JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT

GEOTECHNICAL ENGINEERING STREAM

CAUSES OF PAVEMENT EARLY DETERIORATION AND ITS REMEDIAL MESSURES: CASE STUDY IN AGARO – DEDESA ROAD

A final 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 (Geotechnical Engineering)

By

Bethelhem Habtemariam

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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Examiner   Signature   Date

ABSTRACT

This study has been conducted in Agaro-Dedesa Road segment which is located in western Oromiya regional state to identify causes of pavement early failure and to recommend remedial measures.

The existing engineering properties of the pavement materials, have been the causes of road failure and the extent of defects were evaluated based on this possible measures to meet its design life without further pavement deterioration have been recommended.

In order to determine in-situ conditions of road material previous study in the area and document from the client has been collected. In addition to this, necessary laboratory tests were carried out on representative samples extracted from the site. The data obtained from the field investigation and laboratory tests were analyzed and interpreted by explanatory and comparative analytical methods. Normal test procedures have been used to investigate the property of the soil, even though there may be a possibility that the soil in the study area can be lateritic soil type

The results of the study showed that the causes of early deterioration of the pavement are weakness of subgrade material, pavement material quality, thickness of base and sub base course. In addition to these, premature failure has been induced due to poor compaction of pavement layers during construction. Based on this, it recommended that the subgrade soils shall be replaced or stabilized chemically/mechanically to meet the pavement design life.

Keywords:-*Deterioration, Failure, pavement.*

Acknowledgment

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ACRONYMS

a.s.l   Above Sea Level

AASHTO   American Association of State Highway and Transportation Officials

ASTM	American Society for Testing and Material
CBR	California Bearing Ratio
CPT	Cone Penetration Test
ERA	Ethiopian Road Authority
GB	Granular Base Course
GB1	Graded Crushed Stone
GI	Group Index
GS	Granular Sub-Base
LAA	Lose Angeles Abrasion
PM	Plasticity Modulus
RAI	Road Access Index
RDD	Research and Development Directorate
RSDP	Road Sector Development Program
SPT	Standard penetration test
USCS	Unified Soil Classification System

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Nowadays the government of Ethiopia has placed increased emphasis on improving of road infrastructure in the country because Road improvements bring immediate and sometimes dramatic benefits to road users. At the age of globalization, transportation is fundamental to the development and operation of any society. It permits that geographically distant resources to become accessible, connect people, exchange of technology and also goods needed in different places. This make evident that the economic growth of any society in any part of the world is directly related to the availability of transportation. Therefore a society without an advanced transportation system remains backward from the rest of the world.

Transport investment reduces the cost of raw materials, labor and other products, reducing the cost of production directly. Improvements in transport extend the distance to break-even locations, thereby expanding the area of land under cultivation, and expanding the production of exports. Reduced cost and improved quality of services should also reduce the delivered price of products and, hence, promote regional and international trade. Resulting increases in farm-gate prices should raise farmer incomes, although the extent of this depends on the competitiveness of the transport sector market. Transport investment also contributes to economic diversification, and increases the economy's ability to handle risks (Richard, 2004).

The economic well-being of a country is closely related to the state of its road network. The agricultural, mining, forestry and tourist industries of all countries rely heavily on an adequate network of all-weather roads for their economic viability. The future development of most third-world countries is fundamentally dependent on the existence of adequate road networks (TRH20, 1990).

The primary purpose of the pavement is to reduce the stresses on the subgrade to such a level that the subgrade does not deform under the action of traffic. At the same time, the pavement layers themselves need to be strong enough to tolerate the stresses and strains to which each layer is exposed. However good the pavement design, the condition of the road will slowly deteriorate with time and traffic. The long-term behavior of the road will also depend on the maintenance that is undertaken. The aim is to design the road to carry traffic satisfactorily for a specified period of time without needing major structural maintenance or renewal (Richard, 2004).

The study was conducted the part of the government of the federal democratic republic of Ethiopia with the aim of success fully implementing the road sector development program devised a number of policies among which the adoption of improved road maintenance policies are recognized as a major elements of road management. As part of the maintenance procedure Jimma Dedessa periodic maintenance road project was signed as commencement date November, 1st 2003 and completion date April, 17, 2006. Which was 900 days of project accomplished time? The full source of fund was Ethiopian government (ERA, 2007). However some distress was observed during construction within the first six months after opening to traffic, there was structural failure. Potholes were developed in the travelling lanes.

1.2. Statement of the Problem

Pavements have specific failure mechanisms and each failure mechanism is caused by specific factors. For over a century, paved road ways have been constructed using asphalt concrete mixes across the world. However, a major problem still exists involving premature distresses and pavement failures, e.g. rutting, cracking, potholes etc. Despite all the efforts to develop different methods and procedures of mix design over years, premature distresses and pavement failures couldn't be avoided. Stripping of aggregate from asphalt binder has been a common and the core problem that results in premature pavement failures in Ethiopia (said, 2008).

Ethiopia being in tropical climate receives seasonal and a significant amount of sun light and rainfall throughout the year. Besides climatic factor such as temperature and moisture, high traffic impact stresses also have profound effect on the durability of Hot Mix Asphalt pavements against stripping failures.

The most serious consequence of stripping is the loss of strength and integrity of the pavement. Stripping failures within the asphalt pavement structure can lead into various types of pavement failure such as fatigue cracking, rutting, raveling and potholes. Utilizing roads under such conditions are dangerous and driving comfort and safety are often compromised.

Among the national highway network of Ethiopia, Agaro-Dedessa river road segment is currently under severely damaged condition so that the communities leading their life by selling coffee cash crop to market as well as the general public travelling through this route has been affected.

Moreover, as it is the main access road to Bedele town (one of the major district commercial and Industrial center at the time now), traveling in this road is time taking and deterring for most of the traveler because of that social network of the people has declined from time to time and there is also high risk of damage for vehicles utilizing this road. Usually premature pavement failure of such roads results in frequent road accidents with loss of life and properties, high transportation costs of goods and services, high maintenance costs of vehicles and increase in travel time.

1.3. Objectives

1.3.1. General Objective

The general objective of this research were to investigate the causes leading to the early deterioration of pavement and recommend remedial solutions to ameliorate the current situation considering Agaro – Dedessa river road segment as case study.

1.3.2. Specific Objective

1. To determine the existing engineering properties of the pavement materials by conducting in situ and laboratory tests
2. To evaluate the subgrade, sub-base, and base course materials at existing condition.
3. To recommend possible schemes/measures to meet its design life without further pavement deterioration.

1.4.Research Questions

1. What are the existing engineering properties of the pavement on Agaro-Dedessa road project?
2. What are the causes of failures and its extent of defects in Agaro-Dedessa road Project?
3. What are possible schemes/measures to meet its design life without further pavement deterioration?

1.5. Scope of the study

The focus area of this studied covered identifying causes of early deterioration of Agarro-Dedessa road segment based on identifying types of failure, extent of severity and what kind of remedial measure will take during re-working by comparing numerical output of laboratory results and field relate with standards, so as to introduce new insight into the emerging cause of failures for road before design period and its remedial measure.

1.6. Significance of the study

There is a clear need for a more systematic and comprehensive analysis on road failure. Such analysis can be helpful for stakeholders that directly involving in construction work and professionals evaluating similar project. It also provide useful information in order to solve problems of failure and create safe government budget and transportation with proper designing period for ERA and any other agency who out score and control road projects.

In addition to this, it remind government agencies and policy makers about importance of setting standard on evaluation and maintenance of road construction in specified time span. In general this study can contribute for the professionals dedicated for supervisor and technical staff to control the road projects.

1.7. Structure of the thesis

Chapter one consists of introduction along with a brief of back ground ,objective of the study ,statement of the problem ,research question ,scope, limitation of the study as well as thesis lay out were discussed. Chapter two devoted to literature review of pavement characteristics of pavement, pavement layer material, and cause of deterioration and defect types. Chapter three consists of methodology and specific standards used to classify and evaluate pavement material. Chapter four describes the field investigation and laboratory test result analysis. Chapter five describes desiccation and interpretation of laboratory test results and filed observation. Chapter six consists of recommended possible schemes/measures to meet its design life without further pavement deterioration and conclusion based on the analyzed test results and pavement condition survey observation.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Characteristics of Pavement and its performance

Pavement is an engineering structure placed on natural soils and designed to withstand the traffic loading and the action of the climate with minimal deterioration and in the most economical way (Hodges, 1993). The majority of modern pavement structures may be classified as flexible or rigid pavement structures. A flexible pavement consists of a surface layer constructed of flexible materials typically asphalt concrete over granular base and sub base layers placed on the existing, natural soil. Rigid pavement is a pavement structure that deflects very little under loading because of the high stiffness of the Portland cement concrete used in the construction of surface layer (Paise-Green, 1990).

Flexible pavements are considered here to be pavements that consist of an asphaltic top layers on a bound or unbound base layer which in turn rests on a subgrade. In the design of pavements, the attention is normally concentrated on the structural design. This means that the layer thicknesses and the materials are selected in such a way that the pavement can resist the heavy axle loads without severe cracking of the bound layers and excessive deformation of the subgrade. However next to these aspects, pavements should also be designed in such a way that no excessive permanent deformation occurs in each of the pavement layers; since these deformations are visible at the pavement surface as rutting. Furthermore the pavement should not deteriorate excessively because of environmental effects. Finally the pavement surface should have sufficient durability. Any structure will fail when the stresses induced are higher than the strength of the material from which the structure is built (Molenaar, 2006).When designing pavements, both mix design and structural design, there are three fundamental external design parameters to consider:

1. The characteristics of the subgrade upon which the pavement is placed will have a large impact on structural design. Subgrade stiffness and drainage characteristics help determine pavement layer thickness, the number of layers, seasonal load restrictions and any possible improvements to subgrade stiffness and drainage itself.

2. The expected traffic loading is a primary design input in both mix design and structural design. Traffic loads are used to determine pavement composition, layer type and thickness, all of which affect pavement life.

3. The environment has a large impact on pavement material performance. Environmental factors such as temperature, moisture and ice formation can affect pavement durability, binder rheology, structural support and ultimately pavement life and failure(Awoke, 2006)

The purpose of structural design is to limit the stresses induced in the subgrade by traffic to a safe level at which subgrade deformation is insignificant whilst at the same time ensuring that the road pavement layers themselves do not deteriorate to any serious extent within a specified period of time (Hodges J. , 1993).

Pavement performance is consideration of functional performance and structural performance. The structural performance of a pavement is strength relates to its physical condition i.e. Occurrence of cracking, faulting raveling or other conditions which would adversely affect the load carrying capability of the pavement. And the functional performance of the pavement concerns have well the pavement service the user such as riding comfort or ride quality and safety is the domain characteristic(Chen and Leweas,2003).

The performance of pavements depends upon the quality of subgrades and sub bases. A stable subgrade and properly draining sub base help produce a long-lasting pavement. A high level of spatial uniformity of a subgrade and sub base in terms of key engineering parameters such as shear strength, stiffness, volumetric stability, and permeability is vital for the effective performance of the pavement system.

The subgrade and sub base work as the foundation for the upper layers of the pavement system and are vital in resisting the detrimental effects of climate, as well as static and dynamic stresses that are generated by traffic (AASHTO, 1993).

2.1.1. Subgrade

The type of subgrade soil is largely determined by the location of the road. However, where the soils within the possible corridor for the road vary significantly in strength from place to place, it is desirable to locate the pavement on the stronger soils if this does not conflict with other constraints. For this reason, amongst others, the pavement engineer should be involved in the route selection process. The strength of the road subgrade for flexible pavements is commonly assessed in terms of the California Bearing Ratio (CBR) and this is dependent on the type of soil, its density, and its moisture content. Direct assessment of the likely strength or CBR of the subgrade soil under the completed road pavement is often difficult to make. Its value, however, can be inferred from an estimate of the density and equilibrium or ultimate moisture content of the subgrade together with knowledge of the relationship between strength, density and moisture content for the soil in question. This relationship must be determined in the laboratory. The density of the subgrade soil can be controlled within limits by compaction at suitable moisture content at the time of construction (ERA, 2013).

2.1.2. Density-Moisture Content-Strength Relationships of the Subgrade

During road construction the dry density of the subgrade soil and its moisture content is modified from its original state by compaction at subgrade level in cuts and by compaction of the excavated materials used in embankments. The moisture content is adjusted in order to make it easier to achieve a high level of compaction. Upon completion of the construction operations, the density of the compacted subgrade 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. It is knowledge of this condition of the subgrade that is required in the design process (ERA, 2013).
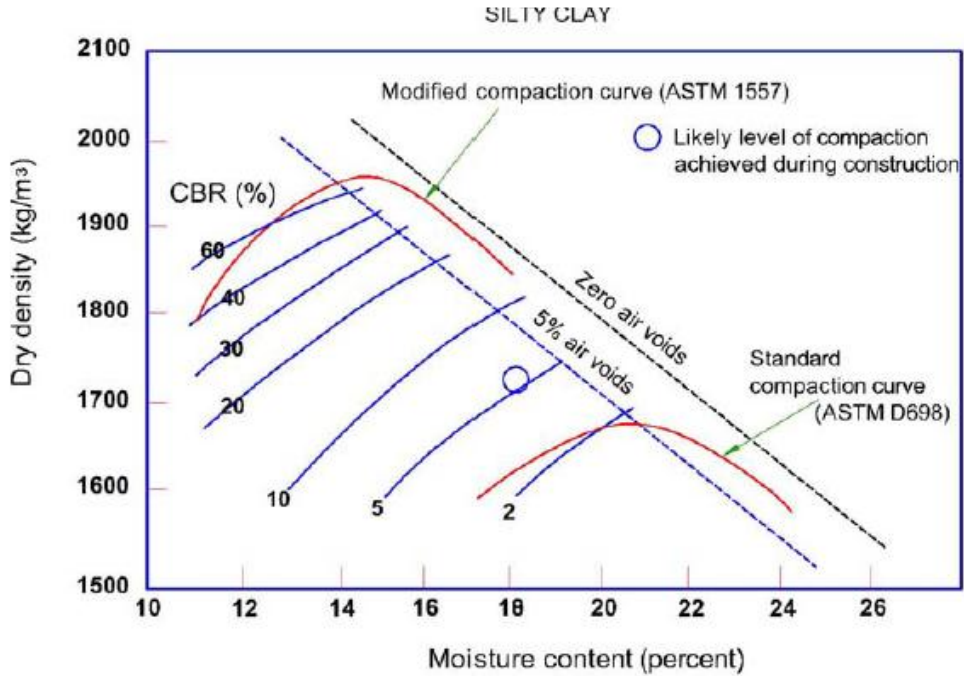
Figure 2. 1: Dry Density, Moisture Content, Soil Strength Relationship for a silty clay (ERA, 2013)
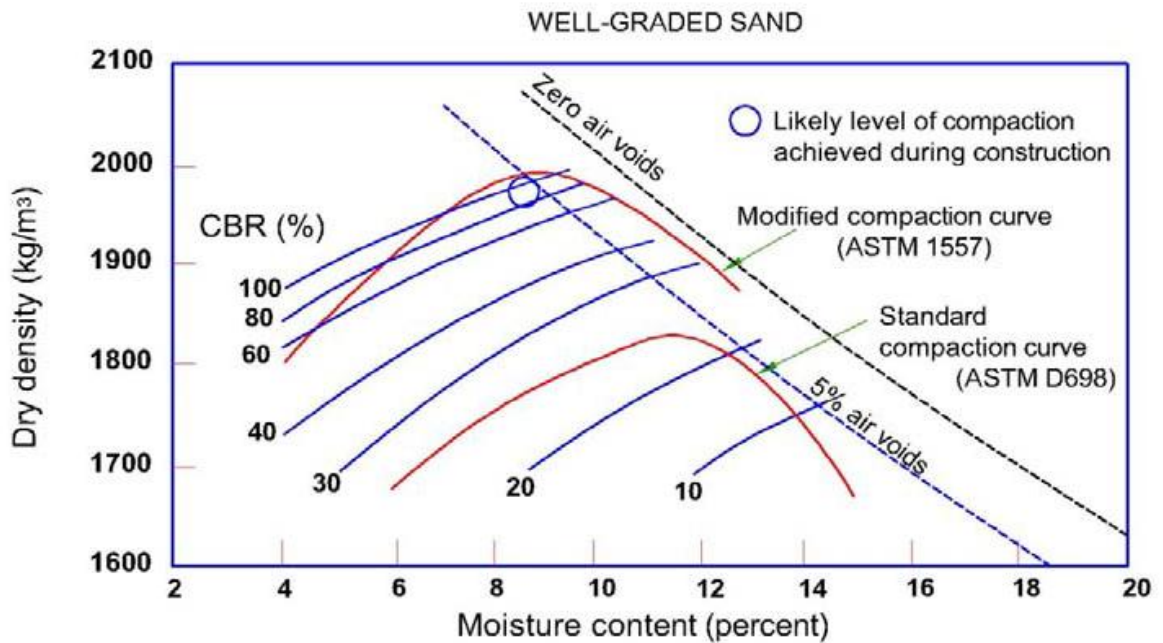
Figure 2. 2: Dry Density, Moisture Content, Soil Strength Relationship for a Well Graded sand (ERA, 2013)

2.1.3. Design Subgrade Strength

To determine the subgrade strength to use for the design of the road pavement, it is apparent from the above that it is necessary to ascertain the density-moisture content strength relationships specific to the subgrade soils encountered along the road under study. It is also necessary to select the density which will be representative of the subgrade once compacted. Estimating the subgrade moisture content that will ultimately govern the design, i.e. the moisture content following the construction, is also required. It is recommended to determine the moisture content as a first step in the process, as this could influence the subsequent ones (ERA, 2013).

2.1.3.1.   Estimated Design Moisture Content of the Subgrade

After the pavement is constructed, the moisture content of the subgrade will generally change. In the dry southeast and northeast parts of Ethiopia, a decrease in the moisture content may be expected. The moisture content can increase elsewhere due to perched water tables during wet seasons. In low-lying areas, the normal water table may be close to the finished subgrade level and influence the ultimate moisture content. In areas with deep water tables and proper design and construction, it is less likely that the subgrade will get wetter after construction (ERA, 2013).

2.1.3.2.   Representative Density

After estimating the subgrade moisture content for design, it is then necessary to determine a representative density at which a design CBR value will be selected. To specify densities during construction, it is recommended that the top 25 cm of all subgrades should be compacted to a relative density of at least 100% of the maximum dry density achieved by ASTM Test Method D 698 light or standard compaction. Alternatively, at least 93% of the maximum dry density achieved by ASTM Test Method D 1557 may be specified. With modern compaction equipment, a relative density of 95% of the density obtained in the heavier compaction test should be achieved without difficulty, but tighter control of the moisture content will be necessary(ERA, 2013).

2.1.3.3.   Design CBR and Design Subgrade Strength Class

Figure.2.3 shows a detailed dry density/moisture content/CBR relationship for a sandy-clay soil that was obtained by compacting samples at several moisture contents to three levels of compaction. By interpolation, a design subgrade CBR of about 15 per cent is obtained if a relative density of 100 per cent of the maximum dry density obtained in the ASTM Test Method D 698 Test is specified and the subgrade moisture content was estimated to be 20 percent.

The procedure outlined above and also detailed in the ERA Site Investigation Manual is not as elaborate as to give complete curves as shown in Figure 2.1, but is never the less sufficient to conduct the necessary interpolations. This laboratory determination is the first and generally preferred option available to obtain a design CBR representative of those expected under the completed pavement.

The structural catalogue given in this manual requires that the subgrade strength for design be assigned to one of six strength classes reflecting the sensitivity of thickness design to subgrade strength. The classes are defined in Table 2.1. For subgrades with CBRs less than2, special treatment is required (ERA, 2013).
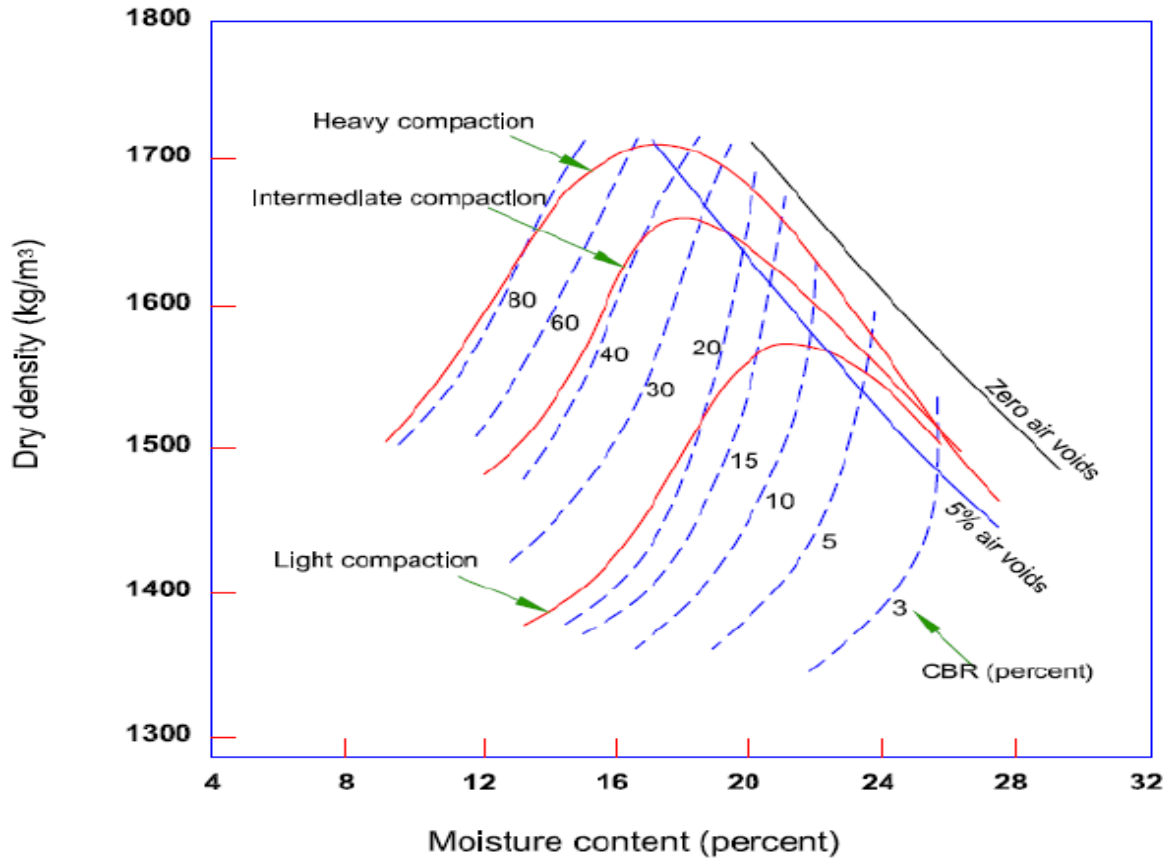
Figure 2. 3: Dry Density, Moisture Content-CBR Relationships for Sandy-Clay soil (ERA, 2013)

The subgrade strength for design is assigned to one of six strength classes reflecting the sensitivity of thickness design to subgrade strength.

Table 2. 1: Sub grade strength class

Class	Range (CBR %)
S1	2
S2	3-4
S3	5-7
S4	8-14
S5	15-29
S6	30+

2.1.4. Sub-Bases (GS)

The sub-base is an important load spreading layer in the completed pavement. It enables traffic stresses to be reduced to acceptable levels in the subgrade, it acts as a working platform for the construction of the upper pavement layers and it acts as a separation layer between subgrade and base course. Under special circumstances, it may also act as a filter or as a drainage layer. In wet climatic conditions, the most stringent requirements are dictated by the need to support construction traffic and paving equipment. In these circumstances, the sub-base material needs to be more tightly specified. In dry climatic conditions, in areas of good drainage, and where the road surface remains well sealed, unsaturated moisture conditions prevail and sub-base specifications may be relaxed. The selection of sub-base materials will therefore depend on the design function of the layer and the anticipated moisture regime, both in service and at construction (Sharad.S.Adlinge, 2004). All sub-base materials shall have a maximum Plasticity Index of 6 or 12, as described in the Contract, and when determined in accordance with AASHTO T-90. The plasticity product PP = PI x percentage passing the 0.075mm sieve shall not be greater than 75(ERA, 2002).

2.1.4.1.   Bering Capacity of Sub -Base

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. Under conditions of good drainage and when the water table is not near the ground surface. The field moisture content under a sealed pavement will be equal to or less than the optimum moisture content in the ASTM Test Method D 698 Light Compaction. In such conditions, the sub-base material should be tested in the laboratory in an unsaturated state. If the base course allows water to drain into the lower layers, as may occur with unsealed shoulders and under conditions of poor surface maintenance where the base course is pervious, saturation of the sub-base is likely. In these circumstances, the bearing capacity should be determined on samples soaked in water for a period of four days.

The test should be conducted on samples prepared at the density and moisture content likely to be achieved in the field.

In order to achieve the required bearing capacity, and for uniform support to be provided to the upper pavement, limits on soil plasticity and particle size distribution may be required (Placeholder1)

Table 2. 2: Typical Particle Size Distribution for Sub-Bases (GS) To Meet Strength Requirements (ERA, 2013)

Test Sieve (mm)	Percentage by mass of total aggregate Passing test sieve (%)
50	100
37.5	80-100
20	60-100
5	30-100
1.18	17-75
0.3	9-50
0.075	5-25

Table 2. 3: Recommended Plasticity Characteristics for Granular Sub-Bases (GS) (ERA, 2013)

Clime	Typical Annual Rainfall	Liquid limit (%)	Plasticity index (%)	Liner shrinkage
Moist tropical and wet tropical	> 500	<35	<6	<3
Seasonally wet trop	>500	<45	<12	<6
Arid and Semi-arid	<500	<55	<20	<10

2.1.5. Base Course Materials (GB)

A wide range of materials can be used as unbound base course including crushed quarried rock, crushed and screened, mechanically stabilized, modified or naturally occurring "as dug" or "pit run" gravels. Their suitability for use depends primarily on the design traffic level of the pavement and climate. However, all base course materials must have a particle size distribution and particle shape which provide high mechanical stability and should contain sufficient fines (amount of material passing the 0.425 mm sieve) to produce a dense material when compacted. In circumstances where several suitable types of base course materials are available, the final choice should take into account the expected level of future maintenance and the total costs over the expected life of the pavement. The use of locally available materials is encouraged, particularly at low traffic volumes. Their use should be based on the results of performance studies and should incorporate any special design features which ensure their satisfactory performance

To meet the requirements consistently, screening and crushing of the larger sizes may be required. The fraction coarser than 10 mm should consist of more than 40 per cent of particles with angular, irregular or crushed faces. The mixing of materials from different sources may be warranted in order to achieve the required grading and surface finish. This may involve adding fine or course materials or combinations of the two (ERA, 2013).

