ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

EVALUATION OF ONE-POINT LIQUID LIMIT TEST FOR RED CLAYS OF ETHIOPIA

By
Feven Girma

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Civil Engineering (Geotechnical Engineering)

By

Feven Girma

Advisor

Professor Alemayehu Teferra

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Approved by the Board of Examiners

Prof. Alemayehu Teferra	____________________	______________
Advisor	Signature	Date
Dr.Ing Samuel Tadesse	____________________	______________
External Examiner	Signature	Date

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EVALUATION OF ONE-POINT LIQUID LIMIT TEST FOR RED CLAYS OF ETHIOPIA

Dedication

To My Mother W/ro Sara Tessema (Mom), who has become the embodiment of the qualities and principles in my work.

Her love, respect, support, and confidence in me over the many years of academic and personal life have helped me to be strong on my day to day life.

Symbols & Abbreviations

LL	Liquid limit	%
PI	Plastic index	%
PL	Plastic Limit	%
ω	moisture content	%
N	Number of Blow	%
USCS		Unified Soil Classification System
AASHTO		American Association of State Highway and Transportation Officials

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Chapter 1

1.1 Introduction

The unique nature of soil properties as it appears naturally is that being divergent spatially and seasonally beyond the designer's control. Geotechnical engineers usually attempts to develop empirical equations specific to a certain region for different soil types. However, these empirical equations are more reliable for the type of soil where the correlation is origin. Hence, it is important to develop empirical equations that best fit for the local area that we can access.

As a result, this study evolved to find the correlation between liquid limit (LL) and water content (ω); and evaluation of its validity for local soils (one point) (non-expansive clay soils). The study has examined the feasibility of single linear regression analysis for correlating liquid limit (LL) with water content (ω).

Accordingly, Seven Hundred Eighty three Multi point Atterberg limits test results were conducted for different locations of Ethiopia in order to achieve the intended correlations.

Specific to this research, statistical software (SPSS) and Excel is employed to investigate the significance of individual independent variables. The correlation is established in the form of an equation of One Point Atterberg limits.

$$LL = \omega . \left(\frac{N}{25} \right)^{\tan \beta}$$

Where:-

LL – Liquid Limit

ω – Moisture Content at each number of blows

N – Number of Blow

The developed correlation entailed a moderate determination coefficient of R^2 = 0.7106 using single regression analysis, for a sample size of Two hundred forty nine.

After validating the developed correlation with control test results, it was noted that the correlation of liquid limit (LL) with water content (ω) is applicable.

1.2 Background of the Study

The physical and mechanical behavior of fine – grained soils is linked to four distinct states: solid, semi-solid, plastic, and liquid, in order of increasing water content. Let us consider a soil initially in a liquid state that is allowed to dry uniformly. If we plot a diagram of volume versus water content as shown in figure 1.1, we can locate the original liquid state as point A. as the soil dries, its water content reduces and, consequently, so does its volume.

At point B, the soil becomes so stiff that it can do longer flow as a liquid. The boundary water content at point B is called the liquid limit; it is donated by LL. As the soil continues to dry, there is a range of water content at which the soil can be molded into any desire shape without rapture. The soil at this state is said to exhibit plastic behavior—the ability to deform continuously without rupture. But if drying is continued beyond the range of water content for plastic behavior, the soil becomes a semisolid. The soil cannot be molded now without visible cracked appearing. The water content at which the soil changes from a plastic to a semisolid is known as the plastic limit, denoted by PL. the range of the water contents over which the soil deforms plastically is known as the plasticity index, PI:

$$PI=LL-PL$$

As the soil continues to dry, it comes to a final state called the solid state. At this state, no further volume change occurs since nearly all the water in the soil has been removed. The liquid and plastic limits are called the "Atterberg Limits”, after their originator, Swedish soil scientist A. Atterberg (1911).

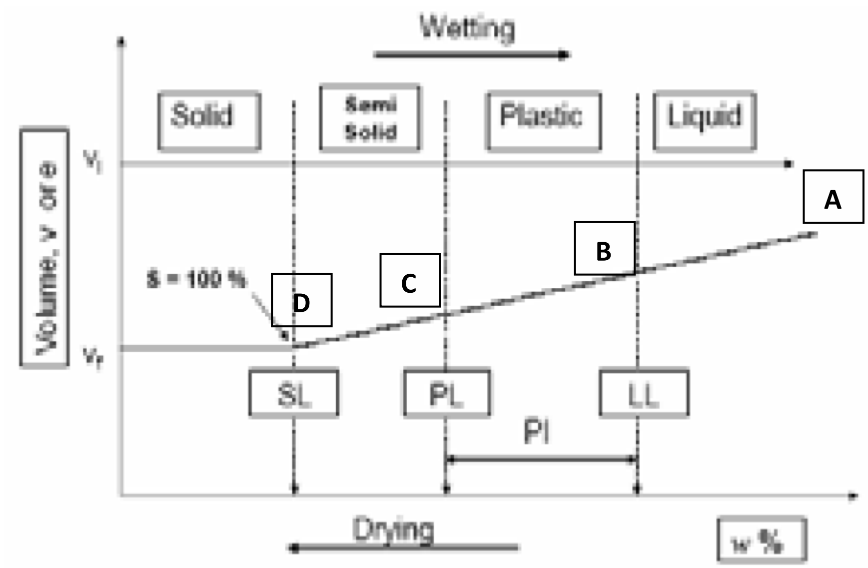

Figure 1. 1 changes in soil state as a function of soil volume and water content

The following moisture conditions - liquid limit, plastic limit, along with shrinkage limit are referred to as the "Atterberg Limits", after the originator of the test procedures.

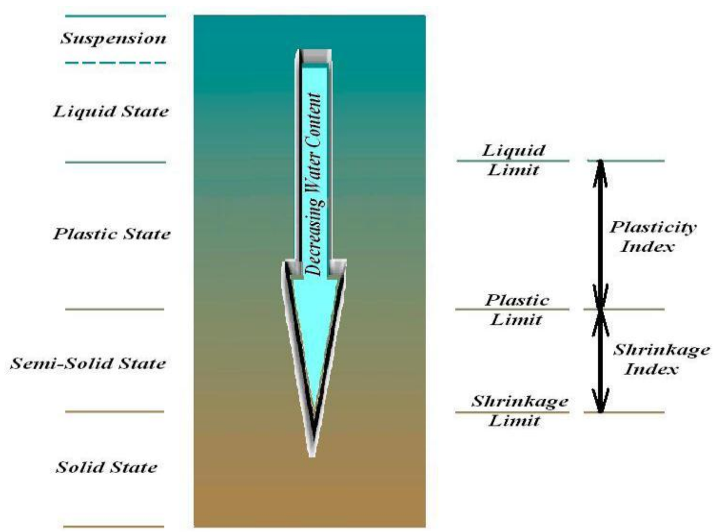

Figure 1. 2 Atterberg Limits and Indices

1.3 Scope of the study

This research will develop a value of tanβ exponent using correlation between liquid limit and water content for local soils (one point). The graphical representation of liquid limit is in semi-logarithmic graph, with logarithmic values on the abscise axis, so that it can be represented as a line. This can be explained by the fact that in the laboratory the line is visually passed through four points in order to determine the moisture content at the liquid limit for N=25 bumps of the standard bowl.

The computation of the tanβ exponent was performed by employing the linear regression method and using the equation of the line passing through multi points, obtained in the laboratory, for 249 flow curves, which is:

$$LL = \omega \cdot \left(\frac{N}{25}\right)^{\tan\beta}$$

Where:-

LL – Liquid Limit

ω – Moisture Content at each number of blow

N – Number of Blow

Or

$$LL = a * N^{\wedge} \tan\beta$$

a= Constant Number that is the ratio of

$$\frac{\omega}{25^{\tan\beta}}$$

This research addresses the above goal by undertaking a detailed investigation on study of Atterberg limits. For this intended purpose, Multi point Atterberg limits test result were conducted form different locations of Ethiopia, each set was used to compute the flow curve by one-point method taking into account either the exponent obtained by these analyses or the exponent recommended by using statistical analysis of the flow curves.

1.4 Organization of the Study

The thesis is organized and presented under six Chapters. The first Chapter highlights introduction of the subject study. Chapter two deals with review of published literature. In Chapter three, discussions on Atterburg Limits, Chapter Four discussions on sample result collection. In Chapter five, correlation and regression analyses were conducted and validating and evaluating the obtained correlation. Under Chapter six, the conclusion and recommendation were presented. At the end, details of the regression and laboratory test results enclosed under appendix section.

1.5 Metedology

In order to achieve the objective of the research Atterberg limit tests results are conducted, on 249 samples test result. This laboratory test results are collected from different thesis's under AAIT and Abiy Tsegaye Consultancy Service for different parts of Ethiopia where red clay soil is found. Using Microsoft® excel and SPSS regression analysis software using the correlation of ω /LL and N, it is to find out the exponent of one point liquid limit. The statistical analysis of the flow curves are Linear regressions analysis and Mean Value Method is used.

Chapter 2

Literature Review

2.1 Red clay soil

2.1.1 General

Clay refers for soil particles finer than 2 microns (0.002mm) and has the property of plasticity when mixed with some amount of water. Plasticity refers for the behavior of material that deforms in shape and keeps its deformation even after the removal of the pressure that primarily caused the deformation. Clay soil may contain clay minerals as well as non-clay minerals. The non-clay minerals that found in clay are quartz, feldspar or mica of clay size. Clay minerals are mostly in the form of sheets; their thickness is relatively smaller than width and length of the sheets, their surface area is so larger than their volume. As the result the behavior of clay is governed by the surface forces (Terzaghi, K. and Peck, R.B., 1967). Soil behavior is attributed to the properties of clay minerals that found in the specific soil. Therefore, it is vital to know the behavior of clay minerals for understanding the engineering behavior of fine grained soils.

2.1.2 Origin of clay soil

On a basic level, clay soil is composed of millions of clay particles which are 0.002 millimeters (0.0000787 inches) in diameter or smaller. These particles are tightly spaced, which is why clay is notorious for having poor water or air movement throughout. Furthermore, clay particles have a very strong affinity for water and, when exposed to water, they swell up and adhere to each other (a process known as cohesion). Clay soil is essentially composed of several minerals that deposit together and, over time, form a hardened clay deposit. Silicates, mica, iron and aluminum hydrous-oxide minerals are the most common minerals found in clay deposits. However, other minerals, such as quartz and carbonate, are also present in clay soils. In order to form clay soil, the particles that compose the soil need to come from somewhere. Erosion is one source of particles for clay soils and it occurs when water rushes over the surface of rock. However, the largest source of clay particles is from weathering of rocks and soil. During weathering, both physical and chemical changes take place that create the small particles required to form clay soil. Lastly, diagenesis--the process that occurs when minerals that are stable in one environment destabilize because of compaction or burial--is another source of clay particles. thickness is relatively smaller than width and length of the sheets, their surface area is so larger than their volume. As the result the behavior of clay is governed by the surface forces. [3]

Soil behavior is attributed to the properties of clay minerals that found in the specific soil. Therefore, it is vital to know the behavior of clay minerals for understanding the engineering behavior of fine grained soils.

2.1.3 Clay Minerals

Clay minerals are small group of minerals that constitute clay soils together with other minerals. Most of clay minerals are formed from two basic units known as octahedral and silica sheets. The octahedral units consist of aluminum, magnesium or iron embedded between two layers of oxygen or hydroxyl layers. The silica sheet consist tetrahedron of four oxygen atoms and one silicon atom in between as shown in fig 2.1. Most of the clay minerals are the product of chemical weathering of rock forming minerals like feldspar and mica. The clay minerals include Illite, Kaolinite, Montmorillonite, Halloysite and Vermiculite; however, the first three are the major ones.

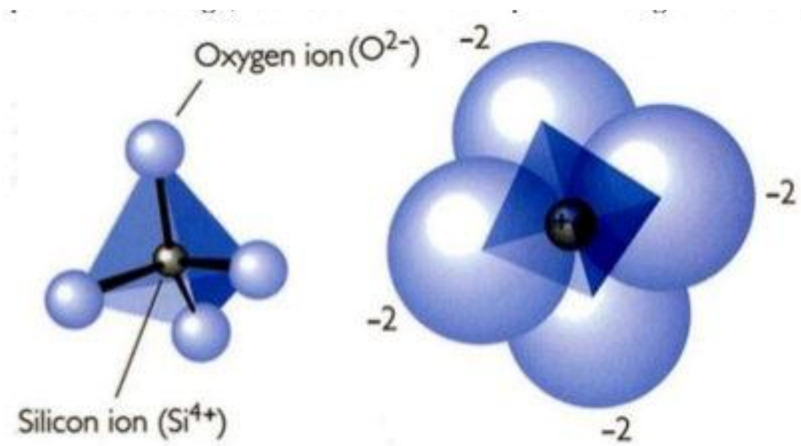

Figure 2. 1 Silica Sheet

2.1.3.1 Illite

Illite is made up of octahedral sheet bonding with two silica sheets: one at the top and another at the bottom. The Illite layers are bonded by potassium ions. Illite particles range from 5Å0 to 500Å in thickness and have specific surface area of about 80m2/g.

2.1.3.2 Kaolinite

Kaolinite is composed of a single tetrahedron sheet and single aluminum octahedral sheet combined in a unit so as the tips of the silica tetrahedron and one of the layers of the octahedral sheet form a common layer. The association of a silica tetrahedral sheet with aluminum octahedral sheet forms one layer of kaolinite. The thickness of kaolinite layer is about ÅÅ7. The kaolinite mineral is formed by stacking the layers Å of th7ick one above the other with the base of silica sheet bonding the hydroxyls of the octahedral sheet by hydrogen bond. Since the hydrogen bonds are relatively strong, therefore, the mineral is stable and water cannot enter between the sheets to expand the unit cells.

2.1.3.3 Montmorillonite

Montmorillonite has similar structure to Illite. The structure has one octahedral sheet sandwiched between two silica sheets and bonded with weak Vander walls forces. Large amount of water is attracted in to the space between the layers and causing the layers to expand significantly. Montmorillonite particles have the lateral dimension of 100Å0 to 5000Å and thickness of 10 Å to 50 Å, and its specific area is about 800m2/g.

2.2 Origin and Mineral Composition of Ethiopian Red Clay soils

According to the study of Morin and Parry (1971) [4], the Ethiopian red clay Soils have formed as residual from basaltic volcanic rocks in places with plenty of rainfall and good drainage. The principal clay minerals that constitute the Ethiopian red clay are kaolinite and halloysite. Montmorillonite is also found in the Ethiopian red clay as accessory or less amount than as in Ethiopian black clay.

The Ethiopian red clay is found to be acidic, which is similar to that of other tropical soils. The cation exchange capacity is from 30 to 77 milli- equivalents per 100g. The Ethiopian red clay soils do not show wide range index properties as other tropical soils. They have also generally lower clay contents, liquid limits and plasticity indices [4].

The shrinkage limit of the red clay varies from 10% to 30%. Morin and Parry (1971) have also indicated that the volume change tendency of the Ethiopian red clay soil is also significant at the lower moisture content. However, red clay soils are less expensive than the Ethiopian black clay soils because of high amount of kaolinite and Halloysite relative to Montmorillonite.

The unconfined compressive strength of the red clay soil varies from 147 to 251kpa and has even more strength. The Ethiopian red clay soils have similar densities, however, lower dry density than other tropical soils when compacted according to AASHTO standard. The red clay soil show less plasticity but some are near to the dividing line between low plasticity and high plasticity groups. The summery of the properties of Ethiopian red clay soil is shown below.

Properties	**Values/Results**
Parent Rock	Olivine basalt, Basalt, Trachyte
Rain fall, cm/yr	122-234
Temperature, o	57-68 F
Drainage	Fair – good
Principal Clay minerals	Kaolinite, Hallysite, Montmorillonite
PH Value	5.1-6.8
Principal Cations	Calcium, magnesium, potassium
Cation Exchange capacity, m.e./100g	30-77
Clay (2μ), %	34-76
Liquid Limit, %	44-66
Plasticity Index, %	14-30
Shrinkage Limit, %	10-30
Specific gravity	2.61-2.91
Organic Content, %	1-4
Compaction Test: Max Density g/cc Optimum Moisture Content, %	1.185-1.698 38-29
CBR Test Value	6-9
Unconfined Compressive Strength, kpa.	147-251
Expansion Pressure, kPa	21-958

Table 2. 1 Properties of Ethiopian red clay soils (Morin and Parry 1971).

2.3 Clay soil distribution in Ethiopia

During road design and construction, soil engineering maps are very essential. These maps show the distribution of soils, and describe their origin, physical characteristics and engineering properties. However, national or regional based soil engineering maps do not exist in Ethiopia. Consequently, maps are often only available in association with specific road construction projects. In the absence of engineering soil maps, it is common practice to use agricultural soil classification systems of the type given in Figure 2.5.

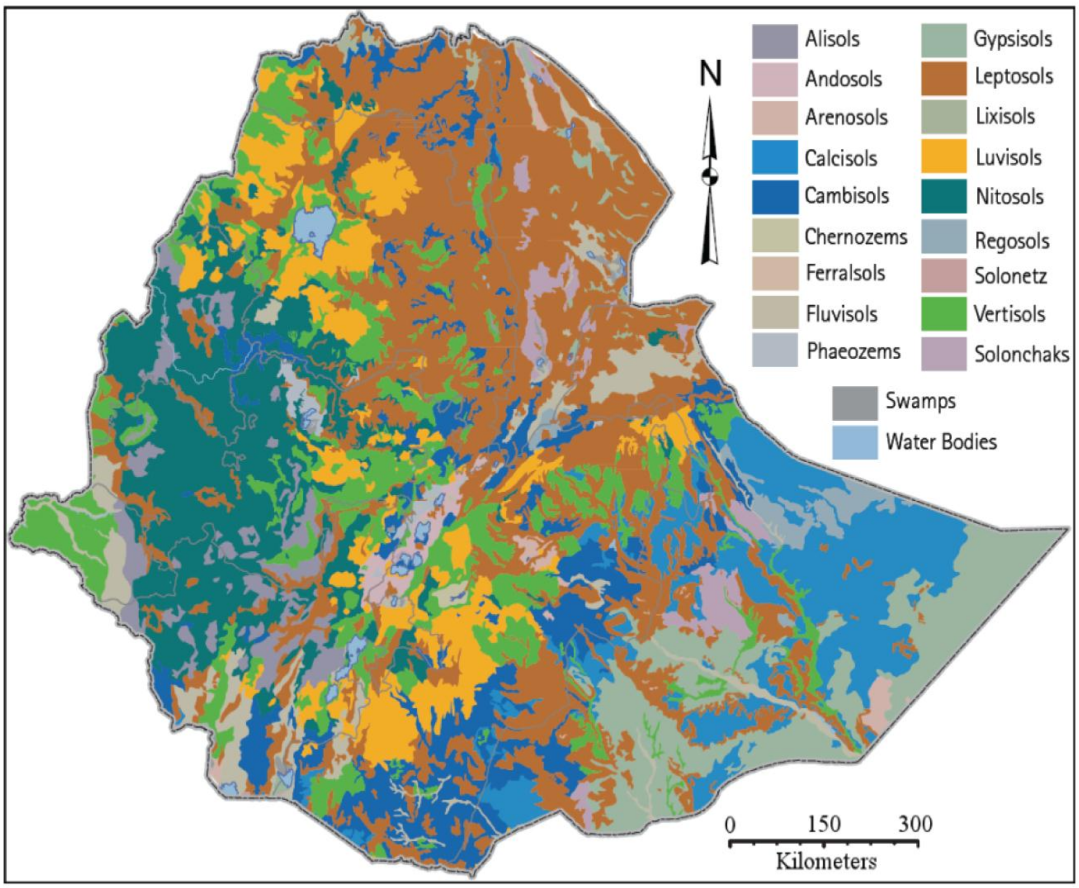

Figure 2. 2Agricultural soil map of Ethiopia

The red soils normally occur on sloping ground close to local high points where there is good drainage (Dumbleton, 1967), a vegetative cover with little organic matter and high temperature and rainfall. Water removes the more soluble bases and silica, leaving the soil rich in iron (in the form of iron oxide) and aluminum (as clay minerals of the kaolin group). Deposits of these soils are present in the western part of Ethiopia (western and north-western highlands), southern lowlands and southern rift, most part of the central highlands, and in pockets of well drained lands throughout the north-east and eastern highlands.

Red soils can be formed from many kinds of rocks if the weathering conditions, climate and drainage are suitable. In Ethiopia, they have developed mainly on volcanic (basalts, ryholites, etc) and pyroclastics rocks. In the western part of the country they have also been seen on granitic terrains. The iron oxide in these soils, which accounts for their dark red colour, occurs in a hydrated (goethite) and an unhydrated form (hematite). Goethite and hydrated halloysite predominate under wetter conditions. The clay mineral is usually kaolin of the halloysite type, which occurs as hydrated and meta-halloysite. Hydrated halloysite is readily converted to meta-halloysite on drying. Kaolin in the form of halloysite has a disordered structure, which gives rise to a soil of higher potential plasticity than well-ordered kaolinites. Red clays in the wetter regions of Ethiopia often show this nature of possessing high plasticity and should be subjected to plasticity tests before they are used for road construction purposes.

Type of soil	Engineering characteristics	Availability in Ethiopia
Red clay soils	The red colour is the result of iron oxide; they contain kaolin in the form of halloysite, which has a disordered structure and may produce a soil with a potential of high plasticity than soils with well-ordered kaolinites.	Present in large quantities in the west, south-west, north-west and western parts of Ethiopia, and in well drained areas of other parts of the country

Table 2. 2 A summary of the characteristics and distribution of Red Clay Soils in Ethiopia

2.4 Identification and Classification of Clay Soils

During field exploration a log must be kept of the materials encountered. A field engineer, a geologist, or the driller usually keeps the field log. Details of the subsurface conditions encountered, including basic material descriptions, and details of the drilling and sampling methods should be recorded. Upon delivery of the samples to the laboratory, an experienced technician will generally verify or modify material descriptions and classifications based on the results of laboratory testing and/or detailed visual-manual inspection of samples. See ASTM D 5434 Material descriptions, classifications, and other information obtained during the subsurface explorations are heavily relied upon throughout the remainder of the investigation program and during the design and construction phases of a project. There are two ways of soil identification that are field and laboratory identification methods,

For different uses samples were collected on different locations of a given project and proper laboratory tests were made. For my study I collect Atterberg test results of different locations by using Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO) systems for sorting out the data for this specific analysis.

2.4.1 Field identification: -

Currently it is evident that soil deposits can be recognized in the field through visual inspection. Some of the important field identification method for fine grained soil is the following:

Test	Test Procedures and Interpretation of Results
Dilatancy	Prepare a pat of moist soil with a volume equivalent to a 25-mm cube. Add water, if necessary, to make the soil soft but not sticky. Place the pat of soil in the open palm of one hand and shake horizontally; strike vigorously against the other hand several times. If the reaction is positive, water appears on the surface of the pat; the consistency of the pat then becomes livery; and the surface of the pat becomes glossy. Next, squeeze the sample between the fingers. The water and gloss should disappear from the surface of the pat; the soil will stiffen and crack or crumble. The rapidity of the appearance of water on the surface of the soil during shaking and its disappearance during squeezing help to identify the character of the fines in the soil. Very fine clean sands give the quickest and most distinct reaction, inorganic silts give a moderately quick reaction, and plastic clays have no reaction.
Dry Strength	Mould a pat of soil to the consistency of putty. If the soil is too dry, add water; if it is too sticky, the specimen should be allowed to dry by evaporation. After the consistency of the pat is correct, allow the pat to dry (by oven, sun, or air). Test its strength by breaking and crumbling between the fingers. The dry strength increases with increasing plasticity. High dry strength is characteristic of high plasticity clays. Silty sand and silts have only slight dry strengths, but can be distinguished by feel when powdered; fine sands feel gritty whereas silts feel smooth like flour. It should also be noted that shrinkage cracks may occur in high plasticity clays. Therefore, precautions should be taken to distinguish between a shrinkage crack as opposed to a fresh break which is the true dry strength of the soil.
Toughness and Plasticity	A specimen of soil which is about the size of a 25-mm cube should be moulded to the consistency of putty; add water or allow drying as necessary. At the proper moisture content, roll the soil by hand on a smooth surface or between the palms into a thread about 3-mm in diameter. Fold the thread of soil and repeat the procedure a number of times. During this procedure, the water content of the soil is gradually reduced. As drying occurs, the soil begins to stiffen and finally loses its plasticity and crumbles at the plastic limit. After the thread has crumbled, the pieces should be lumped together and a kneading action should be applied until the lump crumbles. For higher clay contents, threads are stiffer and lumps are tougher at the plastic limit than for lower plasticity clays.

Table 2. 3 Filed identification procedures for fine grained soils

Plasticity	Adjective	Dry strength
0	Non-plastic	None; crumbles into powder with mere pressure.
1 - 10	Low plasticity	Low; crumbles into powder with some finger pressure.
>10 - 20	Medium plasticity	Medium; breaks into pieces or crumbles with considerable finger pressure.
>20 - 40	High plasticity	High; cannot be broken with finger pressure; spec. will break into pieces between thumb and a hard surface.
>40	Very plastic	Very high; can't be broken between thumb and a hard surface.

Table 2. 4 A field Method to describe plasticity in terms of Dry Strength

Other tests which may help in distinguishing sand and fine grained soils in the field are summarized in Table 2.5. The description (settlement in water) test and the bites test can be used to determine the presence of and relative amounts of sand, silt, and clay fractions. The odour and the peat tests are useful for determining the presence of organic matter, the acid test for identifying the presence of a calcium carbonate cementing agent , and the slaking test for determining whether the rocklike material is shale. Like the other three tests mentioned in Table 2.3, these are also performed on particles that pass the 0.425 mm sieve which is the division between medium and fine sand. For field classification purposes, screening is not necessary. Instead, the removal of the coarse particles that interfere with tests is sufficient.

When both fine and coarse grained soils are present in a soil mass in appreciable quantity, the description is in such a way that the name of the second soil type is used as an adjective. For example when the percentage of the fine-grained soil type is less than 30% but greater than 12% of the total sample, the soil is described as "silty" or "clayey", depending on which particle size is dominating. Similarly, the description becomes "gravelly" or "sandy" if the coarse-grained component is 30% or more of the total sample. When the percentage of the fine- grained soil is 5 to 12%, the description contains "with Silt" or "with clay". The coarse grained equivalent is used when the sand and gravel is less than 30% but higher than 15% of the total sample.

