	6.20	3.10	3.10	0.00	0.00	0.00	0.00	3.10	3.10	1.70	0.55	5.27	1.71
	5	0.00	0.00	6.70	6.70	3.35	3.35	0.00	0.00	0.00	0.00	3.35	3.35	0.54	0.68	1.81	2.28
	avg.	0.00	0.18	6.36	6.54	3.18	3.36	0.00	0.00	0.00	0.00	3.18	3.36	1.33	0.50	4.22	1.67

4.Side Drainage Factor at Shuluke-Jarmat Section

Sample place	sample NO.	shoulder width (m)		carriage width, w (m)	total width, D (m)	half width, d3		from edge of shoulder to edge of drng. d2(m)		c/c of drainage d1(m) at bottom		sum of d3+d2+d1=d (m)		h,bottom of drng to top of surface h		drainage factor, DF= d*h	
		L	R			L	R	L	R	L	R	L	R	L	R	L	R
at flat shuluke forest	1	0.50	0.00	7.00	7.50	4.00	3.50	0.00	0.00	0.00	0.00	4.00	3.50	0.00	0.85	0.00	2.98
	2	0.50	0.00	7.00	7.50	4.00	3.50	0.00	0.00	0.00	0.00	4.00	3.50	0.00	1.54	0.00	5.39
	3	0.50	0.00	7.00	7.50	4.00	3.50	0.00	0.00	0.00	0.00	4.00	3.50	0.00	1.83	0.00	6.41
	4	0.50	0.00	7.00	7.50	4.00	3.50	0.00	0.00	0.00	0.00	4.00	3.50	0.00	1.65	0.00	5.78
	5	0.50	0.00	7.00	7.50	4.00	3.50	0.00	0.00	0.00	0.00	4.00	3.50	0.00	1.87	0.00	6.55
	avg.	0.50	0.00	7.00	7.50	4.00	3.50	0.00	0.00	0.00	0.00	4.00	3.50	0.00	1.55	0.00	5.42
at flat in villages	1	0.50	0.00	6.80	7.30	3.90	3.40	1.47	1.25	0.00	0.00	5.37	4.65	0.52	0.65	2.79	3.02
	2	0.50	0.00	6.50	7.00	3.75	3.25	1.60	0.87	0.00	0.00	5.35	4.12	0.35	0.60	1.87	2.47
	3	0.50	0.00	7.00	7.50	4.00	3.50	1.50	1.00	0.00	0.00	5.50	4.50	0.00	0.45	0.00	2.03
	4	0.50	0.00	7.00	7.50	4.00	3.50	1.60	1.00	0.00	0.00	5.60	4.50	0.00	0.50	0.00	2.25
	5	0.50	0.00	7.00	7.50	4.00	3.50	1.20	1.62	0.00	0.00	5.20	5.12	0.00	0.00	0.00	0.00
	avg.	0.50	0.00	6.86	7.36	3.93	3.43	1.47	1.15	0.00	0.00	5.40	4.58	0.17	0.44	0.93	1.95
at curve and grade	1	0.50	0.00	7.50	8.00	4.25	3.75	0.00	0.00	0.00	0.00	4.25	3.75	0.60	0.65	2.55	2.44
	2	0.50	0.00	7.40	7.90	4.20	3.70	0.00	0.00	0.00	0.00	4.20	3.70	0.47	0.60	1.97	2.22
	3	0.00	0.00	8.00	8.00	4.00	4.00	0.00	0.00	0.00	0.00	4.00	4.00	0.68	0.46	2.72	1.84
	4	0.00	0.00	8.00	8.00	4.00	4.00	0.00	0.00	0.00	0.00	4.00	4.00	0.56	0.45	2.24	1.80
	5	0.00	0.00	8.00	8.00	4.00	4.00	0.00	0.00	0.00	0.00	4.00	4.00	0.40	0.50	1.60	2.00
	avg.	0.20	0.00	7.78	7.98	4.09	3.89	0.00	0.00	0.00	0.00	4.09	3.89	0.54	0.53	2.22	2.06
at flat grade in village	1	0.90	0.76	7.00	8.66	4.40	4.26	1.32	1.29	0.00	0.00	5.72	5.55	0.52	0.63	2.97	3.50
	2	0.85	0.88	7.00	8.73	4.35	4.38	1.25	1.85	0.00	0.00	5.60	6.23	0.55	0.51	3.08	3.18
	3	0.75	0.86	7.00	8.61	4.25	4.36	1.54	1.76	0.00	0.00	5.79	6.12	0.59	0.56	3.42	3.43
	4	0.79	0.85	7.00	8.64	4.29	4.35	1.82	1.54	0.00	0.00	6.11	5.89	0.58	0.60	3.54	3.53
	5	0.89	1.00	7.00	8.89	4.39	4.50	1.45	1.58	0.00	0.00	5.84	6.08	0.83	0.66	4.85	4.01
	avg.	0.84	0.87	7.00	8.71	4.34	4.37	1.48	1.60	0.00	0.00	5.81	5.97	0.61	0.59	3.57	3.53
at flat jardega town	1	1.00	1.00	7.00	9.00	4.50	4.50	1.65	1.58	0.00	0.00	6.15	6.08	1.46	1.50	8.98	9.12
	2	1.00	1.00	7.00	9.00	4.50	4.50	1.70	1.62	0.00	0.00	6.20	6.12	1.62	1.50	10.04	9.18
	3	1.00	1.00	7.00	9.00	4.50	4.50	1.59	1.56	0.00	0.00	6.09	6.06	1.63	1.54	9.93	9.33
	4	1.00	1.00	7.00	9.00	4.50	4.50	1.55	1.65	0.00	0.00	6.05	6.15	1.80	1.58	10.89	9.72
	5	1.00	1.00	7.00	9.00	4.50	4.50	1.61	1.64	0.00	0.00	6.11	6.14	1.67	1.59	10.20	9.76
	avg.	1.00	1.00	7.00	9.00	4.50	4.50	1.62	1.61	0.00	0.00	6.12	6.11	1.64	1.54	10.01	9.42

