JIMMA UNIVERSITY

Institute of Technology

Post Graduate Studies

School of Civil and Environmental Engineering

Department of Civil Engineering

Highway Engineering Stream

Evaluation on Prevailing Pavement Layers Strength using Destructive Test at Distressed Section along Dembi- Bedelle Highway

A Thesis Submitted to The School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Civil Engineering

(Highway Engineering)

By

Boka Olani

November ,2016 G.C

Jimma, Ethiopia

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Advisor: Prof. Emer T. Quezon

Co-Advisor: Eng'r. Bogale Shiferaw (MSc.)

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DECLARATION

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MSc. Thesis
By
Boka Olani Tesso

Approved by the Board of Examiners

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Finally, I am greatly thankful to the Ethiopian Road Authority for their sponsorship of the MSc. program and support during all times with work in partnership course carried out as part of agreements signed with Jimma University.

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ABSTARCT

Pavement distresses are one of the major problems in developing countries and the wide range of problems that occurred on sealed road. While the problems can be occurred on going or after construction of the road has been finished. Broadly speaking, flexible pavement distresses fall into different categories:Cracking,Patching. Surface Deformation, Surface Defects, Potholes and Miscellaneous Distresses. This research study carried out at Ilu-Ababor zone situated within the Western Ethiopia. This place is found in Western Oromia region. Dembi-Bedele highway currently shows pothole, patching, rutting, polished aggregate, cracks and shoving types of distress.

The scope of the research is to determine the type, extent and severity of the pavement distresses and to measure the structural strength of the existing road pavements at distressed sections.

Destructive test method (DCP and Test Pits) were used in the field and laboratory testing tools for the data analysis. Basically, six different data were collected by DCP test and three test pits have been taken. Besides, DCP field data collected were analysed by UK DCP, 3.1 software. From these results,CBR value, pavement layers thickness and structural strength of the pavement were known. Purposive sampling techniques used for DCP test and Test Pits at both distressed and normal section.

Base on the DCP data analysis, thickness ofsurface,base course sub base sub grade layers decreased by 25mm, 31mm, 95mm respectively on (chainage 17+870).Additionally, the CBR values of base course, sub base and sub grade are 78%, 44% and 39% respectively. These results are less than the standard.Besides, at (chainage 25+100) the thickness of pavement surface, base course, sub base and sub grade layers decreased by 10mm, 18mm, 104mm and 47mm respectively.When compared with previous design. The CBR values are 62%, 27% and 21% for base course, sub abse and sub grade respectively.

Keywords:Pavement layers thickness, strength, Destructive test, CBR test, Penetration Index, DCP and Pavement distresses.

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LIST OF ABREVIATION AND ACRONYMS

AASHTOO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BADEA	Arab bank for Economic development in Africa
DCP	Dynamic Cone Penetration Test
NMC	Natural Moisture Content
ERA	Ethiopia Road Authority
CBR	Bearing Capacity Ratio
MDD	Maximum Dry Density
GDP	Growth Domestic Product
ETB	Ethiopian Birr
LL	Liquid Limit
PI	Plastic Index
PL	Plastic Limit
ERCC	Ethiopia Road Construction Corporation
PR	Penetration Rate
DOT	Department of Transportation
UK	United Kingdom
DS1	Design Standard one
AC	Asphalt Concrete
ACP	Asphalt Concrete Pavement
US	United State
DCPI	Dynamic Cone Penetrate Index
AADT	Average Annual Daily Traffic
PP	Plasticity Product
DD	Dry Density
OMC	Optimum Moisture Content
MC	Moisture Content
Log	Logarithm base 10
HIR	Hot in-situ Re-cycle
VTM	Voids in the Total Mix
N/A	Not applicable
N/M	Not measured
SPS	Specific Pavement Study
GB1-GB3	Granular road base

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CHAPTER ONE

INTRODUCTION

1.1 General Background

Pavement distress is the wide ranging of problems that shall be occur as international on flexible pavement.It is one of the hindarace of for serviceability and safety of the roads of the developing countries like Ethiopia.As our country the after highway construction has been copleted. Pavement distress is onather headace for Engineers.This research study carried out at Ilu-Ababor zone situated within the Western Ethiopia. This place is found in Western Oromia region

This highway gives good service for messengers from Nekemte to Jimma. Since the Dembi-Bedele asphalt concrete constructed earlier by the huge amount of cost. But within three years, there isa sign of distresses along the road by unknown causes. Some effects of Dembi to Bedele pavement distresses are: regarding to loss of human life, economical deficiency, social and political impact, and traffic accident.

The construction of Dembi - Bedele road upgrading project is financed by Arab bank for Economic development in Africa (BADEA) 71% and by the government of federal democratic Ethiopia 29%, commenced on 26th June 2006 by MIDROC Construction Ethiopia under the supervision services of PANAFRICAN Consultants in associations with SABA Engineering and GONDWANA consultants who commenced the services effective 23 June 2006. The cost of the construction and construction supervision services are ETB 234,864,490.94 and 3,332,125.00 respectively. The length of the road is 62km.The type of the road is asphalt concrete and Constructed with hot mix asphalt and DS1.The terrain type of the road is flat and rolling. The road alignment crosses two towns: Dembi and Bedele which are under Ilu-Aba Bor zone. This zone is known with cash crops: vegetables, fruits and coffee source: (Contract document of ERA jimma district with contractor)

The research study concerned on Road upgrading Project started at Didesa River Bridge (0+00), which is located about 427 km from Addis, links Dembi, Yembero, Gechi, Bedele and ends at 62+09 km, within Bedele Town. The construction of the road was completed. The location of the study area is fertile soil behavior which is suitable for agricultural products like coffee, other crops and chat.

Simple Methods of Flexible Pavement Evaluation Using Cone Penetrometer (2). Destructive tests require the physical removable damage of pavement layer material to obtain a sample either (disturbed or undisturbed) for laboratory characterization or to conduct an in-situ dynamic cone Penetrometer (DCP) test [2].

Destructive testing ranges from simple tests such as coring (and determining the pavement layer thickness by measuring core lengths) to performing pavement strength and layer thickness of AC cores. Other destructive testing were: Asphalt extraction of hot mix to determine material condition and permanent deformation. Test pits areanother destructive test in order to determine the soil properties and bearing capacity of the materials. It's vital advantages, including the observation of sub-surface conditions of pavement layers and bonding between layers[17].

ASTM-D 6951-3 (2003). Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications.The DCPT test values can be used to estimate the CBR values provided a suitable relationship exists between the CBR and the DCPT value. Development of any such relationship may become a very effective tool for highway engineers. The other benefits of the relationship are the following: (a) It may help enhance highway construction quality control; (b) It may help ensure long-term pavement performance and stability; and (c) It may help achieving more uniform structural property. In the present study DCP tests were conducted along the road after visiting the site. The present study describes a series of DCP tests conducted at in situ conditions and soaked in situ condition. In addition to the above field test, laboratory soaked CBR tests molded at an in - situ density were also carried out. In this research, the results obtained from the tests were presented and discussed.

The DCP tests were conducted according to the procedure laid down in ASTM-D6951-3 (2003). The apparatus consists of 16mm diameter steel rod in which a tempered steel cone with a 20 mm base diameter and a 60 degree point angle is attached.

The DCP is driven into the soil by an 8kg hammer with a free fall of 575mm. The hammer correction factor is unity for 8kg hammer. Figure1 shows the dimensions of the dynamic cone Penetrometer. The DCP index or reading is defined as the penetration depth (D) in mm for a single drop of a hammer. The cone is driven into the ground up to the desired depth and average DCP index is calculated for a single blow. Depth of penetration considered in the study was 800mm because the stresses induced due to the wheel load become negligible beyond this depth. Dynamic Cone Penetrometer and field and laboratory testsoffollowing tests were conducted during the course of this study: Sieve analysis Atterberg limit test, Modified Procter compaction test, DCP test (In situ) and Laboratory CBR test (Soaked condition) [14].

Highway pavement condition deteriorates with time due to one or more of the following factors: Natural impact, design inadequacies, traffic growth, material ageing, Poor management, construction decencies, and environmental conditions, etc.

So that,thesis carried out at this area. Because of rapid and versatile, destructive test (DCP test and Pit test) selected to evaluate the strength of pavement layers at the distressed pavement. The DCP, also known as the Scala Penetrometer was developed in 1956 in South Africa as an in situ pavement evaluation technique for evaluating pavement layer strength (Scala, 1956.) Since, this device has been extensively used in South Africa, the United Kingdom, the United States, Australia, and many other countries. Because of its portability, simplicity, cost effectiveness and the ability to provide rapid measurement of in situ strength of pavement layers and sub grades. Operating the DCP can be physically arduous and the collection and analysis of the data time consuming.

Finally, based on the results, some recommendations justified to report ERA Maintenance road and to give the solution that enables to minimize the adverse impact of pavement distresses.

1.2 Statement of the Problem

Roads are constructed to perform a service to the road user. As international,pavement distress isa wide range of problem. Pavement distress has an impact on social, economical, political and on GDP growth of the wide country.Economical deficiency, environmental suitability, educational, social impact; traffic accident is the major effects of pavement damage It is the core hamper of the Developing countries like Ethiopia. As the expansion of road construction of the country has been increased. But the problem of pavement deterioration also simultaneously increased

Dembi-Bedele road is one of the highway roads where upgrading works had been completed three years ago. Nevertheless, theroad is showingsignsof distressesat somelocationsalong the road sections.

To evaluate the pavement layers strengthof existing asphalt concrete is affordable for pavement distresses. Therefore, the thesis focuses to evaluate the strength of pavement layers atDembi-Bedele existing road and to identify and recommend best practices in handling destructive test

1.3 Research Questions

The main research questions included the following:

1. What are the different types, extent and severity of pavement distresses along Dembi-Bedele highway?
2. What are the strength properties of the existing road pavements at distress sections using Destructive method (Test pits and DCP)?
3. How much deviation of the strength of existing pavement layers with the ERA Standard Specifications?
4. What remedial measures need to be taken to improve the problems?

1.4 Objective

1.4.1 General Objective

The main objective of this research is to evaluate the strength of pavement layers at the prevailing pavement distressed of Dembi -Bedele using Destructive Test.

1.4.2 Specific Objectives

1. To undertake preliminary condition survey along the road in order to determine the type, extent and severity of the pavement distresses.
2. To measure the structural strength of the existing road pavements at distressed sections using Dynamic Cone Penetrometer.
3. To check conformity/compliance of Engineering Properties and strength the Pavement materials.
4. To propose remedial measures for the distressed pavement sections.

1.5 Significance of Study

Therefore, the significance of the study stated as follows:

- It will help for any road maintenance Department to have a strength plan in order to solve the problem
- It will contribute practical knowledge to evaluate pavement distresses in the Ethiopia
- It also helps to undertake further research to refine the conceptual and methodology of the DCP test

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The basic design of the DCP has been relatively unchanged since its inception in the 1950. The mass of the falling weight has been altered several times. The cone tip has also undergone numerous revisions to its basic design. More recently, the automated dynamic cone Penetrometer has been suggested to automate the operation, data collection and analysis procedures[22].

This section covers asphalt concrete-surfaced pavements (ACP) pavements. Each of the distresses has been grouped into one of the following categories: Cracking, Patching and Potholes, Surface Deformation, Surface Defects Miscellaneous Distresses. US Department of Transportation Federal Highway Administration Grouped pavement distress in severity levels

The development of DCP was in response to the need for a simple and rapid device for the characterization of sub-grade soils (Melzer and Smoltczyk, 1982; Mc Grath, 1989; McGrath, et al., 1989; and Mitchell, 1988). In the last few years, some DOT is as well as other organizations have shown considerable interests in the use of the DCP for several reasons (De Beer and Vander Merwe, 1991. First, the DCP is adaptable to many types of evaluations. Second, there are no currently available rapid evaluation techniques. Third, the DCP testing is economical. As shown in Figure 2.1, DCP Test result consists of number of blow counts ever versus penetration depth. Since the recorded blow counts are cumulative values, results of DCPT in general are given as in incremental values defined as follows

$$PI = \frac{\Delta DP}{\Delta ABC} \quad \text{...(2.1)}$$

Where PI = DCPpenetration index in units of length divided by blow count;ΔDp = penetration depth, BC = blow countscorrespondingtopenetrationdepth ΔDp.As a result, the values of the penetration index (PI) represent DCPTcharacteristics at certain depths.

The function with in UK DCP 3.1 compares the strength and thickness of the existing pavement with a pavement using layers of the existing pavement as layers in the proposed pavement. If material in the existing pavement is to be used as a base or sub-base in the proposed new pavement, it is recommended that soaked CBR tests are carried out to accurately determine its strength[13].

The DCP results, when plotted, describes the number of blows to reach a certain depth affording an instantaneous visual illustration of in-situ material strength (Fig 2.3). The slope of the curve at any point expressed in terms of mm/blow is called the dynamic cone penetration index (DCPI) which represents the resistance offered by the material. The lower the DCPI the stiffer the material, and vice versa. As a result, the values of the penetration index (PI) represent DCPT characteristics at certain depths [4].

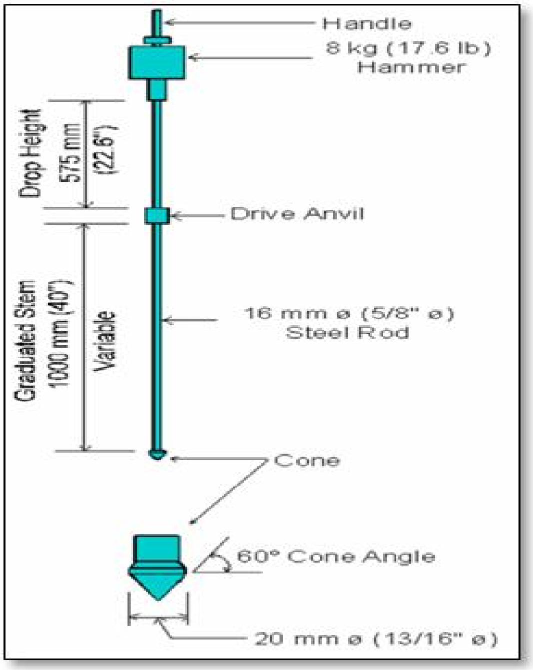


Figure 2. 1 DCP Instrument

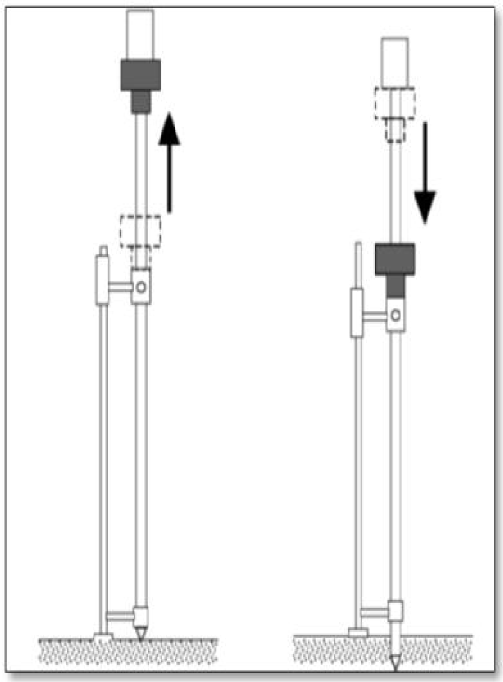


Figure 2. 2 Before and after hammer dropping

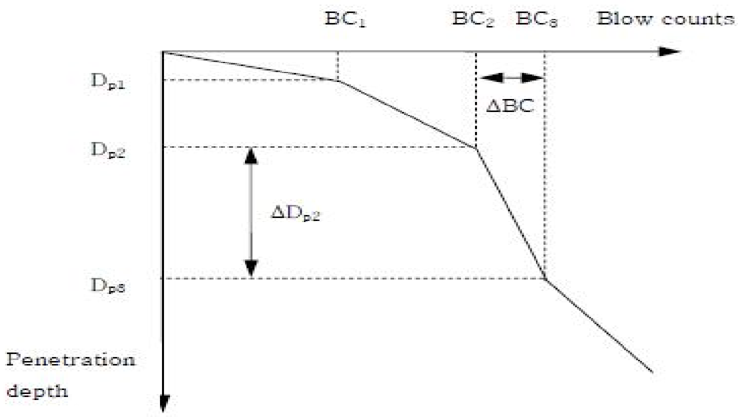


Figure 2. 3 Penetration depth vs. Number of blows

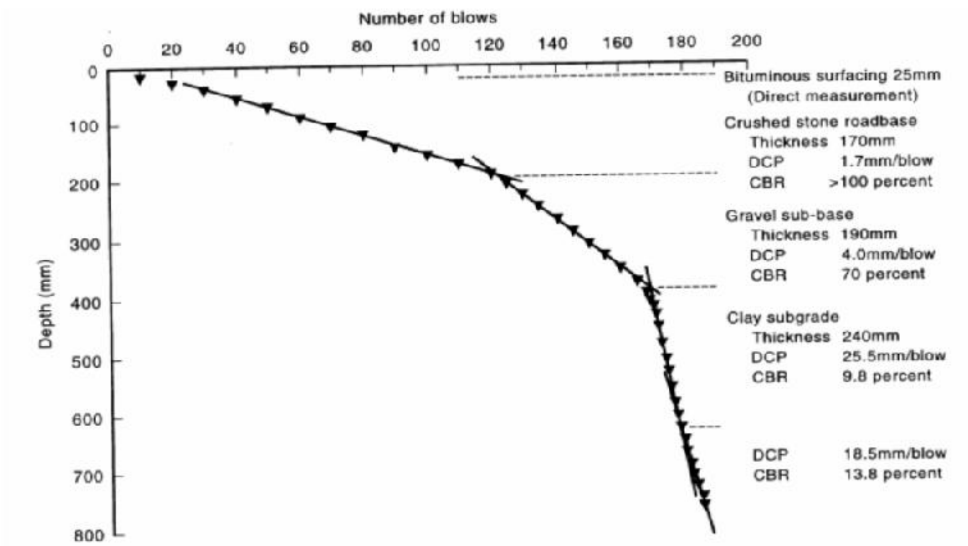


Figure 2. 4 DCP Test result vs. CBR

(Source: ERA Manual 2002, Volume I, Fig. C-3)

2.2 In situ CBR Test

This test method used for the determination of the CBR ratio of soiltested in place by comparing the penetration load of the soil to that of a standard material. Field in-place tests are used to determine the relative strength of soils, sub base and some base materials in the condition in which they exist at the time of testing.Such results have direct application in test section work and in some expedient construction. From the tests, the Atterberglimits (PI, LL, PL), Insitu density, classification (sieve analysis in situ Moisture Content

$$CBR = \frac{\text{unit Load } \frac{\text{for } 2.54}{5.08\text{ mm}} \text{ Penetration in the test specimen}}{\text{Unit Load } \frac{\text{for } 2.54}{5.08\text{ mm}} \text{penetration in standard crushed rocks}} x100 \qquad 2.6$$

From the above equation, it could be seen that the CBR number is a percentage of the standard unit load. CBR values is then determined by reading from the curve the load that causes a penetration of 2.54 mm and 5.08 mm and dividing these values by the standard load.Generally the CBR value at 2.54 mm will be greater that at 5.08 mm and in such a case the former shall be taken as CBR for design purpose. If CBR for 5.08mm exceeds that for 2.54mm, the test should be repeated. If identical results follow, the CBR corresponding to 5.08 mm penetration should be taken for design[9].

Table 2. 1 Pavement Distress and Severity Levels

Distress Types	Unit of measure	Severity Levels	High	Medium	Low
A. Cracking, 1. Fatigue cracking	m/mm	Yes			
2. The block is cracking	m /m^2	Yes	Width>19mm	W idth>6mm	Width ≤6m
3. Edge cracking	m/mm	Yes			
4a. Wheel path longitudinal cracking	m/mm	Yes			
4b.Non-Wheel path Longitudinal Cracking	m/mm	Yes			
B. Transverse Reflection Cracking					
1. Longitudinal Reflection Cracking	N/M	N/A			
2. Transverse Cracking	N/M	N/A			
B. Patching /Potholes					
7. Patch deterioration	No, m/mm	Yes	>12m	6-12m	<6m
8. Potholes	No/mm/m2	Yes	>50mm deep	25-50mm deep	>25mm deep
C. Surface Deformation					
9. Rutting	M	No	-	-	-
10. Shoving	No, m2	No	-	-	-
11.Bleeding	m2	No	-	-	-
12.Polished Aggregate	m2	No	-	-	-
13.Raveling	m2	No	-	-	-
E. Miscellaneous Defects					
14.Lane shoulder Drop off	N/M	N/A	-	-	-
15.water bleeding and Pumping	Noah, m	No	-	-	-

(Source: Republic of Botswana Road Department, Ministry of works Transport and Communication)

2.3 Types of Pavement Distresses and Severity Levels

Block cracks

Rectangular blocks range in size from approximately 0.1m2 to 10 m2.

Severity Levels

Low Cracks with a mean width ≤ 6 millimeters (mm); or sealed cracks with sealant material in good condition and with a width that cannot be determined.

Moderate: Cracks with a mean width > 6 mm and ≤ 19 mm or any crack with a mean width≤19mm and adjacent low severity random cracking.

High: Cracks with a mean width > 19 mm; or any crack with a mean width ≤ 19 mm and adjacent moderate to high severity random cracking. But on this study,the measured block crack was irrigular shape.

How to Measure: Record square meters of affected area at each severity level. If fatigue cracking exists within the block cracking area, the area of block cracking is reduced by the area of fatigue cracking. An occurrence should be at least 15 m long before rating as block cracking[11].

B. Patching and Potholes

Severity Levels

Low: Patch has, at the most low severity distress of any type, including rutting < 6mm; pumping is not evident

Moderate: Patch has moderate severity distress of any type or rutting from 6 mm to 12 mm; pumping is not evident.

High: Patch has highest severity distress of any type, including rutting > 12mm, or the patch has additional different patches and square meters of affected surface area at each severity level. Note: Any distressed in the boundary of the patch included in rating the patch. Rutting (settlement) may be at the perimeter or interior of the patch [11].

Table 2. 2 Severity Level for Patch

Severity levels	Standard Depth (mm) /m^2		Exist on Station
Low	< 6mm deep	Pumping was not evident	-
Moderate	6mm-12 mm	Pumping was not evident	-
High	patching> 12 mm	Pumping was evident	

Table 2. 3 Distress types and Severity levels

Distress Types	Unit of measure (Number, m^2)	Defined severity levels (Yes or No)
1. Fatigue Cracking	Number,m^2	Yes
2. Block Cracking	Number,m^2	Yes
3. Edge Cracking	-	No
4. Longitudinal Cracking	-	No
5. Reflection Cracking at Joints	-	No
6. Transverse Cracking	m	Yes
7. Potholes	m (depth) or m^2	Yes

Potholes: This most of the Dembi Bedelle pavement distresses are potholes**.** Shaped holes of various sizes in the pavement surface. The minimum plan dimension is 150 mm

How to Measure: -By Recording number of potholes and square meters of affected area at each severity level. Pothole depth is the maximum depth below pavement surface. If pothole Occurs within an area of fatigue cracking the area of fatigue cracking is reduced by the area of the pothole

Surface Deformation

Rutting

Severity Levels: Not applicable. Severity levels could be defined by categorizing the measurements taken.

A record of the measurements taken is much more desirable, because it is more accurate and repeatable than severity levels. How to measure Specific pavement studies (SPS) only by recording the maximum rut depth to the nearest millimeter, at 15.25m intervals for each wheel path, as measured with a 1.2m straight edge. Travers profile is measured with a measuring rod profile at 15.25m intervals [18].

Shoving

Severity Levels: Not applicable. However, severity levels defined by the relative effect of shoving on ride quality.

How to Measure: Record number of occurrences and square meters of affected surface area.

Surface Defects

Bleeding

Severity Levels: Not applicable. The presence of bleeding indicates a potent mixture related performance problems. Extent is sufficient to monitor any progression.

How to Measure: Record square meters of surface area affected. Note: Preventative maintenance treatments (slurry seals, chip seals, fog seals, etc.) sometimes exhibit bleeding characteristics.

Polished Aggregate

Severity Levels: Not applicable. However, the degree of polishing may be reflected in a reduction of surface friction. This surface defect occurred at some chain age

How to Measure: Record square meters of affected surface area. Polished aggregate should not rated on test sections that have received a preventive maintenance treatment that has covered the original pavement surface.

Table 2. 4 Assigned CBR rating

Type	Design CBR	Pavement layer	CBR value	Degree
Graded, crushed aggregate,	100	Materials	>80	Excellent
Water bound macadam	100	Sub base	50-80	Very Good
Bituminous base course, hot mix	100	Sub base	30 -50	Good
Lime rock	100	Sub grade	20-30	Very good
Bituminous macadam, *Stabilized aggregate (mechanically)	80	Sub grade	10-20	Fair
Soil cement	80	Sub grade	5-10	Poor- fair

(Source: ERA Site Investigation Manual - 2002 Laboratory Testing)

Clay soils have a CBR value of 6 or less. Silty and sandy soils are next, with CBR values of 6 to 8. The best soils for road-building purpose are sands and gravels whose CBR values normally exceed 10 [8].

Sub base: Min for every 2500 m^3 or fraction California Bearing Ratio Test (CBR) is required as (AASHTO T 180-D) described. Minimum CBR value for sub base is 25%

For crushed aggregate base course

Laboratory Compaction test Soaked CBR value ≥ 80% AASHTO –T193 and field Density ≥ 100% of maximum.

Table 2. 5 Crushed stone Aggregate Recommended for Base course

Test sieve (mm)	Percentage of total aggregate passing sieve		
	Maximum particle size		
	37.5mm	28mm	20mm
50	100	-	-
37.5	95-100	100	-
28	-	-	100
20	60-80	70-85	90-100
10	40-60	50-65	60-75
1	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

Table 2. 6 Recommends Particle size for Sub-base Materials

Test sieve (mm)	Passing test of total aggregate percentage
50	100
37.5	80-100
20	60-100
5	30-100
1.18	17-75
0.3	9-50
	5-35

Source: ERA 2002 Table 6.5 (GS)

-Sub base: Plasticity index <25 and CBR (%) >30

2.4 Compaction Test

Equipment requirement

1. Mold with removable and base
2. Hammer
3. Balance
4. Large mixing pan
5. Drying oven
6. Moisture content cans
7. Sample extruder (optimal)
8. Mortar and rubber tipped pestle

Figure 2. 5 Compaction moulds

Sample preparation: Expose the soil sample to the air until it is dried thoroughly. And pulverize it using a mortar and rubber tipped pestle.

Computation: Calculate the moisture content anddry density for each compacted specimen as below Moisture content $w = ({}^{WW}/w's)$ X 100Where,

w_w= Weight of water.

w_s= Weight of dry soil.

w_{et} = Wet unit weight of the soil

γ_{dry}= Dry unit weight of the soil

w_t =Water content

$$¥_{dry} = \frac{¥_{wet}}{1 + w_t}$$

From the data obtained plot dry density versus moisture content. Obtain the peak value of dry density (maximum dry density) and the corresponding value is the 'optimum moisture content'. Also draw a curve termed the 100% saturation curve (zero air void curve) on this plot.**Sub grade layer**

Should not be less than 98% of the density of the laboratory compacted specimen

Aggregate Sub base :-For every1500m3orfractiononeLaboratorycompactiontestisrequired and for every layer of 150mm of compacted depth/based on the results of compaction trials. At least one group of three in-situ density tests for each 500 m^2 or fractionhereand Compaction of each layer field density of at least 100% [14].

Aggregate base course :-Laboratory Compaction Test soaked CBR value ≥ 80% AASHTO –T193and field Density ≥ 100% of max.Dry density –AASHTO T180, Dfor every layer of 150mm of compacted depth based on the results of compaction trials

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

Pavement distress has impact on pavement strength currently on construction progress and at the coplited work.Decrease the pavement load supporting characteristics,loss of base course,sub baseor sub grade support.Poor drainage resulting in a less stiff base.Sripping on the bottom of the hot mix asphalt layer(the sripped portion contributes little to pavement strength so the effective hot mix asphalt thickness decreases) increasing in load.There are some types of pavement distresses. Potholes,small,bowl-shaped depressions in the pavement surface that penetrate all the way through the hot mix asphalt layer down to base course [21].

Summary of the literature review was presented in Chapter two. Following this, several laboratory tests and field tests on Dembi to Bedelle existing pavement conducted. TheAtterberg limits (PI, LL, PL), Maximum dry density,Optimum moisture content, California bearing ratio,Compaction, Extraction testand Dynamic cone penetration results were acquired. Thus, the collected DCP data for the analysis wasinserted into DCP UK.3.1 software and CBR values of pavement layers calculated automatically. Finally, Conclusions and recommendations made.

The research conducted first by identification of the pavement distresses through Destructive test results on selected prevailing pavement. Data processing and analysis, both descriptive and statistics used in the data analysis. Taking samples for test pits, ERA uses the interval of 250m or 500m by shifting DCP test and in situ test. For this research study, nine samples have been taken. Stations were used to identify the area of data collected.Six samples were taken for DCP test. These road sections were selected by priliminarys tudy to identifiy where the section was damaged and approximately normal to the other.Purposive data collection techniques used for DCP test at distressed and normal test pits. The sample sites decided by pliminary survey. Also, where the highly affected area were sellected for data collection. The depth of penetration was vary within pavement condition. For tet pits,the bore hole depth is 800mm.

These areas were selected by considering the road safety and challenges would be faced. In two sections, the sample was taken at distressed section, which didn't difficult to excavate. For atterberg limit sub grade and sub base soil materials tasted. Each proctor test required 6kg of materials and also CBR. Totally about 200kg of sample collected for test pits. Additionally, Extraction test was done in order to know the amount of bitumen in exsting pavement.

3.1.1 Study Area

The location of study area is located southwest part of Ethiopia, in Oromia regional State, The location of the study area is fertile soil behavior which is suitable for agricultural products like coffee, other crops and chat.With in three years, this highway shows sign of distresses. So that,this area was sellected.The Highway totally located traversing through three Wereda's namely Dembi, Gechi and Bedele Wereda. The road section coverage of these words is shown in the table below

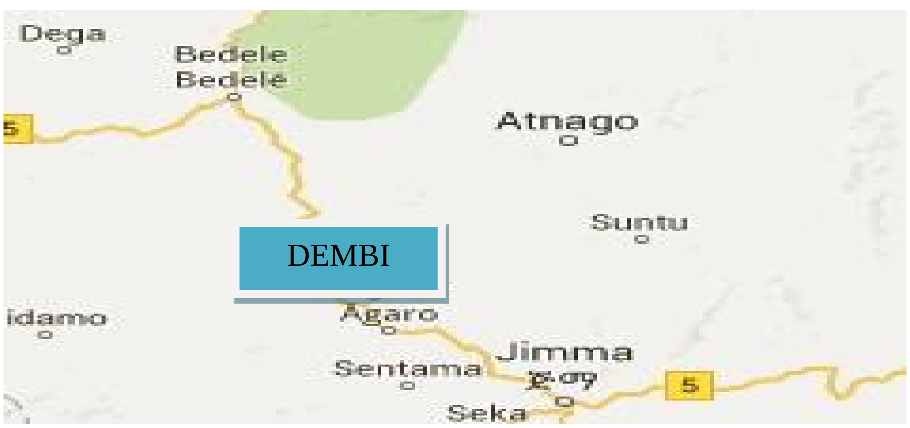


Figure 3. 1 Map of Study Area

This section covers asphalt concrete-surfaced pavements (ACP) pavements. Each of the distresses has been grouped into one of the following categories: Cracking, Patching and Potholes, Surface Deformation, Surface defects Miscellaneous Distresses. US Department of Transportation, Federal Highway Administration Grouped pavement distress in severity levels.

3.1.2 Topography

The route traverses Rolling to mountainous terrain at elevations ranging from 1489 at Didesa River to 2278 at mean sea level. The table below shows the topographic configuration section, as per design document of previous.