2.1.5.1. Crushed Stone

This material is produced by crushing fresh, quarried rock (GB1) and may be an all-in product, usually termed a 'crusher-run', or alternatively the material may be separated by screening and recombined to produce a desired particle size distribution, as per the specifications. After crushing, the material should be angular in shape with a Flakiness Index of less than 35%, and preferably of less than 30%. If the amount of fine aggregate produced during the crushing operation is insufficient, non-plastic angular sand may be used to make up the deficiency. In constructing a crushed stone base course, the aim should be to achieve maximum impermeability compatible with good compaction and high stability under traffic. Alternate gradation limits, depending on the local conditions for a particular project, are shown in table.

Table 2. 4: Grading Limits for Graded Crushed Stone Base Course Materials (GB1) (ERA, 2013)

Test sieve (mm)	Percentage by mass of total aggregate passing test sieve		
	Nominal maximum particle size		
	37.5 mm	28 mm	20 mm
50	100		
37.5	95-100	100	
28			100
20	60-80	70-85	90-100
10	40-60	50-65	60-75
5	25-40	35-55	40-60
2.36	15-30	25-40	30-45
0.425	7-19	12-24	13-27
0.075	5-12	5-12	5-12

The fines of these materials should preferably be non plastic but should normally never exceed a PI of 6.

If the PI approaches the upper limit of 6, it is desirable that the fines content be restricted to the lower end of the range. To ensure this, a maximum PP of 60 is recommended or alternatively a maximum Plasticity Modulus (PM) of 90 where: PM = PI x percentage passing the 0.425 mm sieve. If difficulties are encountered in meeting the plasticity criteria, consideration should be given to modifying the material by the addition of a low percentage of hydrated lime or cement.

The in situ dry density of the placed material should be a minimum of 98% of the maximum dry density obtained in the ASTM Test Method D 1557 Heavy Compaction. The compacted thickness of each layer should not exceed 200 mm. Crushed stone base courses constructed with proper care with the materials described above should have CBR values well in excess of 100 per cent. There is usually no need to carry out CBR tests during construction (ERA, 2013).

2.1.5.2.   Soil Classification System

There are two main soil classification systems in common use for engineering purposes. The Unified Soil Classification System [ASTM D 2487-93] is used for virtually all geotechnical engineering work except highway and road construction, where the AASHTO classification system (AASHTO M 145-87) is used. Both systems use the results of grain-size analysis and determinations of Atterberg limits to determine a soil's classification. Soil components may be described as gravel, sand, silt, or clay. A soil comprising one or more of these components is given a descriptive name and a designation consisting of letters or letters and numbers which depend on the relative proportions of the components and the plasticity characteristics of the soil. Engineering soils are subdivided into two main groups as a function of their predominant sizes and associated plasticity. The coarse-grained soils are composed of sand size and larger particles. They are separated into size ranges by sieving of materials up to cobble size. Except for minor fractions of plastic fines, they characteristically are non-plastic. The fine grained soils consist predominantly of silt and clay-sized particles with differing degrees of plasticity measured by their Atterberg limits rather than by sieving and settling velocity methods. In this thesis the two engineering soil classifications systems were used (AASHTO, 1993).

If Ip≤LL-30 the classification is A-7-5

If Ip >LL-30 the classification is A-7-6
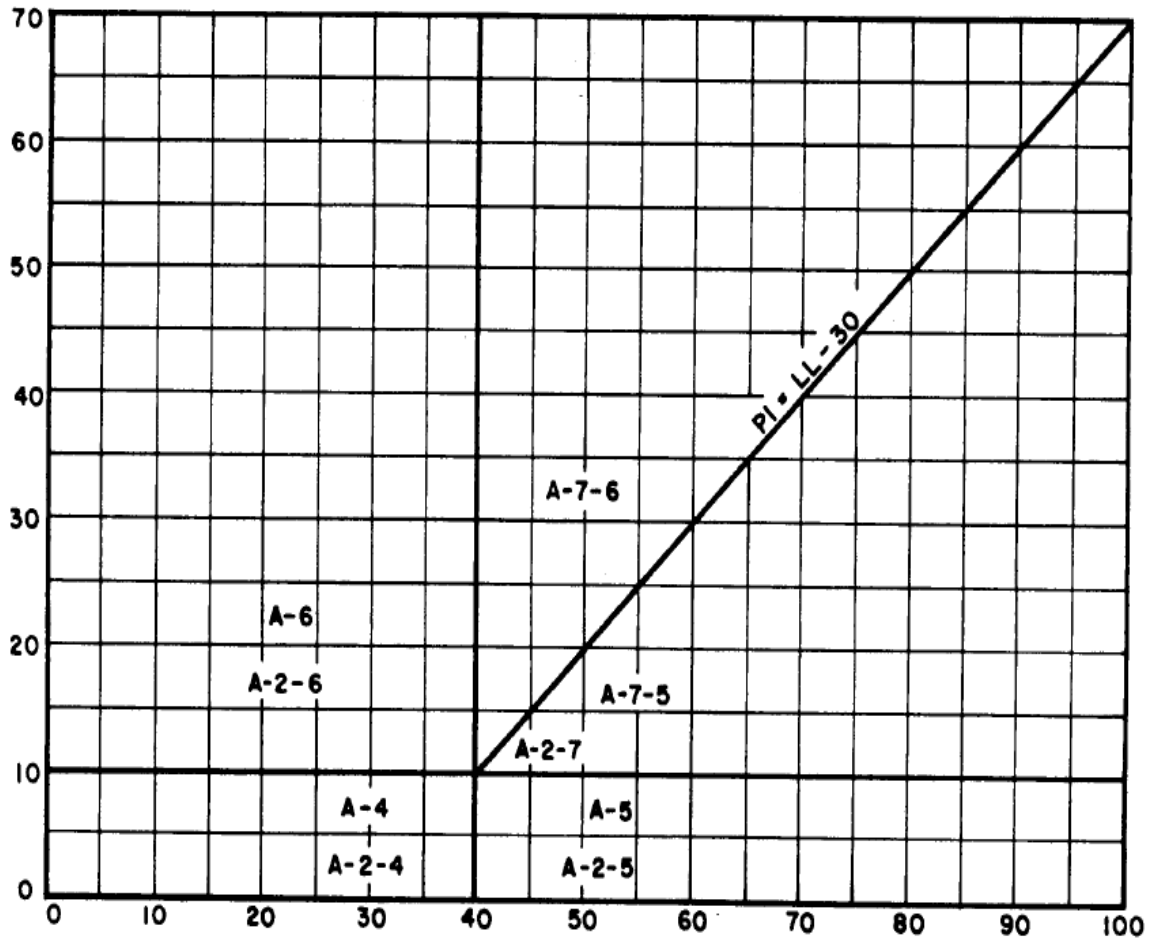
Figure 2. 4: Plasticity chart for AASHTO classification (AASHTO, 1990)

Table 2. 5: Plasticity Index (Filed Exploration lecture not AAiT MSc Program)

Plasticity Index	Plasticity
0	Non-plastic
<7	Low plastic
7-17	Medium
>17	High plastic

2.1.5.3. Unified Soil Classification System

The Unified Soil Classification System is based on the airfield classification system developed by A. Casagrande during World War II. With some modification it was jointly adopted by several U.S. government agencies in 1952. Additional refinements were made and it is currently standardized as ASTM D 2487-93. It is used in the U.S. and much of the world for geotechnical work other than roads and highways (Chen, 2003).In the unified system soils are designated by a two-letter symbol: the first identifies the primary component of the soil, and the second describes its grain size or plasticity characteristics.
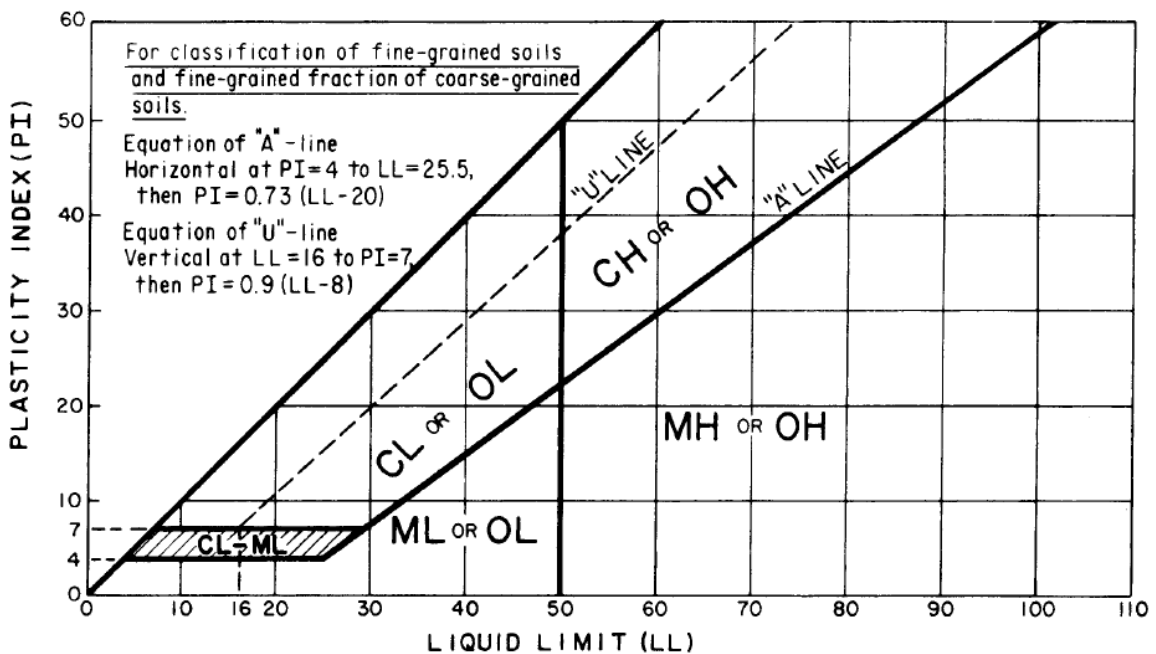
Figure 2. 5: Plasticity chart Unified Soil Classification System (ASTM D 2487-93)

2.2. Road Deterioration

Pavement deterioration is the process by which distress or defects develop in the pavement under the combined effects of traffic loading and environmental conditions (Molenaar P. d., 2007).

Pavement deterioration can be expressed in terms of a damage function or as the development and progression of the actual distresses. A damage function "expresses the performance of the pavement in relation to two standards, the quality of the original construction or initial condition and the 'terminal' level of distress at which maintenance

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or rehabilitation is necessary". Thus, damage functions rely upon prescribed standards which vary often significantly between countries, and even areas within the same country. Structural deterioration is defined as any condition that reduced the load carrying capacity of the pavement (AASHTO, 1993).

Pavement failure is defined in terms of decreasing serviceability caused by the development of cracks and ruts .Before going into the maintenance strategies; we must look into the causes of failure of bituminous pavements. Failures of bituminous pavements are caused due to many reasons or combination of reasons (Sikdar, 1999).

Pavement deterioration can be expressed in terms of a damage function or as the development and progression of the actual distresses. The purpose of structural design is to limit the stresses induced in the subgrade by traffic to a safe level at which subgrade deformation is insignificant whilst at the same time ensuring that the road pavement layers themselves do not deteriorate to any serious extent within a specified period of time. By the nature of the materials used for construction, it is impossible to design a road pavement which does not deteriorate in some way with time and traffic, hence the aim of structural design is to limit the level of pavement distress, measured primarily in terms of riding quality, rut depth and cracking, to predetermined values (Lea, 1995).

Deterioration has three general modes. These are

1. Environmental deterioration due to weathering and aging
2. Structural deterioration caused by repeated traffic loading
3. Deterioration due to unsuitable materials (e.g. consolidation of subgrade, subsidence).

Pavement deterioration result from contributions by one or more of the modes. It is important to try to determine the relative contributions in order to select the most effective rehabilitation techniques. The rate at which pavement deteriorates depends on its environment, traffic loading conditions, original construction quality and interim maintenance procedures. Poor quality materials or poor construction procedures can significantly reduce the life of a pavement. As a result, two pavements constructed at the same time may have significantly different lives, or certain portions of a pavement may

deteriorate more rapidly than others. On the other hand, timely and effective maintenance can extend a pavement's life (Hodges J. , 1993).

Pavements deteriorate due to the combined influences of traffic and environmental loads. This means that at a given moment maintenance activities should be scheduled in order to restore the level of service the pavement should give to the road user (SUDAS, 2013).

It has been universally witnessed that both traffic volume and loads on roads are going on increasing from year to year with alarming rate all over the world. Such heavy traffic growth demands better performance roads for efficient transport of commercial and industrial products without delay.

The repetitive traffic loading that the road experiences during its service life combined with environmental factors causes deformation, fatigue cracking, instability and other forms of deterioration which ultimately degrade the serviceability and durability of pavement structures (Molenaar, 2006).

In some cases, however, design or construction errors or poorly selected materials have considerably reduced pavement life. It is therefore important for pavement engineers to understand materials selection, mixture proportioning, design and detailing, drainage, construction techniques, and pavement performance. It is also important to understand the theoretical framework underlying commonly used design procedures, and to know the limits of applicability of the procedures (Molenaar, 2007).

Pavements fail due to many reasons the factors which include poor construction, poor design or poor materials are some of the primary causes. However, one very important cause of failure lies in the pavement foundations. Subgrade layer, which represents the pavement foundation, is of key importance in the pavement structure. How strong, stiff, and saturated this layer is will control the overall pavement performance.

Paved roads in tropical and sub-tropical climates often deteriorate in different ways to those in the more temperate regions of the world, because of the harsh climatic conditions and often a lack of good road pavement materials. In addition, roads in many countries often suffer from accelerated failures caused by variable quality control during construction, high axle loads and inadequate funding for maintenance (TRL, 1999).

2.3. Major defect types in flexible pavements

Pavements are designed such that they provide a safe and comfortable driving surface to the public. Of course they should be designed and constructed in such a way that they provide this surface for a long period of time at the lowest possible costs. This implies that the thickness design and the material selection should be such that some major defect types are under control meaning that they don't appear too early and that they can be repaired easily if they appear (Molenaar, 2007).

Deterioration has two general causes: environmental due to weathering and ageing and structural caused by repeated traffic loadings. Obviously, most pavement deterioration results from both environmental and structural causes. However, it is important to try to distinguish between the two in order to select the most effective rehabilitation techniques. Major defect types that can be observed on flexible pavements are cracking, Surface deformations, and disintegration and Surface defects (Molenaar, 2006).

2.3.1. Cracking

A. **Transverse cracks:** A crack at approximately right angles to the center line is a transverse crack. They are often regularly spaced. The cause is movement due to temperature changes and hardening of the asphalt with aging. Additional cracking will occur with aging until they are closely spaced within several feet.

These usually begin as hairline or very narrow cracks with aging they widen. If not properly sealed and maintained, secondary or multiple cracks develop parallel to the initial crack. The crack edges can further deteriorate by raveling and eroding the adjacent pavement. Prevent water intrusion and damage by sealing cracks (Molenaar, 2007).

B. **Slippage cracks:** Crescent or rounded cracks in the direction of traffic, caused by slippage between an overlay and an underlying pavement. Slippage is most likely to occur at intersections where traffic is stopping and starting. Repair by removing the top surface and resurfacing using a tack coat (Walker, 2002).

C. **Longitudinal cracks:** Cracks running in the direction of traffic are longitudinal cracks. Center line or lane cracks are caused by inadequate bonding during construction or

reflect cracks in underlying pavement. Longitudinal cracks in the wheel path indicate fatigue failure from heavy vehicle loads. Cracks within one foot of the edge are caused by insufficient shoulder support, poor drainage, or frost action. Cracks usually start as hairline or vary narrow and widen and erode with age. Without crack filling, they can ravel, develop multiple cracks, and become wide enough to require patching. Filling and sealing cracks will reduce moisture penetration and prevent further subgrade weakening. Multiple longitudinal cracks in the wheel path or pavement edge indicate a need for strengthening with an overlay or reconstruction.

D. **Block cracks:** Block cracking is interconnected cracks forming large blocks. Cracks usually intersect at nearly right angles. Blocks may range from one foot to approximately 10' or more across. The closer spacing indicates more advanced aging caused by shrinking and hardening of the asphalt over time. Repair with seal coating during early stages to reduce weathering of the asphalt. Overlay or reconstruction required in the advanced stages.

E. **Alligator cracks:** Interconnected cracks forming small pieces ranging in size from about 1 inch to 6 inch. This is caused by failure of the surfacing due to traffic loading fatigue and very often also due to inadequate base or subgrade support. Repair by excavating localized areas and replacing base and surface. Large areas require reconstruction and improvements in drainage may often be required (Walker, 2002).

F. **Edge Cracking:** Edge cracks typically start as crescent shapes at the edge of the pavement. They will expand from the edge until they begin to resemble alligator cracking. This type of cracking results from lack of support of the shoulder due to weak material or excess moisture. They may occur in a curbed section when subsurface water causes a weakness in the pavement

G. **Reflection cracking:** Reflective cracking occurs when a pavement is overlaid with hot mix asphalt concrete and cracks reflect up through the new surface. It is called reflective cracking because it reflects the crack pattern of the pavement structure below. As expected from the name, reflective cracks are actually covered over cracks reappearing in the surface. They can be repaired in similar techniques to the other cracking noted above. Before placing any overlays or wearing courses, cracks should be properly repaired (Molenaar, 2007).

2.3.2. Surface Deformation

A. **Rutting** is the displacement of pavement material that creates channels in the wheel path. Very severe rutting will actually hold water in the rut. Rutting is usually a failure in one or more layers in the pavement. The width of the rut is a sign of which layer has failed. A very narrow rut is usually a surface failure, while a wide one is indicative of a subgrade failure. Inadequate compaction can lead to rutting. Minor surface rutting can be filled with micro paving or paver-placed surface treatments. Deeper ruts may be shimmed with a truing and leveling course, with an overlay placed over the shim. If the surface asphalt is unstable, recycling of the surface may be the best option. If the problem is in the subgrade layer, reclamation or reconstruction may be needed.

B. **Corrugation:** is referred to as wash boarding because the pavement surface has become distorted like a washboard. The instability of the asphalt concrete surface course may be caused by too much asphalt cement, too much fine aggregate, or rounded or smooth textured course aggregate. Corrugations usually occur at places where vehicles accelerate or decelerate. Minor corrugations can be repaired with an overlay or surface milling. Severe corrugations require a deeper milling before resurfacing.

C. **Shoving:** is also a form of plastic movement in the asphalt concrete surface layer that creates a localized bulging of the pavement. Locations and causes of shoving are similar to those for corrugations.. Repair minor shoving by removing and replacing. For large areas, milling the surface may be required, followed by an overlay.

D. **Depressions:** are small, localized bowl-shaped areas that may include cracking. Depressions cause roughness, are a hazard to motorists, and allow water to collect. Depressions are typically caused by localized consolidation or movement of the supporting layers beneath the surface course due to instability. Repair by excavating and rebuilding the localized depressions. Reconstruction is required for extensive depressions.

E. **Swell: -** a swell is a localized upward bulge on the pavement surface. Swells are caused by an expansion of the supporting layers beneath the surface course or the

subgrade. The expansion is typically caused by frost heaving or by moisture. Subgrades with highly plastic clays can swell in a manner similar to frost heaves but usually in warmer months. Repair swells by excavating the inferior subgrade material and rebuilding the removed area. Reconstruction may be required for extensive swelling (Majidzadeh, 1978).

2.3.3. Disintegration

A. **Potholes:** are bowl-shaped holes similar to depressions. They are a progressive failure. First, small fragments of the top layer are dislodged. Over time, the distress will progress downward into the lower layers of the pavement. Potholes are often located in areas of poor drainage, Potholes are formed when the pavement disintegrates under traffic loading, due to inadequate strength in one or more layers of the pavement, usually accompanied by the presence of water. Most potholes would not occur if the root cause was repaired before development of the pothole. Repair by excavating and rebuilding. Area repairs or reconstruction may be required for extensive potholes.

B. **Patches:** A patch is defined as a portion of the pavement that has been removed and replaced. Patches are usually used to repair defects in a pavement or to cover a utility trench. Patch failure can lead to a more widespread failure of the surrounding pavement. Some people do not consider patches as a pavement defect. While this should be true for high quality patches as is done in a semi-permanent patch, the throw and roll patch is just a cover. The underlying cause is still under the pothole. To repair a patch, a semi-permanent patch should be placed. Extensive potholes may lead to area repairs or reclamation. Reconstruction is only needed if base problems are the root source of the potholes (Delatte, 2008).

2.3.4. Surface defects

A. **Bleeding:** It is an indication of overfilling of the voids in the aggregate skeleton with bituminous mortar. It is an indication that the mixture is not well designed. Due to the high bitumen content, the mixture suffers probably from lack of stability at higher temperatures and high traffic loads might squeeze out the bituminous mortar. Another reason might be that because of the low void content, there is not enough space for the bituminous mortar when it expands with increasing temperatures. In any case, the result is the same being a black, shiny surface with hardly any macro or micro texture and thus a low skid resistance (Molenaar, 2007).

B. **Raveling:** The loss of aggregate from the surface layer. It can occur on any type of asphalt. Mixture but especially open graded mixtures like porous asphalt concrete are sensitive for this damage type. Raveling develops because of cohesive failure in the bituminous mortar or adhesive failure in the interface between aggregate and bituminous mortar (Walker, 2002).

C. **Polishing:** Polishing is the wearing of aggregate on the pavement surface due to traffic. It can result in a dangerous low friction surface. A thin wearing course will repair the surface (Mohammad, 2005).

2.4. Design life

For most road projects an economic analysis period of between 10 and 20 years from date of opening is appropriate design life. But, does not mean that at the end of the period the pavement will be completely worn out and in need of reconstruction. It means that towards the end of the period the pavement will need to be strengthened so that it can continue to carry traffic satisfactory for a further period (Molenaar, 2007).

Premature failure is defined as an unacceptable difference between the expected design life and the observed performance. Premature road pavement failure occurs when it can no longer perform its traditional function of carrying vehicles and people from one location to another in safety and comfort before the anticipated design life (Leonard, 1983). The design life of a component or system of components is the period of time

during which the item is expected, by its designers or as required by specification, to work or perform its intended function within specified design parameters / operating conditions. In other words, the design life is the life expectancy of the item under normal / specified operating conditions. With respect to road drainage, operating conditions can include. if the operating conditions move outside of the original design parameters, service life will be less than design life. In some situations, this reduction in time can be considerable, leading to premature failure (ERA, 2013). The design period of ERA guide lines illustrated in table below.

Table 2. 6: ERA design period guide line (ERA, 2013)

Road Classification	Design period(years)
Trunk Road	20
Link Road	20
Main Access Road	15
Other Road	10

2.5.   Drainage within pavement layers

Drainage within the pavement layers themselves is an essential element of structural design because the strength of the subgrade in service depends critically on the moisture content during the most likely adverse conditions. Since it is impossible to guarantee that road surfaces will remain waterproof throughout their lives, it is critical to ensure that water is able to drain away quickly from within the pavement (ERA, 2013).

2.6.   Moisture content

The engineering properties of a soil, such as the strength and deformation characteristics, depend to a very large degree on the amount of voids and water in the soil. The moisture content is defined as the mass of water contained in a soil sample compared with the oven-dry mass of the sample. It is customarily expressed as a percentage, although the decimal fraction is used in most computations (Terzaghi, 2007).

Table 2.7. Typical Moisture Contents

Material	Moisture Content, w (%)
Gravel	2-10
Sand	5-15
Silts	5-40
Clays	10-50
Organic (Peat)	> 50

2.7.   Shoulders

Shoulders participate in the structural function of a road pavement, providing lateral support for the pavement layers. They should help in removing surface water from the road surface and facilitate the internal drainage of the pavement. They are especially important when unbound materials are used in the pavement. it is also recommended that shoulders on paved roads having a width less than 1m should be paved. Shoulders give additional width for emergency and temporary parking (ERA, 2013).

CHAPTER THREE

3. METHODOLOGY OF RESERCH

3.1. **Study Area**

This study conducted on the Agaro-Dedessa Road segment which is the part of Jimma-Dedessa periodic Maintenance Road project. Which is located in western Oromiya regional state and it is a primary road with a total length of 72.48km.The project starts from Jimma town and terminates at Dedessa River Bridge. The road project traversed through flat and rolling terrain. The project road has a typical section of 7m road mix surface pavement carriage way and shoulder 0.5m on left and right sides both for rural and town section. The thickness of road mix is 60mm from 0+000 to 47+000 and 40mm from station 43+000 to 72+480 Dedessa River Bridge i.e. end of the project. The altitude around station 0+000 of the project is 1710m a.s.l (ERA, 2007). But this study only conducted 29.48 km of the total length which is start from Agaro town to Dedessa River Bridge.

