JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVIROMENTAL ENGINEERING.

DEPARTMENT OF CIVIL ENGINEERING.

Systematically summarizing, storing and displaying of Geotechnical data by GIS software, case of Central Ethiopia.

A research submitted to the School of Graduate Studies of Jimma University, for partial fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Geotechnical Engineering)

By Abebe Edosa

June 2021

Jimma, Ethiopia.

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By Abebe Edosa

Advisor: Prof. Anand M. Hulagabali

Co-Advisor: Jemal Jibril (PhD)

June 2021

Jimma, Ethiopia.

Declaration

This thesis is my own work and I declare that this thesis is not done in any other universities.

Mr. Abebe Edosa ____________________ ______________________

Candidate Signature Date

As master's research advisor, I hereby certify that I have read and evaluated this thesis prepared under my guidance by Mr. Abebe Edosa.

Prof. Anand M. Hulagabali ____________________ 18/09/2020

Main Advisor Signature Date

Dr. Eng. Jemal Jibril ____________________ ______________________

Co- Advisor Signature Date

Mr. Worku Firomsa___ ______________________ ______________________

Internal Examiner Signature Date

Dr.Eng. Fndalu Tadele ____________________ ____________________

External Examiner Signature Date

Mr. Hashim Ware ______________________ ______________________

Chairperson Signature Date

ACKNOWLEDGEMENT

Before everything, I would like to thank my almighty God For helping me to do this research and helping me to reach this stage of my study.

Next, I would like to thank my Adviser **Prof. Anand. M. Hulagabali** And my Co-adviser **Dr. Jemal Jibril** who have invested their golden time to give me the directions and how to overcome this research proposal. Also I want to say thanks to all my instructors those who had shared me their good knowledge when I am on study and also thanks to my class mates and friends of mine.

Finally, I want to say thanks to my families and all who have played any role for completion of this thesis.

ABSTRACT

Engineering properties of soils are all laboratory and field tests of soil property that are used as an input for designs. Engineering properties of soils are very important and necessary in any construction industries. In addition, some constructions are done with limited soil property tests. However, this is not a good practice since lacking geotechnical information may cause structural failures and collapses. So, it is highly recommended to do some tests on engineering properties of soils for our anticipated projects. In addition to this, these geotechnical data have to be managed carefully and made easily available to avoid costs repeating these tests several times for a particular area. So for better and safe design of foundations, it is good to access geotechnical data easily.

Therefore, in this particular research, the author has tried to organize, store and display some important methods of geotechnical data by using GIS (Geographic Information System) software in central parts of Ethiopia particularly in selected cities found within 120 km diameters from the capital city of Ethiopia, Addis Ababa. GIS software is a relevant tool, which is used for this kind of data management. Since the application shows both raster and vector data, the designer can see exact place or point of test pits to choose which test pit's output is relevant for the nearest project site. Hence, in this research the author has attempted to explore and manage the data of previously done engineering properties of soils found in central parts of Ethiopia by using ArcGIS software. As a future work, it is recommended to do some more tests in order to have a reliable and more detail database in the central region of the country.

Key words: GIS, Geotechnical data, engineering properties of soil, raster data, vector data.

TABLE OF CONTENTS

Contents **Page**

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AASHTO……………… ..……American Association of Highway and Transportation Officials

USCS…………………………...Unified Soil Classification System

LL………………………………Liquid Limit

PL………………………………Plastic Limit

PI………………………………Plasticity Index

GIS…………………..................Geographic Information System

JIT……………………………..Jimma Institute of Technology

GPS……………………………Global Positioning System

TP……………………………..Test pits

CAD…………………………...Computer Aided Design.

UTM…………………………..Universe Transverse Mercator

UCS……………………………Unconfined Compressive Strength

OMC…………………………..Optimum Moisture Content

MDD…………………………...Maximum Dry Density

CBR……………………………Californian Bearing Ratio

FAO……………………………Food and Agricultural Organizations.

1. INTRODUCTION

1.1. Background

A geotechnical engineer determines and designs the type of foundation, earthwork, and/or pavement sub grades required for the intended man-made structures to be built. Foundations are designed and constructed for the structures of various sizes such as high-rise buildings, bridges, medium to large commercial buildings, and smaller structures where the soil conditions do not allow code-based design.[16].

Investigation of engineering properties of soil on the project site is prerequisite to the economical design of the substructure elements. It is also necessary to obtain sufficient information for feasibility and economic studies of the proposed project. Many residential apartments and public buildings need engineering properties of soil on the project site as well as geotechnical consults. Unless otherwise, these buildings are not safe for the public to live in or for other commercial purposes. [3].

Insufficient geotechnical data or soil investigation, faulty analysis of test results, or failure to proper results in clearly understandable manner may cause inappropriate design; delays on construction period schedules, uneconomical construction costs, and use of improper borrow materials, environmental impacts to the society around construction site, and also it may cause structural failure and collapse. Therefore, to be safe from the above mentioned problems geotechnical investigation (soil and rocks) is necessary to the site prepared for our project. [16]

In a country like Ethiopia which is developing at high growth rate and which needs many construction works in the future, geotechnical investigation on the engineering property of soil is very essential. Because these data are very important for civil engineers in preliminary design and in designing foundation, pavement, retaining structures for future construction projects in the country. [16]

Many researches were done and there are ongoing researches in most big cities of the country like Addis Ababa, Bahir Dar, Mekele, Hawassa, and etc. To mention some of the researches undertaken are: ‘Investigation into some of the engineering properties of red clay soils in Bahir Dar, ‘Investigation into some of the engineering properties of red clay soils in Addis Ababa’, ‘Investigation into engineering properties of Mekelle soils with emphasis on expansive soils’[16].

1.2. Statement of the problem

A statement of problem is the description of an issue currently existing, which needs to be addressed. It provides the context for the research study and generates the questions that the research aims to answer. The statement of the problem is the focal point of any research. A good problem statement is just one sentence (with several paragraphs of elaboration). Research problem is a situation that needs a solution and for which there are possible solutions. If a situation has no possible solutions then it makes little or no sense expending resources researching it.

It may be also described as the gap in knowledge that needs to be filled. Therefore, in this research the statement of problem is that, engineering properties of soil in this country is not managed and stored in safe way. So it is very difficult to access easily also it may be damaged simply because most of times these data are stored in hard copy. For this reason in case of damage data may be lost and redoing tests for the one project many times is cost and arises economic crises.

Generally, these are the statements of the problem that are encountered on this research. In addition, I have tried to solve these problems especially in central part of Ethiopia by using GIS (Arc map 10.3).

1.3. Research Questions

After completion of this Research, the researcher tries to answer the following research questions. In addition, these research questions are;

- ✓ How are engineering properties of soils in different cities assessed and summarized?
- ✓ How engineering properties of soils in some areas can systematically categorized for a better accessibility?
- ✓ How we can feed these summarized data to GIS?

1.4. Objectives of the research

1.4.1. General objective

The objective of this research is to categorize, store, and display Geotechnical data found in central parts of Ethiopia by using ArcGIS mapping.

1.4.2. Specific objective

Specific objectives of this research are listed as follows.

- ✓ To explore, collect and summarize engineering properties of soil done in central parts of Ethiopia.
- ✓ To systematically categorize engineering properties of soils from the target areas.
- ✓ To feed, store and display soil data on Arc map 10.3.

1.5. Scope of the study

The scope of this study is to summarize and store geotechnical data in GIS software and other researchers previously did these geotechnical data. Therefore, it covers some selected cities from central parts of Ethiopia

In this case these cities are:

- ✓ Addis Ababa
- ✓ Adama
- ✓ Ambo
- ✓ Burayu
- ✓ Debrebrhan and
- ✓ Mojo

In the above selected cities, samples have been taken from ten boreholes except Debrebrahn city. In case of Debrebran, samples have taken from twelve boreholes.

And the other thing is that, Nine engineering properties of soils are conducted and these properties are:

- ✓ Natural moisture content
- ✓ Specific gravity
- ✓ Atterberg limit tests
- ✓ Percent amount of particles
- ✓ Free swell test and
- ✓ Soil classification.
- ✓ Compaction tests (MDD & OMC)
- ✓ Unconfined Compressive strength of soils (UCS)
- ✓ Consolidation (Cv & k)

In general, the researcher used secondary data to store and display these geotechnical data on GIS and it covers the above-mentioned five cities from central part of Ethiopia.

1.6. Limitations of the study

Limitations of this study is that some of engineering properties of soils are not done and the researcher could not get full data. In addition, since lack of enough budget the researcher could not do these laboratory tests, so data that have been used in this particular research has taken from researches that are done by other researchers. So data can be used for preliminary design in case of data is needed quickly for design, and not for final design result.

1.7. Significance of the study

This research is helpful for access of some engineering properties of soil in central parts of Ethiopia and to manage these test results by using some GIS tools. Also this study will be input for different decisions on foundation designs.

In this country especially in Geotechnical fields test results are stored in hard copy and it is very difficult to easily access tested data. So this research will help to solve this problem of data management. And also since this thesis shows all information of test area including aerial photograph of the specific area. So any one can access exact point of test area as it is real and can see also infrastructures and terrains of this test point.

1.8. Structure of the study

This theses have six chapter which specifically covers the objective of the research. In this introduction chapter it covers some background of engineering properties of soil and also goes to statement of the problem. Then after some research questions are listed and general objective of the research is described and also specific objective of this research is listed according to answer the research questions listed. Then some literature had been reviewed in chapter two and chapter three discusses methodology of the research as well as explanation of research areas. After that chapter four explains procedure of the research. The next chapter is chapter five which gives us output of the study and then chapter six comes with conclusion and recommendation. Thus are all about this research structure and finally reference and Appendix finalizes this research structure.

2. LITERETURE REVIEW

2.1. General

From geotechnical, engineering perspective soil is non-cemented material and it may be organic or inorganic material. So soil may be formed by chemically or mechanically. [10]

A term soil is defined in soil engineering as an unconsolidated material, composed of soil material, produced from decomposition of rocks. The void space between the particles may contain water, air or both. [15]

In engineering, soils are considered to include all organic and inorganic earth materials occurring in the zone overlying the rock crust. They are usually non-homogeneous, porous material whose engineering behavior is greatly affected by changes in moisture content and density. The engineering definition of soil is quite different from the agronomist definition of the same. In geology soil has different connotations and simply be stated as a material found in the relatively thin surface zone. [16]

2.2. Soil formation and soil deposits

In geotechnical engineering soil is defined as unconsolidated material, composed of solid particles produced from disintegration of rocks. They are produced from through time by weathering of parent rock. This weathering may be mechanical weathering or it may be by chemical decomposition. So properties of some soils depend on the property of the rock that they are formed from. [12].

There are so many varieties that are encountered in engineering problems, ranging from hard, dense, large pieces of rock through to gravel, sand, silt, and clay to organic deposits of soft compressible peat. To compound the complexity, all of these materials may occur over a range of densities and water contents. At every site, there are many different types of soils, and the composition may vary over intervals of a little as a few inches [10].

It has long been appreciated that the engineering classification of soils is greatly facilitated by taking into account the soil-forming processes by which nature has created the various types of soil conditions. Similar combinations of soil-forming processes in different parts of the world have been found to lead to materials of similar index properties and similar engineering characteristics.

The main factors affecting the formations of soil are Parent materials i.e. Geology of the area, topography and drainage, climate and biological influences. [13]

2.2.1. Parent materials

The two main variables affecting parent materials of soils are: grain size and composition. Grain size is the main determinant of soil texture. Texture influences the soil structure, consistency, profile drainage, moisture retaining capacity and organic content. Soil composition is composed of mineral matter and organic matter and contains pore spaces filled with water or air and soluble nutrients. Organic matter serves as a binder for mineral particles, contributing to soil structure so soil composition is one of the aids to the formation of soil. [10]

2.2.2. Topography and Drainage

Topography has a major influence on drainage characteristics which in turn have major effect on soil mineralogy. Its control over soil properties is particularly strong in tropical environment reflecting the importance of lateral movement of water and soil materials [13].

Topography has a major influence on drainage characteristics which in turn is known to have major effect on soil mineralogy. Its control over soil properties is particularly strong in tropical environment reflecting the importance of lateral movement of water and soil materials [9].

2.2.3. Climate

Climate is the principal factor governing the rate and type of soil formation. The two important components of climate are the amount and distribution of precipitation, and temperature. The temperature variable is adequately represented by mean annual temperature, which doesn’t differ greatly from the nearly constant temperature in the lower part of the regolith. The two main rain fall parameters most widely available are the mean annual total and the length of the dry season. [16]

The amount and distribution of precipitation affects the availability of moisture and the relative humidity of the soil atmosphere; it influences the concentration or chemical activities of solutions in the system [10].

2.2.4. Biological influence

Soil formation is also impacted by biological influence such as plants, animals, bacteria and fungi. Plants help recycle nutrients by decaying as well as by taking up nutrients. Plants also put down roots into the soil, which helps anchor the soil in place and prevent erosion. [16]

2.3. Soil classification

A soil classification is an arrangement of different soils into various groups or subgroups to provide a common language to express briefly the general usage characteristics without detailed descriptions. At the present time, two major soil classification systems that take in to consideration both particle-size distribution and Atterberg limits are available for general engineering use. They are the AASHTO (American Association of State Highway and Transport Official) classification system and USCS (Unified Soil Classification System). [16]

2.4. General types of soil

According to their Grain Size, soil particles are classified as cobbles, gravel, sand, silt and clay. Grains having diameters in the range of 4.75 to 76.2 mm are called gravel. If the grains are visible to the naked eye, but are less than about 4.75 mm in size the soil is described as sand. The lower limit of visibility of grains for the naked eyes is about 0.075 mm. Soil grains ranging from 0.075 to 0.002 mm are termed as silt and those that are finer than 0.002 mm as clay. [10]

2.5. Engineering properties of soil

- ✓ Natural moisture content
- ✓ Percent amount of particles
- ✓ Specific gravity
- ✓ Free swell
- ✓ Compressive strength

And some laboratory test results such as;

- ✓ Simple shear test
- ✓ Consolidation test
- ✓ Compaction test and etc.