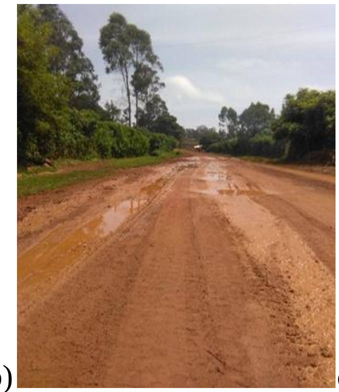
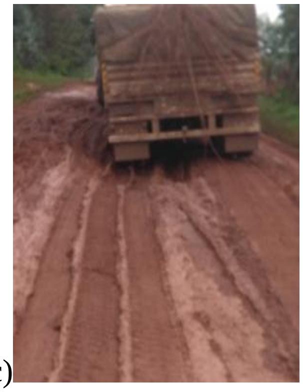
5.Side Drainage Factor at Jarmat –Jarte Section

Sample place	sample NO.	shoulder width (m)		carraige width, w (m)	total width, D (m)	half width, d3		from edge of shoulder to edge of drng. d2(m)		c/c of drainage d1(m) at bottom		sum of d3+d2+d1=d (m)		h,bottom of drng to top of surface h		drainage factor, DF= d*h	
		L	R			L	R	L	R	L	R	L	R	L	R	L	R
at exit of jardega town	1	0.50	1.00	7.00	8.50	4.00	4.50	1.36	1.43	0.00	0.00	5.36	5.93	0.78	1.21	4.18	7.18
	2	0.40	1.00	7.00	8.40	3.90	4.50	1.80	1.61	0.00	0.00	5.70	6.11	1.39	1.65	7.92	10.08
	3	0.41	0.90	7.00	8.31	3.91	4.40	1.55	1.71	0.00	0.00	5.46	6.11	1.42	1.38	7.75	8.43
	4	0.42	0.36	7.00	7.78	3.92	3.86	1.65	1.64	0.00	0.00	5.57	5.50	1.40	1.02	7.80	5.61
	5	0.50	0.47	6.50	7.47	3.75	3.72	1.55	1.67	0.00	0.00	5.30	5.39	1.14	0.92	6.04	4.96
	avg.	0.45	0.75	6.90	8.09	3.90	4.20	1.58	1.61	0.00	0.00	5.48	5.81	1.23	1.24	6.74	7.25
at wandr rolling grade	1	0.00	0.00	6.54	6.54	3.27	3.27	1.34	1.43	0.00	0.00	4.61	4.70	1.62	1.69	7.47	7.94
	2	0.50	0.50	6.20	7.20	3.60	3.60	1.40	1.55	0.00	0.00	5.00	5.15	1.53	1.36	7.65	7.00
	3	0.50	0.40	6.40	7.30	3.70	3.60	1.49	1.10	0.00	0.00	5.19	4.70	0.62	0.62	3.22	2.91
	4	0.50	0.40	7.00	7.90	4.00	3.90	1.68	1.52	0.00	0.00	5.68	5.42	0.57	0.44	3.24	2.38
	5	0.00	0.00	7.00	7.00	3.50	3.50	1.34	2.54	0.00	0.00	4.84	6.04	0.64	0.49	3.10	2.96
	avg.	0.30	0.26	6.63	7.19	3.61	3.57	1.45	1.63	0.00	0.00	5.06	5.20	1.00	0.92	4.93	4.64
at Aga Alabe normal grade	1	0.00	0.60	6.50	7.10	3.25	3.85	0.50	0.00	0.00	0.00	3.75	3.85	0.41	0.00	1.54	0.00
	2	0.00	0.65	6.50	7.15	3.25	3.90	0.50	0.00	0.00	0.00	3.75	3.90	0.24	0.00	0.90	0.00
	3	0.00	0.52	6.50	7.02	3.25	3.77	0.00	0.00	0.00	0.00	3.25	3.77	0.56	0.00	1.82	0.00