PROJECT VICINITY MAP
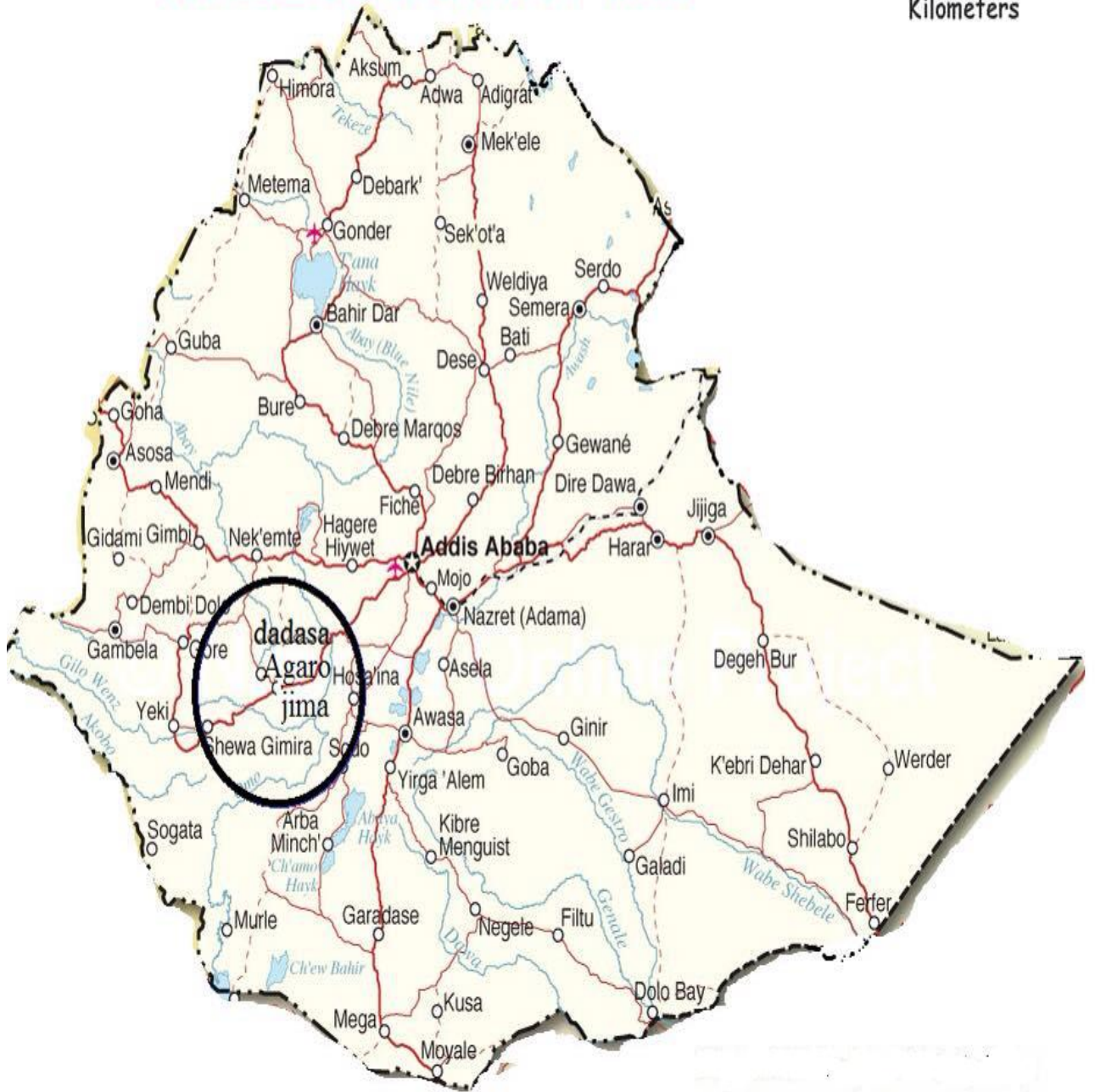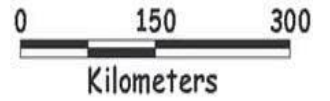
Figure 3. 1 Project Vicinity Map
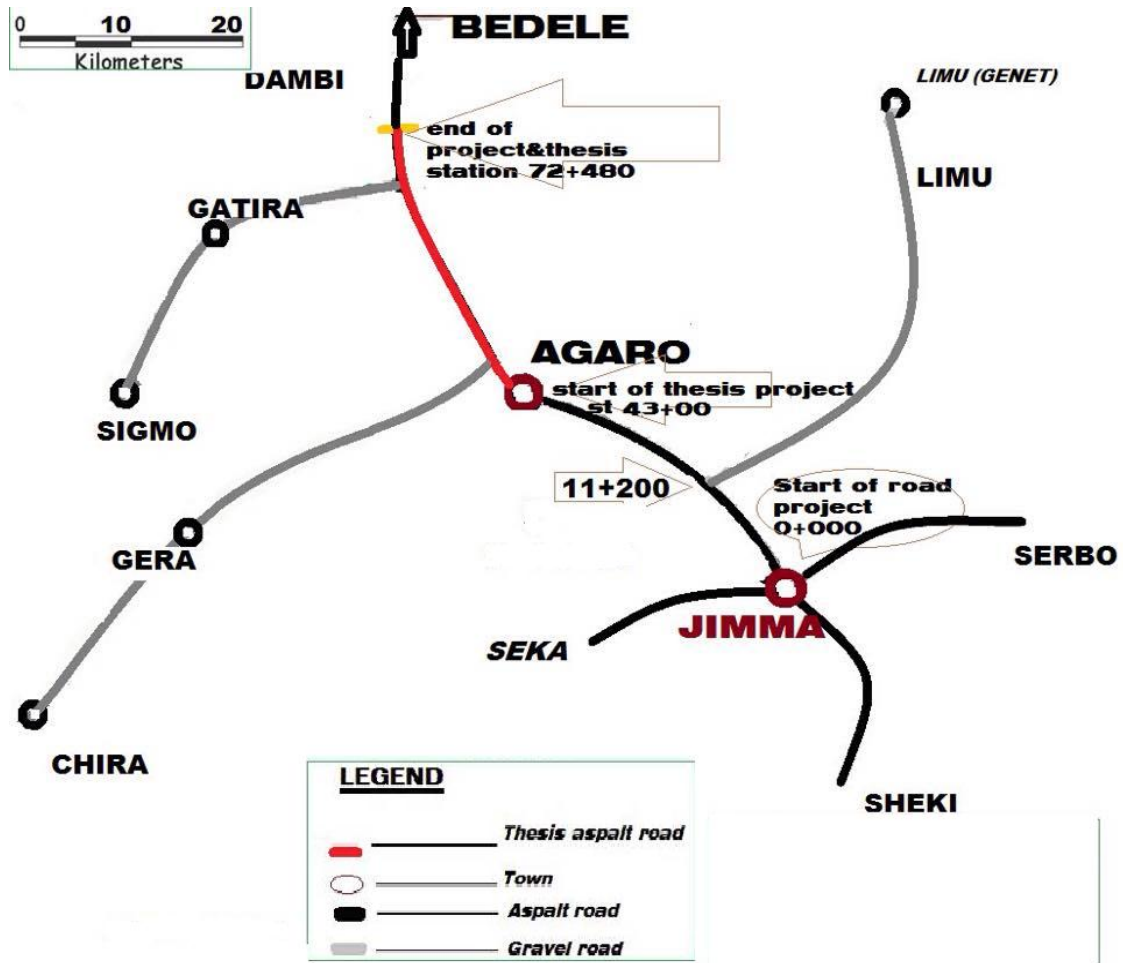
Figure 3. 2: Project Location Area Map

3.2. **Climate Condition**

The duration of the rainy season is long in the vicinity of the project road and the mean annual rainfall is in the order of 2000mm. The mean maximum temperature is 20 and 25and the mean minimum temperature is 10 &15 degree Celsius. The following table summarizes the mean monthly rainfall data of the project area and it is collected from Ethiopian Meteorology Organization (Meteorology, 2006).
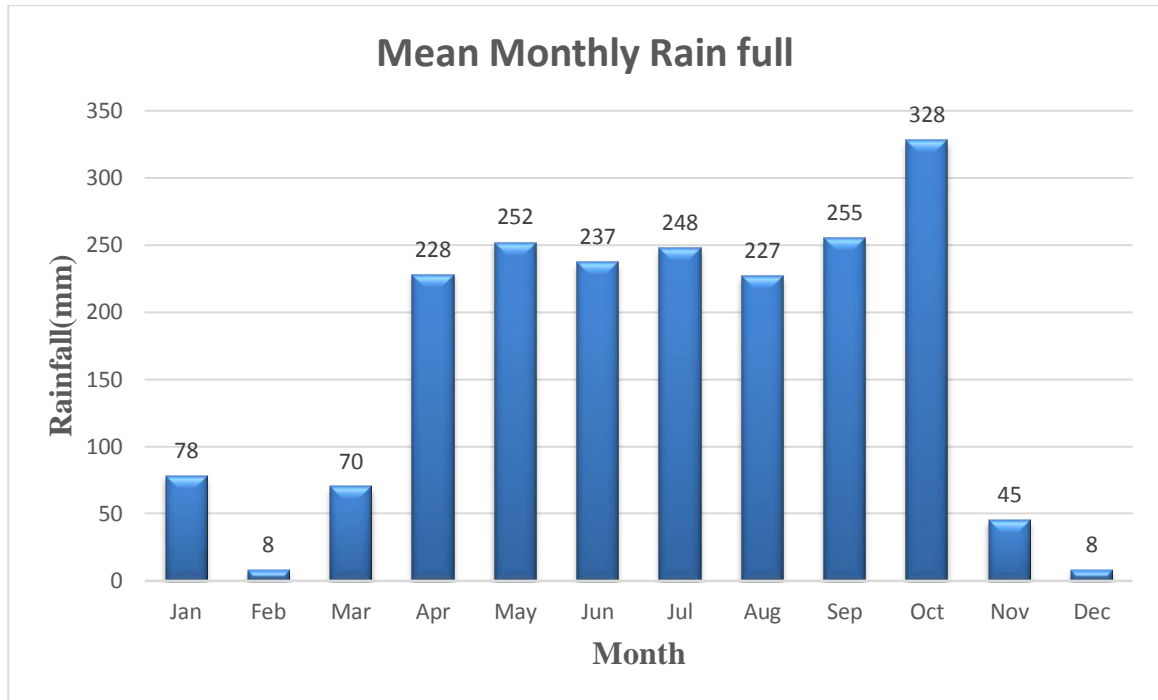
Figure 3. 3: Monthly mean rain full

3.3. Study Design

In order to achieve the intended objectives of the study the research was conducted by using both Experimental and Analytical methods. The quantities and qualitative study were employed in this study. Qualitative study forwards impression of the findings whereas the quantitative study was used to describe the numerical aspects of the findings of this research.

3.4. Sample size and Sampling Procedures

Samples were collected from ten test pit at a depth 1.5m of each road for details laboratory testing to determine geotechnical characteristics of the Soil. Representative sample were taken properly and tied by plastic bags to preserve the loss of moisture and as much as possible no vibration addressed to the sample during transportation.

3.5. Study variables to asses premature failure of pavement

Investigating pavement condition survey, identifying type and level of severity of pavement, impact of drainage system, moisture content, base and sub base quality and thickness, strength of the subgrade material and other geotechnical and index

characteristics of the material obtained by the laboratory which are Atterberg limits, grain size, compaction, free swell, compaction and CBR results are very important to analyze.

3.6. **Data collection processes**

The survey was done to ascertain the need for pavement rehabilitation or reconstruction at selected sections of the road pavement. Field density test was carried out using the sand replacement method to find out the relative compaction of the various layers and soil and gravel samples were collected for different laboratory analysis. The pits are excavated manually with the size of the 1m×1m with the depth range of 0.4 to 1.5m .The excavation started to top and continued layer by layer properly during the stating of excavation of pavement from top layer, bituminous layer were removed carefully to avoid disturbance of the layer below and the thickness of each layer recorded and 650 kg sample were taken to Ethiopian Road Authority Jimma Road Network Branch Directorate laboratory.

3.7. **Data process and analysis**

By conducting laboratory tests, filed test, literature reviews, books, journals, articles and lecture notes the data were gathered. After sorting out the effective data the quantitative or numerical part of the data analyzed using different software's like excel.

3.8. **Field Investigation**

The aim of project area investigation to determine all the information relevant to the study investigation has been a true distinct phase of a disk study, pavement condition survey and laboratory test sampling. The first filed investigations were started in April dry season by taking some photographs that show nature of severity and extent of road deterioration.   During field investigation and observation stage the width of the existing road surface was measured by using meter and the layer thickness of the pavement for each pit were recorded. For details laboratory investigations ten trial pits were excavated manually to collect granular materials as well as subgrade soils.

3.9. **Laboratory test**

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

CHAPTER FOUR

4. FIELD AND LABORATORY TEST RESULTS

4.1. **Field investigation**

4.1.1. **Existing Physical Pavement Condition Survey**

To establish the severity that represents the typical condition of the road way segment appropriate visual inspection with measurement of pavement condition survey were performed. These inspection procedures offer a method of determining pavement condition through observation and recording the presence of specific types and severities of defects in the pavement surface. The elements which were considered during pavement condition survey are:

      1. The type of defect.

      2. The severity of the defect.

      3. The extent to which the road surface is affected by the defect.

Sample photos were taken on March, 2015 and on June, 2015 that give a clear view of the condition of road and show different distresses types on existing road.

Figure 4 1: Alligator Crack at the edge

Figure 4 2: Alligator Crack at the center

Figure 4 3: Crack, Potholes, vegetation cover at side walk and shoulder

Figure 4 4: Potholes at the edge of the road

Figure 4 5: Exposed base material of road at station 44+200

Figure 4. 6: longitudinal deformations, settlements and Rutting in asphalt pavements   at 65+000.

Based on the result of pavement physical conditional survey different distress type and extent of distress visually inspected. As shown on the sample photos three section of the road was selected for detail investigation. The selected road segment categorize high severity, medium severity and low severity. The main purpose in the site categorizing process was to define the characteristics of each site, identify the characteristics of any visible deterioration, Identified type of deterioration and the dominant failure mode at different location and extents are illustrated below in Table 4.1.

Table 4 1: Types of defect and severity level.

Station	Severity level	Observed defect Types
km 43 +400	High	Disintegration, and loss of pavement
km 43+600	High	Crack, Potholes and loss of pavement material along the pavement
km 62+900	High	Alligator Crack, Potholes and moisture penetration in shoulder
km 65+500	High	Longitudinal settlement and cracks
km 65+300	High	Disintegration
km 62+300	High	Cracks, potholes ,and deformation
km 69+000	High	Loss of pavement material and pothole
km 65+000	Intermediate	Disintegration, Raveling, loss of pavement material along the pavement
km 44+300	Intermediate	Exposed base material of road
km 68+500	High	Disintegration, Raveling, loss of pavement material along the pavement
km 59+140	low	Cracks and potholes
km 59+300	low	Cracks and potholes

After finalizing the visual inspection along the study area ten test pit locations are selected for the laboratory tests .The width of the road and thickness of the road materials are measured in each test pit by using a meter tape. The measurement results of distance from the road center and pavement materials thickness for each test pit are presented in Table 4.2.

The test pit excavated manually with the size of the pit was 1m×1m with the depth range of 0 .4 to 1.5m. During the starting of excavation of pavement from top layer, bituminous layer were removed carefully to avoid disturbance of the layer below. Soil samples were collected from lift hand side and   right hand side of the road way some photos of test pits Location for pavement material taken the process of sampling refer Appendix A.

Table 4 2: Test pit station and road layer thickness.

Sample designation	Test pit Station	Thickness of road layer (cm)		Distance from center of road (m)
		Base course	Sub-base	
S1	43 +400	22	16	2.6
S2	43 +600	21	18	2.8
S3	62+300	23	17	2.65
S4	68+500	17	19	2.9
S5	44+300	23.2	19	3
S6	58+940	21.8	18.7	3.1
S7	65+000	20	17	3.15
S8	59+140	23	17.5	3.25
S9	59+300	22.6	17.8	3
S10	59+900	18	18.6	3.2

4.2.1. **Filed density test results**

Filed density tests were performed by AASHTO T-191 method to determine in situ density of the existing pavement materials.

Table 4 3: Filed density results of material

Sample designation	Subgrade		Sub-base		Base course	
	Filed dry density	Water content %	Filed dry density gm/cc	Water content %	Filed dry density gm/cc	Water content %
S1	0.99	22.5	1.17	8.9	1.6	16.8
S2	1.03	21.3	1.14	7.9	1.65	19.2
S3	0.818	21.7	1.12	12.3	1.71	12.5
S4	1.04	19.8	1.21	9.79	1.65	16.17
S5	1.45	28.64	1.34	15.3	1.78	13.02
S6	1.23	24.2	1.29	11.13	1.71	9.53
S7	1.54	26.8	1.315	13.215	1.745	11.275
S8	1.78	20.7	1.64	9.01	1.89	16.8
S9	1.64	29.3	1.56	9.52	2.01	15.4
S10	1.71	25	1.59	9.2	1.95	14.1

4.3. **Laboratory test results**

4.3.1. **Moisture content**

Moisture content of pavement material for each test pit are tabulated below in Table 4.4.and laboratory analyses attached at Appendix B.

Table 4 4: Moisture content at different station

Pavement layer	Location									
	km 43 +400	km 43 +600	km 62+300	km 68+500	km 44+300	km 58+940	km 65+000	km 59+140	km 59+300	km 59+900
Base course	7.65	6.5	7.7	6.39	6.64	6.65	5.03	4.75	6.48	7.2
Sub-base	8.9	7.9	8.3	9.79	10.82	11.13	7.87	9.01	9.52	8.6
Sub-grade	34.0	34.2	34.8	26.15	28.67	28.91	28.4	31.47	30.58	28.7

4.3.2. **Free swell Test**

This test tries to give a fair approximation of the degree of expansiveness of a given soil sample.

Table 4 5: Subgrade and sub-base Free swell results for each station

Types of pavement materials	km 43+600			km 58+940			km 59+300		
	Initial volume(cm)^3	Final volume(cm)^3	Free swell (%)	Initial volume(cm)^3	Final volume(cm)^3	Free swell (%)	Initial volume(cm)^3	Final volume(cm)^3	Free swell (%)
Sub-grade	51.7	117.7	56.1	59.9	109.2	45.16	46.2	70.3	34.3

4.3.3. **Atterberg limits**

The plastic limit and liquid limit test were done on collected samples according to AASHTO T-89 and T-90.Laboratory test results of Atterberg limit of subgrade material is illustrated below in Table 4.8. But the results of base course material and Sub base material had slightly plastic results obtained. Soils which have a high plasticity index are often called fat clays. Fat clays are usually high expansive soil characteristics. The laboratory data analysis attached in Appendix B.

Table 4 6: Liquid limit and plasticity index results of sub grade material

Sample designation	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
S1	77.64	29.13	48.51
S2	77.73	26.8	50.93
S3	68.7	32.23	36.47
S4	67.22	29.65	37.57
S5	67.99	23.58	44.41
S6	66.23	22.7	43.53
S7	64.4	28.06	36.34
S8	59.7	22.11	37.59
S9	57.2	23.4	33.8
S10	55.05	25.29	29.76

Table 4 7: Liquid limit and plasticity index results of sub base material

sample designation	Liquid limit	Plastic limit	Plasticity index
S1	46.65	32	14.65
S2	47.28	31.56	15.72
S3	34.34	21.2	13.14
S4	32.55	19.05	13.5
S5	33.43	20.29	13.14
S6	35.75	24.48	11.27
S7	47.85	36.32	11.53
S8	47.57	37.48	10.09
S9	34.34	23.38	10.96
S10	46.75	37.52	9.23

Table 4 8: Liquid limit and plasticity index results of base course   material

sample designations	Liquid limit	Plastic limit	Plasticity index
S1	30.96	24.03	6.93
S2	31.62	25.13	6.49
S3	30.69	25.04	5.65
S4	29.74	23.65	6.09
S5	28.65	23.95	4.7
S6	16.55	12.96	3.59
S7	18.57	14.2	4.37
S8	24.32	22.56	1.76
S9	22.78	21.2	1.58
S10	28.64	26.36	2.28

Soil which has a high plasticity index are often called fat clays. Fat clays are usually has highly expansive soil characteristics but for this study the expansive test result indicates marginal expansiveness and highly plastics.

4.3.4. **Grain size analysis**

A sieve analysis were conducted by taking a measured amount of dry well pulverized material and passing it through a stack of progressive finer sieve with a pan at the bottom. Comparing the laboratory test results for gradation with that of the specification for sub base and base course materials the results showed that for all Particle size distribution of the pavement layers shown in the figure her after the laboratory analysis attached in Appendixes B.
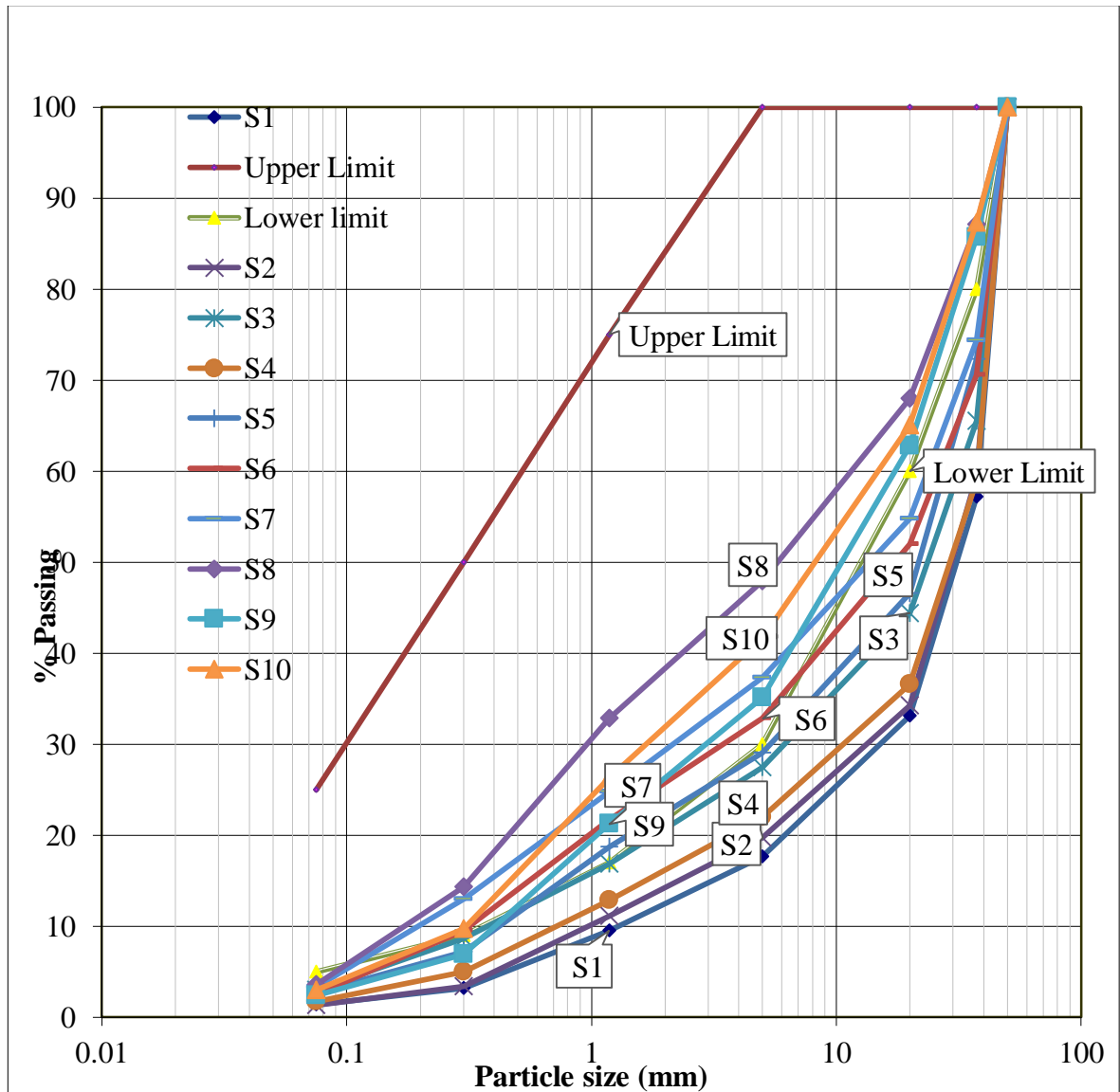
Figure 4 7: Sub base material Particle size distribution curves.
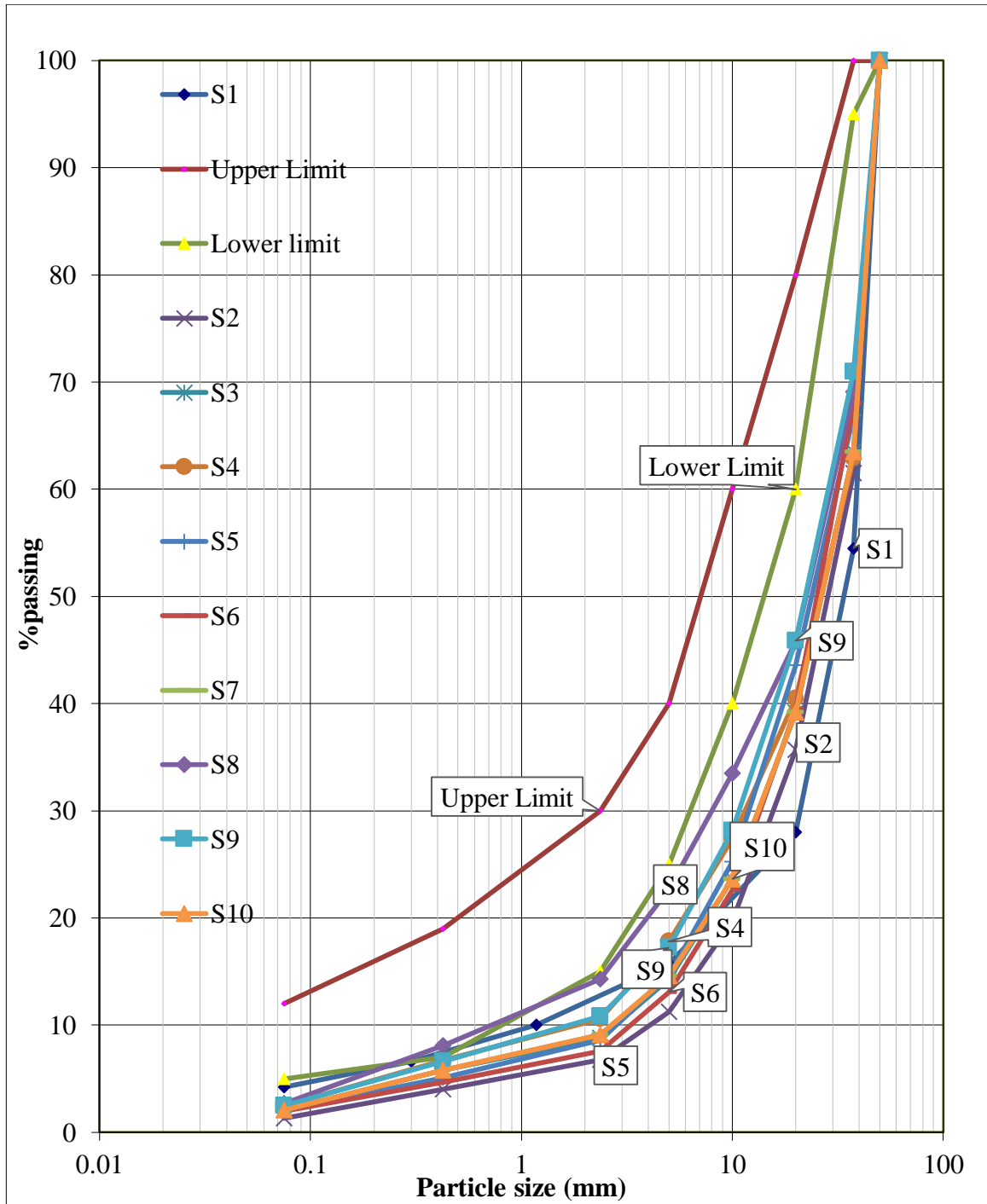
Figure 4 8: Base course material Particle size distribution curves.