Test	Test Procedures and Interpretation of Results
Disperssion test	Place a few hundred grams of soil in a jar containing water. Shake the jar and allow the soil to settle. The rate of settling can be used to judge the (settlement predominate soil type(s) whereas the thicknesses of the various soils can be used to judge the gradation of the soil. Sands settle in 30 to 60 seconds, silts settle in 30 to 60 minutes, and clays may in water) remain in suspension overnight. The interface between fine sands and silts occurs where individual grains cannot be discerned with the unaided eye. The cloudiness of the water indicates the relative clay content.
Bite test	Place a pinch of soil between the teeth and grind lightly. Fine sands grate harshly between the teeth; silts have a gritty feeling but do not stick to the teeth; clays tend to stick to the teeth, but do not have a gritty feeling
Odour test	Organic soils have a musty odour which diminishes upon exposure to air. The odour can be revived by heating a moist sample or by exposing a fresh sample.
Peat	Peat has a fibrous texture and is characterized by partially decayed sticks, leaves, grass, and other vegetation. A distinct organic odour is characteristic of peat. Its colour generally ranges from dull brown to black.
Shine	Moist highly plastic clay will shine when rubbed with a fingernail or pocketknife blade; lean clay will have a dull surface.
Acid test	The presence of calcium carbonate in a soil can be determined by adding a few drops of dilute (3:1 ratio of water to acid) hydrochloric acid to the soil. The relative amount of calcium carbonate in the soil can be determined by the effervescence (fizzing reaction) which occurs. Degrees of reaction range from none to strong. For some very dry non-calcareous soils, the illusion of effervescence as the acid is absorbed by the soil can be eliminated by moistening the soil before the acid is applied.
Slaking test	Certain shales and other soft rock-like materials disintegrate upon drying or soaking. The test is performed by placing the soil in the sun or oven to dry completely. After the sample has been dried, it should then be soaked in water. The degree of slaking should be reported.

Table 2. 5 Additional Tests To Identify Fine Grained Soils In the Field

Soils should be described in general accordance with the Description and Identification of Soils (Visual - Manual Procedure) of ASTM D 2488. This Procedure employs visual examination and simple manual tests to identify soil Characteristics, which are then included in the material description. For example, estimates of grain-size distribution by visual examination indicate whether the soil is fine-grained or coarse-grained. Manual tests for dry strength, dilatancy, toughness, and plasticity indicate the type of fine-grained soil. Organics are identified by color and odor.

2.4.2 *Laboratory identifications: -*

A classification scheme provides a method of identifying soil in a particular group that would likely exhibit similar characteristics. Soil classification is used to specify a certain soil type that is best suited for a given application. Also, it can be used to establish a soil profile along a desired cross section of a given soil mass. The most useful Analysis in identifying soils is determining the Grain-Size. Generally, these can be categorized as Sieve Analysis and Hydrometer methods.

2.4.2.1 Grain-Size Analysis

This test is performed in two stages: sieve analysis for coarse-grained soils (Sands, gravels) and hydrometer analysis for fine-grained soils (clays, silts). Soils Containing both types are tested in sequence, with the material passing the No. 200 sieve (0.075 mm or smaller) analyzed by hydrometer.

2.4.2.1.1 Sieve Analysis

This test provides a direct measurement of the particle size distribution of a soil by causing the sample to pass through a series of wire screens with progressively smaller openings of known size. The amount of material retained on each sieve is weighed.

2.4.2.1.2 Hydrometer

This test is based on Stokes Law. The diameter of a soil particle is defined as the diameter of a sphere which has the same unit mass and which falls at the same velocity as the particle. Thus, a particle size distribution is obtained by using a hydrometer to measure the change in specific gravity of a soil-water suspension as soil particles settle out over time. Results are

reported on a combined grain size distribution plot as the percentage of sample smaller than, by weight, versus the log of the particle diameter. These data are necessary for a complete classification of the soil.
The curve also provides other parameters, such as effective diameter (D10) and 46 Coefficient of uniformity (Cu). Tests shall be performed in accordance with ASTM D 422 (AASHTO T 88).

2.5 Universal Approaches Based on Soil Classification Systems

Many researchers and agencies classify the soil type on the basis of samples obtained from a specific region and soil type. General relationships are also developed using universally accepted soil classification systems, basically based on the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO) systems. These correlation methods take a general approach and attempt to encompass many or all possible soil types.
Each was devised for a specific use. For example, the American Association of State Highway and Transportation Officials (AASHTO) developed one scheme that classifies soils according to their usefulness in roads and highways, while Unified Soil Classification system (USCS) was originally developed for use in airfield construction but was later modified for general use.

The most widely used soil classification is the Unified Soil Classification System (ASTM D 2487). The USCS outlines field procedures for determining plasticity, dilatancy, dry strength, particle size, and other engineering parameters. The AASHTO classification system (M 145), which is also commonly used for highway projects, groups soils into categories having similar load carrying capacity and service characteristics for pavement sub-grade design. The USCS is provided here for information but in most cases of site investigation in Ethiopia, the AASHTO classification system is recommended.

The USCS is based on identifying soils according to their textural and plastic characteristics, and on their grouping with respect to behaviour. Soils seldom exist in nature separately as sand, gravel, or any other single component. They are usually found as mixtures with varying proportions of particle sizes. Each component part contributes its characteristics to the soil mixture. The USCS is based on those characteristics that control how the soil behaves as an engineering material.

2.5.1 Unified Soil Classification system

The USCS is neither too elaborate nor too simplistic. The USCS uses symbols for the particle size groups. These symbols and their representations are G– gravel, S—sand, M—silt, and C—clay. These are combined with other symbols expressing gradation characteristics—W for well graded and P for poorly graded—and plasticity characteristics—H for high and L for low, and a symbol, O, indicating the presence of organic material. A typical classification of CL means a clay soil with low plasticity, while SP means poorly gadded sand.

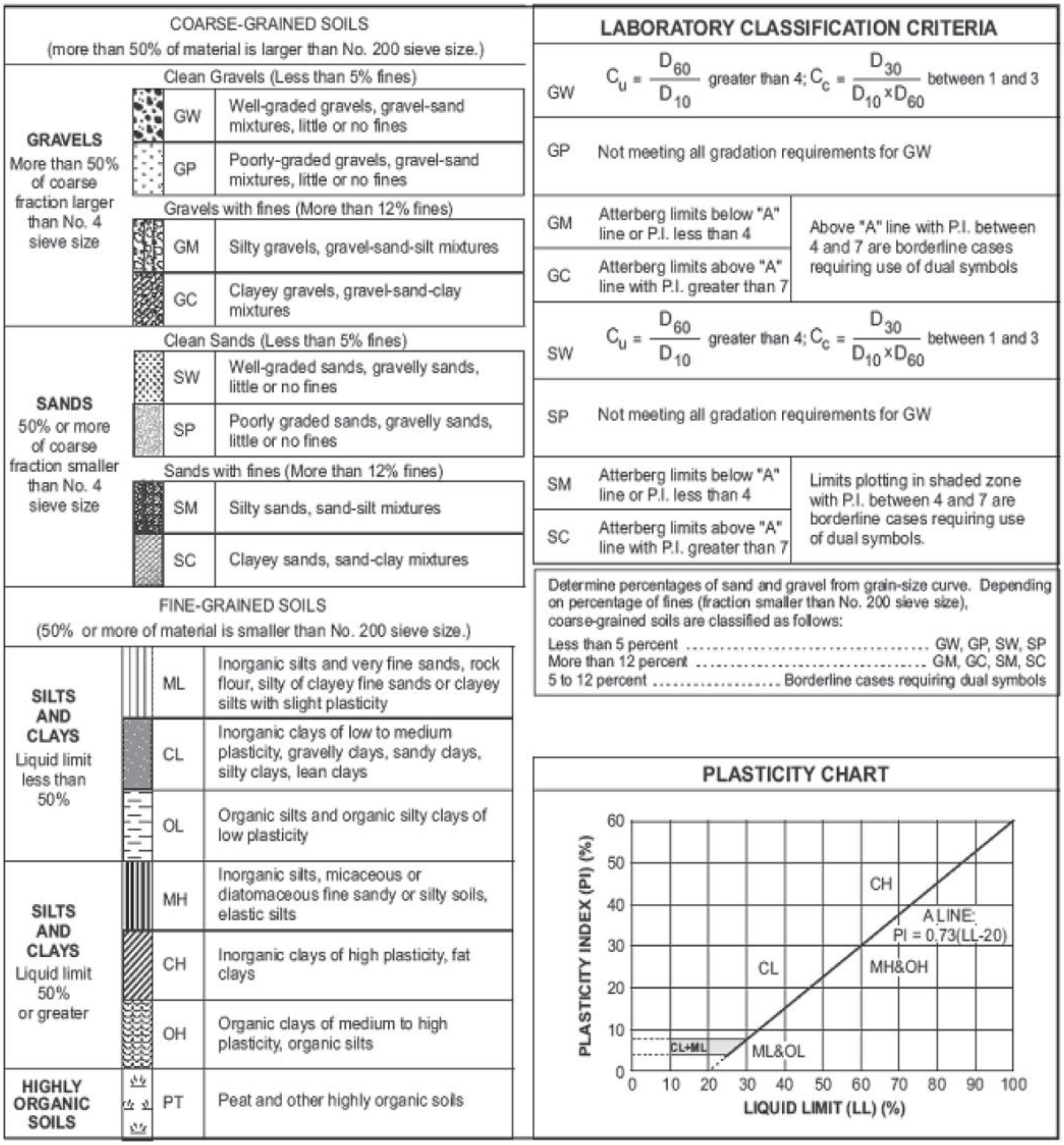

Figure 2. 3 The Unified Soil Classification System (USCS)

2.5.2 American Association of State Highway and Transportation Officials

The AASHTO soil classification system is used to determine the suitability of soils for earthworks, embankments, and road bed materials (subgrade-natural material below a constructed pavement; sub base-a layer of soil above the subgrade; and base- a layer of soil above the sub base that offers high stability to distribute wheel loads). According to AASHTO, granular soils are soils in which 35%or less are finer than the No.200 sieve (0.075mm). Silt-clay soils are soils in which more than 35% are finer than the No.200 sieve.

Gravel	75mm to 2mm (No. 10 sieve)
Sand	2mm (No. 10 sieve) to 0.075mm(No. 200 sieve)
Silt and Clay	<0.075mm (No. 200 sieve)
	silty: PI<10%
	clayey: PI>11%

Table 2. 6 Soil types, Mean Grain size, and Description According to AASHTO

The AASHTO system classifies soils in to seven major groups, A-1 through A-7. The first three groups, A-1 through A-3, are granular (coarse-grained) soils where 35% or less of the particles pass through the 75µm (No. 200 sieve), while the last four groups, A-4 through A-7, are silt-clay (fine- grained)soils that are more than 35% pass the 75µm (No. 200 sieves) .

General classification		Granular materials (35% or less of total sample passing 75 micron (No. 200 sieve)							Silty-clay materials (More than 35% of total sample passing 75 micron (No. 200 sieve)			
Group classification		A-1		A-3	A-2				A-4	A-5	A-6	A-7
		A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6
Sieve analysis, percent passing	2 mm (No 10)	50 max										
	0.425 mm (No. 40)	30 max	50 max	51 min								
	75 micron (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing No 40 (0.425 mm)	LL				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
	PI	6 max		NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
Usual significant constituent materials		Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
Group Index**		0		0	0		4 max		8 max	12 max	16 max	20 max

Table 2. 7: The AASHTO soil classification system

2.6 Engineering Characteristics of Clay soils

In the previous sections, soils are divided into coarse and fine grained using either the USCS or AASHTO classification systems. The engineering characteristic of a soil mass depends on the proportion of these two groups of soils, and is governed by the one which dominates.

The plasticity index (PI) is the main parameter that governs the engineering performance of fine-grained soils. In addition to the PI, the liquidity index (LI) and liquid limit (LL) are also useful indicators of the engineering performance of fine grained soils. The PI represents the range of water content over which the soil remains plastic and normally the higher the PI, the higher the percentage of clay particles in the soil. Also, the more plastic a soil, the more likely it is to be compressible. It will have a greater potential to shrink and swell and it will be less permeable.

In general, the engineering characteristics of inorganic clays (A-6 and A-7) are the following:

- Generally possess low shear strength;
- Plastic and compressible;
- Can lose part of shear strength upon wetting;
- Can lose part of shear strength upon disturbance;
- Can shrink upon drying and expand upon wetting;
- Generally very poor material for backfill;
- Generally poor material for embankments;
- Can be practically impervious;
- Clay slopes are prone to landslides.

Chapter 3

Atterberg limits

3.1 Historical background and basic principles

The Swedish soil scientist Albert Atterberg (1911) originally defined six 'Limits of consistency' to classify fine-grained soils, but in current engineering practice only three of the limits, i.e. Liquid, plastic and shrinkage limits are used. For this study only liquid limit study will be grasped in detail. Atterberg was working in the ceramic industry, and at that time they had several simple tests to describe the plasticity of clay which were important both in molding clay into bricks, for example, and to avoid shrinkage and cracking when fired. After many experiments, Atterberg came to the realization that at least two parameters were required to define plasticity of clays, i.e. the upper limits and lower limits of plasticity. In fact, he was able to define several limits of consistency or behavior and he has developed simple laboratory tests to define these limits. They are:-

1. Upper limits of viscous flow.
2. Liquid limit – lower limit of viscous flow.
3. Sticky limit – clay loses its adhesion to a metal blade.
4. Cohesion limit – grains cease to cohere to each other.
5. Plastic limit – lower limit of the plastic state.
6. Shrinkage limit – lower limit of volume change.

He also defined the plasticity index, which is the range of water content where the soil is plastic, and he was the first to suggest it for soil classification. Later on in the late 1920's K.Terzaghi and A.Casagrande (1948), working for the U.S. Bureau of public Roads standardized the Atterberg limits so that they could be readily used for soils classification purposes. In present geotechnical engineering practice we usually use the liquid limit LL, The plastic limit PL, and the shrinkage limit SL. The sticky and the cohesion limits are more useful in ceramics and agriculture. Since the Atterberg limits are water contents where the soil behavior changes, one can show these limits on a water content continuum as shown in Figure 3.1 .Also in the same figure shown are the types of soil behavior for the given ranges water contents and the generalized material response (stress – Strain curves) corresponding to those states.

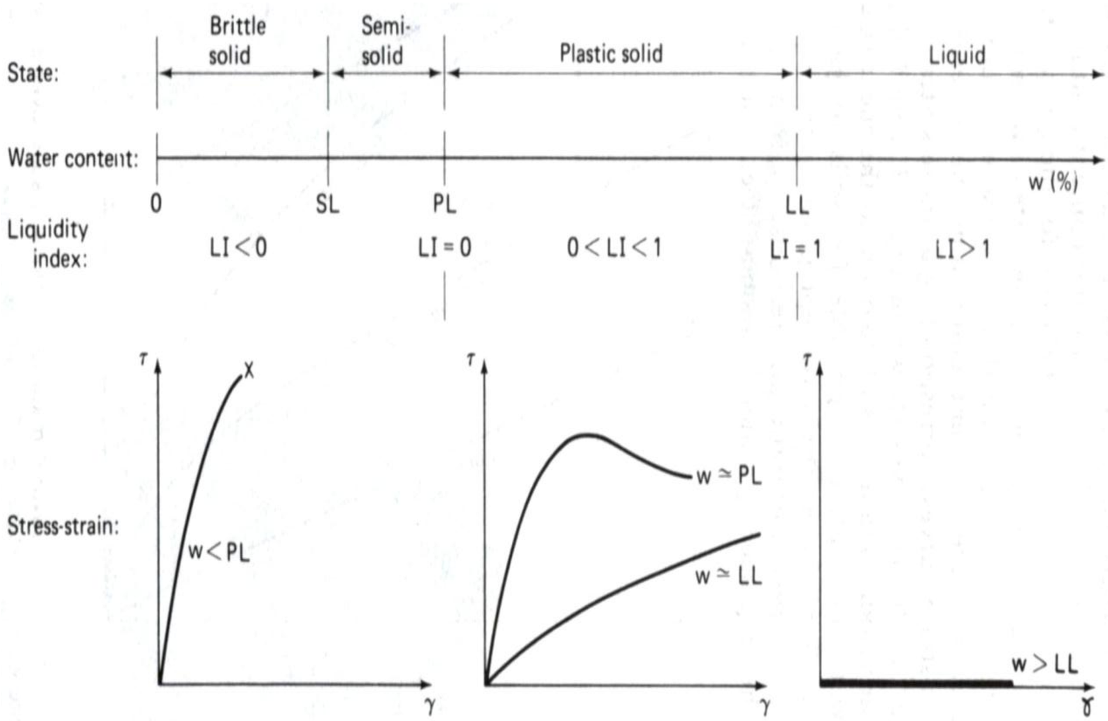

Figure 3. 1 Water content continuum showing the various states of a soil as well as the generalized stress-strain response.

3.2 Liquid limit

A fine grained soil can exist in any of several states; each state depends on the amount of water in the soil system. Liquid limit is the percentage of water content at which the soil has such small shear strength that it flows to close a grove of standard width when jarred in a specified manner. At the moisture content of LL the distance between particles is such that the force of interaction between particles is sufficiently weak to allow easy movement of particles relative to each other. It is dependent on the amount and type of clay, but the latter being very important .According to Skempton (1953) a clay – water system at the liquid limit has a shear resistance of the order of 0.1 psi ≅ 0.7kpa .

Figure 3. 2 Equipment used for Liquid limit test

3.3 The determination of the liquid limit of soils by means of the flow curve method

The liquid limit of a soil as defined below is determined by using the device specified to plot a curve of the number of taps necessary to obtain a specific consistency of the soil fines against the moisture contents in three trials. The procedure is going to be done as per the standard. (AASHTO T 89, Method A). Provision is also made for the calculation of the liquid limit from a one-point determination if that method is specified (AASHTO T 89, Method B).

3.4 Calculations for standard method (Multi point)

A. The water content of the soil shall be expressed as the moisture content in percentage of the weight of the oven-dried soil and calculated as follows:

$$\% \text{ Moisture} = \frac{\text{Weight of Water}}{\text{Weight of Oven-dried Soil}} \times 100$$

B. A "flow curve" representing the relation between moisture content and corresponding number of blows shall be plotted on a semi logarithmic graph. The flow curve shall be a straight line drawn as nearly as possible through the three or more plotted points.

C. Liquid Limit - The moisture content corresponding to the intersection of the flow curve at 25 blows shall be taken as the liquid limit of the soil. Report this value to the nearest whole number.

For the sake of illustration and easy of reference, the typical test results of a soil sample have been demonstrated here under .

No. of blows	17	22	28	35
Water content, %	65.26	63.02	61.01	58.31
LIQUID LIMIT (%)	61.8			

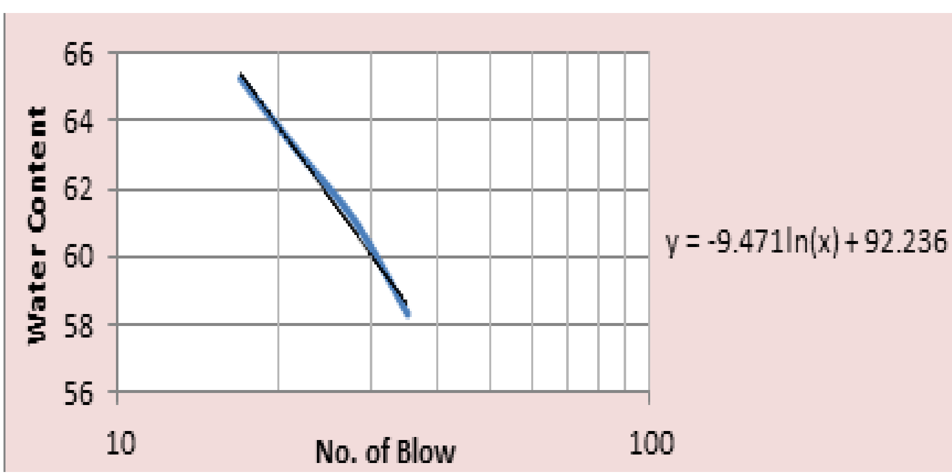

Figure 3. 3 Typical Liquid Limit Graph (Flow Curve)

For further reference, the details of all the Liquid Limit tests results and Liquid Limit Graph of the Two hundred forty nine soil samples and related calculations including graphs have been enclosed under Appendix A of this thesis.

3.5 Calculations - alternate method (One point)

The determination of the plastic limit by the one-point method is standardized as follows: ASTM D 423-66 (renewed in 1972), DIN 18 122, C.P.S. Mode Operatoire G.-4(1964) and BS 1377 (1975). All these standards use the following expression for the computation:

$$LL = \omega . \left(\frac{N}{25} \right)^{\tan \beta}$$

Where:-

LL – Liquid Limit

ω – Moisture Content at each number of blow

N – Number of Blow

Or

$$LL = a * N^{\tan \beta}$$

a= Constant Number that is the ratio of

$$\left(\frac{\omega}{25} \right)^{\tan \beta}$$

where the value of tanβ is taken according to recommendations by the U.S. Waterways Experiment Station (1949) as tanβ =0.12, whereas BS 1377 (1975) yields the value tanβ=0.092, bearing in mind that this value is for British soils. For Ethiopia red clay soils I found tanβ=0.174 and for Addis Ababa red clay soils tanβ=0.14.

Chapter 4

4.1 Test Results collection

In order to have sufficient and reliable data for the target analysis, laboratory tests result conducted on soil samples obtained from different localities of Ethiopia. Most of the samples collected from undergoing road design stage and different theses annex. A total of Two hundred forty nine disturbed samples having Seven hundred three tests of casagrand were gathered. The representative samples selected on the basis of visual identification of a suitable subgrade soil, as such a diversified samples acquired from areas such as; Megenanga-Lamberet road, Winget-Yohannes road, Winget-Addisugebeya ring-road, Total-Addisugebeya road, Kolfe building construction site and Lideta Condominium construction site, Kolfe Keraniyo, Winget Asko, and Teferi Mekonen School of Addis Ababa and different areas of Ethiopia like Hawassa, Ziway, Alaba Sodo, Kelela-Akesta, Tarmaber – Molale – Mehal Meda, Addis -Nekemit. The size of collected soil test result samples site, number of sample and test taken is summarized , shown with the in Table 4.1:

Sr.No.	Location	Sample	Test No.
1	Addis Ababa	122	392
2	Ziway	2	8
3	Hawassa	5	18
4	Alaba Sodo	8	24
5	Kelela-Akesta	15	40
6	Tarmaber – Molale – Mehal Meda	84	169
7	Addis - Nekemit	13	52
	Total	**249**	**703**

Table 4. 1 Samples site, Number of Sample and Test Summery

4.2 Discussion on Laboratory Tests Result Collected

Liquid Limit Test (ASTM D 4318) conducted on the Two hundred forty nine soil samples and a range of test results achieved. Based on the obtained test results of plasticity and grain size distribution the soil classification was made and the result shows that all the sample are classified as fine grained soil. In accordance to the AASHTO classification system the soil is mainly classified as A-7-5 and A-7-6 and also pursuant to USCS classification system the samples have been classified as MH and the remaining soils classified as CL, ML and CH. From the conventional Atterberg limit tests

4.3 Input of Laboratory Test Results Analysis

In order to analyze the intended correlation, the test results were compiled and summarized in a way that the SPSS and Excel Software inputs the data as shown in Appendix B

Chapter 5

Regression Analysis and Correlations

5.1 Introduction

Regression analysis is a statistical technique that is very useful in the field of engineering and science in modeling and investigating relationships between two or more variables. The method of regression analysis is used to develop the line or curve which provides the best fit through a set of data points. This basic approach is applicable in situations ranging from single linear regression to more sophisticate nonlinear multiple regressions. The best fit model could be in the form of linear, parabolic or logarithmic trend. A linear relationship is usually practiced in solving different engineering problems because of its simplicity.

Fitting a regression model requires several assumptions. The method of least squares is used in order to choose the best fitting line for a set of data. Estimation of the model parameters requires the assumption that, the residuals (actual values less estimated values) corresponding to different observations are uncorrelated random variables with zero mean and constant variance (N).

A convenient way of measuring how well the regression model performs as a predictor of the dependent variable is to compute the reduction in the sum of squares of deviations that can be attributed to regressor variables and this quantity termed the coefficient of determination, R^2. The value of R^2 is always between 0 and 1, because R is between -1 and +1, whereby a negative value of R indicates inversely relationship and positive value implies direct relationship. Many problems in engineering require that we decide whether to accept or reject a statement about some correlations. A number of techniques can be used to judge the adequacy of a regression model some of which are standard error (α), R-squared value (R^2), R-adjusted and the t-test.

5.2 Scatter Plot

In the subject study, the ratio of Moisture Content and Liquid Limit is taken as the dependent variable where as the Number of Blow **is** independent variables of Seven Hundred three points.

Prior to carrying out the regression analysis using the Two hundred forty nine test results, a scatter diagram is generated by applying the Excel Spreadsheet, in order to study the relationships developed between the dependent variable and the regressor variables so as to determine the model that best suits the test results.