Table 3. 1 Terrain Categories of the Route

Number	Section from/to	Terrain Type	Number	Section from/to	Terrain
1	0+000 to 10+900	Mountainous	11	15+560 to 16+040	Mountainous
2	6+920 to 10+380	Flat	12	16+060 to 18+640	Rolling
3	10+400 to 11+160	Rolling	13	18+660 to 32+140	Flat
4	11+180 to 12+240	Flat	14	32+160 to 32+980	Rolling
5	12+260 to 12+760	Mountainous	15	33+000 to 35+380	Rolling
6	12+780 to 12+980	Flat	16	35+400 to 35+640	Rolling
7	13+000 to 15+060	Mountainous	17	35+660 to 36+840	Flat
8	15+080 to 15+140	Rolling	18	36+860 to 38+940	Rolling
9	15+160 to 15+380	Flat	19	38+960 to 62+120	Flat
10	15+400 to 15+540	Rolling			

(Source: Geometric Design voulme 2,Report number, 49,2010)

Most of the study area of the route is Rolling and Flat terrain type. From two major train types rolling is the dominant one is flat. Rolling 36.7%, Mountainous 26.6% and Flat 36.7% from a percentage. Flat and rolling are the dominant one. The road, cross section of flat train type were caused by drainage problem

3.1.3 Traffic Data

Table 3. 2 Composition of Traffic Flow on Major Roads and AADT in 2008 G.C

Road Section	Length (Km)	Surface Type	AADT	Cars	%	Bus	%	Trucks	%	T& T	%
Jimma- Agaro	44	A	952	143	15	466	49	306	32	37	4
Agaro-Bedele	93	A	563	64	11	191	34	270	48	38	7
Comparison on 2010 and 2011 Average Vehicle Kilometer by Road section											
Road Section	Length	Surface	2010	2011	%						
Jimma- Agaro	44	A	40,524	41,888	3						
Agaro-Bedele	93	A	44,454	52,359	18						

Source:(Document volume 1,Monthly progress Report Number,50,November,2010)
T/T-Truck Trail

Traffic volume from Agaro Bedele was higher than Jimma Agaro in 2010 and 2011 traffic volume increase AADT increase. Unless and otherwise the pavement design didn't match with traffic volume

Table 3. 3 Road vehicle count sheet. Location Bedele East Direction Agaro

Date	Car	L/Lovel	S/Bus	L/Bus	S/Truck	M/Truck	H/Truck	T/Truck	Total
01/11/15	3	182	220	4338	89	39	38	27	64.1
02/11/15	2	196	250	34	99	67	34	32	71.8
03/11/15	4	195	254	9	102	61	30	28	708
03/11/15	-	53	54	19	77	21	11	4	229
04/11/15	5	169	236	23	93	123	45	41	731
05/11/15	3	146	207	6	85	101	32	26	623
05/11/15	-	41	40	18	105	29	19	19	259
06/11/15	1	155	181	31	129	78	46	39	647
07/07/15	2	176	225	221	45	46	25	19	569
Total	20	1313	1667	221	824	565	280	235	5125
Date	Car	L/Lovel	S/Bus	L/Bus	S/Truck	M/Truck	H/Truck	T/Truck	Total
01/07/16	22	186	349	32	183	241	214	42	1269
01/07/16	6	100	100	2	53	111	123	11	506
02/07/16	8	252	358	22	147	236	281	22	1326
03/07/16	16	245	309	38	125	280	279	21	1213
04/07/16	2	168	324	26	66	156	200	39	981
05/07/16	-	184	269	19	81	110	155	18	836
06/07/16	-	33	8	-	32	67	76	9	225
06/07/16	4	147	961	28	76	88	126	21	651
07/07/16	4	153	235	15	101	93	172	30	303
Total	622	1468	2113	182	864	1282	1626	213	7810

Table 3. 4 Future Traffic volume of Dembi-Bedele Highway

Section/Year	AADT Vehicle Per day			
	1997	2002	2012	2021
Dembi-Bedele (without diversion)	131	179	339	529
Dembi-Bedele (with diversion)	131	135	255	397

Source: Traffic data (Document volume 1,Monthly Progress Report Number,50)

Taking the base year traffic (AADT) and Annual growth rates were discussed atabove table and the traffic on the road section in the futureis computed and given below. This data was taken from the engineering report of the Pan African Consultants in Associate with Saba Engineering and Gondwana Consultants which is reported to ERA for the sake of Dembi Bedele road distress.

3.1.4 Study Design

The data were analyzed and interpreted using both descriptive and analytical methods approaches. Both field test and laboratory test were incorporated

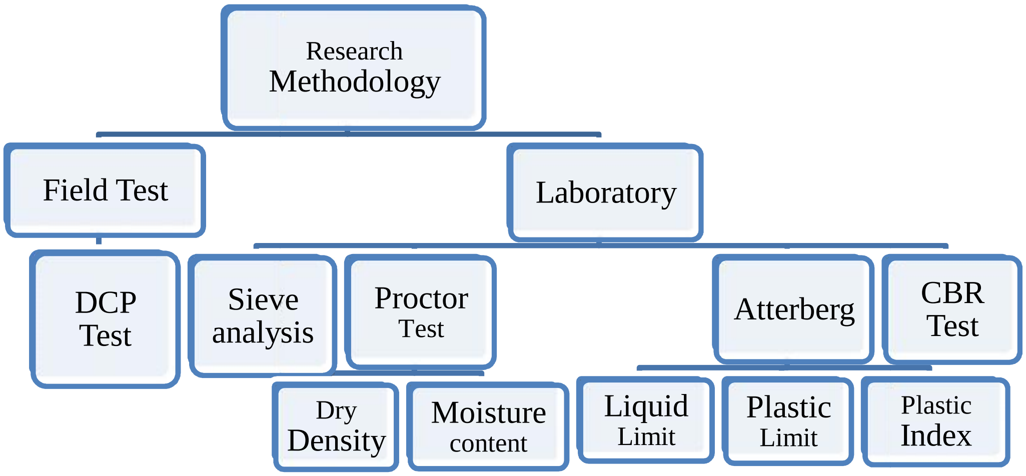


Figure 3. 2 Study Design

3.1.5 Population

The population for this research, pavement layers strength:Wearing course, Base course, Sub base, Sub grade layer strength.Samples were collected by using DCP and Test pits.

3.2 Data Collection

Data were collected both from field for software input and laboratory anlysis

3.2.1 Source of Data

Adequate data are important for carrying out the required analyses in order to achieve the objectives of this research study. The data for the study were collected by conducting field and laboratory tests in Dembi-Bedele prevailing highway from km 9+150 to km 51+300 from Jimma town along the road.Dembi-Bedele road upgrading is located in the south west part of Ethiopia, in Oromia regional State, along the main road connecting Addis -Jimma Metu.Two major sources of data are primary and secondary data

3.2.2 Primary Data

Primary data’s are those data’s directly collected from sites such as in-situ (DCP) tests and Test pits. The output of laboratory tests and interview about the pavement road details.

Primary data's were as the following:-
Field survey-to identify pavement distress and measuring the severity of the distressed section.

Laboratory Test-Inorder to find the CBR,Compaction, PI and amount of bitumen

Field Test-For the sake of pavement thickness

3.2.3 Secondary Data

Office document review: -Contract document, Take off sheet, Cross-section, Traffic data were collected.

3.3 Data Collection Techniques

Purposive sampling techniques used for DCP test and Test Pits.The depth of penetration was vary within pavement condition. Furthermore, at normal section, penetration depth was maximum than at distressed section.

3.3.1 DCP Test

This test method was used in the field test. The sample was taken according to the limited coverage area of the selected at pavement distresses sections. Considering depth, Interval and number of DCP tests**;** The DCP survey carried out up to a depth of 800 mm, the so-called material depth of the pavement.
It is recommended that DCP testing carried out at 200 m intervals with additional testing in someobvious problematic areas (wet and cracked). In relatively uniform areas, testing at up to 500 m intervals accepted. In general a minimum of about 10 tests per uniform section carried out. In this thesis, the distressed section of pavement could not measured by interval. Because of its variable distance with each other. Date collection was collected at distressed section. Therefore, it was not considered the interval.
Testing stopped when penetration depth reached one meter more upon refusal. The original plan includes collecting disturbed soil samples to establish the DCP/PRrelationship. The depth of the uniform layer recorded by tube sample taken at the center of the road and at right and left direction where the pavement damaged totally.

The Penetration rates as low as 0.5mm/blowis acceptable, but there was no measurable penetration after 20 consecutive blows, it could assume that the DCP couldn't penetrate the material. Data were acquired by conducting field and laboratory test.These tests were done on all pavement layers and six DCP tests were conducted at different locations from station 17+870, 25+00, 24+900, 24+990, 17+600 and 25+100. The moisture conditions at the time of the DCP survey need to be carefully estimated. As the moisture content at the time of testing determines the in situ strength at that time, this needs tocarefully assess and preferably supported by laboratory determinations of the moisture content.

3.4.1 Test pits

In order to minimize the moisture condition of the materials and Test pits used to find co-relation of CBR and DCP test. Although required for the objective of the result. To know the pavement strength,CBR laboratory and compaction was compulsory for this study. This data was collected at distressed and normal pavement condition. Digging the normal pavement is one of the challengesof this technique. About 0.8m hole was excavated even if to get the sub grade materials. But at distressed section nomore challenge was faced. About 200kg soil data were collected for CBR soaked, Compaction, Atterberg Limits of soil properties and also 20kg asphalt sample were collected for Extraction test conducted by remolding the samples at in situ moisture content and density were obtained from the laboratory tests.

The field (in situ) data collected comprises of Dynamic Cone Penetration tests. In order to avoid the seasonal variations of the soil properties due to rainfall and other factors, both the laboratory and field tests were conducted in the same period, during the month of July,2016.

3.4.2 Study Variables

The variables that the core ofthe study of this research were divided into two types.
Dependent variables and Independent variables.

Dependent variables

-Strength of pavement layers

Independent variable

Wearing course, Base course, Sub base and Sub grade

3.4.3 Tools (Equipment)

By Considering Destructive test (DCP test and Test pits) method systems laboratory tools Whererequired.

-IS Sieve sizes ASTM

-Cylindrical Metal Mold

-DCP Test

-Pan, Spoon, Spatula, Dish, Bottle, Oven Dry, can, jar, Ruler, meter, ax, bag

-CBR machine, molds (modified), balance, oven dry

3.4.4 Ethical Consideration

The research and field test data sample was conducted after approval given from the civil engineering department and ERA to proceed the work. Before the DCP field test the purpose of the extractor sample was clearly described to the organizations by the sample taking and the principal investigator. The sample collected based on the willingness of the organizations to give information. The sample taken would keep confidential and used only for the research purpose.

3.4.5 Data quality Assurance

In order to increase the quality of the data, this study prepared a field and laboratory work manually to check progress every day. Starting from sample collection to the laboratory work good, caring was taken until the result approved by advisors and researcher.

3.5.1Liquid Limit Test

Objective: - to determine the liquid limit of a soil

Apparatus:- Mixing (Evaporating dish) about 114 mm diameter, spatula or peal knife having blade about 76mm length and 19mm width, motorized liquid limit device, Grooving tool moisture can (container), Balance sensitive to 0.01 gm pan (small), Drying oven gradation measuring cylinder 10-50ml.

Sample preparation: -The soil sample as received sufficient from a sample taken from the thoroughly mixed portion of the of material passing the No. 40 (0.425mm) sieve which has been obtained inaccordance with the standard method of preparing a disturbed soil sample or the standard method of wet preparation of disturbed soil sample for test**.**

Dry preparation: **-** Allow the sample in air to dry at room temperature or in an oven at a temperature not exceeding 60^{o}c. Break down aggregations of particles in a mortar using a rubber pestle, but avoid crushing individual particles place in the cue or dish a sample weighing about more than 100gm.

Figure 3. 3 Drying sample

Figure 3. 4 Gradation 2nd step

Figure 3. 5 Sieving 3rd step

Figure 3. 6 Soaking for Liquid limit 4th step

Figure 3. 7 Preparing material for LL, PL 5thstep

3.5.2 Plastic Limit Test

Objective: to determine the plastic limit of soil

Apparatus: Glass plate reserved for roving of threads, palette knife, or spatula, A short length 100mm length 3mm diameter of metal rod, standard moisture content apparatus.

Sample preparation: If the plastic limit analysis required to take a required/quantity of soil weighing about 30-50gm from the thoroughly mixed portion of the material passing No 40 (0.425mn) sieve

Test procedure:

Figure 3. 8 Rolling sample for Plastic Limit

Figure 3. 9 Soaking materials for plastic limit and Plastic index

3.5.3 California Bearing Ratio (CBR)

This test carried out in accordance with AASHTO T 193.Material in the specimens retained on the 19 mm sieve and Assigned CBR rating for base course,sub base and sub grade material.

Objective: - to determine the strength of soil. The strength of a sub grade, sub base and base course materials are expressed in terms of their CBR value.

Apparatus: - Test sieves, sizes 20mm and 5mm, A cylindrical metal mold, A metal rammer of either 2.5kg or 4.5kg, a steel rod, A steel straightedge, A spatula, A balance, Apparatus for moisture content determination, filter paper 150mm in diameter.

Sample Preparation:-First 6 kg of sample material prepared. If the soil or material is damp (moist) when relieved of field,until it becomes friable under a towel drying may be in the air or by over dry not exceeding 60oc. Thoroughly break up aggregation, being careful to avoid reducing the natural size of the individual particles and passing the 19mm or 4.75mm sieve would be required

3.5.4 Extraction Test

Aim: To determine the bitumen content as per ASTM 2172.

Apparatus: Centrifuge Extractor

I) Centrifuge extractor

II) Miscellaneous - bowl, filter paper, balance and benzene

Sample: used 500g sample

Procedure

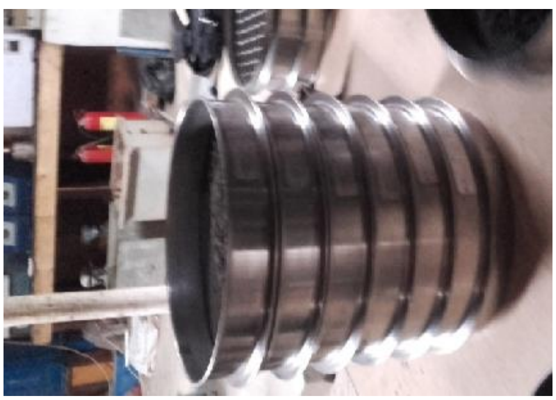


Figure 3. 10 Sieve Size

Figure 3. 11 Sieving material for Extraction Test

Figure 3. 12 Material after oven dry

Figure 3. 13 Balancing material

Figure 3. 14 Washing Sample

Figure 3. 15 Filtration bitumen

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Data Analysis

4.1.1Manual survey of the road pavement condition

There are two primary methods of collecting pavement distress data: manual distress surveys and automated distress surveys. A manual distress survey is a walking survey of the pavement in which the entire limits of the project are evaluated and all distresses are measured, recorded, and mapped, either on paper or directly into computers. Manual surveys rely on raters who identify the distress type, severity, and extent as part of the survey process. This can be a very resource intensive way to collect pavement distress information,pleminary survey data collection was proceded

This study was preceded by real measurement and preliminary survey. The measurement had been taken by meter in order to know the damaged, how much it is wide, depth, length and area of the deterioration. In another way the type of pavement distress could be identified by the visual view by its signs, even if rutting, crack, potholes, raveling,and

4.1.2 Severity Levels of Flexible Pavement Distresses

A. Fatigue Cracking

Figure 4. 1 Fatigue crack distress type, high severity level, Chainage 29+450 and fatigue crack distress type, high severity level , Chainage 29+00

Figure 4. 2 Fatigue crack distress type and fatigue crack Distress type high severity level ,Chainage 17+670 moderate severity level, chainage 30+00

Figure 4. 3 Wheel paths Distress type, Low severity level,Chainage 46+700 and Block crack distress type ,high severity level, change 42+100

Figure 4. 4 Patch Distress type, high severity level Chainage 28+900

At chain age 25+100 and 28+900 after maintenance by cut and replace the patching pavement distress occurred. As the data collected the length of the patching section is 2.65m and width of patching section is 2.55m. The depth is 18cm. Therefore, this area was a serious deterioration of pavement. High Patch has highest severity distress of any type, including rutting > 12mm or the patch has additional different patches and square meters of affected surface area at each severity level. So it is greater than the above severity level of the distressed pavement and it is high severity level.

Table 4. 1 Severity levels of Potholes

Severity levels	Standard Depth (mm)	Exist on Station
Low	< 25 mm deep	12+400,51+120,52+040
Moderate	25 mm to 50 mm deep	30+100,37+040,45+080,25+800
High	> 50 mm deep	25+100, 18+980,32+300

Figure 4. 5 Potholes distress type, high severity level, Chainage 19+300 and Potholes distress type Low Severity level, Chainage 26+00

. Figure 4. 6 Potholes Distress type, high severity level ,Chainage 25+800 and Potholes distress type, high severity level, Chain age 25+100

Most of Dembi-Bedele defects are potholes

Figure 4. 7 Potholes Distress type, high severity level, Chainage 34+200 and Potholes distress type ,high severity level, Chainage 32+00

Figure 4. 8 Potholes Distress type, high Severity level, Chainage 28+200

Figure 4. 9 Patching Distress type ,high Severity level Chainage 40+236

Figure 4. 10 Polished aggregate Distress Type,, Chainage 19+300

Figure 4. 11 Water in Ruts Distress Type, High Severity level, Chainage 18+850

Some severity levels of pavement distree are not applicaple.Raveling,water bleeding and polished aggregate stiil now there is no description on severity levels by any authors

Figure 4. 12 Deformation of pavement , high Severity Levels, chainage 17+870

Table 4. 2 Properties of Soil from DCP Test

Sample chain age	CBR (%)	Soil Type USCS class	DPI(mm/blow)
17+600			
Base course	65	Gravel (G-W)	6
Sub base	36	Sand (S-W)	4
Sub grade	32	Sand (S-W)	5
24+990			7
Base course	75	Gravel (G-W)	6
Sub base	70	Gravel (G-W)	5
Sub grade	50	Sand (S-W)	4
25+100			6
Base course	75	Gravel (G-W	8
Sub base	51	Sand (S-W)	9
Sub grade	36	Clay (CL)	3

Table 4. 3 Summary of Types, extent and severity of the pavement distresses

Distress Types	Unit of measure	Chainage	Type of Distress	Defined severity levels (Yes or No)	W, D,,A,L (m, m^2)	Severity Levels
A. Cracks 1. Fatigue cracks	m^2/cm/mm	29+00	ACP-1	Yes		High
	"	17+670	ACP-1	Yes	0.20,--,--,--	High
	"	29+450	ACP-1	Yes	0.40,--,--,--	High
	"	30+00	ACP-1	Yes	0.29,--,--,--	High
2. Block crack	"	26+00	ACP-2	Yes	0.31,--,--,--	High
	"	46+700	ACP-2	Yes	0.22,--,--,--	
B. Patching and Potholes 3.Patch /Patch Deterioration	m/cm/mm					
	"	29+900	ACP-7	Yes	0.30,---,---,--	High
	"	40+236	ACP-7	Yes	0.44,---,--,---	High
4. Potholes	"	19+300	ACP-8	Yes	1.06, 0.36, 0.39m^2---	High
	"	32+00	ACP-8	Yes	0.79,0.13, 0.103m^2 ---	High
	"	34+200	ACP-8	Yes	0.53,0.8,0.77m^2 ---	High
	"	28+200	ACP-8	Yes	0.90, 0.6, 0.54m^2 ---	High
	"	25+100	ACP-8	Yes	.89, 0.9,0.8m^2 ----	High
	"	24+900	ACP-8	Yes	0.75,0.86, 0.64m^2 ---	High
	"	30+100	ACP-8	Yes	0.45,0.13, 0.06m^2 ---	moderate
	"	25+800	ACP-8	Yes	0.68, 0.83, 0.56m^2 ---	moderate
	"	37+040	ACP-8	Yes	0.35,0.48, 0.17m^2 ---	moderate
	"	45+080	ACP-8	Yes	0.59,0.14, 0.08m^2, ---	moderate
	"	12+400	ACP-8	Yes	0.38,0.23, 0.09m^2,---	Low
	"	51+120	ACP-8	Yes	0.15.0.6, 0.09m^2, ---	Low
	"	24+900	ACP-8	Yes	0.41,0.03, 0.01m^2 ---	Low
C. Surface deformation 5. Rutting						
	m/cm/mm	28+200				
	"	17+870	ACP-9	No	---	---
	"	18+850	ACP-9	No	----	----
	"	24+00	ACP-9	No	----	----
	"	20+144	ACP-9	No	----	----
	"	18+050	ACP-9	No	-----	----
		52+040	ACP-9	No	-----	----
4. Shoving	m^2					
C. Surface Defects	No/m^2					
6.Bleeding	"	---	ACP-11	No	---	---
7.Raveling	"	17+015		No	---	---
8. Raveling: miscellaneous	m^2		---	No	---	---
	m^2		---	No	---	---
	----	---		No	---	---

4.2 DCP Field Result Analysis and Scator Plot

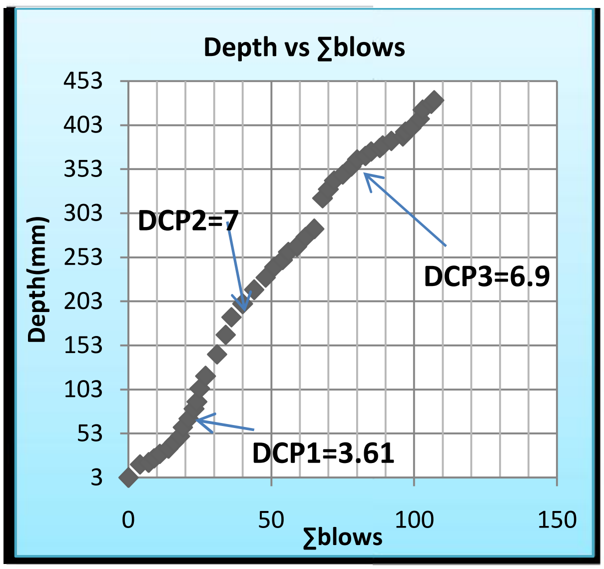
Data were analysed by cummulative number of blows versus penetration depth.

4.2.1 Depth vs. blows and Depth vs. PI

Pavement condition: Distressed area

Test method; DCP Tes Chainage: 17+870

Depth vs. Penetration Index



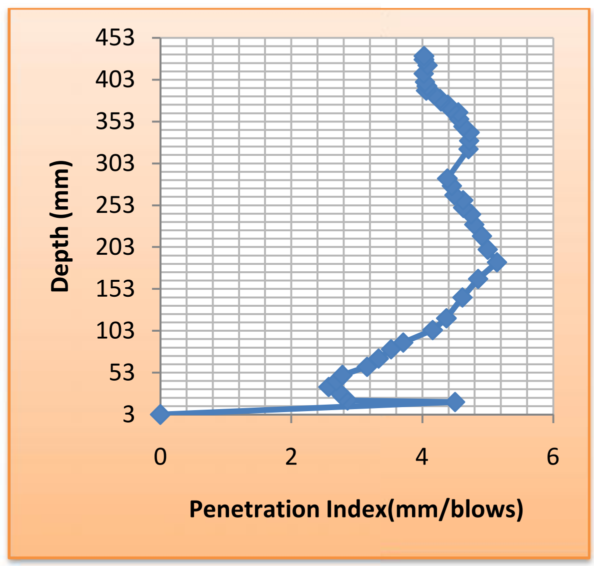


Figure 4. 13 Calculated DCP value at distressed section, Chainage 17+870

In Figure 4.13 the x-axis represents the cumulative numbers of blowsand y-axis represents the cumulative penetration in mm/blows. Cumulative penetration was measured by scale per 5 blowintervals. The first, second and thirdlayer indicate base course, sub-base and sub grade layer respectively. DCP was measured on the basisof maximum depth. DCP values shows that penetration rate.So that, from the slope of the curve 3.61mm/blow, 6.2mm/blow and 6.9mm/blow.The DCP values of base course, sub base and sub grade respectively. It was seen that the DCP was increasing as penetrated deeper and deeper.The DCP was first lower, higher and higher again.. So that data for first layer was more scattered than the second, third and fourth layer respectively. This represents a certain deviation that occurred in the case of the pavement layers, penetration at 127 blows was 586 mm which was quite extraordinary. This shows that the strength of the pavement was decreased as DCP values increased and also minimum number of blows required for maximum depth.This implies that, weak pavement strenght.

Depth vs. Penetration Index

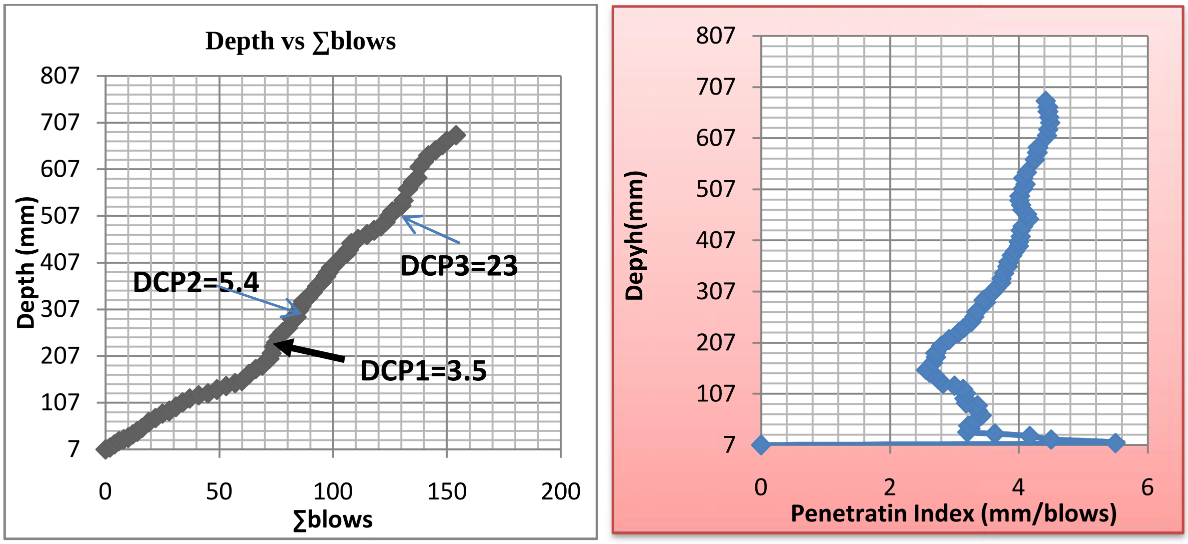
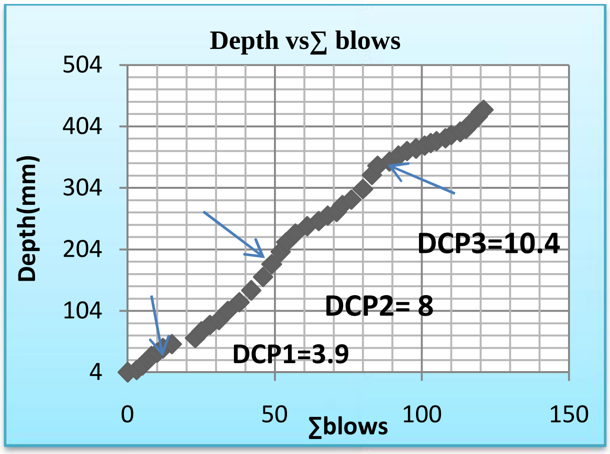


Figure 4. 14 Calculation of DCP Value at normal Section, Chainage 17+600

In Figure 4.14 Cumulative numbers of blows were taken up to 150 blows.Cumulative penetration was measured by scale per 5 blow intervals. DCP penetration rate and pavement thickness values from DCP UK 3.1 software shows for base course, sub-base and sub garde 3.5mm/blow,5.4mm/blow and 23mm/blowand the thickness 43mm, 256mm, 245mm and 115mm respectively. for this layer. Penetration at 154 blows was 680 mm which was quite fair rather than the distressed. Maximum number of blows required for minimum depth.This implies that, good pavement strenght

Test Method:DCP Test Chainage:24+900

Depth vs. ∑blows Depth vs. Penetration Index



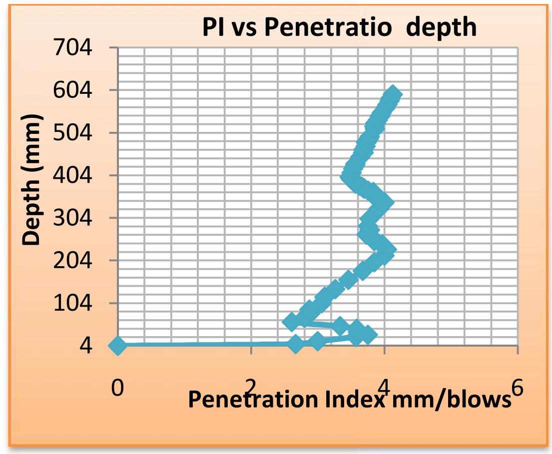
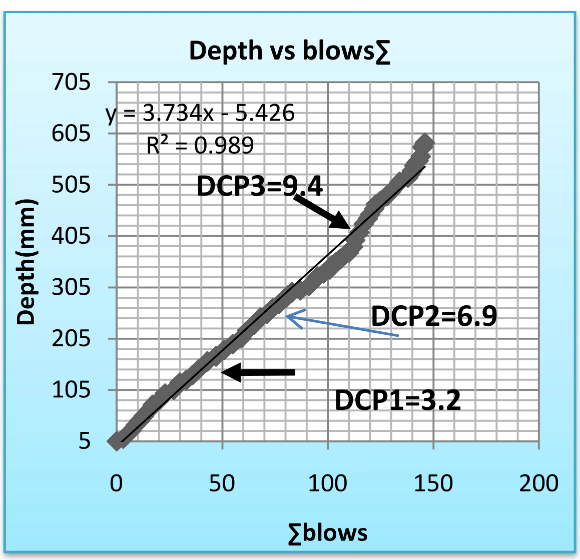


Figure 4. 15 Calculation of DCP value at distressed section, Chainage 24+900

In Figure 4.15 DCP values from the slope of the curve was found 3.9mm/blow, 8.0mm/blow and10.4mm/blow base course, sub base and sub grade respectively.While the thickness of surface, base course, sub base and sub grade 40mm,147mm,80mm and 261mm respectively.This represents a certain deviation that occurred in the case of the pavement layers, penetration at 142 blows was 548 mm which was in bad condition.

Chainage 24+990 Normal area Depth vs. Penetration Index



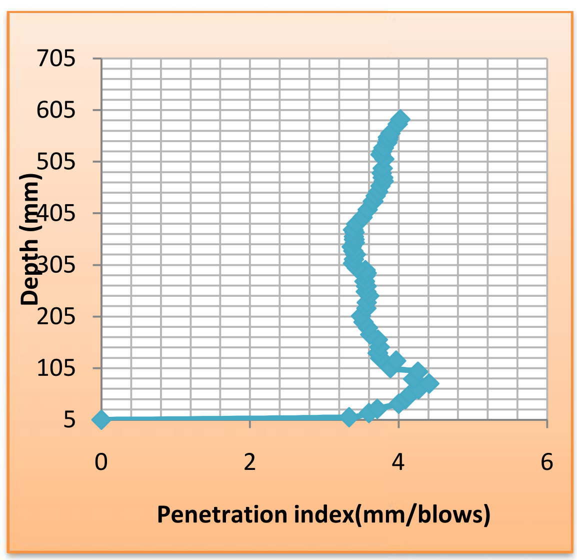
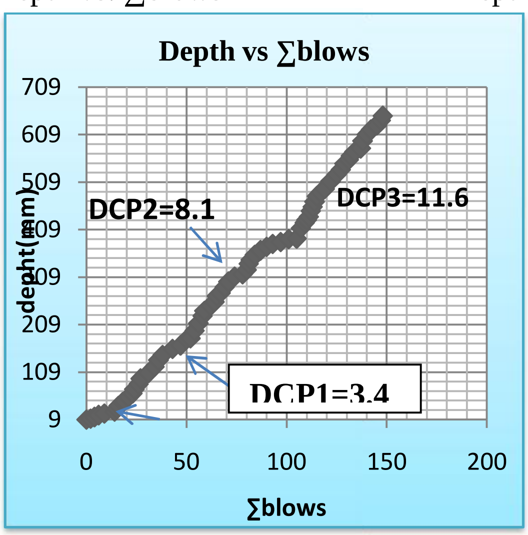


Figure 4. 16 Calculation of DC, Value at Normal Section,Chainage 24+990

In Figure 4.16 Cumulative numbers of blows were taken up to 127 blows.Therefore, in the future, Base course layer will be of sufficient strength. Cumulative penetration was measured by scale per 5 blow intervals. DCP values from the slope of the curve was found 3.2mm/blow, 6.9mm/blow and 9.4mm/blow base course, sub base and sub gradrespectively. Additinally, the thickness surface, base course, sub base and sub grade were 48mm,141mm,104mm and 281mm respectively.For this layer. Penetration at 127 blows was 586 mm which was quite fair.Inorder to penetrate the pavement,it requires maximum number of blows. But base course layer of normal section greater than the distressed one.Therefore,the normal area didn't distressed, but surface and sub base layers are good.