Among these laboratory and field tests, I will try to conduct some of tests, then manage and store it in GIS. [16]

2.6. GIS based data management

Depending on these test results that have been done by the above researchers this research will explore test results and show how to manage geotechnical data by using GIS (Arc map 10.3). This data management will include some cities found in central part of this country. [16]

GIS is different from other Information Systems insofar as it contains geographically referenced data consisting of spatial data component which defines location, and attribute data component which defines characteristics. GIS has shown a very important role in various aspects of geotechnical engineering including preliminary site investigations, identification of potential project barriers (like mines etc.), interpolation for obtaining data at inaccessible locations, data visualization, data processing as well as preparation of post processing graphs and charts. Hence GIS finds its applications at all the stages of a geotechnical engineering project. Geographical Information System is a very effective tool for capturing, displaying and analyzing geographically referenced data. GIS is different from other Information Systems insofar as it contains geographically referenced data consisting of spatial data component which defines location, and attribute data component which defines characteristics. GIS has shown a very important role in various aspects of geotechnical engineering including preliminary site investigations, identification of potential project barriers (like mines etc.), interpolation for obtaining data at inaccessible locations, data visualization, data processing as well as preparation of post processing graphs and charts. Hence GIS finds its applications at all the stages of a geotechnical engineering project. [22]

In geotechnical practice, GIS can be used in at least four ways: data integration, data visualization, analysis, planning and summarizing site activities. And data presentation in geotechnical practice, the conventional approach to data integration for working site model creation can be an arduous task. Existing data sources are found in a variety of hard copy, electronic, and paper formats such as maps, plans, reports, books, aerial photos, etc. Integrating these data together with photos, notes, borings, and other site-specific data can require a significant effort. Less time may be spent on data analysis and acquisition than on data integration. Also, making copies of the work may take as much time as the initial production and yield unprofessional looking or illegible results. Using GIS as a tool can greatly improve the efficiency and effectiveness of these efforts [6]

GIS provides tools for integrating these multiple data types such as raster format data (e.g. photos and scanned maps) and vector format data (e.g. Computer-Aided Drafting (CAD) files, northing and easting point files, drainage lines, etc.). This data may consist of readily available existing information such as soil surveys and topographic maps, or project specific information such as proposed centerlines, project extents, survey points, aerial photos, and site investigation results. Many federal, state, and local agencies provide wide-ranging types of GIS data for download on the Internet. [5]

When integrating data from various sources, two important considerations are data limitations and data coordinate systems. Each data set has inherent limitations. The source of the data must be considered; positional accuracy may vary from tenths to hundreds of meters, and the applicability of the data to their intended use also needs to be considered. The site model is only as accurate as its components. In some cases, the data accuracy may be inadequate for detailed design, however it may be more than adequate for preliminary investigations. [4]

For disparate data sets to be integrated, each must be converted to the same base coordinate system. Readily available data sets may utilize a coordinate system such as the Universal Transverse Mercator (UTM) with varying datum. Project specific data sets may use a standard coordinate system (such as State Plane) or a project specific system. Most GIS programs contain routines for performing coordinate transformations relatively simply to enable integration of data sets having different coordinate systems [8]

This paper describes the use of GIS in processing and presenting geotechnical data into formats that are useful to engineers, planners and land development professionals. [5]

Geotechnical data is necessary for site design and usually acquired by site investigation and as well as laboratory test results. All test results give information on types of soil and activity or strengths of soil on the specific test pits. The information is very important for safe and economic design of foundations and other infrastructures. The valuable information is also often left scattered, in its original report and, in the respective project offices after completion of the projects. [5]

The reports provide very useful data for overall development planning of a district, state or even region. It is because the information can be used as preliminary indicative geotechnical requirements and costs. It is also important in deciding suitable land use zoning. [3]

A system that could provide means to efficiently stored, analyzed, updated data, and then could produce other forms of information such as maps and tables is something that could expedite decision-making and design works. These kinds of systems will be useful to engineers and planners in land development industry. GIS is known to be able to provide these facilities as it can store information in a multi layered database. Moreover, it can be used to process information in spatial data. Thus, GIS is used in a lot of engineering applications such as in geotechnical, environment, human resources, construction, transportation, and etc. [9]

In geotechnical engineering, GIS is used in determine the location of boreholes as it helps engineers or planners to do new investigation especially for new site locations. Meanwhile, for environmental engineering, many locations of waste site are selected using this software, as it is difficult to retrieve as housing areas, production facilities and highways cover a lot of area. The next application is in construction. GIS is used for preliminary stage as to determine the site layout and the location of temporary facilities. The decision making to select the site layout and location of temporary facilities become faster with the application of Global Positioning System (GPS). GIS become popular in transportation engineering. For example, GIS is used in traffic planning to display the densities of origin/ destination, noise complaints, trip generation, routes between destinations and transportation accessibility [5].

This paper describes the use of GIS for storing, analyzing geotechnical data and presenting it in a format that will be useful to planners, architects and engineers that will help them to make better decisions and to carry out safer and economical designs [1].

2.7. General concept of data management and GIS

Geographic Information System is a very important tool for capturing, displaying and analyzing geographically referenced data. GIS have played very important role in the field of geotechnical engineering including preliminary site investigation, identification of potential project, interpolation for obtaining data on inaccessible locations, data visualization and many others. [5]

A data management system is all about efficiency, timely reports and summaries and also ease of data access and usability. These data may includes

- ✓ Survey data
- ✓ Geology data (regional, site-specific)
- ✓ Historical borings
- ✓ Maintenance records (settlement and repairs)
- ✓ Laboratory test results
- ✓ Field test results

All the above data have to be carefully handled and stored to get at a time it is needed. So to sore all these data the best tool is GIS. [4]

GIS is a type of database with specialized fields to handle spatial and data. It can handle both location and attributes of the data. This means all test pits location can be stored including coordinates and aerial photos of true locations. All existing structures as well as natural and man-made features are seen on this aerial photo. So it is very easy to access data and also to determine borehole locations. [5]

2.8. Geotechnical data management by GIS software

Geotechnical data management by GIS software is a system that gives means of data management by efficiently stored, analyzed, and updated data, and then could produce other forms of information such as maps and tables is something that could expedite decision making and design works. These kinds of systems are used for engineers and cadastral workers. GIS is known to be able to provide these facilities as it can store information in a multilayered database. Moreover, it can be used to process information in spatial data. Thus, GIS is used in a lot of engineering applications such as in geotechnical, environment, human resources, construction, transportation, and etc. [4]

In geotechnical engineering, GIS is used to determine position of test pits as it helps engineers or planners to do new investigation especially for new site locations. Meanwhile, for environmental engineering, many locations of waste site are selected using this software, as it is really difficult to retrieve as housing areas, production facilities and highways cover a lot of area. The next application is in construction. GIS is used for preliminary stage as to determine the site layout and also the location of temporary facilities. [4]

Geotechnical information acquired from site and laboratory tests are vital for a safe and economical design of building and infrastructure works especially in land development projects. This paper describes the use of GIS in processing and presenting geotechnical data into formats that are useful to engineers, planners and land development professionals. [3]

Geotechnical data for site design and development is usually acquired by site investigation works utilizing site and lab tests. The site and lab tests produce information especially on the type and strength of soils. The information is vital in the economic and safe design of infrastructure and buildings. The valuable information is also often left scattered, in its original report and, in the respective project offices after completion of the projects. [2]

The reports provide very useful data for overall development planning of a district, state or even region. It is because the information can be used as preliminary indicative geotechnical requirements and costs. It is also important in deciding suitable land use zoning. [1]

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This paper describes the use of GIS for storing, analyzing geotechnical data and presenting it in a format that will be useful to planners, architects and engineers that will help them to make better decisions and to carry out safer and economical designs. [5]

2.8.1. Geotechnical data visualization by GIS

After data has been integrated into a working site model, the model can be used to visualize site data and analyze the site. This model is continually refined as more information is gathered and integrated into the existing model. One of the primary benefits of using GIS in this effort is its flexibility. Data layers can be combined and turned on and off as needed. Data can be symbolized to graphically represent relationships and queried to filter out extraneous information. Spatial queries can be performed to identify the relationships between features and help to determine engineering conclusions. For example, buffers of varying distances around features can be created to identify other features within critical proximity (e.g. drinking water wells within a specified distance from a leaking underground storage tank) or create an exclusion zone (e.g. not advancing soil borings within 8 meters of a sensitive wetland). [5]

GIS can be used to identify project constraints and potential barriers to successful project completion early in the design process. Early identification of these barriers can avoid costly and time-consuming changes after significant site design has been completed. Depending on the data sets, some potential geotechnical issues that can be identified include weak and/or compressible soils (e.g. from soil surveys); potentially unstable slopes (e.g. from topographic maps); distance to and type of borrow sources (e.g. from road networks and soil surveys); geologic hazards (e.g. from aerial photos, geologic and topographic maps, soil surveys); environmental hazards (e.g. from underground storage tank location maps); etc. [2]

2.8.2. Planning and summarizing site activities.

After identifying in the office potential problem areas or areas needing further study, GIS can be used for both planning site activities and to integrate data collected during these activities into the site model, thus further refining it. In the GIS site model, boring and test pit locations can be planned, field reconnaissance locations noted, and maps, layouts, and figures can be created for use by field personnel. Global Positioning System (GPS) coordinates and/or project specific coordinates for investigation locations can be exported to guide surveyors and field staff in locating features and laying out investigation programs. [5]

During field work the locations of features can be captured using GPS, swing ties, offset distances from known features, etc., which can then be imported to GIS for integration into the site model. Digital photos taken during field activities can be linked to map features. Descriptive database tables can be created and linked to boring location maps to provide searchable features or scanned boring logs can be linked for retrieval through GIS. [5]

2.8.3. Data presentation

Another benefit of using GIS is data presentation. Layouts can be created for use in reports, papers, posters, and presentations in varying page sizes and formats. Labels, symbols, scale bars, north arrows, and text can be added to maps to provide clarity and improve information transfer. This capability provides an excellent communication tool between office and field staff, consultants and their clients, field crews and utility locators, etc. Professional looking figures can be created for reports that are editable and reproducible. In the present study some of the case studies ranging from soil survey planning to soil management, and furthermore, hydrologic response unit generation using GIS have been illustrated. [1]

2.9. Review of previous literature

There are so many researches have been done in this country on the title of engineering properties of soil.

Investigation of soils is very important in providing necessary data or information that can be used in designing civil engineering structures. Many investigators have studied on soils of Ethiopia.

Morin and Perry (1971) studied the origin and mineralogical composition of Ethiopian red clay soils. According to their study Ethiopian red clay soils are principally residual, derived from the weathering of volcanic rocks. The parent rock for black and red clays in Ethiopia is mainly olivine basalt, basalt and trachyte.

Ethiopian red clay soils have developed where rain fall is plentiful and drainage is good, and contain Kaolinite and Halloysite as the principal clay minerals, but Montmorillonite is also frequently present in significant amounts. The red color of the Ethiopian soils indicates the presence of iron.

Hailemariam (1992) has studied about investigation into shear strength characteristics of red clay soils of Addis Ababa. Based on experimental results of index property test soil under investigation are not expansive and no significant variations in the investigated depths as well as in different pits were found. The comparison of Addis Ababa red clay soil and lateritic soils of West Africa shows that the red clay soils investigated are not lateritic.

Dagnachew (2011) has studied engineering properties of soil in Adama city and have been concluded and discussed some results he had got in his research. And also Dagnachew had recommended some engineering properties to be done by other researchers in his research paper.

So depending on test results done above in different parts the country, Author is going to show how to manage and display geotechnical data by using GIS software.

In this case, after completion of getting some engineering properties of soil in this city, Author will use these test data to manage and store test result on GIS (Arc map 10.3) software and report it to JiT.

3. STUDY AREA AND MATERIALS USED

3.1. Study Area

Study area of this research is some important cities of this country especially central part of Ethiopia including Addis Ababa. So this research is done to manage and store some engineering properties of soil found in the following cities by using GIS (Arc map 10.3). These cities are selected randomly by using a buffer of 120km diameter from Addis Ababa.

In this case the following cities are selected to be done depending on availablity of data as well as idustry areas that are frequently data is needed for some construction industries.

So these cities are:

- ✓ **Addis Ababa**
- ✓ **Adama**
- ✓ **Burayu**
- ✓ **Mojo**
- ✓ **Ambo**
- ✓ **Debre Brhan**

Figure below shows some areas of this study area.

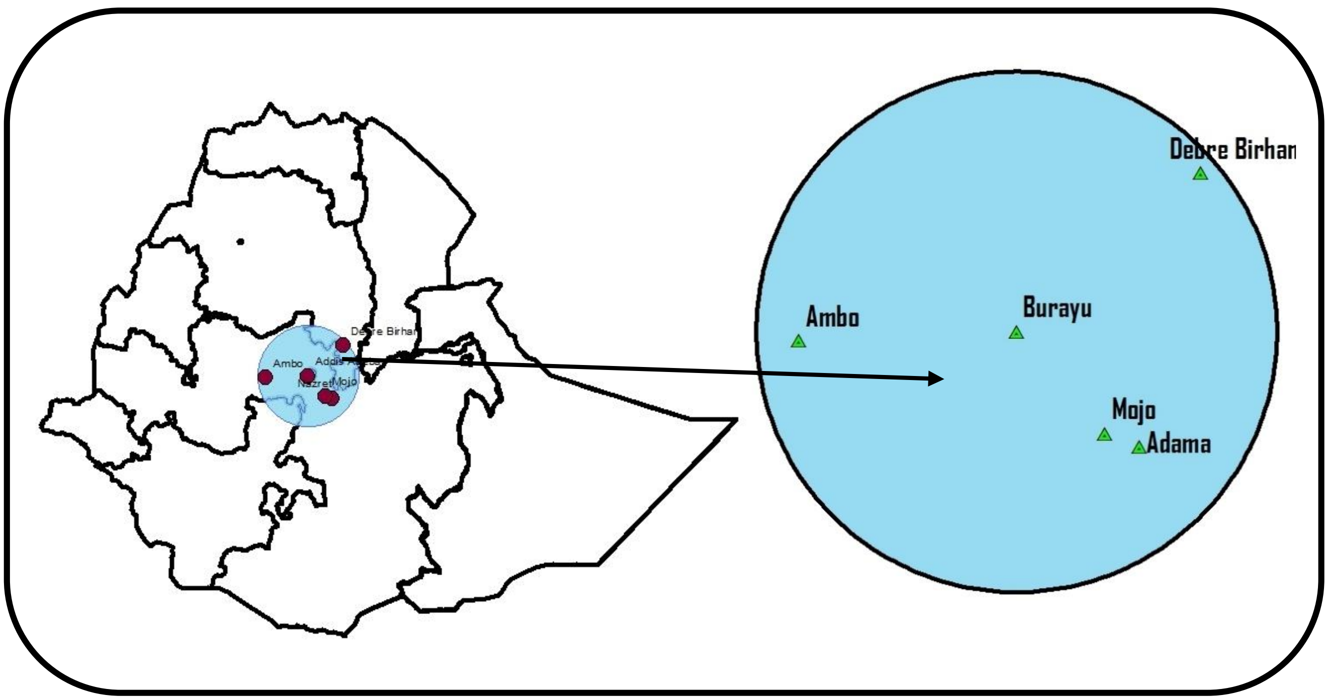

Figure 3-1: Selected cities from Central part of Ethiopia.

3.2. Summarizing and arranging of data

All data that have been summarized are collected and listed in a table to simplify while we add data to GIS. Therefore, these data are in a list of table as follow. Then after collecting and summarizing all these data. All data had inserted to GIS and anybody can simply access and display data for any construction purpose and design purposes.

3.2.1. Some of engineering properties of soil in Addis Ababa

Addis Ababa is capital of Ethiopia and located in central areas of the country. In addition, some of engineering properties of soil that have been done by other researchers are summarized in the following table.

One of Addis Ababa university student who is called Yared Leliso in 2013 does these properties. And his research area covers western and central part of Addis Ababa. [10]

Table 3-1: Engineering properties of soil in Addis Ababa city (According to thesis paper of Yared Leliso)

Engineering Properties of Soils and their test results										
			Atterber limit test(%)			Soil Classification		Compaction test		
Test Pits		Collected sample sites	LL	PL	PI	USCS	AASHTO	MDD	OMC	CBR
TP1	3m	Megenagna to Lamberet road project	52.63	31.9	20.75	ML	A-7-5 (14)	1.56	20.6	6.83
TP2	3m	Winget to Yohannis road project	59.6	33.2	26.5	MH	A-7-5 (20)	1.59	23.2	6.16
TP3	3m	Total Addisu gebeya road project	60.6	34.6	26.0	CH	A-7-6 (31)	1.54	22	6
TP4	3m	Lideta Condominium Building & road construction project	57.4	29.6	27.9	MH	A-7-5 (19)	1.49	25.9	5.33
TP5	3m	Winget to Addisu gebeya ring road project	50	28	22	CL	A-7-6 (21)	1.6	23.4	6.8
TP6	3m	Kolfe area construction site	62.86	36.0	26.9	MH	A-7-5 (23)	1.5	28.4	4.21

3.2.2. Some of engineering properties of soil in Adma city.

Adama is located in eastern Showa of Oromia regional state. It is one of the most developed city and most populated cities in Oromia. It is located at 8º33'35''N – 8º3'46'' N latitude and 39º11'57'' E – 39º21'15'' E longitude. It is about 100 kilometers away from Addis Ababa in southeast direction. Adama has a total area of about 14,000 hectares, which has been subdivided into 14 kebeles and two urban kebeles (least administrative structure) administrations.