In order to consider the set unambiguously, considering parameter tanβ, it was necessary to standardize the flow curve. This was performed by dividing each value from each curve of liquid limit LL divided by the respective moisture content verses each number of blows divided by 25.

$$\frac{LL}{\omega}$$

A curve of the following type was passed through that set by the linear regression method:

$$LL = a * N^{\tan\beta}$$

Consequently, the scatter plot of red clay soils for Ethiopia and Addis Ababa is presented on Figure 5-1 and Figure 5-2 :

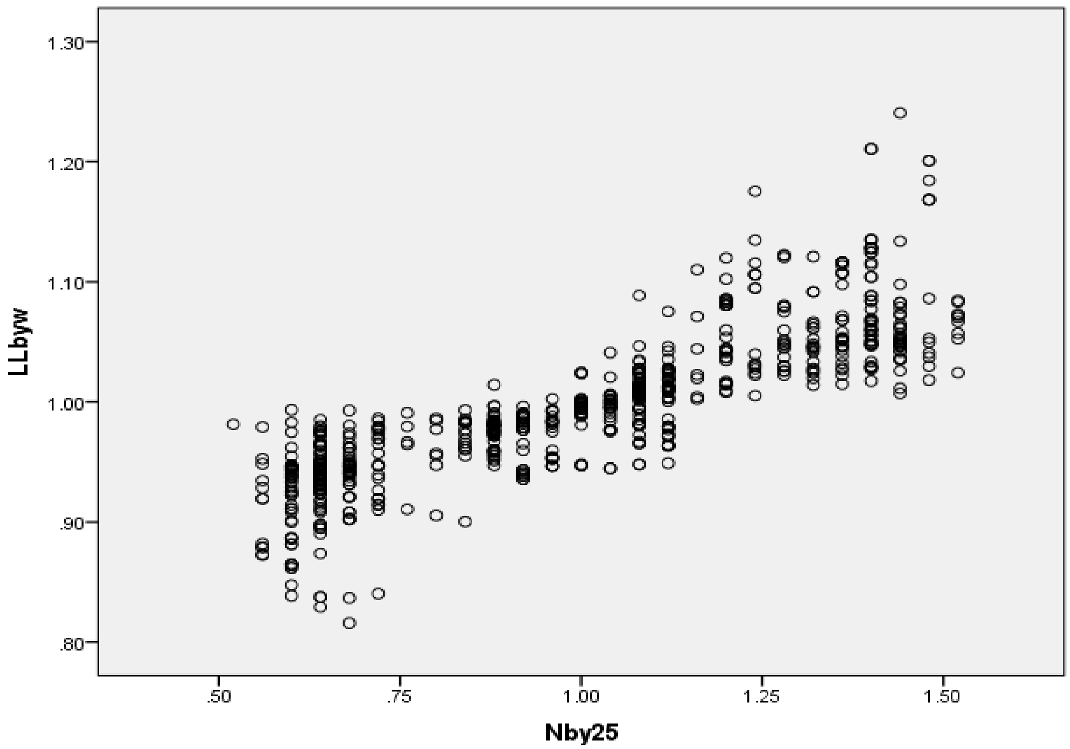

Figure 5. 1 Scatter Plot of **LL/ω** Vs N/25 for Ethiopia

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations		
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	.812	.004		187.887	.000	.804	.820			
	N/25	.184	.004	.849	44.194	.000	.176	.192	.849	.849	.849

a. Dependent Variable: LL/w

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.849[a]	.721	.721	.03248	.721	1953.153	1	756	.000

a. Predictors: (Constant), N/25

Table 5. 1 Tables of coefficients and model summary for Ethiopia

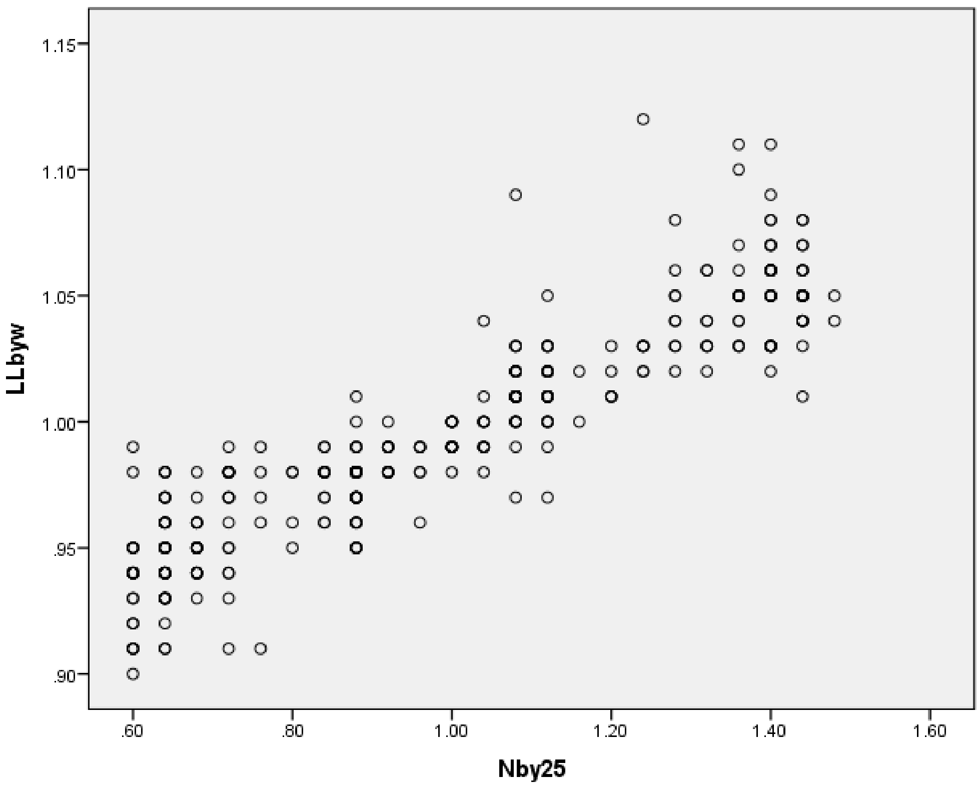

Figure 5. 2 Scatter Plot of **LL/ω** Vs N/25 for Ethiopia

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	.856	.003		263.561	.000			
	N/25	.141	.003	.916	44.904	.000	.916	.916	.916

a. Dependent Variable: LLbyw

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.916[a]	.838	.838	.01684	.838	2016.395	1	389	.000

a. Predictors: (Constant), Nby25

Table 5. 2 Tables of coefficients and model summary for Ethiopia

Descriptive Statistics

	Mean	Std. Deviation	N
LL/w	.9958	.06145	758
N/25	.9978	.28334	758

Table 5. 3 Descriptive Statistics for Ethiopia

Descriptive Statistics

	Mean	Std. Deviation	N
LL/w	.9962	.04183	391
N/25	.9980	.27172	391

Table 5. 4 Descriptive Statistics for Addis Ababa

There were fourteen outliners on scatter plot of Ethiopia for several reasons which are removed from the input data to get more reliable value.

Relatively the above scatter plot shows a linear response and hence, a linear regression model expresses the association between the subject parameters. Statistical analysis of the flow curves.

This obtained the same method as in the case of individual flow curves, presented by equation. Figure 5.1 & 5.2 are graphical representation of a set of normalized points through which a regression curve was passed by the linear regression methods.

The above scatters diagrams provide a visual method of displaying a relationship between variables as plotted in a two dimensional coordinate system. Inspection of the scatter diagrams indicate that, although no simple curve will pass exactly through all the points, there is a reasonable indication that the points lie scattered randomly around a straight line, particularly for the Ratio of Moisture content and liquid limit, Number of blow .

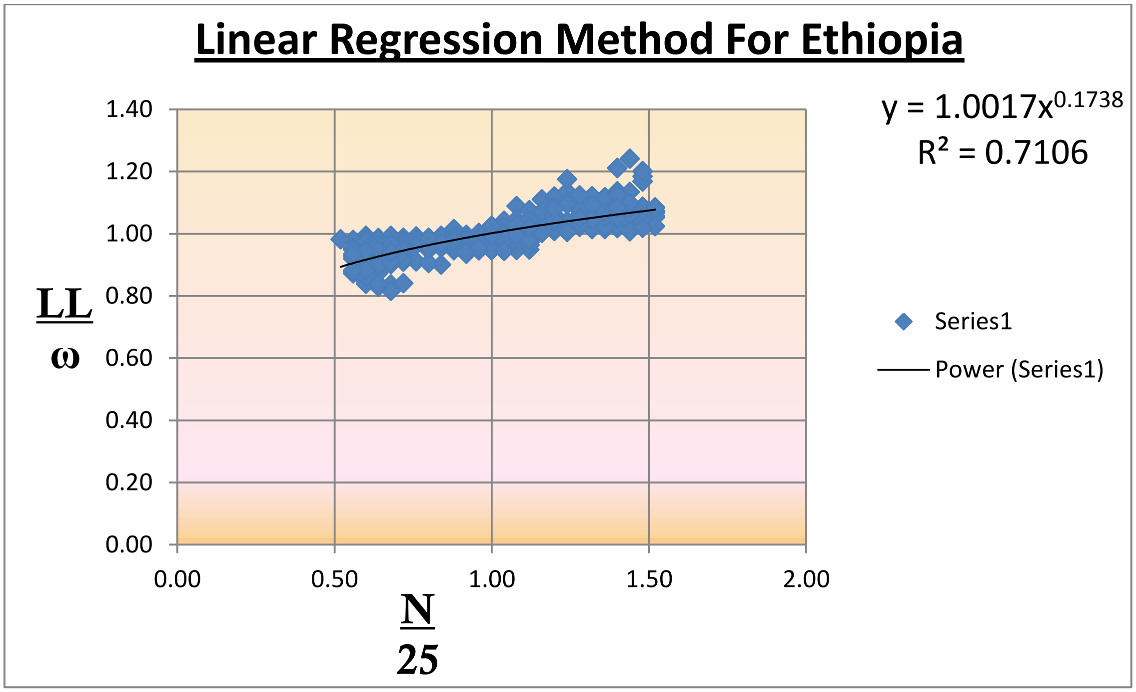

Figure 5. 3 Analaised Regression Curve

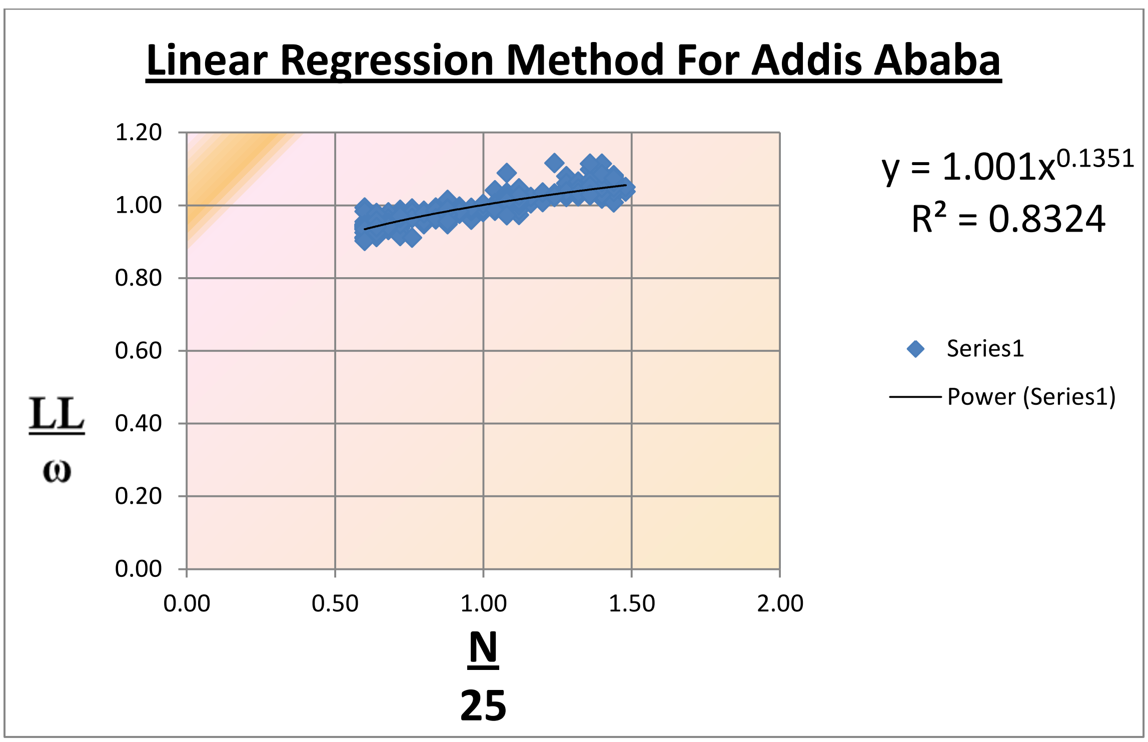

Figure 5. 4 Analaised Regression Curve

EVALUATION OF ONE-POINT LIQUID LIMIT TEST FOR RED CLAYS OF ETHIOPIA

The statistical analysis was performed by two independent methods. It was proved, primarily, by using the x^2 test, that the liquid limit for the set under consideration was a random variable that follows the law of normal distribution. In that case the statistical analysis was performed by analyzing and comparing the Mean values of the considered set and the sets used to prove stochastic similarity.

In this approach it was necessary to compute the value of exponent tanβ for each of 249 curves, which was subsequently subjected to additional statistical analysis. The equation of the flow curve is as follows:

$$LL = a\ N^{\tan\beta}$$

It is generally graphically represented in semi logarithmic graph, with logarithmic values on the abscise axis, so that it can be represented as a line. This can be explained by the fact that in the laboratory the line is visually passed through four points in order to determine the moisture content at the liquid limit for N=25 bumps of the standard bowl.

The computation of the tanβ exponent was performed by employing the linear regression method and using the equation of the line passing through four points, obtained in the laboratory

Consequently, it can be concluded that the value of parameter tanβ is a variable of random distribution and that the statistically obtained values can be accepted for the moisture computation at the liquid limit LL, by using one-point test.

5.3 Single Linear Regression Analysis

Correlation between $\left(\frac{LL}{\omega}\right)$ and $\left(\frac{N}{25}\right)$

The resulting regression analysis after correlating LL/ ω with N/25 is expressed by the following single exponential equation with its corresponding correlation coefficients for Ethiopia and Addis Ababa Respectively:

- For Ethiopia

$$y = 1.0017x^{0.1738}$$

We put the ratio of LL/ ω on Y axis and N/25 on X axis

Therefore

$$\left(\frac{LL}{\omega}\right) = 1.0017^{*}\left(\frac{N}{25}\right)^{0.1738}$$

$$LL = \omega\left(\frac{N}{25}\right)^{0.1738}$$

Therefor the value of Tanβ is 0.1738 for Ethiopia with $R^2 = 0.7106$

- For Addis Ababa

$$y = 1.001x^{0.1351}$$

We put the ratio of LL/ ω on Y axis and N/25 on X axis

Therefore

$$\left(\frac{LL}{\omega}\right) = 1.001 * \left(\frac{N}{25}\right)^{0.1351}$$

$$LL = \omega \left(\frac{N}{25} \right)^{0.1351}$$

Therefor the value of Tanβ is 0.1351 for Addis Ababa with $R^2 = 0.8324$

5.4 Discussion on Correlation Results

The Developed Correlation

The validation of the developed correlation is conducted by using Seven hundred three test results which follows similar testing procedures with the subject research. These control test results were obtained for different localities of Ethiopia. Depending on the relative significance order, $LL = \omega \left(\frac{N}{25} \right)^{0.1738}$ and $LL = \omega \left(\frac{N}{25} \right)^{0.1351}$

is the correlations for further verifications for Ethiopia and Addis Ababa Respectively.

The standard error of the estimated value is 0.03248 and 0.01684 for Ethiopia and Addis Ababa Respectively

5.5 Mean Value Method

In this approach it was necessary to compute the value of exponent tan β for each of Two hundred forty nine curves, which was subsequently subjected to additional statistical analysis. All input data are attached on Annex.
The equation of the flow curve is as follows:

$$LL = \omega . \left(\frac{N}{25} \right)^{\tan \beta}$$

- For Ethiopia

Tan β

N	Valid	209
	Missing	0
Mean		.1746
Std. Error of Mean		.00562
Median		.1600
Mode		.12
Std. Deviation		.08130
Variance		.007
Minimum		.01
Maximum		.52

Table 5. 5 Statistics for Ethiopia

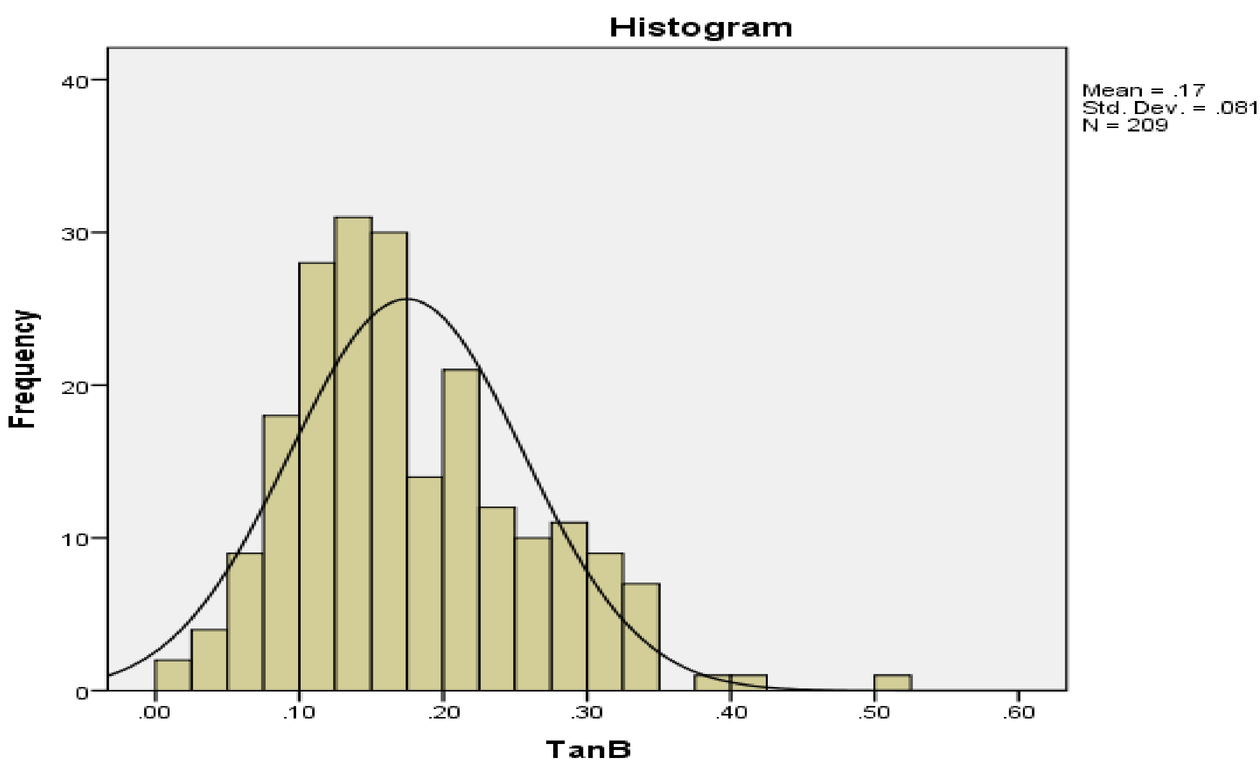

Figure 5. 5 The distribution Curve of tanβ value of Ethiopia

Values

Mean = 0.17

Standard deviation =0.081

N= 209

- For Addis Ababa

Tan β

N	Valid	109
	Missing	0
Mean		.1417
Std. Error of Mean		.00579
Median		.1300
Mode		.12
Std. Deviation		.06047
Variance		.004
Minimum		.01
Maximum		.40

Table 5. 6 Statistics of Addis Ababa

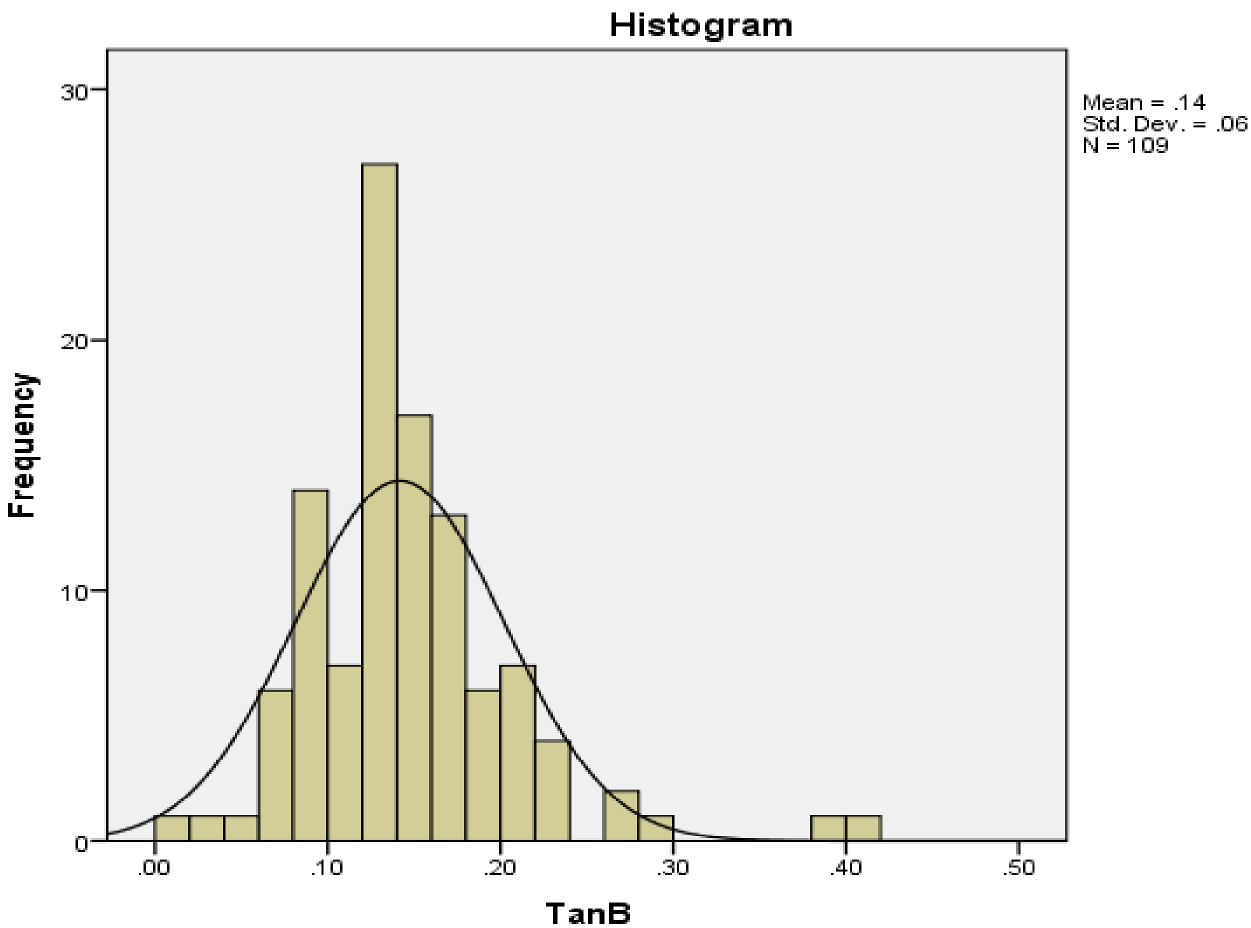

Figure 5. 6 The distribution Curve of tanβ value of Addis Ababa

Values

Mean = 0.14

Standard deviation =0.06

N= 109

Chapter 6

6.1 Conclusions

The research was conducted to find a localized correlation between Ratio of Water Content and Liquid Limit and Number of blow within the scope of the study. Accordingly, the required laboratory tests results were conducted on samples retrieved from different geographical area of Ethiopia. Using the obtained Seven Hundred Eighty Three test results a single linear regressions and Mean value method were analyzed and a relationship was developed that predict tan β value in terms of LL, ω and N.

The suitability of the developed correlation is evaluated by utilizing a separate control test results. From the results of this study the following conclusions are drawn:

- Among the single linear regression analysis and Mean Value method the correlation has resulted the following relationship For Ethiopia and Addis Ababa Respectively:

$LL = \omega \left(\frac{N}{25}\right)^{0.1738}$ and $LL = \omega \left(\frac{N}{25}\right)^{0.1351}$

6.2 Recommendations

In this research it is observed that, there is a relationship between Ratio of Water Content , Liquid Limit and Number of blow for red clay soils of Ethiopia and Addis Ababa is correlated with the β value of 0.1738 and 0.1351 respectively. To get reliable correlation it is necessary to increase the number of test samples and also the coverage of sites in Ethiopia where red clay is found.

The exposure encountered in trying to conduct the current research has revealed areas where further efforts may be proved in the future. Following are some of the recommendations in relation to the subject study:

- It is recommended to carry out this correlation with a large number of samples including different geographical areas in Ethiopia which are not covered by this research.