Test Method: DCP Test Chainage: 25+00

Depth vs. ∑blows Depth vs. Penetration Index



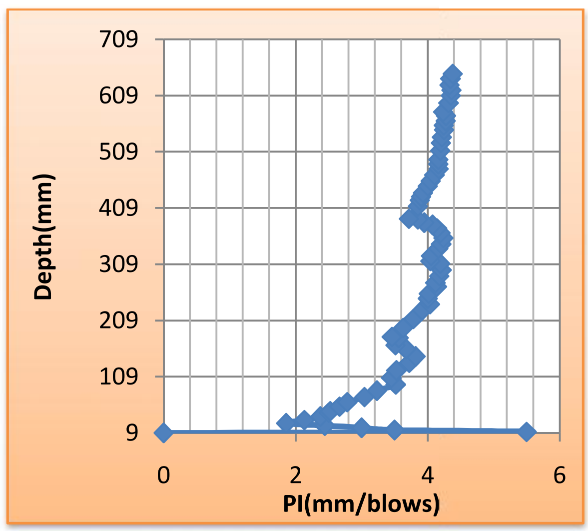


Figure 4. 17 Calculation of DCPValue.at Normal Section,Chainage 25+00

In Figure above ,DCP values from the slope of the curve was found 3.4mm/blow, 8.1mm, 11.6mm/blow and the existingpavement thickness were good. As PI increase, the strength of the pavement layers decreases. Therefore, at chainage 25+00 the maximum value of PI was 6mm/blows. But at chainage 25+100, the value of PI is 9mm/blows.

Chain age 25+100Depth vs. Penetration Index

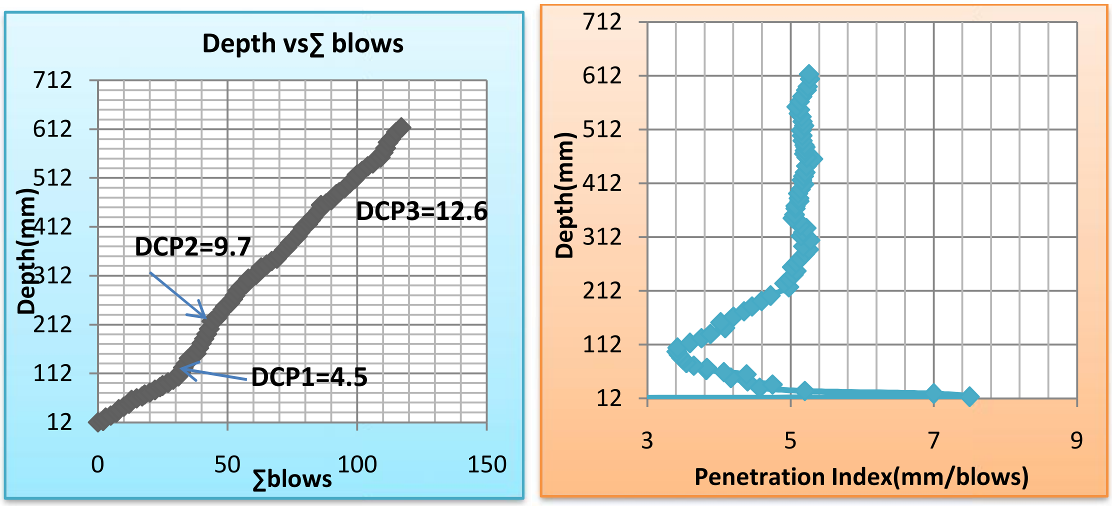


Figure 4. 18 Calculation of DCP Value at Distressed Section,Chainage 25+100

Table 4.18 shows DCP penetration rate 4.5mm/blow,9.7mm/blow,12.6mm/blow and calculated DCP pavementthickness values of surface,base course,sub base and sub grade decreased by 10mm,18mm,104mm and 47mm respectively.The DCP was first lower and then became higher and higher again. High scatter data means lower DCP. So, data for first layer was more scattered than the second, third and layer respectively. As we know, the surface layer is harder than the base course layer.Therefore,all pavement layershave insufficient thickness

Table 4. 4 Summary of existing pavement properties with ERA Standard Specifications

	Computation of total pavement thickness at chain age 17+870, Pavement Condition: Distressed area					
Pavement layers	DCP PR (mm/blow)	Recommended thickness according to design	Existing thickness (mm)	Number of blows	Depth (mm)	Required thickness (mm)
Surface		50	25			25
Base course	3.6	175	144		169	31
Sub base	6.2	250	155		324	95
Sub grade	6.9	300	242		566	58
Pavement				117	586	209
	Computation of total pavement thickness at Chain age 17+600, Pavement Condition: Normal					
Pavement layers	DCP PR (mm/blow)	Recommended thickness according to design	Existing thickness (mm)	Number of blows	Depth (mm)	Required thickness (mm)
Surface		50	43			7
Base course	3.54	175	256		299	Fair
Sub base	5.4	250	245		544	5
Sub grade	23	300	115		659	185
Pavement				154	680	190
	Computation of total pavement thickness at Chain age 24+900, Pavement Condition: Distressed area					
Pavement layers	DCP PR (mm/blow)	Recommended thickness according to design	Existing thickness (mm)	Number of blows	Drepth (mm)	Required thickness (mm)
Surface		50	39			11
Base course	3.92	175	147		187	28
Sub base	8.0	250	80		267	170
Sub grade	10.4	300	261		528	39
Pavement				142	548	248
	Computation of total pavement thickness at Chain age 24+990,Pavement Condition :Normal area					
Pavement layers	DCP (mm/blow)	Recommended thickness according to design	Existing thickness(mm)	Number of blows	Drepth (mm)	Required thickness(mm)
Surface		50	48			2
Base course	3.2	175	141		189	34
Sub base	6.9	250	104		293	146
Sub grade	9.4	300	281		574	19
Pavement				144	594	201
	Computation of total pavement thickness at Chain age 25+100, Pavement condition:					**Distressed area**
Pavement layers	DCP (mm/blow)	Recommended thickness according to design	Existing thickness(mm)	Number of blows	Drepth (mm)	Required thickness(mm)
Surface		50	40			10
Base course	4.5	175	157		197	18
Sub base	9.7	250	146		343	104
Sub grade	12.6	300	253		596	47
Pavement				117	615	147
	Computation of total pavement thickness at Chain age			**25+00,Pavement condition:Normal area**		
Pavement layers	DCP (mm/blow)	Recommended thickness according to design	Existing thickness mm	Number of blows	Drepth (mm)	Required thickness(mm)
Surface		50	40			10
Base course	3.4	175	182		222	Excess
Sub base	8.1	250	121		343	129
Sub grade	11.6	300	290	148	633	10
Pavement					648	149

4.3 Summary of DCP CBR and Test Pits CBR results.

Table 4. 5 Summary of DCP CBR and Test Pits CBR results.

Chainage 17+870 Distressed Section		Chainage 18+850 Distressed Section
Pavement layers	DCP Software CBR	Test Pit result
Base course	78	38
Sub base	44	24
Sub grade	39	12
Chainage 17+600 Distressed Section		Chainage 19+300 Distressed Section
Base course	79	45
Sub base	50	26
Sub grade	11	13
Chainage 24+990 Normal Section		Chainage 26+00 Normal Section
Base course	87	67
Sub base	39	20
Sub grade	28	16
Chainage 24+900 Distressed Section		
Base course	71	
Sub base	34	
Sub grade	25	
Chainage 25+00 Normal Section		
Base course	83	
Sub base	33	
Sub grade	23	
Chainage 25+100 Distressed Section		
Base course	62	
Sub base	27	
Sub grade	21	

The CBR values are less than ERA standard specification. ERA recommends that Base course gtreater than 80%, sub base 50-80% and Sub grade 12-30%.

4.2.2 Structural strength of pavement layers

The pavement design method that was developed using the results of the AASHO Road Test involves the calculation of the so called structural number in relation

1. The structural stength propreties of the existing pavement from DCP test reults,at chainage 17+870 thickness of pavement surface course,base course, sub base and sub grade layers decreased by 25mm, 31mm, 95mm and 58mm respectively from designwhich is not sufficient strength of the proposed traffic load.

The stractural strength of surface,base course,sub-base and pavement layers were 0.1,0.73, 0.66 and 1.49 respectively.While the penetration rate of base course,sub abse and sub grade were 4.48mm/blow,9.73mm/blow and 12.65mm/blow (chainage:17+870) respectively.As penetration rate increased the stractural strength of the pavement could be decreased. When we copare with normal section (chainage 17+600) thickness of pavement surface layer decreased by 3mm and sub grade decreased by 5mm which is relatively normal.This section is was good performance.

Also the value of existing CBR is 78%, 44% of base course and sub base continously (17+870). But ERA recommends ≥80% for base course and 50-80% for base coarse.at chainage (17+870)

2. At chainage ,24+900 (distressed section) the DCP value of base course, sub-base and sub grade were 3.92mm/blows, 8.0mm/blows and 10.4mm/blows respectively. While the existing thickness of surface,basecourse and sub grade were, 43mm,147mmand 80 respectively. But the previous design of the road said, 175mm,250mm and 300mm for base course, sub base and sub grade layers respectively. Also the value of existing CBR of base course nd sub abse were 75.5%. and 33.2 respectively. While at chainage 24+990 (at normal section), the PR values of pavement layers less than at distressed section. DCP software shows that,stiffer pavement thickness and sufficient CBR values exist at this section.

3. At chainage,25+100(distressed section) the DCP value of sub base was 9.73mm/blows, with 26% CBR value which is minimum value when comparing with ERA standard. This value is not sufficient strength of the proposed traffic load. While at chainage 25+00 (at normal section), the DCP value of the sub base is 8.1mm/blows. A large value of penetration rate depth leads todecrease the strength of pavement layers. This section is good stiffer and good CBR values.

4.2.3 CBR Test Result

Table 4. 6 Comparison of Soil Test with ERA Standard

Stat	Test Pits									ERA	
										LL%	PI%
		Properties of soil				CBR Test		Compaction			
	Types of Layers	LL	PL	PI	W.C %	DD	CBR %	OMC %	DD g/cm^3		
18+850	Base course					1.8	38	22	2.29		No
	Sub- base course	34.2	25.8	8.4	36.8 1	2	24	8.3	2.17	≤35	6-12
	Sub-grade	32.5	20.7	11.8	33.4	1.9	12	17.3	1.3	25-30	≤12
19+300	Base course					1.8	45	17.3	2.33	CBR ≥80	
	Sub- base course	26.0	17.9	8.1	25.8	1.9	26	11.9	1.88	CBR 50-80%	
	Sub-grade	27.8	9.81	17.9	27.5	1.7	13	11.7	2.22	CBR 15-30%	
26+00	Base course					1.8	18	16.4	2.15	CBR ≥80%	
	Sub- base course	25.0	17.9	7.1	25	1.7	34	12.7	2.19	CBR 50-80%	
	Sub-grade	39.3	23.6	15.7	35	1.7	12			CBR 15-30%	
								15.8	2.25		
34+200	Base course					1.6	67	14	2.3	CBR ≥80%	
	Sub- base course	28.6	13.6	14.9	25	1.8	20	13.7	2.1	CBR 50-80%	
	Sub-grade	31.5	20.7	10.9	31.7	1.8	16	16	1.8	15-30%	

And also ERA recommends LL ≤ 35% and PI≤ 12 % But the value that I got is less than this recommends ERA. Therefore, At chainage 19+300, 26+00 the PI values of sub grade is 17.97% and 15.7 % respectively. And also at chainage 24+200 and 34+200 PI value of sub base is 13.8% and 14.9%. It must be blended or stabilize with other materials. LL Aggregate Sub base Course Size: Max. Size passing = 2" -100% sieve shall be used & retained #200 sieve 12%a. For fraction passing #200 sieve <0.66 of fraction passing 0.425, #40 sieve. For fraction passing #40 sieve LL ≤ 35%PI ≤ 12 %c.

Inorder to keep the following terms, remidial measures should be taken

1. To retain highway safety and standards
2. To preserve structural integrity & design life
3. Minimize vehicle operating cost
4. the traveling public and to preserve the Government's Investment in the Road network

4.2.4 Remidial Measures of Pavement Distress from the Study

Fatigue crack-Remove the cracked pavement area then digout and replace the area of poor sub grade (chainage 29+450, 29+00, 30+00, 17+670). At high severity level of fatigue cracked, place an hot mix asphalt overlay over the entire pavement surface. Additionally, the thickness of surface ,base course, sub base and sub grade as the design (50mm, 175mm, 250mm and 300mm) respectively

Block crack- remove and replace if block cracking has led to other severe distress and adequate compaction, Applying seal coats at first sign of distress at (chainage 42+100).

Photoles-is the end result of fatgue cracking. Adequate structural design and adequate compaction and drainage structures neccessary at (chainage 32+00, 28+200, 34+200, 25+100 and 25+800,19+300). But for chainage 25+100 from DCP result the thickness of surface,base course sub base and sub grade must be increased by 10mm, 18mm, 104mm and 47mm respectively.

Polished aggregate-Applying a skid resistance slury seal overla and applying sufficient amount of bitumen at(chainage 19+300).

Rutting- good mix design procedure required.,monitor construction and removing that rutting section

Surface deformation-Removing the distressed section and reconstruct starting from sub grade.Increasing the sub grade compaction and adequate materials. Protecting the right of of the land slide which causes surface deformation at (chainage 17+870). The pavement layers thickness surface, base course, sub base and sub grade layers must be increased by 25mm, 31mm, 95mm, 58mm respectively. Patching-Cutting the previous cut and replaced section at (chainage 40+236) and on chainage 24+900 the surface, base course sub base and sub grade layer must be increased by 11mm, 28mm, 170mm and 39mm respectively. ERA recommends, CBR values for base course ≥80% for sub base, 50%-80% and for sub grade soil 12-30%.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the result of DCP data analysis, chainage 25+100, the thickness of pavement surface, base course, sub base and sub grade layers decreased by 10mm, 18mm, 104mm and 47mm respectively.When compared with previous design.The CBR values are 62%, 27% and 21% for base course,sub abse and sub grade respectively.The calculated results are less than the standard.

Relative to this, the strength properties of the existing road pavements at distress sections using destructive test showed at chainage 17+870 thickness of surface course, base course, sub base and sub grade layers decreased by 25mm, 31mm, 95mm and 242mm respectively from design. Additionally, the CBR values of base course, sub base and sub grade are 78%,44% and 39% respectivel. These results are less than the standard.

Additionally,from extraction test, the amount of bitumen on chainage 19+300 is 3.2% which is inadequate for this pavement surfacing. The PI of sub grade soil on chainage 19+300 is 17.9%.ERA recommends that PI values for sub grade less than 12%. This value shows that more fines at this layers and also the OMC is 27.5% which decrease the sub grade strengthIt should be 5%. At chanage 34+200 the amount of bitumen that used in previous pavement construction was 4.8% and also at chainage 18+850 the bitumen content was 3.8%.

The PR of DCP for base course, sub base and sub grade were is 3.61mm/blows, 6.2 and 6.9mm/blows. As penetration rate increased, the srength of pavement decreased. From chainage 24+900, thickness of pavement surface, base course, sub base and sub grade layers decreased by 10mm, 28mm, 170mm and 39mm respectively when compared with design. Traffic flow increased by 208 AADT in five years difference. The future traffic count for 2021 G.C. it is estimated 529 AADT. Therefore increasing traffic flow has impact on previous designed road and for future safety of the road.

5.2 Recommendation

DCP test is the best choice ument to evaluate the existing pavement layers strength for the road maintenance. Also, it helps to know the CBR and the thickness of the existing distressed pavement inorder to safe economy and servicebility of the road. The thickness of all pavement layers must be as the design for Surface course, base course, sub base and sub grade 50mm, 175mm, 250mm and 300mm respectivly. However, there is some drawbacks using DCP test: After penetration stoped, it is difficulty to remove steel rod from the pavement. Besides, it can't penetrate hard materials, so that care must be considered.

5.2.1 ERA Consultants

The Consultants involved in the implementation of road projects should exercise proper monitoring during construction stage to reduce the possibility of inferior materials incorporated by the contractor. Also, require the contractor to provide sufficient laboratory equipments and apparatus in order to test the proper materials on time. These activities must be exercised by both parties to attain the desired quality of pavement materials during construction. However, in the case of some traces of distresses or deficiencies on the carriageway and road side features, proper application of a maintenance management system must be undertaken to avoid further deterioration of the pavement layers. Routine maintenance, periodic maintenance and preventive maintenance must be scheduled at the right time, place and quality. This research guides ERA's maintenance Department for road maintenace of Dembi-Bedele highway.

5.2.2 The Contractor

The contractor must Always adhere with the provision of the contract agreement and to apply the design in to practical. Besides, adhere the contract's special provisionof the technical specification.

REFERENCES

[1] Loizos, A. and Plati,(2007).Accuracy of pavement Thicknesses Estimation Using Different Ground Penetrating Radar Analysis Approaches, NDT & E International,40(2)

[2] Lahouar, S. and Qadi, I.L,(2008).Automatic Detection of Multiple Pavement Layers from GPR Data, NDT & E International,41 (2),pp.69-81

[3] E. G. Kleyn, (19,1975) "The use of the dynamic cone penetrate (DCP)," report 2/74.Transversal roads department, "Rehabilitated Pavement Structures ,Final Document

[4] HARISON J.A, (1989) In Situ CBR Determination by DCP Using a Laboratory-Based Correlation. Australian Roads Research 19(4)

[5] KLIMOCHKO, Dennis, The Application of Dynamic Cone Penetrater Test in Determining In Situ Sub grade CBR.

[6] Statewide Urban Design and Specification, Design Manual Chapter 6 Geotechnical,6E-Sub grade Design Construction, Sudas, October..

[7] American Society for Testing and Materials (ASTM), (2004),Volume 04 Soils and Rock(I),United State of America

[8] MakWaik in, California Bearing Ratio Correlation with Soil Index Properties, Faculty of Civil Engineering, University of Technology, Malaysia

[9] ZelalemWorku, (2010) Prediction of CBR values from index Property tests, Addis Ababa University, Ethiopia

[10] Farshad Amini, (2003) Potential Applications of Dynamic and Static ConePenetrometer in Mndot Pavement Design and Construction, Mississippi Department of Transportation and the U.S. Department of Transportation Federal Highway Administration, Jackson State University,Mississippi,September

[11] Republic of Botswana Road Department, Ministry of works Transport and Communication

[12] Bowles Joseph,E (1984) Engineering Properties of Soils and Their Measurement,McGraw-Hill,Singapore, second edition,

[13] Jones C R and J Rolt (1991). Operating instructions for the TRL dynamic cone penetrometer (2nd edition). Information Note. Crowthorne: Transport Research Laboratory

[14] ASTM (2004). Standard Test Methods for soils, American Society for Testing Materials,United State of America.

[15] Atkin, H. N. (2003). Highway Materials, Soils, and Concretes, 4th ed. Prentice Hall, UpperSaddle River New Jersey

[16] Paige-Green, P, and Plessis, L. D. (2009).The use and interpretation of the Dynamic Cone Penetrometer (DCP) test.CSIR Built Environment Pretoria

[17] Hodges J W, J Rolt and T.E Jones (1975). The Kenya road transport cost study: researchon road deterioration. TRRL Research Report LR 673.Transport and Road ResearchLaboratory, Crowthorne, UK

[18] Rolt J and C C Parkman (2000). Characterisation of Pavement Strength in HDM III andchanges adopted for HDM-4. 10th International Conference of the Road EngineeringAssociation of Asia and Australia.

[19] International Conference on the Structural Design of Asphalt Pavements. Ann Arbor, 1962 Proceedings 2nd

[20] Fundamental Modeling of Design and Performance of Concrete Pavements (2006), Old Turnhout

[21] Robert etal.,1996

APPENDIX-A DCP TEST FIELD RESULTS

DCP Calculated Result of Distressed Section, Chain age 17+870

Stat.	No. Blows	∑ Blows	Depth (mm)	PImm/blow	No. Blows	∑ Blows	Depth (mm)	PI (mm/blow)	No. Blows	∑ Blows	Depth (mm)	PI mm/blows
17+870	0	0	3	0	4	48	230		3	106	427	4.0
	4	4	18	4.5	3	51	242	4.7	1	107	431	4.0
	3	7	20	2.9	3	54	250	4.6	1	108	444	4.1
	2	9	25	2.8	2	56	259	4.6	1	109	456	4.2
	2	11	30	2.7	3	59	265	4.5	1	110	468	4.3
	3	14	36	2.6	3	62	276	4.5	1	111	476	4.3
	2	16	43	2.7	3	65	285	4.4	1	112	489	4.4
	2	18	50	2.8	3	68	320	4.7	1	112	498	4.4
	1	19	60	3.2	2	70	330	4.7	1	113	508	4.5
	2	21	70	3.3	2	72	340	4.7	1	114	514	4.5
	2	23	81	3.5	3	75	347	4.6	1	115	520	4.5
	1	24	89	3.7	3	78	356	4.6	1	116	526	4.5
	1	25	104	4.2	2	80	364	4.6	2	118	532	4.5
	2	27	118	4.4	3	83	368	4.4	2	120	538	4.5
	4	31	143	4.6	2	85	373	4.4	1	121	544	4.5
	3	34	165	4.9	3	88	377	4.3	1	122	552	4.5
	2	36	185	5.1	1	89	380	4.3	1	123	558	4.5
	4	40	200	5.0	3	92	385	4.2	1	124	565	4.6
	4	44	216	4.9	4	96	390	4.1	1	125	572	4.6
	0	0	3	0	1	97	395	4.1	1	126	579	4.6
	4	4	18	4.5	2	99	400	4.0	1	127	586	4.6
	3	7	20	2.9	3	102	410	4.0				
	2	9	25	2.8	1	103	420	4.1				

DCP Calculated Result of Normal Section, Chainage 17+600

Stat.	No.	Σ Blows	Depth (mm)	PImm/blow	No. Blows	Σ Blows	Depth (mm)	PI(mm/blow)	No. blows	Σ Blows	Depth (mm)	PI mm/blows
17+870	0	0	7	0	3	66	179	2.7	3	106	427	4.0
	2	2	11	5.5	3	69	187	2.7	4	107	435	4.1
	2	4	18	4.5	3	72	201	2.8	3	108	449	4.2
	2	6	25	4.2	1	73	213	2.9	3	111	458	4.1
	2	8	29	3.6	1	74	227	3.1	2	115	467	4.1
	2	10	32	3.2	1	75	236	3.1	2	118	476	4.0
	2	12	39	3.3	1	76	248	3.3	1	121	485	4.0
	2	14	45	3.2	2	78	258	3.3	2	123	494	4.0
	2	16	53	3.3	2	80	267	3.3	2	125	508	4.1
	3	19	65	3.4	2	82	286	3.5	1	126	517	4.1
	3	22	74	3.4	2	84	290	3.5	4	130	529	4.1
	3	25	84	3.4	1	85	305	3.6	1	131	540	4.1
	3	28	89	3.2	1	86	314	3.7	2	133	565	4.2
	3	31	98	3.2	1	87	324	3.7	1	135	579	4.3
	3	34	108	3.2	2	89	332	3.7	2	137	589	4.3
	3	37	116	3.1	2	91	343	3.8	1	138	612	4.4
	4	41	123	3.0	2	93	356	3.8	2	140	624	4.4
	4	45	127	2.8	2	95	365	3.8	2	142	637	4.5
	4	49	135	2.8	2	97	378	3.9	3	145	648	4.5
	4	53	143	2.7	2	98	386	3.9	3	148	659	4.5
	4	57	149	2.6	3	99	396	4.0	2	150	668	4.5
	3	60	154	2.6	1	101	404	4.0	4	154	680	4.4
	3	63	168	2.7	1	103	415	4.0				

DCP Calculated Result of normal Section, Chainage 24+990

Stat.	No. Blows	Σ Blows	Depth (mm)	PI mm/blow	No. Blows	Σ Blows	Depth (mm)	PI mm/blow	No. Blows	Σ Blows	Depth (mm)	PI (mm/blow	Nn..blows	Σ Blow	Depth (mm)	PI (mm/blo)
24+0 0	0	0	4	0	3	57	230	4.0	3	113	395	3.5	1	140	562	4.0
	3	3	8	2.7	4	61	242	4.0	2	115	400	3.5	1	141	570	4.0
	2	5	15	3.0	4	65	250	3.8	2	117	410	3.5	1	142	579	4.1
	2	7	25	3.6	3	68	259	3.8	2	119	420	3.5	1	143	585	4.1
	1	8	30	3.8	3	71	265	3.7	1	120	427	3.6	1	144	594	4.1
	2	10	36	3.6	2	73	276	3.8	1	121	431	3.6				
	2	12	43	3.6	3	76	285	3.8	2	123	447	3.6				
	3	15	50	3.3	4	80	302	3.8	1	124	457	3.7				
	8	23	60	2.6	3	83	325	3.9	2	126	464	3.7				
	2	25	70	2.8	2	85	340	4.0	1	127	472	3.7				
	3	28	81	2.9	4	89	347	3.9	2	129	481	3.7				
	3	31	89	2.9	3	92	356	3	1	130	489	3.8				
	3	34	104	3.1	3	95	364	3	1	131	495	3.8				
	4	38	118	3.1	3	98	368	3	2	133	513	3.9				
	4	42	137	3.3	3	101	373	3	2	135	519	3.8				
	4	46	159	3.5	2	103	377	2	1	136	526	3.9				
	3	49	180	3.7	2	105	380	2	1	137	534	3.9				
	3	52	200	3.8	3	108	385	3	1	138	543	3.9				
	2	54	216	4.0	2	110	390	2	1	139	550	4.0				

DCP Calculated Result of distressed Section, Chainage 24+900

Stat.	No. Blows	∑ Blows	Depth (mm)	PImm /blows	No. Blows	∑ Blows	Depth (mm)	PI mm/blows	No. Blows	∑ Blows	Depth (mm)	PI mm/blows
24+900	0	0	5	0	3	68	245	3.6	1	120	447	8.0
	3	3	10	3.3	3	71	253	3.6	2	122	458	11.0
	2	5	18	3.6	3	74	264	3.6	1	123	467	9.0
	2	7	26	3.7	3	77	273	3.5	2	125	474	7.0
	2	9	36	4.0	3	80	284	3.6	3	128	483	9.0
	2	11	45	4.1	1	81	289	3.6	2	130	492	9.0
	2	13	54	4.2	2	83	295	3.6	4	134	510	18.0
	2	15	64	4.3	4	87	299	3.4	4	138	519	9.0
	2	17	75	4.4	4	91	308	3.4	1	139	525	6.0
	3	20	84	4.2	2	93	316	3.4	1	140	532	7.0
	3	23	98	4.3	2	95	325	3.4	1	141	542	10.0
	4	27	105	3.9	3	98	332	3.4	1	**142**	**548**	6.0
	3	33	124	3.8	1	102	348	3.4				
	3	36	134	3.7	2	104	354	3.4				
	3	39	146	3.7	2	106	360	6.0				
	4	43	160	3.7	2	108	368	8.0				
	4	47	170	3.6	2	110	373	5.0				
	4	51	183	3.6	2	112	384	11.0				
	4	55	194	3.5	1	113	397	13.0				
	4	59	206	3.5	2	115	412	15.0				
	3	62	221	3.6	2	117	428	16.0				
	3	65	232	3.6	2	119	439	11.0				

DCP Test Calculated Result of Normal Section, Chainage 25+00

Stat.	No. Blows	Σ Blows	Depth (mm)	PImm/blows	DCP mm/blo	No. Blows	Σ Blows	Depth (mm)	PI mm/blo	DCP m/blow	No. Blows	Σ Blows	Depth (mm)	DCP mm/blo	PI mm/blo
25+100	0	0	9	error	0	2	54	196	3.63	16	2	109	423	11	3.88
	2	2	14	7.00	5	2	56	212	3.79	16	1	110	429	6	3.90
	2	4	15	3.75	1	2	58	227	3.91	15	1	111	436	7	3.93
	2	6	17	2.83	2	1	59	238	4.03	11	1	112	448	12	4.00
	3	9	22	2.44	5	3	62	248	4.00	10	1	113	457	9	4.04
	5	14	28	2.00	6	2	64	257	4.02	9	1	114	468	11	4.11
	1	15	32	2.13	4	1	65	269	4.14	12	1	115	479	11	4.17
	1	16	38	2.38	6	2	67	276	4.12	7	2	117	487	8	4.16
	2	18	45	2.50	7	2	69	288	4.17	12	2	119	495	8	4.16
	1	19	48	2.53	3	2	71	299	4.21	11	3	122	511	16	4.19
	2	21	56	2.67	8	3	74	310	4.19	11	3	125	525	14	4.20
	2	23	68	2.96	12	4	78	315	4.04	5	2	127	535	10	4.21
	1	24	76	3.17	8	2	80	324	4.05	9	2	129	548	13	4.25
	2	26	85	3.27	9	1	81	337	4.16	13	2	131	556	8	4.24
	1	27	90	3.33	5	1	82	345	4.21	8	1	132	564	8	4.27
	4	31	113	3.65	23	2	84	356	4.24	11	2	134	573	9	4.28
	3	34	125	3.68	12	3	87	365	4.20	9	3	137	580	7	4.23
	2	36	136	3.78	11	3	90	373	4.14	8	1	138	596	16	4.32
	2	38	145	3.82	9	3	93	379	4.08	6	2	140	609	13	4.35
	5	43	158	3.67	13	4	97	383	3.95	4	2	142	619	10	4.36
	4	47	165	3.51	7	4	101	389	3.85	6	3	145	628	9	4.33
	3	50	178	3.56	13	4	105	390	3.71	1	2	147	639	11	4.35
											1	**148**	**648**	4.38	9.0

DCP Test Calculated Result of Distressed Section, Chainage:25+100

Stat.	No. Blows	Σ Blows	Depth (mm)	PI mm/blo	DCP mm/blo	No. Blows	Σ Blow	Depth (mm)	PI mm/blo	blows	Σ Blows	Depth (mm)	PI mm/blo ws	DCP mm/blo
25+100	0	0	12	0	0	1	49	249	5.1	2	95	491	5.2	8.0
	2	2	15	7.5	3.0	2	51	256	5.0	2	97	501	5.2	10.0
	1	3	21	7.0	6.0	1	52	264	5.1	2	99	510	5.2	9.0
	2	5	26	5.2	5.0	1	53	272	5.1	1	100	519	5.2	9.0
	2	7	32	4.6	6.0	1	54	281	5.2	2	102	527	5.2	8.0
	1	8	38	4.8	6.0	1	55	289	5.3	2	104	536	5.2	9.0
	2	10	44	4.4	6.0	2	57	295	5.2	2	106	542	5.1	6.0
	2	12	50	4.2	6.0	1	58	306	5.3	1	107	549	5.1	7.0
	1	13	57	4.4	7.0	3	61	314	5.1	1	110	564	5.1	5.0
	2	15	61	4.1	4.0	1	62	321	5.2	1	111	573	5.2	10.0
	2	17	65	3.8	4.0	1	63	329	5.2	1	112	585	5.2	9.0
	1	18	69	3.8	4.0	2	65	334	5.1	1	113	592	5.2	12.0
	2	20	73	3.7	4.0	2	67	342	5.1	2	115	606	5.3	7.0
	2	22	78	3.5	5.0	2	69	347	5.0	2	**117**	**615**	5.3	14.0
	2	24	84	3.5	6.0	1	70	354	5.1	2				
	1	25	87	3.5	3.0	2	72	365	5.1	2				
	2	27	93	3.4	6.0	1	73	370	5.1	2				
	2	29	99	3.4	6.0	1	74	379	5.1	1				
	2	31	106	3.4	7.0	1	75	384	5.1	2				
	1	32	115	3.6	9.0	2	77	393	5.1	2				
	1	33	124	3.8	9.0	1	78	401	5.1	2				
	1	34	132	3.9	8.0	1	79	410	5.2	1				
	1	35	143	4.1	11.0	2	81	418	5.2	2				
	3	38	153	4.0	10.0	1	82	425	5.2	1				
	1	39	164	4.2	11.0	1	83	432	5.2	1				
	1	40	174	4.4	10.0	2	85	444	5.2	2				
	1	41	183	4.5	9.0	1	86	457	5.3	1				
	1	42	193	4.6	10.0	2	88	460	5.2	2				
	1	43	203	4.7	10.0	2	90	467	5.2	2				
	1	44	219	5.0	16.0	1	91	473	5.2	1				