Test results that have been done by one of Addis Ababa University student who is called Dagnachew Debebe is as follows. [8]

Table 3-2: Engineering properties of Adama City (From Thesis paper of Dagnachew Debebe)

Engineering Properties of Soils and their test results																		
				Atterber limit test(%)			Percent ammount of particle					Soil Classification		Compaction tes			1D Consolidation	
Test Pits		Natural MC	Specific Gravity (G)	LL	PL	PI	Gravel	Sand	Silt	Clay	Free swell	USCS	AASHTO	MDD	OMC	UCS (Kpa)	Coff. Of consolidation (CV) in 10^-3	Coff. Of permeablity (K) in 10^-3
TP1	1.5m	9.60	2.56	29	22	7	24.78	52.23	17.62	5.37	18.0	SM	A-2-4	1.5	17.5			
	3m	19.30	2.62	38	24	14	6.08	44.85	34.18	15.49	20.0	SM	A-4					
TP2	1.5m	16.60	2.52	48	31	17	0.00	27.23	49.76	23.02	30.0	ML	A-7-5	1.3	33.0			
	3m	27.62	2.57	48	35	13	0.64	14.48	54.31	30.57	50.0	ML	A-7-5	1.5	23.5			
TP3	1.5m	27.16	2.53	49	24	25	9.54	33.59	28.70	28.17	50.0	CL	A-7-6	1.3	32.0			
	3m	37.52	2.61	73	39	34	0.00	30.29	39.18	30.54	50.0	MH	A-7-6	1.4	26.8		0.883-9.05	0.62-28.57
TP4	1.5m	23.65	2.52	42	28	14	0.00	40.84	47.25	11.91	19.5	ML	A-5	1.4	28.2			
	3m	21.16	2.55	39	30	9	4.32	26.93	47.92	20.83	20.0	ML	A-5	1.5	23.5		6.28-14.1	1.38-55.12
TP5	1.5m	15.45	2.46	47	32	15	2.03	20.91	60.72	16.33	50.0	ML	A-7-5					
	3m	31.86	2.57	47	33	14	0.00	23.34	59.47	17.18	30.0	ML	A-7-5	1.3	31.0		4.61-11.7	2.88-56.66
TP6	1.5m	21.17	2.59	48	31	17	0.15	29.97	52.54	17.34	28.0	ML	A-7-5	1.4	27.0			
	3m	14.06	2.62	29	21	8	13.80	47.14	31.19	5.87	30.0	SM	A-4	1.6	20.2			
TP7	1.5m	15.81	2.48	41	30	11	0.00	33.00	52.01	14.99	30.0	ML	A-7-5	1.4	22.5			
	3m	12.46	2.62	35	28	7	1.22	36.80	47.18	14.80	25.0	ML	A-4	1.5	26.0			
TP8	1.5m	16.97	2.46	42	31	11	0.80	24.00	60.78	14.42	30.0	ML	A-7-5	1.4	25.8			
	3m	15.21	2.63	31	24	7	0.00	36.34	49.90	13.76	40.0	ML	A-4	1.4	29.3			
TP9	1.5m	35.30	2.46	52	35	17	0.61	31.52	36.25	31.62	30.0	MH	A-7-5	1.2	33.5			
	3m	27.01	2.56	57	29	28	0.00	17.98	62.14	19.88	50.0	MH	A-7-6	1.3	36.5		0.427-1.34	0.3-2.72
TP10	1.5m	25.01	2.57	41	30	11	4.86	33.47	44.11	17.56	30.0	ML	A-4	1.4	29.5			
	3m	25.44	2.57	30	25	5	1.22	54.60	33.15	11.02	20.0	SM	A-4	1.4	22.5			

3.2.3. Some of engineering properties of soil in Burayu city.

Burayu is one of special zone of Oromia regional state, which is located in western part of Addis Ababa. The city is located in 90^{o}02'00” - 90^{o}02'30" North latitudes and 38^{o}03'30" – 38^{O}41'30" East longitudes. The city is located in 90^{o}02'0”90^{o}02'30" North latitudes and 38^{o}03'30" to 38$_{o}$41'30" East longitudes.

ngineering properties of this town was done by one of Addis Ababa University student named Wubshet Hirphasa in 2015 for his MSc. Final theses. Therefore, the test results are listed in the following table. [5]

In the following table, all data are done by laboratory tests and depending on these laboratory test results soil classification is done by using both USCS and AASHTO classification methods.

Table 3-3: Engineering properties of soil in Burayu city (From thesis paper of Wubshet Hirphasa)

Engineering Properties of Soils and their test results																		
				Atterber limit test(%)			Percent ammount of particle					Soil Classification		Compaction test			1D Consolidation	
Test Pits		Natural MC	Specific Gravity (G)	LL	PL	PI	Gravel	Sand	Silt	Clay	Free swell(%)	USCS	AASHTO	OMC	MDD	UCS (Kpa)	Coff. Of consolidation (CV) in 10^-3	Coff. Of permeablity (K) in 10^-3
TP1	1.5m	32.4	2.79	68.9	32.4	36.5	0.80	16.70	18.7	63.7	47.5	CH	A-7-5					
	3m	31.9	2.74	71.3	34.0	37.3	0.00	14.20	21.6	64.2	52.5	CH	A-7-5	30.4	1.33			
TP2	1.5m	32.7	2.81	71.3	34.0	37.3	0.01	8.20	23.3	68.5	50.0	CH	A-7-5					
	3m	33.6	2.78	69.1	32.7	36.4	0.00	7.90	19.9	72.2	52.5	CH	A-7-5	30.5	1.31			
TP3	1.5m	32.9	2.82	70.8	33.0	37.8	0.70	13.30	28.3	57.7	40.0	CH	A-7-5					
	3m	31.1	2.76	71.5	33.3	38.2	0.00	8.30	19.4	72.3	52.5	CH	A-7-5	33.8	1.38	465.2	1.05-2.2	0.41.4.06
TP4	1.5m	32.4	2.70	69.3	32.4	36.9	0.40	14.60	29.3	55.7	45.0	CH	A-7-5					
	3m	31.5	2.74	73.4	34.1	39.3	0.00	5.20	22.8	72.0	48.0	CH	A-7-5			372.8		
TP5	1.5m	30.8	2.73	71.0	33.1	37.9	0.00	2.80	34.1	63.1	53.0	CH	A-7-5					
	3m	31.9	2.74	71.0	33.1	37.9	1.80	5.30	30.1	62.9	55.0	CH	A-7-5	35.0	1.37	328.9		
TP6	2m	33.2	2.74	68.8	31.0	37.8	0.30	5.60	27.7	66.4	42.5	CH	A-7-5					
TP7	2m	32.9	2.73	72.1	32.7	39.4	0.10	4.70	31.5	63.7	53.0	CH	A-7-5	32.1	1.32		0.84-2.49	0.92-6.94
TP8	2m	33.2	2.76	72.1	32.3	39.8	0.30	7.50	22.8	69.4	45.0	CH	A-7-5					
TP9	1.5m	32.9	2.76	68.8	31.8	37.0	0.00	2.80	24.7	72.5	50.0	CH	A-7-5					
	3m	33.7	2.81	70.3	32.1	38.2	0.00	3.60	23.6	72.8	55.0	CH	A-7-5	31.9	1.35	306.7		
TP10	1.5m	31.8	2.79	70.7	32.7	38.0	0.10	3.70	25.0	71.3	52.5	CH	A-7-5					
	3m	32.9	2.78	69.5	31.8	37.7	0.00	6.70	19.5	73.8	47.5	CH	A-7-5					

3.2.4. Some of engineering properties of soil in Mojo city.

Mojo is one of well-known town from Estern Showa zone towns of Oromia regional state. In addition, this town is located at around 25km from capital city of East showa zone Adama town. Geographically this town is located at 80 35’ N latitude and 390 07’ E latitude.

Mastewal Getahun does some of engineering properties of this town in 2016 while he is studying his MSc. From Addis Ababa University for his final theses is listed in the following table. [7]

In the following table, all data are done by laboratory tests and depending on these laboratory test results soil classification is done by using both USCS and AASHTO classifications.

Table 3-4: Engineering properties of soil in Mojo town (From Thesis paper of Mastewal G.)

Engineering Properties of Soils and their test results																		
				Atterber limit test(%)			Percent ammount of particle					Soil Classification		Compaction test			1D Consolidation	
Test Pits		Natural MC	Specific Gravity (G)	LL	PL	PI	Gravel	Sand	Silt	Clay	Free swell	USCS	AASHTO	OMC	MDD	UCS(Kpa)	Coff. Of consolidation (CV) in 10^-3	Coff. Of permeablity (K) in 10^-3
TP1	1.5m	28.24	2.63	82	39	43	0.68	14.76	60.48	24.08	50	MH		31.65	1.28	161		
	3m	25.87	2.68	76	40	36	9.35	15.63	51.07	23.95	45	MH		31.86	1.27	176		
TP2	1.5m																	
	3m																	
TP3	1.5m	31.56	2.69	63	32	31	0.46	19.12	69.15	69.15	35	MH		33.22	1.36			
	3m	5.29	2.64	29	18	11	4.98	95.03	0.00	0.00	25	SP		14.57	1.83			
TP4	1.5m	31.62	2.65	74	42	32	0.09	9.23	80.65	10.03	60	MH		24.77	1.46	139		
	3m	35.85	2.70	71	40	31	2.15	9.73	65.33	22.70	50	MH		39.63	1.19	135		
TP5	1.5m	25.94	2.64	82	49	33	3.72	13.69	54.97	27.62	55	MH		37.04	1.27	169		
	3m	32.18	2.67	85	50	35	0.00	11.17	58.77	30.06	45	MH		44.33	1.18	137	0.36-0.82	2.6-20.52
TP6	1.5m	21.58	2.66	65	34	31	0.00	21.02	67.26	11.72	40	MH		39.01	1.23	179		
	3m	24.97	2.63	66	39	27	18.77	31.67	36.83	12.73	35	MH		40.08	1.26	173		
TP7	1.5m	24.96	2.65	77	41	36	0.00	5.77	70.62	23.61	20	MH		24.78	1.46	164		
	3m	23.88	2.67	49	30	18	0.00	6.11	66.26	27.63	50	ML		33.1	1.33	166	0.24-0.36	1.83-23.47
TP8	1.5m	17.68	2.66	49	33	17	0.13	14.79	60.42	24.66	40	MH		33.1	1.15			
	3m	28.82	2.65	65	45	20	0.07	8.44	73.35	18.14	20	MH		41	1.19			
TP9	1.5m	27.77	2.62	72	49	27	6.22	13.86	50.27	29.65	40	MH		38.2	1.24			
	3m	29.49	2.63	87	48	40	4.04	11.97	56.20	27.79	40	MH		43.3	1.22			
TP10	1.5m	26.02	2.64	67	42	24	0.00	11.86	56.63	31.51	50	MH		37.3	1.21			
	3m	17.27	2.63	64	44	20	0.00	13.03	59.17	27.80	40	MH		35.6	1.23			

3.2.5. Some of engineering properties of soil in Ambo city.

Ambo is capital city of west showa zone which is located at around 115km from Addis Ababa to the west direction. Ambo is known for its mineral water, which is bottled outside of the town; it is reportedly the most popular brand in Ethiopia. Ambo is also the location of a research station of the Ethiopian institution of Agricultural research; initiated in 1977, this station hosts research in protecting major crops in Ethiopia.

Engineering properties of soil for this town was done in 2014 by Behailu Hunde while he is studying is MSc. At Addis Ababa University for his final theses. Therefore, this test results are listed in the following table. [9]

In the following table, all data are done by laboratory tests and depending on these laboratory test results soil classification is done by using both USCS and AASHTO classifications.

Table 3-5: Engineering properties of soil in Ambo town (From thesis paper of Behailu Hunde)

Engineering Properties of Soils and their test results																		
				Atterber limit test(%)			Percent ammount of particle size					Soil Classification		Compaction tes			1D Consolidation	
Test Pits		Natural MC	Specific Gravity(G)	LL	PL	PI	Gravel	Sand	Silt	Clay	Free swell	USCS	AASHTO	OMC	MDD	UCS (Kpa)	Coff. Of consolidation (CV) in 10^-3	Coff. Of permeablity (K) in 10^-3
TP1	1.5m	30.7	2.76	114	31	83	0.00	3.10	32.14	64.76	115	CH	A-7-5(20)					
	3m	32.5	2.75	109	35	73	0.00	4.30	33.45	62.25	110	CH	A-7-5(20)					
TP2	1.5m	23.4	2.71	76	34	42	0.00	3.10	29.30	67.60	60	CH	A-7-5(20)					
	3m	28.4	2.72	78	33	45	0.00	4.70	42.53	52.77	75	CH	A-7-5(20)			545.00		
TP3	1.5m	33.0	2.68	99	32	67	0.00	3.70	43.17	53.13	125	CH	A-7-5(20)					
	3m	39.6	2.69	93	38	55	0.00	4.40	37.79	57.81	90	CH	A-7-5(20)					
TP4	1.5m	41.0	2.78	112	34	78	0.00	1.90	36.80	61.30	85	CH	A-7-5(20)			127.53		
	3m	41.0	2.75	107	47	60	0.00	1.10	36.12	62.78	135	MH	A-7-5(20)			151.09	0.5-1.63	
TP5	1.5m	30.2	2.51	112	37	75	15.30	2.60	23.30	58.80	95	CH	A-7-5(20)					
	3m	35.1	2.66	113	47	66	8.40	1.90	31.70	58.00	155	MH	A-7-5(20)					
TP6	1.5m	37.4	2.78	110	32	78	14.50	2.80	22.77	59.93	115	CH	A-7-5(20)			128.53		
	3m	38.0	2.73	109	34	75	2.70	2.00	35.70	59.60	120	CH	A-7-5(20)			179.18		
TP7	1.5m	31.1	2.69	73	42	31	4.10	11.10	54.39	30.41	50	MH	A-7-5(20)					
	3m	31.2	2.67	64	34	30	5.00	13.20	53.81	27.99	35	MH	A-7-5(20)					
TP8	1.5m	32.0	2.74	99	40	59	3.80	1.20	43.14	51.86	95	CH	A-7-5(20)			530.22		
	3m	35.1	2.75	62	30	32	3.80	12.00	35.76	48.44	45	CH	A-7-5(20)			385.00		
TP9	1.5m	37.8	2.72	101	33	68	4.00	3.40	39.90	52.70	105	CH	A-7-5(20)			147.43		
	3m	40.7	2.74	114	40	74	4.00	3.40	39.90	52.70	100	CH	A-7-5(20)			112.00	0.88-2.65	
TP10	1.5m	40.7	2.69	110	34	76	0.00	2.70	38.30	59.00	115	CH	A-7-5(20)					
	3m	42.1	2.70	105	33	72	0.00	6.30	36.70	57.00	105	CH	A-7-5(20)					

3.2.6. Some of engineering properties of soil in Debrebrhan city.

Debre Berhan is one of cities found in central part of Ethiopia. It is located in the North Shewa Zone of the Amhara regional state, about 120 kilometers northeast of Addis Ababa on the paved highway leading to Dessie. The town has a latitude and longitude of 9°41′N 39°32′E coordinates, the town is divided in to nine kebeles. The town has around 40,000 populations.

One of Addis Ababa University student Solomon Mebratu did some of engineering properties of soils found in this city in 2015 for his MSc theses. Moreover, the test results are found on the following table. [6]

In the following table, all data are done by laboratory tests and depending on these laboratory test results soil classification is done by using both USCS and AASHTO classifications.