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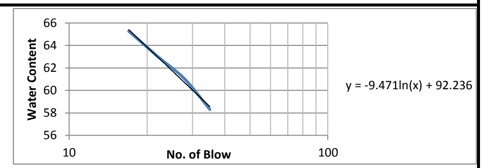
Evaluation of One - Point Liquid Limit Test for Red Clays of Ethiopia

Addis Ababa Flow Chart

1

No. of blows	17	22	28	35
Water content, %	65.26	63.02	61.01	58.31
LIQUID LIMIT (%)	61.8			



2

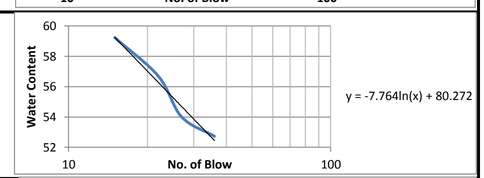
No. of blows	35	27	21	16
Water content, %	52.44	53.63	54.96	55.86
LIQUID LIMIT (%)	54.0			

3

No. of blows	36	28	22	16
Water content, %	56.19	58.25	60.2	62.07
LIQUID LIMIT (%)	59.0			

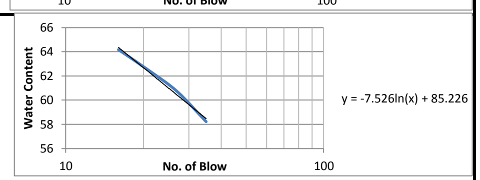
4

No. of blows	36	27	22	15
Water content, %	52.73	54	56.69	59.24
LIQUID LIMIT (%)	55.3			



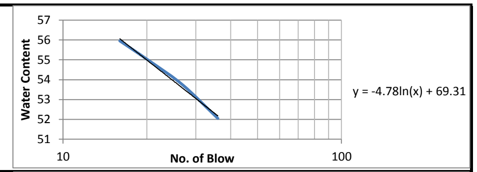
5

No. of blows	35	27	21	16
Water content, %	58.22	60.72	62.45	64.17
LIQUID LIMIT (%)	61.0			



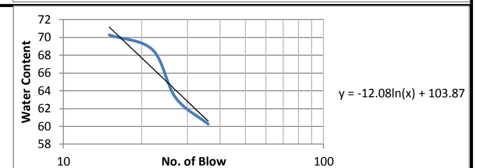
6

No. of blows	36	27	21	16
Water content, %	58.49	59.69	60.42	62.19
LIQUID LIMIT (%)	60.0			



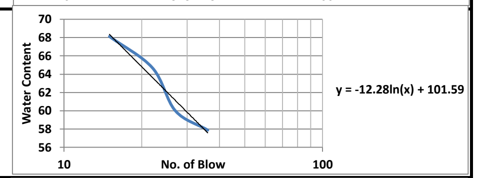
7

No. of blows	36	27	21	16
Water content, %	52.05	53.72	54.83	55.95
LIQUID LIMIT (%)	53.9			



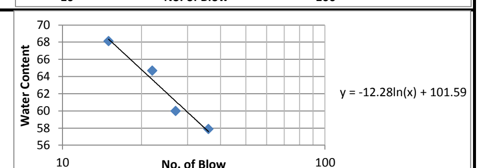
8

No. of blows	36	27	22	15
Water content, %	60.26	63.22	68.62	70.28
LIQUID LIMIT (%)	65.0			



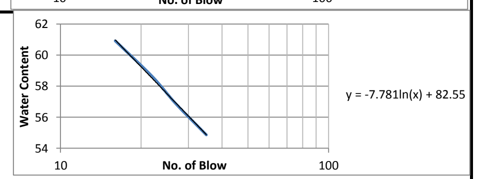
9

No. of blows	36	27	22	15
Water content, %	57.89	59.99	64.69	68.12
LIQUID LIMIT (%)	62.1			



10

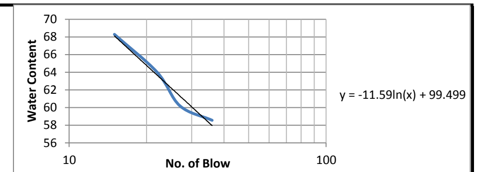
No. of blows	35	27	22	16
Water content, %	54.87	56.85	58.62	60.92
LIQUID LIMIT (%)	57.5			



Evaluation of One - Point Liquid Limit Test for Red Clays of Ethiopia

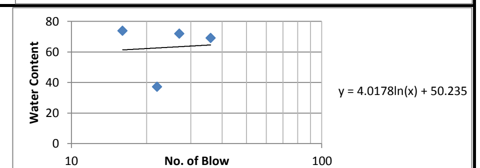
11

No. of blows	36	27	22	15
Water content, %	58.55	60.18	63.99	68.28
LIQUID LIMIT (%)	62.2			



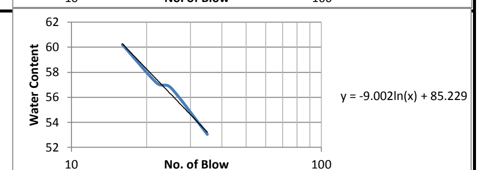
12

No. of blows	36	27	22	16
Water content, %	69.13	72	37.2	73.81
LIQUID LIMIT (%)	37.3			



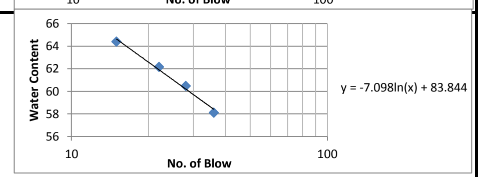
13

No. of blows	35	25	22	16
Water content, %	53.04	56.77	57.13	60.21
LIQUID LIMIT (%)	56.3			



14

No. of blows	36	28	22	15
Water content, %	58.1	60.47	62.16	64.4
LIQUID LIMIT (%)	61.0			

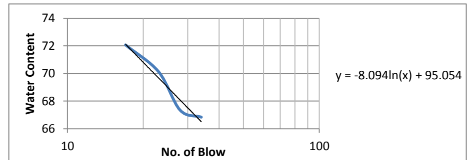


15

No. of blows	36	27	22	15
Water content, %	59.24	61.52	63.13	65.52
LIQUID LIMIT (%)	62.0			

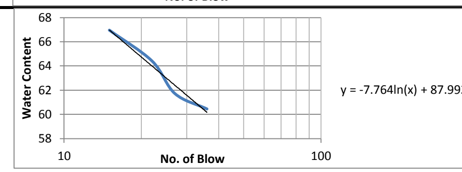
16

No. of blows	34	28	23	17
Water content, %	66.84	67.35	70.13	72.07
LIQUID LIMIT (%)	69.0			



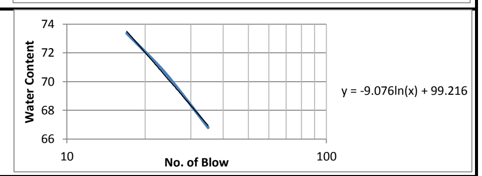
17

No. of blows	36	27	22	15
Water content, %	60.45	61.72	64.41	66.96
LIQUID LIMIT (%)	63.0			



18

No. of blows	35	28	23	17
Water content, %	66.8	69.07	70.95	73.36
LIQUID LIMIT (%)	70.0			

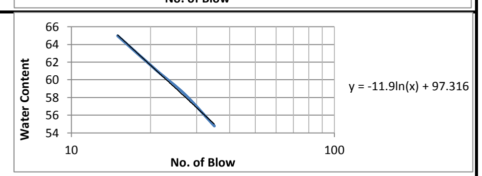


19

No. of blows	34	27	22	16
Water content, %	59.79	62.08	64.45	67.69
LIQUID LIMIT (%)	63.0			

20

No. of blows	35	27	21	15
Water content, %	54.78	58.37	61.11	64.97
LIQUID LIMIT (%)	59.0			



21

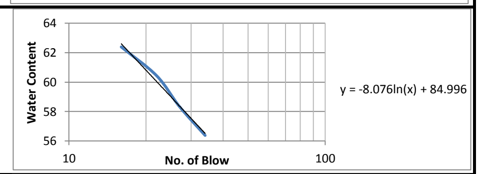
No. of blows	36	28	22	16
Water content, %	62.75	65.33	67.32	69.39
LIQUID LIMIT (%)	66.0			

22

No. of blows	36	28	22	16
Water content, %	51.65	60.64	61.45	63.55
LIQUID LIMIT (%)	59.0			

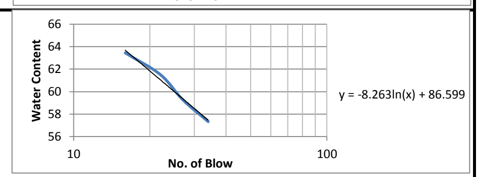
23

No. of blows	34	27	22	16
Water content, %	56.38	58.34	60.43	62.39
LIQUID LIMIT (%)	59.0			



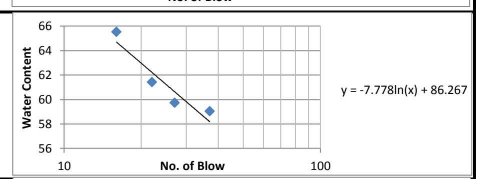
24

No. of blows	34	27	22	16
Water content, %	57.33	59.27	61.52	63.45
LIQUID LIMIT (%)	60.0			



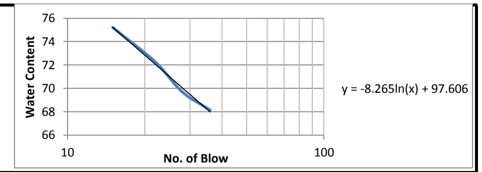
25

No. of blows	37	27	22	16
Water content, %	59.04	59.74	61.43	65.53
LIQUID LIMIT (%)	61.2			



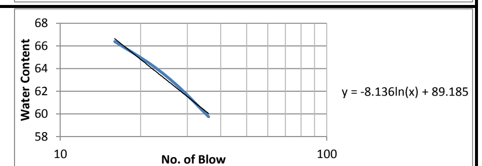
26

No. of blows	36	28	22	15
Water content, %	68.15	69.71	72.26	75.21
LIQUID LIMIT (%)	71.0			



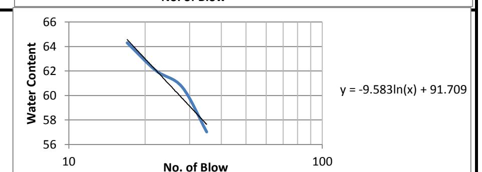
27

No. of blows	36	28	22	16
Water content, %	59.75	62.32	64.32	66.38
LIQUID LIMIT (%)	63.0			



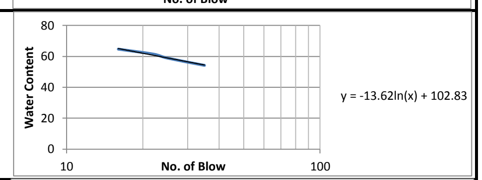
28

No. of blows	35	28	22	17
Water content, %	57.02	60.69	62.05	64.3
LIQUID LIMIT (%)	60.9			



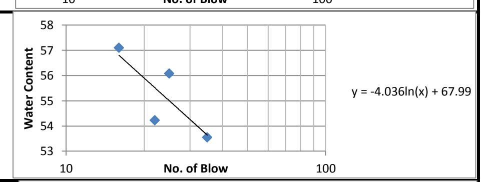
29

No. of blows	35	25	22	16
Water content, %	54.19	58.9	61.46	64.7
LIQUID LIMIT (%)	59.0			



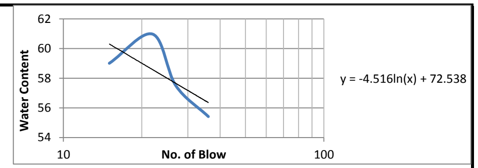
30

No. of blows	35	25	22	16
Water content, %	53.55	56.08	54.23	57.1
LIQUID LIMIT (%)	55.0			



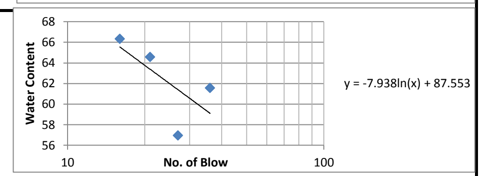
31

No. of blows	36	27	22	15
Water content, %	55.41	57.5	60.98	59.01
LIQUID LIMIT (%)	58.0			



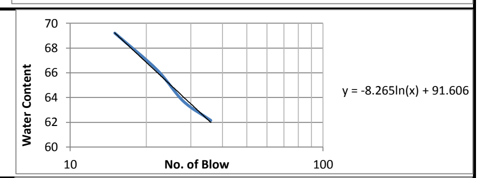
32

No. of blows	36	27	21	16
Water content, %	61.57	56.96	64.57	66.33
LIQUID LIMIT (%)	62.0			



33

No. of blows	36	28	22	15
Water content, %	62.15	63.71	66.26	69.21
LIQUID LIMIT (%)	65.0			

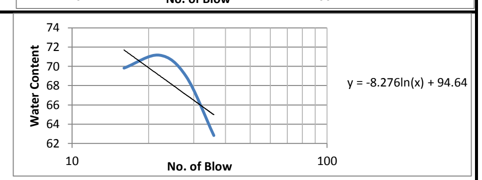


34

No. of blows	35	28	23	17
Water content, %	62.54	64.81	66.69	70.16
LIQUID LIMIT (%)	66.0			

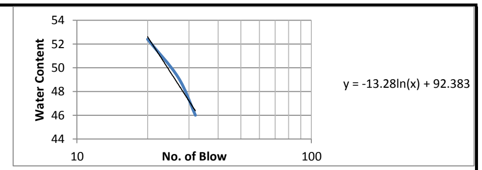
35

No. of blows	36	28	22	16
Water content, %	62.83	68.98	71.16	69.82
LIQUID LIMIT (%)	68.0			



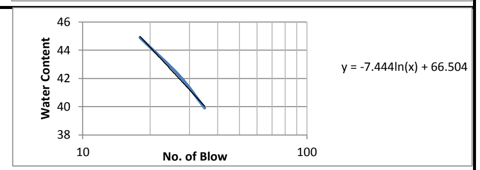
36

No. of blows	32	27	20
Water content, %	46	49.2	52.4
LIQUID LIMIT (%)		49.6	



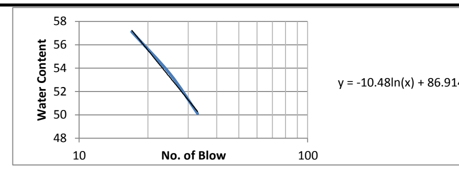
37

No. of blows	35	27	18
Water content, %	39.9	42.2	44.9
LIQUID LIMIT (%)		42.5	



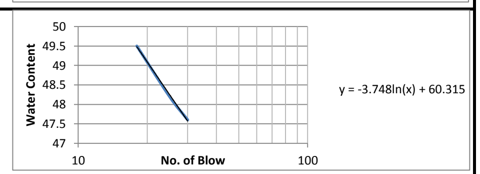
38

No. of blows	33	25	17
Water content, %	50.1	53.5	57.1
LIQUID LIMIT (%)		53.2	



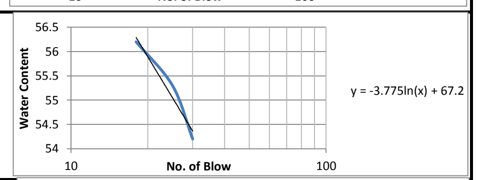
39

No. of blows	30	25	18
Water content, %	47.6	48.2	49.5
LIQUID LIMIT (%)		68.0	



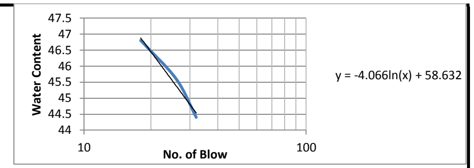
40

No. of blows	30	25	18
Water content, %	54.2	55.3	56.2
LIQUID LIMIT (%)		55.0	



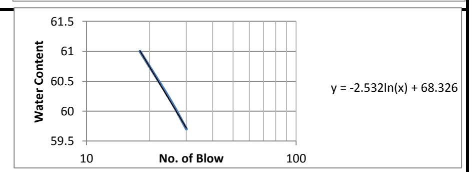
41

No. of blows	32	26	18
Water content, %	44.4	45.6	46.8
LIQUID LIMIT (%)	45.5		



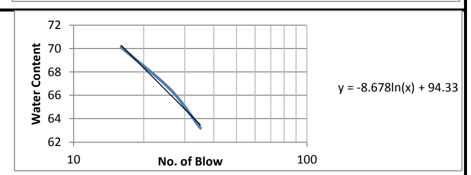
42

No. of blows	30	25	18
Water content, %	59.7	60.2	61
LIQUID LIMIT (%)	60.2		



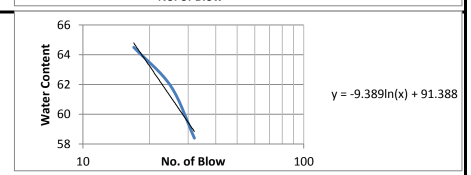
43

No. of blows	35	26	16
Water content, %	63.2	66.5	70.1
LIQUID LIMIT (%)	66.4		



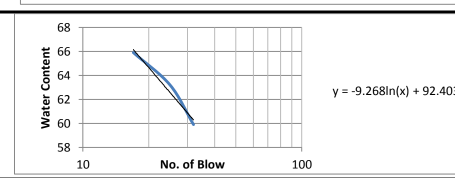
44

No. of blows	32	25	17
Water content, %	58.4	61.9	64.5
LIQUID LIMIT (%)	61.2		



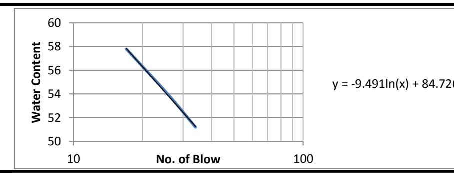
45

No. of blows	32	25	17
Water content, %	59.9	63.2	65.9
LIQUID LIMIT (%)	62.6		



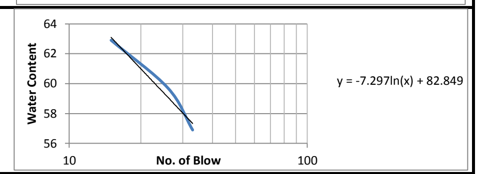
46

No. of blows	34	26	17
Water content, %	51.2	53.9	57.8
LIQUID LIMIT (%)		54.2	



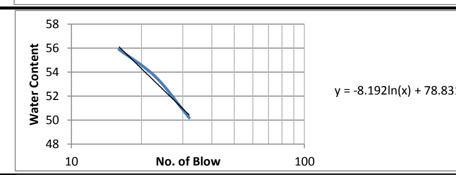
47

No. of blows	33	26	15
Water content, %	56.9	59.7	62.9
LIQUID LIMIT (%)		59.4	



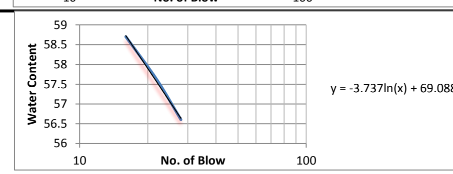
48

No. of blows	32	23	16
Water content, %	50.2	53.6	55.9
LIQUID LIMIT (%)		52.5	



49

No. of blows	28	22	16
Water content, %	56.6	57.6	58.7
LIQUID LIMIT (%)		57.1	

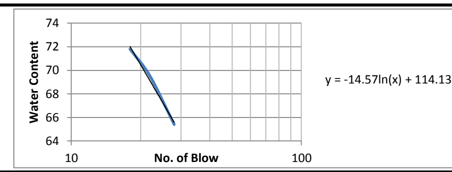


50

No. of blows	34	29	22
Water content, %	58.7	59.6	62
LIQUID LIMIT (%)		60.9	

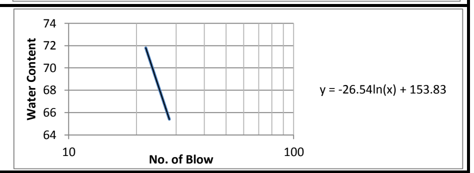
51

No. of blows	28	22	18
Water content, %	65.4	69.5	71.8
LIQUID LIMIT (%)	67.2		



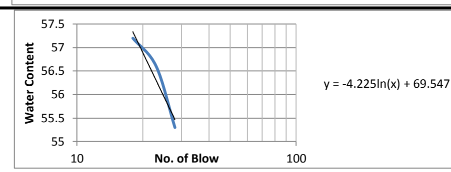
52

No. of blows	28	22	18
Water content, %	65.4	71.8	69.5
LIQUID LIMIT (%)	68.4		



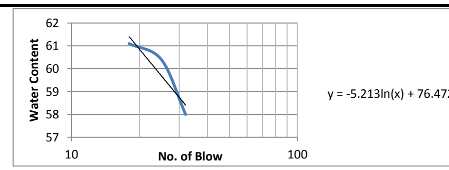
53

No. of blows	28	23	18
Water content, %	55.3	56.6	57.2
LIQUID LIMIT (%)	55.9		



54

No. of blows	32	25	18
Water content, %	58	60.4	61.1
LIQUID LIMIT (%)	59.7		

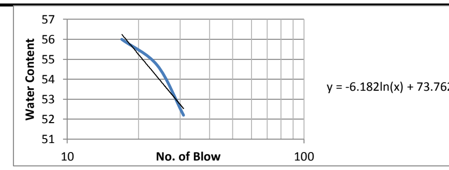


55

No. of blows	33	28	18
Water content, %	61.4	62.8	64.6
LIQUID LIMIT (%)	63.0		

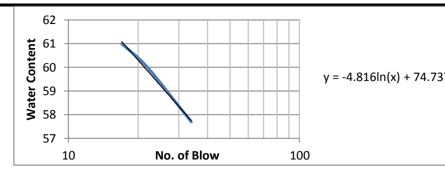
56

No. of blows	31	24	17
Water content, %	52.2	54.7	56
LIQUID LIMIT (%)	53.9		



57

No. of blows	34	22	17
Water content, %	57.7	60	61
LIQUID LIMIT (%)	59.2		

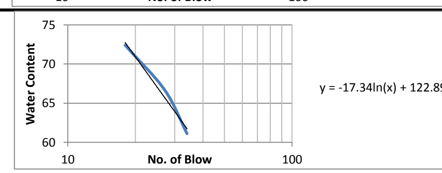


58

No. of blows	31	24	19
Water content, %	59	61.3	62.9
LIQUID LIMIT (%)	60.8		

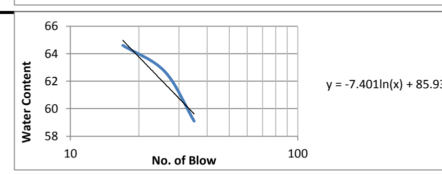
59

No. of blows	34	27	18
Water content, %	61.1	66.7	72.4
LIQUID LIMIT (%)	67.1		



60

No. of blows	35	26	17
Water content, %	59.1	62.7	64.6
LIQUID LIMIT (%)	62.1		

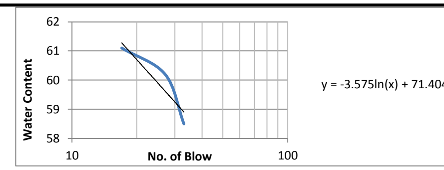


61

No. of blows	32	26	17
Water content, %	67.8	73	75.9
LIQUID LIMIT (%)		71.8	

62

No. of blows	33	27	17
Water content, %	58.5	60.2	61.1
LIQUID LIMIT (%)		59.9	

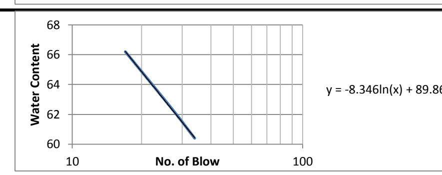


63

No. of blows	31	25	17
Water content, %	66.2	68.4	70.7
LIQUID LIMIT (%)		68.0	

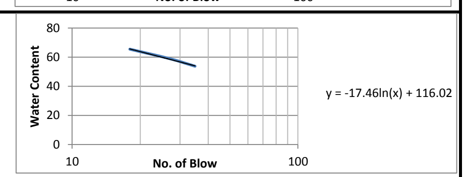
64

No. of blows	34	27	17
Water content, %	60.4	62.4	66.2
LIQUID LIMIT (%)		63.0	



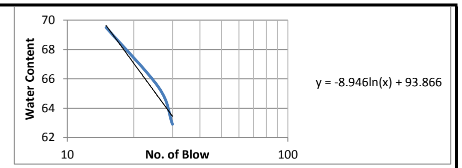
65

No. of blows	35	27	18
Water content, %	53.7	58.9	65.4
LIQUID LIMIT (%)		59.8	



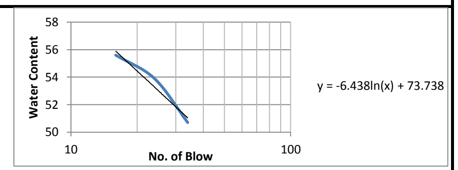
66

No. of blows	30	26	15
Water content, %	62.9	65.4	69.5
LIQUID LIMIT (%)	65.1		



67

No. of blows	34	24	16
Water content, %	50.7	53.9	55.6
LIQUID LIMIT (%)	53.0		



68

No. of blows	35	24	18
Water content, %	66.2	71.5	74.6
LIQUID LIMIT (%)	70.6		

69

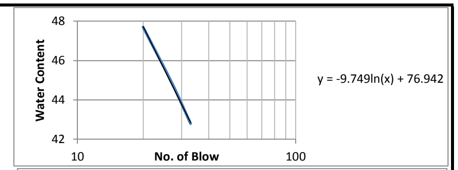
No. of blows	33	26	19
Water content, %	42.4	43.7	44.5
LIQUID LIMIT (%)	43.6		

70

No. of blows	31	25	18
Water content, %	47.8	48.9	50.4
LIQUID LIMIT (%)	48.9		

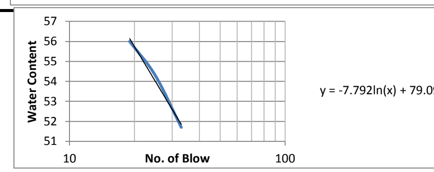
71

No. of blows	33	27	20
Water content, %	42.8	44.9	47.7
LIQUID LIMIT (%)	45.6		



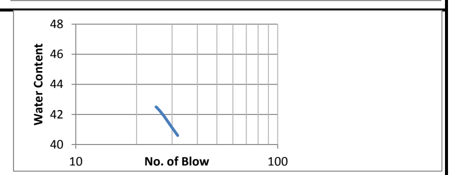
72

No. of blows	33	25	19
Water content, %	51.7	54.3	56
LIQUID LIMIT (%)	54.0		



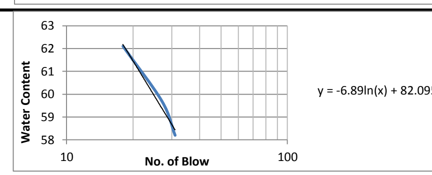
73

No. of blows	32	25	20
Water content, %	40.6	42.5	43.1
LIQUID LIMIT (%)	42.1		



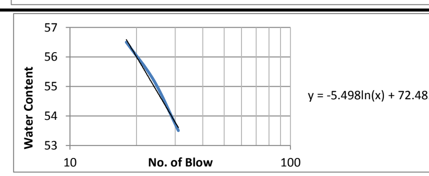
74

No. of blows	31	27	18
Water content, %	58.2	59.7	62.1
LIQUID LIMIT (%)	59.9		



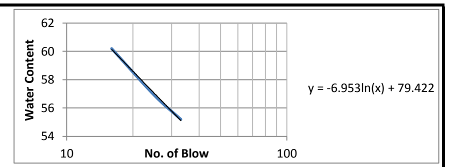
75

No. of blows	31	24	18
Water content, %	53.5	55.2	56.5
LIQUID LIMIT (%)	54.8		



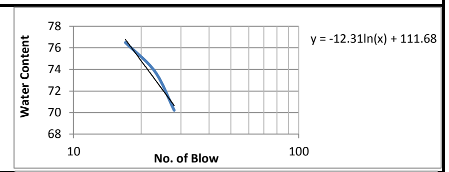
76

No. of blows	33	25	16
Water content, %	55.2	56.9	60.2
LIQUID LIMIT (%)	57.0		



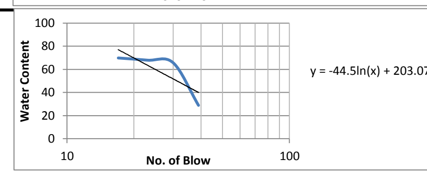
77

No. of blows	28	23	17
Water content, %	70.2	73.8	76.5
LIQUID LIMIT (%)	72.1		



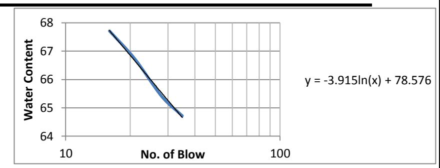
78

No. of blows	39	30	23	17
Water content, %	28.91	65.67	67.9	69.81
LIQUID LIMIT (%)	59.8			



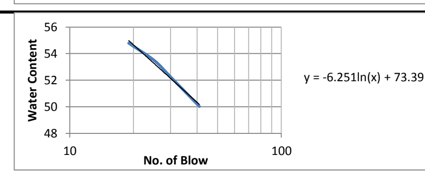
79

No. of blows	35	28	21	16
Water content, %	64.72	65.41	66.73	67.71
LIQUID LIMIT (%)	66.0			



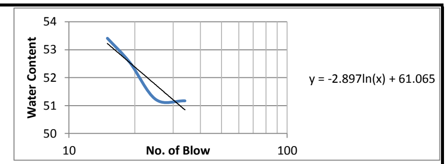
80

No. of blows	41	30	25	19
Water content, %	50.025	52.243	53.504	54.787
LIQUID LIMIT (%)	53.3			



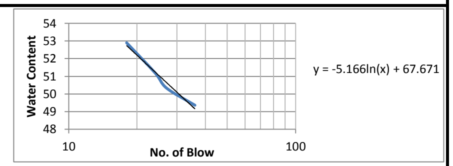
81

No. of blows	34	25	19	15
Water content, %	51.171	51.219	52.543	53.409
LIQUID LIMIT (%)	51.7			