4.3.5. **Compaction test results**

Compaction test were made for all severe level of pavement type and each pavement layers material according to AASHTO-180 the results of maximum dry density and optimum moisture content are shown in Tables below the laboratory data analysis attached in Appendix B.

Table 4 9: Compaction test results of materials

Sample station	Subgrade		Sub base		Base course	
	Maximum dry density (gm./cc)	Optimum moisture content (%)	Maximum dry density (gm./cc)	Optimum moisture content (%)	Maximum dry density (gm./cc)	Optimum moisture content (%)
km 43+400	1.15	14.92	1.45	9.25	1.82	15.2
km 43+600	1.16	14.8	1.35	10.7	1.94	16.6
km 62+300	1.13	13.7	1.36	11.7	1.98	13.8
km 68+500	1.13	13	1.45	12.6		
km 44+300	1.53	22.2	1.45	19.15	1.97	10.6
km 58+940	1.57	21.5	1.39	18	1.94	12
km 59+140	1.83	19.5	1.66	19.7	2.07	10.3
km 59+300	1.82	19.75	1.64	20.8	2.07	14.2

4.3.6. California Bearing Ratio (CBR) test results

Four days soak California Bearing Ratio test were performed to determine the strength of Sub grade soil as well as sub base layer of the pavement road according to AASHTO T-193-93 the laboratory output is shown below and some analysis of laboratory attached in Appendix B.

Table 4 10: California Bearing Ratio (CBR) values test results

sample designation	CBR% Subgrade	CBR% Sub base	CBR% Base course
S1	3.95	33.11	35.85
S2	3.92	34.84	34.73
S3	4.46	34	36.71
S4	4.25	32.67	38.37
S5	5.9	35.74	38.11
S6	5.6	38	39.42
S7	6.63	36.11	42.3
S8	6.94	36.96	41.1
S9	8.43	48.87	41.4
S10	9.02	68	40.8

4.3.7. Los Angeles Abrasion (LAA) test results

Los Angeles Abrasion test were made on pavement material Base course and Sub base to evaluate the strength properties of aggregate. The mass of sample passed sieve size 1.7mm helps to determine the amount of Abrasion (friction) by vehicle. The results are illustrated in Table 4.11 and Table 4.12.

Table 4 11: Los Angeles Abrasion test results of Sub base

Sample designation	Weight of Retained on sieve 1.7mm	Weight of passing sieve 1.7mm	Percent Loss (%)
S1	1981	3019	39.6
S5	1480	3520	26.6
S9	1104	3896	22.1

Table 4 12: Los Angeles Abrasion test results of Base course

Sample designation	Weight of Retained on sieve 1.7mm	Weight of passing sieve 1.7mm	Percent Loss (%)
S1	1992	3008	39.8
S5	1715	3285	34.3
S9	1326	3672	26.5

CHAPTER 5

5. DISCUSSION AND RESULT INTERPRETATION

5.1. Field test result

5.1.1.Discussion on Pavement condition Survey

During the field road physical conditional survey the following defects were identified such as massive shoving, rutting, disintegration settlement; potholes, Alligator Crack, sag, and longitudinal cracks were observed on the existing road.

1. Alligator cracks: this defect can be caused due to traffic loading and in adequate base or subgrade support.
2. Rutting: it may occurrence for a very narrow rut is a surface failure but a wide indicative of subgrade failure and in adequate compaction.
3. A pothole: can be occurred due to in adequate strength in one or more layer of the pavement.
4. Shoving: it can be occurred due to plastic movement of asphalt that create localized bulging of pavement.
5. Swelling: which can be caused by an expansion of the supporting layer beneath the surface course or subgrade.
6. Longitudinal crack: occurred due to in adequate bonding during construction, heavy vehicle load insufficient shoulder support and poor derange.

The result implies that majority of flexible pavement defects were exist in the study area this show that study project road is in bad condition.

5.1.2.Drainage and shoulder

Based on ERA Geometric Design Manual – 2002 Shoulders participate in the structural function of a road pavement, providing lateral support for the pavement layers. They should help in removing surface water from the road surface and facilitate the internal drainage of the pavement. They are especially important when unbound materials are used in the pavement. From a functional point of view a minimum width of 1m is recommended and it is also recommended that shoulders on paved roads having a width

less than 1m should be paved. Shoulders give additional width for emergency and temporary parking.

Drainage of the road surface is provided by the shaping the carriage way with a comber or a cross slope the combination of stagnant water on the road surface and traffic can quickly cause erosion of the road surface. If surface water penetrates in to the road body. It reduced the load carrying capacity of the pavement which may cause further damage to the road. but in this project area the shoulder width for some area is less than 0.5m in some place there is no constructed shoulder not only in rural area even if at town. In addition the shoulder missing problems as we can observe from pavement condition survey photos there are drainage problems.

The observed derange and shoulder constructed in the existing road is very bad because shoulder missing and derange system cover by vegetation common throughout the rut at the time of the research conducted. As representative photos shown in chapter four and Appendix A even if the people use the road as sidewalk because the road near around cover by vegetation.

Basically Pavement design depend on the expected level of traffic. It can be deteriorate by traffic results (i.e magnitude of the individual wheel loads and the number of times loads are applied). Based on the data collected from the client the pavement is primary road type and the casted equivalent single axel load (ESA) value is 5.2×10^6 which is classified as T5. As shown the laboratory test result the sub grade CBR value are between the range of four and nine. According to ERA pavement design volume I standard specification, the sub grade strength of the study area class is S4. For pavement which are S4 and T5 TRL Road Not 31 granular road base thickness chart 1 suggest that the sub base and base course thicknesses should be 20cm and 25cm respectively. Even if the TRL 31 standard recommends that the result from the pavement condition survey indicate that the average thickness of base course at high level, intermediate level and low level severity are 20.75cm, 22cm and 21cm respectively. Similarly the sub base average thickness are 17.5cm, 18.2cm and 17.96cm respectively. In addition to these the existing carriageway width is on average 6.3m. It's also observed some road section shoulder and external derange system were covered by vegetation.

5.2. Laboratory Test result analysis

The free swell subgrade result show that at high, intermediate and low level of severity is 56.08%, 45.16% and 34.32% respectively. In the same token the sub base results are 35.1%, 30.55% and 31.88% respectively. According to ERA expansiveness soil classification the sub grade soil high severity level is greater than 50% it implies that in the area the material is high expansive but the average results of sub-base in medium expansive soil classification.

5.2.1. Subgrade material

The laboratory results of sub grade indicate the material used is poor based on sub grade soil strength classification. The laboratory test result showed that the natural sub-grade used to construct the pavement road is inorganic clays of highly plastic. High plasticity index and high liquid limit and the CBR values of four days soaked are very small. The materials have high CBR value have high strength. Based on AASHTO T-258 the degree of expansion is high with PI values greater than 35 and LL greater than 60. The sub grade LL values result of the project except three points above 60 percent.

From the free swell test results values for sub grade at highly damaged area is 56.08 % greater than 50% in the range of high expanse and the value of intermediate and low severe area are 45.16% and 34.32%. Based on ERA standard expansiveness soil classification in medium expanse class.

5.2.1.1.Sub grade Soil classification

According to the Unified Soil Classification (USC) system subgrade material of chart and the plastic value chart of the project all soil samples under investigation are between line A and liquid limit value of 50. The soil is classified as inorganic clays high plasticity

(CH) or organic clay high to intermediate plasticity (OH) as subgroup of clays liquid limit greater than 50%.
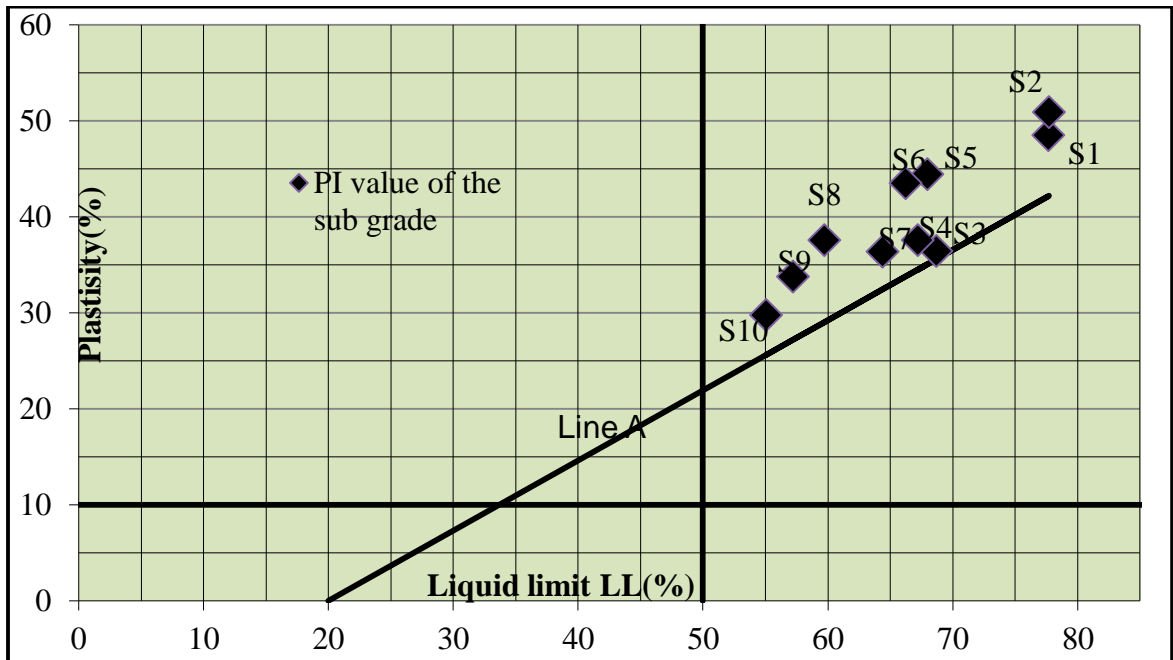
Figure 5 1: Unified soil classification (USC) system chart of the project

With similar AASHTO standard soil classification Plasticity chart the project test result as indicated in the below figure most of the materials in the class A-7-6 and the two station only class A-7-5.Based on Approximate equivalence between AASHTO and USC system soil class A-7-5 can be either of (OH,MH,CL,OL) and for soil class A-7-6 is (CH,CL,OH).
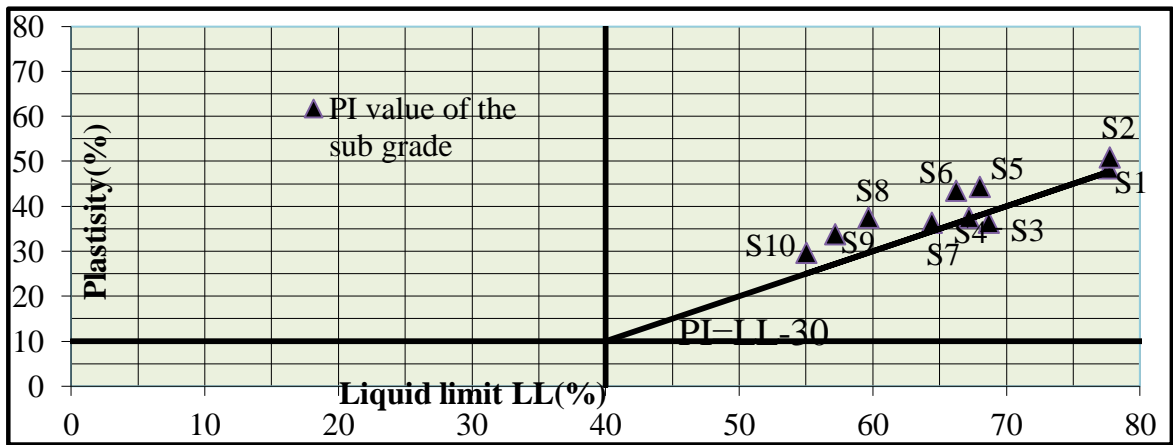
Figure 5 2: AASHTO subgrade soil classification system chart of the project

Based on the ERA pavement design manual to specify densities during construction it is recommended that the top 25cm of all subgrades should be compacted to a relative density of at least 100% for light (standard) test method or 93% of maximum dry density achieved for heavier or modified compaction. For this study the heavy compaction test method used as we can see from the result of the laboratory test the average OMC of high severity area, intermediate severity and low severity are 14.11%, 21.23% and 19.63% respectively average MDD of these location 1.14 gm/cm^3 1.55 gm/cm^3 and 1.8 gm/cm^3. From the results of laboratory and filed density the average result of compaction at road categorized high severity level intermediate level and low severity level are 84.9 %, 90.6 % and 96.3% the only the low level of severity pavement part have relatively with in required standard specification but for all level the water content much higher than the optimum moisture content result.

5.2.2. Sub base material

The comparison of the study area particle size distribution result with the ERA manual standard of upper limit and lower limit indicate in the case of highly damaged area (S1, S2, S3 and S4) almost all of the test value lower than the lower limit which means the material is courser than the standards. In the case of intermediate level of severity (S5, S6 and S7) it seems similar the lower limit and the lower severity level (S8, S9 and S10) satisfy the standard specification. The gradation curves of the materials of existing pavement with comparison to standard specification and the laboratory analysis results are attached in Appendix B.

Based on standard technical specification the minimum compaction value for the sub base material not chemically stabilized is 95%. The average maximum dry density and optimum moisture content of high sever, intermediate sever and low sever part of road section are 1.4gm/cc, 1.42gm/cc, 1.65gm/cc & 11.06%, 18.58% and 20.24% respectively. The sub base result indicated most values of water content at the field lower than the laboratory optimum moisture content and some of the remaining are approximate to optimum moister content. Compaction value for high severity level is 82%, intermediate

level 92.6% and 96.97%. But this material result show low severs level road section within the limit of standard specification dedicated by ERA.

According to ERA Standard Technical Specification 2002 when determining Los Angeles Abrasion with requirements of AASHTO T-96 the value for sub base not exceed 51% if the material is crushed stone the value not exceed 45%.From the test results of the samples the value of sub base for severity level High, Intermediate and low are 39.6%, 26.6% and 22.1% respectively. All of the results less than 51% it satisfy the requirement

5.2.3. Base course material

 As shown on the gradation value curve of the base course material below the lower limit standard recommended by ERA. Which is courser than recommended value. In general the materials used, are relatively unstable enough and have not a good resistant to erosion. The stability of courser grained materials depend on the grain to grain contact and are difficult to compact. A very dense compacted material can produce and develop good bearing capacity and shearing resistance.

The average compaction of the base course at road section high severity intermediate severity and low severity are 86.4 %,89.3% and 94.2% respectively .which are the all section parts of the project road high damaged , intermediate and low damage road parts are not satisfy the require standard specification of ERA base course compaction value 98%. For intermediate and low sever level the optimum moisture content 0.18%, and 10.8% exceed that of water content filed results.

According to ERA Standard Technical Specification 2002 when determining Los Angeles Abrasion with requirements of AASHTO T-96 the value for crushed stone base course material the value shall not exceed 30%.. The same test of base course material results for high, intermediate and low level of severity are 39.8%, 34.3% and 26.5% respectively. The values of high level of severity and intermediate level of severity are not in the limit of the specification requirement.

Table 5 1: Relative density of pavement material

Sample designation	Subgrade			Sub base			Base course		
	Filed dry density	Max. dry density	Relative density	Filed dry density	Max. dry density	Relative density	Filed dry density	Max. dry density	Relative density
S1	0.99	1.15	0.86	1.17	1.45	0.81	1.6	1.82	0.88
S2	1.03	1.16	0.89	1.14	1.35	0.84	1.65	1.85	0.89
S3	0.818	1.13	0.72	1.12	1.36	0.82	1.71	1.98	0.86
S4	1.04	1.13	0.92	1.21	1.45	0.83	1.65	1.92	0.86
S5	1.45	1.53	0.95	1.34	1.45	0.92	1.78	1.83	0.97
S6	1.23	1.57	0.78	1.29	1.39	0.93	1.71	1.97	0.87
S7	1.54	1.56	0.99	1.315	1.42	0.93	1.745	1.94	0.9
S8	1.78	1.83	0.97	1.64	1.66	0.99	1.89	2.07	0.91
S9	1.64	1.82	0.94	1.56	1.64	0.95	2.01	2.07	0.97
S10	1.71	1.75	0.98	1.59	1.5	1.06	1.95	2.2	0.89

The average CBR values of subgrade, sub base and base course material for highly deterioration area are 3.95%, 33.11% and 35% respectively. The values of intermediate deteriorate area are 5.6%, 34.84 %and 30.1% respectively. For low deteriorate area sub grade sub base and base course material CBR values are 9.02%, 38% and 41.4% respectively. The average CBR obtained for sub grade soil is 4% up to 9.02% which indicates the sub grade strength   soil class S4. In general, the CBR values of base course material lower than the standard specification which means not strong material. The sub base values are in the limit of standard specification.

 As the laboratory result analysis shown   sieve analysis result almost all values are out of the upper limit and lower limit standards which mines the material either to fine or too courser but for this project the values supposedly fail below the lower limit which indicates more courser material are used to construct this road and also Open graded

gravel (sub-base or base) has been placed on soft sub-grades of clay & silt. In such case the gravel has become contaminated with the sub-grade, due to intrusion of soil into it, causing a decrease in bearing capacity of pavement. The test results in good condition are Los Angeles aberration test results which have good resistance of wearing condition. And the CBR value for sub base material approximate to satisfy the standard if compacted at its optimum moisture content and compacted to its maximum dry density. But in the case of base course material less value than standard specification.

The compaction test result analysis for all severity levels are not in the limits of standard specification. The field water content is higher than the optimum moisture content it may the causes of decreasing dry density of the project area in addition to using poor compaction effort during construction. The material compacted at a water content less than the optimum moisture content generally have fluctuated structure regardless of the method of compaction. Whereas material compacted at a water content more than the optimum moisture content usually have a dispersed structure. The maximum free swell expansive value of Sub base material is 35.14% it is in the class of medium according to expansiveness soil classification.

In general all laboratory results showed the values at the road are highly deteriorated is not satisfy the standard provided by ERA and the values of intermediate and low level of deteriorate some test results in the limit of standard specification.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Based on pavement condition survey, visual inspection, laboratory, field test out puts and the desk study of the project contract agreement document and monthly progress report document of the road during construction the following conclusions are drawn from the study:

- The laboratory test results show that the material used for sub grade is week, because the nature of the soil is partly organic clay(OH) and partly inorganic high plasticity clay (CH) .

- Insufficient thickness of sub base and base material used to distribute the wheel load stress to a safe value on the sub grade soil. Compared to the ERA standard for base and sub base material layer thickness, which depend on CBR value and sub grade soil strength, the pavement layer thicknesses are too thin to support the traffic load.

- In adequate quality control were exercised during manufacturing and mixing of construction material which allowed the material to be finer or courser to lead poor particle size distribution..

- Lack of properly managed water flow causes road deteriorates seriously and occurs more rapidly. Based on laboratory test result of liquid limit and moisture content there is high water content and liquid limit. This excess moisture in the subgrade soil resulted to degradation of material quality, strength reduction, deformation increase, and loss of bond between pavement layers of the pavement.

- Insufficient shoulder width and sidewalk constructed on left and right side both for rural and town area. In addition to this there are vegetation near the road side.

6.2. Recommendation addressed by researcher

The following recommendations are suggested based on the result of the study.

- To improve the situation of the pavement it shall be rehabilitated with over lays by removal and reconstruction of the existing pavement or recycling of part of the existing pavement.
- The sub grade material of the pavement shall be removed and replaced with more competent material or stabilized chemically/ mechanically stabilized.
- Existing road base and sub base thickness of pavement shall be modified based on the CBR value of subgrade and expected traffic load
- The material should be compacted with suitable depth until well enough to support the pavement and attainable compressive strength value based on standard specification limit.
- There is need for better quality control manpower for material production and construction of pavement.
- In order to control drainage problem road surface drainage shall be facilitate and side drain must be considered during rehabilitation of the pavement.
- Maintenance activates needed on shoulder by removing obstruction, reshaping, vegetation control and periodically adding shoulder material.
- Proper pavement preservation techniques, guidelines and policy should be implemented in any highway design and construction project.

6.3. Proposed for future research

Further studies can made to know unexpected increment of traffic load, compliance compare of test results with lateritic soil test procedures after classify the soil is lateritic.

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Appendix

Appendix A: Field and laboratory Photos

Disintegration of road at station 65+300

Disintegration, Raveling, loss of pavement material along the pavement at station 65+000

Crack, Potholes and loss of pavement material along the pavement at 43+600.

Potholes, settlement and cracks at 62+900

Pothole cracks and Sag in asphalt at 62+300

Cracks and settlement at 62+600

Drainage and vegetation problems

Test pit at S1 before sample collected
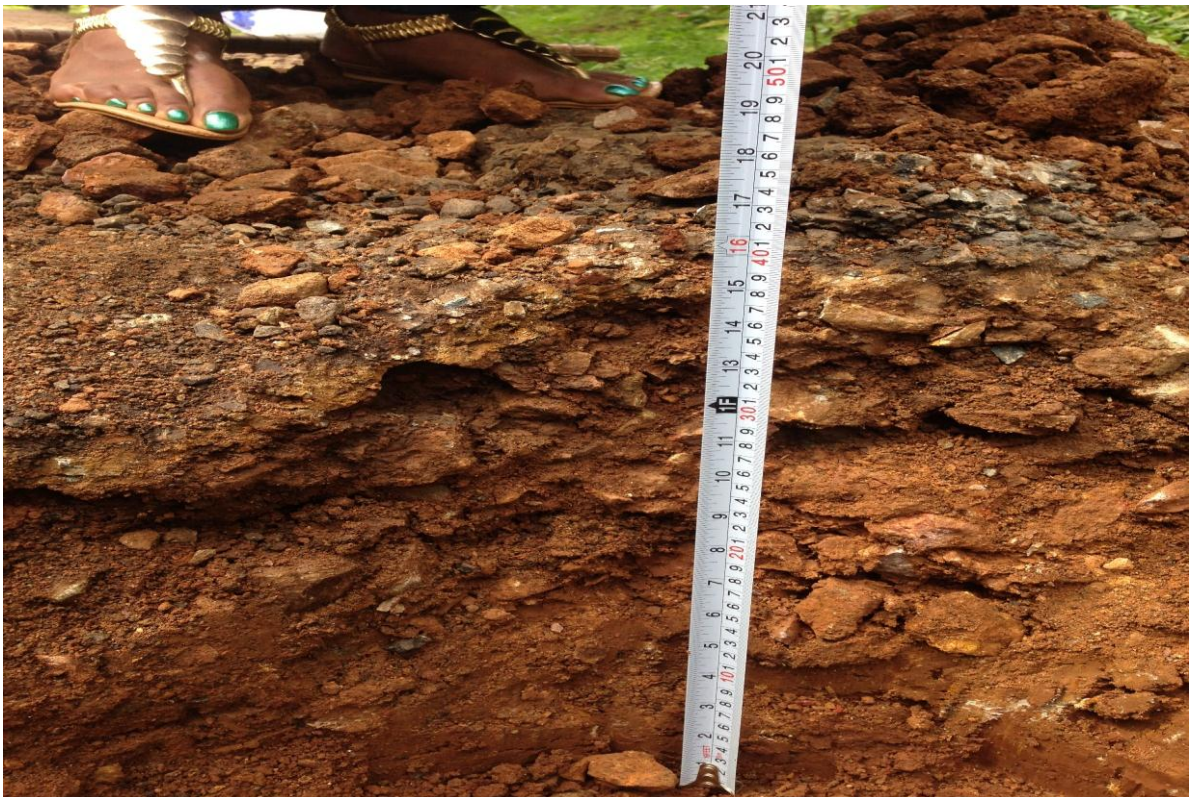
Sample collected test pit at S1

Reinstatement pit at after sample collected.