	4	0.00	0.40	6.80	7.20	3.40	3.80	0.25	0.00	0.00	0.00	3.65	3.80	0.35	0.00	1.28	0.00
	5	0.00	0.38	7.00	7.38	3.50	3.88	0.30	0.00	0.00	0.00	3.80	3.88	0.40	0.00	1.52	0.00
	avg.	0.00	0.51	6.66	7.17	3.33	3.84	0.31	0.00	0.00	0.00	3.64	3.84	0.39	0.00	1.41	0.00
at kata ali	1	0.50	0.00	8.00	8.50	4.50	4.00	1.76	0.00	0.00	0.00	6.26	4.00	0.00	0.38	0.00	1.52
	2	0.50	0.00	7.50	8.00	4.25	3.75	1.80	0.00	0.00	0.00	6.05	3.75	0.00	0.87	0.00	3.26
	3	0.50	0.00	7.30	7.80	4.15	3.65	1.79	0.00	0.00	0.00	5.94	3.65	0.00	0.56	0.00	2.04
	4	0.60	0.00	6.00	6.60	3.60	3.00	1.72	0.00	0.00	0.00	5.32	3.00	0.00	1.04	0.00	3.12
	5	0.60	0.00	6.50	7.10	3.85	3.25	1.66	0.00	0.00	0.00	5.51	3.25	0.00	0.49	0.00	1.59
	avg.	0.54	0.00	7.06	7.60	4.07	3.53	1.75	0.00	0.00	0.00	5.82	3.53	0.00	0.67	0.00	2.31
at hula sogida	1	0.75	0.75	7.00	8.50	4.25	4.25	2.24	1.75	0.00	0.00	6.49	6.00	0.00	0.64	0.00	3.84
	2	0.75	0.75	6.50	8.00	4.00	4.00	2.00	1.50	0.00	0.00	6.00	5.50	0.00	0.71	0.00	3.91
	3	0.75	0.75	6.80	8.30	4.15	4.15	1.60	1.40	0.00	0.00	5.75	5.55	0.00	0.86	0.00	4.77
	4	0.75	0.75	7.00	8.50	4.25	4.25	1.29	1.00	0.00	0.00	5.54	5.25	0.00	0.72	0.00	3.78
	5	0.75	0.75	7.20	8.70	4.35	4.35	1.04	1.00	0.00	0.00	5.39	5.35	0.00	0.75	0.00	4.01
	avg.	0.75	0.75	6.90	8.40	4.20	4.20	1.63	1.33	0.00	0.00	5.83	5.53	0.00	0.74	0.00	4.06
at jarte entrance town	1	1.00	1.00	8.00	10.00	5.00	5.00	1.45	1.75	0.00	0.00	6.45	6.75	1.35	0.40	8.71	2.70
	2	1.00	1.00	8.00	10.00	5.00	5.00	1.50	1.50	0.00	0.00	6.50	6.50	1.72	0.57	11.18	3.71
	3	1.00	1.00	8.00	10.00	5.00	5.00	1.20	1.40	0.00	0.00	6.20	6.40	1.68	0.62	10.42	3.97
	4	1.00	1.00	8.00	10.00	5.00	5.00	0.92	1.00	0.00	0.00	5.92	6.00	1.70	0.73	10.06	4.38
	5	1.00	1.00	8.00	10.00	5.00	5.00	0.80	1.00	0.00	0.00	5.80	6.00	1.76	0.70	10.21	4.20
	avg.	1.00	1.00	8.00	10.00	5.00	5.00	1.17	1.33	0.00	0.00	6.17	6.33	1.64	0.60	10.12	3.79