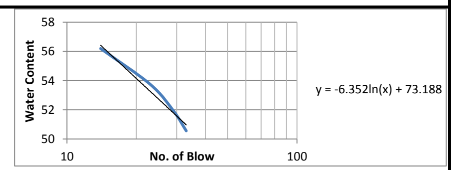
82

No. of blows	36	27	24	18
Water content, %	49.362	50.334	51.2	52.899
LIQUID LIMIT (%)	51.0			



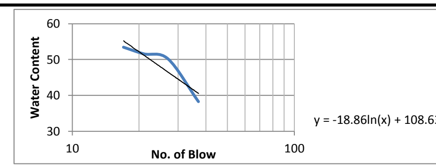
83

No. of blows	33	29	23	14
Water content, %	50.57	51.948	53.752	56.198
LIQUID LIMIT (%)	52.7			



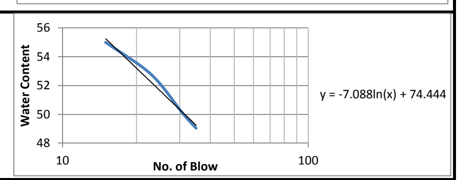
84

No. of blows	37	27	21	17
Water content, %	38.254	50.178	51.593	53.451
LIQUID LIMIT (%)	47.9			



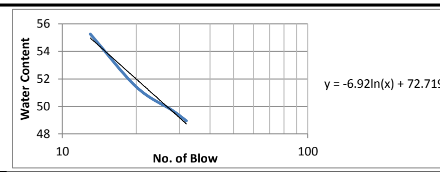
85

No. of blows	35	31	23	15
Water content, %	49.034	50.029	52.758	54.992
LIQUID LIMIT (%)	51.6			



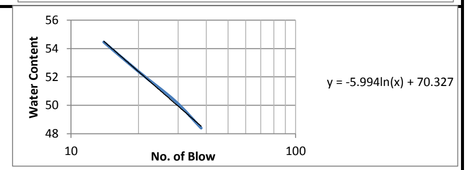
86

No. of blows	32	28	20	13
Water content, %	48.954	49.721	51.42	55.256
LIQUID LIMIT (%)	50.4			



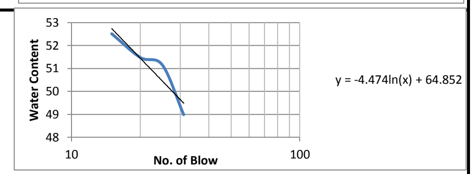
87

No. of blows	38	29	20	14
Water content, %	48.392	50.32	52.375	54.457
LIQUID LIMIT (%)	51.0			



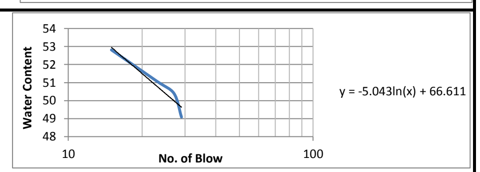
88

No. of blows	31	25	20	15
Water content, %	48.985	51.151	51.478	52.512
LIQUID LIMIT (%)	50.5			



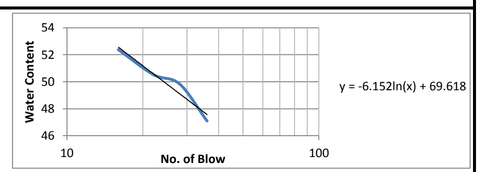
89

No. of blows	29	27	23	15
Water content, %	49.081	50.404	51.075	52.812
LIQUID LIMIT (%)	50.4			



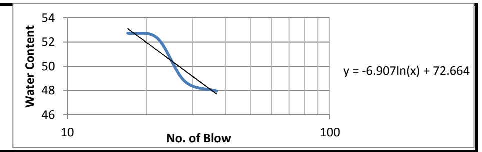
90

No. of blows	36	28	22	16
Water content, %	47.101	49.84	50.537	52.378
LIQUID LIMIT (%)	49.8			



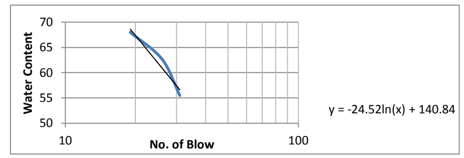
91

No. of blows	37	28	22	17
Water content, %	47.95	48.768	52.33	52.73
LIQUID LIMIT (%)	50.4			



92

No. of blows	31	26	19
Water content, %	55.5	62.7	68
LIQUID LIMIT (%)	61.9		

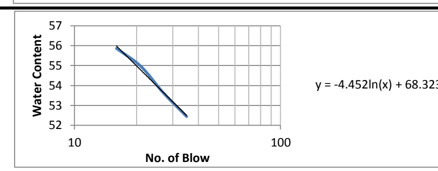


93

No. of blows	35	28	22	17
Water content, %	57.02	59.04	62.05	64.3
LIQUID LIMIT (%)	60.4			

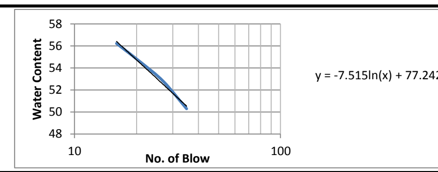
94

No. of blows	35	27	21	16
Water content, %	52.44	53.63	54.96	55.86
LIQUID LIMIT (%)	54.0			



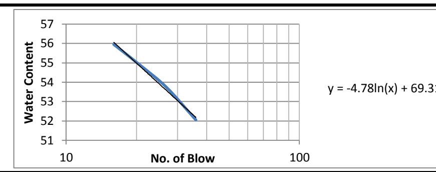
95

No. of blows	35	27	21	16
Water content, %	50.28	52.77	54.5	56.22
LIQUID LIMIT (%)	53.1			



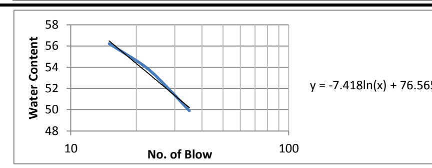
96

No. of blows	36	27	21	16
Water content, %	52.05	53.72	54.83	55.95
LIQUID LIMIT (%)	53.9			



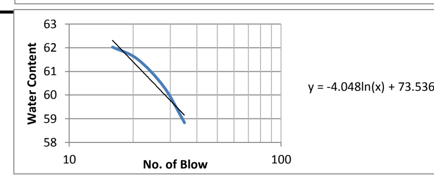
97

No. of blows	35	28	22	15
Water content, %	49.9	52	54.03	56.22
LIQUID LIMIT (%)	52.7			



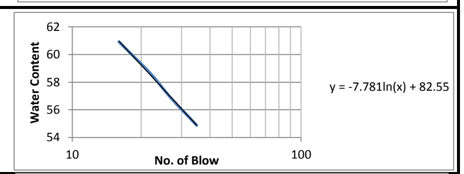
98

No. of blows	35	28	21	16
Water content, %	58.83	60.34	61.52	62.03
LIQUID LIMIT (%)	60.5			



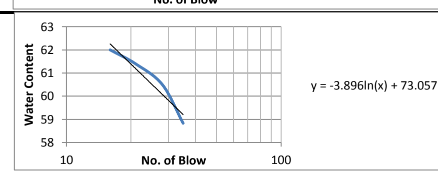
99

No. of blows	35	27	22	16
Water content, %	54.87	56.85	58.62	60.92
LIQUID LIMIT (%)	57.5			



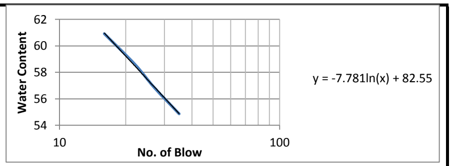
100

No. of blows	35	28	21	16
Water content, %	58.83	60.5	61.4	62
LIQUID LIMIT (%)	60.5			



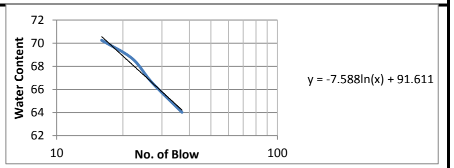
101

No. of blows	35	27	22	16
Water content, %	54.87	56.85	58.62	60.92
LIQUID LIMIT (%)	57.5			



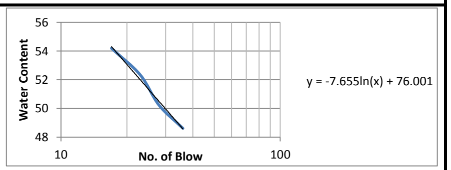
102

No. of blows	37	27	22	16
Water content, %	64.01	66.61	68.67	70.25
LIQUID LIMIT (%)	67.2			



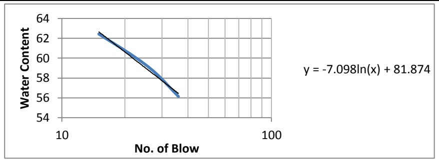
103

No. of blows	36	28	23	17
Water content, %	48.61	50.23	52.34	54.2
LIQUID LIMIT (%)	51.4			



104

No. of blows	36	28	22	15
Water content, %	56.13	58.5	60.19	62.43
LIQUID LIMIT (%)	59.0			

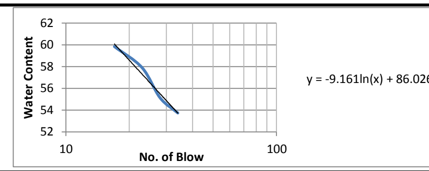


105

No. of blows	36	27	22	15
Water content, %	52.36	54.64	56.24	58.64
LIQUID LIMIT (%)	55.1			

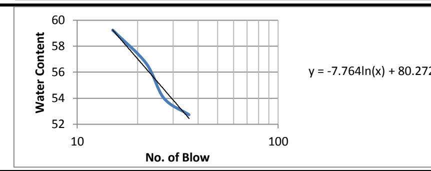
106

No. of blows	34	28	23	17
Water content, %	53.73	55.13	57.9	59.84
LIQUID LIMIT (%)	56.5			



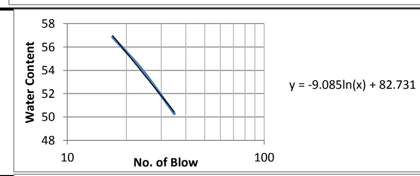
107

No. of blows	36	27	22	15
Water content, %	52.73	54	56.69	59.24
LIQUID LIMIT (%)	55.3			



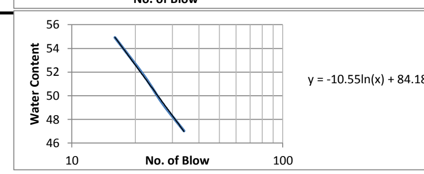
108

No. of blows	35	28	23	17
Water content, %	50.28	52.56	54.43	56.85
LIQUID LIMIT (%)	53.5			



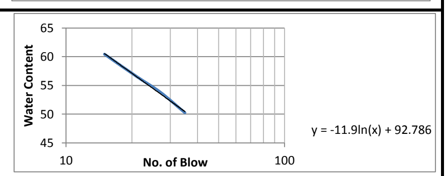
109

No. of blows	34	27	22	16
Water content, %	47.03	49.31	51.68	54.92
LIQUID LIMIT (%)	50.2			



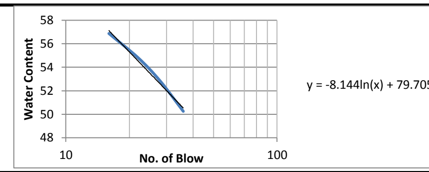
110

No. of blows	35	27	21	15
Water content, %	50.25	53.84	56.58	60.44
LIQUID LIMIT (%)	54.5			



111

No. of blows	36	28	22	16
Water content, %	50.24	52.82	54.81	56.88
LIQUID LIMIT (%)	53.5			

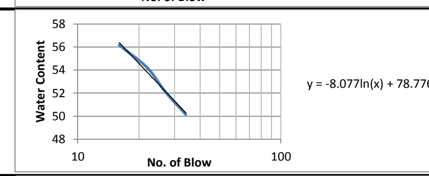


112

No. of blows	36	28	22	16
Water content, %	46.03	48.18	50.86	53.51
LIQUID LIMIT (%)	49.4			

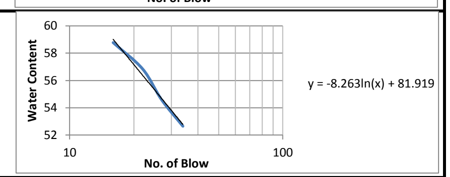
113

No. of blows	34	27	22	16
Water content, %	50.16	52.11	54.2	56.17
LIQUID LIMIT (%)	52.8			



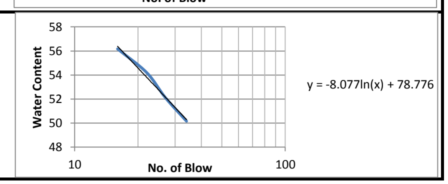
114

No. of blows	34	27	22	16
Water content, %	52.65	54.59	56.84	58.77
LIQUID LIMIT (%)	55.3			



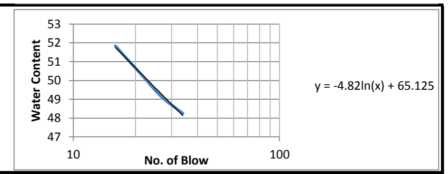
115

No. of blows	34	27	22	16
Water content, %	50.16	52.11	54.2	56.17
LIQUID LIMIT (%)	52.8			



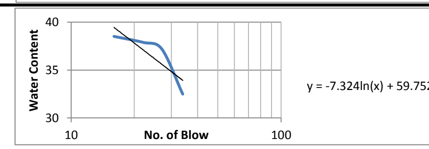
116

No. of blows	34	27	22	16
Water content, %	48.25	49.1	50.16	51.84
LIQUID LIMIT (%)	49.6			



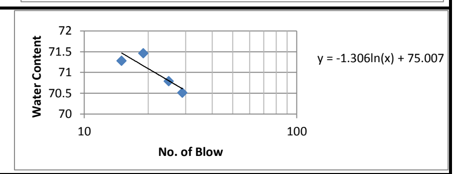
117

No. of blows	34	27	22	16
Water content, %	32.49	37.21	37.89	38.51
LIQUID LIMIT (%)	36.2			



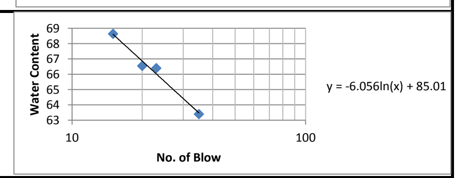
118

No. of blows	15	19	25	29
Water content, %	71.28	71.46	70.79	70.51
LIQUID LIMIT (%)	70.8			



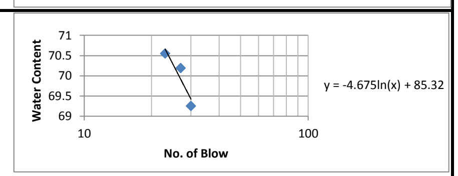
119

No. of blows	15	20	23	35
Water content, %	68.64	66.54	66.4	63.4
LIQUID LIMIT (%)	65.5			



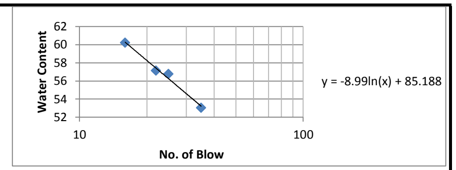
120

No. of blows	23	30	27
Water content, %	70.55	69.25	70.19
LIQUID LIMIT (%)	70.3		



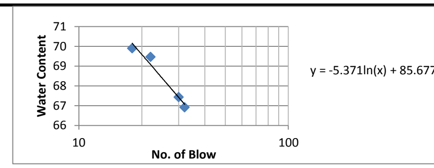
121

No. of blows	35	25	22	16
Water content, %	53.04	56.77	57.13	60.2
LIQUID LIMIT (%)	56.3			



122

No. of blows	18	22	30	32
Water content, %	69.9	69.46	67.43	66.91
LIQUID LIMIT (%)	68.4			

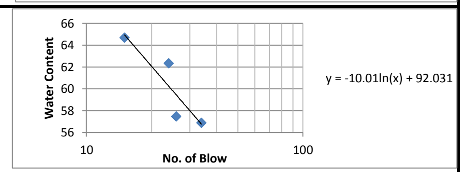


123

No. of blows	2	16	26	35
Water content, %	58.72	59.48	58.26	57.21
LIQUID LIMIT (%)	58.2			

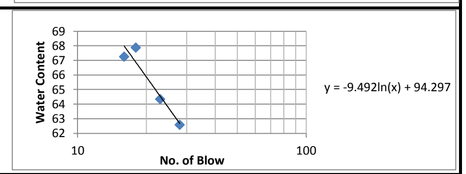
124

No. of blows	15	24	26	34
Water content, %	64.69	62.33	57.46	56.87
LIQUID LIMIT (%)	59.8			



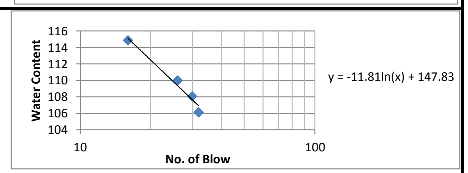
125

No. of blows	28	23	18	16
Water content, %	62.58	64.34	67.87	67.25
LIQUID LIMIT (%)	63.7			



126

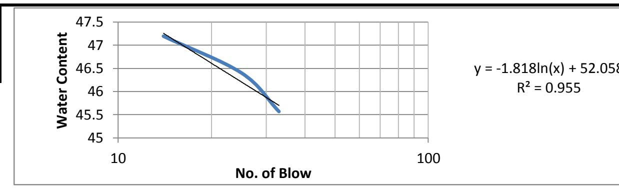
No. of blows	16	26	30	32
Water content, %	114.87	109.99	108.06	106.12
LIQUID LIMIT (%)	109.8			



Alaba Sodo Road Flow Chart

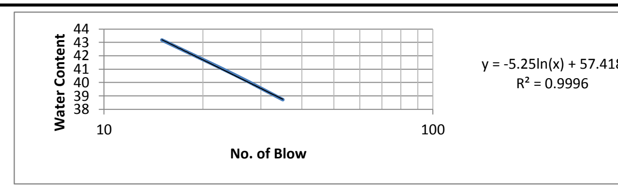
1

No. of blows	33.0	25.0	14.0
Water content, %	45.6	46.4	47.2
LIQUID LIMIT (%)		46.2	



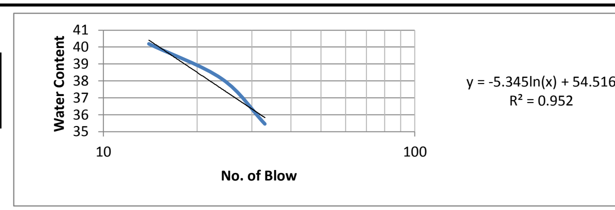
2

No. of blows	35.0	25.0	15.0
Water content, %	38.7	40.6	43.2
LIQUID LIMIT (%)		40.5	



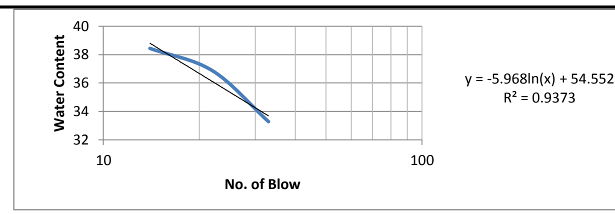
3

No. of blows	33.0	24.0	14.0
Water content, %	35.5	38.1	40.2
LIQUID LIMIT (%)		37.3	



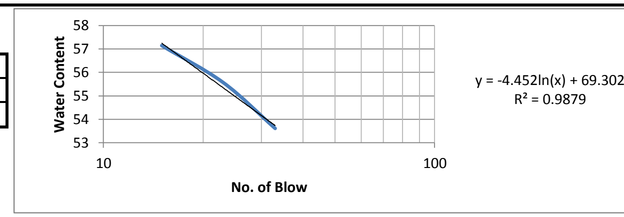
4

No. of blows	33.0	22.0	14.0
Water content, %	33.3	36.9	38.4
LIQUID LIMIT (%)		35.3	



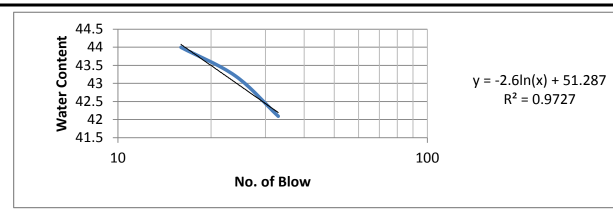
5

No. of blows	33.0	23.0	15.0
Water content, %	53.6	55.6	57.1
LIQUID LIMIT (%)	55.0		



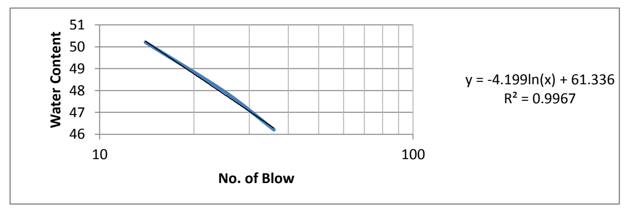
6

No. of blows	33.0	24.0	16.0
Water content, %	42.1	43.2	44.0
LIQUID LIMIT (%)	42.9		



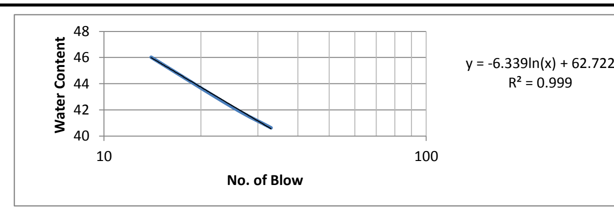
7

No. of blows	36.0	25.0	14.0
Water content, %	46.2	48.0	50.2
LIQUID LIMIT (%)	47.8		



8

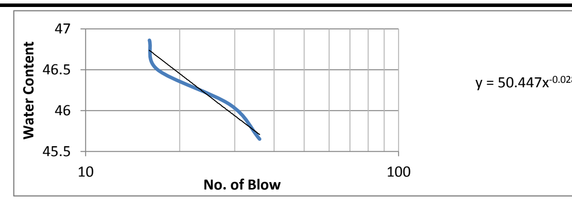
No. of blows	33.0	25.0	14.0
Water content, %	40.6	42.2	46.0
LIQUID LIMIT (%)	42.3		



Hawasa Flow Chart

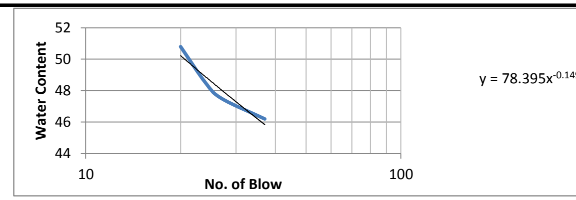
1

No. of blows	16	17	29	36
Water content, %	46.861	46.5	46.07	45.65
LIQUID LIMIT (%)	46.2			



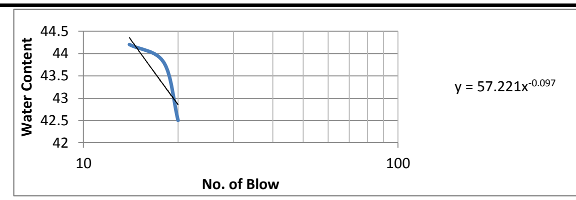
2

No. of blows	20	24	27	37
Water content, %	50.8	48.5	47.5	46.2
LIQUID LIMIT (%)	48.6			



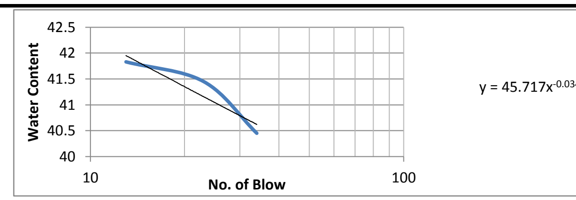
3

No. of blows	14	18	20	30
Water content, %	44.2	43.8	42.5	41.3
LIQUID LIMIT (%)	41.9			



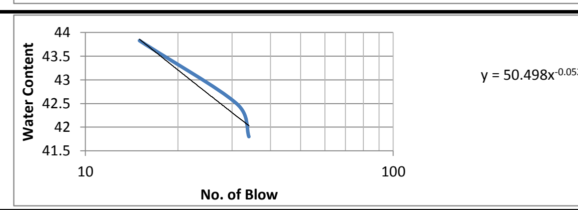
4

No. of blows	13	23	34
Water content, %	41.83	41.45	40.45
LIQUID LIMIT (%)	41.0		



5

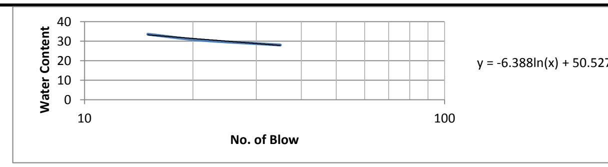
No. of blows	15	31	34
Water content, %	43.83	42.5	41.8
LIQUID LIMIT (%)	42.7		



Kelela Akesta Road Flow Chart

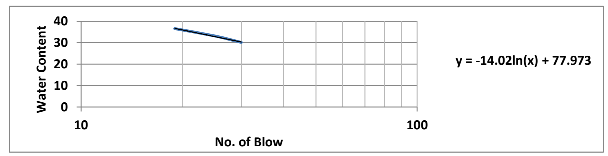
1

No. of blows	15.0	21.0	35.0
Water content, %	33.5	30.6	28.0
LIQUID LIMIT (%)	30.0		



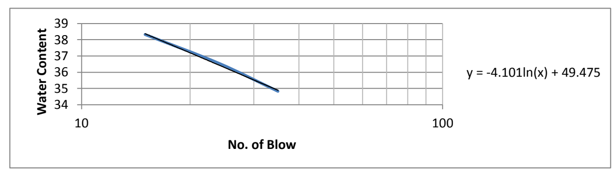
2

No. of blows	19.0	25.0	30.0
Water content, %	36.6	33.1	30.1
LIQUID LIMIT (%)	32.8		



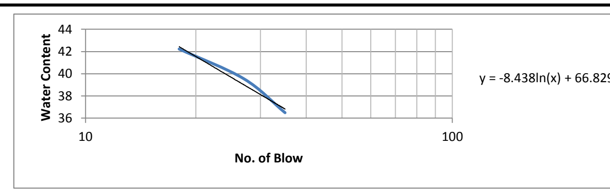
3

No. of blows	35.0	24.0	15.0
Water content, %	34.8	36.6	38.3
LIQUID LIMIT (%)	36.3		



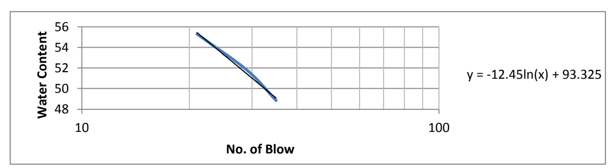
4

No. of blows	18.0	27.0	35.0
Water content, %	42.2	39.6	36.5
LIQUID LIMIT (%)	39.7		