Test pit at station 62+300 before sample collected

Sample collected test pit at S2

Reinstatement pit S2 after sample collected

Test pit location at S8 during sampling

Settlement, Shoving   and material movement at 65+100

APPENDEX B: Laboratory test analysis

ATTERBERG LIMITS
AASHTO T-89 & T - 90

Type of Material :-					Subgrade	
Date of Sampling :-					12/06/15	
Date of Testing :-					21/6/2015	

Oven Dried at _ _ _ 110 ºC
Proportion retained on 0.425 mm Sieve %
Sample designation:- S8

	Liquid Limit				Plastic Limit	
Container No.	23	138	11		4	15A
No. of Blows	35	27	21		32	28
Wgt. of Wet soil + Cont.(gm)	63.5	56	55.3		37.8	41.1
Wgt. of Dry soil + Cont.(gm)	53.5	48.6	46.8		36.7	39.5
Wgt. of Moisture (gm)	10	7.4	8.5		1.1	1.6
Wgt. of Container (gm)	33.7	36.5	34.2		32.9	32.8
Wgt. of Dry soil (gm)	19.8	12.1	12.6		3.8	6.7
Moisture Content, %	50.51	61.16	67.46		28.95	23.9
	Avg.LL	59.71		Avg.PL	26.41	

Summary , Liquid Limit	59.71
Plasticity Limit	26
Plasticity Index	33

ATTERBERG LIMITS
AASHTO T-89 & T - 90

Type of Material :-   Subgrade
Date of Sampling :-   12/06/15
Date of Testing :-   21/6/2015
Oven Dried at _ _ _ 110 ºC   S3
Proportion retained on 0.425 mm Sieve %

	Liquid Limit				Plastic Limit	
Container No.	23	138	11		4	15A
No. of Blows	33	28	22			
Wgt. of Wet soil + Cont.(gm)	60.4	57.9	56.3		42.5	40.3
Wgt. of Dry soil + Cont.(gm)	49.6	49.2	47.2		40.25	38.4
Wgt. of Moisture (gm)	10.8	8.7	9.1		2.3	1.9
Wgt. of Container (gm)	33.7	36.5	34.2		32.9	32.8
Wgt. of Dry soil (gm)	15.9	12.7	13.0		7.350	5.6
Moisture Content, %	67.6	68.5	70.0		30.61	33.93
	Avg.LL	68.7		Avg.PL	32.27	

Summary , Liquid Limit   68.70
             Plasticity Limit   32
             Plasticity Index   36
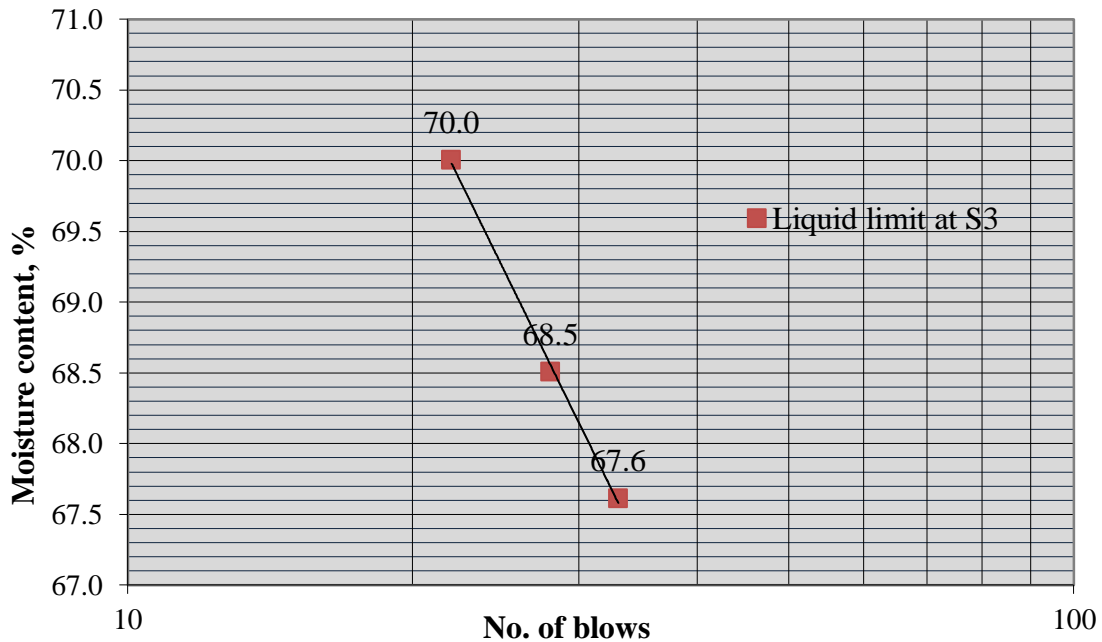
ATTERBERG LIMITS
AASHTO T-89 & T - 90

Type of Material :-   <u>**Subgrade**</u>

Date of Sampling :-   **12/06/15**

Date of Testing :-   **21/6/2015**

Oven Dried at _ _ _ 110 ºC

Proportion retained on 0.425 mm Sieve %

Sample designation:-   S6

	Liquid Limit				Plastic Limit	
Container No.	31	9	5		11	20
No. of Blows	34	28	17			
Wgt. of Wet soil + Cont.(gm)	63.0	72.0	66.0		42.5	39.5
Wgt. of Dry soil + Cont.(gm)	52.0	56.2	53		41	38.1
Wgt. of Moisture (gm)	11.0	16	13.1		1.5	1.4
Wgt. of Container (gm)	34.7	32.1	34.1		34.2	32.1
Wgt. of Dry soil (gm)	17.4	24.1	18.8		6.8	6.0
Moisture Content, %	63.40	65.56	69.7		22.06	23.33
	Avg.PL	66.21		Avg.PL	22.70	

Summary , Liquid Limit   **66.21**

         Plasticity Limit   **23**

         Plasticity Index   **44**
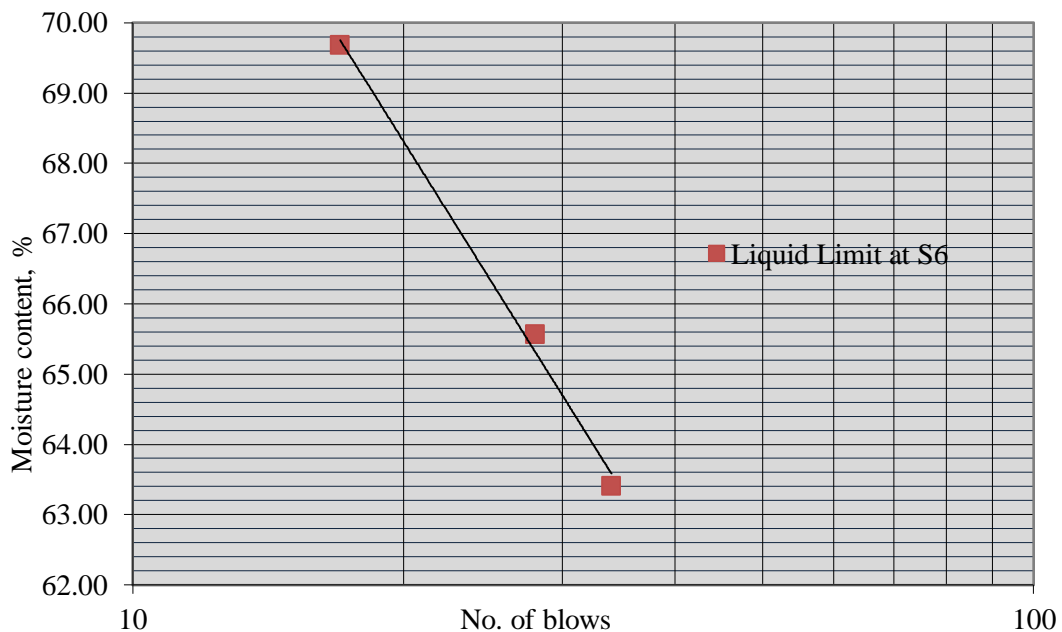
PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Sub base

Sample designation :- S5   Date of Sampled :-   12/6/2015

Method of sieving: Dry sieve   Date of Testing :-   20/06/2015

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
50	0.0	0.0	0.0	100.0
37.5	225	4.5	4.5	95.5
20	360	7.2	11.7	88.3
5	1660	33.2	44.9	55.1
1.18	1165	23.3	68.2	31.8
0.3	1120	22.4	90.6	9.4
0.075	340	6.8	97.4	2.6
Pan	130	2.6	100.0	0.0
Total weight	5000.0			
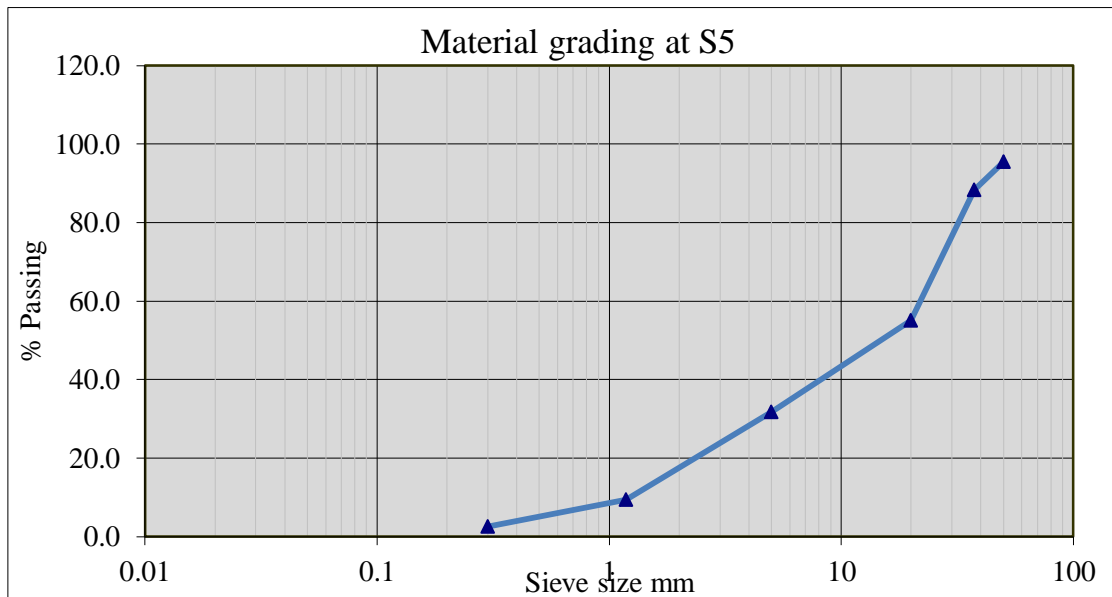
Material grading at S5

73

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Sub base

Sample designation:- S9

Date of Sampled :-   12/6/2015

Method of sieving:-   Dry sieve

Date of Testing :-   20/06/2015

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
50	0.0	0.0	0.0	100.0
37.5	635.0	12.7	12.7	87.3
20	1110.0	22.2	34.9	65.1
5	1174.02	23.5	58.4	41.6
1.18	764.5	15.3	73.7	26.3
0.3	830.0	16.6	90.3	9.7
0.075	335.0	6.7	97.0	3.0
Pan	150.0	3.0	100.0	0.0
Total weight	4998.52			
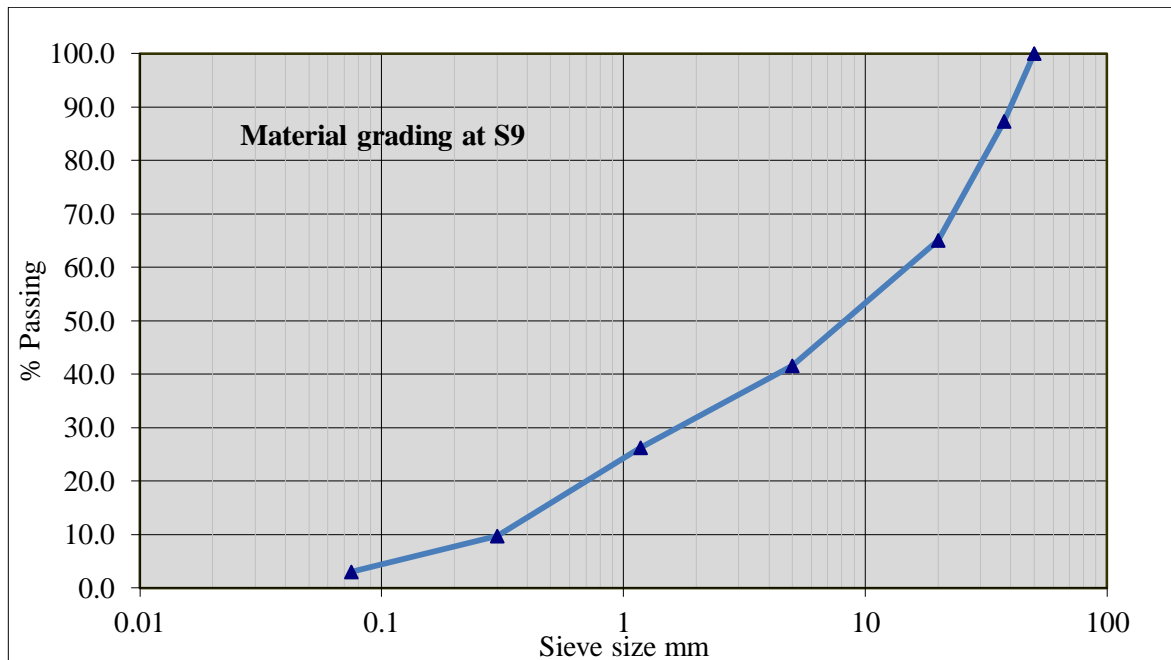
Material grading at S9

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Sub base

Sample designation:- S1　　　　　　　　　　　　　**Date of Sampled :-   12/6/2015**

Method of sieving:-   Dry sieve　　　　　　　　　　**Date of Testing :-   20/06/2015**

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
50	0.0	0.0	0.0	100.0
37.5	2025.0	40.5	40.5	59.5
20	1259.3	25.2	65.7	34.3
5	725.0	14.5	80.2	19.8
1.18	429.6	8.6	88.8	11.2
0.3	385.0	7.7	96.5	3.5
0.075	105.0	2.1	98.6	1.4
Pan	70.0	1.4	100.0	0.0
Total weight	4998.9			
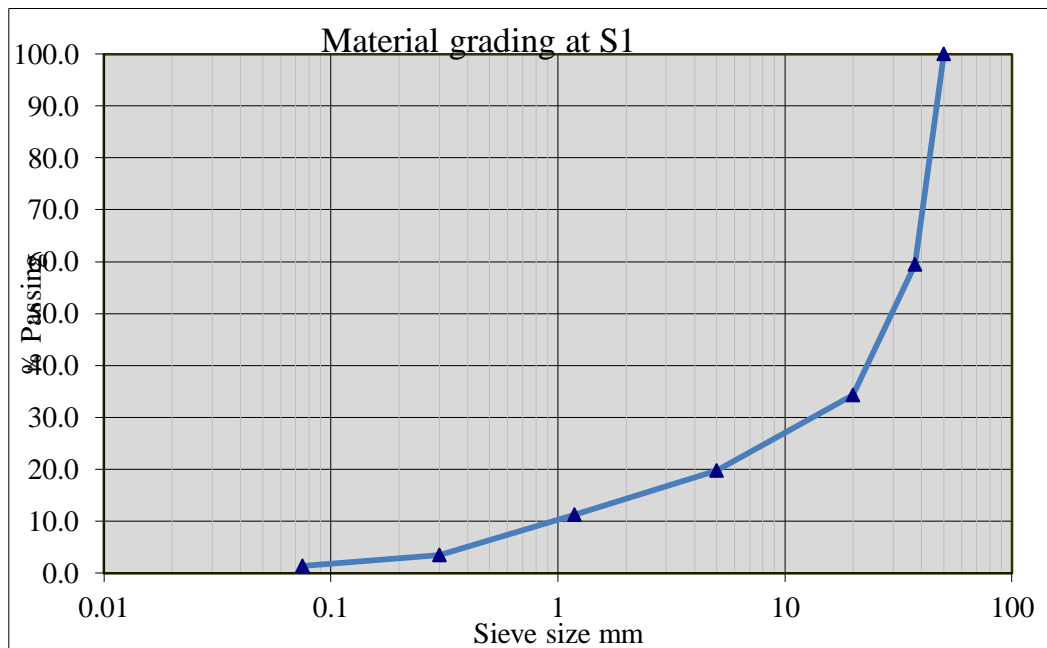
Material grading at S1

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Base course

Sample designation:- S5

Method of sieving:- Dry sieve

Date of Sampled :-   **12/6/2015**

Date of Testing :-   **20/06/2015**

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
50	0	0.0	0.0	100.0
37.5	1655	33.1	33.1	66.9
20	1165	23.3	56.4	43.6
10	915	18.3	74.7	25.3
5	530	10.6	85.3	14.7
2.36	300	6.0	91.3	8.7
0.425	165	3.3	94.6	5.4
0.075	164	3.3	97.9	2.1
Pan	105	2.1	100.0	0.0
Total weight	4998.8			
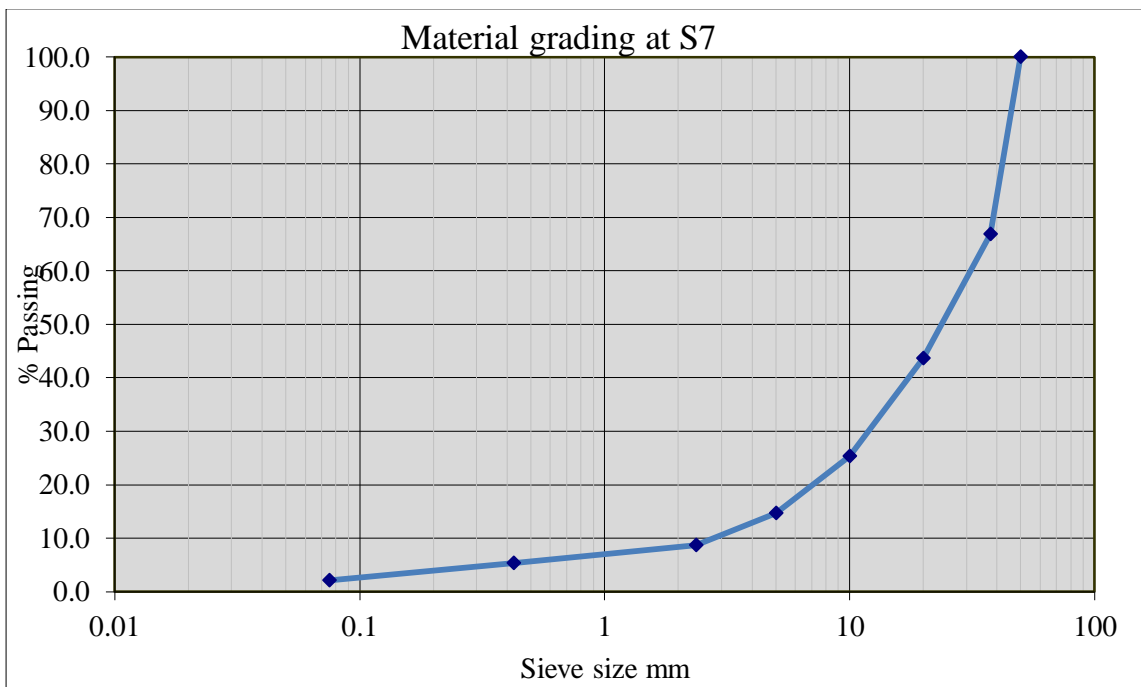
Material grading at S7

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Base course

Sample designation:- S8

Method of sieving:- Dry sieve

Date of Sampled :-   **12/6/2015**

Date of Testing :-   **20/06/2015**

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
50	0	0.0	0.0	100.0
37.5	1825	36.5	36.5	63.5
20	1215	24.3	60.8	39.2
10	777.5	15.6	76.4	23.6
5	451.5	9.0	85.4	14.6
2.36	275	5.5	90.9	9.1
0.425	150	2.5	93.4	6.6
0.075	185	3.7	97.1	2.9
Pan	120	2.4	99.5	0.5
Total weight	4999.0			
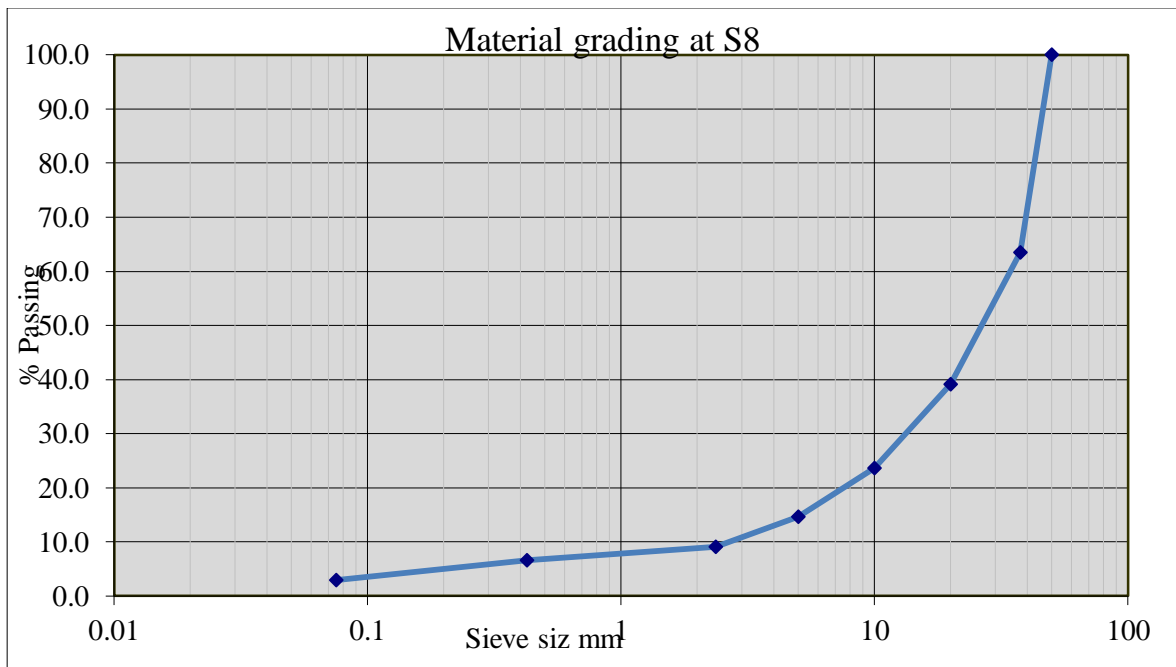
Material grading at S8

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Base course

Sample designation:- S7   **Date of Sampled :-**   **12/6/2015**

Method of sieving:- Dry sieve   **Date of Testing :-**   **20/06/2015**

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
50	0	0.0	0.0	100.0
37.5	1600	32.0	32.0	68.0
20	1425	28.5	60.5	39.5
10	840	16.8	77.3	22.7
5	465	9.3	86.6	13.4
2.36	274.6	5.5	92.1	7.9
0.425	145	2.9	95.0	5.0
0.075	145	2.9	97.9	2.1
Pan	105	2.1	100.0	0.0
Total weight	4999.6			
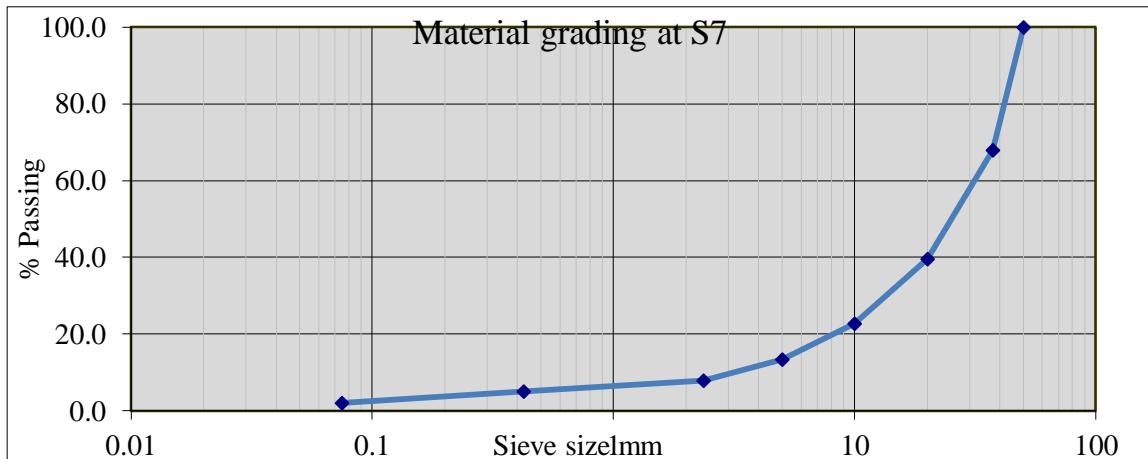
Material grading at S7

PARTICLE SIZE DISTRBUTION

(AASHTO T-11 /T 27)

Type of Material :- Base course   **Date of sampled**
12/6/2015   Date of testing:- 20/06/2015

Sample designation:- S2

Method of sieving:- Dry sieve

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
50	0	0	0	100
37.5	1760	35.2	35.2	64.8
20	1245	24.9	60.1	39.9
10	959.2	19.2	79.3	20.7
5	420	8.4	87.7	12.3
2.36	263.2	5.3	93.0	7.0
0.425	145	2.9	95.9	4.1
0.075	140	2.8	98.7	1.3
Pan	65	1.3	100.0	0.0
Total weight	4997.4			
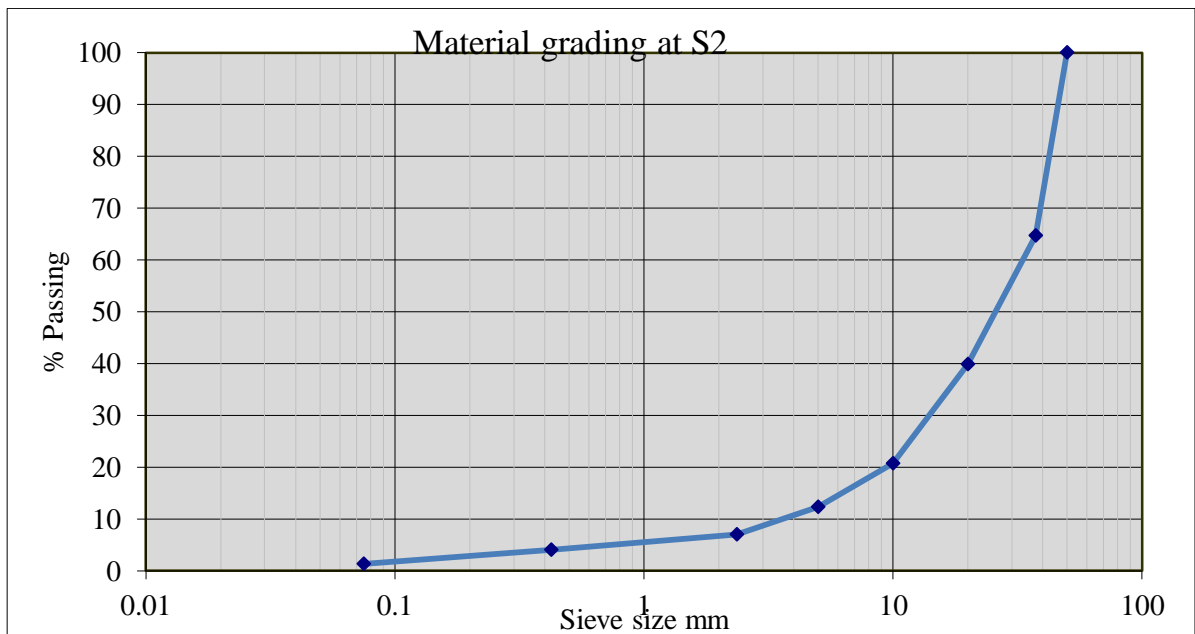
Material grading at S2