APPENDEX-B DETAILS OF DCP UK.3.1 SOFTWARE RESULT

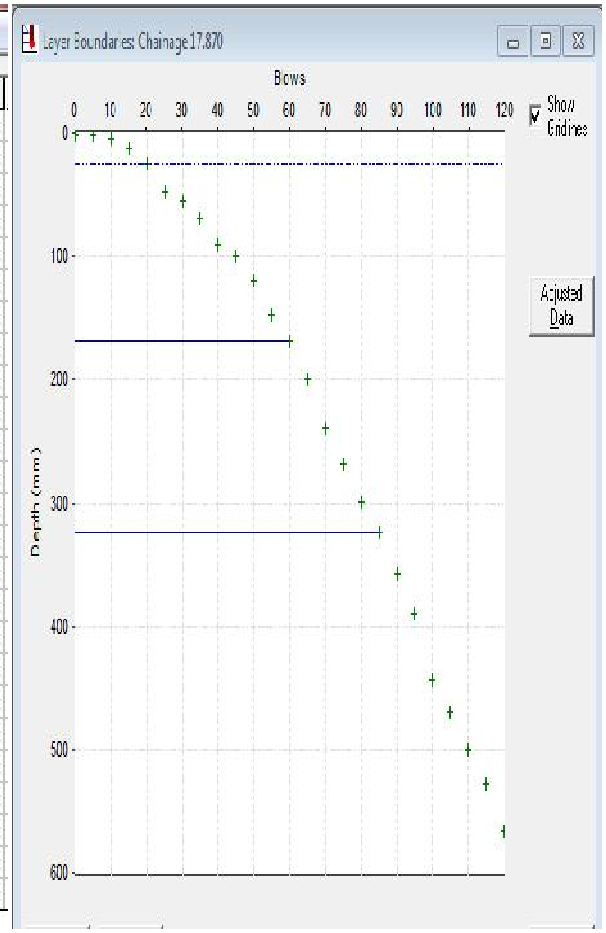
Test Method: DCP Test

Pavement Condition: Distressed areaChain age:17+870

Structural strength of pavement | Relationships of ∑blows vs. Penetration depth

File Modules Report Window Help

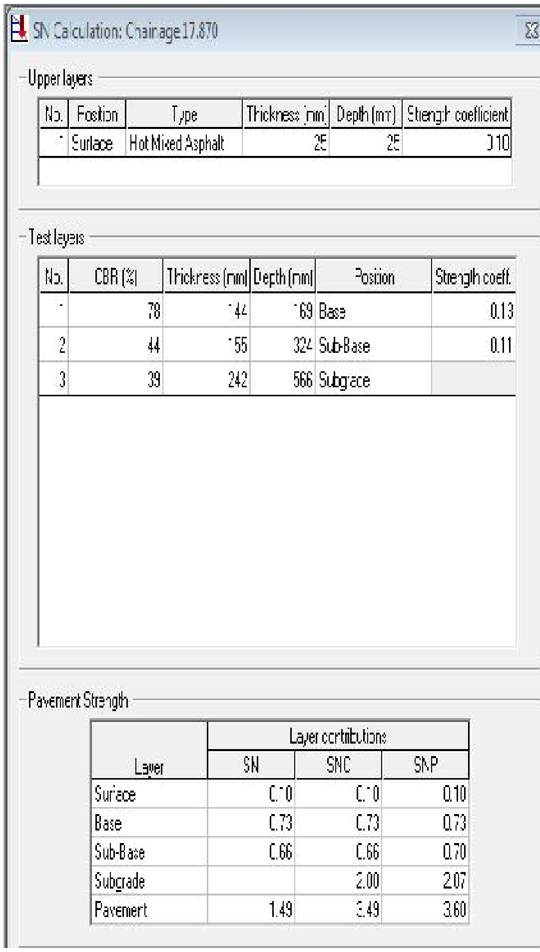
Point	Cum. Blows	Depth (mm)	Penetration Rate (mm/blow)
1	0	1	0.00
2	5	2	0.20
3	10	5	0.60
4	15	12	1.40
5	20	24	2.40
6	25	48	4.80
7	30	56	1.60
8	35	69	2.60
9	40	90	4.20
10	45	99	1.80
11	50	120	4.20
12	55	147	5.40
13	60	169	4.40
14	65	200	6.20
15	70	240	8.00
16	75	269	5.80
17	80	299	6.00
18	85	324	5.00
19	90	358	6.80
20	95	390	6.40
21	100	443	10.60
22	105	470	5.40
23	110	500	6.00
24	115	528	5.60
25	120	566	7.60



Test Method: DCP Test

Pavement Condition: Distressed areaChain age:17+870

Structural strength of pavement Relationships of CBR vs. Penetration depth



SN Calculation: Chainage 17.870

Upper layers

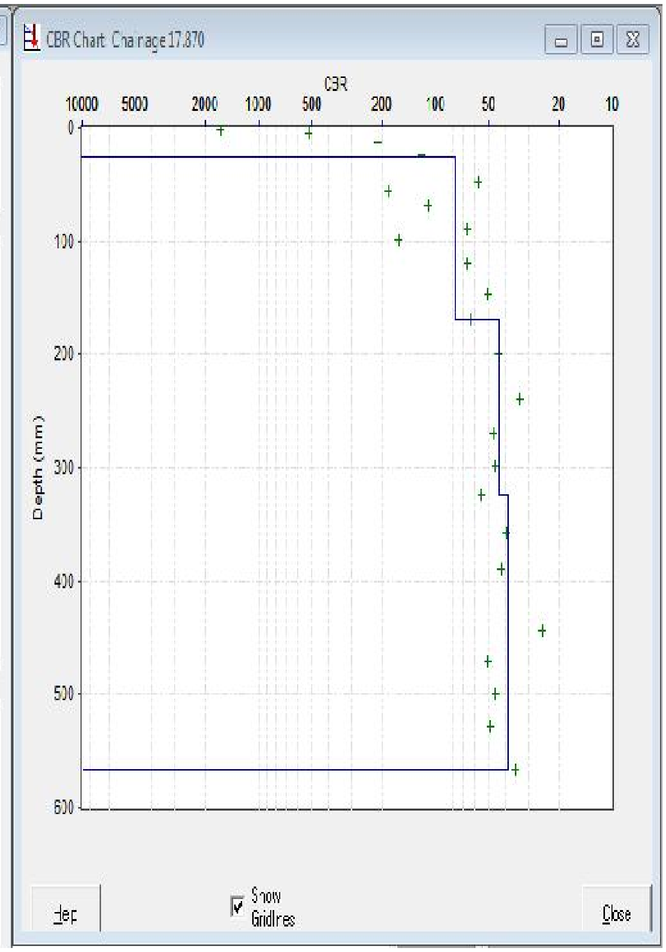
No.	Position	Type	Thickness (mm)	Depth (mm)	Strength coefficient
1	Surface	Hot Mixed Asphalt	25	25	0.10

Test layers

No.	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength coeff.
1	78	144	169	Base	0.13
2	44	155	324	Sub-Base	0.11
3	39	242	566	Subgrade	

Pavement Strength

Layer	Layer contributions		
	SN	SNC	SNP
Surface	0.10	0.10	0.10
Base	0.73	0.73	0.73
Sub-Base	0.66	0.66	0.70
Subgrade		2.00	2.07
Pavement	1.49	3.49	3.60



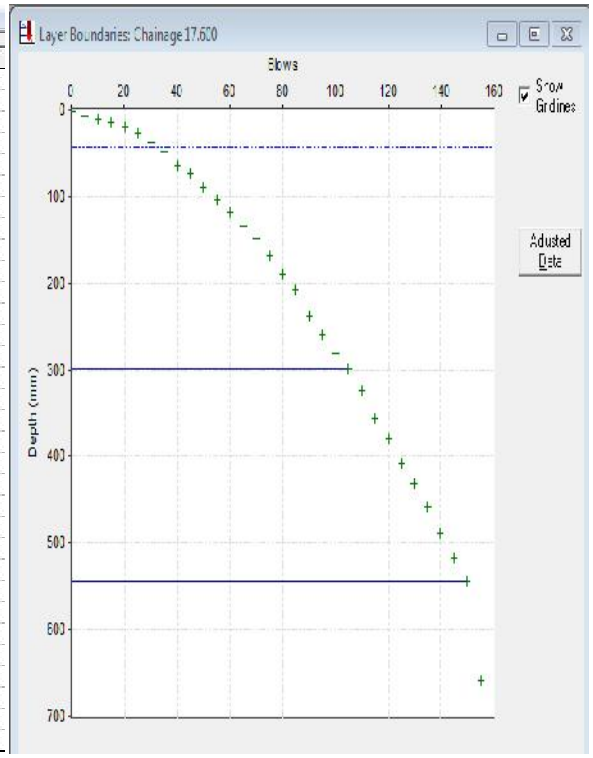
Test Method: DCP Test

Pavement Condition:Normal areaChain age:17+600

Structural strength of pavement properties Relationships of ∑blows vs. Penetration depth

File Modules Report Window Help

Point	Cum. Blows	Depth (mm)	Penetration Rate (mm/blow)
1	0	2	0.00
2	5	8	1.20
3	10	11	0.60
4	15	15	0.80
5	20	19	0.80
6	25	27	1.60
7	30	37	2.00
8	35	49	2.40
9	40	64	3.00
10	45	74	2.00
11	50	89	3.00
12	55	104	3.00
13	60	119	3.00
14	65	134	3.00
15	70	149	3.00
16	75	169	4.00
17	80	189	4.00
18	85	208	3.80
19	90	239	6.20
20	95	260	4.20
21	100	281	4.20
22	105	299	3.60
23	110	324	5.00
24	115	357	6.60
25	120	380	4.60
26	125	408	5.60
27	130	432	4.80
28	135	459	5.40
29	140	488	5.80
30	145	517	5.80
31	150	544	5.40
32	155	659	23.00



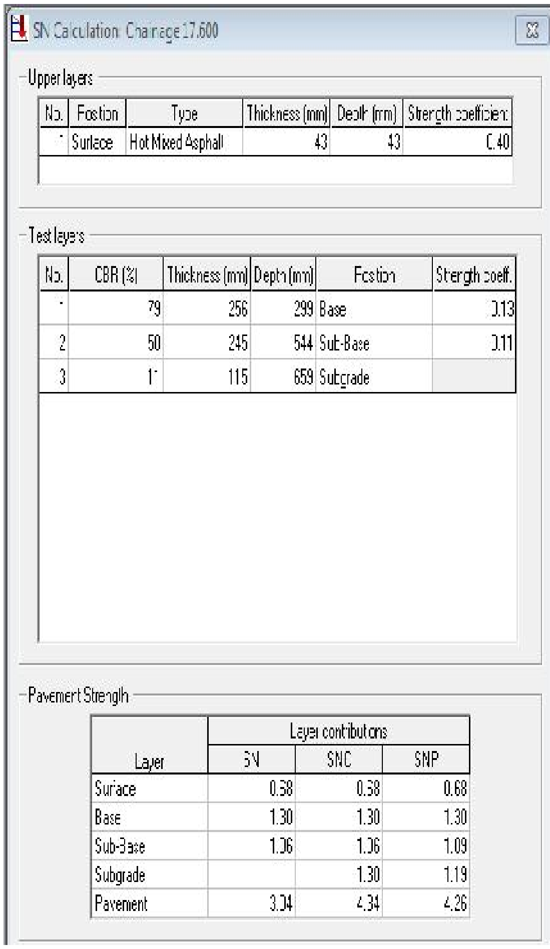
Test Method: DCP Test

Pavement Condition: Normal area

Chain age:17+600

Structural strength of pavement

Relationships of CBR vs. Penetration depth



SN Calculation: Chainage 17.600

Upper layers

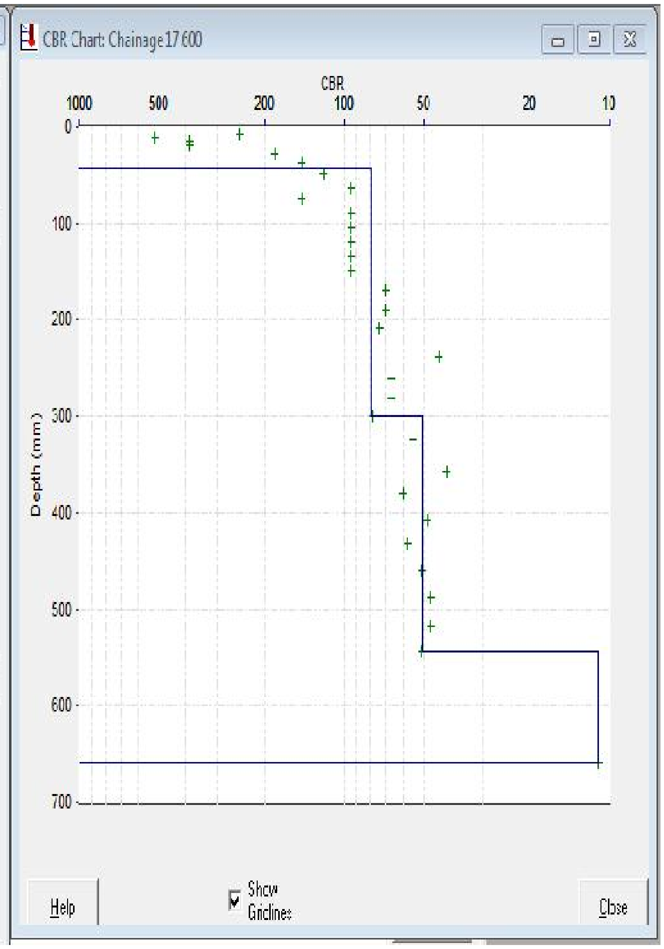
No.	Position	Type	Thickness (mm)	Depth (mm)	Strength coefficient
1	Surface	Hot Mixed Asphalt	43	43	0.40

Test layers

No.	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength coeff.
1	79	256	299	Base	0.13
2	50	245	544	Sub-Base	0.11
3	11	115	659	Subgrade	

Pavement Strength

Layer	Layer contributions		
	SN	SNC	SNP
Surface	0.68	0.68	0.68
Base	1.30	1.30	1.30
Sub-Base	1.06	1.06	1.09
Subgrade		1.30	1.19
Pavement	3.04	4.34	4.26



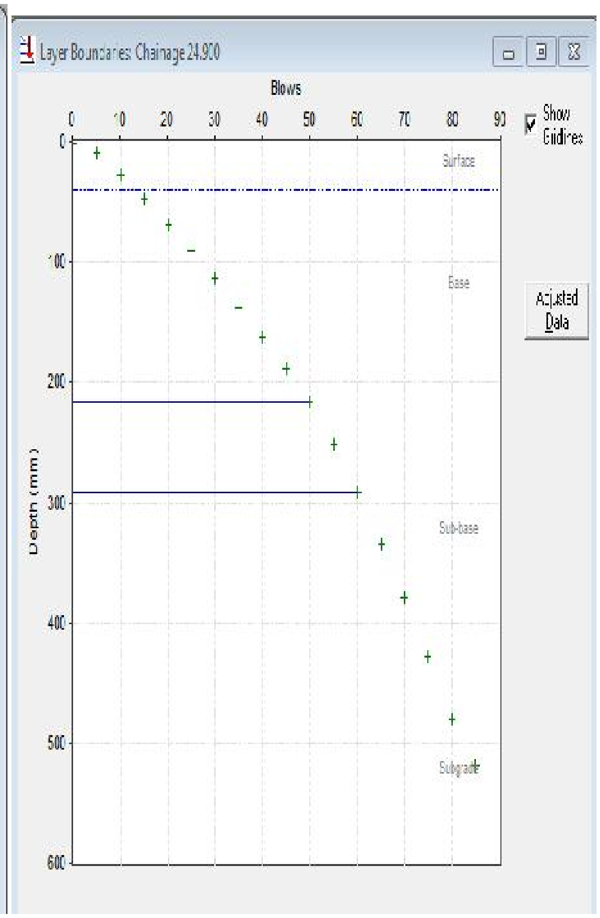
Test Method: DCP Test

Pavement Condition:Distressed area Chain age:24+900

Structural strength of pavement properties Relationships of ∑ blows vs. Penetration depth

Adjusted Penetration Data: Chainage 24.900

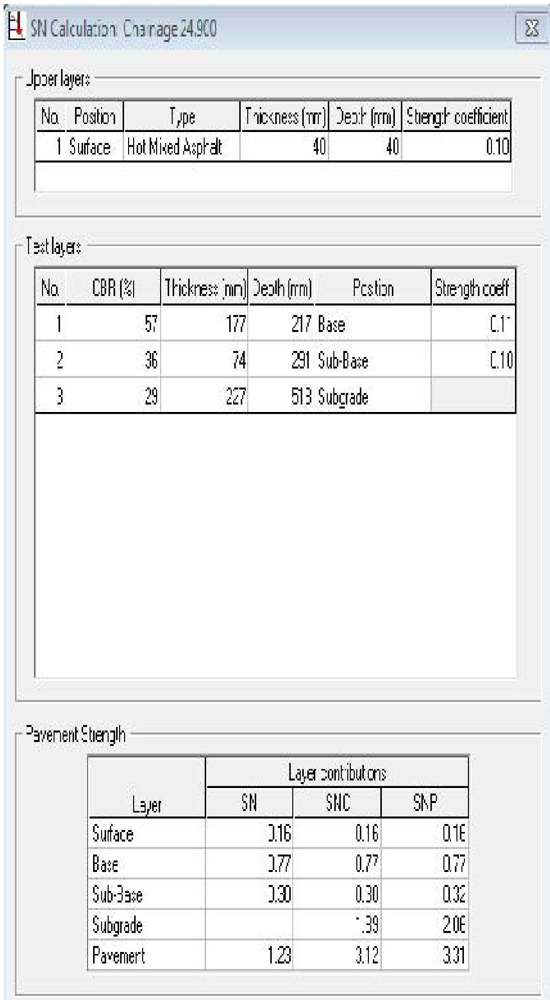
Point	Cum. Blows	Depth (mm)	Penetration Rate (mm/blow)
1	0	2	0.00
2	5	9	1.40
3	10	27	3.60
4	15	48	4.20
5	20	69	4.20
6	25	91	4.40
7	30	114	4.60
8	35	138	4.80
9	40	163	5.00
10	45	189	5.20
11	50	217	5.60
12	55	252	7.00
13	60	291	7.80
14	65	334	8.60
15	70	379	9.00
16	75	428	9.80
17	80	481	10.60
18	85	518	7.40



Test Method: DCP Test

Pavement Condition: Distressed areaChain age:24+900

Structural strength of pavement Relationships of CBR vs. Penetration depth



SN Calculation: Chainage 24.900

Upper layers

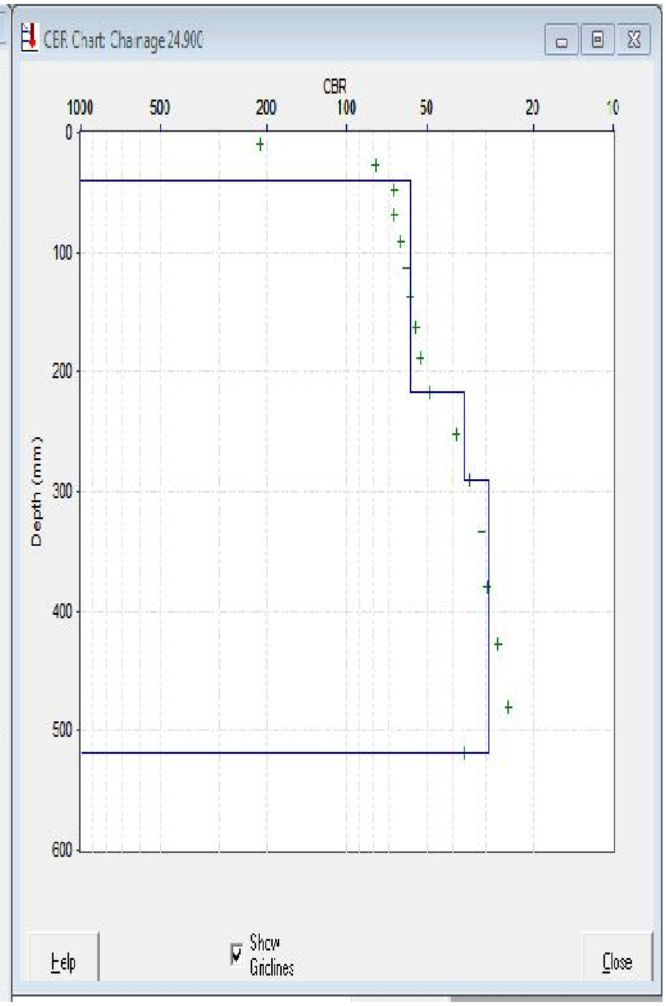
No.	Position	Type	Thickness (mm)	Depth (mm)	Strength coefficient
1	Surface	Hot Mixed Asphalt	40	40	0.10

Test layers

No.	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength coeff
1	57	177	217	Base	0.1
2	36	74	291	Sub-Base	0.10
3	29	227	513	Subgrade	

Pavement Strength

Layer	Layer contributions		
	SN	SNC	SNP
Surface	0.16	0.16	0.16
Base	0.77	0.77	0.77
Sub-Base	0.30	0.30	0.32
Subgrade		1.39	2.06
Pavement	1.23	3.12	3.31



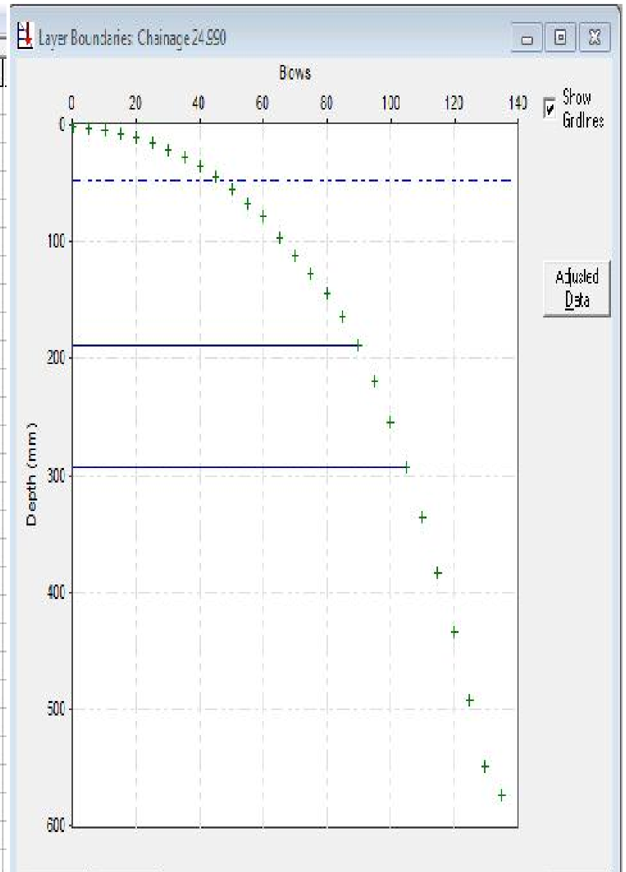
Test Method: DCP Test

Pavement Condition:Normal area Chain age:24+990

Structural strength of pavement properties Relationships of ∑ blows vs.Penetration depth

File Modules Report Window Help

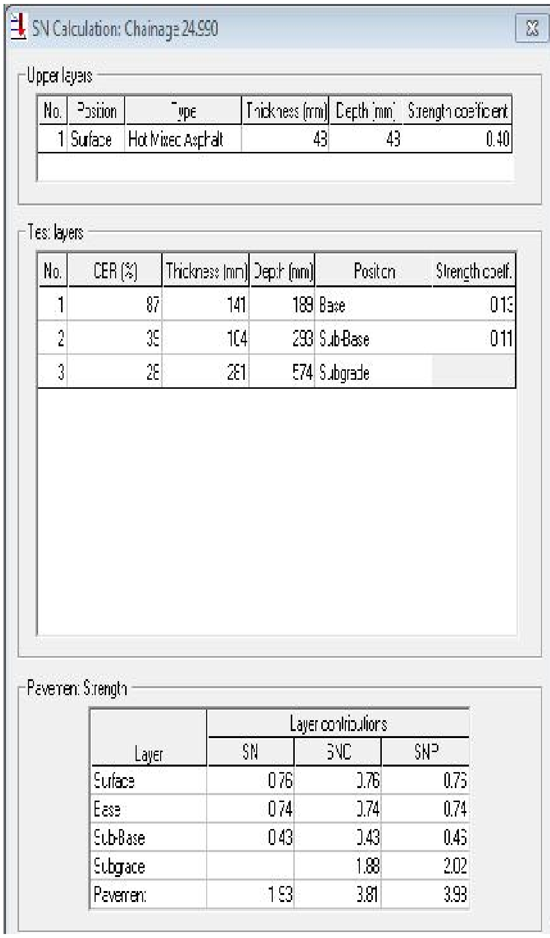
Point	Cum. Blows	Depth (mm)	Penetration Rate (mm/blow)
1	0	1	0.00
2	5	3	0.40
3	10	5	0.40
4	15	7	0.40
5	20	11	0.80
6	25	16	1.00
7	30	21	1.00
8	35	27	1.20
9	40	36	1.80
10	45	45	1.80
11	50	56	2.20
12	55	67	2.20
13	60	79	2.40
14	65	97	3.60
15	70	112	3.00
16	75	128	3.20
17	80	145	3.40
18	85	164	3.80
19	90	189	5.00
20	95	219	6.00
21	100	255	7.20
22	105	293	7.60
23	110	336	8.60
24	115	384	9.60
25	120	434	10.00
26	125	492	11.60
27	130	550	11.60
28	135	574	4.80



Test Method: DCP Test

Pavement Condition: Normal area Chain age:24+990

Structural strength of pavement Relationships of CBR vs. Penetration depth



SN Calculation: Chainage 24.990

Upper layers

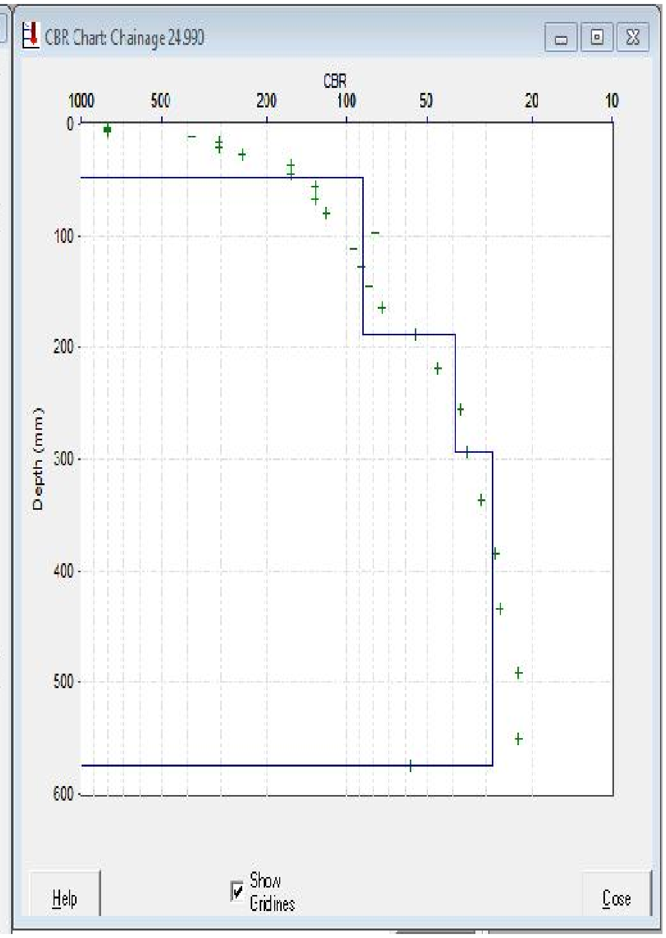
No.	Position	Type	Thickness (mm)	Depth (mm)	Strength coefficient
1	Surface	Hot Mixed Asphalt	43	43	0.40

Test layers

No.	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength coelf.
1	87	141	189	Base	0.13
2	39	104	293	Sub-Base	0.11
3	28	281	574	Subgrade	

Pavement Strength

Layer	Layer contributions		
	SN	SNC	SNP
Surface	0.76	0.76	0.73
Base	0.74	0.74	0.74
Sub-Base	0.43	0.43	0.45
Subgrade		1.88	2.02
Pavement	1.93	3.81	3.93



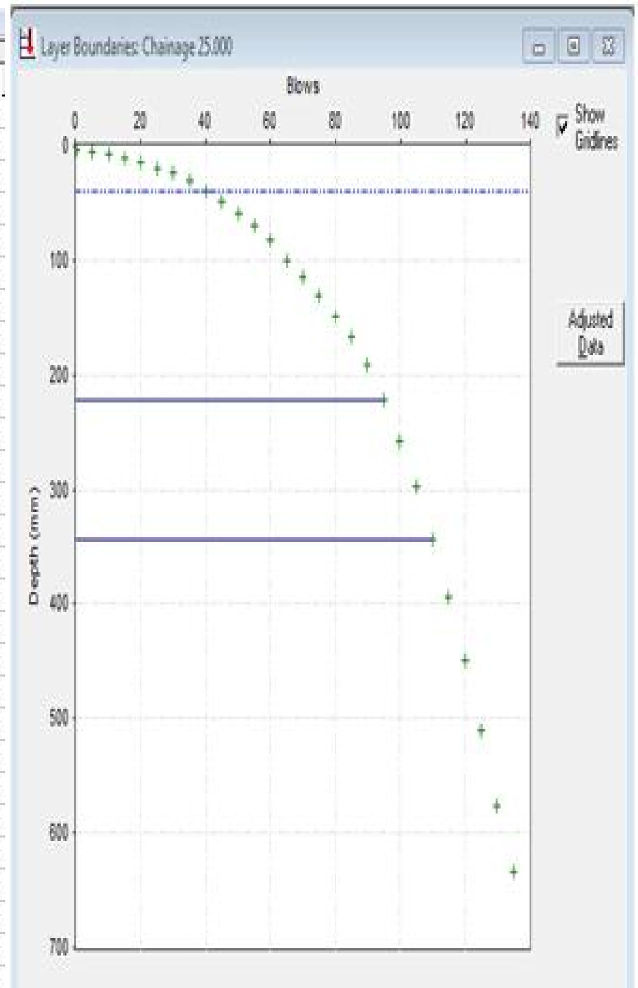
Test Method: DCP Test

Pavement Condition: Normal area Chain age:25+00

Structural strength of pavement properties Relationships of ∑blows vs.Penetration depth

File Modules Report Window Help

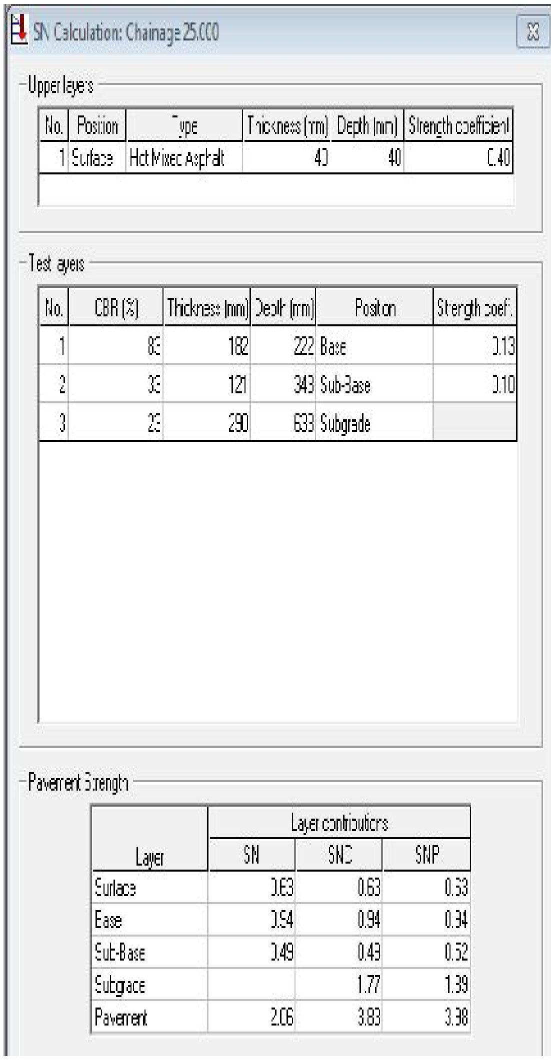
Point	Cum. Blows	Depth (mm)	Penetration Rate (mm/blow)
1	0	4	0.00
2	5	6	0.40
3	10	8	0.40
4	15	10	0.40
5	20	14	0.80
6	25	19	1.00
7	30	24	1.00
8	35	30	1.20
9	40	39	1.80
10	45	48	1.80
11	50	59	2.20
12	55	70	2.20
13	60	82	2.40
14	65	100	3.60
15	70	115	3.00
16	75	131	3.20
17	80	148	3.40
18	85	167	3.80
19	90	192	5.00
20	95	222	6.00
21	100	258	7.20
22	105	298	8.00
23	110	343	9.00
24	115	394	10.20
25	120	449	11.00
26	125	510	12.20
27	130	577	13.40
28	135	633	11.20