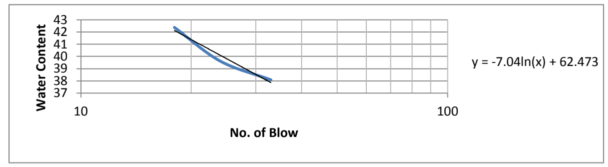
5

No. of blows	21.0	29.0	35.0
Water content, %	55.3	51.8	48.8
LIQUID LIMIT (%)	53.2		



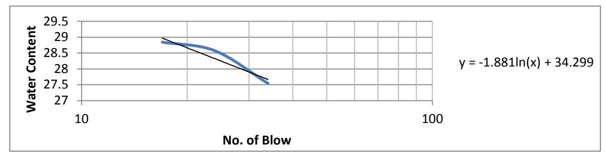
6

No. of blows	18.0	24.0	33.0
Water content, %	42.4	39.6	38.1
LIQUID LIMIT (%)	39.8		



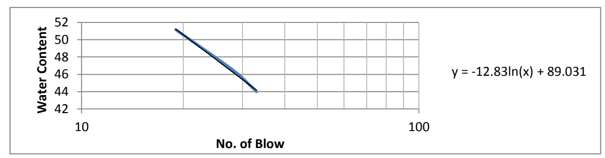
7

No. of blows	17.0	24.0	34.0
Water content, %	28.8	28.6	27.5
LIQUID LIMIT (%)	28.2		



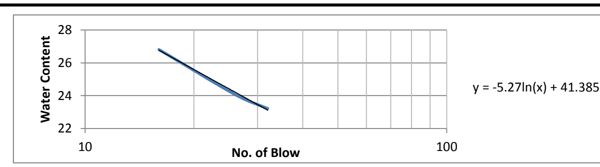
8

No. of blows	19.0	28.0	33.0
Water content, %	51.2	46.5	44.0
LIQUID LIMIT (%)	47.7		



9

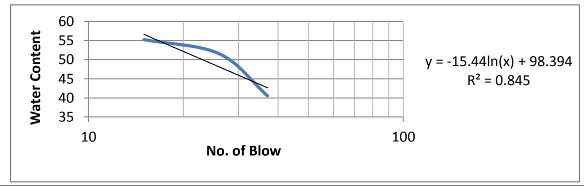
No. of blows	16.0	26.0	32.0
Water content, %	26.8	24.1	23.2
LIQUID LIMIT (%)	24.4		



Tarmaber Molale Mehal Meda Road Flow Chart

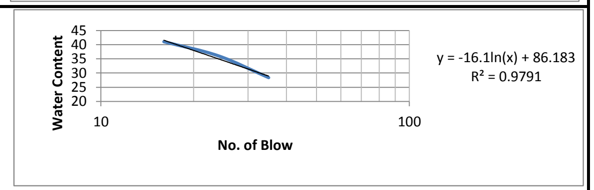
1

No. of blows	37.0	26.0	15.0
Water content, %	40.6	51.5	55.2
LIQUID LIMIT (%)	48.7		



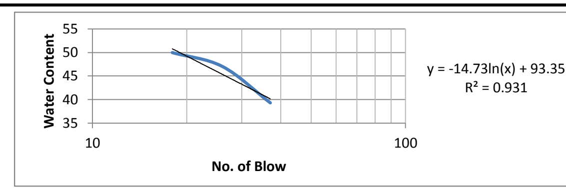
2

No. of blows	35.0	24.0	16.0
Water content, %	28.4	36.1	41.0
LIQUID LIMIT (%)	34.4		



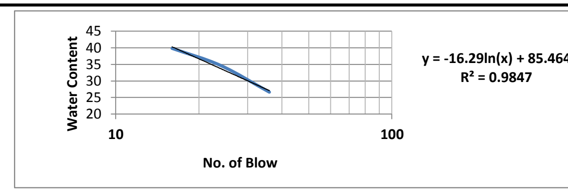
3

No. of blows	37.0	26.0	18.0
Water content, %	39.3	47.0	50.0
LIQUID LIMIT (%)	45.9		



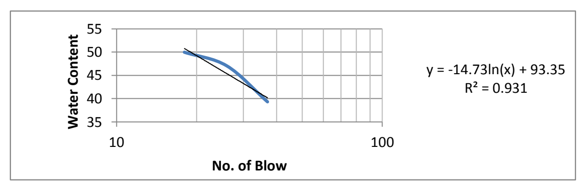
4

No. of blows	36.0	24.0	16.0
Water content, %	26.6	34.7	39.8
LIQUID LIMIT (%)	33.0		



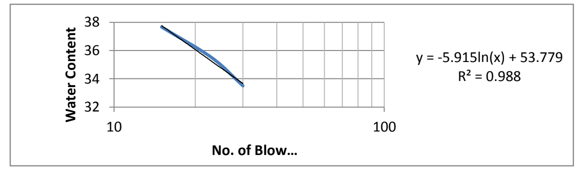
5

No. of blows	37.0	26.0	18.0
Water content, %	39.3	47.0	50.0
LIQUID LIMIT (%)	45.9		



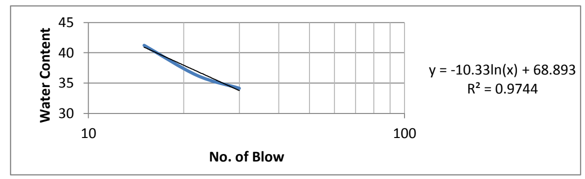
6

No. of blows	30.0	23.0	15.0
Water content, %	33.5	35.5	37.7
LIQUID LIMIT (%)	34.7		



7

No. of blows	30.0	22.0	15.0
Water content, %	34.1	36.3	41.2
LIQUID LIMIT (%)	35.6		

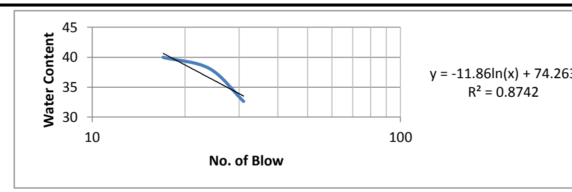


8

No. of blows	35.0	26.0	15.0
Water content, %	45.6	52.0	59.8
LIQUID LIMIT (%)	51.7		

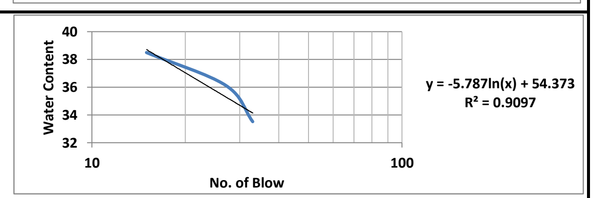
9

No. of blows	31.0	24.0	17.0
Water content, %	32.6	38.1	40.0
LIQUID LIMIT (%)	36.1		



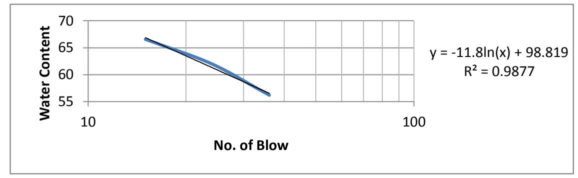
10

No. of blows	33.0	27.0	15.0
Water content, %	33.5	36.1	38.5
LIQUID LIMIT (%)	35.7		



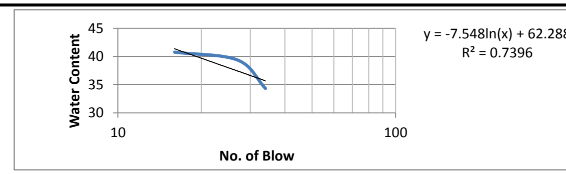
11

No. of blows	36.0	24.0	15.0
Water content, %	56.2	62.0	66.6
LIQUID LIMIT (%)	60.8		



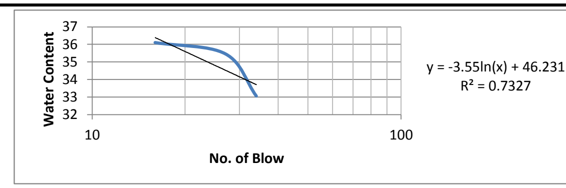
12

No. of blows	34.0	27.0	16.0
Water content, %	34.3	39.4	40.8
LIQUID LIMIT (%)	38.0		



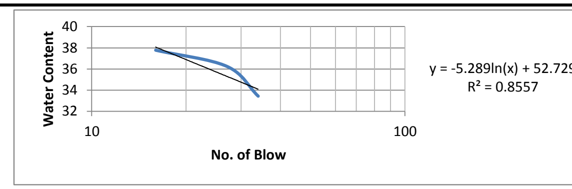
13

No. of blows	34.0	27.0	16.0
Water content, %	33.1	35.5	36.1
LIQUID LIMIT (%)	34.8		



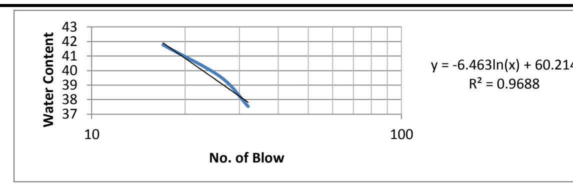
14

No. of blows	34.0	27.0	16.0
Water content, %	33.4	36.2	37.8
LIQUID LIMIT (%)	35.7		



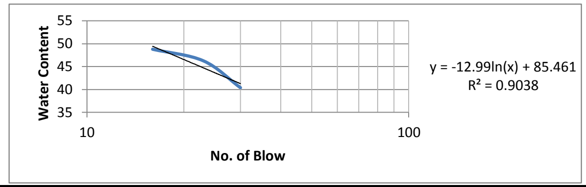
15

No. of blows	32.0	26.0	17.0
Water content, %	37.5	39.6	41.8
LIQUID LIMIT (%)	39.4		



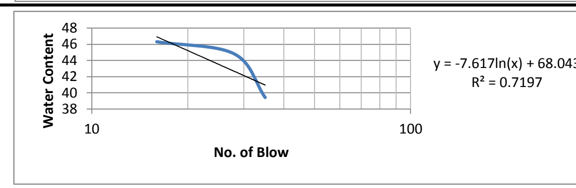
16

No. of blows	30.0	23.0	16.0
Water content, %	40.4	46.3	48.8
LIQUID LIMIT (%)		43.6	



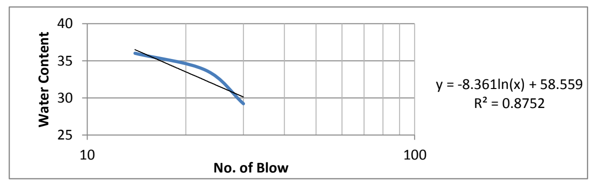
17

No. of blows	35.0	28.0	16.0
Water content, %	39.4	44.8	46.3
LIQUID LIMIT (%)		43.5	



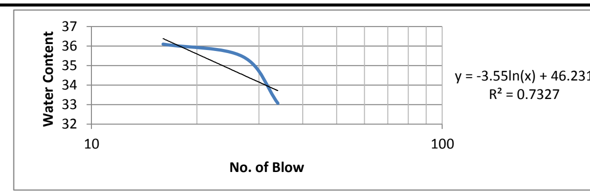
18

No. of blows	30.0	23.0	14.0
Water content, %	29.2	33.7	36.0
LIQUID LIMIT (%)		31.6	



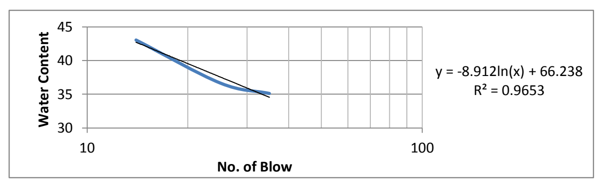
19

No. of blows	34.0	27.0	16.0
Water content, %	33.1	35.5	36.1
LIQUID LIMIT (%)		34.8	



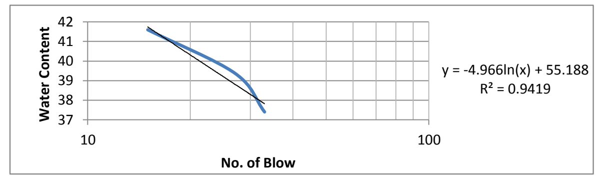
20

No. of blows	35.0	25.0	14.0
Water content, %	35.1	36.7	43.0
LIQUID LIMIT (%)		37.6	



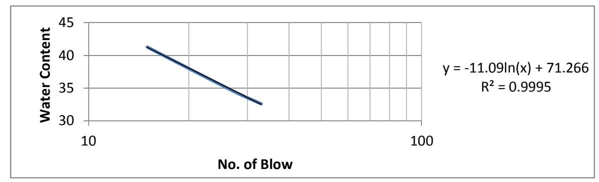
21

No. of blows	33.0	27.0	15.0
Water content, %	37.4	39.4	41.6
LIQUID LIMIT (%)	39.2		



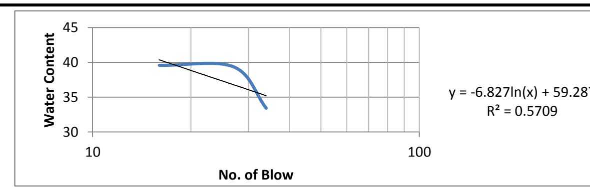
22

No. of blows	33.0	27.0	15.0
Water content, %	32.6	34.6	41.3
LIQUID LIMIT (%)	35.6		



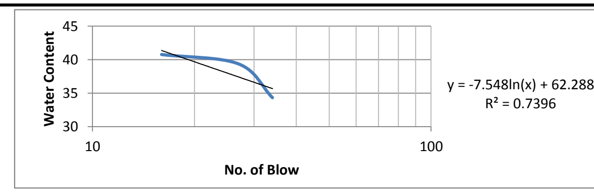
23

No. of blows	34.0	27.0	16.0
Water content, %	33.4	39.4	39.6
LIQUID LIMIT (%)	37.3		



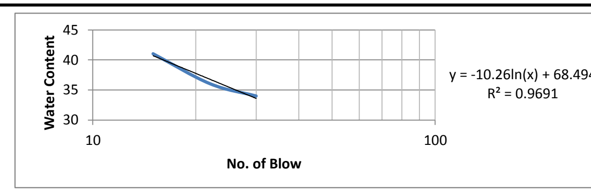
24

No. of blows	34.0	27.0	16.0
Water content, %	34.3	39.4	40.8
LIQUID LIMIT (%)	38.0		



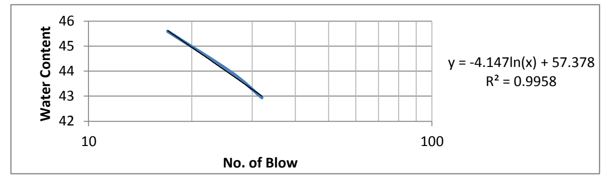
25

No. of blows	30.0	22.0	15.0
Water content, %	34.0	36.0	41.0
LIQUID LIMIT (%)	35.5		



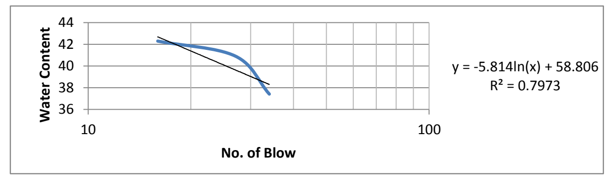
26

No. of blows	32.0	26.0	17.0
Water content, %	42.9	44.0	45.6
LIQUID LIMIT (%)	44.0		



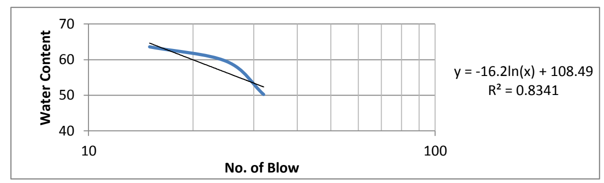
27

No. of blows	34.0	27.0	16.0
Water content, %	37.4	40.9	42.3
LIQUID LIMIT (%)	40.1		



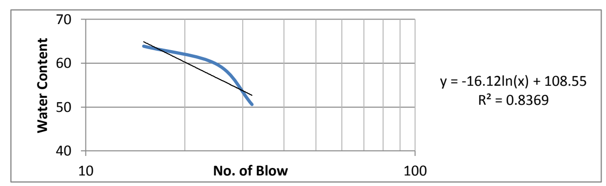
28

No. of blows	32.0	25.0	15.0
Water content, %	50.2	59.5	63.6
LIQUID LIMIT (%)	56.3		



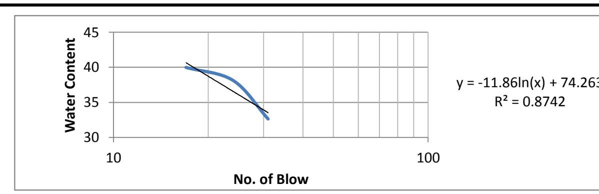
29

No. of blows	32.0	25.0	15.0
Water content, %	50.6	59.8	63.9
LIQUID LIMIT (%)	56.7		

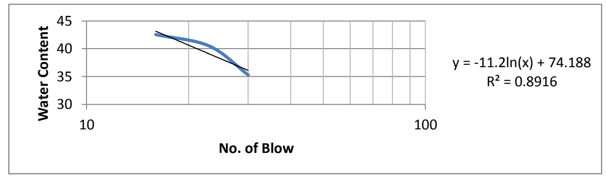


30

No. of blows	31.0	24.0	17.0
Water content, %	32.6	38.1	40.0
LIQUID LIMIT (%)	36.1		

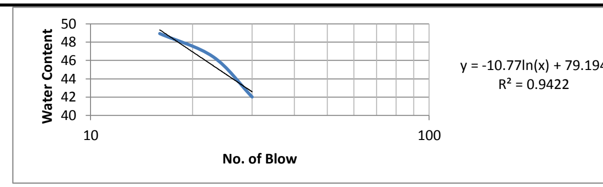


31	No. of blows	30.0	23.0	16.0
	Water content, %	35.3	40.5	42.5
	LIQUID LIMIT (%)	38.1		



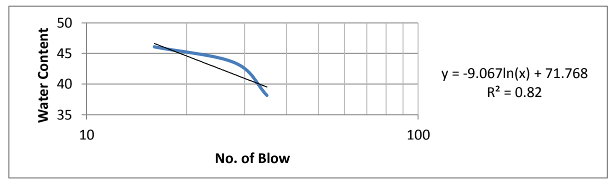
32

No. of blows	30.0	23.0	16.0
Water content, %	42.0	46.4	48.9
LIQUID LIMIT (%)	44.5		



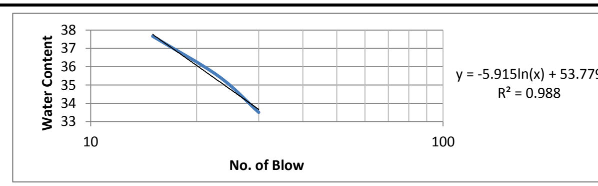
33

No. of blows	35.0	28.0	16.0
Water content, %	38.2	43.5	46.1
LIQUID LIMIT (%)	42.6		



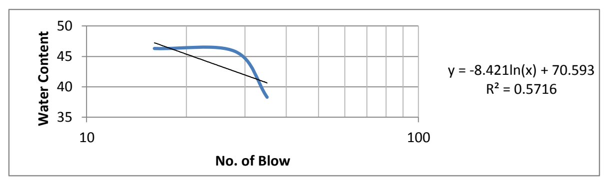
34

No. of blows	30.0	23.0	15.0
Water content, %	33.5	35.5	37.7
LIQUID LIMIT (%)	34.7		



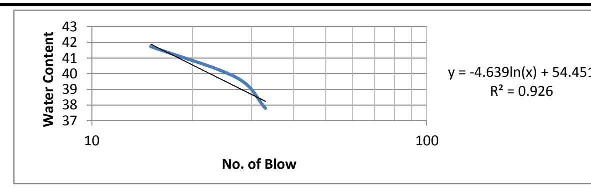
35

No. of blows	35.0	28.0	16.0
Water content, %	38.3	45.8	46.3
LIQUID LIMIT (%)	43.5		



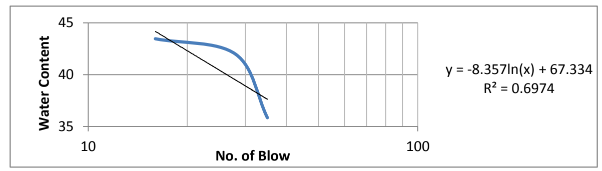
36

No. of blows	33.0	27.0	15.0
Water content, %	37.8	39.8	41.7
LIQUID LIMIT (%)	39.5		



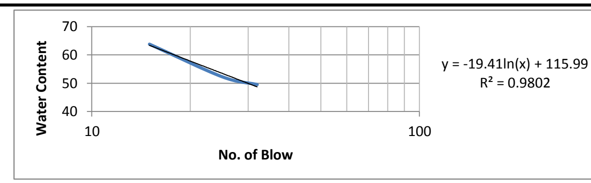
37

No. of blows	35.0	28.0	16.0
Water content, %	35.8	42.0	43.5
LIQUID LIMIT (%)	40.4		



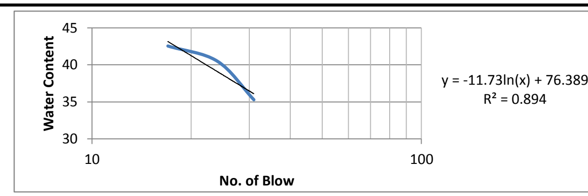
38

No. of blows	32.0	25.0	15.0
Water content, %	49.5	52.3	63.8
LIQUID LIMIT (%)	53.5		



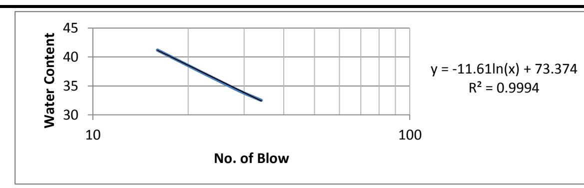
39

No. of blows	31.0	24.0	17.0
Water content, %	35.3	40.5	42.5
LIQUID LIMIT (%)	50.6		



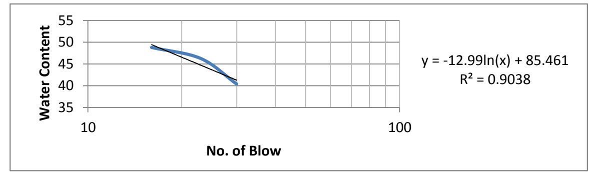
40

No. of blows	34.0	28.0	16.0
Water content, %	32.5	34.5	41.2
LIQUID LIMIT (%)	36.0		



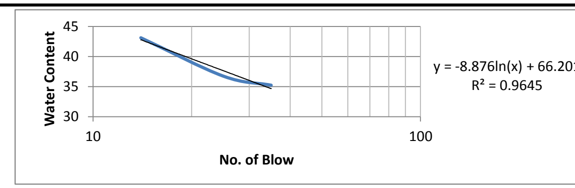
41

No. of blows	30.0	23.0	16.0
Water content, %	40.4	46.3	48.8
LIQUID LIMIT (%)	43.6		



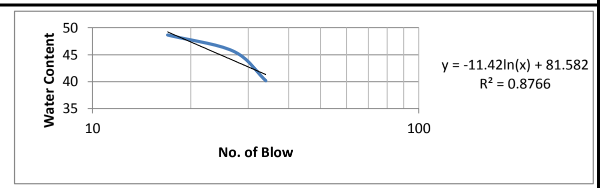
42

No. of blows	35.0	25.0	14.0
Water content, %	35.2	36.7	43.1
LIQUID LIMIT (%)	37.6		



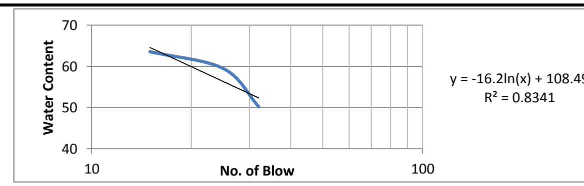
43

No. of blows	34.0	27.0	17.0
Water content, %	40.2	45.7	48.7
LIQUID LIMIT (%)	44.8		



44

No. of blows	32.0	25.0	15.0
Water content, %	50.2	59.5	63.6
LIQUID LIMIT (%)	56.3		

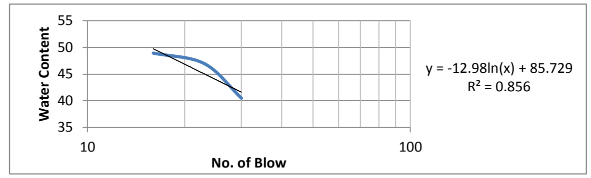


45

No. of blows	35.0	28.0	16.0
Water content, %	36.0	42.1	43.6
LIQUID LIMIT (%)	40.6		

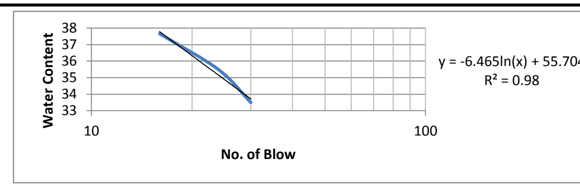
46

No. of blows	30.0	23.0	16.0
Water content, %	40.5	47.0	48.9
LIQUID LIMIT (%)	43.9		



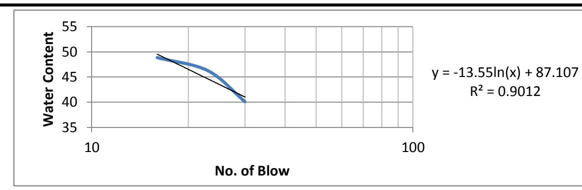
47

No. of blows	30.0	24.0	16.0
Water content, %	33.5	35.5	37.7
LIQUID LIMIT (%)	34.9		



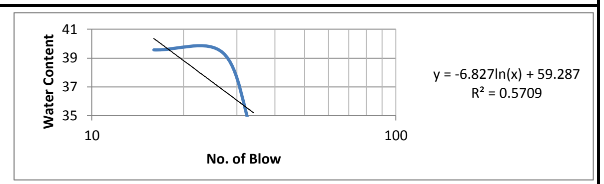
48

No. of blows	30.0	23.0	16.0
Water content, %	40.1	46.3	48.9
LIQUID LIMIT (%)	43.5		



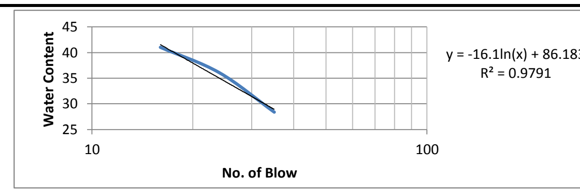
49

No. of blows	34.0	27.0	16.0
Water content, %	33.4	39.4	39.6
LIQUID LIMIT (%)	37.3		