Table 3-6: Engineering properties of soil in Debrebrhan town (From thesis paper of Solomon Mebratu)

Engineering Properties of Soils and their test results																			
				Atterber limit test(%)			Percent ammount of particle					Soil Classification		Compaction tes			1D Consolidation	
Test Pits		Natural MC	Specific Gravity(G)	LL	PL	PI	Gravel	Sand	Silt	Clay	Free swell	USCS	AASHTO	OMC	MDD	UCS (Kpa)	Coff. Of consolidation (CV) in 10^-3	Coff. Of permeablity (K) in 10^-3
TP1	1.5m	33.9	2.72	73	33	40	0.35	2.84	29.31	67.50	80	CH	A-7-5			176		
	3m	58.99	2.78	80	34	46	0.00	2.37	47.92	49.71	100	CH	A-7-6					
TP2	1.5m	22.01	2.69	47	30	17	4.04	23.44	48.74	23.78	50	ML	A-7-5					
	3m	24.27	2.70	43	29	14	1.68	34.11	55.44	8.77	55	ML	A-7-6			83		
TP3	1.5m	30.02	2.81	66	28	38	0.11	14.03	42.41	43.45	70	CH	A-7-6					
	3m	31.14	2.70	32	17	15	17.88	38.74	27.81	15.57	60	SC	A-6			75		
TP4	1.5m	37.47	2.65	56	31	25	2.42	15.39	47.08	35.11	50	MH	A-7-5			134		
	3m	23.62	2.62	44	29	15	0.43	33.23	48.53	17.81	50	ML	A-7-5					
TP5	1.5m	32.85	2.78	77	34	43	1.31	7.91	41.72	49.06	95	CH	A-7-5					
	3m	30.93	2.72	64	34	30	0.11	8.74	47.04	44.11	85	MH	A-7-5			203		
TP6	1.5m	43.04	2.77	73	43	30	0.17	4.84	46.53	48.46	90	MH	A-7-5			233		
	3m	46.96	2.74	60	28	32	1.45	7.39	47.23	43.93	85	CH	A-7-6				0.14-0.41	1.24-12.97
TP7	1.5m	31.49	2.73	70	32	38	0.03	7.26	36.24	56.47	80	CH	A-7-6					
	3m	43.64	2.80	56	39	17	2.11	28.36	55.90	13.63	50	MH	A-7-5			120	0.42-2.18	1.95-19.26
TP8	1.5m	43.64	2.81	72	32	40	0.01	2.44	45.15	52.40	85	CH	A-7-5			114		
	3m	40.48	2.77	48	22	26	0.05	17.27	35.08	47.60	70	CH	A-7-6				0.43-1.52	3.05-22.17
TP9	1.5m	25.55	2.78	47	25	22	1.46	20.70	43.07	34.77	45	CH	A-7-6					
	3m	28.47	2.72	45	20	25	1.91	34.07	30.00	34.02	35	CH	A-7-6			194		
TP10	1.5m	27.69	2.79	62	29	33	0.00	6.86	42.91	50.23	95	CH	A-7-6			141		
	3m	20.11	2.81	41	30	11	24.63	37.02	27.28	11.07	50	SM	A-7-5					
TP11	1.5m	33.8	2.71	58	29	29	0.00	15.40	39.55	45.05	75	CH	A-7-5					
	3m	26.87	2.76	41	19	22	0.82	36.32	32.70	30.16	50	CH	A-7-6			186		

4. PROCEDURE OF THE STUDY

4.1. Preparation of aerial photo for each city

4.1.1. Aerial photo:

Aerial photo is the taking of photographs of the some areas of the earth from the aircraft or from other flying objects. This aerial photo may be used for deferent purposes. In case of this research, it is used to know the plan of the mentioned city from the top for best understanding of the area and places of test pits. This aerial photo is visible as an image not as a vector data. So any one can understand the place only by zooming and seeing of the place.

Figure 4-1: Sample of Aerial photograph taken from Burayu town.

4.1.2. Downloading aerial photo:

Aerial photo can be downloaded by many methods. Some of aerial photos are captured by satellite while an airplane directly captures others. In case of this research, aerial photographs are directly downloaded from Google earth and geo-referenced. In addition, there are other methods to download this aerial photo by a website of https://earthexplorer.usgs.gov and from this web, one can download any earth information including satellite images and soil dynamics information such as earthquake and land slide hazards that are occurred on this planet earth.

So in case of this research aerial photo of these selected cities are downloaded from Google earth with help of other software called ***smart GIS.*** This smart GIS software is very important to download aerial photo from Google earth because it directly downloads geo-referenced image images.

The following image shows smart GIS. Icon used to connect to google earth

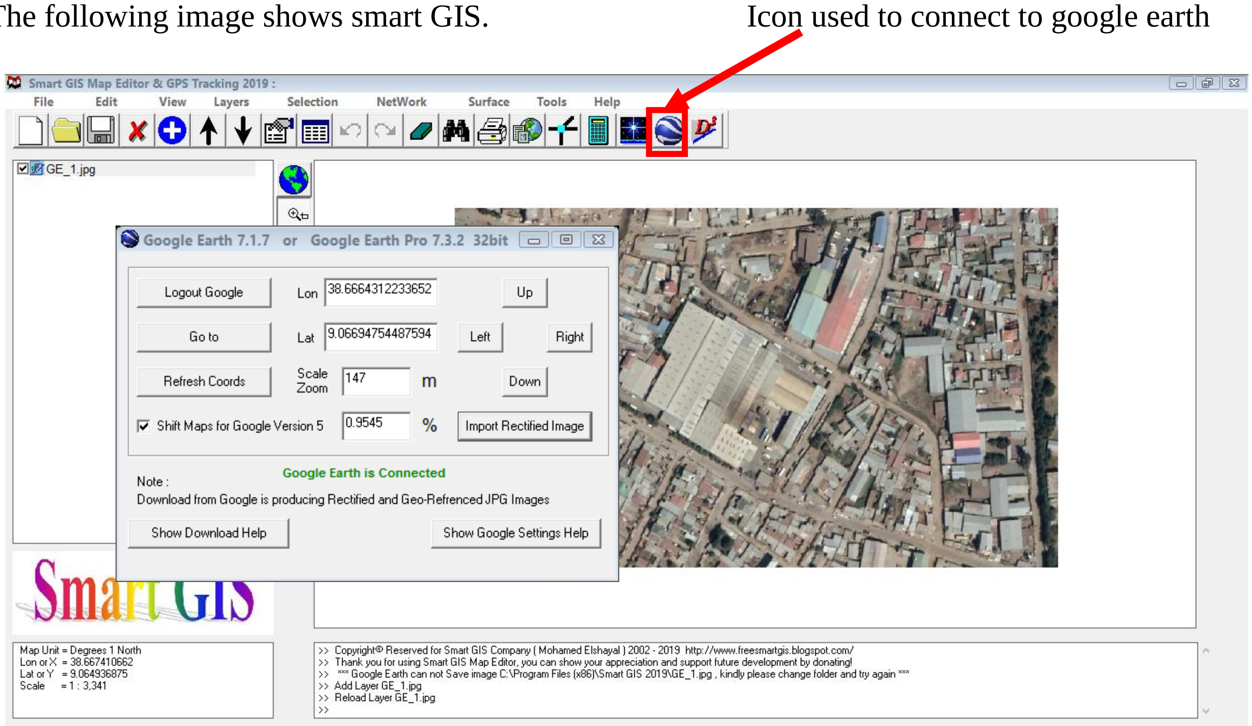

Figure 4-2: Image of smart GIS software used to download rectified Aerial photo.

In this software the first thing that have to be done is connecting the software with Google earth, after connecting these two software the place we are interested to download images will be zoomed to the extent. Then after zooming, we refresh the place from smart GIS and download it to the specified folder by clicking on the tab called *import-rectified image.*

4.2. Inserting each test pit on the aerial photo

Each test pit that have been done on the cities have their own coordinate and by converting these coordinates to CSV. Excel format we can insert test pits on the aerial photo. First, these aerial photos have to be added to Arc map and its coordinate system have be corrected to overlap these aerial photos and test pit coordinates. Then after insertion of these points, their real location will be marked as a point.

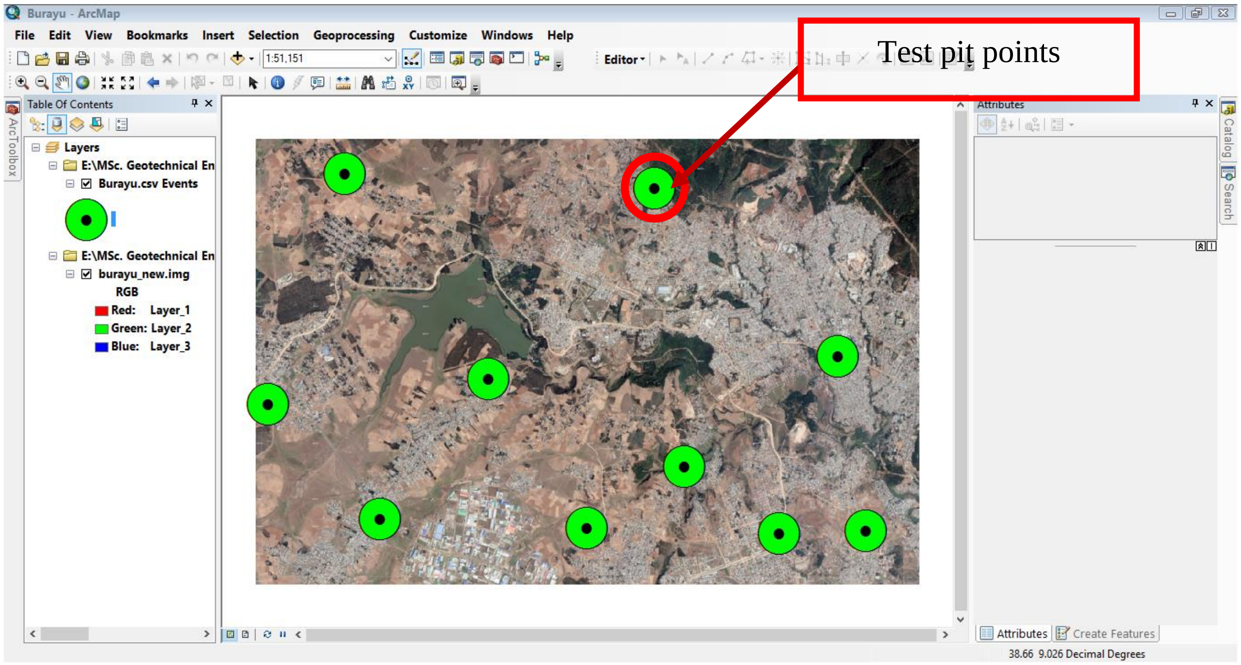

Figure 4-3: Figure shows test pits and their respective place on the aerial photo.

The above green points seen on Arc map are all test pits placed on their own coordinates and it is real point of the places where test samples have been taken during the research.

Then after identifying the exact places of test pits, the next duty is to digitize this point again and filling summarized data to these point.

4.3. Creating file geo-database on GIS (Arc map)

File geo-database is simply uses us as a folder in Arc GIS. It is a place where our all executed and digitized data will be stored. This file geo-database is created in a folder where our all data have been stored. Then all digitization and storage of all data will be done in this file geo-database.

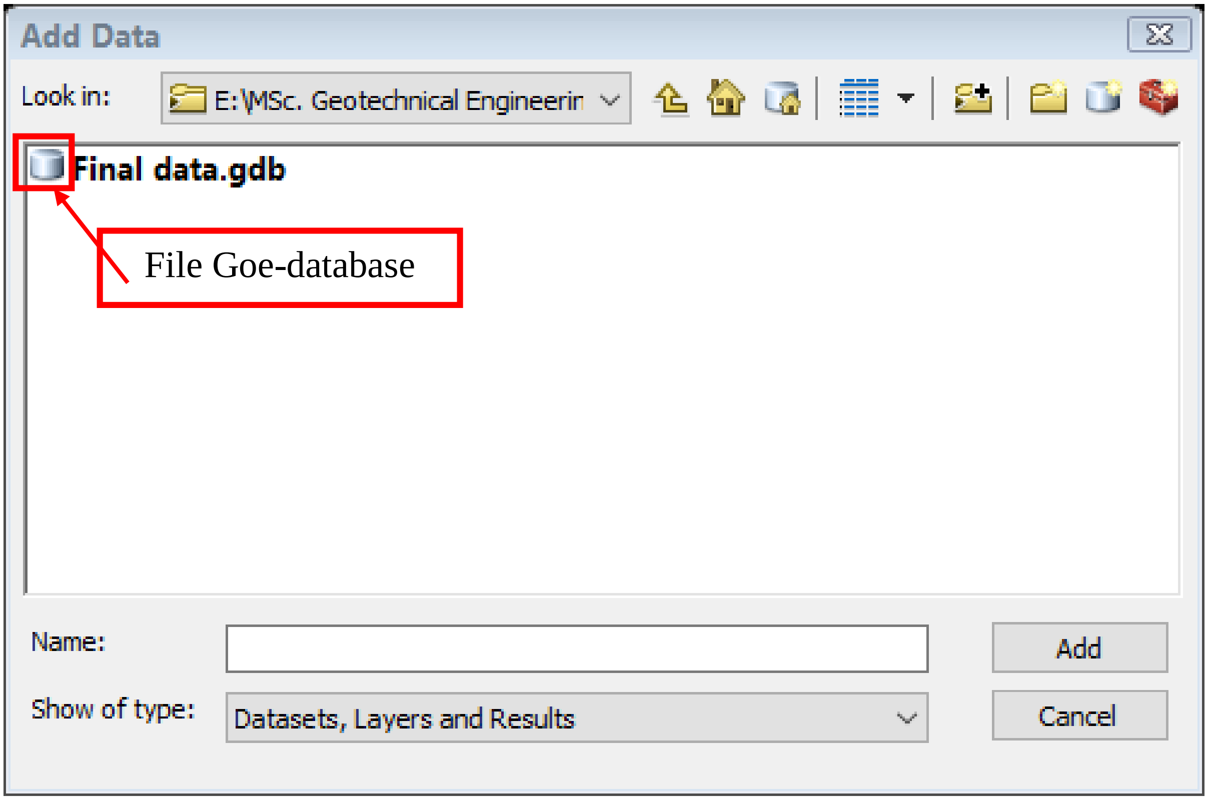

Figure 4-4: File geo-database created on GIS to store all our works as a folder

In the above file geo-database, there are two features that are used to categorize and digitizing of our data. The first one is **feature dataset** which is used to categorize our data by its or by its places or etc. In addition, the second one is feature class. This feature c ass is used to digitize and store all information that are important to store and it has many features. It may be polygon, point, line or polyline. So depending on our features, we will create these feature classes in this file geo-database.

4.4. Creating feature dataset and feature class for each city

Feature data set is as explained above it is used to categorize our data depending on places of our research area. This feature dataset is created in file geo-database and all coordinate system of feature classes that are created in this feature dataset is identified. Therefore, after creating these feature datasets in the file geo-database, in correspondence of their cities feature class that is used to digitize all test points will be created.

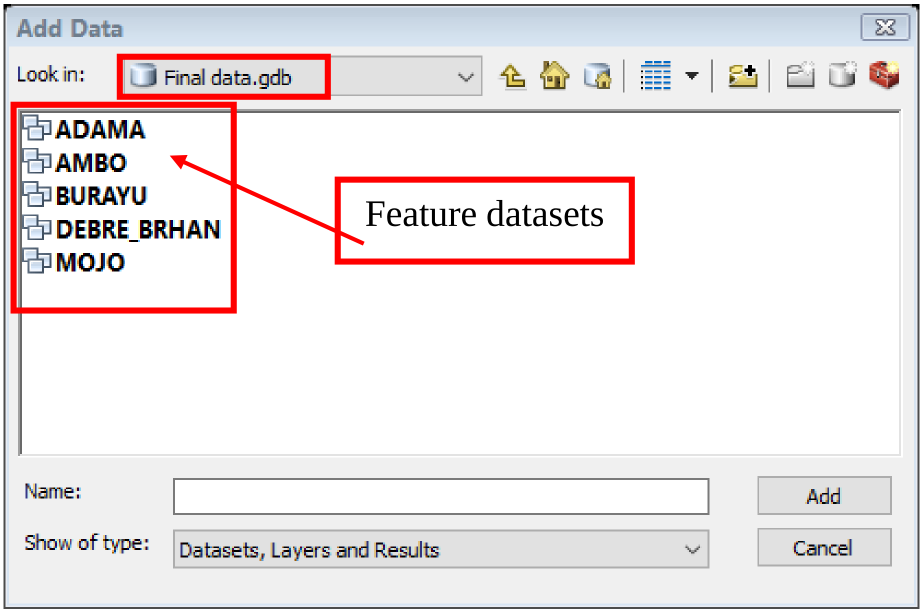

Figure 4-5: Feature datasets created in our file geo database

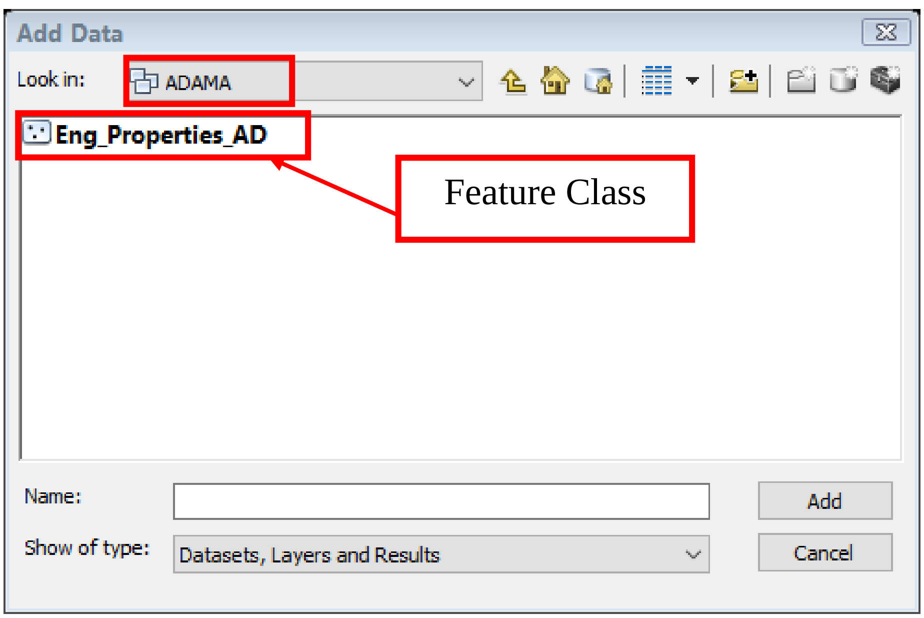

Figure 4-6: Feature classes created in feature dataset to digitize our test pit points

4.5. Digitization and inputting summarized data for each test pits.

Digitizing all these test pits can be done by using feature classes that have been created previously. When feature class is created all fields that are used to fill all engineering properties are created and by editing test points above, all information are filled. The following figure shows fields created while feature class is created.