Test Method: DCP Test Chainage:25+00

Pavement Condition: Normalarea

Structural strength of pavement Relationships of CBR vs. Penetration depth



SN Calculation: Chainage 25.000

Upper layers

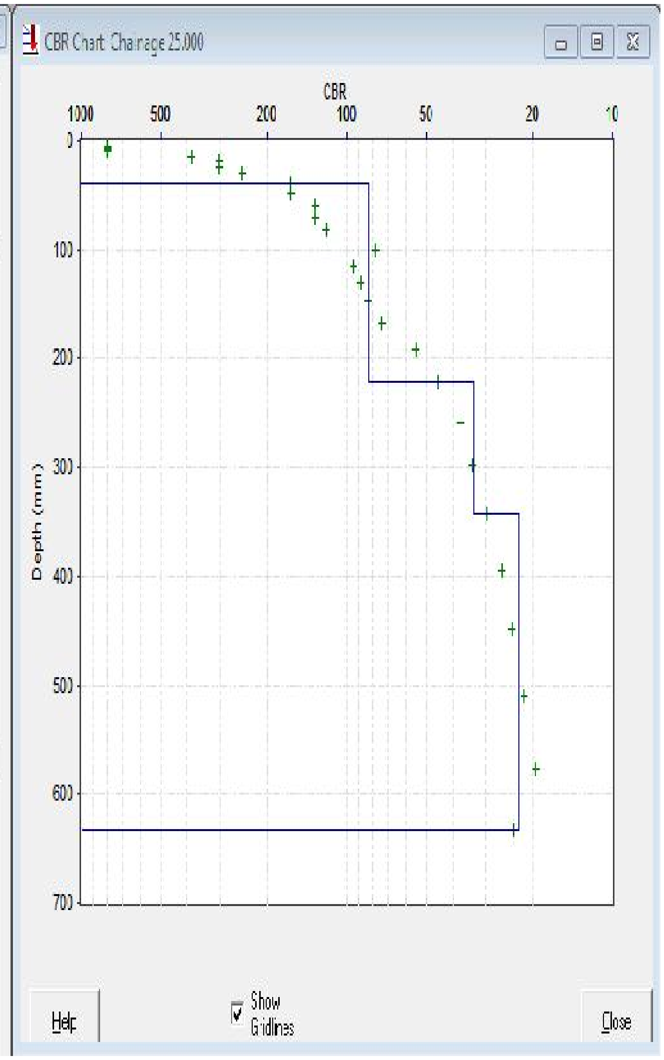
No.	Position	Type	Thickness (mm)	Depth (mm)	Strength coefficient
1	Surface	Hot Mixed Asphalt	40	40	0.40

Test layers

No.	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength coef.
1	83	182	222	Base	0.13
2	33	121	343	Sub-Base	0.10
3	23	290	633	Subgrade	

Pavement Strength

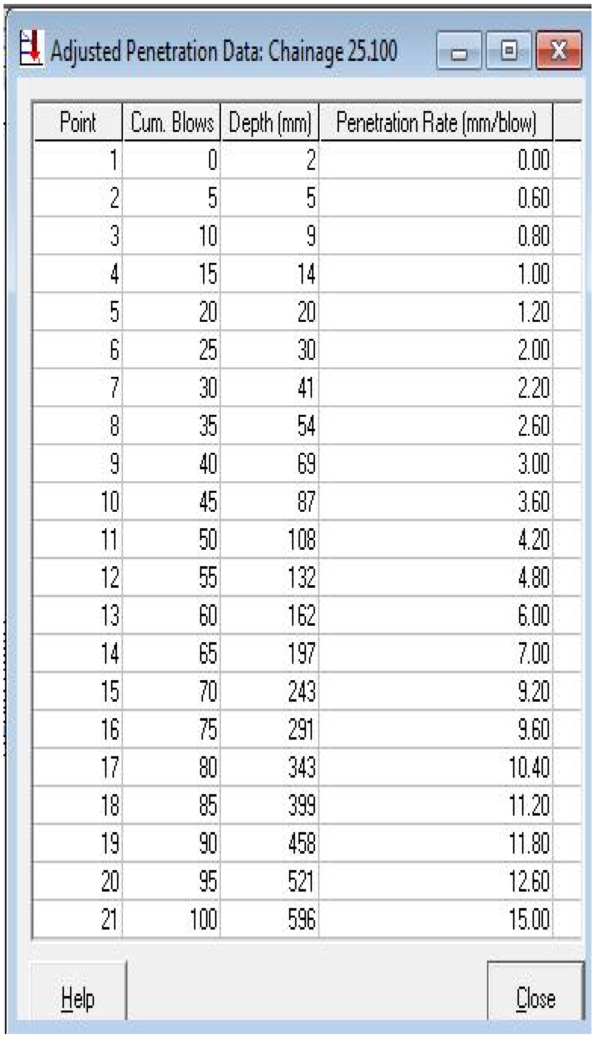
Layer	Layer contributions		
	SN	SNC	SNP
Surface	0.63	0.63	0.63
Base	0.94	0.94	0.94
Sub-Base	0.49	0.49	0.52
Subgrade		1.77	1.39
Pavement	2.06	3.83	3.38



Test Method: DCP Test

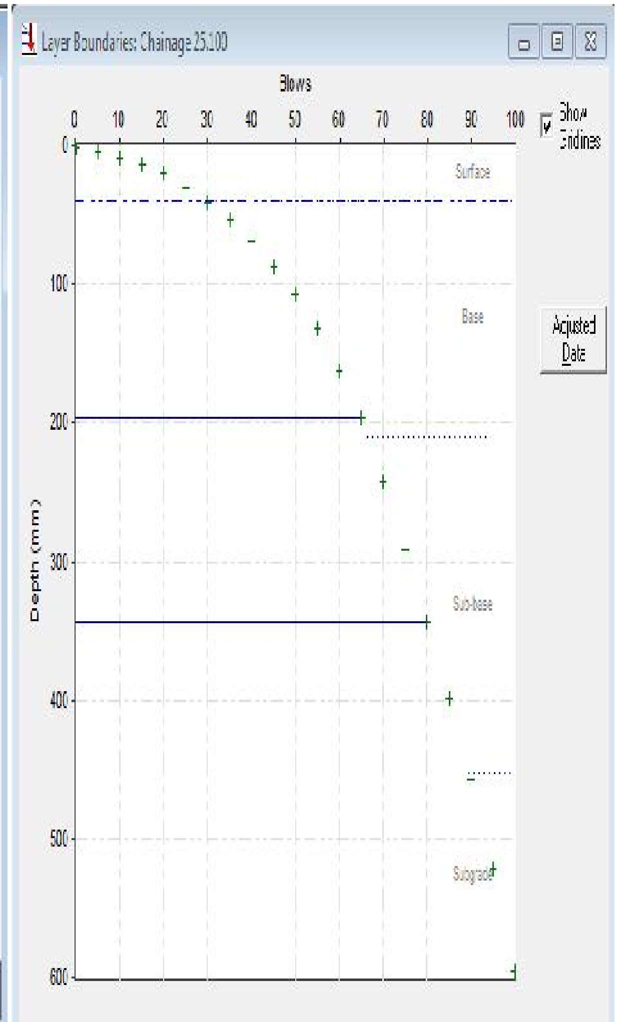
Pavement Condition: Distressed areaChain age:25+100

Structural strength of pavement properties Relationships of ∑blows vs. Penetration depth


Adjusted Penetration Data: Chainage 25.100

Point	Cum. Blows	Depth (mm)	Penetration Rate (mm/blow)
1	0	2	0.00
2	5	5	0.60
3	10	9	0.80
4	15	14	1.00
5	20	20	1.20
6	25	30	2.00
7	30	41	2.20
8	35	54	2.60
9	40	69	3.00
10	45	87	3.60
11	50	108	4.20
12	55	132	4.80
13	60	162	6.00
14	65	197	7.00
15	70	243	9.20
16	75	291	9.60
17	80	343	10.40
18	85	399	11.20
19	90	458	11.80
20	95	521	12.60
21	100	596	15.00

Help Close



Test Method: DCP Test

Pavement Condition:Normal Area Chain age:25+00

Structural strength of Pavement Relationships of CBR vs. cumulative depth

SN Calculation: Chainage 25.100

Upper layers

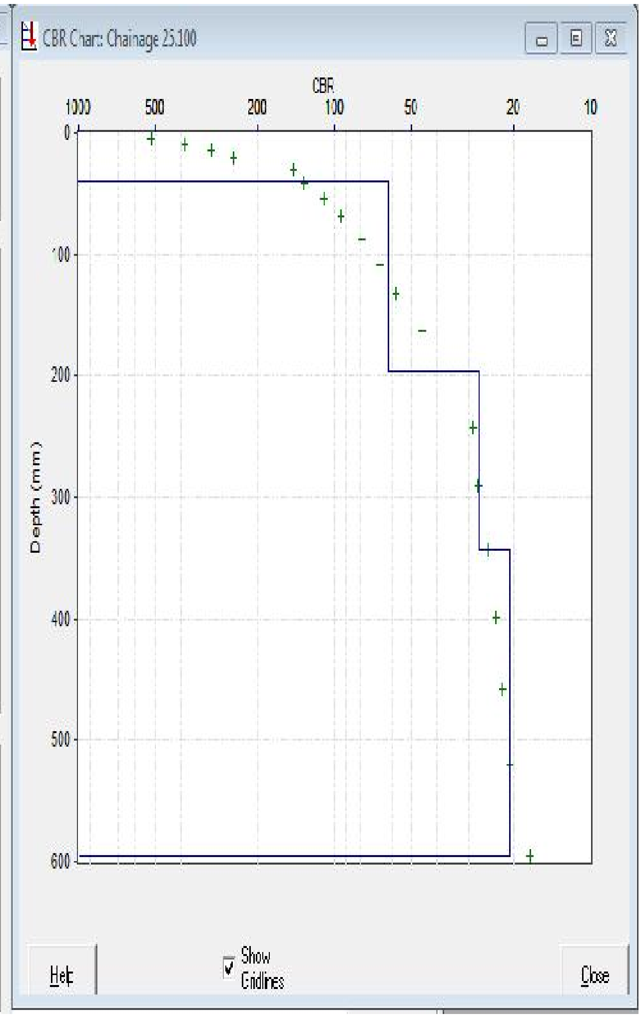
No.	Position	Type	Thickness (mm)	Depth (mm)	Strength coefficient
1	Surface	Hot Mixed Asphalt	40	40	0.10

Test layers

No.	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength coeff
1	62	157	157	Base	0.12
2	27	146	343	Sub-Base	0.10
3	21	253	596	Subgrade	

Pavement Strength

Layer	Layer contributors		
	SN	SNC	SNP
Surface	0.13	0.13	0.13
Base	0.71	0.71	0.71
Sub-Base	0.59	0.59	0.60
Subgrade		1.72	1.73
Pavement	1.43	3.15	3.25



APPENDIX-C COMPACTION TEST

Proctor Test for Sub grade soil, Chainage 18+850

Trial No.	1	2	3	4	5
Weight of Mold + Wet Soil (g) =m1	4370.9	4423.2	4473.9	4570.3	4508.3
Weight of Mold (g) =wmol	2994.2	2994.2	2994.2	2994.2	2994.2
Weight of wet Soil (gm) =m2	1376.7	1429	1479.7	1576.1	1514.1
Volume of Mold (cc)	1005	1005	1005	1005	1005
Wet density (g/cm3)= γwet	1.37	1.42	1.47	1.57	1.51
Moisture Content determination					
No. of blows/layer=25					
Moisture can	21	11	8	121	14
Weight of wet soil +cont. (g)=m3	172.5	167.3	178	177.6	169.9
Weight of Dry Soil + Cont.(g) =m4	158.1	151.3	159.3	156.5	147.3
Weight of Container (g) =wcont	34.4	34.2	34.8	34.7	35.8
Weight of water (moisture) (g) =ww	14.4	16	18.7	21.1	22.6
Weight of Dry Soil (g) ws=m4-wcon	123.7	117.1	124.5	121.8	111.5
Moisture Content (%)= w	11.6	13.7	15.0	17.3	20.27
Dry density (g/cm$^{3)}$	1.23	1.25	1.28	1.30	1.25
w (%)	11.6	13.66	15.02	17.32	20.27
γ_{dry} g/cm3)	1.23	1.25	1.28	1.30	1.25

Proctor Test for Sub-base soil, Chainage 18+850

Trial No.	1	2	3	4	5
Weight of Mold + Wet Soil (g)	11019.2	11154.4	11180	11289.4	11237.4
Weight of Mold (g)	6250.2	6250.2	6250.2	6250.2	6250.6
Weight of wet Soil (gm)	4769	4904.2	4929.3	5039.2	4986.8
Volume of Mold (cc)	2123	2123	2123	2123	2123
Wet density (g/cm3	2.25	2.31	2.32	2.37	2.35
Moisture Content determination					NMC
Moisture can	21	11	8	121	BN
Weight of wet soil +cont. (g)	243.9	232	213	203.5	188.1
Weight of Dry Soil + Cont.(g)	231.4	218.5	199	188.8	180.3
Weight of Container (g)	34.4	36.5	34.2	34.7	33.2
Weight of water (moisture) (g)	12.5	13.5	14	14.7	7.8
Weight of Dry Soil (g)	197	182	164.8	154.1	147.1
Moisture Content (%)	6.3	7.4	8.5	9.5	11.9
Dry density(g/cm^3) =γ_{dry}	2.11	2.15	2.14	2.17	2.10

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Proctor Test for Base course Chainage 18+850

Trial No.	1	2	3	4	
Weight of Mold + Wet Soil (g)	11229	11329.1	11446	11395.1	
Weight of Mold (g)	6250.6	6250.6	6250.6	6250.6	
Weight of wet Soil (gm)	4978	5078.5	5195.5	5144.5	
Volume of Mold (cc)	2123	2123	2123	2123	
Wet density (g/cm3)= γwet	2.34	2.39	2.45	2.42	
Moisture Content determination					NMC
Moisture can	25	17	14	141	BN
Weight of wet soil +cont. (g)	226.2	246.1	257.6	226.1	696
Weight of Dry Soil + Cont.(g)	218.7	235	243.6	213.2	688.2
Weight of Container (g)	32.8	33.4	35.8	37.7	74.3
Weight of water (moisture) (g)	7.5	11.1	14	12.9	7.8
Weight of Dry Soil (g)	185.9	201.6	207.8	175.5	613.9
Moisture Content (%)	4.0	5.5	6.7	7.4	1.27
Dry density (g/cm$^{3)}$	2.25	2.27	2.29	2.26	
$\gamma_{dry\ (g/cm3)}$	2.25	2.27	2.29	2.26	2.25
w (%)	4.0	5.5	6.7	7.4	4.0

Proctor Tes for Sub grade Soil, Chainage 19+300

Trial No.	1	2	3	4	
Weight of Mold + Wet Soil (g)=m1	11199.2	11523.1	11599	11587.9	
Weight of Mold (g) =wmol	6250.2	6250.2	6250.2	6240.2	
Weight of wet Soil (gm) =m2	4949	5272.9	5348.3	5347.7	
Volume of Mold (cc)	2123	2123	2123	2123	
Wet density (g/cm3)= γwet	2.33	2.48	2.52	2.52	
Moisture Content determination					NMC
Moisture can	24	13	26	34	BN
Weight of wet soil +cont. (g)=m3	249.7	268.8	290	276.4	680
Weight of Dry Soil + Cont.(g) =m4	231.9	243.9	256.9	242.5	673
Weight of Container (g) =wcont	34.4	36.5	34.2	34.7	74.3
Weight of water (moisture) (g) =ww	17.8	24.9	33.1	33.9	7
Weight of Dry Soil (g) ws=m4-wcon	197.5	207.4	222.7	207.8	606
Moisture Content (%)= w	9.0	12.0	14.9	16.3	1.23
Dry density (g/cm$^{3)}$	2.14	2.22	2.19	2.17	
$\gamma_{dry\ (g/cm3)}$	2.14	2.22	2.19	2.17	2.24
w (%)	9.0	12.0	14.9	16.3	7.6

Proctor Test for Sub base soil, Chainage 19+300

Trial No.	1	2	3	4	5	
Weight of Mold + Wet Soil (g)=m1	4790.9	4873.6	5109	5109.3	4903.7	
Weight of Mold (g) =wmol	2994.2	2994.2	2994.2	2994.2	2994.2	
Weight of wet Soil (gm) =m2	1796.7	1879.4	2114.8	2115.1	1909.5	
Volume of Mold (cc)	1005	1005	1005	1005	1005	
Wet density (g/cm3)= γwet	1.79	1.87	2.10	2.10	1.90	
Moisture Content determination						NMC
Moisture can	21	11	8	121	14	
Weight of wet soil +cont. (g)=m3	163.5	168.3	178	218	222.9	442.4
Weight of Dry Soil + Cont.(g) =m4	151.9	155.3	163	194.9	196.3	413.9
Weight of Container (g) =wcont	34.4	34.2	34.8	34.3	34.5	74.4
Weight of water (moisture) (g) =ww	11.6	13	15	23.1	26.6	28.5
Weight of Dry Soil (g) ws=m4-wcon	117.5	121.1	128.2	160.6	161.8	339.5
Moisture Content (%)= w	9.9	10.7	11.7	14.4	16.4	8.39
Dry density (g/cm$^{3)}$	1.63	1.69	1.88	1.84	1.63	
γ_{dry}	1.63	1.69	1.88	1.84	1.63	
w	9.9	10.7	11.7	14.4	16.4	

Proctor Test for Base course, Chainage 19+300

Trial No.3	**1**	**2**	**3**	**4**	**5**
Weight of Mold + Wet Soil (g)=m1	11287.9	11429.2	11786	11625.8	
Weight of Mold (g) =wmol	6250.6	6250.6	6250.6	6250.6	
Weight of wet Soil (gm) =m2	5037	5178.6	5535.8	5375.2	
Volume of Mold (cc)	2123	2123	2123	2123	
Wet density (g/cm3)= γwet	2.37	2.44	2.61	2.53	
Moisture content					NMC
Moisture can	25	17	14	141	BN
Weight of wet soil +cont. (g)=m3	232.4	251.6	269.5	233.1	597.3
Weight of Dry Soil + Cont.(g) =m4	219.6	235	244.6	209.6	583.7
Weight of Container (g) =wcont	32.8	33.4	35.8	37.7	74.3
Weight of water (moisture) (g) =ww	12.8	16.6	24.9	23.5	13.6
Weight of Dry Soil (g) ws=m4-wcon	186.8	201.6	208.8	171.9	509.4
Moisture Content (%)= w	6.9	8.2	11.9	13.7	2.67
Dry density (g/cm$^{3)}$	2.22	2.25	2.33	2.23	
γ_{dry}	2.22	2.25	2.33	2.23	
w	6.9	8.2	11.9	13.7	

Proctor Test for Sub grade Soil,Normal section, Chainage 26+00

Trial No.	1	2	3	4	5
Weight of Mold + Wet Soil (g)=m1	11524.3	11779.7	11884	11927.6	
Weight of Mold (g) =wmol	6250.6	6250.6	6250.6	6250.6	
Weight of wet Soil (gm) =m2	5274	5529.1	5633.3	5677	
Volume of Mold (cc)	2123	2123	2123	2123	
Wet density (g/cm3)= γwet	2.48	2.60	2.65	2.67	
Moisture content					NMC
Moisture can	25	17	14	141	BN
Weight of wet soil +cont. (g)=m3	248.2	266.8	277.5	246.4	745
Weight of Dry Soil + Cont.(g) =m4	222.7	235	238	209.3	715.2
Weight of Container (g) =wcont	32.8	33.4	35.8	37.7	74.3
Weight of water (moisture) (g) =ww	25.5	31.8	39.5	37.1	29.8
Weight of Dry Soil (g) ws=m4-wcon	189.9	201.6	202.2	171.6	640.9
Moisture Content (%)= w	13.4	15.8	19.5	21.6	4.65
Dry density (g/cm$^{3)}$	2.19	2.25	2.22	2.20	
γ_{dry}	2.19	2.25	2.22	2.20	

Proctor Test for Sub base soil, Chainage 26+00

Trial No.	1	2	3	4	5
Weight of Mold + Wet Soil (g)=m1	11127	11197.8	11487	11443.3	
Weight of Mold (g) =wmol	6250.6	6250.6	6250.6	6250.6	
Weight of wet Soil (gm) =m2	4876	4947.2	5235.9	5192.7	
Volume of Mold (cc)	2123	2123	2123	2123	
Wet density (g/cm3)= γwet	2.30	2.33	2.47	2.45	
Moisture content					NMC
Moisture can	25	17	14	141	BN
Weight of wet soil +cont. (g)=m3	222.2	236.1	247.6	239.1	696
Weight of Dry Soil + Cont.(g) =m4	208.7	220.1	223.6	214.2	688.2
Weight of Container (g) =wcont	32.8	33.4	35.8	37.7	74.3
Weight of water (moisture) (g) =ww	13.5	16	24	24.9	7.8
Weight of Dry Soil (g) ws=m4-wcon	175.9	186.7	187.8	176.5	613.9
Moisture Content (%)= w	7.7	8.6	12.8	14.1	6.27
Dry density (g/cm$^{3)}$	2.13	2.15	2.19	2.14	
γ_{dry}	2.13	2.15	2.19	2.14	
w	7.7	8.6	12.8	14.1	

Proctor .st for Base course ,Chainage 26+00

Trial No.	1	2	3	4	5
Weight of Mold + Wet Soil (g) =m1	11426.6	11527.9	11643	11690.5	
Weight of Mold (g) =wmol	6250.6	6250.6	6250.6	6250.6	
Weight of wet Soil (gm) =m2	5176	5277.3	5392.5	5439.9	
Volume of Mold (cc)	2123	2123	2123	2123	
Wet density (g/cm3)= γwet	2.44	2.49	2.54	2.56	
Moisture content					NMC
Moisture can	25	17	14	141	BN
Weight of wet soil +cont. (g)=m3	246.2	266.1	277.6	246.1	766
Weight of Dry Soil + Cont.(g) =m4	218.7	235	243.6	213.2	688.2
Weight of Container (g) =wcont	32.8	33.4	35.8	37.7	74.3
Weight of water (moisture) (g) =ww	27.5	31.1	34	32.9	77.8
Weight of Dry Soil (g) ws=m4-wcon	185.9	201.6	207.8	175.5	613.9
Moisture Content (%)= w	14.8	15.4	16.4	18.7	12.67
Dry density (g/cm$^{3)}$	2.12	2.15	2.18	2.16	
γ_{dry}	2.12	2.15	2.18	2.16	
w	14.8	15.4	16.4	18.7	

APPENDIX-D LIQUID LIMIT AND PLASTICITY INDEX ANALYSIS

Plastic Index for sub grade Soil, Chainage 18+850

Representative sample	No 3				
	Liquid Limit (LL)			Plastic Limit	
No of blows	35	25	17		
Container number	A-66	100	AR	O2	O4
Weight of wet Soil +Tare (gm)	48.3	56	62.3	15.3	16
Weight of Dry Soil + Tare (gm)	44.3	46.5	49.4	14.3	15.5
Weight of water (gm)	4	9.5	12.9	1	0.5
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	23.8	26.1	29.1	3.1	5.5
Water Content %	16.81	36.40	44.33	32.26	9.09
LL at 25 blows & Avg. PL		32.51		20.67	
PI = LL-PL=32.51-20.67=11.81%					

Plastic Index for Sub base Soil, Chainage 18+850

Representative sample	No 2				
	Liquid Limit (LL)			Plastic Limit (PL)	
No of blows	32	23	18		
Container number	A-66	100	AR	O2	O4
Weight of wet Soil +Tare (gm)	41.6	43	44	15.2	13.8
Weight of Dry Soil + Tare (gm)	36.5	37.2	37.7	14.3	13.1
Weight of water (gm)	5.1	5.8	6.3	0.9	0.7
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	16	16.8	17.4	3.1	3.1
Water Content %	31.88	34.52	36.21	29.03	22.58
Average Liquid Limit		34.20		Av. Plastic Limit	25.81
LL at 25 blows & Avg. PL		34.20		25.81	
PI = LL-PL=34.2-25.81=8.4%					

Plastic Index for Sub grade Soil,at distressed section, Chainage 19+300

Representative sample	**No:3**				
	Liquid Limit (LL)			Plastic Limit (PL)	
No of blows	35	25	17		
Container number	A-66	100	AR	O2	O4
Weight of wet Soil +Tare (gm)	45.6	46	50.5	18.4	18.6
Weight of Dry Soil + Tare (gm)	42.6	40.4	41.6	17.7	17.9
Weight of water (gm)	3	5.6	8.9	0.7	0.7
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	22.1	20	21.3	6.5	7.9
Water Content %	13.57	28.00	41.78	10.77	8.86
LL at 25 blows & Avg. PL (%)		27.79			9.81
PI = LL-PL=27.79-9.81=17.97%					

Plastic Index for Sub-base Soil, Chainage 19+300

Representative sample	No:1	Chain age		19+300	
Test Type	Plastic Index				
Pavement layer	Sub base				
	Liquid Limit (LL)			Plastic Limit (PL)	
No of blows	32	23	18		
Container number	A-66	100	AR	O2	O4
Weight of wet Soil +Tare (gm)	45.4	43.8	53.5	19.4	18.9
Weight of Dry Soil + Tare (gm)	40.6	38.9	46.3	18.2	17.5
Weight of water (gm)	4.8	4.9	7.2	1.2	1.4
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	20.1	18.5	26	7	7.5
Water Content %	23.88	26.49	27.69	17.14	18.67
LL at 25 blows & Avg.PL		26.02			17.90
PI = LL-PL=26.02-17.9=8.1%					

Plastic Index for Sub-grade Soil, Chainage 24+00

Representative sample	No:3		Chain age		24+00
Test Type	Plastic Index				
Pavement layer	Sub grade				
	Liquid Limit (LL)		Plastic Limit (PL)		
No of blows	35	25	17		
Container number	A-66	100	AR	O2	o4
Weight of wet Soil +Tare (gm)	55.6	48	58.4	18.4	17.7
Weight of Dry Soil + Tare (gm)	50.3	40.6	44.4	16.5	16.6
Weight of water (gm)	5.3	7.4	14	1.9	1.1
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	29.8	20.2	24.1	5.3	6.6
Water Content %	17.79	36.63	58.09	35.85	16.6
LL at 25 blows & Avg. PL		37.50		26.26	
PI = LL-PL=37.5-26.26=11.25%					

Plastic Index for Sub-base Soil,Distressed section,Chainage 24+00

Location	Dembi-Bedele	Chain age		24+00	
Representative sample	No:1	Pavement layer		Sub base	
Test Type	Plastic Index				
	Liquid Limit (LL)			Plastic Limit (PL)	
No of blows	32	23	18		
Container number	A-66	100	AR	O2	O4
Weight of wet Soil +Tare (gm)	64	58.6	57.5	19.4	18.9
Weight of Dry Soil + Tare (gm)	63.5	48.4	44.6	18.1	17.8
Weight of water (gm)	0.5	10.2	12.9	1.3	1.1
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	43	28	24.3	6.9	7.8
Water Content %	1.16	36.43	53.09	18.84	14.10
LL at 25 blows & Avg. PL		30.23			16.47
PI = LL-PL=30.23-16.47=13.8%					

Plastic Index for Sub-grade Soil, Chainage 26+00

Sampling Station		Chain age		26+00	
Representative sample	No:2	Pavement layer		sub grade	
Test Type	Plastic Index				
	Liquid Limit (LL)			Plastic Limit(PL)	
No of blows	35	25	17		
Container number	A-66	100	AR	O2	o4
Weight of wet Soil +Tare (gm)	50.4	59.6	57	20.4	19.5
Weight of Dry Soil + Tare (gm)	44	48.7	44.4	18.2	18.2
Weight of water (gm)	6.4	10.9	12.6	2.2	1.3
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	23.5	28.3	24.1	7	8.2
Water Content %	27.23	38.52	52.28	31.43	15.8
LL at 25 blows & Avg. PL		39.34		23.64	
PI=LL-PL=39.34-23.64=15.7%					

Table 4. 7 Plastic Index for Sub-base Soil, Chainage 26+00

Representative sample	No:3	Chain age		26+00	
Test Type	Plastic Index	Location	Dembi-Bedele		
Pavement layer	Sub base				
	Liquid Limit (LL)			Plastic Limit (PL)	
No of blows	32	23	18		
Container number	A-66	100	AR	O2	O4
Weight of wet Soil +Tare (gm)	36.9	43.8	53.5	19.4	18.9
Weight of Dry Soil + Tare (gm)	35.3	38.2	45.3	18.2	17.5
Weight of water (gm)	1.6	5.6	8.2	1.2	1.4
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	14.8	17.8	25	7	7.5
Water Content %	10.81	31.46	32.80	17.14	18.67
LL at 25 blows & Avg. **PI=LL-PL= 25-17.9=7.1%**		25.02			17.90

Plastic Index for Sub-grade Soil, Chainage 34+200

Representative sample	No 2	Chain age	34+200		
Test Type	Plastic Index	Location	Dembi-Bedele		
Pavement layer	sub grade				
	Liquid Limit (LL)			Plastic Limit (PL)	
No of blows	35	25	17		
Container number	A-66	100	AR	O2	o4
Weight of wet Soil +Tare (gm)	62.1	58.6	63	17.9	19.5
Weight of Dry Soil + Tare (gm)	58	49.4	48.4	16.6	18.1
Weight of water (gm)	4.1	9.2	14.6	1.3	1.4
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	37.5	29	28.1	5.4	8.1
Water Content %	10.93	31.72	51.96	24.07	17.28395
LL at 25 blows & Avg.PL		31.54		20.68	
PI=LL-PL=31.54-20.68=10.86%					

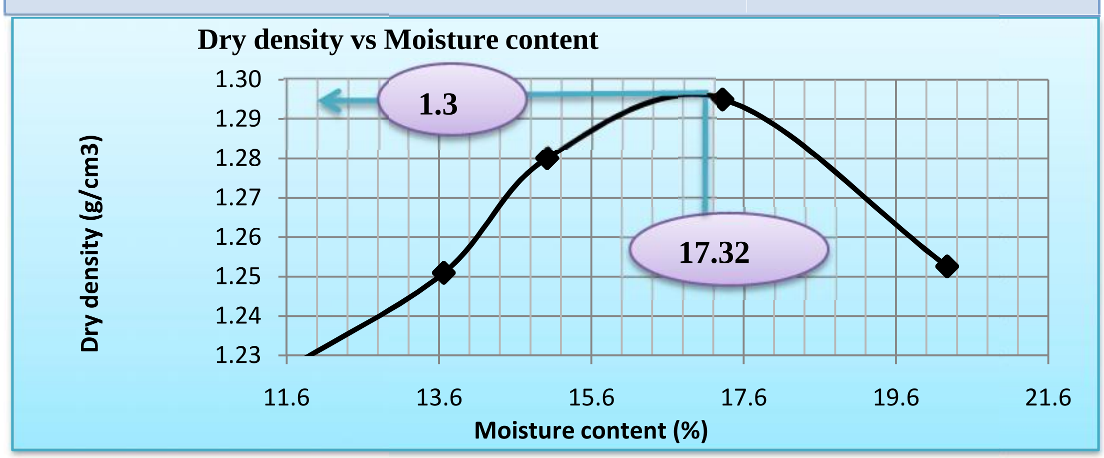
Plastic Index for Sub-base Soil, Chainage 34+200

Chain age	26+00	Location		Dembi-Bedele	
Representative sample	No:3	Pavement layer		Sub base	
Test Type	Plastic Index				
	Liquid Limit (LL)			Plastic Limit (PL)	
No of blows	32	23	18		
Container number	A-66	100	AR	O2	O4
Weight of wet Soil +Tare (gm)	54	61.2	58.7	26.2	24.1
Weight of Dry Soil + Tare (gm)	49.5	51.9	47.6	24.1	22.7
Weight of water (gm)	4.5	9.3	11.1	2.1	1.4
Weight of Tare (gm)	20.5	20.4	20.3	11.2	10
Weight of Dry Soil (gm)	29	31.5	27.3	12.9	12.7
Water Content %	15.52	29.52	40.66	16.28	11.02
LL at 25 blows & Avg.	28.57			13.65	
PI=LL-PL=28.57-13.65=14.9%					

APPENDIX-E DRY DENSITY VS. MOISTURE CONTENT SCATOR PLOT

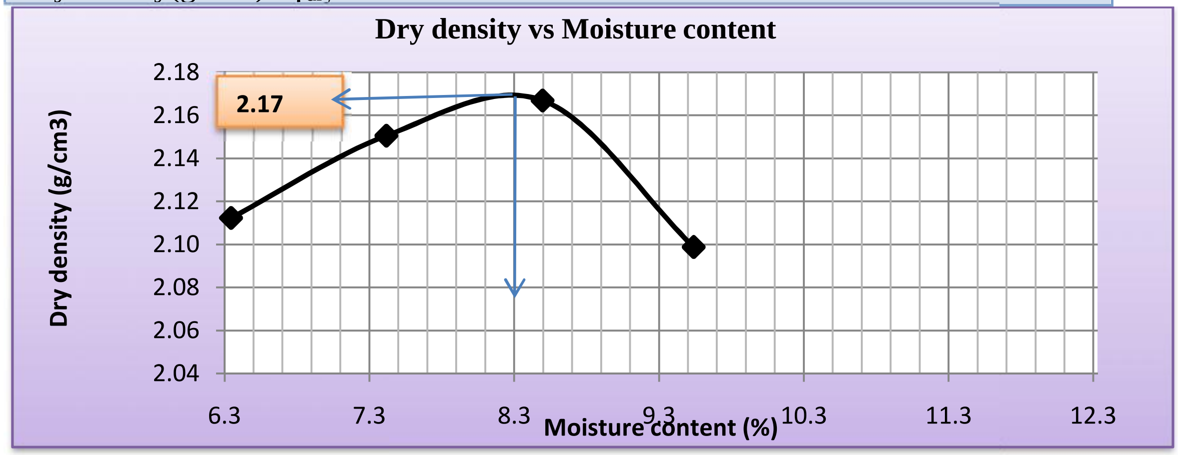
Proctor Test for Sub grade soil, Chainage 18+850

w (%)	**11.6**	**13.66**	**15.02**	**17.32**	**20.27**
γdry g/cm3)	1.23	1.25	1.28	1.30	1.25