50

No. of blows	35.0	24.0	16.0
Water content, %	28.4	36.1	41.0
LIQUID LIMIT (%)	34.4		

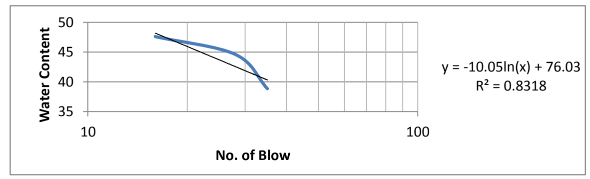


51

No. of blows	35.0	28.0	16.0
Water content, %	39.4	44.8	46.3
LIQUID LIMIT (%)	43.5		

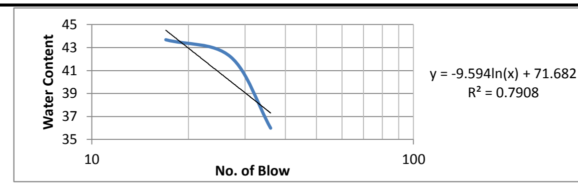
52

No. of blows	35.0	28.0	16.0
Water content, %	38.9	44.6	47.6
LIQUID LIMIT (%)	43.7		



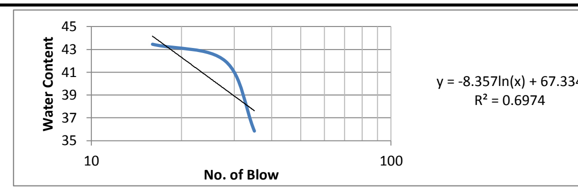
53

No. of blows	36.0	27.0	17.0
Water content, %	36.0	42.2	43.7
LIQUID LIMIT (%)	40.8		



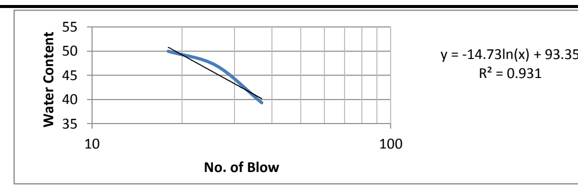
54

No. of blows	35.0	28.0	16.0
Water content, %	35.8	42.0	43.5
LIQUID LIMIT (%)	40.4		



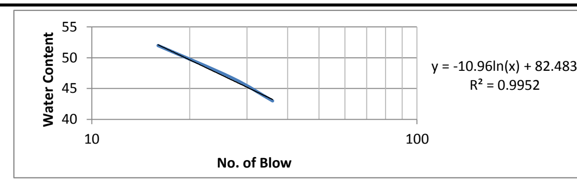
55

No. of blows	37.0	26.0	18.0
Water content, %	39.3	47.0	50.0
LIQUID LIMIT (%)	45.9		



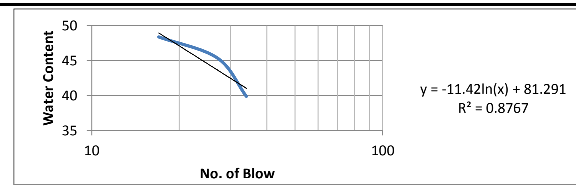
56

No. of blows	36.0	27.0	16.0
Water content, %	43.0	46.7	52.0
LIQUID LIMIT (%)	47.2		



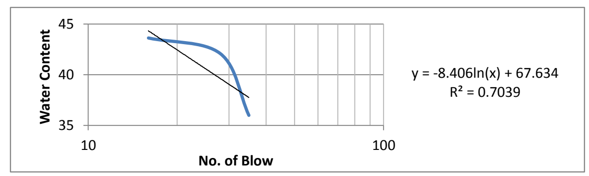
57

No. of blows	34.0	27.0	17.0
Water content, %	39.9	45.4	48.4
LIQUID LIMIT (%)	44.5		



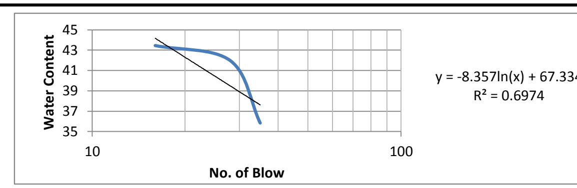
58

No. of blows	35.0	28.0	16.0
Water content, %	36.0	42.1	43.6
LIQUID LIMIT (%)	40.6		



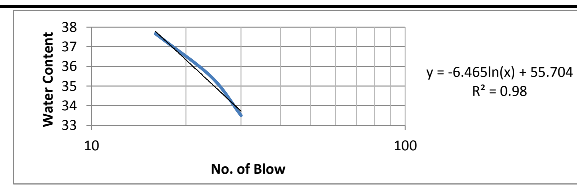
59

No. of blows	35.0	28.0	16.0
Water content, %	35.8	42.0	43.5
LIQUID LIMIT (%)	40.4		



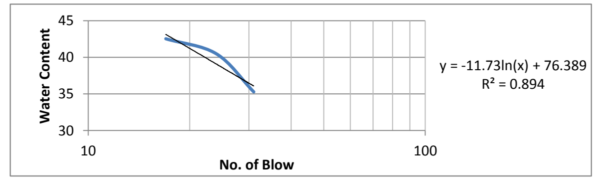
60

No. of blows	30.0	24.0	16.0
Water content, %	33.5	35.5	37.7
LIQUID LIMIT (%)	34.9		



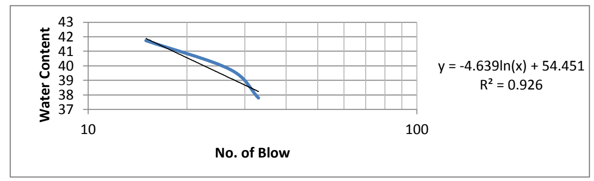
61

No. of blows	31.0	24.0	17.0
Water content, %	35.3	40.5	42.5
LIQUID LIMIT (%)	38.6		



62

No. of blows	33.0	27.0	15.0
Water content, %	37.8	39.8	41.7
LIQUID LIMIT (%)	39.5		

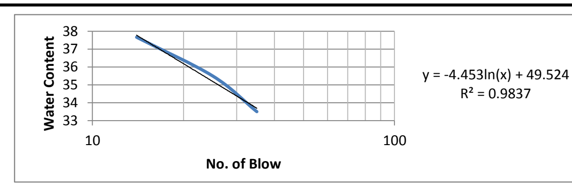


63

No. of blows	35.0	26.0	15.0
Water content, %	43.0	46.7	52.0
LIQUID LIMIT (%)	46.8		

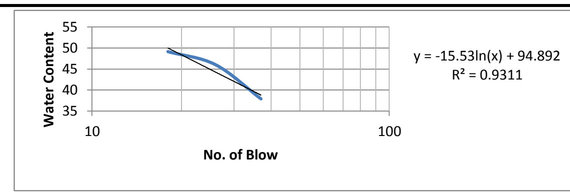
64

No. of blows	35.0	25.0	14.0
Water content, %	33.5	35.5	37.7
LIQUID LIMIT (%)	35.2		



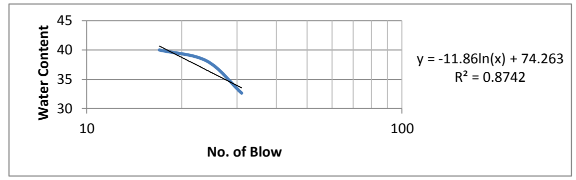
65

No. of blows	37.0	26.0	18.0
Water content, %	37.9	46.0	49.1
LIQUID LIMIT (%)	44.9		



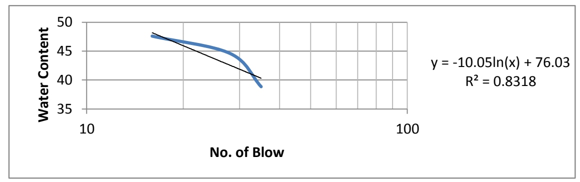
66

No. of blows	31.0	24.0	17.0
Water content, %	32.6	38.1	40.0
LIQUID LIMIT (%)	36.1		



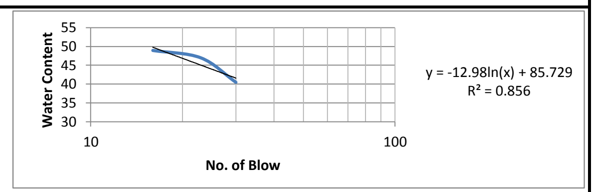
67

No. of blows	35.0	28.0	16.0
Water content, %	38.9	44.6	47.6
LIQUID LIMIT (%)	43.7		



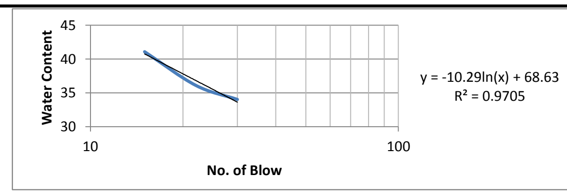
68

No. of blows	30.0	23.0	16.0
Water content, %	40.5	47.0	48.9
LIQUID LIMIT (%)	43.9		



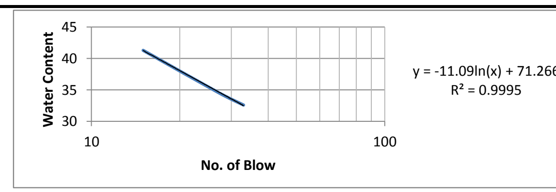
69

No. of blows	30.0	22.0	15.0
Water content, %	34.0	36.1	41.1
LIQUID LIMIT (%)	35.5		



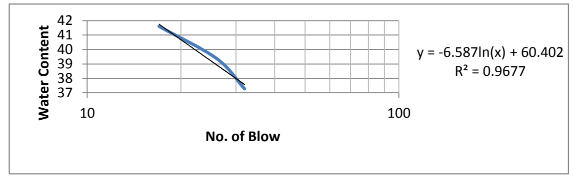
70

No. of blows	33.0	27.0	15.0
Water content, %	32.6	34.6	41.3
LIQUID LIMIT (%)	35.6		



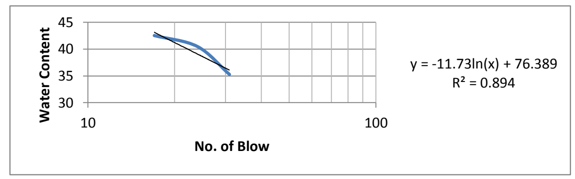
71

No. of blows	32.0	26.0	17.0
Water content, %	37.3	39.4	41.6
LIQUID LIMIT (%)	39.2		



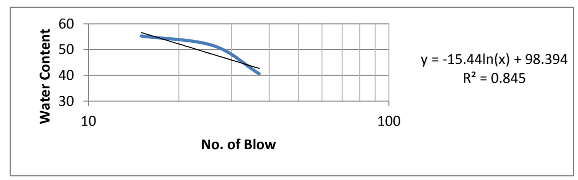
72

No. of blows	31.0	24.0	17.0
Water content, %	35.3	40.5	42.5
LIQUID LIMIT (%)	38.6		



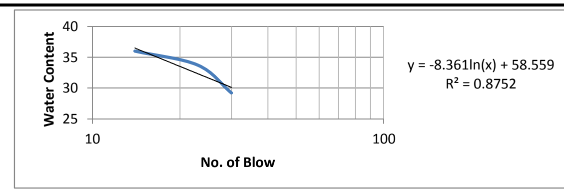
73

No. of blows	37.0	26.0	15.0
Water content, %	40.6	51.5	55.2
LIQUID LIMIT (%)	48.7		



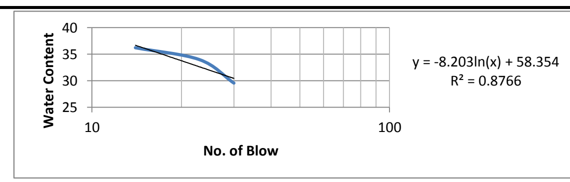
74

No. of blows	30.0	23.0	14.0
Water content, %	29.2	33.7	36.0
LIQUID LIMIT (%)	31.6		

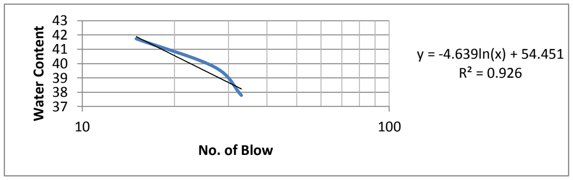


75

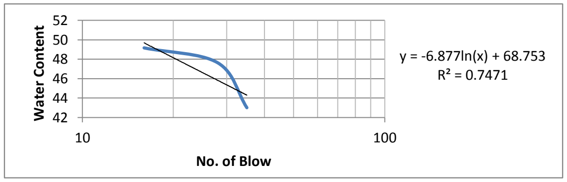
No. of blows	30.0	23.0	14.0
Water content, %	29.6	34.0	36.2
LIQUID LIMIT (%)	31.9		

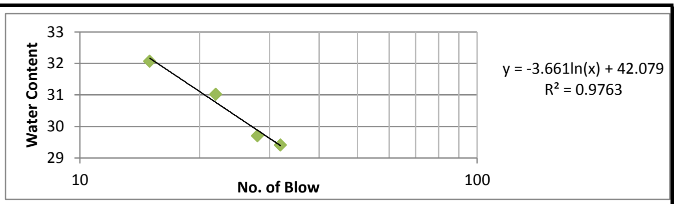
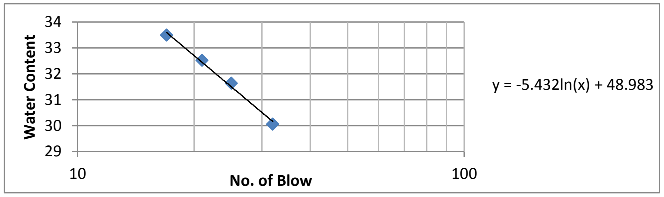


76	No. of blows	33.0	27.0	15.0
	Water content, %	37.8	39.8	41.7
	LIQUID LIMIT (%)	39.5		



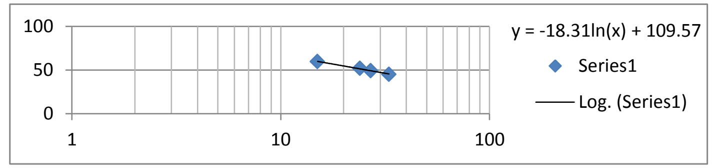
77	No. of blows	35.0	28.0	16.0
	Water content, %	43.0	47.6	49.2
	LIQUID LIMIT (%)	46.6		



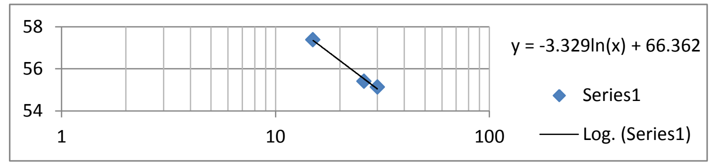
1	No. of blows	32	28	22	15	
	Water content, %	29.41	29.7	31.02	32.07	
	LIQUID LIMIT (%)	30.3				
2	No. of blows	32	21	17	25	
	Water content, %	30.05	32.52	33.49	31.63	
	LIQUID LIMIT (%)	31.5				

Addis Nekemit Road Flow Chart

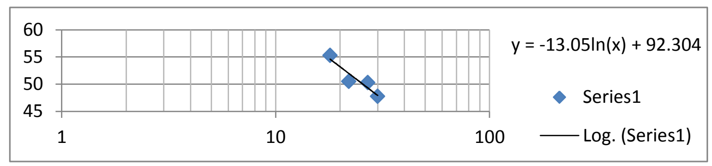
	No. of blows	Water content, %	LIQUID LIMIT (%)
1	33	45.17	50.6
	27	49.31	
	24	51.92	
	15	59.75	



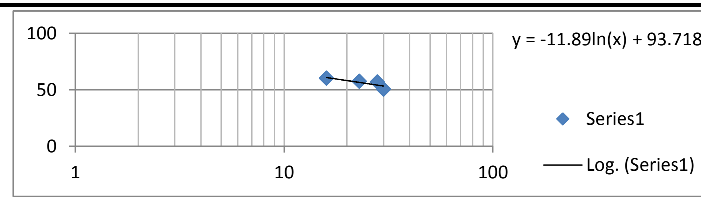
	No. of blows	Water content, %	LIQUID LIMIT (%)
2	30	55.13	55.6
	26	55.4	
	15	57.37	



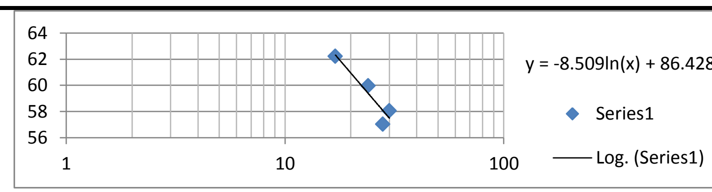
	No. of blows	Water content, %	LIQUID LIMIT (%)
3	30	47.73	50.3
	27	50.25	
	22	50.48	
	18	55.28	



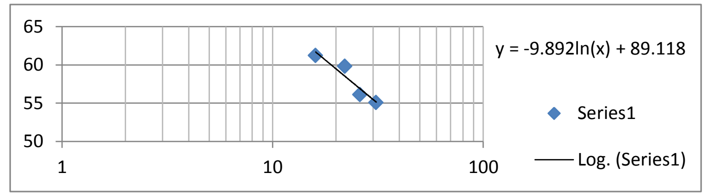
	No. of blows	Water content, %	LIQUID LIMIT (%)
4	30	50.3	55.4
	28	56.76	
	23	57.44	
	16	60.02	



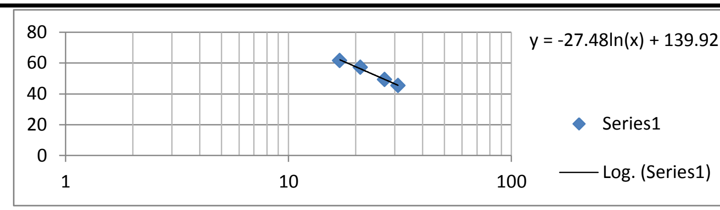
	No. of blows	Water content, %	LIQUID LIMIT (%)
5	30	58.06	59.0
	28	57.02	
	24	59.96	
	17	62.22	



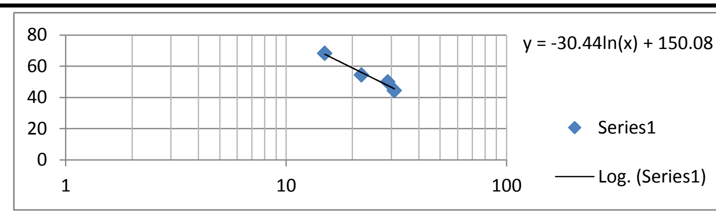
	No. of blows	Water content, %	LIQUID LIMIT (%)
6	31	55.09	57.3
	26	56.13	
	22	59.82	
	16	61.23	



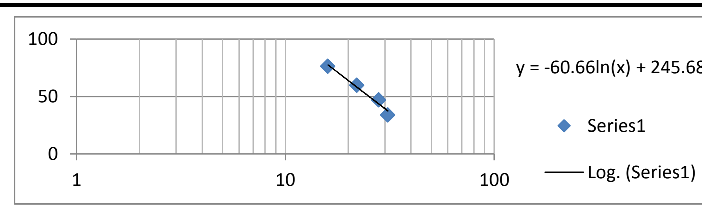
	No. of blows	Water content, %	LIQUID LIMIT (%)
7	31	45.36	51.5
	27	49.18	
	21	57.16	
	17	61.51	



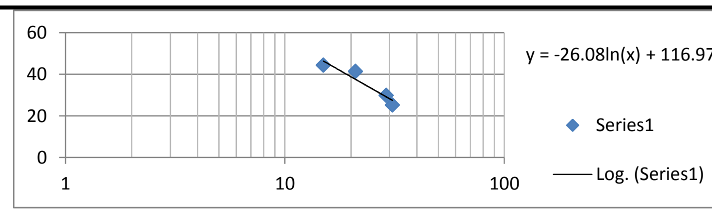
	No. of blows	Water content, %	LIQUID LIMIT (%)
8	31	44.33	52.1
	29	49.9	
	22	54.36	
	15	68.22	



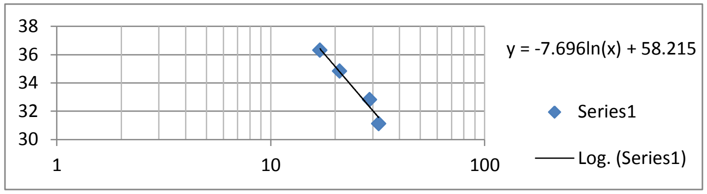
	No. of blows	Water content, %	LIQUID LIMIT (%)
9	31	33.84	50.4
	28	46.89	
	22	59.69	
	16	76.21	



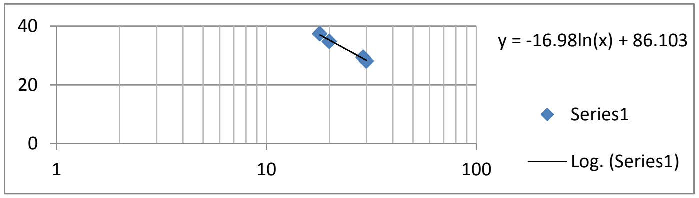
	No. of blows	Water content, %	LIQUID LIMIT (%)
10	31	25.13	33.0
	29	29.75	
	21	41.35	
	15	44.27	



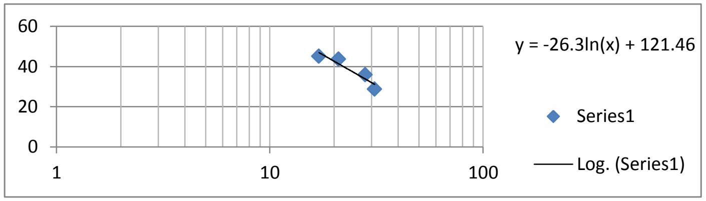
	No. of blows	Water content, %	LIQUID LIMIT (%)
11	32	31.11	33.4
	29	32.8	
	21	34.82	
	17	36.31	



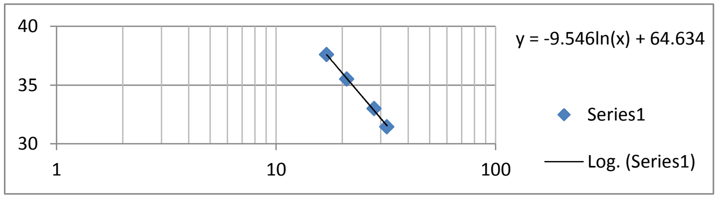
	No. of blows	Water content, %	LIQUID LIMIT (%)
12	30	28.08	31.4
	29	29.36	
	20	34.73	
	18	37.42	



	No. of blows	Water content, %	LIQUID LIMIT (%)
13	31	28.66	36.8
	28	35.82	
	21	43.67	
	17	45.11	



	No. of blows	Water content, %	LIQUID LIMIT (%)
14	32	31.43	33.9
	28	33	
	21	35.51	
	17	37.59	



Linear Regression Input Data for Addis Ababa					
Sr. No.	**N**	**ω**	**LL**	**N/25**	**LL/ω**
1	15	71.28	70.80	0.60	0.99
	19	71.46	70.80	0.76	0.99
	25	70.79	70.80	1.00	1.00
	29	70.51	70.80	1.16	1.00
2	15	68.64	65.52	0.60	0.95
	20	66.54	65.52	0.80	0.98
	23	66.40	65.52	0.92	0.99
	35	63.40	65.52	1.40	1.03
3	23	70.55	70.27	0.92	1.00
	30	69.25	70.27	1.20	1.01
	27	70.19	70.27	1.08	1.00
4	35	53.04	56.25	1.40	1.06
	25	56.77	56.25	1.00	0.99
	22	57.13	56.25	0.88	0.98
	16	60.20	56.25	0.64	0.93
5	18	69.90	68.39	0.72	0.98
	22	69.46	68.39	0.88	0.98
	30	67.43	68.39	1.20	1.01
	32	66.91	68.39	1.28	1.02
6	16	59.48	58.20	0.64	0.98
	26	58.26	58.20	1.04	1.00
	35	57.21	58.20	1.40	1.02
7	15	64.69	59.81	0.60	0.92
	24	62.33	59.81	0.96	0.96
	26	57.46	59.81	1.04	1.04
	34	56.87	59.81	1.36	1.05
8	28	62.58	63.74	1.12	1.02
	23	64.34	63.74	0.92	0.99
	18	67.87	63.74	0.72	0.94
	16	67.25	63.74	0.64	0.95
9	17	65.26	61.75	0.68	0.95
	22	63.02	61.75	0.88	0.98
	28	61.01	61.75	1.12	1.01
	35	58.31	61.75	1.40	1.06
10	35	52.44	53.99	1.40	1.03
	27	53.63	53.99	1.08	1.01
	21	54.96	53.99	0.84	0.98
	16	55.86	53.99	0.64	0.97

Linear Regression Input Data for Addis Ababa					
Sr. No.	**N**	**ω**	**LL**	**N/25**	**LL/ω**
11	36	56.19	59.00	1.44	1.05
	28	58.25	59.00	1.12	1.01
	22	60.20	59.00	0.88	0.98
	16	62.07	59.00	0.64	0.95
12	36	52.73	55.28	1.44	1.05
	27	54.00	55.28	1.08	1.02
	22	56.69	55.28	0.88	0.98
	15	59.24	55.28	0.60	0.93
13	35	58.22	61.00	1.40	1.05
	27	60.72	61.00	1.08	1.00
	21	62.45	61.00	0.84	0.98
	16	64.17	61.00	0.64	0.95
14	36	58.49	60.00	1.44	1.03
	27	59.69	60.00	1.08	1.01
	21	60.42	60.00	0.84	0.99
	16	62.19	60.00	0.64	0.96
15	36	52.05	53.92	1.44	1.04
	27	53.72	53.92	1.08	1.00
	21	54.83	53.92	0.84	0.98
	16	55.95	53.92	0.64	0.96
16	36	60.26	64.99	1.44	1.08
	27	63.22	64.99	1.08	1.03
	22	68.62	64.99	0.88	0.95
	15	70.28	64.99	0.60	0.92
17	36	57.89	62.06	1.44	1.07
	27	59.99	62.06	1.08	1.03
	22	64.69	62.06	0.88	0.96
	15	68.12	62.06	0.60	0.91
18	35	54.87	57.50	1.40	1.05
	27	56.85	57.50	1.08	1.01
	22	58.62	57.50	0.88	0.98
	16	60.92	57.50	0.64	0.94
19	36	58.55	62.19	1.44	1.06
	27	60.18	62.19	1.08	1.03
	22	63.99	62.19	0.88	0.97
	15	68.28	62.19	0.60	0.91
20	35	53.04	56.25	1.40	1.06
	25	56.77	56.25	1.00	0.99
	22	57.13	56.25	0.88	0.98
	16	60.21	56.25	0.64	0.93