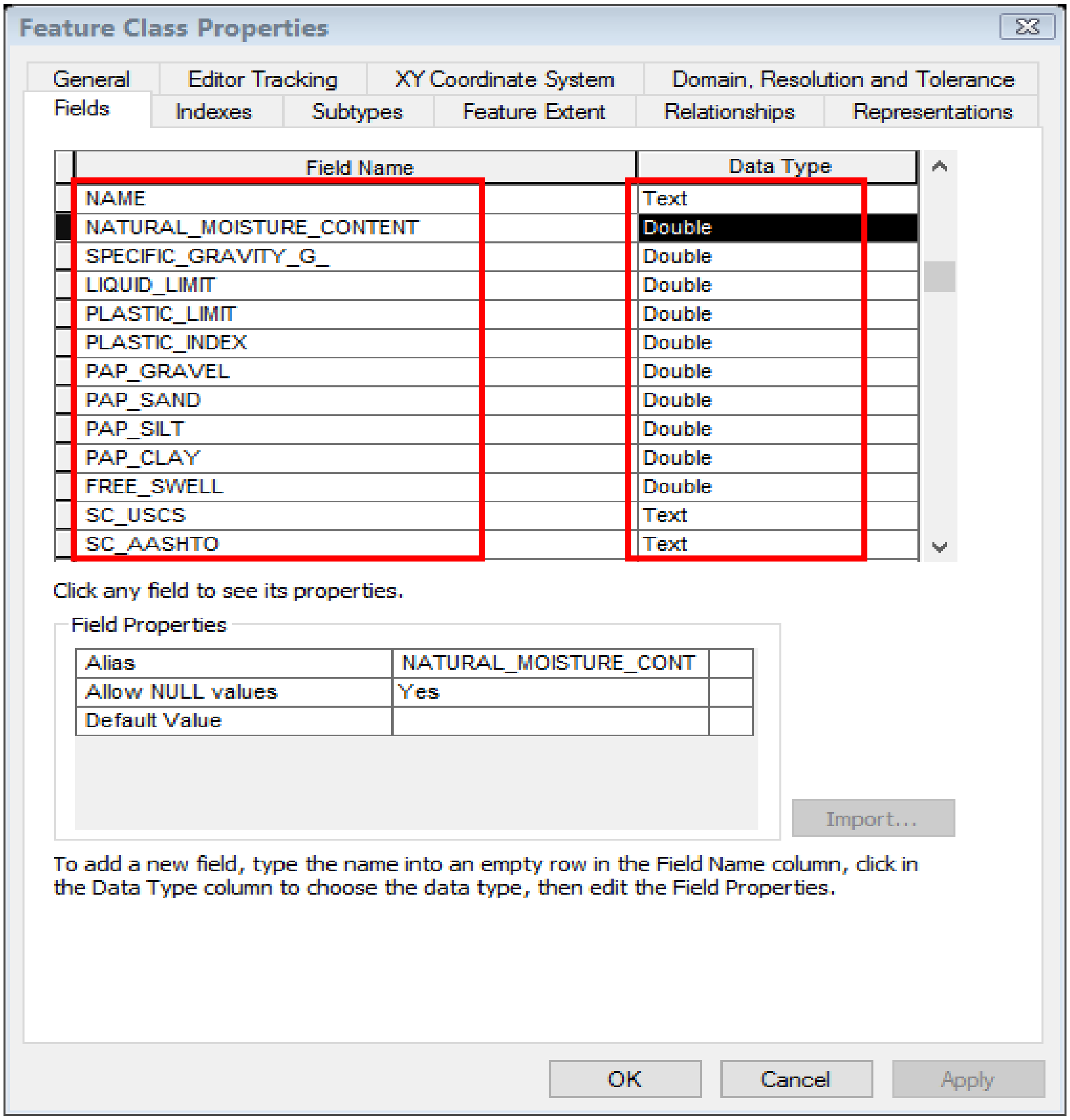

Figure 4-7: Figure shows preparation of fields for data input when digitizing TP

In the above dialogue box, fields that are found in red triangle are engineering properties of soils field name that are created while creating feature classes. While creating these fields one have, be care full about the formats of the fields. If the value we are going to fill is text, also it must be created by text format in the feature class creation process. Nevertheless, in case of mistakes it can be edited again in the file geo-database also. In this case, after creating all needed fields directly we go to editing points to fill values of these fields in Arc map. Then after starting editing tool, one test pit will be selected and all data have to be filled as follows.

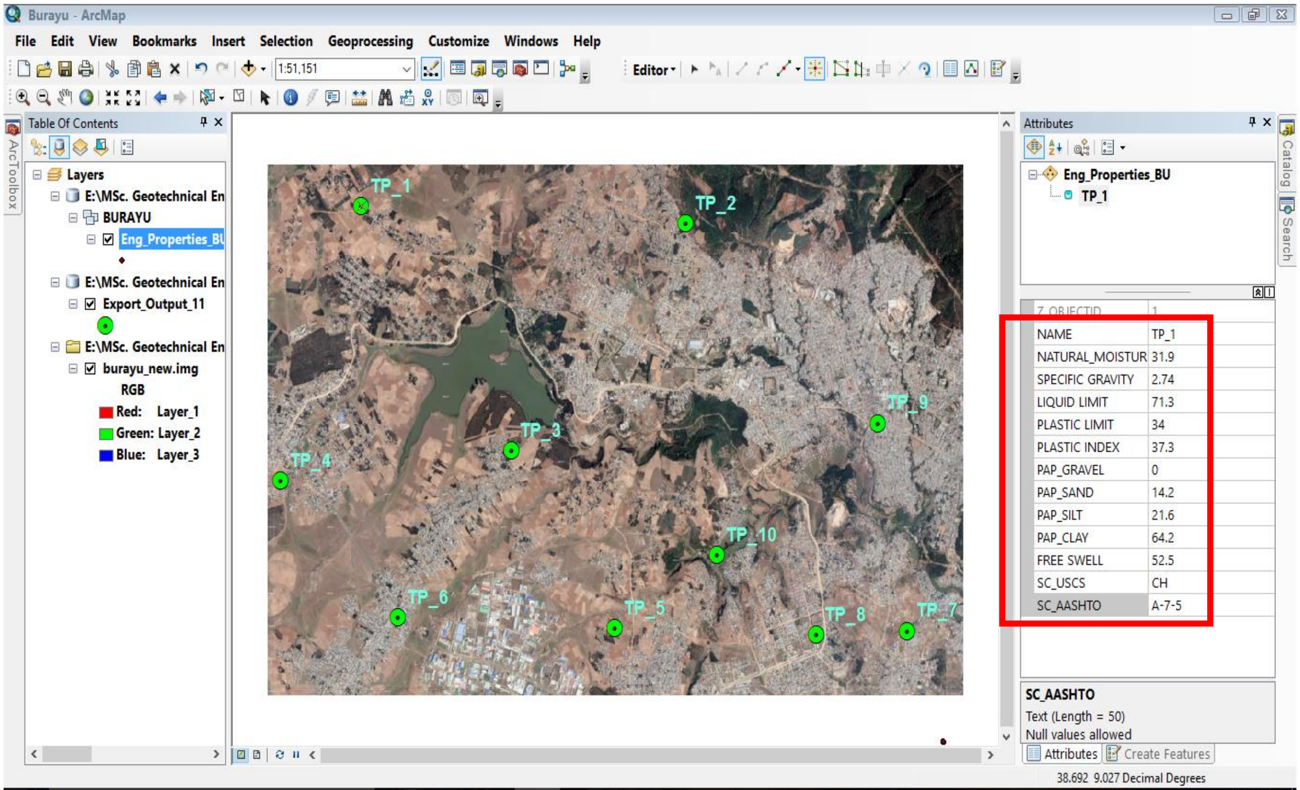

Figure 4-8: Figure shows a place where Geo-data is filled when digitizing.

Therefore, in the above selected fields all information or data that have been summarized have to be filled properly at this stage of editing and filling fields. For example, the above filled data are for only test pit 1(TP_1). Then after one have to save edits after closing this Arc map.

5. OUTPUT OF THE STUDY

5.1. Engineering properties of soil in selected cities and their soil maps

All engineering properties of selected cities are shown on the GIS. These properties are stored on this software in a simple form and every one can access and display all information by only one click on the aerial photo of the cities and specially by clicking on test pits that are found on the aerial photo.

Therefore, while designer is designing foundation this method of data management helps and saves time to get and access data simply. In addition, the other advantage of this method of data management is when designing foundation for high raising buildings, the designer will simply chooses which test pit's result is good or which test pit is the nearest pit for foundation to be designed.

In addition, digital soil map of these selected cities are extracted from digital soil map of the world that has been done by FAO. These soil maps have its own catalogue for abbreviations that are found on legends of digital soil maps.

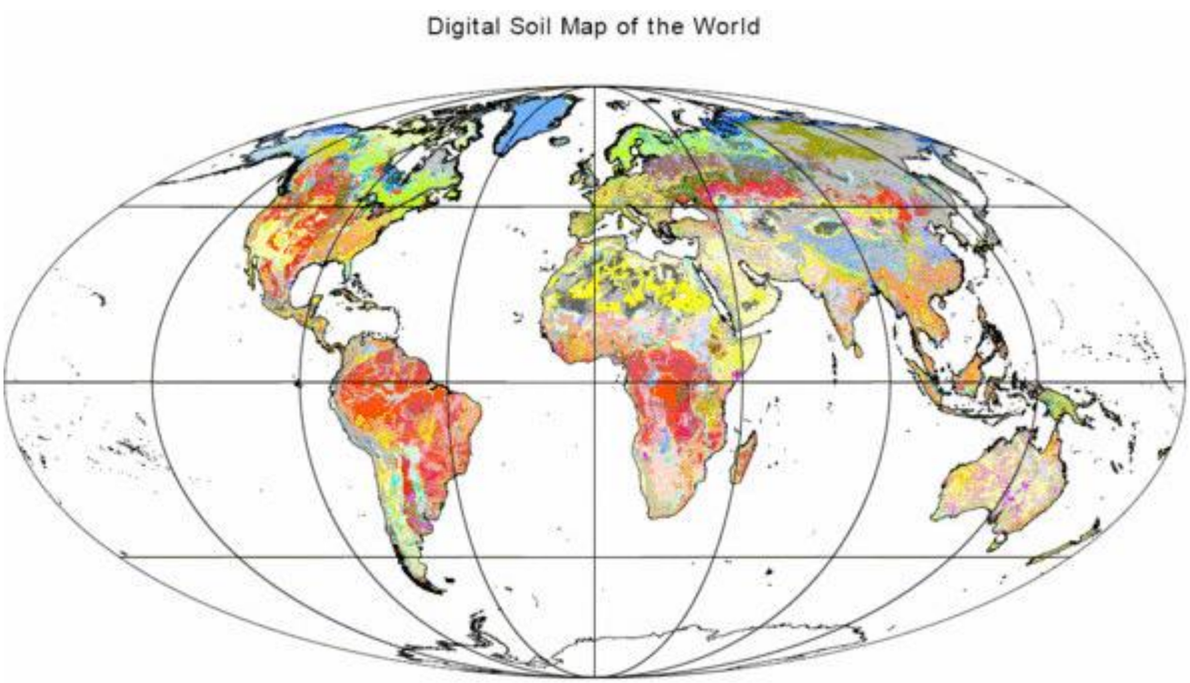

Figure 5-1: Digital soil map of the world according to FAO

Figure 5-2: Legend for digital soil map of the world

5.1.1. Engineering properties of soil in Adama city and soil map of the city.

In the following image, all test pits are placed on their respective points or coordinates and all values are inserted in GIS. So for example if one is needed to know engineering properties of soil for any test pit by only picking identify icon from standard tool bars them click on any test pit. Then all engineering properties of soil in this test pit is displayed as follows.

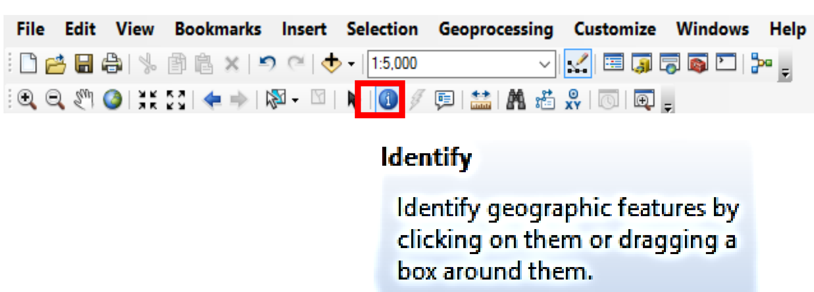

Figure 5-3: Identify icon from GIS to display soil properties

As shown on the following figure engineering property of the soil that is displayed on the figure is properties of the soil for test pit 3 (TP_3). So in this way any one can access the data in asiple manner.

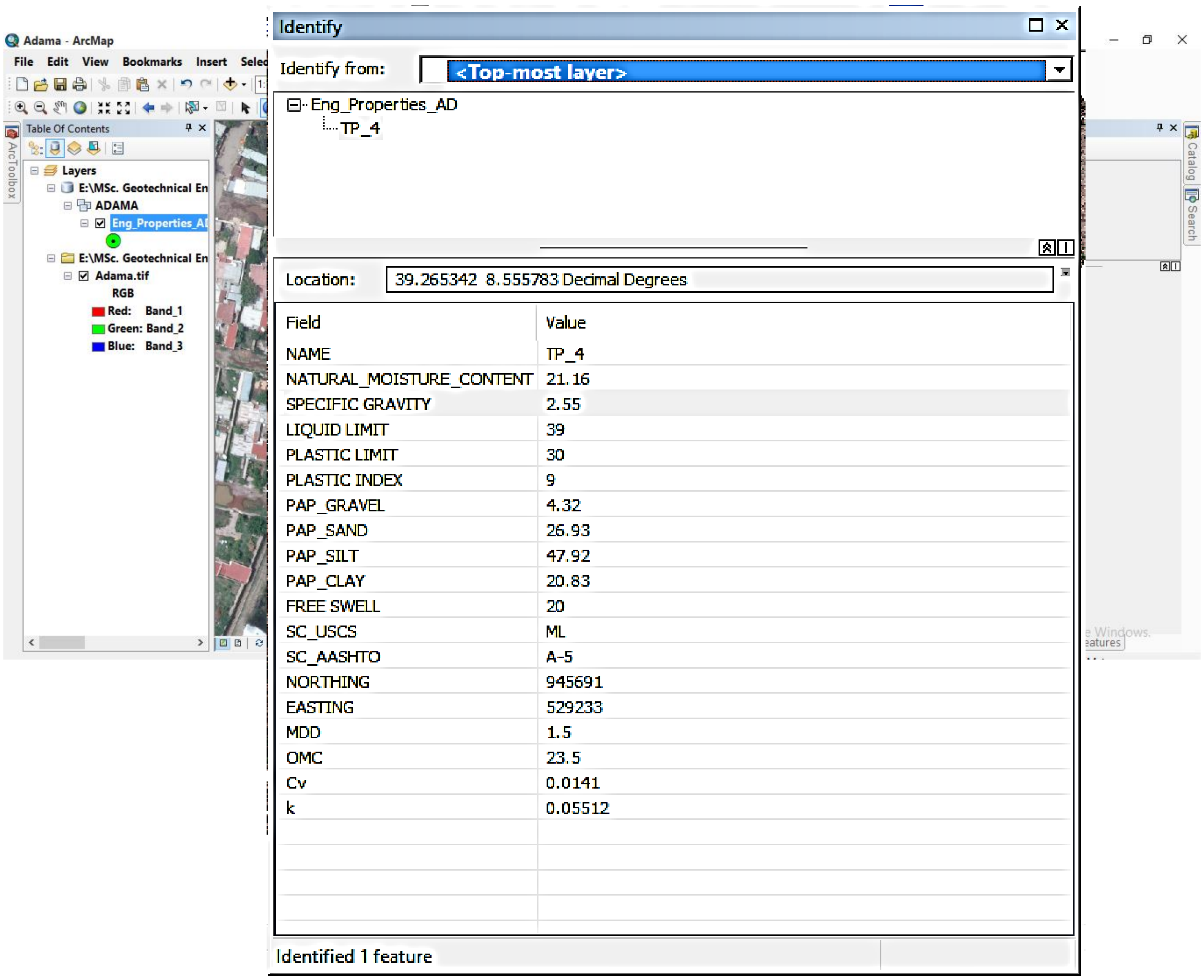

Figure 5-4: Engineering properties of soil in Adama City

And digital soil map of Adama city is shown on the following figure.