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Base course

Sample designation:- S1   **Date of Sampled :-**   **12/6/2015**

Method of sieving:- Dry sieve   **Date of Testing :-**   **20/06/2015**

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
50	0	0	0	100
37.5	2275	45.5	45.5	54.5
20	1335	26.7	72.2	27.8
10	615	12.3	84.5	15.5
5	285	5.7	90.2	9.8
2.36	170	3.4	93.6	6.4
0.425	114.75	2.3	95.9	4.1
0.075	134.34	2.7	98.6	1.4
Pan	70	1.4	100.0	0.0
Total weight	4999.1			

Material grading at S1

MOISETURE DENSITY RELATION
(AASHTO T-180)

Sample designation:- S8   Type of Material :-   Sub-grade

No.of Blows : 56   Weight of Hammer ,Kg :-   4.5

No.of Layers : 5   Volume of Molud ,cm^3 :-   2123

Date of Sampling :-   12-Jun-15

Date of Testing :-   25-Jun-15

Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	
Volume of Mould (cc)	2123	2123	2123	2123	2123
Wgt. of Mould + Wet soil (gm)	8516	8756	8994	9051	8910
Wgt. of Mould (gm)	4965	4965	4965	4965	4965
Wgt. of Wet soil (gm)	3551	3791	4029.0	4086	3941.2
Wet Density (gm/cc)	1.673	1.786	1.898	1.925	1.856
Container No.	2	5	121	127	5
Wgt. of Wet soil + Cont.(gm)	234.5	198.3	199.4	191.3	196.4
Wgt. of Dry soil + Cont.(gm)	207.2	173.0	169.8	158.9	160
Wgt. of Container (gm)	34.2	34.5	36.6	37.1	34.5
Wgt. of Moisture (gm)	27.3	25.3	29.6	32.4	36.4
Wgt. of Dry soil (gm)	173.0	138.5	133.2	121.8	125.5
Moisture Content, %	15.8	18.3	22.2	26.6	29.0
Dry Density (gm/cc)	1.445	1.510	1.553	1.520	1.439
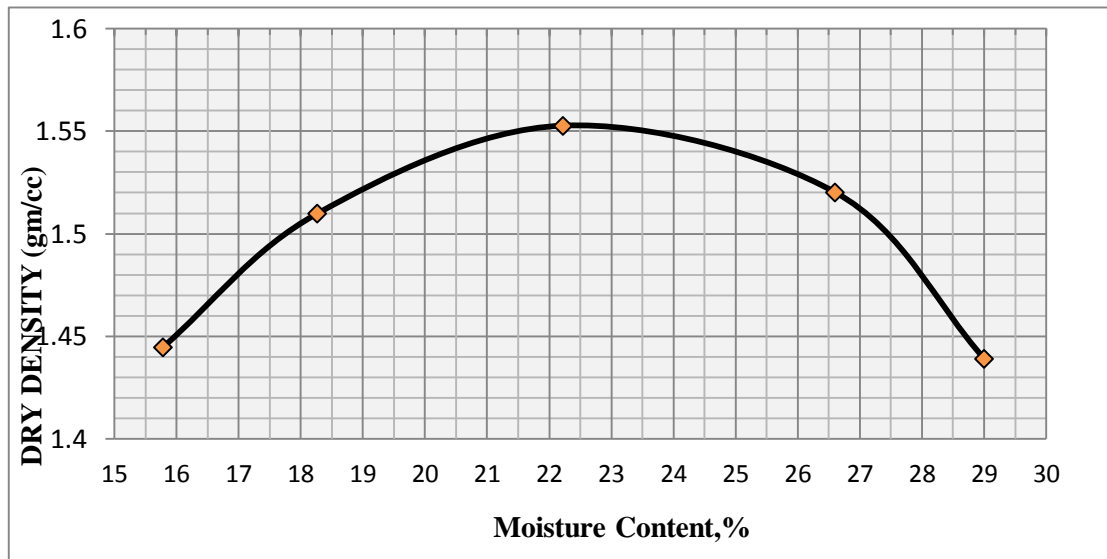
MOISETURE DENSITY RELATION
(AASHTO T-180)

Sample designation:- S4

No.of Blows : 56

No.of Layers : 5

Type of Material :- Sub-grade

Weight of Hammer ,Kg :- 4.5

Volume of Molud ,cm^3 :- 2123

Date of Sampling :- 12-Jun-15

Date of Testing :- 25-Jun-15

Amount of water added,%		4	6	8
Volume of Mould (cc)		2123	2123	2123
Wgt. of Mould + Wet soil (gm)		8926	9098	8967
Wgt. of Mould (gm)		6366	6366	6366
Wgt. of Wet soil (gm)		2560	2732	2601
Wet Density (gm/cc)		1.206	1.287	1.225
Container No.		BE	AO	CB
Wgt. of Wet soil + Cont.(gm)		309.7	277.0	398.2
Wgt. of Dry soil + Cont.(gm)		286.3	252.7	355.0
Wgt. of Container (gm)		79.7	74.7	76.6
Wgt. of Moisture (gm)		23.4	24.3	43.2
Wgt. of Dry soil (gm)		206.6	178	278.4
Moisture Content, %		11.3	13.7	15.5
Dry Density (gm/cc)		1.083	1.132	1.061
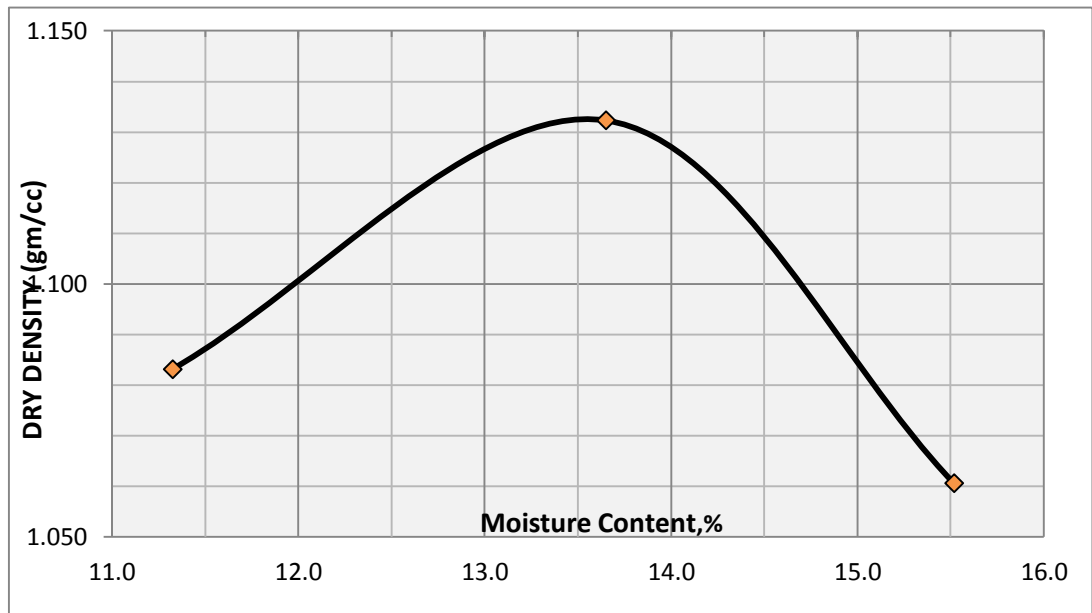
MOISETURE DENSITY RELATION
(AASHTO T-180)

Sample designation: - S1 Type of material Base course

No. of Blows: - 56   Weight of hammer kg: - 4.5

No. of Layers: - 5   Volume of Mould, cm^3

 Date of sampling: - 12-Jun-15

Date of sampling: - 25-Jun-15

Trial No.	1	2	3	4	5
Amount of water added,%	2	4	8	6	10
Volume of Mould (cc)	2123	2123	2123	2123	2123
Wgt. of Mould + Wet soil (gm)	9129.0	9460	9620	9597	9329
Wgt. of Mould (gm)	6366	6366	6380	6366	6366
Wgt. of Wet soil (gm)	2341.0	3094	3298	3231	2963
Wet Density (gm/cc)	1.103	1.457	1.553	1.522	1.396
Container No.	127	21	AO	15	19
Wgt. of Wet soil + Cont.(gm)	168.7	184.0	277.0	209.0	196.3
Wgt. of Dry soil + Cont.(gm)	157.2	169.0	252.7	185.0	171.6
Wgt. of Container (gm)	37.1	34.4	74.7	30	34.4
Wgt. of Moisture (gm)	11.5	15	24.3	24.0	24.7
Wgt. of Dry soil (gm)	120.1	134.6	178.0	155.0	137.2
Moisture Content, %	9.6	11.1	13.7	15.5	18.0
Dry Density (gm/cc)	1.006	1.311	1.367	1.318	1.183
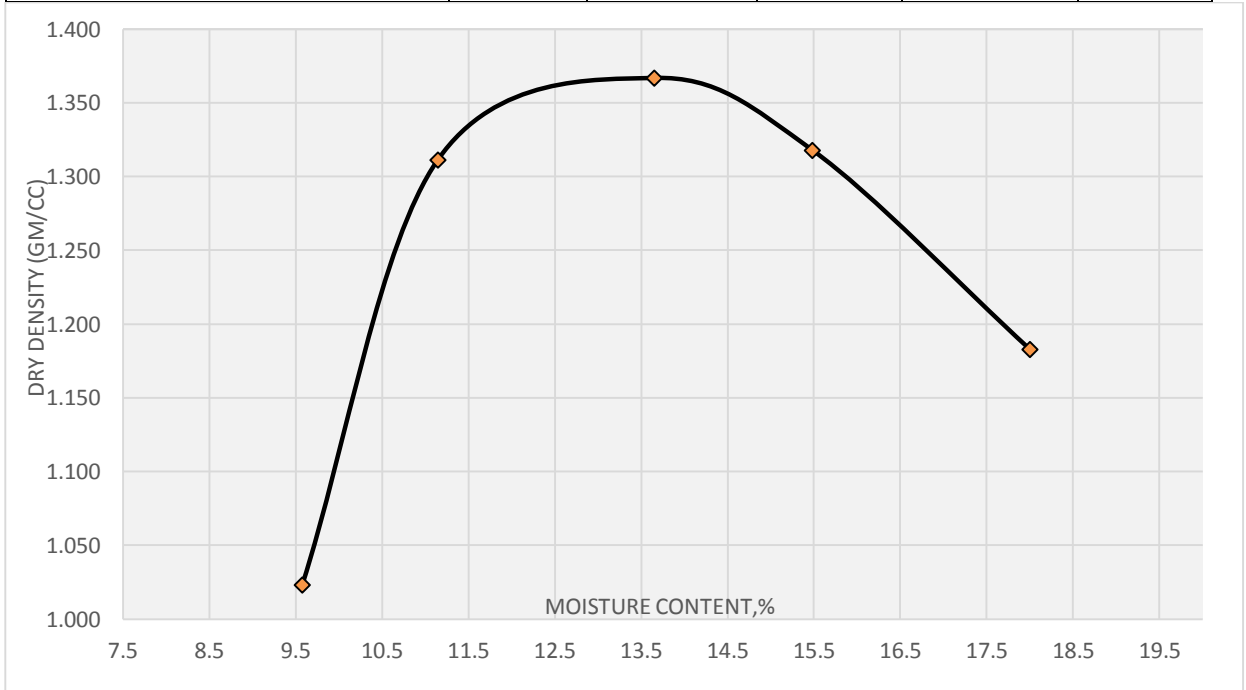
MOISETURE DENSITY RELATION
(AASHTO T-180)

Sample designation: - S8 Type of material: - Sub base

No. of Blows: - 56   Weight of hammer kg: - 4.5

No. of Layers: - 5   Volume of Mould, cm^3

Date of sampling: - 12-Jun-15

Date of sampling: - 25-Jun-15

Trial No.	1	2	3
Amount of water added,%	2	4	6
Volume of Mould (cc)	2123	2123	2123
Wgt. of Mould + Wet soil (gm)	9719.0	10224	10108
Wgt. of Mould (gm)	6005	6005	6005
Wgt. of Wet soil (gm)	3714.0	4219.0	4103.0
Wet Density (gm/cc)	1.749	1.987	1.933
Container No.	20	2	11
Wgt. of Wet soil + Cont.(gm)	249.2	224.3	198.4
Wgt. of Dry soil + Cont.(gm)	221.8	193.0	166.8
Wgt. of Container (gm)	35.4	34.1	34.2
Wgt. of Moisture (gm)	27.4	31.3	31.6
Wgt. of Dry soil (gm)	186.4	158.9	132.6
Moisture Content, %	14.7	19.7	23.8
Dry Density (gm/cc)	1.525	1.660	1.561

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type:-Sub gradeHigh of specimen118mm

Date of sampled: - 12/6/2015   Plunger cross-section 1935.5mm^2

Test type: - modified proctor   No layers:-5

Sample type; - soaked   No of Blows:-30

Wight of sample: - 6000gm   Date of tested: - 29/6/2015

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	10441	10881	Container No	2	14	Date of Soaking	12/06/15
Wt. of Mould ,gm	6540.0	6540	Wt of Cont +Wet soil ,gm	188.90	173.50	Date of Penetration	29/06/15
Volume of wet soil ,gm/cc	3901.0	4341	Wt of Cont + Dry soil ,gm	165.00	140.30	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142	Wt container, gm	33.60	34.20	No of Days	4
Wet density of soil,gm/cc	1.821	2.027	Wt of Moisture ,gm	23.90	33.20	Initial reading	0.2
			Wt of dry soil ,gm	131.40	106.10	Final Reading, di	1.74
			Moisture content,%	18.19	31.29	Swell,in	0.06
			Dry density of Soil ,gm/cc	1.541	1.544	Spec.height,in	4.584
						% Swell	1.32

Ring Factor: N/Division		12.07			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %
0	0.00	0	0.00	0.00	
0.025	0.64	19	0.23	0.12	
0.050	1.27	31	0.37	0.19	
0.075	1.91	38	0.46	0.24	
0.100	2.54	47	0.57	0.29	4.25
0.125	3.18	54	0.65	0.34	
0.150	3.81	58	0.70	0.36	
0.175	4.45	63	0.76	0.39	
0.200	5.08	68	0.82	0.42	4.10

30 Blows Sub grade

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Subgrade   High of specimen118mm

Date of sampled: -   12/6/2015   Plunger cross-section 1935.5mm^2

Test type: - modified proctor   No layers:-5

Sample type; - soaked   No of Blows:-10

Wight of sample: - 6000gm   Date of tested: - 29/6/2015

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	9864	10509	Container No	121	142	Date of Soaking	24/06/2015
Wt. of Mould ,gm	6540.0	6540.0	Wt of Cont.+Wet soil ,gm	253.90	184.50	Date of Penetration	29/06/2015
Volume of wet soil ,gm/cc	3324.0	3969.0	Wt of Cont + Dry soil ,gm	220.40	142.80	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	33.70	35.40	No of Days	4
Wet density of soil,gm/cc	1.552	1.853	Wt of Moisture ,gm	33.50	41.70	Initial reading	0.20
			Wt of dry soil ,gm	186.70	107.40	Final Reading, div	1.84
			Moisture content ,%	17.94	38.83	Swell, in	0.06
			Dry density of Soil ,gm/cc	1.316	1.335	Spec.height,in	4.584
						% Swell	1.41
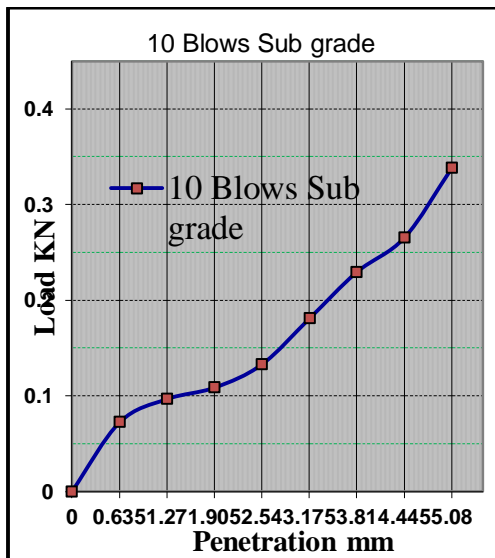
10 Blows Sub grade

Ring Factor: N/Division		12.07				
Pen (in)	pen (mm)	Bottom		1935.5		
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %	
0	0.00	0	0	0.00		
0.025	0.64	6	0.07	0.04		
0.050	1.27	8	0.10	0.05		
0.075	1.91	9	0.11	0.06		
0.100	2.54	11	0.13	0.07	1.00	
0.125	3.18	15	0.18	0.09		
0.150	3.81	19	0.23	0.12		
0.175	4.45	22	0.27	0.14		
0.200	5.08	28	0.34	0.17	1.69	

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CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Base course

High of specimen118mm

Date of sampled: - 12/6/2015

Plunger cross-section

1935.5mm^2

Test type: - modified proctor

No layers:-5

Sample type; - soaked

No of Blows:-65

Wight of sample: - 6000gm

Date of tested: -

29/6/2015

Low sever area

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	11482	11522	Container No	2	14	Date of Soaking	24/06/2015
Wt. of Mould ,gm	6577.0	6577.0	Wt of Cont.+Wet soil ,gm	202.70	196.80	Date of Penetration	29/06/2015
Volume of wet soil ,gm/cc	4905.0	4945.0	Wt of Cont + Dry soil ,gm	191.40	169.20	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	32.10	33.70	No of Days	4
Wet density of soil, gm/cc	2.290	2.309	Wt of Moisture ,gm	11.30	27.60	Initial reading	0.13
			Wt of dry soil ,gm	159.30	135.50	Final Reading, div	0.22
			Moisture content ,%	7.09	20.37	Swell,in	0.00
			Dry density of Soil ,gm/cc	2.138	1.918	Spec.height,in	4.584
						% Swell	0.08
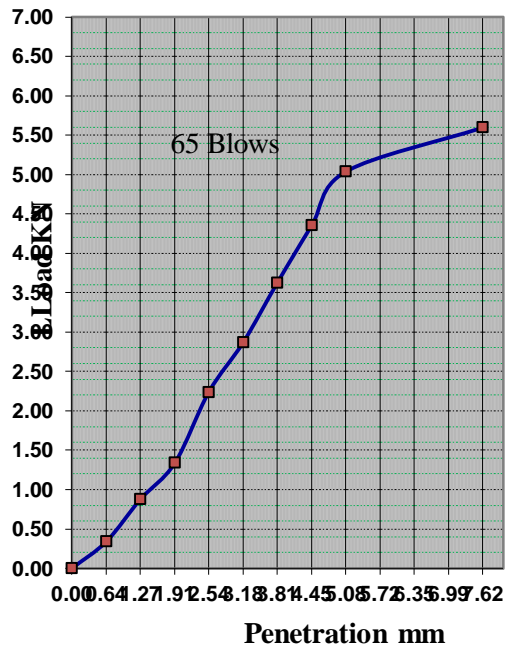
Ring Factor: N/Division		24.33			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %
0	0.00	0	0.00	0.00	
0.025	0.64	14	0.34	0.18	
0.050	1.27	36	0.88	0.45	
0.075	1.91	55	1.34	0.69	
0.100	2.54	92	2.24	1.16	16.78
0.125	3.18	118	2.87	1.48	
0.150	3.81	149	3.63	1.87	
0.175	4.45	179	4.36	2.25	
0.200	5.08	207	5.04	2.60	25.17
0.300	7.62	230	5.60	2.89	
0.400	10.16	245	5.96	3.08	
0.500	12.70	284	6.90972	3.5699923	

65 Blows

Load KN

Penetration mm

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Base course

High of specimen118mm

Date of sampled: - 12/6/2015

Plunger cross-section

1935.5mm^2

Test type: - modified proctor

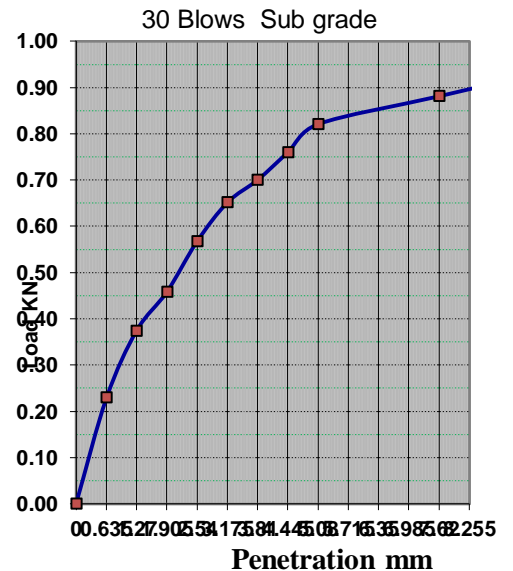No layers:-5

Sample type; - soaked

No of Blows:-30

Wight of sample: - 6000gm

Date of tested: -

29/6/2015

Low sever area

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	11282	11327	Container No	121	142	Date of Soaking	24/06/2015
Wt. of Mould ,gm	6264.0	6264.0	Wt of Cont.+Wet soil ,gm	216.40	226.20	Date of Penetration	29/06/2015
Volume of wet soil ,gm/cc	5018.0	5063.0	Wt of Cont + Dry soil ,gm	202.50	209.70	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	35.80	35.90	No of Days	4
Wet density of soil, gm/cc	2.343	2.364	Wt of Moisture ,gm	13.90	16.50	Initial reading	0.00
			Wt of dry soil ,gm	166.70	173.80	Final Reading, div	0.18
			Moisture content ,%	8.34	9.49	Swell,in	0.01
			Dry density of Soil ,gm/cc	2.162	2.159	Spec.height,in	4.584
						% Swell	0.15
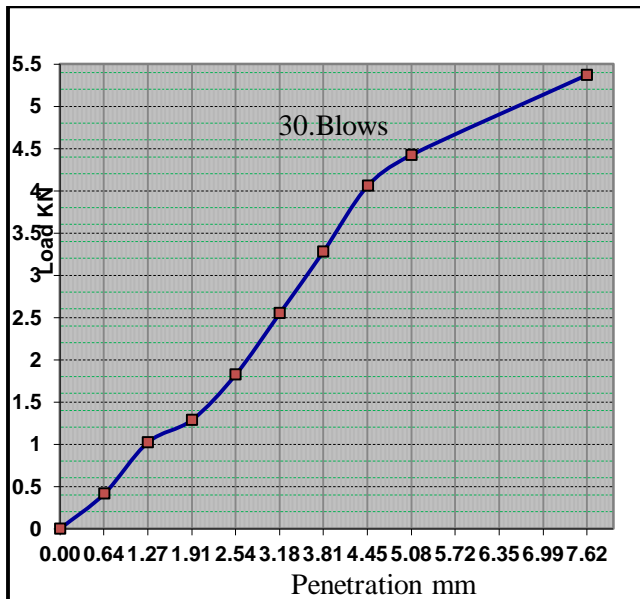
30.Blows

Ring Factor: N/Division		24.3			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %
0	0.00	0	0	0.00	
0.025	0.64	17	0.41	0.21	
0.050	1.27	42	1.02	0.53	
0.075	1.91	53	1.29	0.67	
0.100	2.54	75	1.82	0.94	13.67
0.125	3.18	105	2.55	1.32	
0.150	3.81	135	3.28	1.69	
0.175	4.45	167	4.06	2.10	
0.200	5.08	182	4.42	2.28	22.10
0.300	7.62	221	5.37	2.77	

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Base course

High of specimen118mm

Date of sampled: -   12/6/2015

Plunger cross-section
1935.5mm^2

Test type: - modified proctor

No layers:-5

Sample type; - soaked

No of Blows:-10

Wight of sample: - 6000gm

Date of tested: -
29/6/2015

Low sever area

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	11567	11629	Container No	2	14	Date of Soaking	24/06/2015
Wt. of Mould ,gm	6775.0	6775.0	Wt of Cont.+Wet soil ,gm	226.30	183.30	Date of Penetration	29/06/2015
Volume of wet soil ,gm/cc	4792.0	4854.0	Wt of Cont + Dry soil ,gm	212.80	171.30	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	32.80	34.10	No of Days	4
Wet density of soil,gm/cc	2.237	2.266	Wt of Moisture ,gm	13.50	12.00	Initial reading	0.05
			Wt of dry soil ,gm	180.00	137.20	Final Reading, div	0.18
			Moisture content ,%	7.50	8.75	Swell,in	
							0.01
			Dry density of Soil ,gm/cc	2.081	2.084	Spec.height,in	4.584
						% Swell	
							0.11
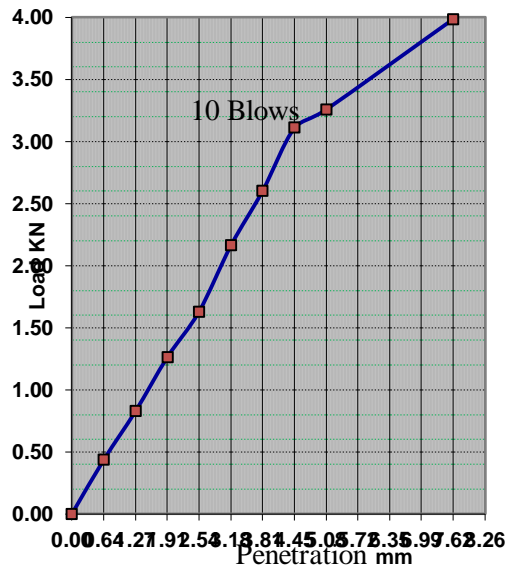
10 Blows

Ring Factor: N/Division		24.3				
Pen (in)	pen (mm)	Bottom			1935.5	
		Dial Reading	Load(KN)		Stress N/mm^2	CBR %
0	0.00	0	0.00		0.00	
0.025	0.64	18	0.44		0.23	
0.050	1.27	34	0.83		0.43	
0.075	1.91	52	1.26		0.65	
0.100	2.54	67	1.63		0.84	12.21
0.125	3.18	89	2.16		1.12	
0.150	3.81	107	2.60		1.34	
0.175	4.45	128	3.11		1.61	
0.200	5.08	134	3.26		1.68	16.27
0.300	7.62	164	3.99		2.06	