Linear Regression Input Data for Addis Ababa					
Sr. No.	**N**	**ω**	**LL**	**N/25**	**LL/ω**
21	36	58.10	61.00	1.44	1.05
	28	60.47	61.00	1.12	1.01
	22	62.16	61.00	0.88	0.98
	15	64.40	61.00	0.60	0.95
22	36	59.24	62.00	1.44	1.05
	27	61.52	62.00	1.08	1.01
	22	63.13	62.00	0.88	0.98
	15	65.52	62.00	0.60	0.95
23	34	66.84	69.00	1.36	1.03
	28	67.35	69.00	1.12	1.02
	23	70.13	69.00	0.92	0.98
	17	72.07	69.00	0.68	0.96
24	36	60.45	63.00	1.44	1.04
	27	61.72	63.00	1.08	1.02
	22	64.41	63.00	0.88	0.98
	15	66.96	63.00	0.60	0.94
25	35	66.80	70.00	1.40	1.05
	28	69.07	70.00	1.12	1.01
	23	70.95	70.00	0.92	0.99
	17	73.36	70.00	0.68	0.95
26	34	59.79	62.99	1.36	1.05
	27	62.08	62.99	1.08	1.01
	22	64.45	62.99	0.88	0.98
	16	67.69	62.99	0.64	0.93
27	35	54.78	59.01	1.40	1.08
	27	58.37	59.01	1.08	1.01
	21	61.11	59.01	0.84	0.97
	15	64.97	59.01	0.60	0.91
28	36	62.75	66.00	1.44	1.05
	28	65.33	66.00	1.12	1.01
	22	67.32	66.00	0.88	0.98
	16	69.39	66.00	0.64	0.95
29	28	60.64	59.00	1.12	0.97
	22	61.45	59.00	0.88	0.96
	16	63.55	59.00	0.64	0.93
30	34	56.38	59.00	1.36	1.05
	27	58.34	59.00	1.08	1.01
	22	60.43	59.00	0.88	0.98
	16	62.39	59.00	0.64	0.95

Linear Regression Input Data for Addis Ababa					
Sr. No.	N	ω	LL	N/25	LL/ω
31	34	57.33	60.00	1.36	1.05
	27	59.27	60.00	1.08	1.01
	22	61.52	60.00	0.88	0.98
	16	63.45	60.00	0.64	0.95
32	37	59.04	61.23	1.48	1.04
	27	59.74	61.23	1.08	1.02
	22	61.43	61.23	0.88	1.00
	16	65.53	61.23	0.64	0.93
33	36	68.15	71.00	1.44	1.04
	28	69.71	71.00	1.12	1.02
	22	72.26	71.00	0.88	0.98
	15	75.21	71.00	0.60	0.94
34	36	59.75	63.00	1.44	1.05
	28	62.32	63.00	1.12	1.01
	22	64.32	63.00	0.88	0.98
	16	66.38	63.00	0.64	0.95
35	35	57.02	60.86	1.40	1.07
	28	60.69	60.86	1.12	1.00
	22	62.05	60.86	0.88	0.98
	17	64.30	60.86	0.68	0.95
36	35	54.19	58.99	1.40	1.09
	25	58.90	58.99	1.00	1.00
	22	61.46	58.99	0.88	0.96
	16	64.70	58.99	0.64	0.91
37	35	53.55	55.00	1.40	1.03
	25	56.08	55.00	1.00	0.98
	22	54.23	55.00	0.88	1.01
	16	57.10	55.00	0.64	0.96
38	36	55.41	58.00	1.44	1.05
	27	57.50	58.00	1.08	1.01
	22	60.98	58.00	0.88	0.95
	15	59.01	58.00	0.60	0.98
39	36	61.57	62.00	1.44	1.01
	27	56.96	62.00	1.08	1.09
	21	64.57	62.00	0.84	0.96
	16	66.33	62.00	0.64	0.93
40	36	62.15	65.00	1.44	1.05
	28	63.71	65.00	1.12	1.02
	22	66.26	65.00	0.88	0.98
	15	69.21	65.00	0.60	0.94

Linear Regression Input Data for Addis Ababa					
Sr. No.	**N**	**ω**	**LL**	**N/25**	**LL/ω**
41	35	62.54	66.00	1.40	1.06
	28	64.81	66.00	1.12	1.02
	23	66.69	66.00	0.92	0.99
	17	70.16	66.00	0.68	0.94
42	36	62.83	68.00	1.44	1.08
	28	68.98	68.00	1.12	0.99
	22	71.16	68.00	0.88	0.96
	16	69.82	68.00	0.64	0.97
43	32	46.00	49.64	1.28	1.08
	27	49.20	49.64	1.08	1.01
	20	52.40	49.64	0.80	0.95
44	35	39.90	42.54	1.40	1.07
	27	42.20	42.54	1.08	1.01
	18	44.90	42.54	0.72	0.95
45	33	50.10	53.18	1.32	1.06
	25	53.50	53.18	1.00	0.99
	17	57.10	53.18	0.68	0.93
46	30	54.20	55.05	1.20	1.02
	25	55.30	55.05	1.00	1.00
	18	56.20	55.05	0.72	0.98
47	32	44.40	45.54	1.28	1.03
	26	45.60	45.54	1.04	1.00
	18	46.80	45.54	0.72	0.97
48	30	59.70	60.18	1.20	1.01
	25	60.20	60.18	1.00	1.00
	18	61.00	60.18	0.72	0.99
49	35	63.20	66.40	1.40	1.05
	26	66.50	66.40	1.04	1.00
	16	70.10	66.40	0.64	0.95
50	32	58.40	61.17	1.28	1.05
	25	61.90	61.17	1.00	0.99
	17	64.50	61.17	0.68	0.95

Linear Regression Input Data for Addis Ababa					
Sr. No.	**N**	**ω**	**LL**	**N/25**	**LL/ω**
51	32	59.90	62.57	1.28	1.04
	25	63.20	62.57	1.00	0.99
	17	65.90	62.57	0.68	0.95
52	34	51.20	54.18	1.36	1.06
	26	53.90	54.18	1.04	1.01
	17	57.80	54.18	0.68	0.94
53	33	56.90	59.36	1.32	1.04
	26	59.70	59.36	1.04	0.99
	15	62.90	59.36	0.60	0.94
54	32	50.20	52.46	1.28	1.05
	23	53.60	52.46	0.92	0.98
	16	55.90	52.46	0.64	0.94
55	28	56.60	57.06	1.12	1.01
	22	57.60	57.06	0.88	0.99
	16	58.70	57.06	0.64	0.97
56	34	58.70	60.94	1.36	1.04
	29	59.60	60.94	1.16	1.02
	22	62.00	60.94	0.88	0.98
57	28	65.40	67.23	1.12	1.03
	22	69.50	67.23	0.88	0.97
	18	71.80	67.23	0.72	0.94
58	28	65.40	68.40	1.12	1.05
	22	71.80	68.40	0.88	0.95
	18	69.50	68.40	0.72	0.98
59	28	55.30	55.95	1.12	1.01
	23	56.60	55.95	0.92	0.99
	18	57.20	55.95	0.72	0.98
60	32	58.00	59.69	1.28	1.03
	25	60.40	59.69	1.00	0.99
	18	61.10	59.69	0.72	0.98

Linear Regression Input Data for Addis Ababa					
Sr. No.	**N**	**ω**	**LL**	**N/25**	**LL/ω**
61	33	61.40	63.04	1.32	1.03
	28	62.80	63.04	1.12	1.00
	18	64.60	63.04	0.72	0.98
62	31	52.20	53.86	1.24	1.03
	24	54.70	53.86	0.96	0.98
	17	56.00	53.86	0.68	0.96
63	34	57.70	59.23	1.36	1.03
	22	60.00	59.23	0.88	0.99
	17	61.00	59.23	0.68	0.97
64	31	59.00	60.80	1.24	1.03
	24	61.30	60.80	0.96	0.99
	19	62.90	60.80	0.76	0.97
65	34	61.10	67.07	1.36	1.10
	27	66.70	67.07	1.08	1.01
	18	72.40	67.07	0.72	0.93
66	35	59.10	62.11	1.40	1.05
	26	62.70	62.11	1.04	0.99
	17	64.60	62.11	0.68	0.96
67	32	67.80	71.84	1.28	1.06
	26	73.00	71.84	1.04	0.98
	17	75.90	71.84	0.68	0.95
68	33	58.50	59.90	1.32	1.02
	27	60.20	59.90	1.08	0.99
	17	61.10	59.90	0.68	0.98
69	31	66.20	68.02	1.24	1.03
	25	68.40	68.02	1.00	0.99
	17	70.70	68.02	0.68	0.96
70	34	60.40	63.00	1.36	1.04
	27	62.40	63.00	1.08	1.01
	17	66.20	63.00	0.68	0.95

Linear Regression Input Data for Addis Ababa					
Sr. No.	N	ω	LL	N/25	LL/ω
71	35	53.70	59.82	1.40	1.11
	27	58.90	59.82	1.08	1.02
	18	65.40	59.82	0.72	0.91
72	30	62.90	65.07	1.20	1.03
	26	65.40	65.07	1.04	0.99
	15	69.50	65.07	0.60	0.94
73	34	50.70	53.01	1.36	1.05
	24	53.90	53.01	0.96	0.98
	16	55.60	53.01	0.64	0.95
74	35	66.20	70.64	1.40	1.07
	24	71.50	70.64	0.96	0.99
	18	74.60	70.64	0.72	0.95
75	33	42.40	43.58	1.32	1.03
	26	43.70	43.58	1.04	1.00
	19	44.50	43.58	0.76	0.98
76	31	47.80	48.85	1.24	1.02
	25	48.90	48.85	1.00	1.00
	18	50.40	48.85	0.72	0.97
77	33	42.80	45.56	1.32	1.06
	27	44.90	45.56	1.08	1.01
	20	47.70	45.56	0.80	0.96
78	33	51.70	54.01	1.32	1.04
	25	54.30	54.01	1.00	0.99
	19	56.00	54.01	0.76	0.96
79	32	40.60	42.11	1.28	1.04
	25	42.50	42.11	1.00	0.99
	20	43.10	42.11	0.80	0.98
80	31	58.20	59.92	1.24	1.03
	27	59.70	59.92	1.08	1.00
	18	62.10	59.92	0.72	0.96

Linear Regression Input Data for Addis Ababa					
Sr. No.	**N**	**ω**	**LL**	**N/25**	**LL/ω**
81	31	53.50	54.78	1.24	1.02
	24	55.20	54.78	0.96	0.99
	18	56.50	54.78	0.72	0.97
82	33	55.20	57.04	1.32	1.03
	25	56.90	57.04	1.00	1.00
	16	60.20	57.04	0.64	0.95
83	28	70.20	72.06	1.12	1.03
	23	73.80	72.06	0.92	0.98
	17	76.50	72.06	0.68	0.94
84	31	55.50	61.91	1.24	1.12
	26	62.70	61.91	1.04	0.99
	19	68.00	61.91	0.76	0.91
85	35	57.02	60.43	1.40	1.06
	28	59.04	60.43	1.12	1.02
	22	62.05	60.43	0.88	0.97
	17	64.30	60.43	0.68	0.94
86	35	52.44	53.99	1.40	1.03
	27	53.63	53.99	1.08	1.01
	21	54.96	53.99	0.84	0.98
	16	55.86	53.99	0.64	0.97
87	35	50.28	53.05	1.40	1.06
	27	52.77	53.05	1.08	1.01
	21	54.50	53.05	0.84	0.97
	16	56.22	53.05	0.64	0.94
88	36	52.05	53.92	1.44	1.04
	27	53.72	53.92	1.08	1.00
	21	54.83	53.92	0.84	0.98
	16	55.95	53.92	0.64	0.96
89	35	49.90	52.69	1.40	1.06
	28	52.00	52.69	1.12	1.01
	22	54.03	52.69	0.88	0.98
	15	56.22	52.69	0.60	0.94
90	35	58.83	60.51	1.40	1.03
	28	60.34	60.51	1.12	1.00
	21	61.52	60.51	0.84	0.98
	16	62.03	60.51	0.64	0.98

Linear Regression Input Data for Addis Ababa					
Sr. No.	**N**	**ω**	**LL**	**N/25**	**LL/ω**
91	35	54.87	57.50	1.40	1.05
	27	56.85	57.50	1.08	1.01
	22	58.62	57.50	0.88	0.98
	16	60.92	57.50	0.64	0.94
92	35	58.83	60.52	1.40	1.03
	28	60.50	60.52	1.12	1.00
	21	61.40	60.52	0.84	0.99
	16	62.00	60.52	0.64	0.98
93	35	54.87	57.48	1.40	1.05
	27	56.85	57.48	1.08	1.01
	22	58.62	57.48	0.88	0.98
	16	60.92	57.48	0.64	0.94
94	37	64.01	67.19	1.48	1.05
	27	66.61	67.19	1.08	1.01
	22	68.67	67.19	0.88	0.98
	16	70.25	67.19	0.64	0.96
95	36	48.61	51.36	1.44	1.06
	28	50.23	51.36	1.12	1.02
	23	52.34	51.36	0.92	0.98
	17	54.20	51.36	0.68	0.95
96	36	56.13	59.03	1.44	1.05
	28	58.50	59.03	1.12	1.01
	22	60.19	59.03	0.88	0.98
	15	62.43	59.03	0.60	0.95
97	36	52.36	55.12	1.44	1.05
	27	54.64	55.12	1.08	1.01
	22	56.24	55.12	0.88	0.98
	15	58.64	55.12	0.60	0.94
98	34	53.73	56.54	1.36	1.05
	28	55.13	56.54	1.12	1.03
	23	57.90	56.54	0.92	0.98
	17	59.84	56.54	0.68	0.94
99	36	52.73	55.28	1.44	1.05
	27	54.00	55.28	1.08	1.02
	22	56.69	55.28	0.88	0.98
	15	59.24	55.28	0.60	0.93
100	35	50.28	53.49	1.40	1.06
	28	52.56	53.49	1.12	1.02
	23	54.43	53.49	0.92	0.98
	17	56.85	53.49	0.68	0.94

Linear Regression Input Data for Addis Ababa					
Sr. No.	N	ω	LL	N/25	LL/ω
101	34	47.03	50.22	1.36	1.07
	27	49.31	50.22	1.08	1.02
	22	51.68	50.22	0.88	0.97
	16	54.92	50.22	0.64	0.91
102	35	50.25	54.48	1.40	1.08
	27	53.84	54.48	1.08	1.01
	21	56.58	54.48	0.84	0.96
	15	60.44	54.48	0.60	0.90
103	36	50.24	53.49	1.44	1.06
	28	52.82	53.49	1.12	1.01
	22	54.81	53.49	0.88	0.98
	16	56.88	53.49	0.64	0.94
104	36	46.03	49.42	1.44	1.07
	28	48.18	49.42	1.12	1.03
	22	50.86	49.42	0.88	0.97
	16	53.51	49.42	0.64	0.92
105	34	50.16	52.78	1.36	1.05
	27	52.11	52.78	1.08	1.01
	22	54.20	52.78	0.88	0.97
	16	56.17	52.78	0.64	0.94
106	34	52.65	55.32	1.36	1.05
	27	54.59	55.32	1.08	1.01
	22	56.84	55.32	0.88	0.97
	16	58.77	55.32	0.64	0.94
107	34	50.16	52.78	1.36	1.05
	27	52.11	52.78	1.08	1.01
	22	54.20	52.78	0.88	0.97
	16	56.17	52.78	0.64	0.94
108	34	48.25	49.61	1.36	1.03
	27	49.10	49.61	1.08	1.01
	22	50.16	49.61	0.88	0.99
	16	51.84	49.61	0.64	0.96
109	34	32.49	36.18	1.36	1.11
	27	37.21	36.18	1.08	0.97
	22	37.89	36.18	0.88	0.95
	16	38.51	36.18	0.64	0.94

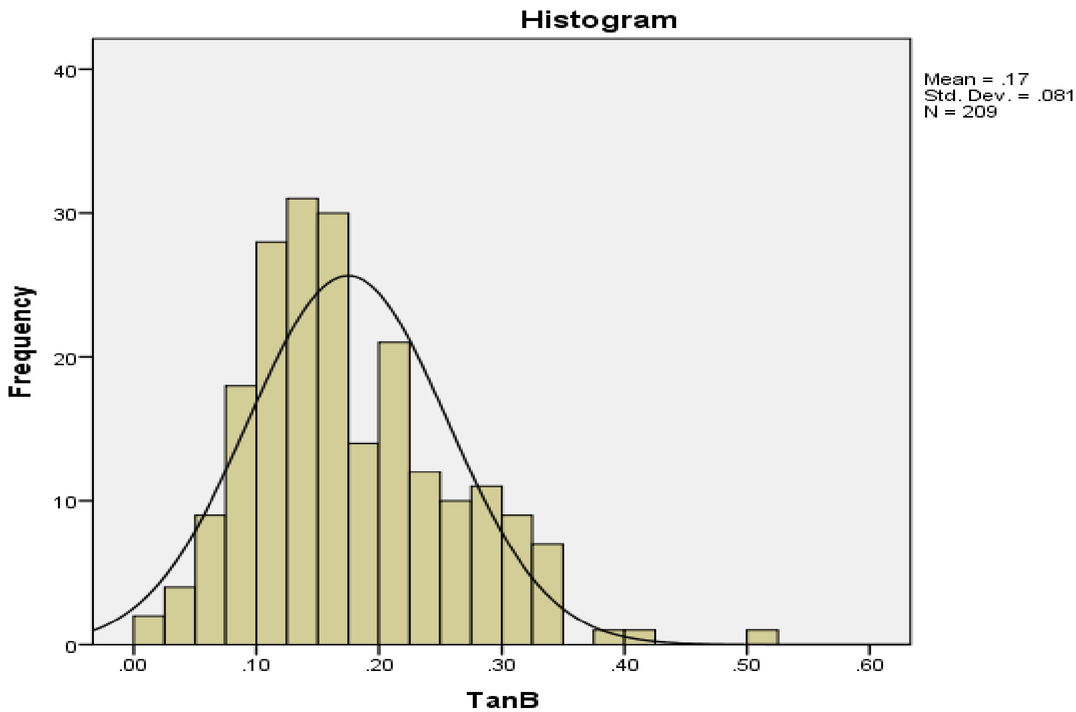
Input Data for Average method of Ethiopia											
Sr. No.	tan β	Sr. No.	tan β	Sr. No.	tan β	Sr. No.	tan β	Sr. No.	tan β	Sr. No.	tan β
1	0.02	36	0.23	71	0.29	106	0.19	141	0.12	176	0.25
2	0.09	37	0.07	72	0.14	107	0.15	142	0.21	177	0.12
3	0.07	38	0.08	73	0.12	108	0.1	143	0.32	178	0.15
4	0.16	39	0.13	74	0.18	109	0.21	144	0.29	179	0.03
5	0.08	40	0.13	75	0.09	110	0.32	145	0.23	180	0.15
6	0.01	41	0.16	76	0.1	111	0.33	146	0.26	181	0.1
7	0.17	42	0.12	77	0.22	112	0.33	147	0.28	182	0.03
8	0.15	43	0.27	78	0.15	113	0.17	148	0.21	183	0.05
9	0.15	44	0.18	79	0.13	114	0.28	149	0.29	184	0.12
10	0.08	45	0.2	80	0.11	115	0.31	150	0.18	185	0.17
11	0.12	46	0.07	81	0.1	116	0.33	151	0.31	186	0.04
12	0.14	47	0.09	82	0.12	117	0.16	152	0.19	187	0.13
13	0.12	48	0.04	83	0.17	118	0.2	153	0.18	188	0.14
14	0.09	49	0.13	84	0.4	119	0.1	154	0.23	189	0.17
15	0.19	50	0.15	85	0.17	120	0.15	155	0.24	190	0.08
16	0.2	51	0.15	86	0.08	121	0.16	156	0.21	191	0.06
17	0.2	52	0.17	87	0.14	122	0.29	157	0.33	192	0.09
18	0.13	53	0.12	88	0.08	123	0.18	158	0.23	193	0.15
19	0.18	54	0.16	89	0.14	124	0.26	159	0.26	194	0.21
20	0.16	55	0.07	90	0.09	125	0.1	160	0.21	195	0.11
21	0.12	56	0.13	91	0.14	126	0.23	161	0.21	196	0.21
22	0.12	57	0.21	92	0.07	127	0.13	162	0.18	197	0.24
23	0.12	58	0.39	93	0.13	128	0.3	163	0.3	198	0.18
24	0.12	59	0.08	94	0.11	129	0.19	164	0.12	199	0.07
25	0.13	60	0.09	95	0.15	130	0.2	165	0.22	200	0.27
26	0.17	61	0.08	96	0.12	131	0.27	166	0.13	201	0.21
27	0.2	62	0.11	97	0.13	132	0.09	167	0.33	202	0.35
28	0.12	63	0.08	98	0.16	133	0.15	168	0.23	203	0.25
29	0.23	64	0.13	99	0.14	134	0.28	169	0.29	204	0.21
30	0.14	65	0.26	100	0.17	135	0.28	170	0.27	205	0.14
31	0.14	66	0.12	101	0.21	136	0.33	171	0.3	206	0.17
32	0.13	67	0.17	102	0.22	137	0.29	172	0.17	207	0.52
33	0.12	68	0.06	103	0.15	138	0.24	173	0.3	208	0.23
34	0.13	69	0.11	104	0.19	139	0.17	174	0.32	209	0.28
35	0.16	70	0.13	105	0.15	140	0.2	175	0.26	**Avg.**	**0.174**

Statistics of Ethiopia

Tan β

N	Valid	209
	Missing	0
Mean		.1746
Std. Error of Mean		.00562
Median		.1600
Mode		.12
Std. Deviation		.08130
Variance		.007
Minimum		.01
Maximum		.52

The distribution Curve of tanβ value of Ethiopia



Values

Mean = 0.17

Standard deviation =0.081

N= 209

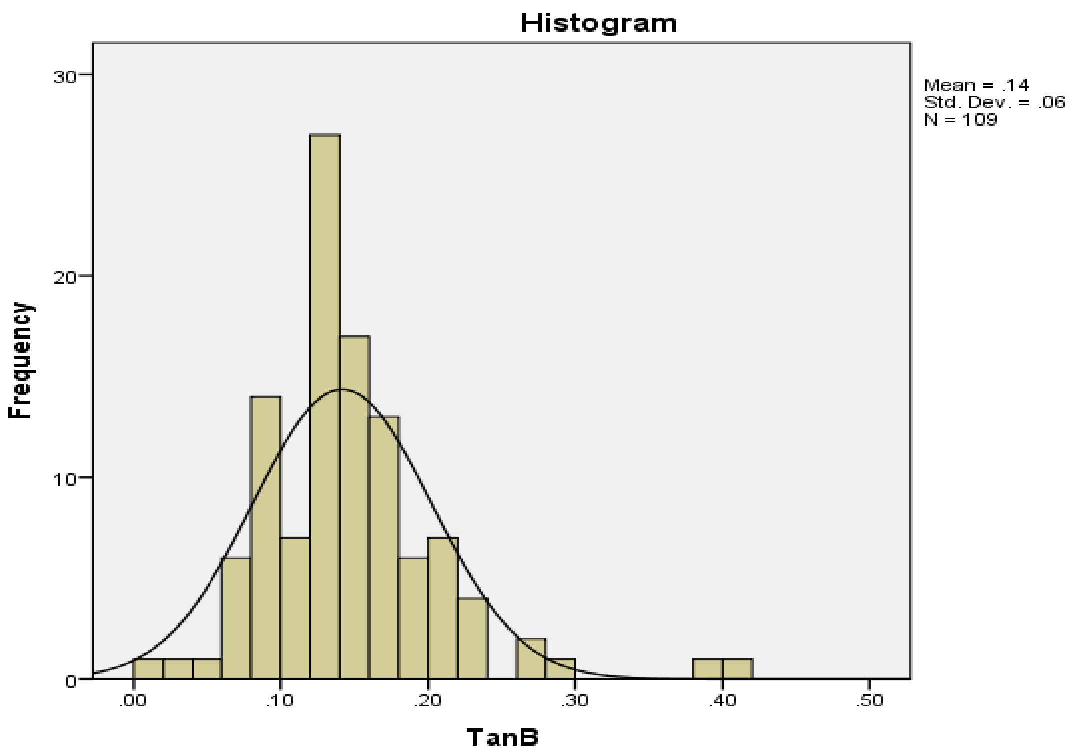
Input Data for Mean Value method of Addis Ababa							
Sr. No.	tan β	Sr. No.	tan β	Sr. No.	tan β	Sr. No.	tan β
1	0.02	31	0.14	61	0.08	91	0.14
2	0.09	32	0.13	62	0.11	92	0.07
3	0.07	33	0.12	63	0.08	93	0.13
4	0.16	34	0.13	64	0.13	94	0.11
5	0.08	35	0.16	65	0.26	95	0.15
6	0.01	36	0.23	66	0.12	96	0.12
7	0.17	37	0.07	67	0.17	97	0.13
8	0.15	38	0.08	68	0.06	98	0.16
9	0.15	39	0.13	69	0.11	99	0.14
10	0.08	40	0.13	70	0.13	100	0.17
11	0.12	41	0.16	71	0.29	101	0.21
12	0.14	42	0.12	72	0.14	102	0.22
13	0.12	43	0.27	73	0.12	103	0.15
14	0.09	44	0.18	74	0.18	104	0.19
15	0.19	45	0.20	75	0.09	105	0.15
16	0.20	46	0.07	76	0.10	106	0.19
17	0.20	47	0.09	77	0.22	107	0.15
18	0.13	48	0.04	78	0.15	108	0.10
19	0.18	49	0.13	79	0.13	109	0.21
20	0.16	50	0.15	80	0.11	**Avg.**	**0.14**
21	0.12	51	0.15	81	0.10		
22	0.12	52	0.17	82	0.12		
23	0.12	53	0.12	83	0.17		
24	0.12	54	0.16	84	0.40		
25	0.13	55	0.07	85	0.17		
26	0.17	56	0.13	86	0.08		
27	0.20	57	0.21	87	0.14		
28	0.12	58	0.39	88	0.08		
29	0.23	59	0.08	89	0.14		
30	0.14	60	0.09	90	0.09		

Statistics of Addis Ababa

Tan β

N	Valid	109
	Missing	0
Mean		.1417
Std. Error of Mean		.00579
Median		.1300
Mode		.12
Std. Deviation		.06047
Variance		.004
Minimum		.01
Maximum		.40

The distribution Curve of tanβ value of Addis Ababa



Values

Mean = 0.14

Standard Deviation =0.06

N= 109