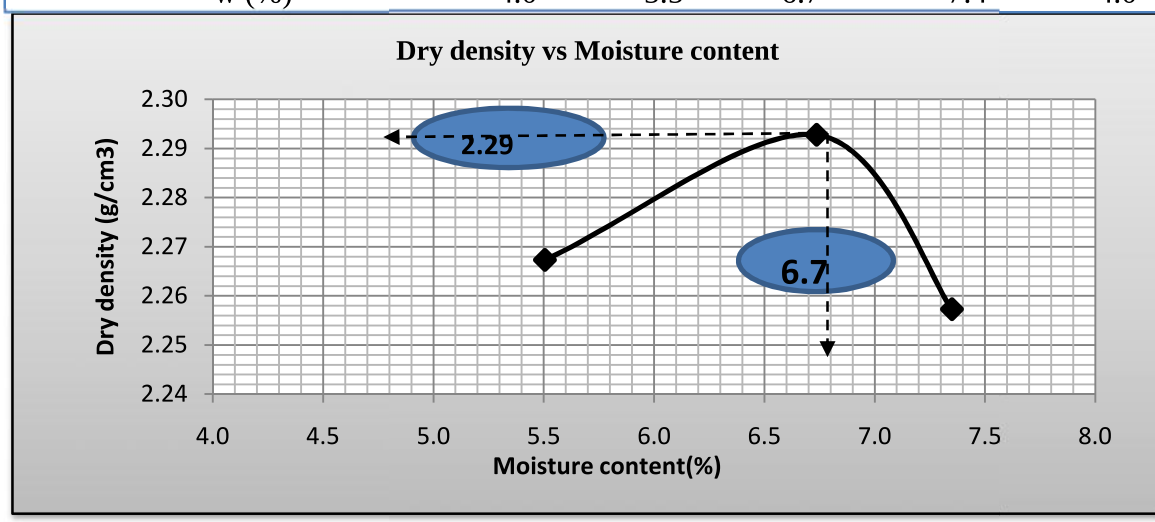
Proctor Test for Sub-base soil MC Vs. DD, Chainage 18+850

Moisture Content (%)	6.3	7.4	8.5	9.5	11.9
Dry density(g/cm^3) =γ_{dry}	2.11	2.15	2.14	2.17	2.10



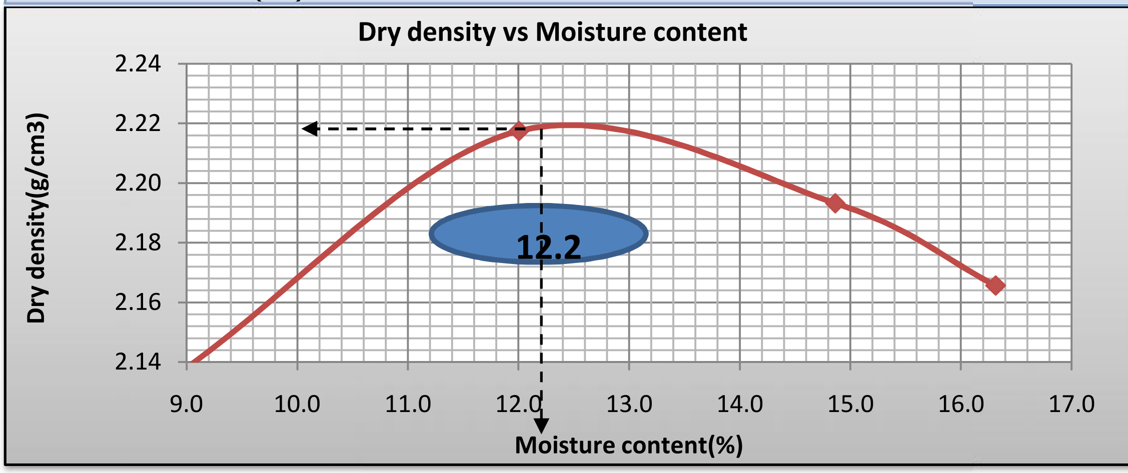
Proctor Test MC vs. DD of Base course Soil, Chainage 18+850

γ_{dry} (g/cm3)	2.25	2.27	2.29	2.26	2.25
w (%)	4.0	5.5	6.7	7.4	4.0



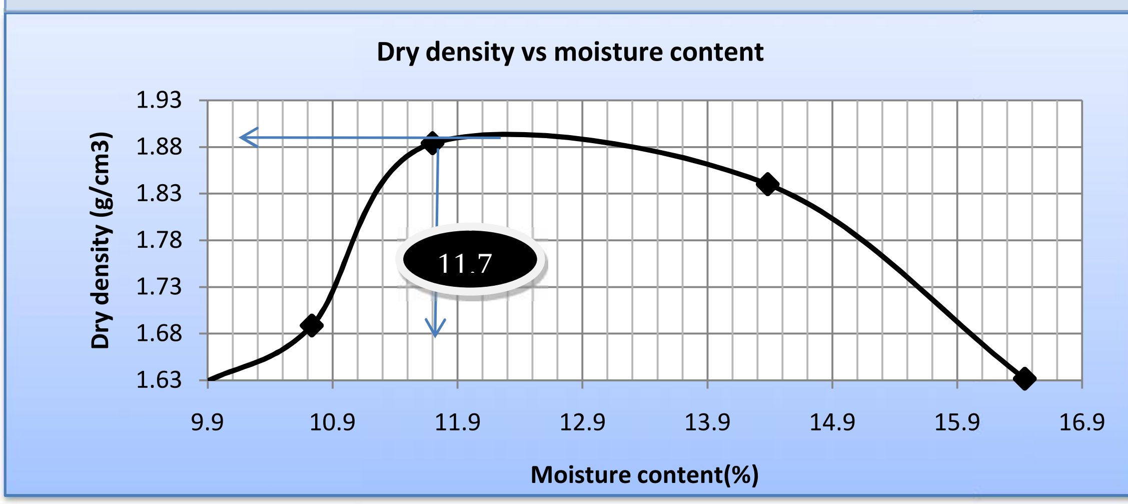
Proctor Tes OM vs. DD of Sub grade Soil ,Chainage 19+300

γ_{dry} (g/cm3)	2.14	2.22	2.19	2.17	2.24
w (%)	9.0	12.0	14.9	16.3	7.6



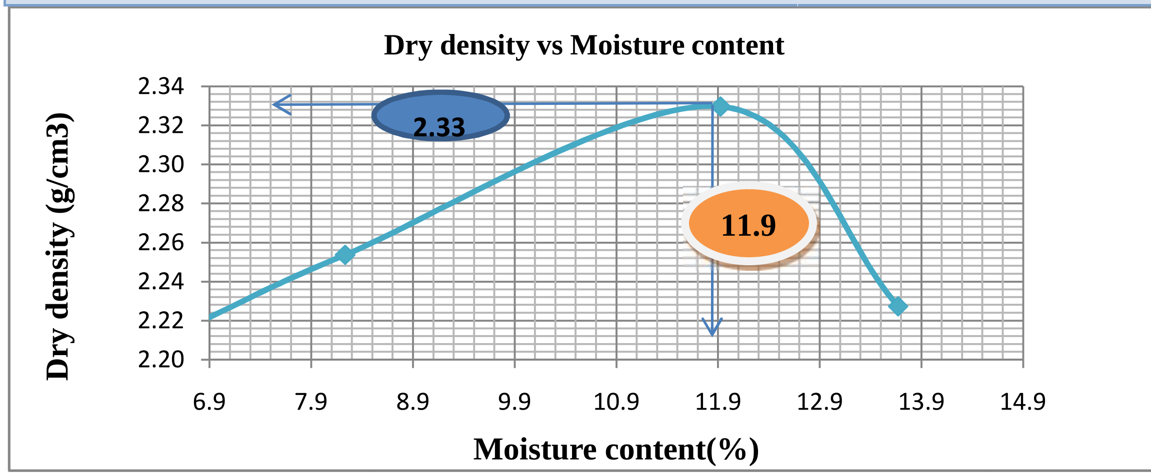
Proctor Test for OM vs. DD of Sub base Soil, Chainage 19+300

γ_{dry}	1.63	1.69	1.88	1.84	1.63
w	9.9	10.7	11.7	14.4	16.4



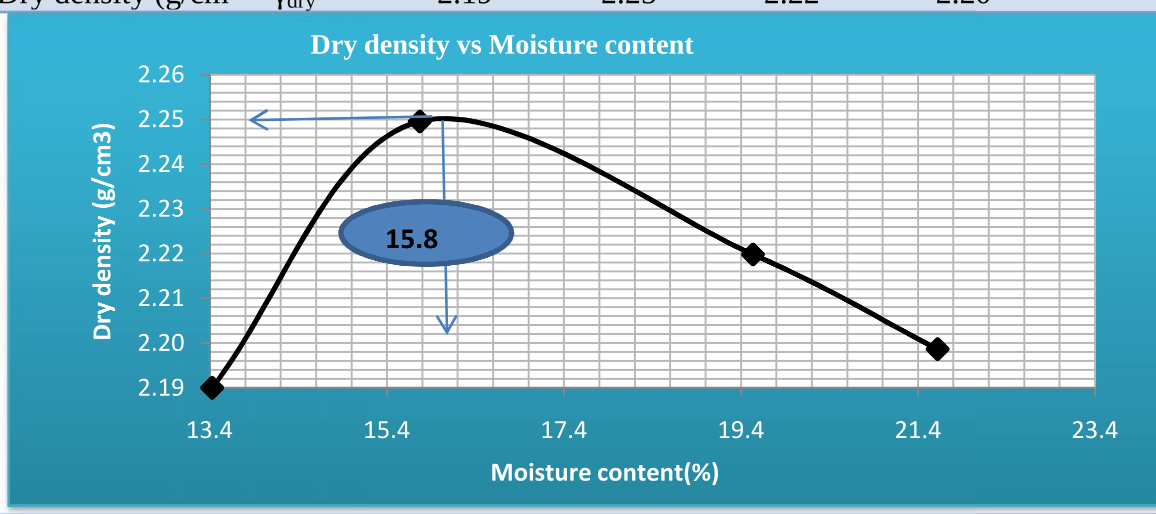
Proctor Test, OM vs. DD of Base course, Chainage 19+300

γ_{dry}	**2.22**	**2.25**	**2.33**	**2.23**
w	6.9	8.2	11.9	13.7



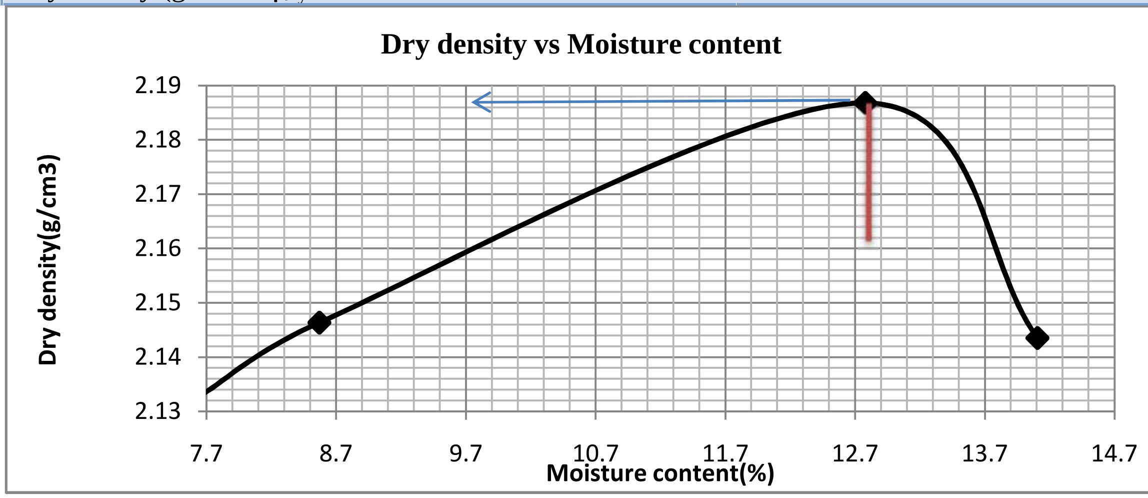
Proctor Test,MC vs. DD of sub grade soil, Chainage 26+00

Moisture Content (%)= w	**13.4**	**15.8**	**19.5**	**21.6**	**4.65**
Dry density (g/cm$^{3)}$= γ_{dry}	2.19	2.25	2.22	2.20	



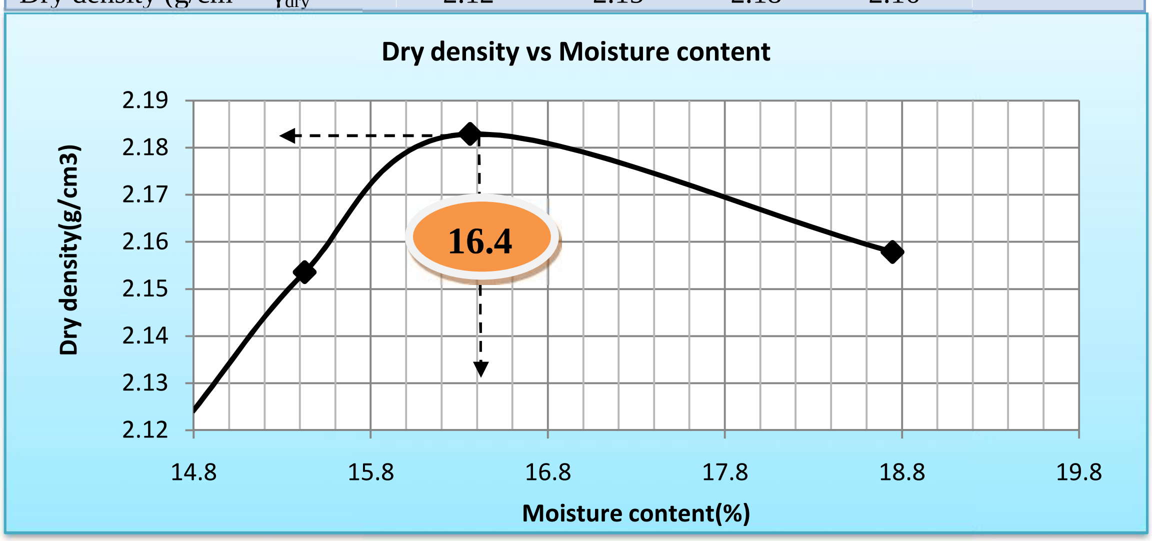
Proctor Test,MC vs. DD of Sub base Soil, Chainage 26+00

Moisture Content (%)= w	**7.7**	**8.6**	**12.8**	**14.1**	**6.27**
Dry density (g/cm$^{3)}$= γ_{dry}	2.13	2.15	2.19	2.14	



Proctor Test for MC vs. DD of Base course, Chainage 26+00

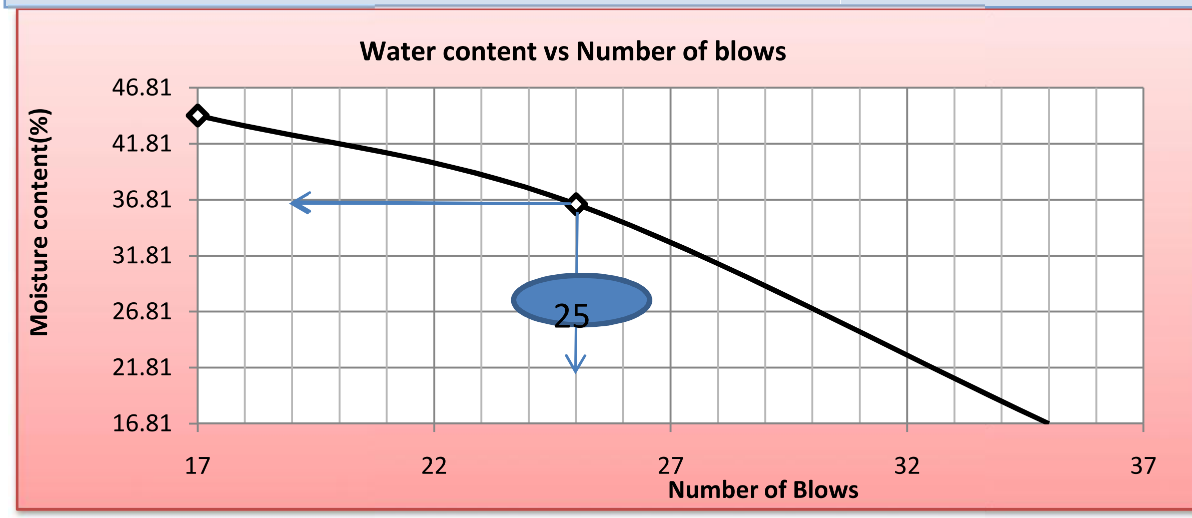
Moisture Content (%)= w	**14.8**	**15.4**	**16.4**	**18.7**	**12.67**
Dry density (g/cm$^{3)}$= γ_{dry}	2.12	2.15	2.18	2.16	



APPENDIX-F LIQUID LIMIT AND PLASTICITY INDEX

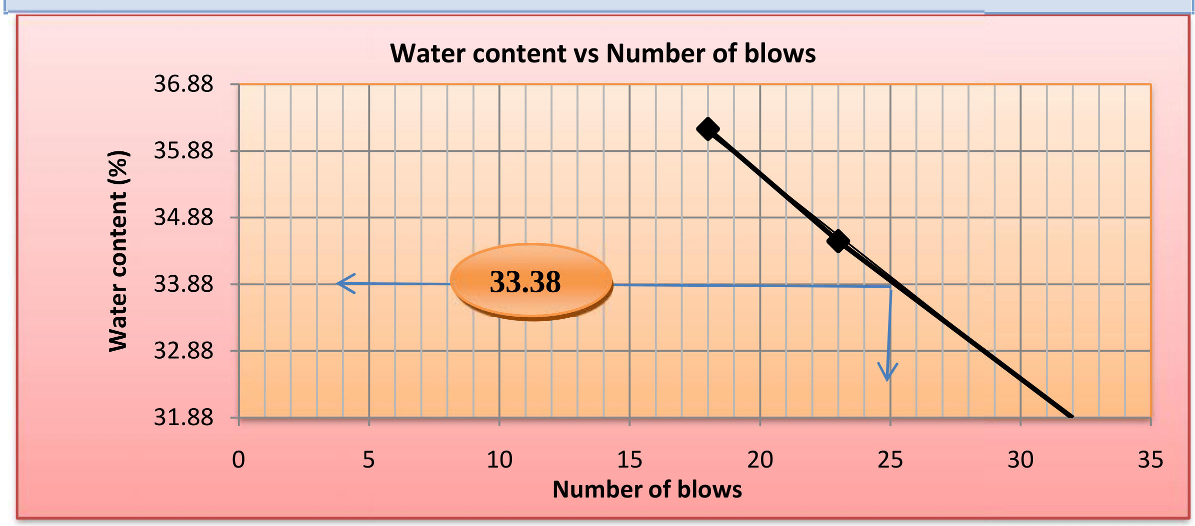
Water content vs. Number of blows, Sub grade soil,Chainage 18+850

Representative sample	No 3				
	Liquid Limit (LL)			Plastic Limit	
No of blows	35	25	17		
Water Content %	16.81	36.40	44.33	32.26	9.09



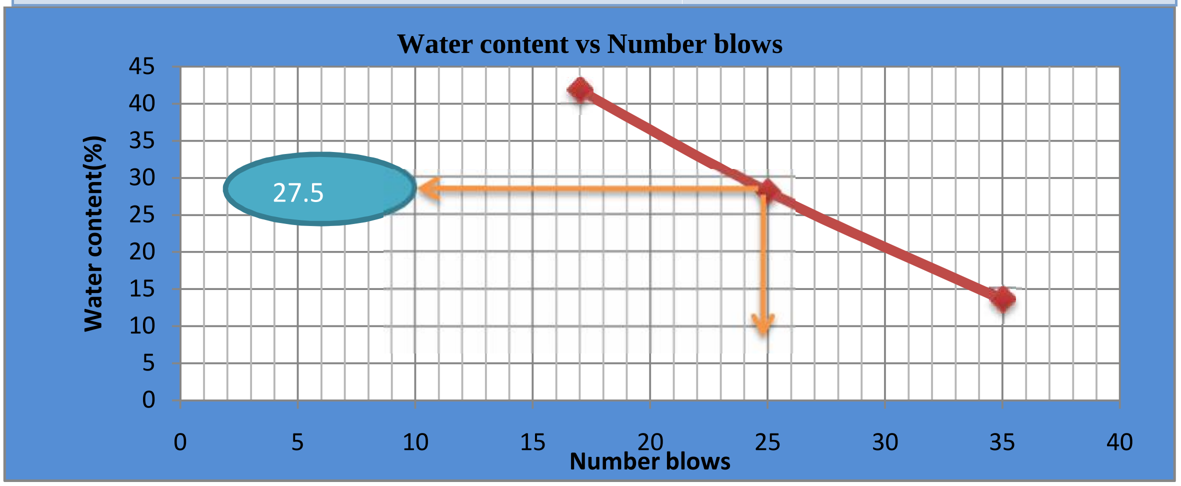
Water content vs. number of blows , Sub base soil, Chainage 18+850

Representative sample	No 2				
	Liquid Limit (LL)			Plastic Limit (PL)	
No of blows	32	23	18		
Water Content %	31.88	34.52	36.21	29.03	22.58



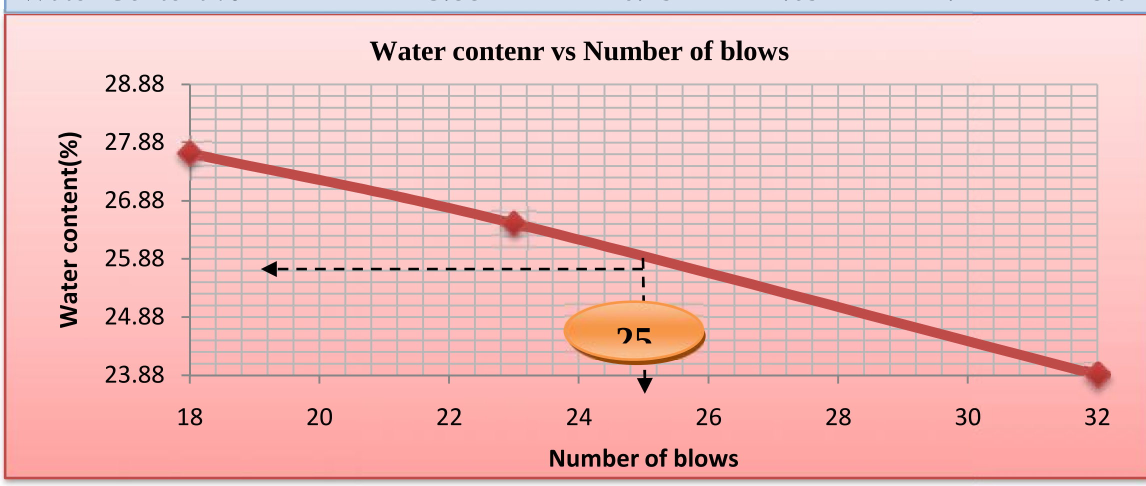
Water content vs. Number of blows ,sub grade soil,Chainage 19+300

Representative sample	**No:3**				
No of blows	35	25	17		
Water Content %	13.57	28.00	41.78	10.77	8.86



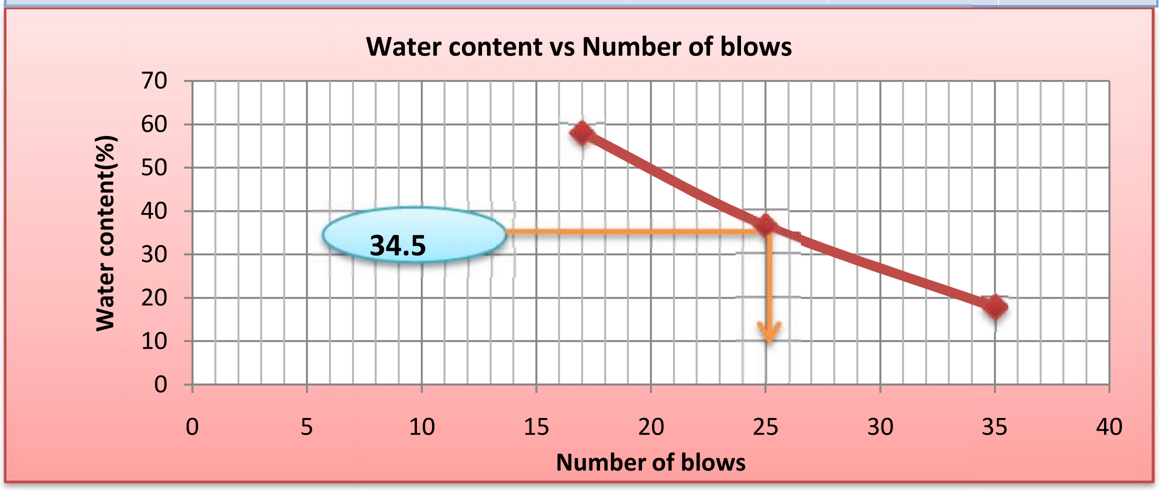
Water content vs. Number of blows ,sub base soil,Chainage 19+300

Representative sample	No:1	Chain age		19+300	
Pavement layer	Sub base				
No of blows	32	23	18		
Water Content %	23.88	26.49	27.69	17.14	18.67



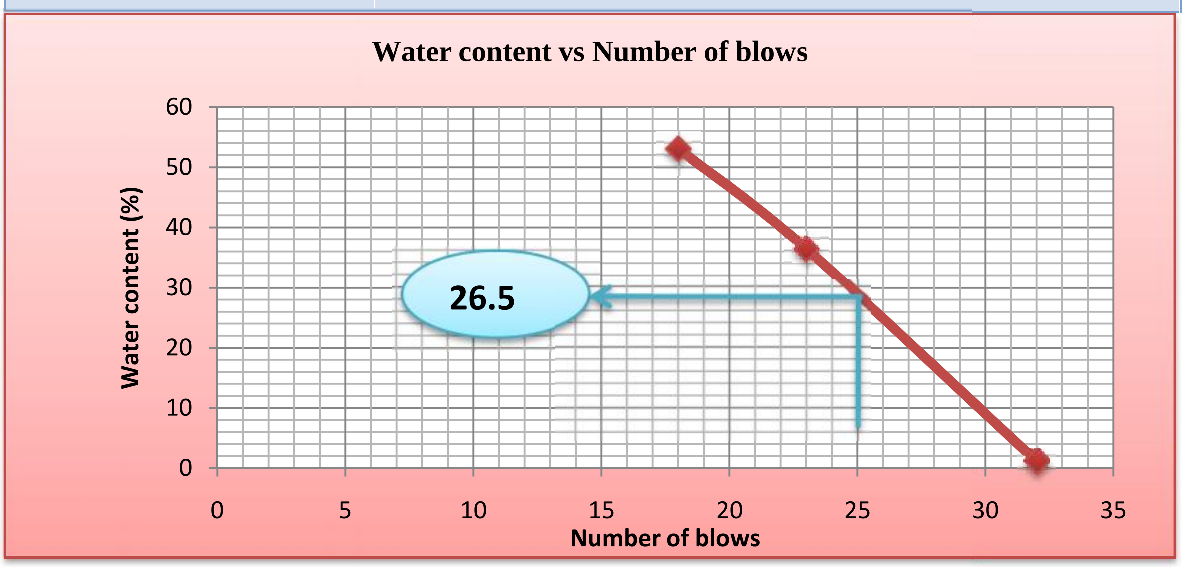
Water content vs. number of blows, Sub base soil, Chainage 24+00

No of blows	35	25	17		
Water Content %	17.79	36.63	58.09	35.85	16.6



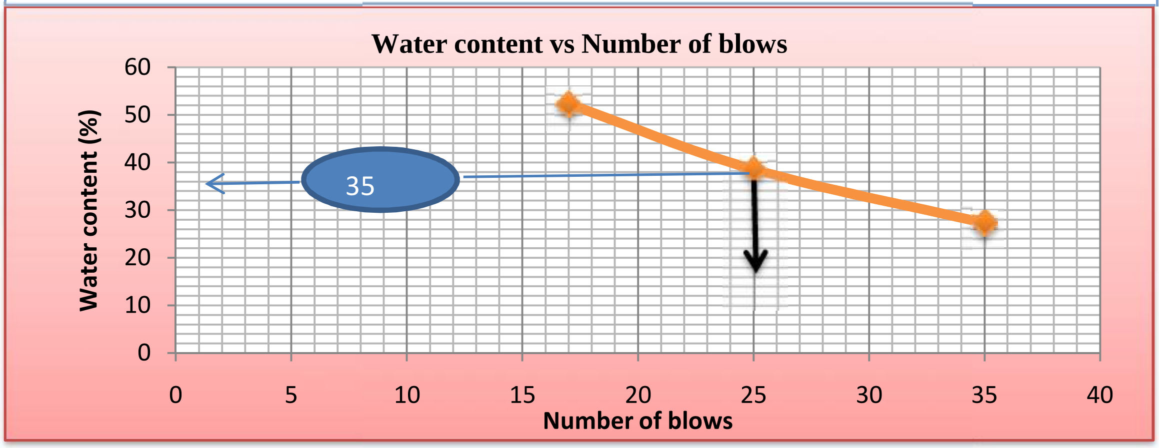
Water content vs. number of blows Sub-grade Soil, Chainage 26+00

No of blows	32	23	18		
Water Content %	1.16	36.43	53.09	18.84	14.10



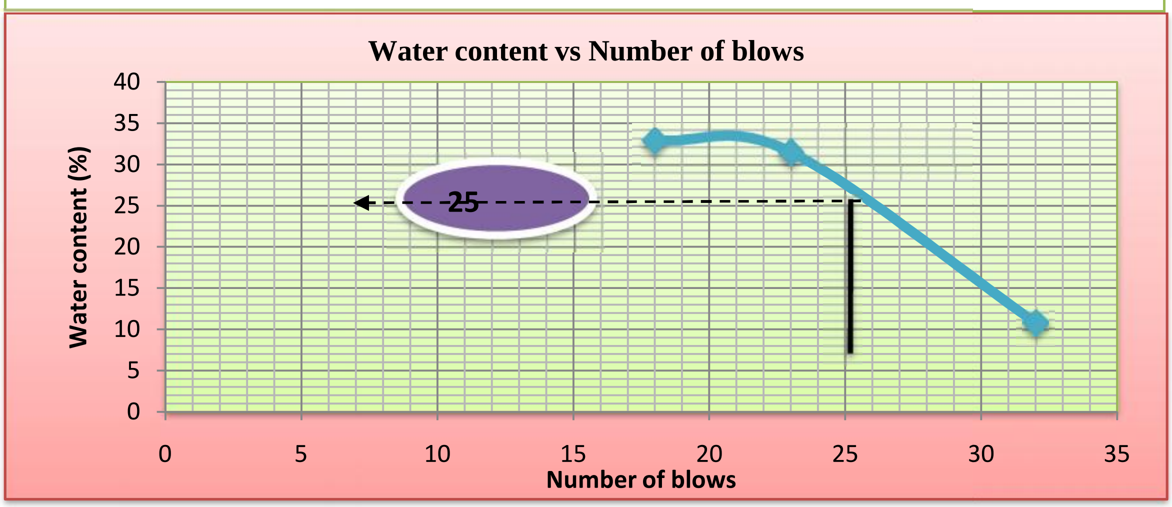
Water content vs. number of blows, Sub-base Soil, Chainage 26+00

Sampling Station		Chain age			26+00
No of blows	35	25	17		
Water Content %	27.23	38.52	52.28	31.43	15.8



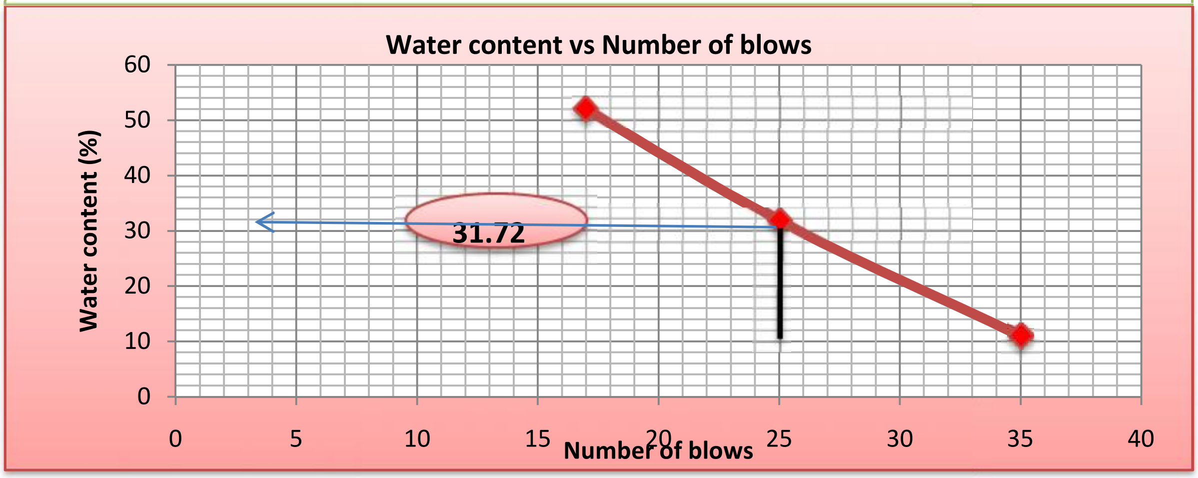
Water content vs. number of blows, Sub-grade Soil, Chainage 34+200