6.Side Drainage Factor at Jarte to Amuru Section

Sample place	sample NO.	shoulder width (m)		carriage width, w (m)	total width, D	half width, d3		from edge of shoulder to edge of drng. d2(m)		c/c of drainage d1(m) at bottom		d= d3+d2+d1 (m)		h,bottom of drng to top of surface h		drainage factor, DF= d*h	
		L	R			L	R	L	R	L	R	L	R	L	R	L	R
at grade of Iro village	1	0.50	0.00	5.10	5.60	3.05	2.55	0.00	0.00	0.00	0.00	3.05	2.55	0.00	1.00	0.00	2.55
	2	0.50	0.00	5.60	6.10	3.30	2.80	0.00	0.00	0.00	0.00	3.30	2.80	0.00	1.12	0.00	3.14
	3	0.50	0.00	4.80	5.80	2.90	2.90	0.00	0.00	0.00	0.00	2.90	2.90	0.00	0.98	0.00	2.84
	4	0.50	0.00	5.00	5.50	3.00	2.50	0.00	0.00	0.00	0.00	3.00	2.50	0.00	0.78	0.00	1.95
	5	0.50	0.00	4.80	6.10	2.90	2.40	0.00	0.00	0.00	0.00	2.90	2.40	0.00	0.84	0.00	2.02
	avg.	0.50	0.00	5.06	5.82	3.03	2.63	0.00	0.00	0.00	0.00	3.03	2.63	0.00	0.94	0.00	2.50
flat grade at Iro shool	1	0.50	0.40	6.20	7.10	3.60	3.50	1.50	1.35	0.00	0.00	5.10	4.85	0.65	1.23	3.32	5.97
	2	0.50	0.50	7.00	8.00	4.00	4.00	1.20	1.37	0.00	0.00	5.20	5.37	0.90	1.28	4.68	6.87
	3	0.50	0.40	7.00	7.90	4.00	3.90	1.50	1.25	0.00	0.00	5.50	5.15	0.86	1.40	4.73	7.21
	4	0.50	0.40	7.00	7.90	4.00	3.90	1.60	1.25	0.00	0.00	5.60	5.15	0.50	1.30	2.80	6.70
	5	0.50	0.40	7.00	7.90	4.00	3.90	1.20	1.62	0.00	0.00	5.20	5.52	0.43	1.15	2.24	6.35
	avg.	0.50	0.42	6.84	7.76	3.92	3.84	1.40	1.37	0.00	0.00	5.32	5.21	0.67	1.27	3.55	6.62
at hangar curves and steep grades	1	0.30	0.00	6.00	6.30	3.30	3.00	0.50	0.00	0.00	0.00	3.80	3.00	0.84	0.00	3.19	0.00
	2	0.00	0.00	4.60	4.60	2.30	2.30	0.50	0.00	0.00	0.00	2.80	2.30	0.93	0.00	2.60	0.00
	3	0.40	0.00	5.80	6.20	3.30	2.90	0.00	0.00	0.00	0.00	3.30	2.90	0.90	0.00	2.97	0.00
	4	0.40	0.00	6.40	6.80	3.60	3.20	0.25	0.00	0.00	0.00	3.85	3.20	0.40	0.00	1.54	0.00
	5	0.35	0.00	6.20	6.55	3.45	3.10	0.30	0.00	0.00	0.00	3.75	3.10	0.45	0.00	1.69	0.00
	avg.	0.29	0.00	5.80	6.09	3.19	2.90	0.31	0.00	0.00	0.00	3.50	2.90	0.70	0.00	2.40	0.00