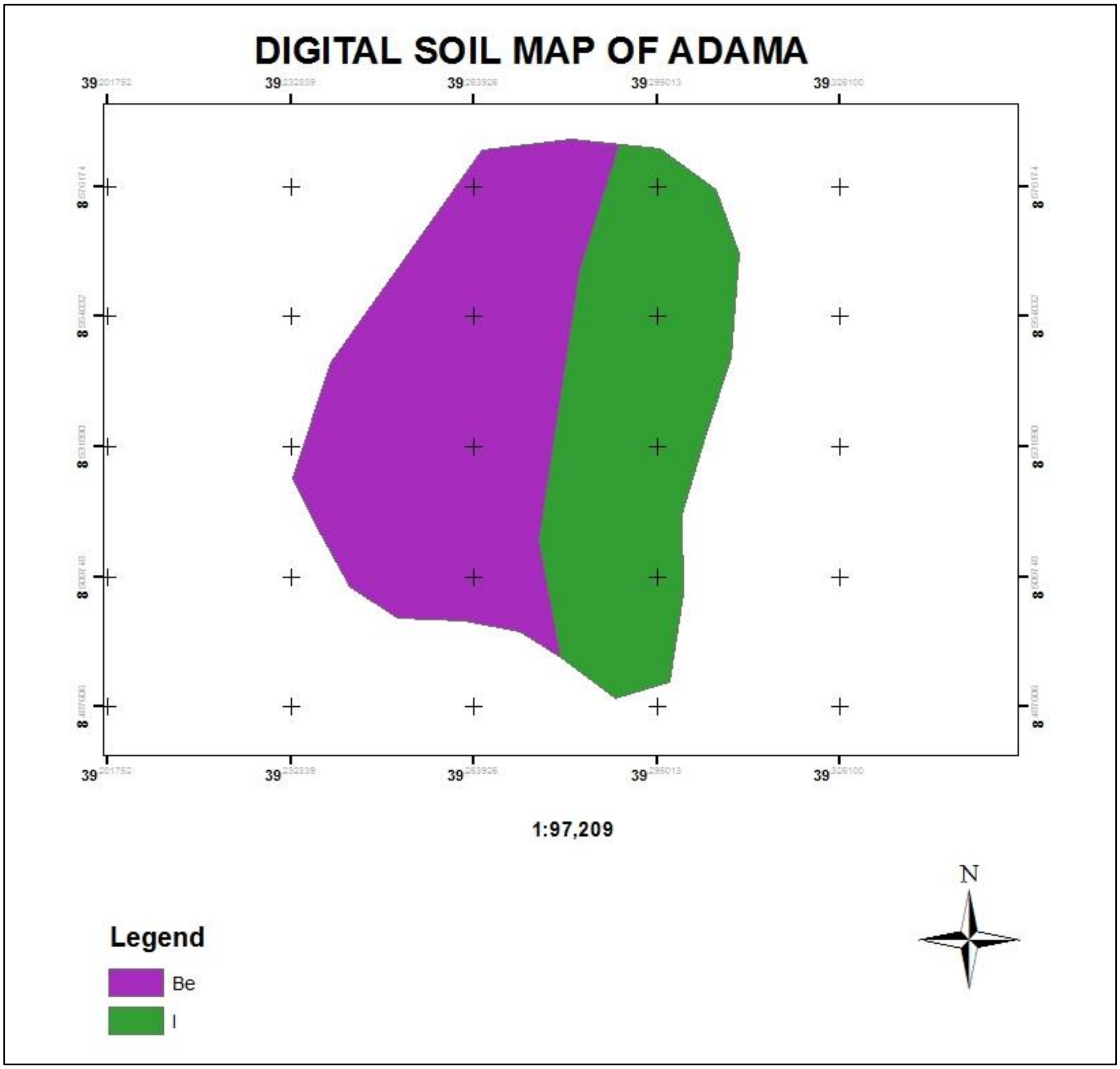

Figure 5-5 : Digital soil map of Adama city

5.1.2. Engineering properties and soil map of Ambo city.

In the same way, the following figure shows engineering properties of soil in Ambo town. This figure shows only one test pit that is test pit 4 (TP_4).

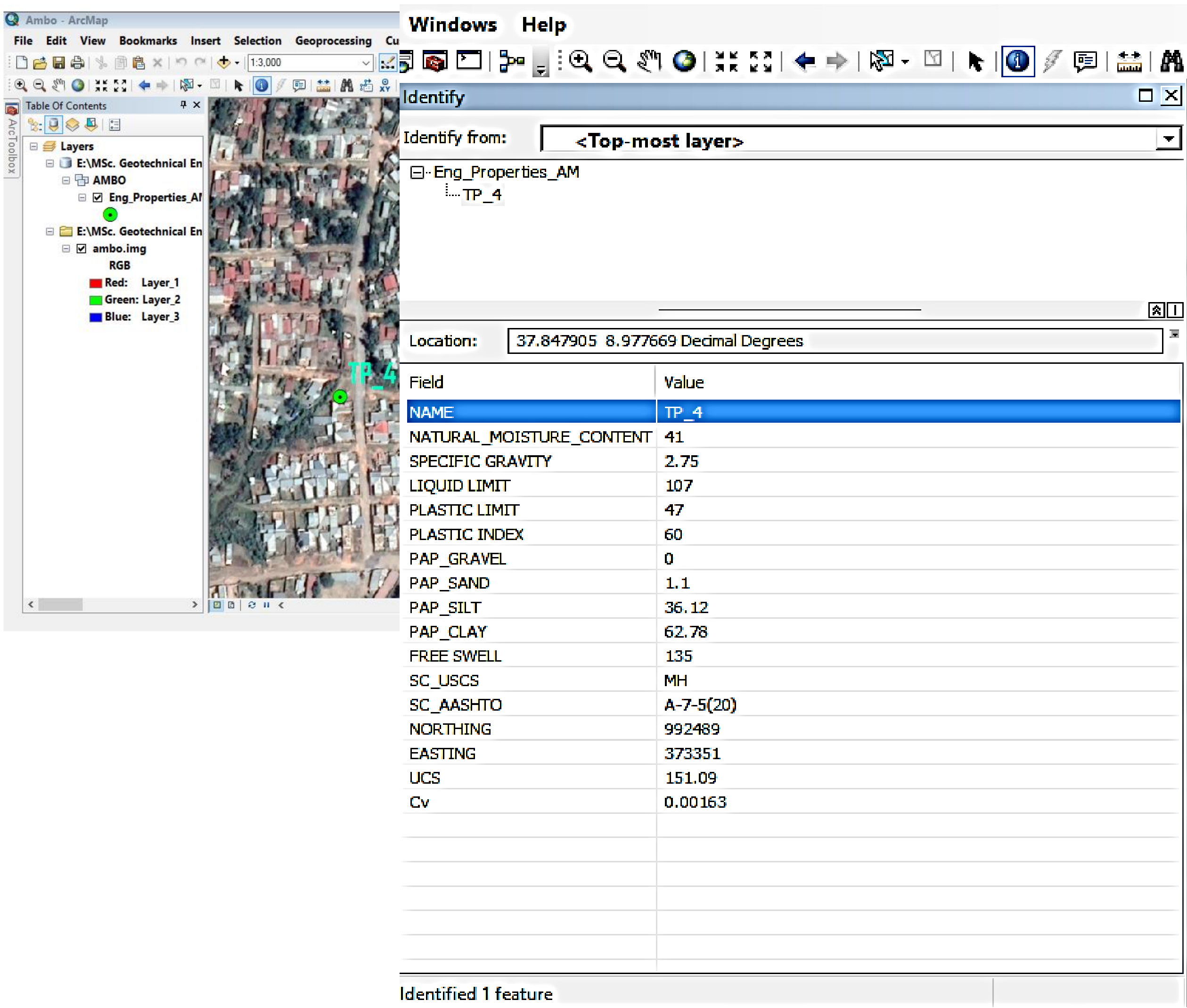

Figure 5-6 : Engineering properties of Ambo city case of test pit 4

Digital soil map of Ambo city. As mentioned above digital soil map of Ethiopia is extracted from world digital soil map and Ambo is from Ethiopia.

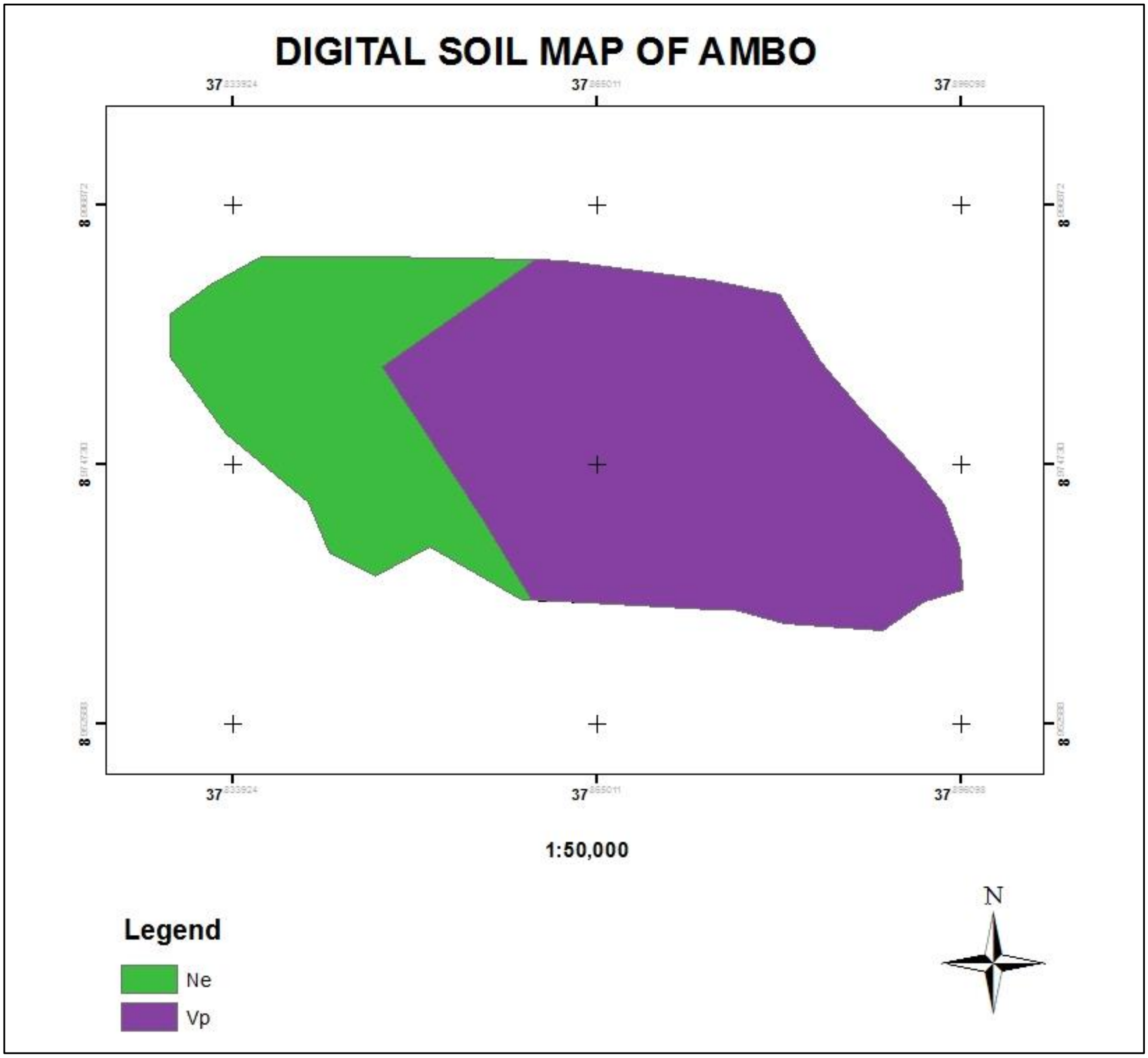

Figure 5-7: Digital soil map of Ambo city

5.1.3. Engineering properties of soil and soil map in Burayu city.

The following figure shows engineering properties of soil in Burayu city. Displayed result is for test pit 3 among ten test pits.

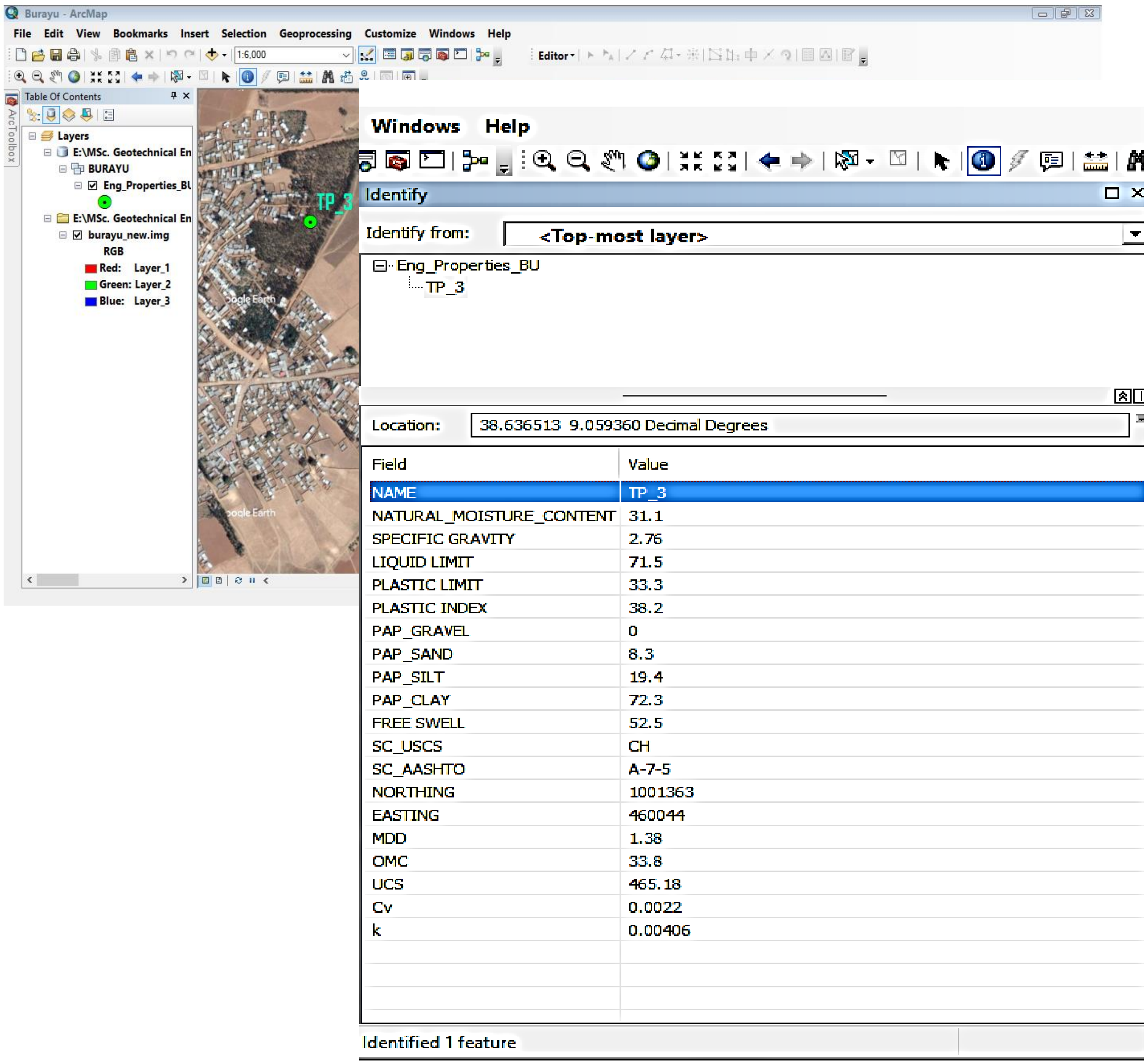

Figure 5-8: Engineering properties of soil in Burayu town case of test pit 3

In case of Addis Ababa and Burayu cities, since the location of both cities are on the on the border of each other digital soil map of both city is displayed on one map as follows.