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Base course

High of specimen118mm

Date of sampled: -   12/6/2015

Plunger cross-section
1935.5mm^2

Test type: - modified proctor

No layers:-5

Sample type; - soaked

No of Blows:-65

Wight of sample: - 6000gm

Date of tested: -
29/6/2015

High sever area

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	12718	12808	Container No	A34	A66	Date of Soaking	26/06/2015
Wt. of Mould ,gm	7716.0	7716.0	Wt of Cont.+Wet soil ,gm	275.00	253.80	Date of Penetration	30/06/2015
Volume of wet soil ,gm/cc	5002.0	5092.0	Wt of Cont + Dry soil ,gm	258.00	238.20	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	34.40	34.90	No of Days	4
Wet density of soil,gm/cc	2.335	2.377	Wt of Moisture ,gm	17.00	15.60	Initial reading	0.2
			Wt of dry soil ,gm	223.60	203.30	Final Reading, div	0.4
			Moisture content %	7.60	7.67	Swell,in	0.01
			Dry density of Soil ,gm/cc	2.170	2.208	Spec.height,in	4.584
						% Swell	0.17
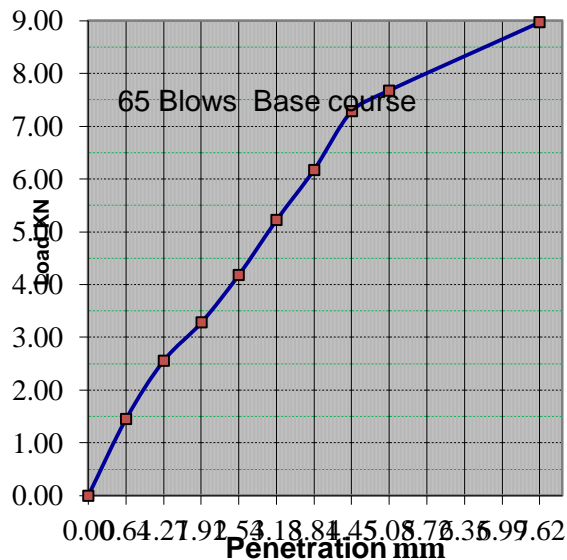
65 Blows Base course

Ring Factor: N/Division		24.3			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %
0	0.00	0	0.00	0.00	
0.025	0.64	41	1.00	0.51	
0.050	1.27	90	2.19	1.13	
0.075	1.91	125	3.04	1.57	
0.100	2.54	172	4.18	2.16	31.34
0.125	3.18	215	5.22	2.70	
0.150	3.81	254	6.17	3.19	
0.175	4.45	300	7.29	3.77	
0.200	5.08	316	7.68	3.97	38.37
0.300	7.62	369	8.97	4.63	

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Base course

Date of sampled: -   12/6/2015

Test type: - modified proctor

Sample type; - soaked

Wight of sample: - 6000gm
29/6/2015

High sever area

High of specimen118mm

Plunger cross-section 1935.5mm^2

No layers:-5

No of Blows:-30

Date of tested: -

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	11269	11420	Container No	121	142	Date of Soaking	26/06/2015
Wt. of Mould ,gm	6602.0	6602.0	Wt of Cont.+Wet soil gm	276.80	219.40	Date of Penetration	30/06/2015
Volume of wet soil ,gm/cc	4667.0	4818.0	Wt of Cont + Dry soil ,gm	264.60	204.50	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	34.50	34.00	No of Days	4
Wet density of soil,gm/cc	2.179	2.249	Wt of Moisture gm	12.20	14.90	Initial reading	0.20
			Wt of dry soil ,gm	230.10	170.50	Final Reading, div	0.45
			Moisture content ,%	5.30	8.74	Swell,in	0.01
			Dry density of Soil ,gm/cc	2.069	2.069	Spec.height,in	4.584
						% Swell	0.21
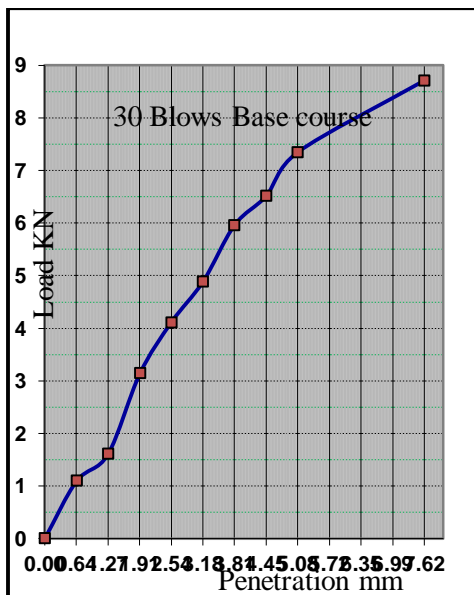
30 Blows Base course

Ring Factor: N/Division		24.33			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %
0	0.00	0	0	0.00	
0.025	0.64	72	1.75	0.91	
0.050	1.27	120	2.92	1.51	
0.075	1.91	150	3.65	1.89	
0.100	2.54	169	4.11	2.12	30.83
0.125	3.18	201	4.89	2.53	
0.150	3.81	245	5.96	3.08	
0.175	4.45	268	6.52	3.37	
0.200	5.08	302	7.35	3.80	36.71
0.300	7.62	358	8.71	4.50	

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Base course

High of specimen118mm

Date of sampled: - 12/6/2015

Plunger cross-section
1935.5mm²

Test type: - modified proctor

No layers:-5

Sample type; - soaked

No of Blows:-10

Wight of sample: - 6000gm

Date of tested: -
29/6/2015

High sever area

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	12058	12195	Container No	A656	61	Date of Soaking	26/06/2015
Wt. of Mould ,gm	7623.0	7623.0	Wt of Cont.+Wet soil ,gm	319.90	259.50	Date of Penetration	30/06/2015
Volume of wet soil ,gm/cc	4435.0	4572.0	Wt of Cont + Dry soil ,gm	299.00	238.80	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	33.40	34.40	No of Days	4
Wet density of soil,gm/cc	2.070	2.134	Wt of Moisture ,gm	20.90	20.70	Initial reading	0.20
			Wt of dry soil ,gm	265.60	204.40	Final Reading, div	0.52
			Moisture content ,%	7.87	10.13	Swell,in	0.01
			Dry density of Soil ,gm/cc	1.919	1.938	Spec.height,in	4.584
						% Swell	0.27
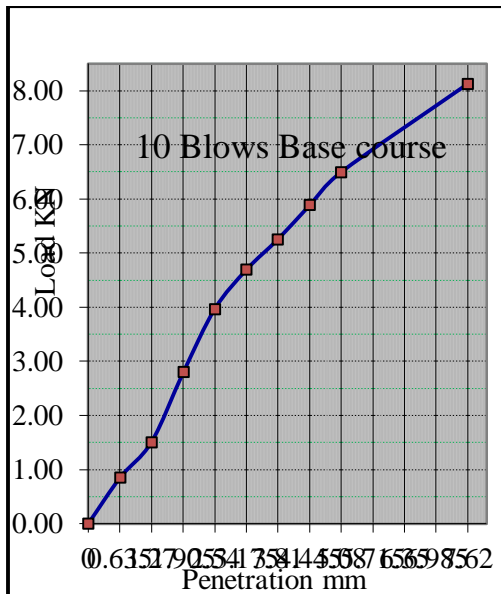
10 Blows Base course

Ring Factor: N/Division		24.33			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm²	CBR %
0	0.00	0	0.00	0.00	
0.025	0.64	41	1.00	0.52	
0.050	1.27	86	2.09	1.08	
0.075	1.91	128	3.11	1.61	
0.100	2.54	163	3.97	2.05	29.74
0.125	3.18	193	4.70	2.43	
0.150	3.81	216	5.26	2.72	
0.175	4.45	242	5.89	3.04	
0.200	5.08	267	6.50	3.36	32.46
0.300	7.62	334	8.13	4.20	

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Base course

Date of sampled: - 12/6/2015
1935.5mm²

Test type: - modified proctor

Sample type; - soaked

Wight of sample: - 6000gm
29/6/2015

Intermediate sever area

High of specimen118mm

Plunger cross-section

No layers:-5

No of Blows:- 65

Date of tested: -

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	12709	12871	Container No	A34	A66	Date of Soaking	26/06/2015
Wt. of Mould ,gm	7904.0	7904.0	Wt of Cont.+Wet soil ,gm	286.00	234.30	Date of Penetration	30/06/2015
Volume of wet soil ,gm/cc	4805.0	4967.0	Wt of Cont + Dry soil ,gm	266.40	215.90	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	34.10	33.40	No of Days	4
Wet density of soil,gm/cc	2.243	2.319	Wt of Moisture ,gm	19.60	18.40	Initial reading	0.2
			Wt of dry soil ,gm	232.30	182.50	Final Reading, div	0.35
			Moisture content ,%	8.44	10.08	Swell,in	0.01
			Dry density of Soil ,gm/cc	2.069	2.106	Spec.height,in	4.584
						% Swell	0.13
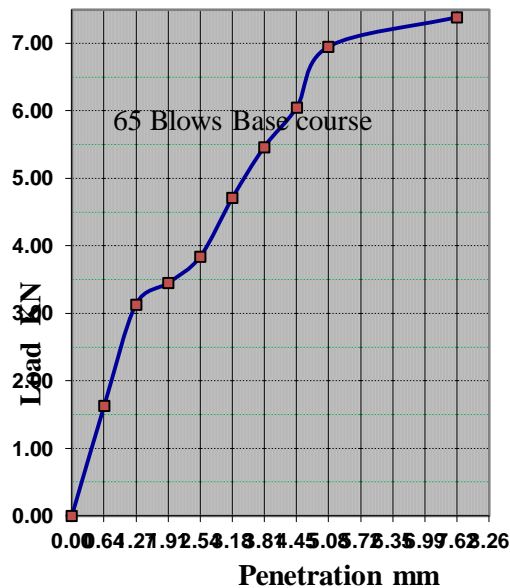
Ring Factor: N/Division		24.3			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm²	CBR %
0	0.00	0	0.00	0.00	
0.025	0.64	67	1.63	0.84	
0.050	1.27	129	3.13	1.62	
0.075	1.91	142	3.45	1.78	
0.100	2.54	158	3.84	1.98	28.79
0.125	3.18	194	4.71	2.44	
0.150	3.81	225	5.47	2.82	
0.175	4.45	249	6.05	3.13	
0.200	5.08	286	6.95	3.59	34.73
0.300	7.62	304	7.39	3.82	

65 Blows Base course

Penetration mm

CALIFORNIA BEARING RATIO

(AASHTO T-193-93)

Material type: - Base course High of specimen118mm

Date of sampled: - 12/6/2015 Plunger cross-section
1935.5mm^2

Test type: - modified proctor No layers:-5

Sample type; - soaked No of Blows:- 30

Wight of sample: - 6000gm Date of tested: -
29/6/2015
Intermediate sever area

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	12067	12208	Container No	121	142	Date of Soaking	0-Jan-00
Wt. of Mould ,gm	7521.0	7521.0	Wt of Cont.+Wet soil ,gm	289.80	227.60	Date of Penetration	0-Jan-00
Volume of wet soil ,gm/cc	4546.0	4687.0	Wt of Cont + Dry soil ,gm	275.60	211.60	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	34.00	36.60	No of Days	4
Wet density of soil,gm/cc	2.122	2.188	Wt of Moisture ,gm	14.20	16.00	Initial reading	0.20
			Wt of dry soil ,gm	241.60	175.00	Final Reading, div	0.35
			Moisture content ,%	5.88	9.14	Swell,in	0.01
			Dry density of Soil ,gm/cc	2.005	2.005	Spec.height,in	4.584
						% Swell	0.13
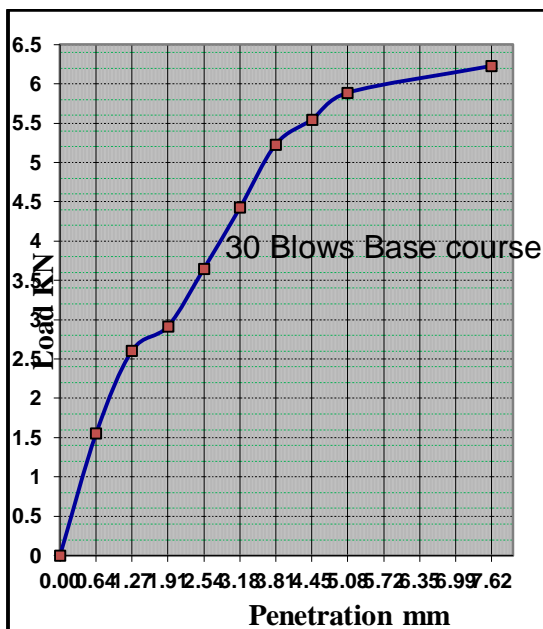
30 Blows Base course

Ring Factor: N/Division		24.33				
Pen (in)	pen (mm)	Bottom			1935.5	
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %
0	0.00	0	0	0.00	
0.025	0.64	64	1.56	0.80	
0.050	1.27	107	2.60	1.35	
0.075	1.91	120	2.92	1.51	
0.100	2.54	150	3.65	1.89	27.37
0.125	3.18	182	4.43	2.29	
0.150	3.81	215	5.23	2.70	
0.175	4.45	228	5.55	2.87	
0.200	5.08	242	5.89	3.04	29.42
0.300	7.62	256	6.23	3.22	

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CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Base course

High of specimen118mm

Date of sampled: - 12/6/2015
1935.5mm^2

Plunger cross-section

Test type: - modified proctor

No layers:-5

Sample type; - soaked

No of Blows: - 10

Wight of sample: - 6000gm
29/6/2015

Date of tested: -

Intermediate sever area

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	11571	11828	Container No	A656	61	Date of Soaking	0-Jan-00
Wt. of Mould ,gm	7321.0	7321.0	Wt of Cont.+Wet soil ,gm	261.70	247.10	Date of Penetration	0-Jan-00
Volume of wet soil ,gm/cc	4250.0	4507.0	Wt of Cont + Dry soil ,gm	245.30	223.80	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	34.40	33.70	No of Days	4
Wet density of soil,gm/cc	1.984	2.104	Wt of Moisture ,gm	16.40	23.30	Initial reading	0.20
			Wt of dry soil ,gm	210.90	190.10	Final Reading, div	0.35
			Moisture content ,%	7.78	12.26	Swell,in	0.01
			Dry density of Soil ,gm/cc	1.841	1.874	Spec.height,in	4.584
						% Swell	0.13
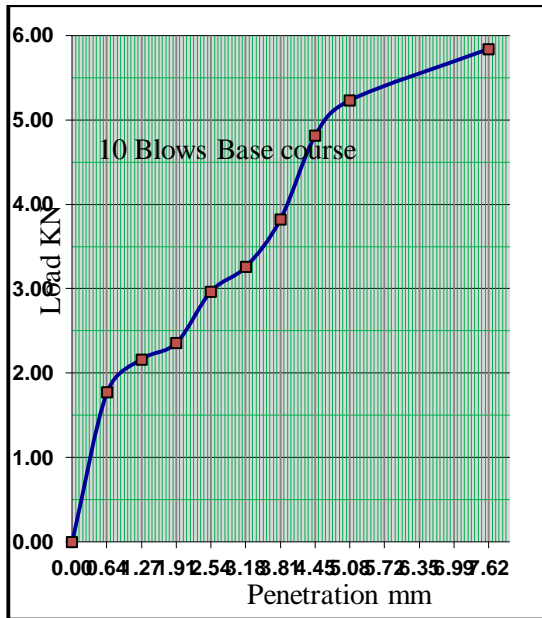
10 Blows Base course

Ring Factor: N/Division		24.33			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %
0	0.00	0	0.00	0.00	
0.025	0.64	73	1.78	0.92	
0.050	1.27	89	2.17	1.12	
0.075	1.91	97	2.36	1.22	
0.100	2.54	122	2.97	1.53	22.26
0.125	3.18	134	3.26	1.68	
0.150	3.81	157	3.82	1.97	
0.175	4.45	198	4.82	2.49	
0.200	5.08	215	5.23	2.70	26.14

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Sub base   High of specimen118mm

Date of sampled: - 12/6/2015   Plunger cross-section
1935.5mm^2

Test type: - modified proctor   No layers:-5

Sample type; - soaked   No of Blows: - 65

Wight of sample: - 6000gm   Date of tested: -
29/6/2015

High sever area

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	12441	12569	Container No	A34	A66	Date of Soaking	26/06/2015
Wt. of Mould ,gm	7723.0	7723.0	Wt of Cont.+Wet soil ,gm	259.00	177.50	Date of Penetration	30/06/2015
Volume of wet soil ,gm/cc	4718.0	4846.0	Wt of Cont + Dry soil ,gm	226.20	152.80	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	33.70	36.30	No of Days	4
Wet density of soil,gm/cc	2.203	2.262	Wt of Moisture ,gm	32.80	24.70	Initial reading	0.2
			Wt of dry soil ,gm	192.50	116.50	Final Reading, div	0.91
			Moisture content ,%	17.04	21.20	Swell,in	0.03
			Dry density of Soil ,gm/cc	1.882	1.867	Spec.height,in	4.584
						% Swell	0.61
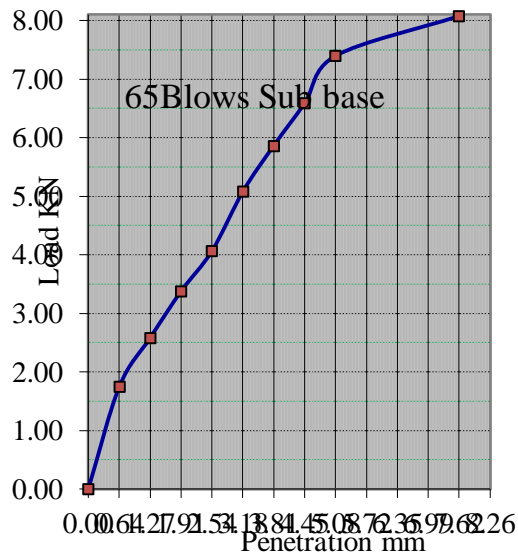
65Blows Sub base

Ring Factor: N/Division		24.33				
Pen (in)	pen (mm)	Bottom			1935.5	
		Dial Reading	Load(KN)	Stress N/mm²	CBR %	
0	0.00	0	0.00	0.00		
0.025	0.64	72	1.75	0.91		
0.050	1.27	106	2.58	1.33		
0.075	1.91	139	3.38	1.75		
0.100	2.54	167	4.06	2.10	30.47	
0.125	3.18	209	5.08	2.63		
0.150	3.81	241	5.86	3.03		
0.175	4.45	271	6.59	3.41		
0.200	5.08	304	7.40	3.82	36.96	
0.300	7.62	332	8.08	4.17		

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Sub base   High of specimen118mm

Date of sampled: - 12/6/2015   Plunger cross-section
1935.5mm^2

Test type: - modified proctor   No layers:-5

Sample type; - soaked   No of Blows: - 30

Wight of sample: - 6000gm   Date of tested: - 29/6/2015

High sever area

Compactor	Before	After	Moisture Content		Before	After	Swelling	
Wt of wet soil + mould,gm	11355	11494	Container No		121	142	Date of Soaking	26/06/2015
Wt. of Mould ,gm	6679.0	6679.0	Wt of Cont.+Wet soil ,gm		311.80	235.10	Date of Penetration	30/06/2015
Volume of wet soil ,gm/cc	4676.0	4815.0	Wt of Cont + Dry soil ,gm		290.90	216.70	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm		32.10	34.00	No of Days	4
Wet density of soil,gm/cc	2.183	2.248	Wt of Moisture ,gm		20.90	18.40	Initial reading	0.20
			Wt of dry soil ,gm		258.80	182.70	Final Reading, div	1.05
			Moisture content ,%		8.08	10.07	Swell,in	0.03
			Dry density of Soil ,gm/cc		2.020	2.042	Spec.height,in	4.584
							% Swell	0.73

30 Blows sub base

	Ring Factor: N/Division	24.33			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm²	CBR %
0	0.00	0	0	0.00	
0.025	0.64	32	0.78	0.40	
0.050	1.27	49	1.19	0.62	
0.075	1.91	65	1.58	0.82	
0.100	2.54	150	3.65	1.89	27.37
0.125	3.18	268	6.52	3.37	
0.150	3.81	313	7.62	3.93	
0.175	4.45	354	8.61	4.45	
0.200	5.08	402	9.78	5.05	48.87
0.300	7.62	560	13.62	7.04	

CALIFORNIA BEARING RATIO
(AASHTO T-193-93)

Material type: - Sub base

High of specimen118mm

Date of sampled: -   12/6/2015

Plunger cross-section
1935.5mm^2

Test type: - modified proctor

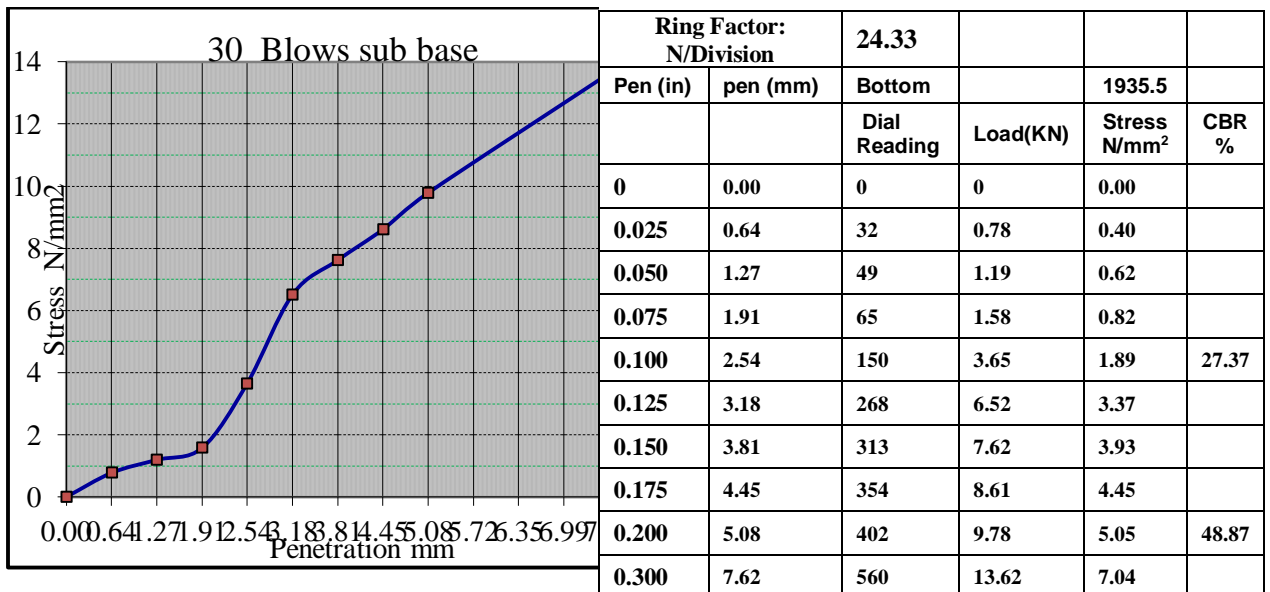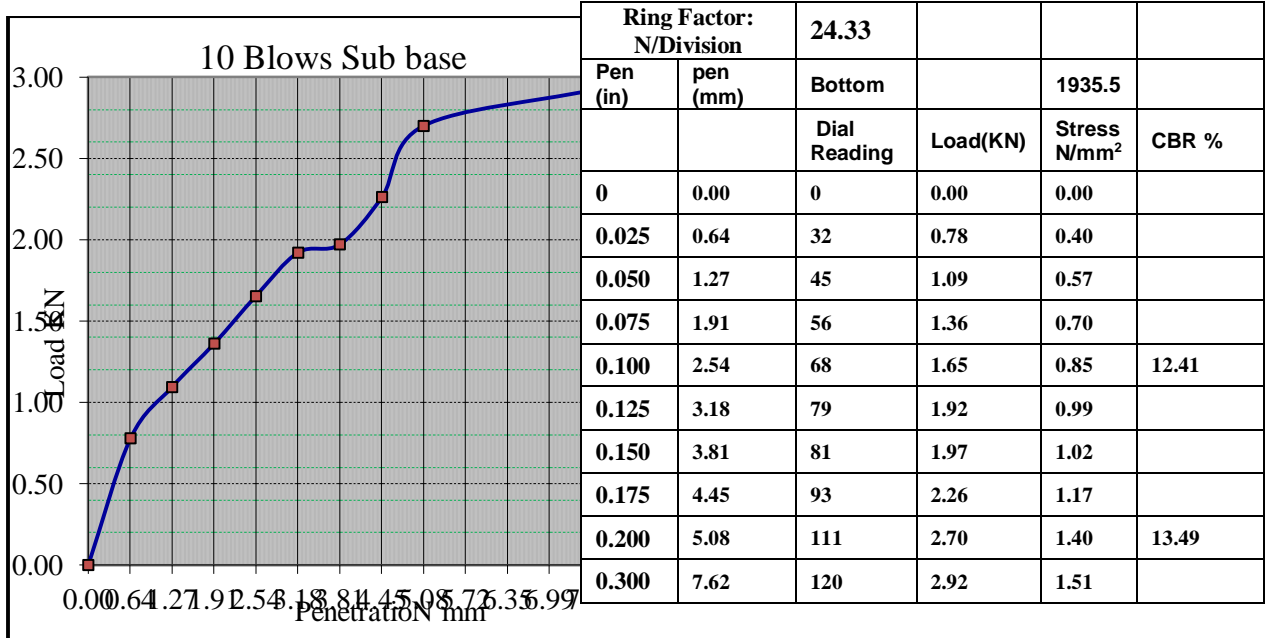No layers:-5

Sample type; - soaked

No of Blows: - 10

Wight of sample: - 6000gm

Date of tested: -
29/6/2015

Compactor	Before	After	Moisture Content	Before	After	Swelling	
Wt of wet soil + mould,gm	11571	11828	Container No	A656	61	Date of Soaking	26/06/2015
Wt. of Mould ,gm	7321.0	7321.0	Wt of Cont.+Wet soil ,gm	261.70	247.10	Date of Penetration	30/06/2015
Volume of wet soil ,gm/cc	4250.0	4507.0	Wt of Cont + Dry soil ,gm	245.30	223.80	Time Soaking	11.00AM
Volume of mould,gm/cc	2142.0	2142.0	Wt container ,gm	34.40	33.70	No of Days	4
Wet density of soil,gm/cc	1.984	2.104	Wt of Moisture ,gm	16.40	23.30	Initial reading	0.20
			Wt of dry soil ,gm	210.90	190.10	Final Reading, div	1.25
			Moisture content ,%	7.78	12.26	Swell,in	0.04
			Dry density of Soil ,gm/cc	1.841	1.874	Spec.height,in	4.584
						% Swell	0.90