Representative sample	No:3	Chain age		26+00	
No of blows	32	23	18		
Water Content %	10.81	31.46	32.80	17.14	18.67

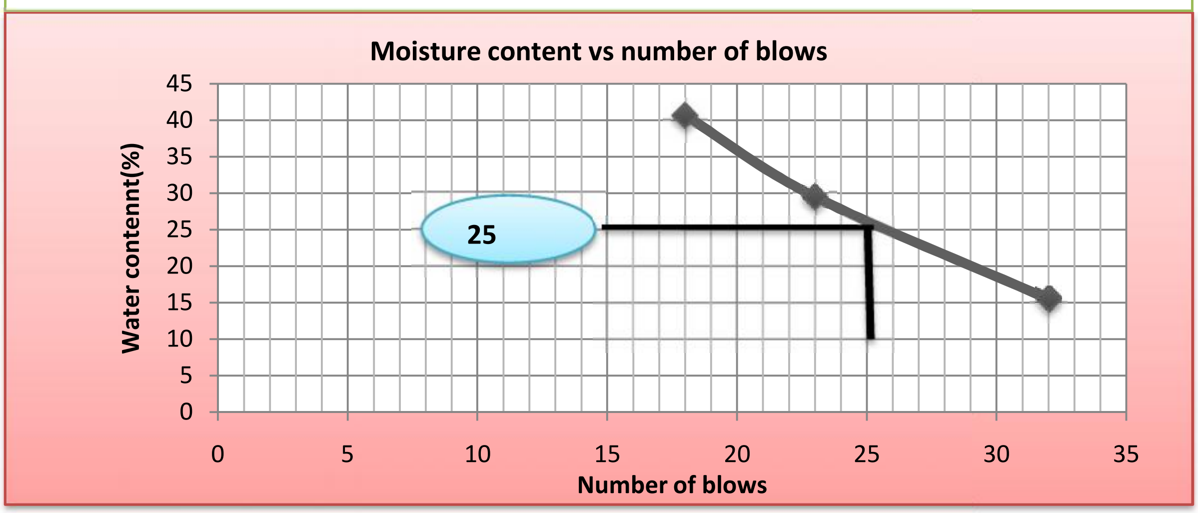


Water content vs. number of blows Sub base Soil,Chainage 34+200

Representative sample	No 2	Chain age		34+200	
		Location		Dembi-Bedele	
No of blows	35	25	17		
Water Content %	10.93	31.72	51.96	24.07	17.29



Chain age	26+00	Location		Dembi-Bedele	
Representative sample	No:3	Pavement layer		Sub base	
No of blows	32	23	18		
Water Content %	15.52	29.52	40.66	16.28	11.0



APPENDIX -G CBR LABORATORY DATA

Representative Sample:1

Purpose: CBR(AASHTOO T-193

Sub-grade Soil,Density Determination,Chainage18+850

Soaking condition	10 Blows		30 Blows		65 Blows	
	Before	After	Before	After	Before	After
Mold Number	14-10		30Y	30Y	R65	R65
Weight of soil +Mold (gm)	12214.6	12736.8	12859.5	13688.7	13368.6	13461.4
Weight of Mold (gm)	7792.8	7792.8	7524.2	7794.2	7710.7	7710.7
Weight of soil (gm)	4421.8	4944	5335.3	5894.5	5657.9	5750.7
Volume of Mold (cc)	2358	2358	2358	2358	2358	2358
Wet density of Soil (g/cc)	1.88	2.10	2.26	2.50	2.40	2.44
Dry density of Soil (g/cc)	1.74	1.88	1.96	2.09	1.96	1.92

Sub-grade Soil, Moisture Determination,Chainage 18+850

Soaking Condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before		
		Top 1	Avg		Top	Avg		Top	Avg
Container number	140	17		142	25		141	21	
Wet Soil +Container (gm)	163.2	145.7		133.6	124		154	129.8	163
Dry Soil + Container (gm)	154.1	134.2		120.6	109		132.9	109.6	154
Weight of water(gm)	9.1	11.5		13.0	15.0		21.1	20.2	9.1
Weight of Container (gm)	34	33.3		36.3	32.7		37.8	34.4	34
Weight of Dry Soil (gm)	120.1	100.9		84.3	76.3		95.1	75.2	120
Moisture content (%)	7.58	11.40		15.42	19.7		22.2	26.9	7.6

Sub-grade Soil,Penetration Test,Chainage 18+850

Penetration (mm)	10 Blows				30 Blows				65 Blows			
	Dial Rdg	Load (kn)	Cor. Load(kn)	CBR %	Dial Rdg	Load (kn)	Cor .Load (kn)	CBR %	Dial Rdg (kn)	Load (kn)	Cor Load (kn)	CBR %
0	-			-			-		-			
0.64	24	0.29	0.3		58	0.70			6338	76.94		
1.27	41	0.50			100	1.21			100	1.21		
1.96	53	0.64			118	1.43			104	1.26		
2.54	94	1.14	1	9	130	1.58	2	12	138	1.68	2	13
3.18	67	0.81			143	1.74			150	1.82		
3.81	69	0.84			154	1.87			160	1.94		
4.45	78	0.95			162	1.97			176	2.14		
5.08	86	1.0440	1	5	170	2.06	2	10	199	2.42	2	12

Swell value			
No. of Blows	10	35	65
Rdg (Before Soaking)	5.60	6.90	8.90
Rdg (After Soaking)	6.1	7.2	9.5
Present Swell	0.43	0.26	0.52
Average Percent Swell:		**0.40**	

Representative Sample:2

Purpose: CBR(AASHTOO T-193)

Sub-base Soil,Density Determination,Chainage 18+850

Soaking condition	10 Blows		30 Blows		65 Blows	
	Before	After	Before	After	Before	After
Mold Number	B10		30(2A)		65	
Weight of soil +Mold (gm)	12538	12486.2	11419.5	11503.9	11726.8	11709.5
Weight of Mold (gm)	7892.6	7892.6	6456.4	6456.4	6592.7	6592.7
Weight of soil (gm)	4645.4	4593.6	4963.1	5047.5	5134.1	5116.8
Volume of Mold (cc)	2358	2258	2358	2358	2358	2358
Wet density of Soil (g/cc)	1.97	2.03	2.10	2.14	2.18	2.17
Dry density of Soil (g/cc)	1.84	1.86	1.89	1.90	1.88	1.87

Sub-base Soil, Moisture Determination,Chainage 18+850

Soaking Condition	10 Blows			30 Blows			65 Blows		
		After			After			After	
	Before	Top 1	Avg	Before	Top	Avg	Before	Top 1	Avg
Container number	11	121		14	50		140	21	
Wet Soil +Container (gm)	197.3	185.1		174.6	192.8		176.8	190.5	
Dry Soil + Container (gm)	187.1	172.8		160.6	174.8		158	168.7	
Weight of water(gm)	10.2	12.3		14.0	18.0		18.8	21.8	
Weight of Container (gm)	34.2	36.5		35.8	34.8		37.8	34.4	
Weight of Dry Soil (gm)	148.2	135.3		124.8	140		120.2	134.3	
Moisture content (%)	6.9	9.1		11.2	12.86		15.6	16.2	

Sub-base Soil, Penetration Test,Chainage 18+850

Penetration (mm)	10 Blows				30 Blows						
	Dial Rdg	Load (kn)	Cor.Load (kn)	CBR (%)	Dial Rdg	Load (kn)	Cor.Load (kn)	CBR %	Dial Load (kn)	Load (kn)	Cor Load (kn)
0	-	-	-		-		-			-	-
0.64	35	0.49	0.5		93	1.13			69	0.84	
1.27	63	0.96			140	1.70			110	1.34	
1.96	97	1.43			220	2.67			250	3.04	
2.54	129	1.65	2	12	268	3.25	3	24	347	4.21	4
3.18	152	2.31			424	5.15			259	3.14	
3.81	185	2.79			468	5.68			305	3.70	
4.45	215	3.51			536	6.51			350	4.25	
5.08	245	5.16	5	26	540	6.56	7	33	378	4.59	5
7.62											
10.16											
12.7											

Swell value			
No. of Blows	10	30	65
Rdg (Before Soaking)	0.25	0.20	0.78
Rdg (Before Soaking)	0.43	0.61	0.89
Present Swell	0.15	0.35	0.09
Average Percent Swell:		0.54	

Sampling station:18+850

Purpose: CBR (AASHTOO T-193)

Sample from Dembi-Bedele

Representative Sample: No.3

Base Course Density Determination ,Chainage 18+850

Soaking condition	10 Blows		30 Blows		65 Blows	
	Before	After	Before	After	Before	After
Mold Number	5D10		Ag-30		88-65	
Weight of soil +Mold (gm)	11238.6	12430	12645	12676	12188.1	11802
Weight of Mold (gm)	6792.8	7792.8	7524.2	7524.2	6628.3	6628.3
Weight of soil (gm)	4445.8	4637.2	5120.8	5151.8	5559.8	5173.7
Volume of Mold (cc)	2358	2358	2358	2358	2358	2358
Wet density of Soil (g/cc)	1.89	1.97	2.17	2.18	2.36	2.19
Dry density of Soil (g/cc)	1.72	1.74	1.84	1.78	1.89	1.75

Base course Moisture Determination,Chainage 18+850

Soaking Condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before		
		Top	Avg		Top	Avg		Top	Avg
Container number	17	O8		25	142		50	140	
Wet Soil +Container (gm)	239.3	210.52		247.93	237.51		266.64	245.77	
Dry Soil + Container (gm)	221.8	189.8		215.2	200		220.9	203.3	
Weight of water (gm)	17.5	20.7		32.7	37.5		45.7	42.5	
Weight of Container (gm)	33.6	32.8		34.4	34		36.2	34.1	
Weight of Dry Soil (gm)	188.2	157		180.8	166		184.7	169.2	
Moisture content (%)	9.30	13.20		18.10	22.60		24.76	25.10	

Sampling Station:19+300 Representative:1 Sample from: Dembi-Bedele

Purpose: CBR(AASHTOO T-193)

Sub-grade Soil, Density Determination,Chainage19+300

Soaking condition	10 Blows		30 Blows		65 Blows	
	Before	After	Before	After	Before	After
Mold Number	14-10		30Y	30Y	R65	R65
Weight of soil +Mold (gm)	12610.3	13678	13059.5	12188.7	12185.6	14471.4
Weight of Mold (gm)	7792.8	7792.8	7524.2	7794.2	7710.7	7710.7
Weight of soil (gm)	4817.5	4494.5	5535.3	4394.5	4474.9	6760.7
Volume of Mold (cc)	2358	2358	2358	2358	2358	2358
Wet density of Soil (g/cc)	2.04	1.91	2.35	1.86	1.90	2.87
Dry density of Soil (g/cc)	1.56	1.44	1.76	1.61	1.28	2.12

Sub-grade Soil Moisture Determination,Chainage 19+300

Soaking Condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before		
		Top	Avg		Top	Avg		Top	Avg
Container number	140	17		142	25		141	21	
Wet Soil +Container (gm)	165.2	149.7		136.6	127		157	133.6	
Dry Soil + Container (gm)	134.1	121.2		111.6	114		117.9	107.6	
Weight of water(gm)	31.1	28.5		25.0	13.0		39.1	26.0	
Weight of Container (gm)	34	33.3		36.3	32.7		37.8	34.4	
Weight of Dry Soil (gm)	100.1	87.9		75.3	81.3		80.1	73.2	
Moisture content (%)	31.07	32.42		33.2	15.99		48.8	35.5	

Sub-grade Soil Penetration Test,Chainage 19+300

Penetration (mm)	10 Blows				30 Blows				65 Blows			
	Dial Rdg	Load(kn)	Cor. Load (kn)	CBR (%)	DilR.g	Load(kn)	Cor Load (kn)	CBR (%)	Dial Rdg	Load (kn)	Cor Load (kn)	CBR %
0	-	-	-	-	-	-	-	-	-	-	-	
0.64	34	0.41	0.4		58	0.70			63	76.94		
1.27	47	0.57			100	1.21			100	1.21		
1.96	69	0.84			118	1.43			104	1.26		
2.54	109	1.32	1	10	130	1.58	2	12	138	1.68	2	13
3.18	140	1.70			143	1.74			150	1.82		
3.81	170	2.06			154	1.87			160	1.94		
4.45	211	2.56			162	1.97			176	2.14		
5.08	236	2.87	3	14	170	2.06	2	10	199	2.42	2	12
7.62												
10.16												
12.7												

Swell			
No. of Blows	10	35	65
Rdg (Before Soaking)	4.50	5.20	6.20
Rdg (Before Soaking)	4.9	6.8	6.9
Present Swell	0.34	1.37	0.60
Average Percent Swell:		0.77	

Sampling Station:19+300

Representative Sample:2

Purpose: CBR

Sample from: Dembi-Bedele

Sub-base Soil Density Determination,Chainage 19+300

Soaking condition	10 Blows		30 Blows		65 Blows	
	Before	After	Before	After	Before	After
Mold Number	B10		30(2A)		65	
Weight of soil +Mold (gm)	12548.5	12529.3	11586	11719.99	11886.8	12045.4
Weight of Mold (gm)	7892.6	7892.6	6456.4	6456.4	6592.2	6592.7
Weight of soil (gm)	4655.9	4636.7	5129.6	5263.59	5294.6	5452.7
Volume of Mold (cc)	2358	2258	2358	2358	2358	2358
Wet density of Soil (g/cc)	1.97	2.05	2.18	2.23	2.25	2.31
Dry density of Soil (g/cc)	1.78	1.81	1.88	1.90	1.88	1.86

Sub-base Soil Moisture Determination,Chainage 19+300

Soaking Condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before		
		Top	Avg		Top	Avg		Top	Avg
Container number	11	121		14	50		140	21	11
Wet Soil +Container (gm)	203.4	190.6		180.4	199.6		181.4	201.3	203.4
Dry Soil + Container (gm)	187.1	172.8		160.6	174.8		158	168.7	187.1
Weight of water(gm)	16.3	17.8		19.8	24.8		23.4	32.6	16.3
Weight of Container (gm)	34.2	36.5		35.8	34.8		37.8	34.4	34.2
Weight of Dry Soil (gm)	148.2	135.3		124.8	140		120.2	134.3	148.2
Moisture content (%)	11.0	13.2		15.9	17.71		19.5	24.3	11.0

Sub-base Soil Penetration Test,Chainage 19+300

Penetration (mm)	10 Blows				30 Blows				65 Blows			
	Dial Rdg	Load(kn)	Cor. Load (kn)	CBR (%)	Dial Rdg	Load (kn)	Cor Load (kn)	CBR %	Dial Rdg	Load (kn)	Cor Load (kn)	CBR %
0												
0.64	56	0.68	0.7		93	1.13			69	0.84		
1.27	98	1.19			140	1.70			110	1.34		
1.96	135	1.64			220	2.67			250	3.04		
2.54	178	2.16	2	16	268	3.25	3	24	347	4.21	4	32
3.18	269	3.27			424	5.15			259	3.14		
3.81	290	3.52			468	5.68			305	3.70		
4.45	370	4.49			536	6.51			350	4.25		
5.08	460	5.58	6	28	540	6.56	7	33	378	4.59	5	23
7.62												
10.16												
12.7												

Swell			
No. of Blows	10	35	65
Rdg (Before Soaking)	0.35	0.25	0.70
Rdg (Before Soaking)	0.60	0.55	0.80
Present Swell	0.21	0.26	0.09
Average Percent Swell:		**0.50**	

Sampling Station:19+300

Representative Sample:3

Purpose: CBR

Sample from: Dembi-Bedele

Base Course layer Density Determination,Chainage 19+300

Soaking condition	10 Blows		30 Blows		65 Blows	
	Before	After	Before	After	Before	After
Mold Number	5D10		Ag-30		88-65	
Weight of soil +Mold (gm)	11217.6	12411.9	12425.8	12659.3	11810.4	11693.1
Weight of Mold (gm)	6792.8	7792.8	7524.2	7524.2	6628.3	6628.3
Weight of soil (gm)	4424.8	4619.1	4901.6	5135.1	5182.1	5064.8
Volume of Mold (cc)	2358	2358	2358	2358	2358	2358
Wet density of Soil (g/cc)	1.88	1.96	2.08	2.18	2.20	2.15
Dry density of Soil (g/cc)	1.70	1.72	1.81	1.86	1.84	1.74

Base course ,Moisture Determination,Chainage 19+300

Soaking Condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before		
		Top	Avg		Top	Avg		Top	Avg
Container number	17	o8		25	142		50	140	17
Wet Soil +Container (gm)	241.31	211.43		242.32	228.51		256	243.5	241.3
Dry Soil + Container (gm)	221.8	189.8		215.2	200		221.	203.3	221.8
Weight of water(gm)	19.5	21.6		27.1	28.5		35.3	40.2	19.5
Weight of Container (gm)	33.6	32.8		34.4	34		36.2	34.1	33.6
Weight of Dry Soil (gm)	188.2	157		180.8	166		184. 7	169.2	188.2
Moisture content (%)	10.37	13.78		15.00	17.17		19.1	23.76	10.37

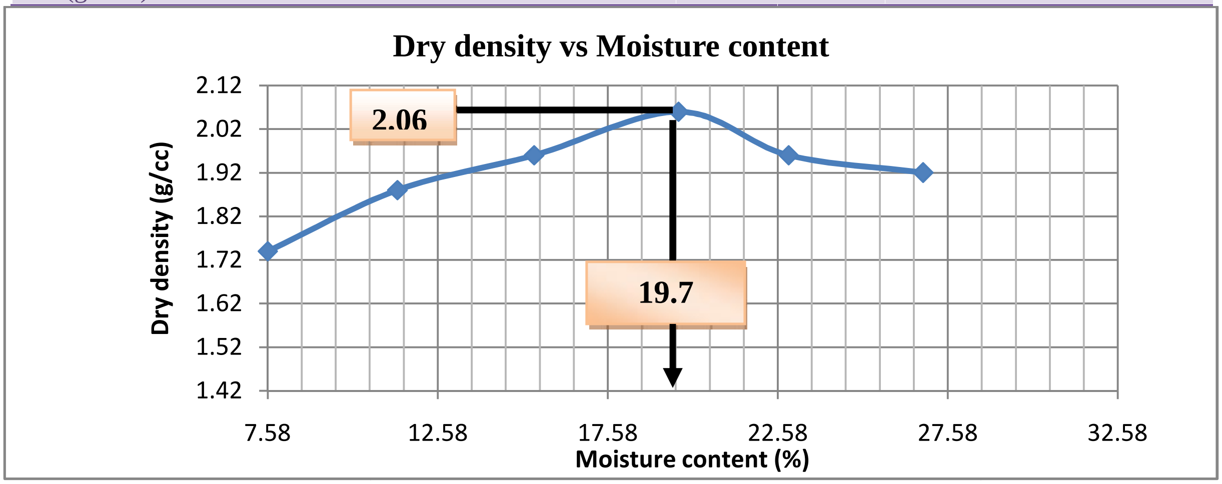
Base course layer Penetration Test ,Chainage 19+300

Penetration (mm)	10 Blows				30 Blows				65 Blows			
	Dial Rdg	Load(kn)	Cor. Load (kn)	CBR (%)	Dial Rdg	Load(kn)	Cor Load (kn)	CBR %	Dial	Load (kn)	Cor Load (kn)	CBR %
0												
0.64	45	0.55	0.5		60	0.73			120	1.46		
1.27	67	0.81			140	1.70			360	4.37		
1.96	154	1.87			230	2.79			450	5.46		
2.54	187	2.27	2	17	378	4.59	5	34	600	7.28	7	55
3.18	236	2.87			415	5.04			640	7.77		
3.81	329	3.99			470	5.71			690	8.38		
4.45	392	4.76			520	6.31			738	8.96		
5.08	488	5.92	6	30	545	6.62	7	33	720	8.74	9	44
7.62												
10.16												
12.7												

Swell			
No. of Blows	10	35	65
Rdg (Before Soaking)	0.15	0.19	0.14
Rdg (Before Soaking)	0.45	0.60	0.32
Present Swell	0.26	0.35	0.16
Average Percent Swell:		0.26	

CBR for Sub-grade Soil, Chainage 18+850

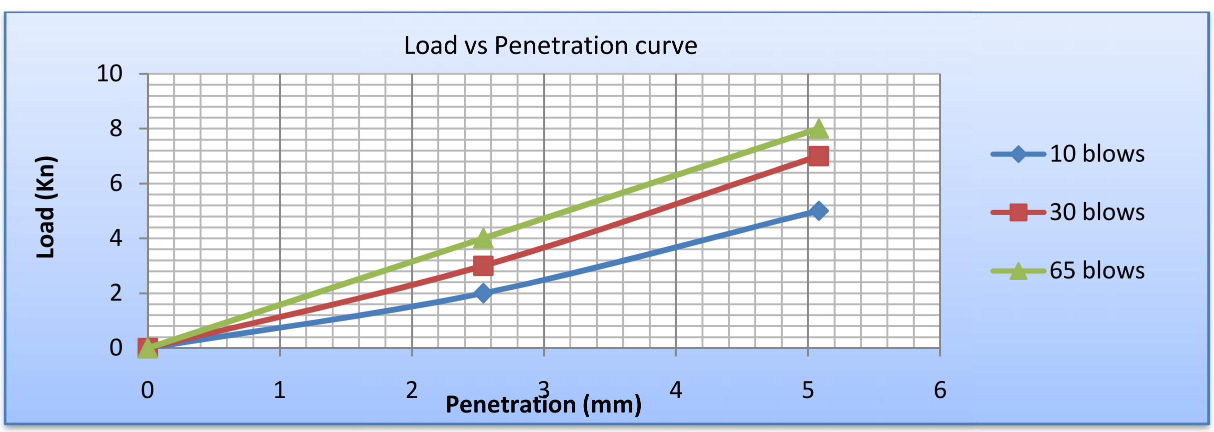
Chain age	18+850	Pavement layer		Sub -grade soil	
Purpose	CBR	Test Method		Test Pit	
Sample from	Dembi-Bedele	Depth(m)		0.24	
MC(%)	7.58	11.4	15.42	19.66	22.9	26.86
DD(g/cm3)	1.74	1.88	1.96	2.06	1.96	1.92



Dry density vs.OMC of Sub grade Soil, Chainage 18+850

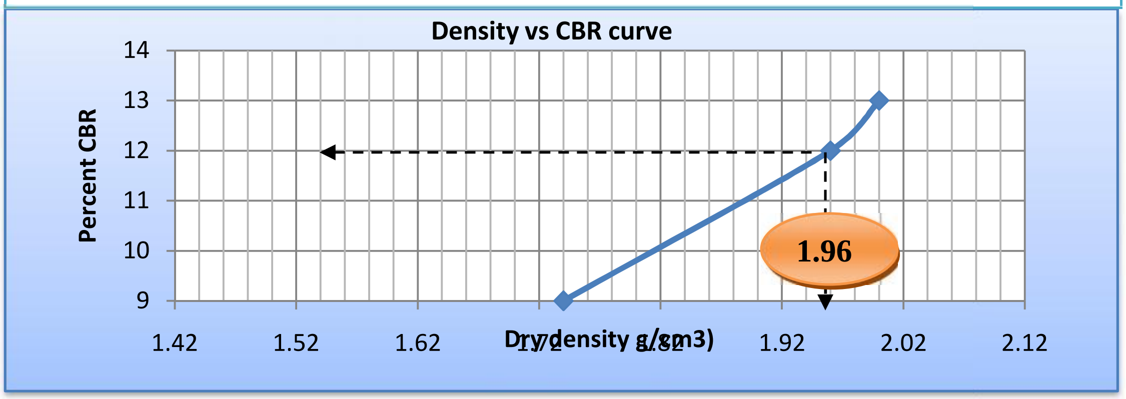
From compaction curve:MDD =2.06g/cm3 and OMC =19.7%						
Blows		Load(KN)		CBR (%)		Swell(%)
	0	2.54	5.08	2.54	5.08	0.15
10	0	2	5	12	26	0.35
30	0	3	7	24	33	0.09
65	0	4	8	32	23	0.53
Ring factor: 12.14 N/Div						

Load vs. Penetration of Sub grade Soil,Chainage 18+850



Dry Density vs. CBR sub grade soil Chainage 18+850

blows	Dry density before soaking(g/cm3)	CBR(%)
10	1.74	9
30	1.96	12
65	2.00	13

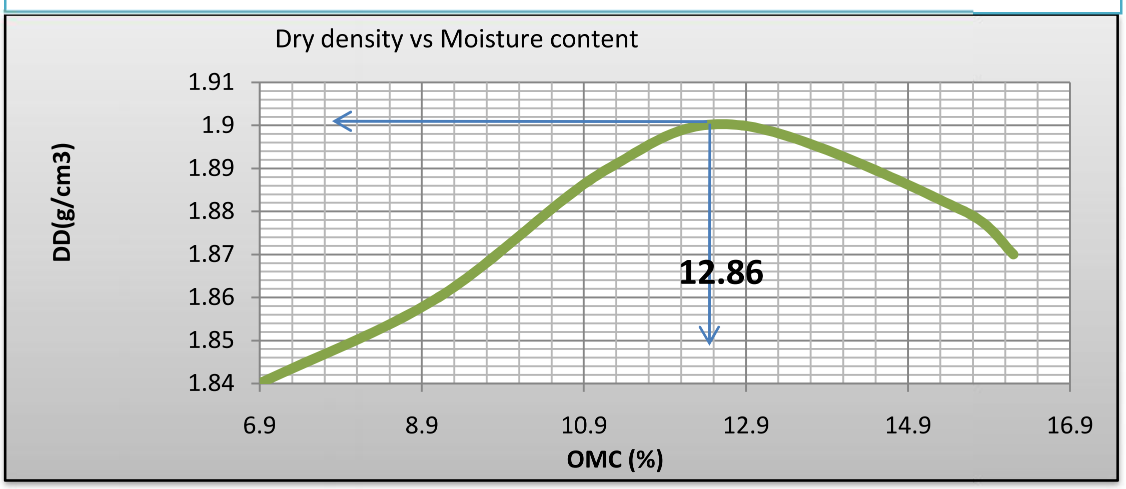


From Density -CBR curve at 95% MDD (1.96g/cm3) :CBR=12%

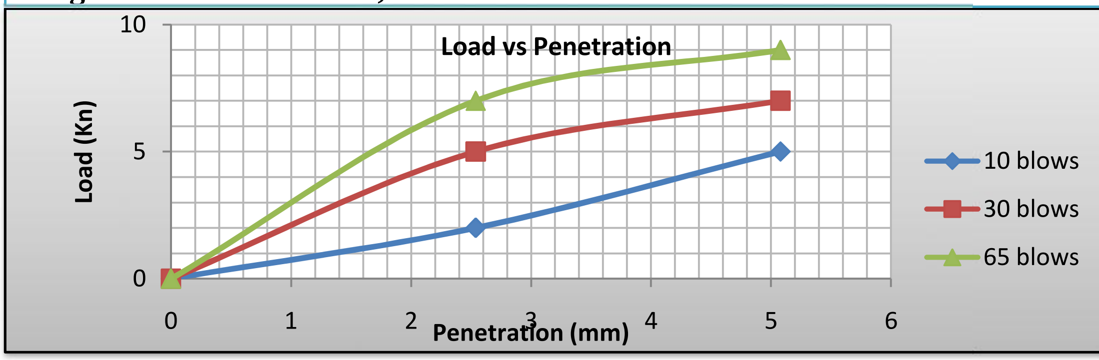
Chain age	18+850	Pavement layer	Sub -base
Dry density v	Vvs.OMC		
Purpose	CBR	OMC (%)	12.86
		Test Method	Test pit

MC (%)	6.9	9.1	11.2	12.86	15.6	16.2
DD(g/cm3	1.84	1.86	1.89	1.9	1.88	1.87

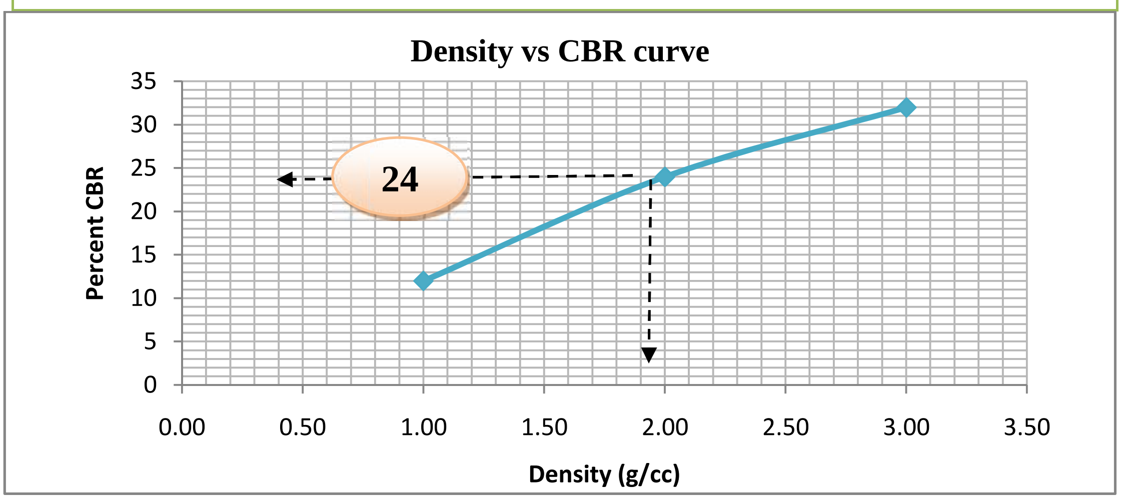
From Compaction curve : MDD=(1.9g/cm3) and OMC=12.86%



Load vs.Penetration of sub base soil. Chainage 18+850					
Load(KN)			CBR (%)		Swell(%)
0	2.54	5.08	2.54	5.08	0.15
0	3	6	12	26	0.35
0	4	8	24	33	0.09
0	5	9	32	23	0.53
Ring factor: 12.14 N/Div, Penetration Rate = 1.24mm/min					



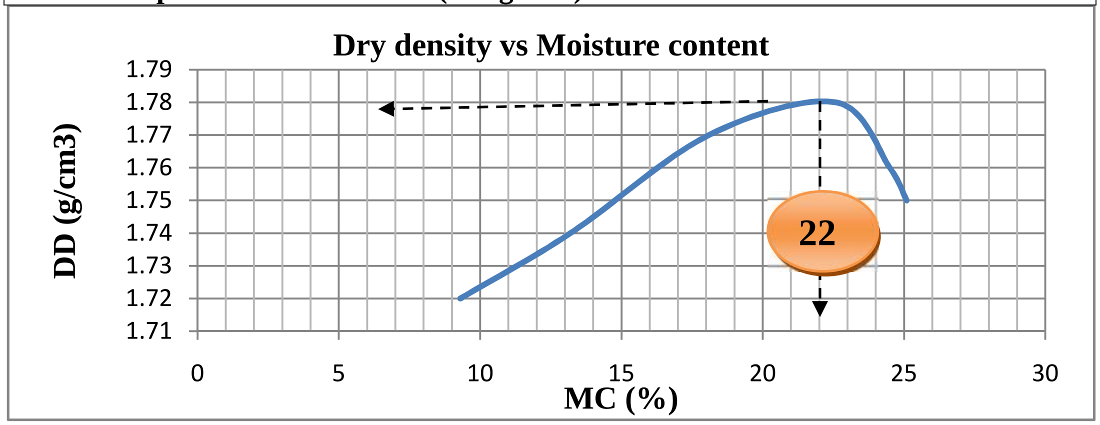
CBR vs.Dry Density chainage 18+850		
Blow	**Dry density(g/cm^3)**	CBR (%)
10	1.84	12
30	2	24
65	1.88	32