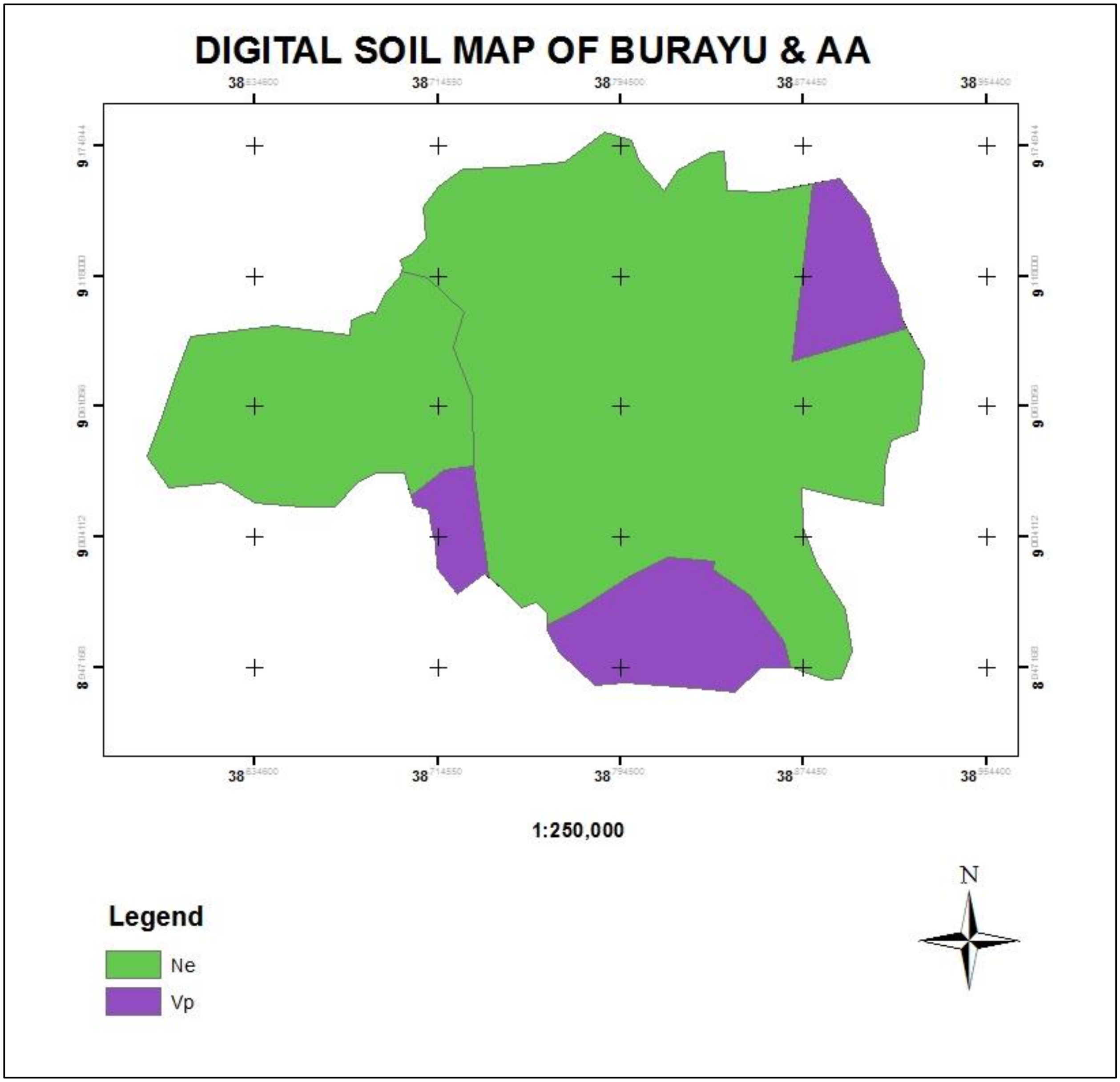

Figure 5-9: Digital soil map of Addis Ababa and Burayu city

5.1.4. Engineering properties of soil and soil map in Debrebrhan city.

The following figure shows engineering properties of soil in Debrebrhan city. Displayed result is for test pit 10 among ten test pits.

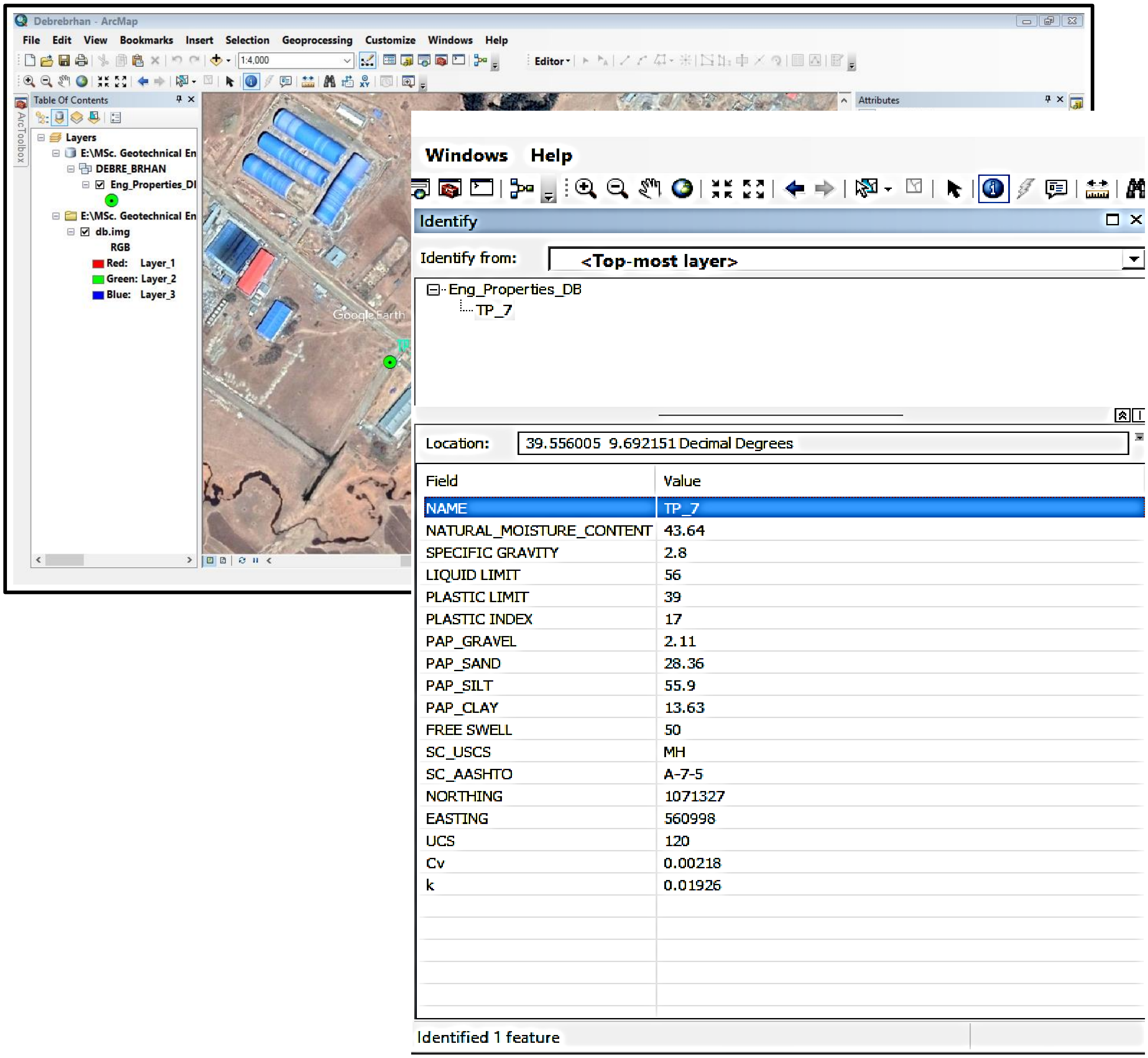

Figure 5-10: Engineering properties of Debre Brhan city case of test pit 7

Digital soil map of Debre Brhan city is shown on the following map.

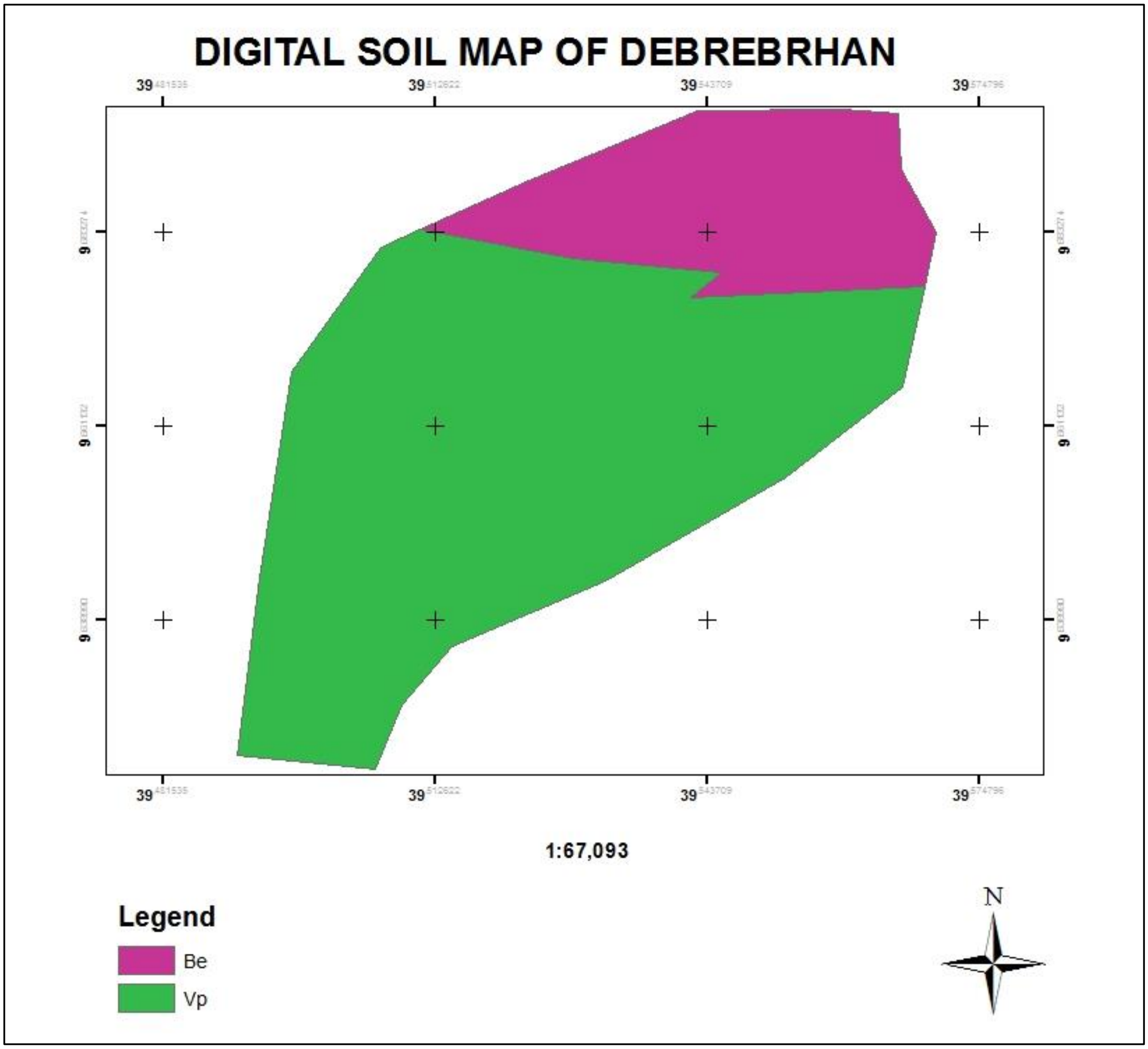

Figure 5-11: Digital soil map of Debre Brhan city

5.1.5. Engineering properties of soil and soil map in Mojo city.

The following figure shows engineering properties of soil in Mojo city. Displayed result is for test pit 1 among ten test pits.

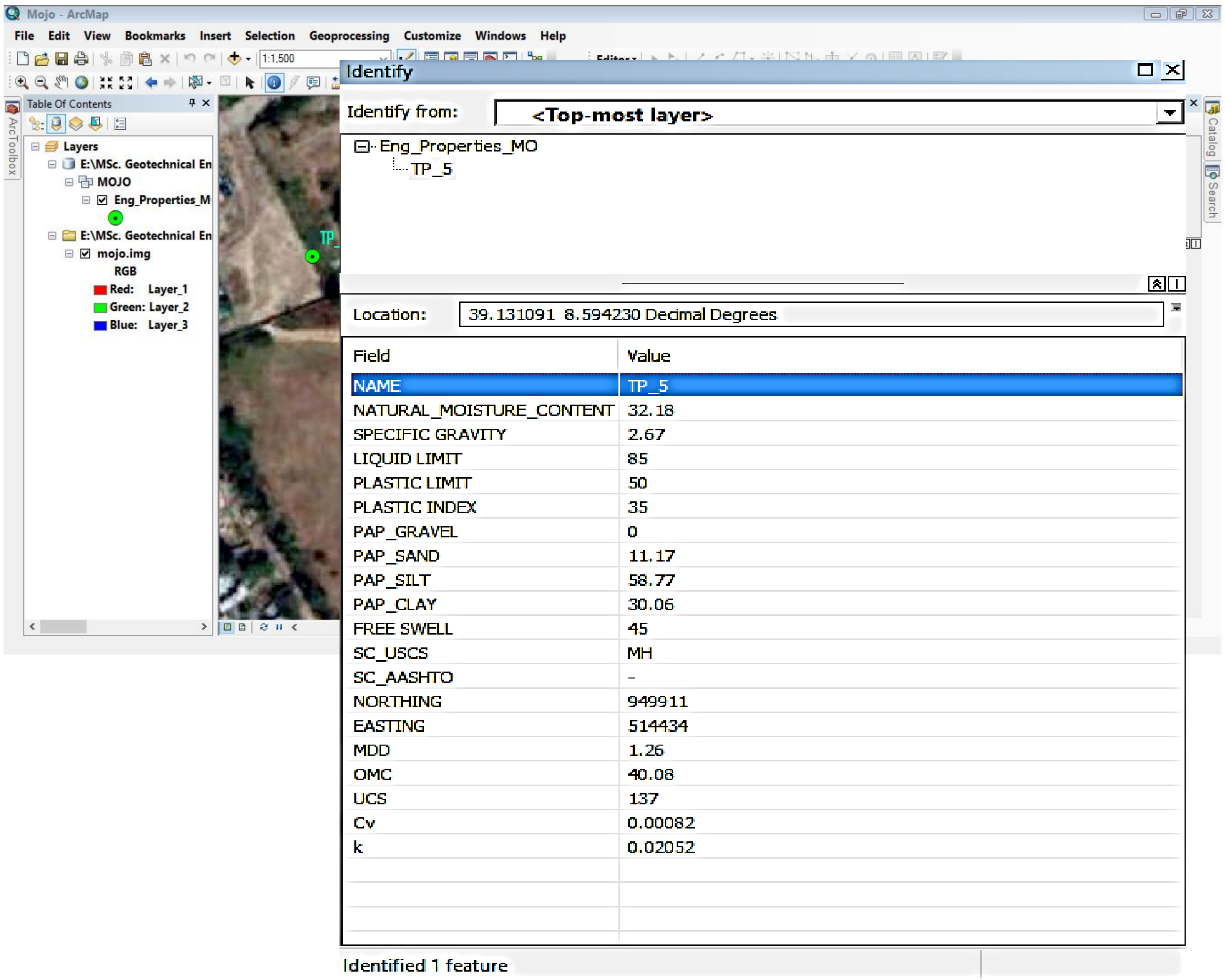

Figure 5-12: Engineering properties of Mojo city case of test pit 5

Digital soil map of Mojo city.