10 Blows Sub base

Ring Factor: N/Division		24.33			
Pen (in)	pen (mm)	Bottom		1935.5	
		Dial Reading	Load(KN)	Stress N/mm^2	CBR %
0	0.00	0	0.00	0.00	
0.025	0.64	32	0.78	0.40	
0.050	1.27	45	1.09	0.57	
0.075	1.91	56	1.36	0.70	
0.100	2.54	68	1.65	0.85	12.41
0.125	3.18	79	1.92	0.99	
0.150	3.81	81	1.97	1.02	
0.175	4.45	93	2.26	1.17	
0.200	5.08	111	2.70	1.40	13.49
0.300	7.62	120	2.92	1.51	

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Base course

Sample designation :- S9   Date of Sampled :-   12/6/2015

Method of sieving: Dry sieve   Date of Testing :-   20/06/2015

Comparison with standard

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass	Lower Limit	Upper Limit
50	0	0	0	100	100	100
37.5	1655	33.108	33.108	66.892	95	100
20	1165	23.306	56.414	43.586	60	80
10	915	18.304	74.718	25.3	40	60
5	530	10.603	85.321	14.679	25	40
2.36	299.75	5.9965	91.317	8.7	15	30
0.425	165	3.3008	94.618	5.3821	7	19
0.075	164.04	3.2816	97.899	2.1005	5	12
Pan	105	2.1005	100	0		
Total weight	4998.8					

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Sub base
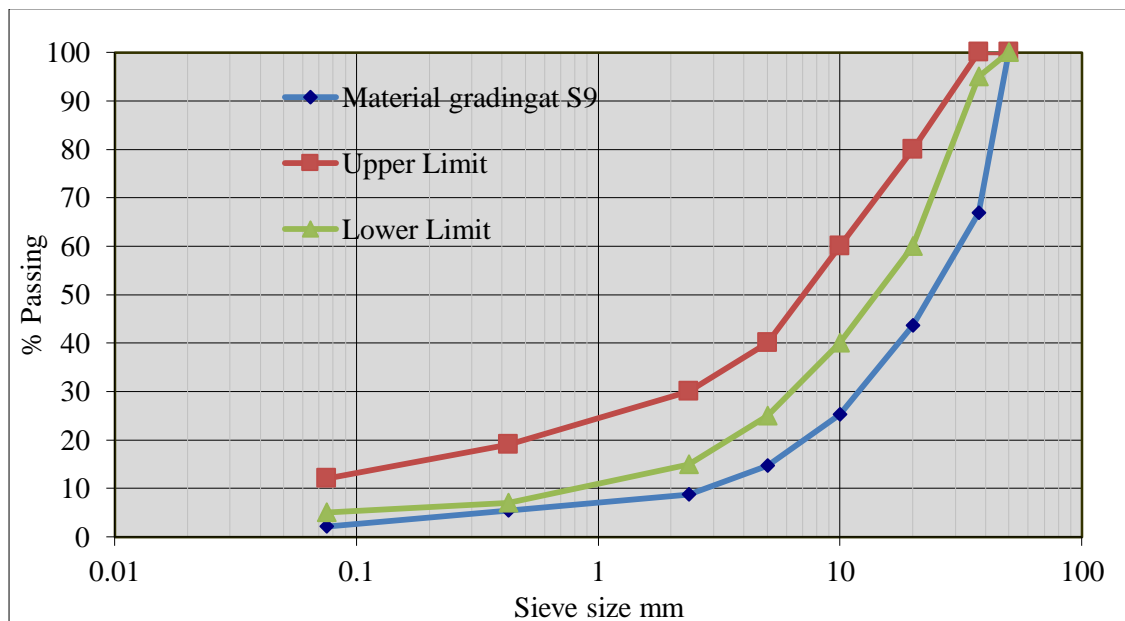
Sample designation :-   S8

Date of Sampled :-   12/6/2015

Method of sieving: Dry sieve

Date of Testing :-   20/06/2015

Comparison with standard

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass	Lower Limit	Upper Limit
50	0	0.0	0.0	100.0	100	100
37.5	1825	36.5	36.5	63.5	95	100
20	1215	24.3	60.8	39.2	60	80
10	777.5	15.6	76.4	23.6	40	60
5	451.5	9.0	85.4	14.6	25	40
2.36	275	5.5	90.9	9.1	15	30
0.425	150	2.5	93.4	6.6	7	19
0.075	185	3.7	97.1	2.9	5	12
Pan	120	2.4	99.5	0.5		
Total weight	4999.0					

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Base course

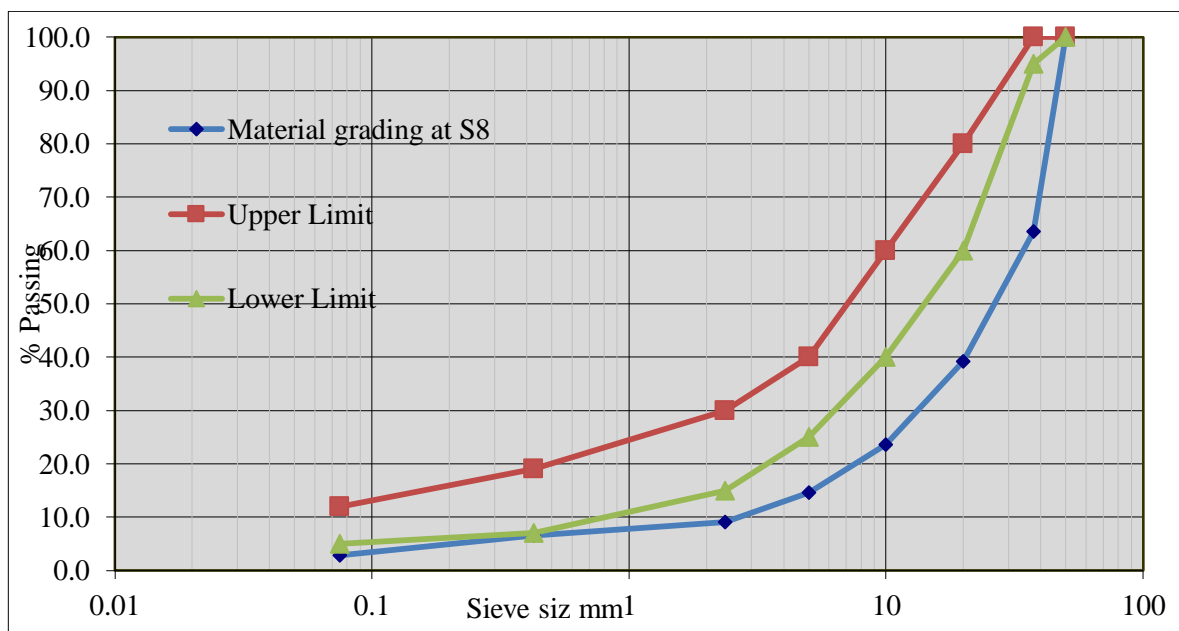Sample designation :- S5   Date of Sampled :-   12/6/2015

Method of sieving: Dry sieve   Date of Testing :-   20/06/2015

Comparison   with standard

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass	Lower Limit	Upper Limit
50	0	0.0	0.0	100.0	100	100
37.5	1600	32.0	32.0	68.0	95	100
20	1425	28.5	60.5	39.5	60	80
10	840	16.8	77.3	22.7	40	60
5	465	9.3	86.6	13.4	25	40
2.36	274.6	5.5	92.1	7.9	15	30
0.425	145	2.9	95.0	5.0	7	19
0.075	145	2.9	97.9	2.1	5	12
Pan	105	2.1	100.0	0.0		
Total weight	4999.6					

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Base course

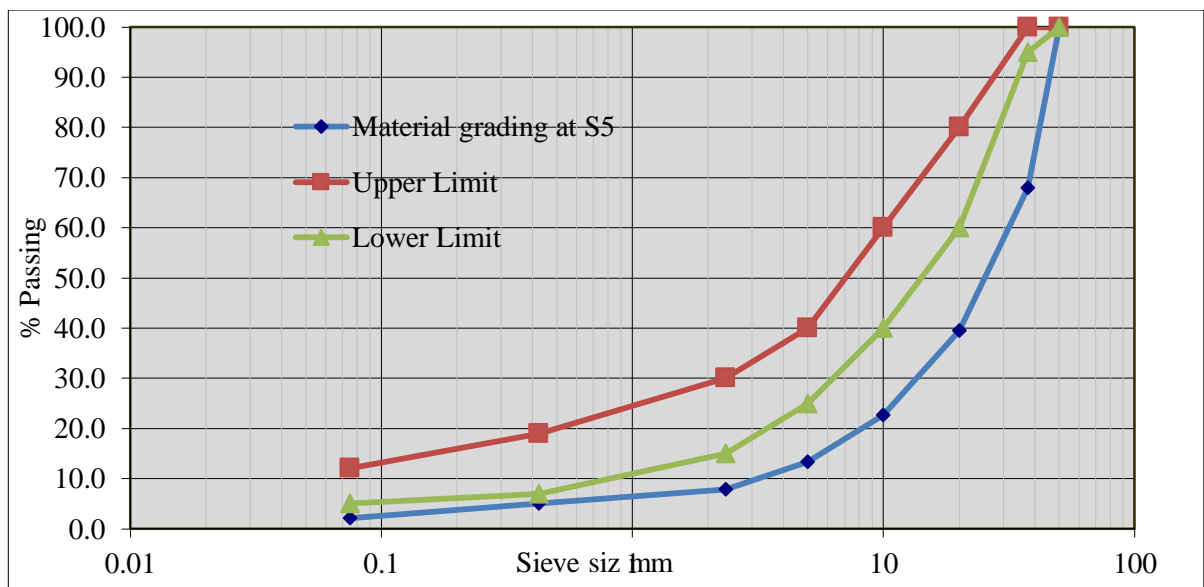Sample designation :-   S2   Date of Sampled:-   12/6/2015

Method of sieving: Dry sieve   Date of Testing :-   20/06/2015

Comparison   with standard

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass	Specification Limit	
					Lower Limit	Upper Limit
50	0	0.0	0	100	100	100
37.5	1760	35.2	35.2	64.8	95	100
20	1245	24.9	60.1	39.9	60	80
10	959.2	19.2	79.3	20.7	40	60
5	420	8.4	87.7	12.3	25	40
2.36	263.2	5.3	93.0	7.0	15	30
0.425	145	2.9	95.9	4.1	7	19
0.075	140	2.8	98.7	1.3	5	12
Pan	65	1.3	100.0	0.0		
Total weight	4997.4					

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Base course

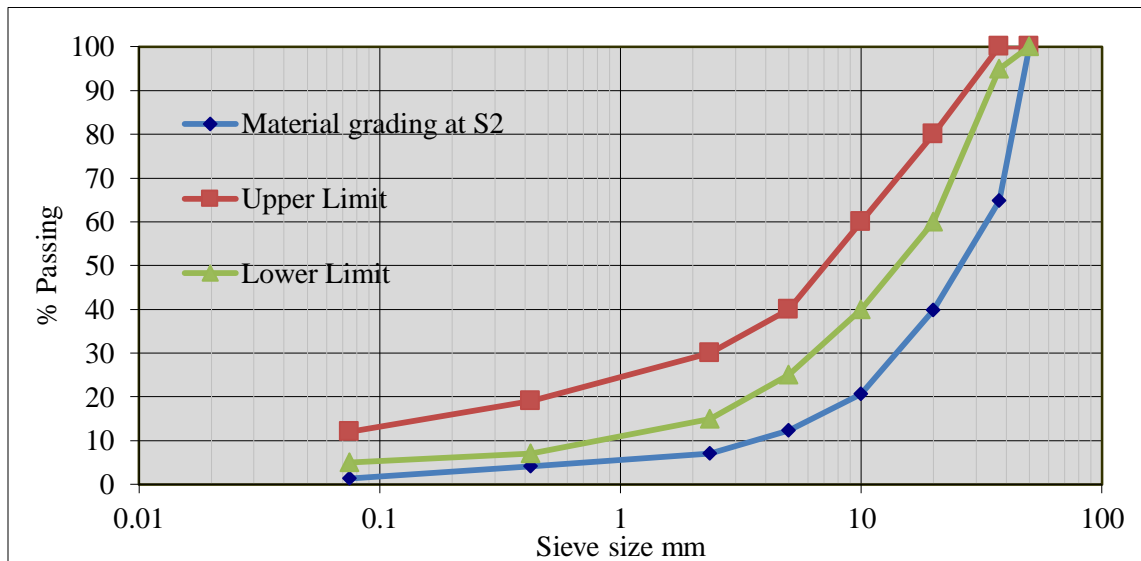Sample designation :-   S1   Date of Sampled :-   12/6/2015

Method of sieving: Dry sieve   Date of Testing :-   20/06/2015

Comparison   with standard

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass	Specification Limit	
					Lower Limit	Upper Limit
50	0	0.0	0	100	100	100
37.5	2275	45.5	45.5	54.5	95	100
20	1335	26.7	72.2	27.8	60	80
10	615	12.3	84.5	15.5	40	60
5	285	5.7	90.2	9.8	25	40
2.36	170	3.4	93.6	6.4	15	30
0.425	114.75	2.3	95.9	4.1	7	19
0.075	134.34	2.7	98.6	1.4	5	12
Pan	70	1.4	100.0	0.0		
Total weight	4999.1					

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Sub base

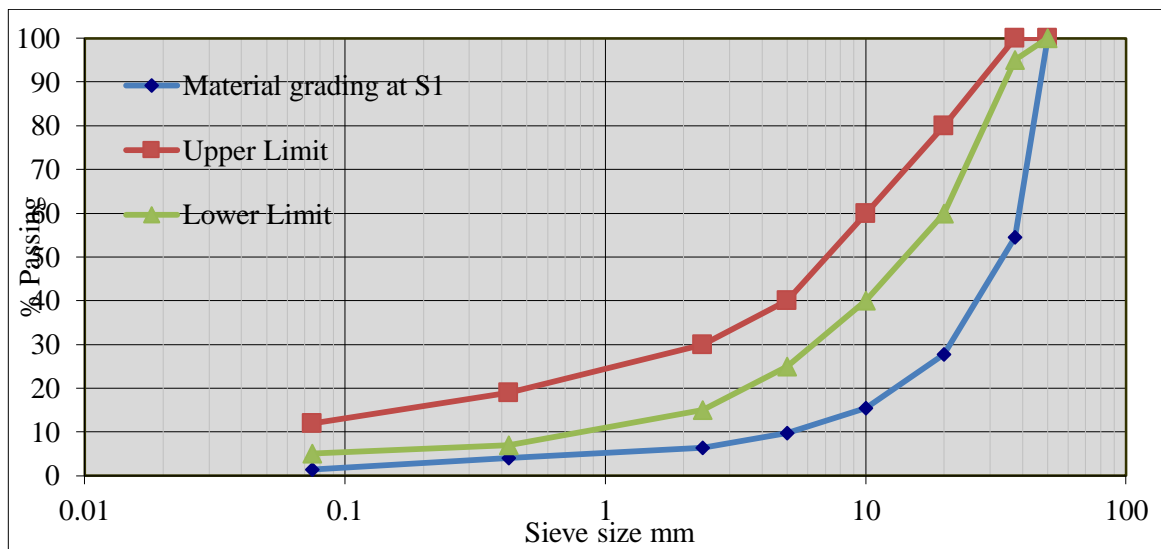Sample designation :- S5   Date of Sampled :-   12/6/2015

Method of sieving: Dry sieve   Date of Testing :-   20/06/2015

Comparison   with standard

Sieve Opening, mm	Wt. Retained, gm	% Retained	Cumulative Retained	% Pass	Specification Limit	
					Lower Limit	Upper Limit
50	0.0	0.0	0.0	100.0	100.0	100.0
37.5	225.0	4.5	4.5	95.5	80	100
20	360.0	7.2	11.7	88.3	60	100
5	1660.0	33.2	44.9	55.1	30	100
1.18	1165.0	23.3	68.2	31.8	17	75
0.3	1120.0	22.4	90.6	9.4	9	50
0.08	340.0	6.8	97.4	2.6	5	25
Pan	130.0	2.6	100.0	0.0		
Total weight	5000.0					

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Sub base
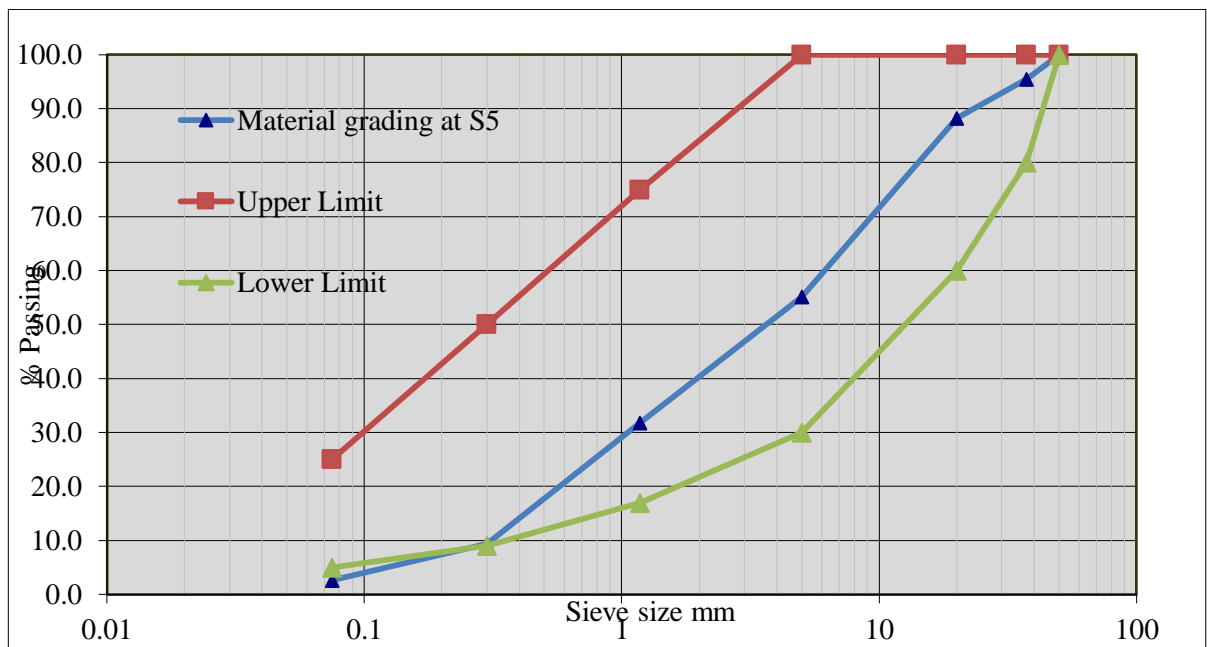
Sample designation :- S9 Date of Sampled :- 12/6/2015

Method of sieving: Dry sieve Date of Testing :- 20/06/2015

Comparison   with standard

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass	Specification Limit	
					Lower Limit	Upper Limit
50	0.0	0.0	0.0	100.0	100.0	100.0
37.5	635.0	12.7	12.7	87.3	80	100
20	1110.0	22.2	34.9	65.1	60	100
5	1174.0	23.5	58.4	41.6	30	100
1.18	764.5	15.3	73.7	26.3	17	75
0.3	830.0	16.6	90.3	9.7	9	50
0.08	335.0	6.7	97.0	3.0	5	25
Pan	150.0	3.0	100.0	0.0		
Total weight	4998.52					

PARTICLE SIZE DISTRBUTION
(AASHTO T-11 /T 27)

Type of Material :- Sub base

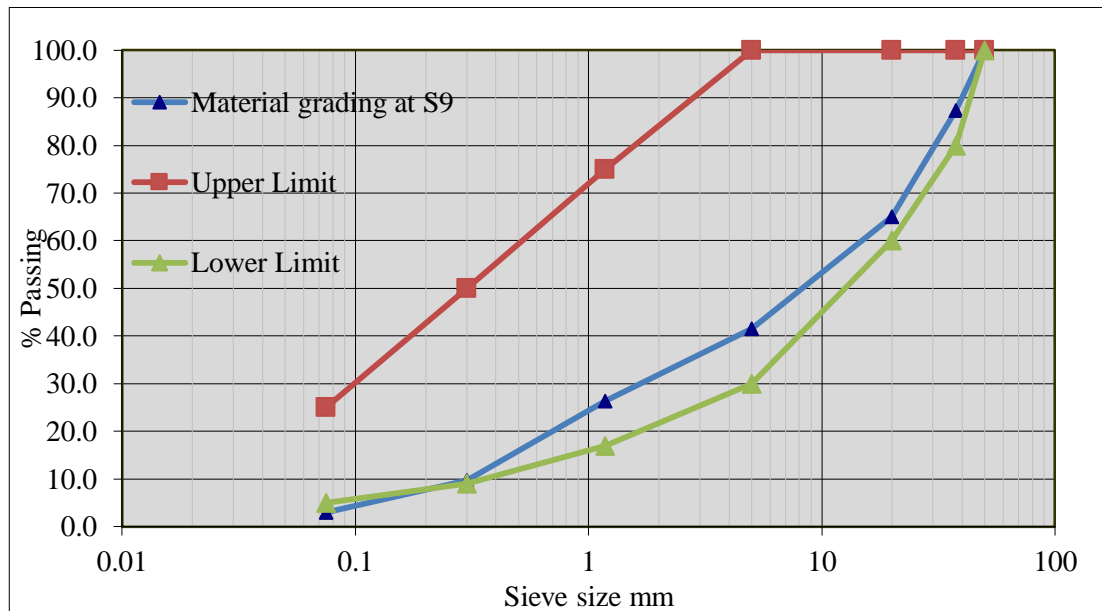Sample designation :-   S1   Date of Sampled :-   12/6/2015

Method of sieving: Dry sieve   Date of Testing :-   20/06/2015

Comparison   with standard

Sieve Opening,mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass	Lower Limit	Upper Limit
50	0.0	0.0	0.0	100.0	100.0	100.0
37.5	2025.0	40.5	40.5	59.5	80	100
20	1259.3	25.2	65.7	34.3	60	100
5	725.0	14.5	80.2	19.8	30	100
1.18	429.6	8.6	88.8	11.2	17	75
0.3	385.0	7.7	96.5	3.5	9	50
0.08	105.0	2.1	98.6	1.4	5	25
Pan	70.0	1.4	100.0	0.0		
Total weight	4998.9					
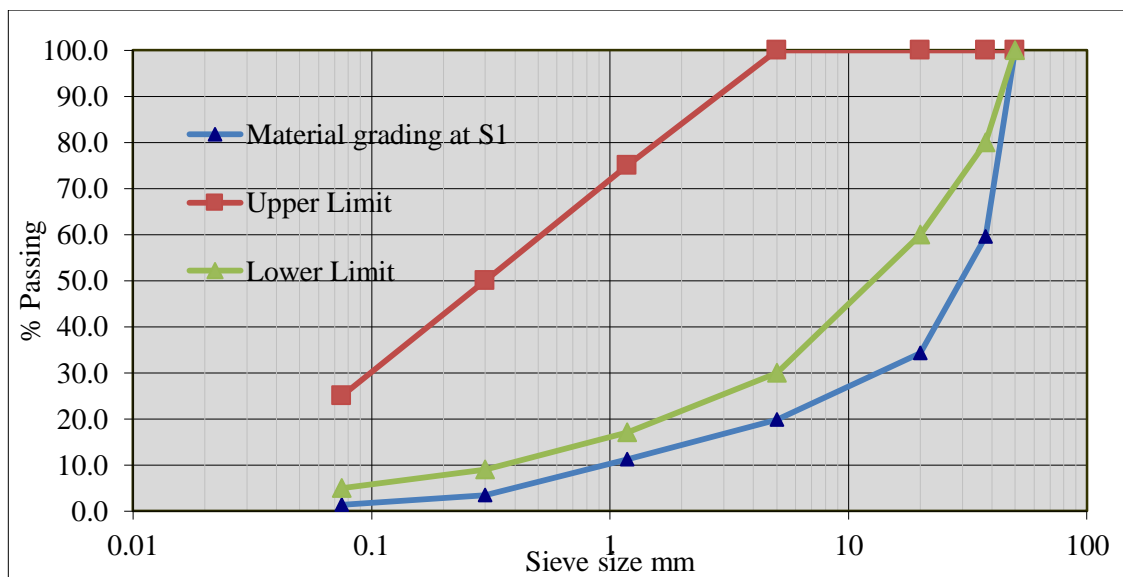
Water content determination record

Soil Sample Type:- Subgrade
Sample designation: S7

Date 6/10/2007

Determination number	1	2
Container number	AL	BN
Weight of container W1 g	67.1	74.5
Weight of container +Weight of wet Soil W2 g	298.4	265
Weight of container + Oven dry soil W3g	247.3	219.4
Weight of water (W2-W3) g	51.1	45.6
Weight of Oven dry soil (W3 -W1) g	180.2	144.9
Water content W=[(W2-W3)/(W3-W1)]*100%	28.3573807	31.4699793
Average Water content % =	28.36	

Soil Smple Type Sub-Base
Sample designation :- S7
Date 6/10/2007

Determination number	1	2
Container number	CK	AG
Weight of container W1 g	68.9	67.9
Weight of container +Weight of wet Soil W2 g	244.2	265.1
Weight of container + Oven dry soil W3g	231.4	248.8
Weight of water (W2-W3) g	12.8	16.3
Weight of Oven dry soil (W3 -W1) g	162.5	180.9
Water content W=[(W2-W3)/(W3-W1)]*100%	7.88	9.01
Average Water content %	8.44	

Soil Sample Type Base Course
Date 6/10/2007
Sample designation :- S7

Determination number	1	2
Container number	AO	AB
Weight of container W1 g	74.8	78.3
Weight of container +Weight of wet Soil W2 g	300.1	285.2
Weight of container + Oven dry soil W3 g	289.3	275.8
Weight of water (W2-W3) g	10.8	9.4
Weight of Oven dry soil (W3 -W1) g	214.5	197.5
Water content W=[(W2-W3)/(W3-W1)]*100%	5.0350	4.76
Average Water content % =	4.9	