at Goromti flat grade	1	0.47	0.36	7.00	7.83	3.97	3.86	1.32	1.29	0.00	0.00	5.29	5.15	0.64	0.71	3.39	3.66
	2	0.32	0.35	7.00	7.67	3.82	3.85	1.25	1.85	0.00	0.00	5.07	5.70	0.68	0.65	3.45	3.71
	3	0.41	0.38	7.00	7.79	3.91	3.88	1.54	1.76	0.00	0.00	5.45	5.64	0.92	0.76	5.01	4.29
	4	0.45	0.42	7.00	7.87	3.95	3.92	1.82	1.54	0.00	0.00	5.77	5.46	0.85	0.74	4.90	4.04
	5	0.47	0.44	7.00	7.91	3.97	3.94	1.45	1.58	0.00	0.00	5.42	5.52	0.83	0.66	4.50	3.64
	avg.	0.42	0.39	7.00	7.81	3.92	3.89	1.48	1.60	0.00	0.00	5.40	5.49	0.78	0.70	4.25	3.87
at ejere rolling grade	1	0.50	0.40	6.40	7.30	3.70	3.60	1.58	1.60	0.00	0.00	5.28	5.20	0.65	0.32	3.43	1.66
	2	0.50	0.33	6.50	7.33	3.75	3.58	1.65	1.65	0.00	0.00	5.40	5.23	0.72	0.51	3.89	2.67
	3	0.45	0.00	6.30	6.75	3.60	3.15	1.59	1.56	0.00	0.00	5.19	4.71	0.61	0.46	3.17	2.17
	4	0.50	0.00	6.00	6.50	3.50	3.00	1.54	1.55	0.00	0.00	5.04	4.55	0.38	0.71	1.92	3.23
	5	0.51	0.00	6.50	7.01	3.76	3.25	1.50	1.57	0.00	0.00	5.26	4.82	0.37	0.58	1.95	2.80
	avg.	0.49	0.15	6.34	6.98	3.66	3.32	1.57	1.59	0.00	0.00	5.23	4.90	0.55	0.52	2.87	2.50
at Amumu entrance town	1	0.70	0.70	7.00	8.40	4.20	4.20	1.58	1.60	0.00	0.00	5.78	5.80	1.35	1.41	7.80	8.18
	2	1.00	1.00	7.00	9.00	4.50	4.50	1.65	1.65	0.00	0.00	6.15	6.15	1.72	1.45	10.58	8.92
	3	1.00	1.00	7.00	9.00	4.50	4.50	1.59	1.56	0.00	0.00	6.09	6.06	1.68	1.48	10.23	8.97
	4	1.00	1.00	7.00	9.00	4.50	4.50	1.54	1.55	0.00	0.00	6.04	6.05	1.70	1.51	10.27	9.14
	5	1.00	1.00	7.00	9.00	4.50	4.50	1.50	1.57	0.00	0.00	6.00	6.07	1.76	1.49	10.56	9.04
	avg.	0.94	0.94	7.00	8.88	4.44	4.44	1.57	1.59	0.00	0.00	6.01	6.03	1.64	1.47	9.89	8.85

APPENDIX I-Some Performance indicator Category Photos

a)  b)  c) 

d)  e)  f) 

 g) 

a)subgrade exposure, b) severely damaged due to lack of good crown, c)lack of surface wearing course, d) closed cross pipe drainage due to luck of maintenance, e) longitudinal erosion damaged surface, f) partial failure of road way due land slide, g) poor side drainage damaged by scouring and erosion.