From Density-CBR curve at 95% MDD (2g/cm3) and CBR=24%

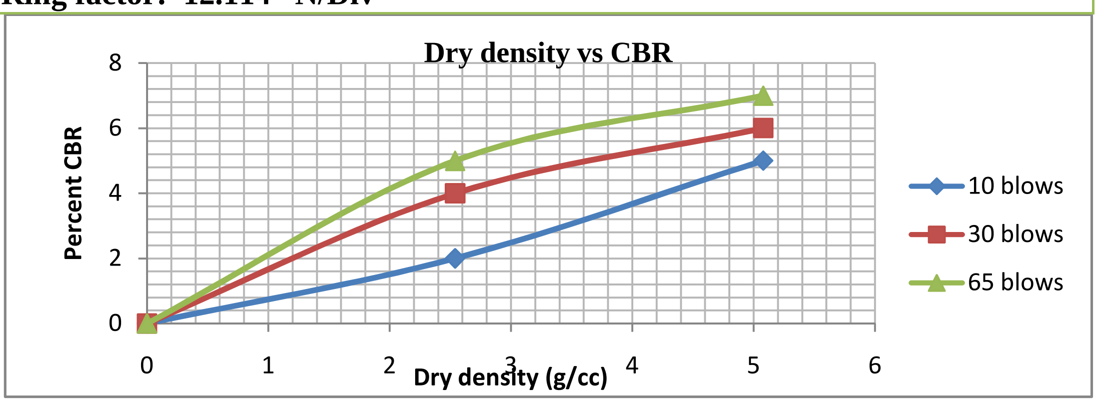
CBR for Base course soil, Chainage 18+850

Chain age	18+850	Pavement layer		Base course		
Purpose	CBR	Test Method		Test Pit		
Sample from	Dembi-Bedele	Depth(m)		0.24		
MC(%)	9.3	13.2	18.1	22.6	24.5	25.1
DD(g/cm3)	1.72	1.74	1.77	1.78	1.76	1.75
From Compaction curve : MDD=(1.78g/cm3) and OMC= 22%						



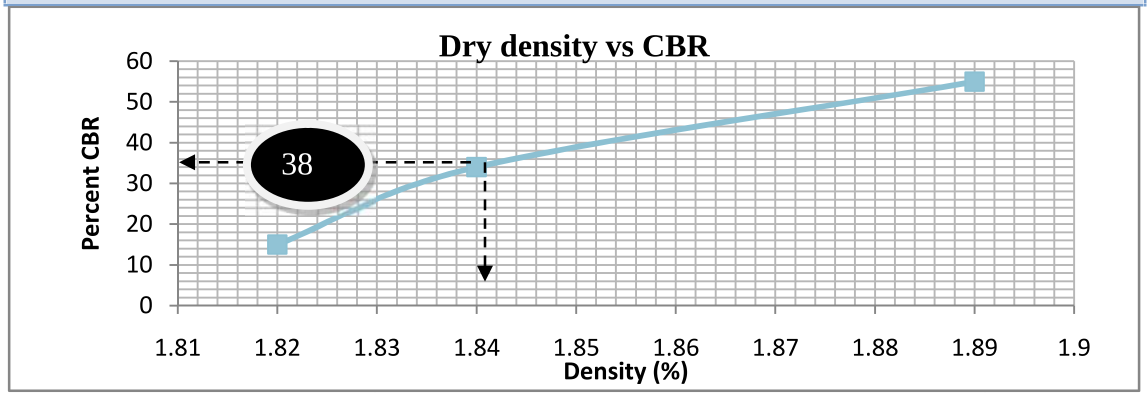
Dry Density vs. OMC of Base course Soli,Chainage 18+850

Blows	Load(KN)			CBR (%)		Swell(%)
	0	2.54	5.08	2.54	5.08	
10	0	2	5	15	27	0.26
30	0	5	7	34	33	0.35
65	0	7	9	55	44	0.48
						0.36
Ring factor: 12.114 N/Div						

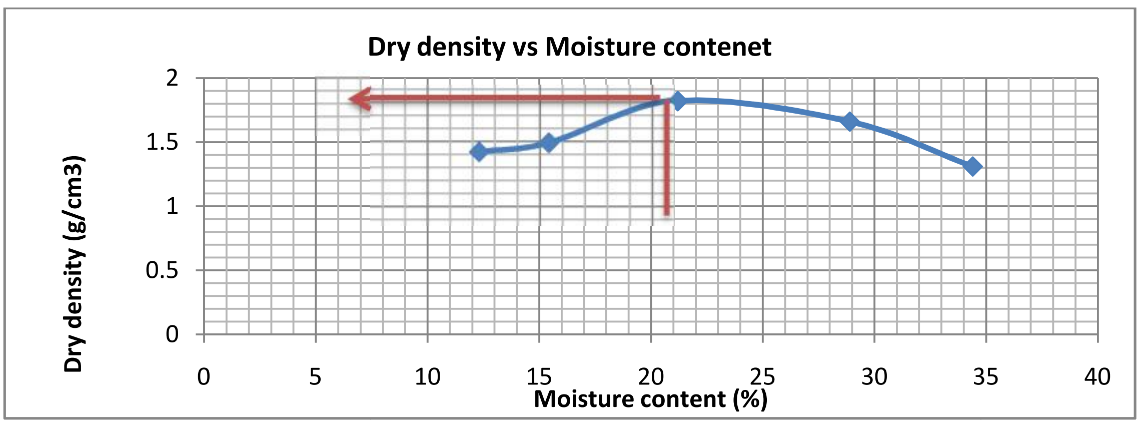


CBR vs. Dry Density of Base course Soil,Chainage 18+850

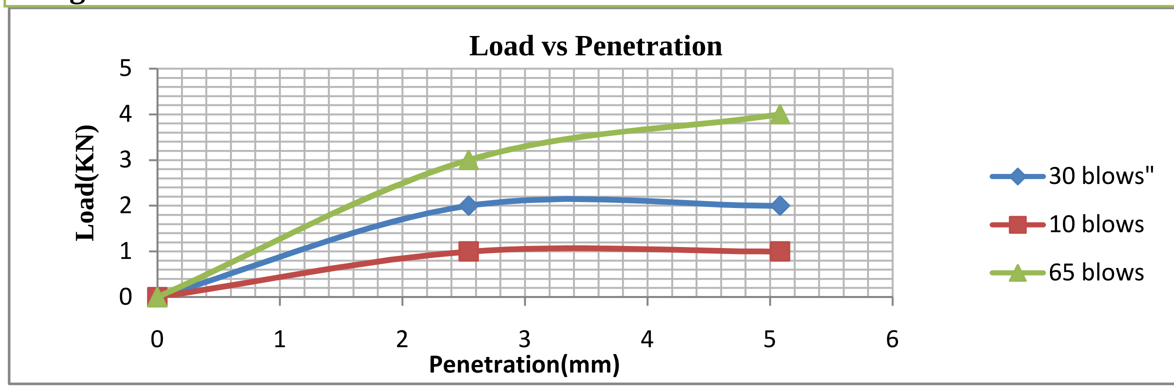
blows	Dry density before soaking(g/cm3)	CBR(%)
Chainage 18+850	Base course	
10	1.82	15
30	1.84	34
65	1.89	55
From Density-CBR curve at 95% MDD (1.84g/cm3) and CBR=38%		



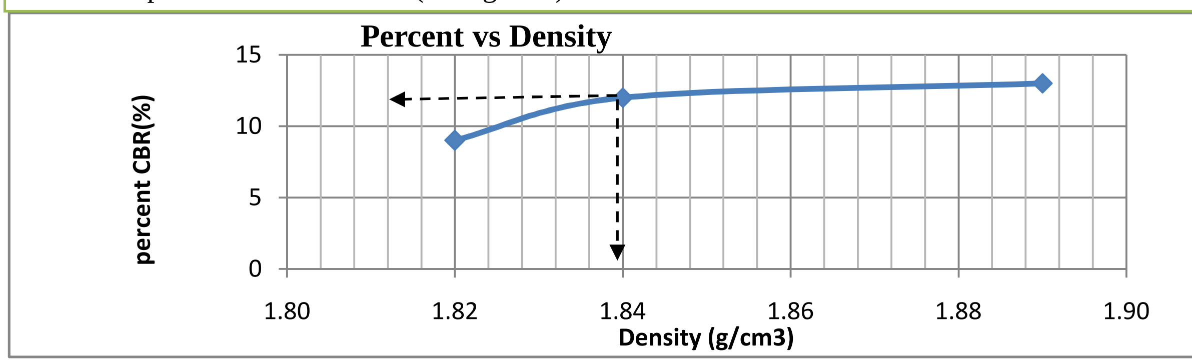
Chain age	19+300	Pavement layer		Sub grade			
Purpose	CBR	Test Method		Test Pit			
Sample from	Dembi-Bedele	Depth(m)					
MC(%)		**12.3**	**15.4**	**21.2**	**28.9**	**34.4**	**38.6**
DD(g/cm3)		1.42	1.49	1.82	1.66	1.31	1.28
From Compaction curve : MDD=(1.8 g/cm3) and OMC= 22%							



	CBR Test	Sub grade soil Chainage 19+300				
Blows		Load(KN)		CBR (%)		Swell(%)
	0	2.54	5.08	2.54	5.08	1.37
10	0	1	1	9	5	1.29
30	0	2	2	12	10	0.52
65	0	3	4	13	12	2.83
Ring factor: 12.14 N/Div						

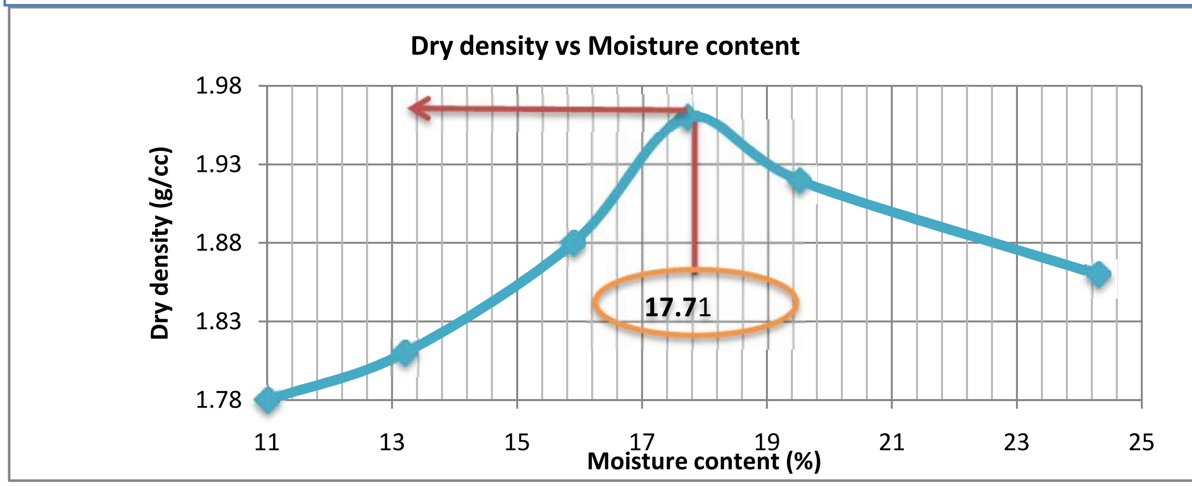


Blow	Dry density (g/cm3)	CBR (%)
10	1.81	9
30	1.84	12
65	1.87	13
From Compaction curve : MDD=(1.84 g/cm3) and OMC= 12%		

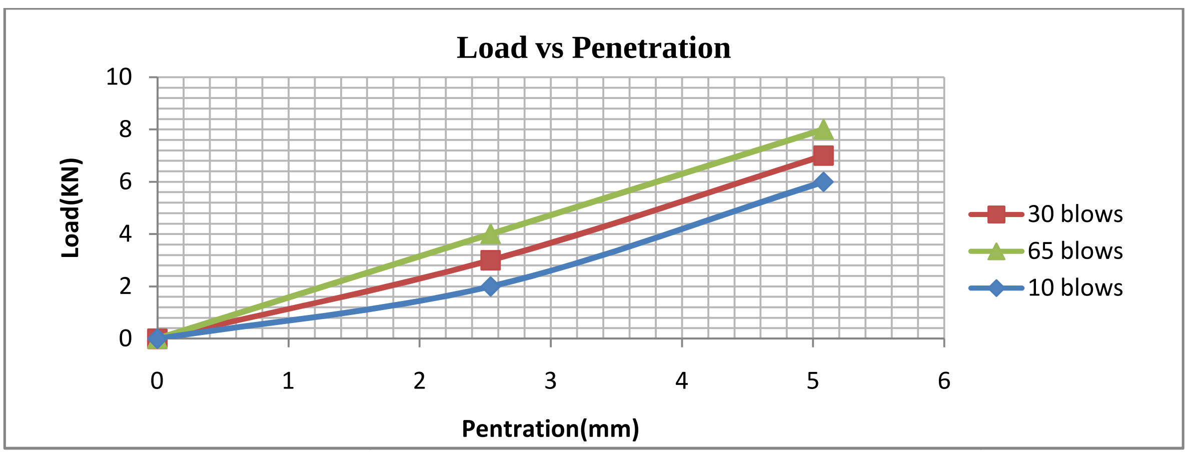


CBR for Sub-base soil, Chainage 19+300

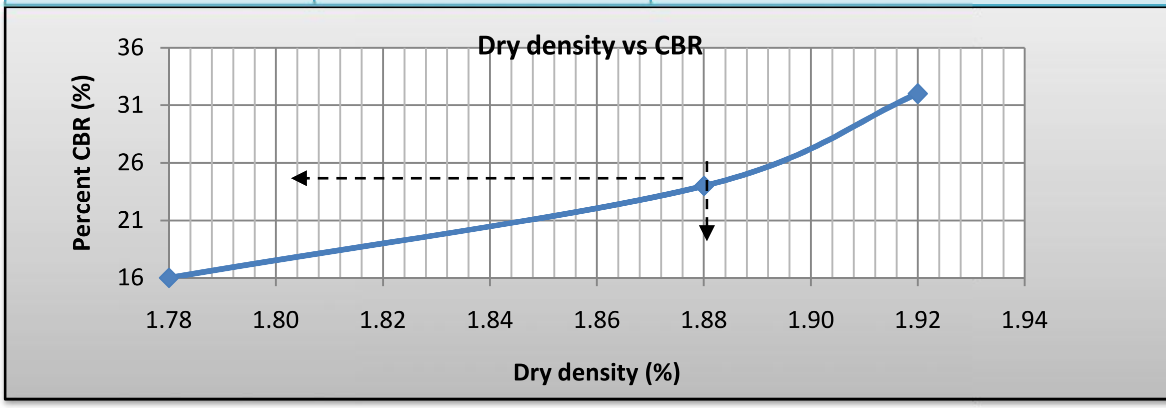
Chain age	**19+300**	**Pavement layer**	**Sub -base**		
Purpose	CBR	Test Method	Test Pit		
Sample from	Dembi-Bedele	Depth(m)			
MC(%)	13.2	15.9	17.71	19.5	24.3
DD(g/cm3)	1.81	1.88	1.96	1.92	1.86
From Compaction curve : MDD=(1.96 g/cm3) and OMC=17.71%					



Blows	**Load(KN)**			**CBR (%)**		**Swell(%)**
	0	2.54	5.08	2.54	5.08	
10	0	2	6	16	6	
30	0	3	7	24	33	
65	0	4	5	32	23	
Ring factor:	**12.14 N/Div**					



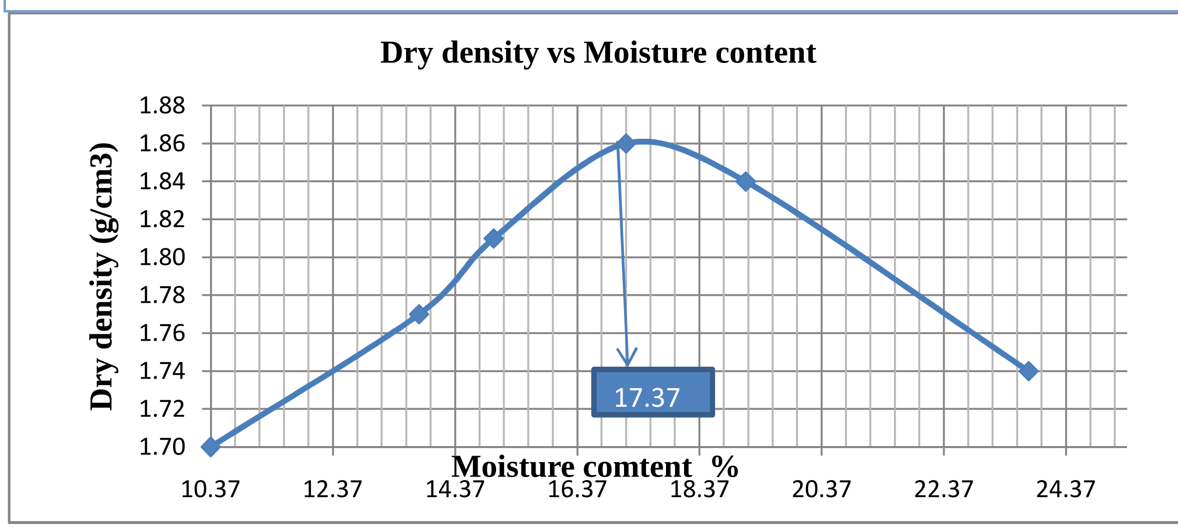
Blow	Dry density	CBR (%)
10	1.78	16
30	1.88	26
65	1.92	32



From Density-CBR curve at 95% MDD(1.92g/cm3) and CBR=26%

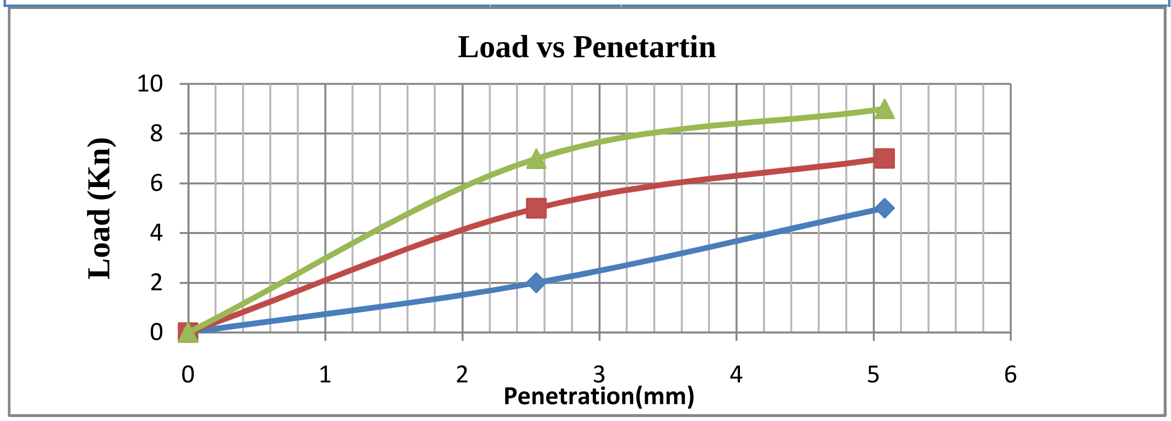
CBR for Base course Soil,Chainage 19+300

Chain age	19+300	Pavement layer		Base course	
Purpose	CBR	Test Method		Test Pit	
Sample from	Dembi-Bedele	Depth(m)			
MC(%)	**10.37**	**13.78**	**15**	**17.17**	**19.13**	**23.76**
DD(g/cm3)	1.70	1.77	1.81	1.85	1.84	1.74
From Compaction curve : MDD=(1.85 g/cm3) and OMC=17.3%						



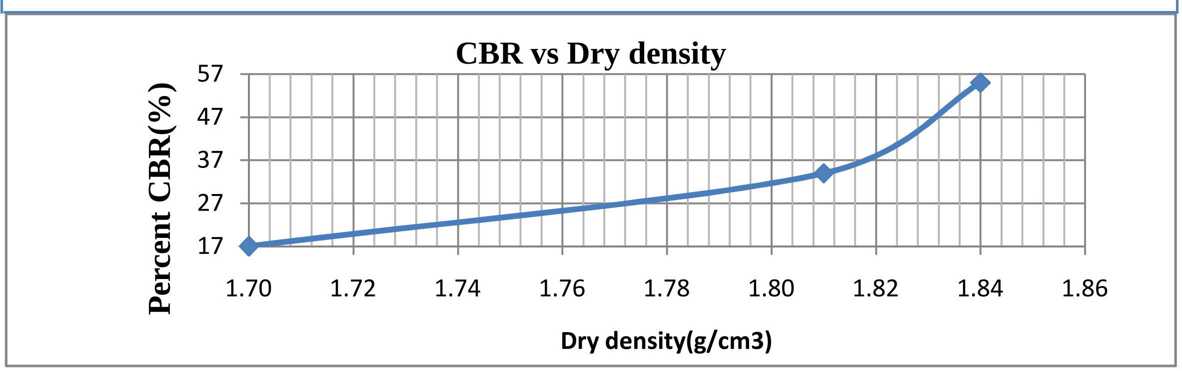
Dry Density vs.OMC of Base course ,Chainage 19+300

Blow	LOAD (KN)			CBR(%)		Swell %
	0	2.54	5.08	2.54	5.08	
10	0	2	5	17	30	0.26
30	0	5	7	34	33	0.35
65	0	7	9	55	44	0.16
						0.26



Load vs. Penetration of base course,Chainage 19+300

Blow	Dry density	CBR (%)
10	1.70	17
30	1.81	34
65	1.84	55



APPENDIX-H EXTRACTION TEST DATA

Sample representative:Trial No.2

Extraction Test Result,Chainage 18+850,at distressed section

	Wt. (g)	Sieve (mm)	Wt. Ret. (g)	% Ret.	% passing	JMF	Spc. L.Limit	Spec. U.Limit	ToleranceU. Limit	ToleranceL. Limit	Tolerance From JMF	Remark
Mass of sample (A)	1535.3	25	0.0	0.0	100	100	100	100	100	95.0	±5.0	*100*
Mass of aggregate in bowl after extraction(g) (B)	1440.7	19	32.0	2.2	97.81	97.9	85	100	103	92.9	±5.0	*92.5*
Mass of filler +Filter(g) (C)	26.4	13.2	349.1	23.9	73.94	74.6	71	84	79.6	69.6	±5.0	*77.5*
Mass of Filter(g) (D)	24.8	9.5	244.1	16.7	57.25	58.4	62	76	63.4	53.4	±5.0	*69.0*
Mass of filler (E=C-D)	1.6	4.75	219.7	15.0	42.23	43.8	42	60	47.8	39.8	±4.0	*51.0*
Mass of total aggregate (F=B+E+I	1462.6	2.36	182.4	12.5	29.76	31.6	30	48	35.6	27.6	±4.0	*39.0*
Mass of bitumen (g) (G=A-F)	72.7	1.18	128.0	8.8	21.01	23.1	22	38	27.1	19.1	±4.0	*30.0*
Bitumen content(%) (H=G/A*100)	3.8	0.6	83.5	5.7	15.3	17.5	16	28	21.5	13.5	±4.0	*22.0*
		0.3	55.0	3.8	11.54	13.9	12	20	16.9	10.9	±3.0	*16.0*
Mass of filler of per total Extraction		0.15	37.6	2.6	8.97	11.4	8	15	13.4	9.4	±2.0	*11.5*
		0.075	31.6	2.2	6.81	9.3	4	10	10.3	8.3	±1.0	*7.0*
		Pan	99.6	6.8	0.0							
		Total	1463									

Representative Sample: Trial No.2,AASHTO T30-36 Test Method

Extraction Test Result, Chainage 19+300, at distressed section

	Wt. (gm)	Sieve (mm)	Wt.Ret .(gm)	% Ret.	% passing	JMF	Spc. L.Limit	Spec. U.Limit	ToleranceU.Limit	ToleranceL.Limit	Tolerance From JMF	Remark
Mass of sample (A)	1547.6	25	0.0	0.0	100.0	100	100	100	100	95.0	±5.0	*10*
Mass of aggregate in bowl after extraction(g) (B)	1447.3	19	25.2	1.7	98.3	97.9	85	100	102.9	92.9	±5.0	*92.5*
Mass of filler +Filter(g) (C)	27.0	13.2	363.7	24.6	73.7	74.6	71	84	79.6	69.6	±5.0	*77.5*
Mass of Filter(g) (D)	26.1	9.5	226.7	15.3	58.4	58.4	62	76	63.4	53.4	±5.0	*69.0*
Mass of filler (E=C-D)	0.9	4.75	209.6	14.2	44.2	43.8	42	60	47.8	39.8	±4.0	*51.0*
Mass of total aggregate (F=B+E+I	1478.2	2.36	192.1	13.0	31.2	31.6	30	48	35.6	27.6	±4.0	*39.0*
Mass of bitumen (g) (G=A-F)	69.4	1.18	131.3	8.9	22.3	23.1	22	38	27.1	19.1	±4.0	*30.0*
Bitumen content(%) (H=G/A*100)	3.2	0.6	86.1	5.8	16.5	17.5	16	28	21.5	13.5	±4.0	*22.0*
		0.3	56.8	3.8	12.6	13.9	12	20	16.9	10.9	±3.0	*16.0*
Mass of filler of per total Extraction	30	0.15	37.4	2.5	10.1	11.4	8	15	13.4	9.4	±2.0	*11.5*
		0.075	32.5	2.20	7.9	9.3	4	10	10.3	8.3	±1.0	*7.0*
		Pan	82.5	5.6	2.3							
		Total	1478									

Representative Sample: Trial No.3 Sample,AASHTO T30-36 Test Method

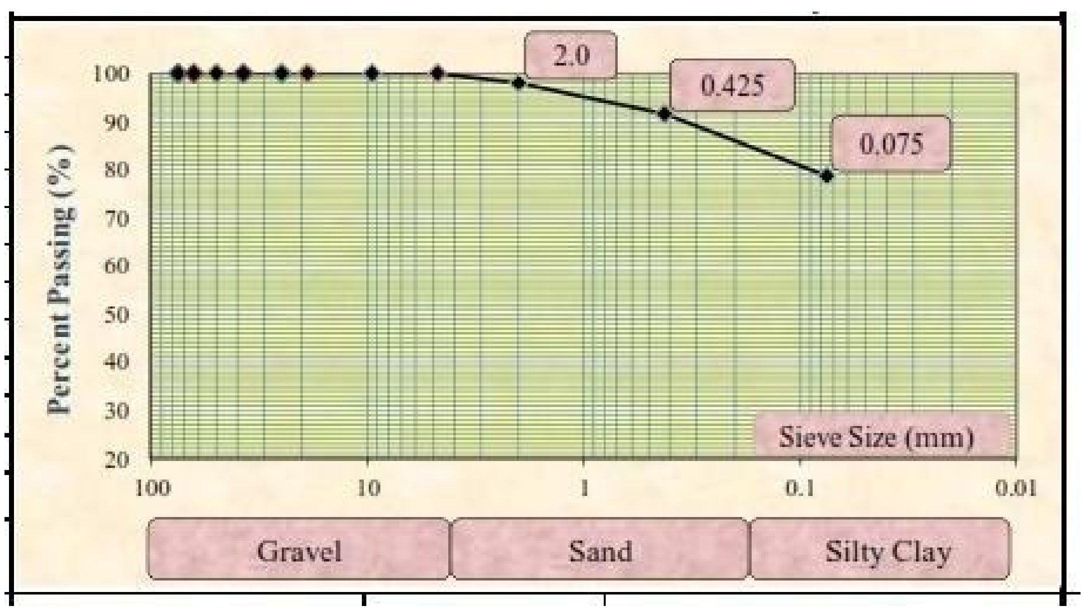
Extraction Test Result, Chainage 34+200 at Normal section

	Wt. (gm)	Sieve (mm)	Wt.Ret .(gm)	% Ret.	% passing	JMF	Spc. L.Limit	Spec. U.Limit	ToleranceU.Limit	ToleranceL.Limit	Tolerance From JMF	Remark
Mass of sample (A)	1564.6	25	25	0.00	0.00	100	100	100	100	100	±5.0	*100*
Mass of aggregate in bowl after extraction(g) (B)	1430.3	19	19	28.30	1.94	98.1	97.9	87	100	102.9	±5.0	*92.5*
Mass of filler +Filter(g) (C)	26.8	13.2	13.2	360.7	24.70	73.4	74.6	71	84	79.6	±5.0	*77.5*
Mass of Filter(g) (D)	26.2	9.5	9.5	227.9	15.61	57.8	58.4	62	76	63.4	±5.0	*69.0*
Mass of filler (E=C-D)		4.75	4.75	207.6	14.22	43.5	43.8	42	60	47.8	±4.0	*51.0*
Mass of total aggregate (F=B+E+I	1460	2.36	2.36	193.4	13.24	30.3	31.6	30	48	35.6	±4.0	*39.0*
Mass of bitumen (g) (G=A-F)	104.3	1.18	1.18	129.3	8.85	21.4	23.1	22	38	27.1	±4.0	*30.0*
Bitumen content(%) (H=G/A*100)	4.8	0.6	0.6	85.30	5.84	15.6	17.5	16	28	21.5	±4.0	*22.0*
		0.3	0.3	53.50	3.66	11.9	13.9	12	20	16.9	±3.0	*16.0*
Mass of filler of per total Extraction	30	0.15	0.15	35.8	2.45	9.5	11.4	8	15	13.4	±2.0	*11.5*
		0.08	0.08	31.20	2.14	7.4	9.3	4	10	10.3	±1.0	*7.0*
			Pan	82.50	5.7	1.7						
			Total	1460.30								

APPENDIX I- GRAIN SIZE ANALYSIS

Grain Size Analysis (ASTM D422) Chainage 18+850

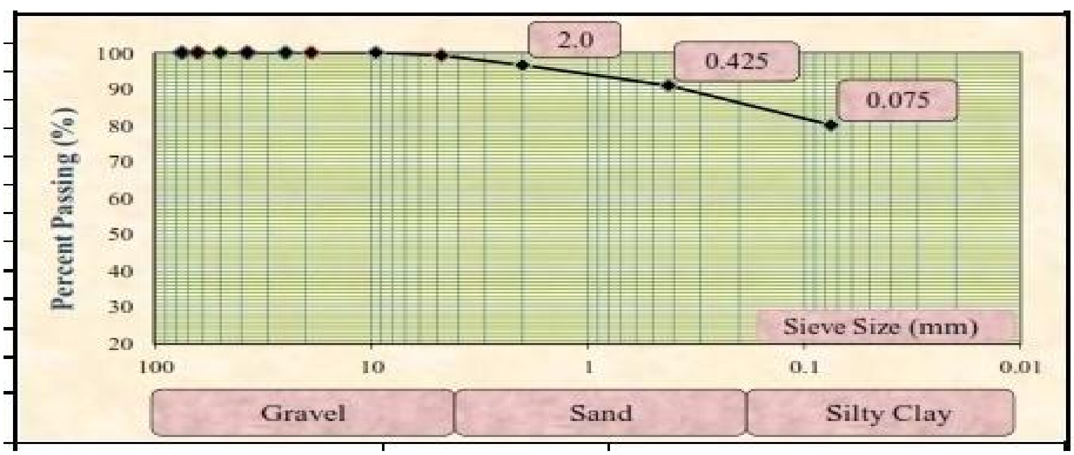
	Sieve opening	Weight retained(watered(gm)	Percent retained	%passing	
Gain Size Analysis	75	0	0.0	100.0	**Percentage passing**
	63.5	0	0.0	100.0	
	50	0	0.0	100.0	
	37.5	0	0.0	100.0	
	25	0	0.0	100.0	
	19	0	0.0	100.0	
	9.5	0	0.0	100.0	
	4.75	0	0.0	100.0	
	2	15	2.0	97	
	0.425	52	6.2	90.8	
	0.075	102	14.0	77.7	
	pan	623	77.7	0.0	
	Weight of dry soil before washing =792.5gm Soil classification A-7-5(39),USCS=MH,ERA Sub grade Soil classification=S3				



Grain Size Analysis (ASTM D422) Chainage 34+200

	Sieve opening	Weight retained(watered(gm)	Percent retained	%passing
Gain Size Analysis	75	0	0.0	100.0
	63.5	0	0.0	100.0
	50	0	0.0	100.0
	37.5	0	0.0	100.0
	25	0	0.0	100.0
	19	0	0.0	100.0
	9.5	0	0.0	100.0
	4.75	0	0.0	100.0
	2	0	0.0	100.0
	0.425	18	2.4	97.3
	0.075	86	9.8	85.7
	Pan	728	86.9	-
	Weight of dry soil before washing =829gm Soil classification A-7-6(21),USCS-CL,ERA Soil classification=S4			

Gradation Curve of Wet Sieve Analysis Chainage



Grain Size Analysis (ASTM D422) Chainage 19+300

	Sieve opening	Weight retained(watered(gm)	Percent retained	%passing
Gain Size Analysis	75	0	0.0	100.0
	63.5	0	0.0	100.0
	50	0	0.0	100.0
	37.5	0	0.0	100.0
	25	0	0.0	100.0
	19	0	0.0	100.0
	9.5	0	0.0	100.0
	4.75	0	0.0	100.0
	2	24	2.3	97.2
	0.425	50	5.7	91.4
	0.075	103	9.4	79.9
	pan	806	80.1	-
	Weight of dry soil before washing 980gm Soil classification A-7-5(25),USCS-CL,ERA Soil classification=S2			

Gradation Curve of Wet Sieve Analysis