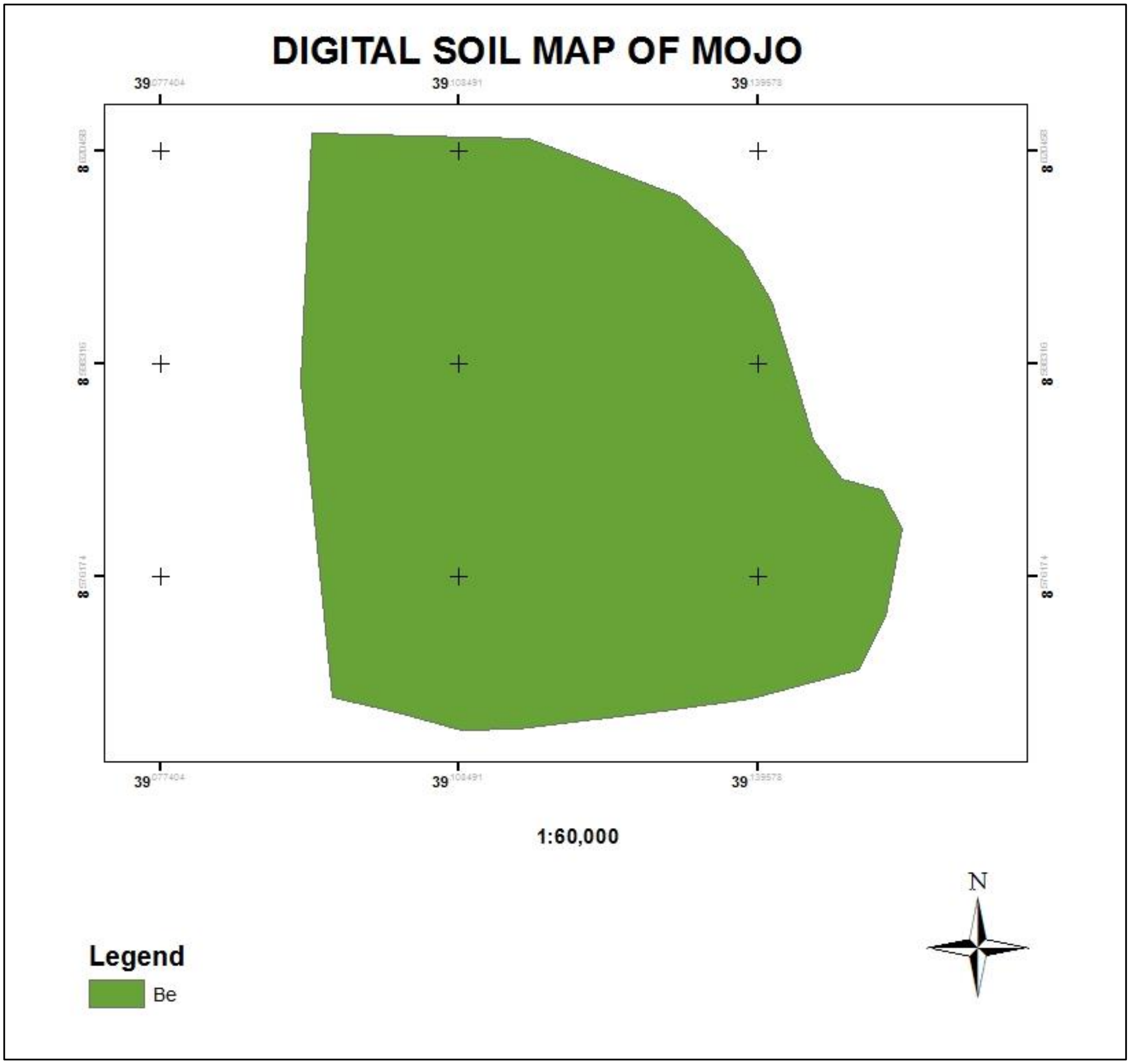

Figure 5-13: Digital soil map of Mojo city

5.1.6. Engineering properties of soil in Addis Ababa city.

The following figure shows engineering properties of soil in Addis Ababa city. Displayed result is for test pit 1 among six test pits.

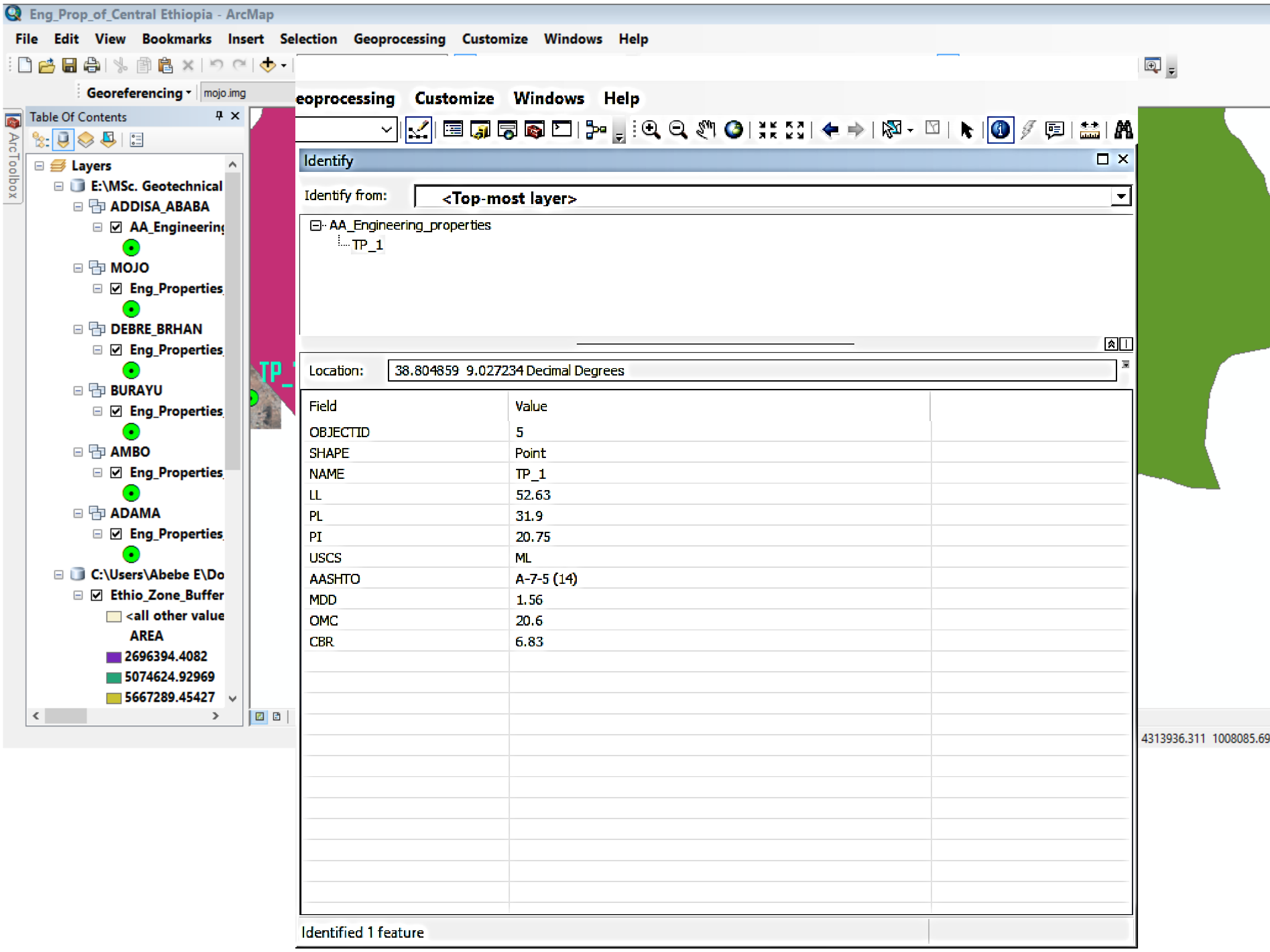

Figure 5-14: Engineering properties of Addis Ababa city

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

In general engineering properties of soils or any geotechnical data have to be managed and stored in a good manner to access and use it easily for any foundation design and other uses.

Any data that will be re sued for any design or purpose can be damaged or lost if it does not stored. Therefore, this particular research tried to explore previously done researches on engineering properties of soils and systematically categorize, summarize, and feed to GIS software to access easily. In addition to this so for safe design of foundation in or any other input parameters, it is must to get correct and well-managed data. To manage these geotechnical data it is better to use GIS software since it can store both raster and vector data that is attribute table. Moreover, this method of data management is very important for time saving, accessibility of data and simplicity of data storing.

Generally, this research gives new methods of geotechnical data management, which means systematically categorizing, storing and displaying of data in a simple manner and helps the user of data to access data in a simple way.

6.2. Recommendation

1. In case of this research the author have used secondary data to show how manage geotechnical data. So it is recommended to use only for preliminary design these results, and other researcher can do laboratory tests and can manage data by this method with its own responsibility about accuracy of data.
2. This research is only for academic purpose and it’s done only to show direction how to store and display data in a simple way, so any interested researcher can fill the gap by using this method in any construction projects to store and data.

REFERENCE.

1. Amardeep S., Shahid, N., Manish, G. GIS applications in geotechnical engineering. International Journal of Latest trends in Engineering and Technology. 2015; 5(2): 36-42.
2. Parveen, C., Rajiv, C., Rajesh, K. Geotechnical data Analysis using GIS. International journal of interdisciplinary research and innovations. 2018; 6(2): 438-445.
3. Tsangaratos, K., & Rozos. GIS- based application for geotechnical data managing. Bulletin of the Geological Society of Greece. (2010); 43, 1656-1666
4. Yagya, S., Purohit, D., Sunil, S. Appcablity aspects of Geoinformatics in geotechnical engineering. American journal of engineering research. 2017; 6(10): 71-75.
5. Wubshet, H. Investigation on the engineering properties of soil in Burayu town. A theses submitted to Addis Ababa University. 2015;
6. Solomon, M. Investigation in to some of engineering properties of soil found in Debr brhan town. A theses submitted to Addis Ababa University. 2015;
7. Mastewal, G. Investigation in to some engineering properties of soils found in mojo. A theses submitted to Addis Ababa University. 2016;
8. Dagnachew, D. Investigation on some of engineering properties of soil found in adama city. A theses submitted to Addis Ababa University. 2011;
9. Behaylu, H. Ivestigation on some of engineering properties of soils found in Ambo town. A theses submitted to Addis Ababa University. 2014;
10. Yared, L. correlation of CBR value with soil index properties for Addis Ababa subgrade soils. 2013;
11. Arora, K.R., Soil Mechanics and Foundation Engineering. 6^{th} edition. New Delhi: Standard Publishers Distributors; 2004.
12. ASTM, Special Procedures for Testing Soil and Rock for Civil Engineering Purpose, U.S. America: 2004.
13. Bowls, J.K., Engineering properties of soil and their measurements. 2^{nd} edition. U.S. America: McGraw Hill Book Company; (1978).

14. Bowles, J.E., Foundation Analysis and Design. 5th edition. New York: McGraw-Hill Companies Inc.; (1996).
15. Giorgis K., T. A. and T. D., Estimating crop water use and simulating yield reduction for Maize and sorghum in Adama and Miesso districts using the crop wat model.
16. James K.M., Fundamentals of soil behavior. University of California Berkeley: John Wily& sons, Inc.; 1976.
17. Labib, M. Nashed, A. GIS and geotechnical mapping of expansive soil in Toshka region. Ain Shams Engineering Journal. 2013; 4(3): 423-433.
18. Murthy, V. N. S., Principles and Practices of Soil Mechanics and Foundation Engineering. New York: Marcel Dekker, Inc.; 1990.
19. Taylor R.M., Tropical Residual soils. London: The Quaternary Journal of Engineering Geology. 1990.
20. Punmia, B. C., soil mechanics and foundation Engineering, Bengaluru: Laxmi publications; 2008.
21. Teferra A., Estimation of settlement of rigid footing. Journal of the Ethiopian Association of Engineers and Architects (EAEA), Vol.6. 1984.
22. www.google.com
23. www.wikipidea.com

APPENDIXES

APPENDIX A:

Engineering Properties of Soils and their test results														
				Atterber limit test(%)			Percent ammount of particle				Free swell	Soil Classification	
Test Pits		Natural MC	Specific Gravity (G)	LL	PL	PI	Gravel	Sand	Silt	Clay		USCS	AASHTO
TP1	1.5m	9.60	2.56	29	22	7	24.78	52.23	17.62	5.37	18.0	SM	A-2-4
	3m	19.30	2.62	38	24	14	6.08	44.85	34.18	15.49	20.0	SM	A-4
TP2	1.5m	16.60	2.52	48	31	17	0.00	27.23	49.76	23.02	30.0	ML	A-7-5
	3m	27.62	2.57	48	35	13	0.64	14.48	54.31	30.57	50.0	ML	A-7-5
TP3	1.5m	27.16	2.53	49	24	25	9.54	33.59	28.70	28.17	50.0	CL	A-7-6
	3m	37.52	2.61	73	39	34	0.00	30.29	39.18	30.54	50.0	MH	A-7-6
TP4	1.5m	23.65	2.52	42	28	14	0.00	40.84	47.25	11.91	19.5	ML	A-5
	3m	21.16	2.55	39	30	9	4.32	26.93	47.92	20.83	20.0	ML	A-5
TP5	1.5m	15.45	2.46	47	32	15	2.03	20.91	60.72	16.33	50.0	ML	A-7-5
	3m	31.86	2.57	47	33	14	0.00	23.34	59.47	17.18	30.0	ML	A-7-5
TP6	1.5m	21.17	2.59	48	31	17	0.15	29.97	52.54	17.34	28.0	ML	A-7-5
	3m	14.06	2.62	29	21	8	13.80	47.14	31.19	5.87	30.0	SM	A-4
TP7	1.5m	15.81	2.48	41	30	11	0.00	33.00	52.01	14.99	30.0	ML	A-7-5
	3m	12.46	2.62	35	28	7	1.22	36.80	47.18	14.80	25.0	ML	A-4
TP8	1.5m	16.97	2.46	42	31	11	0.80	24.00	60.78	14.42	30.0	ML	A-7-5
	3m	15.21	2.63	31	24	7	0.00	36.34	49.90	13.76	40.0	ML	A-4
TP9	1.5m	35.30	2.46	52	35	17	0.61	31.52	36.25	31.62	30.0	MH	A-7-5
	3m	27.01	2.56	57	29	28	0.00	17.98	62.14	19.88	50.0	MH	A-7-6
TP10	1.5m	25.01	2.57	41	30	11	4.86	33.47	44.11	17.56	30.0	ML	A-4
	3m	25.44	2.57	30	25	5	1.22	54.60	33.15	11.02	20.0	SM	A-4

Engineering Properties of Soils and their test results														
				Atterber limit test(%)			Percent ammount of particle size				Free swell	Soil Classification	
Test Pits		Natural MC	Specific Gravity(G)	LL	PL	PI	Gravel	Sand	Silt	Clay		USCS	AASHTO
TP1	1.5m	30.7	2.76	114	31	83	0.00	3.10	32.14	64.76	115	CH	A-7-5(20)
	3m	32.5	2.75	109	35	73	0.00	4.30	33.45	62.25	110	CH	A-7-5(20)
TP2	1.5m	23.4	2.71	76	34	42	0.00	3.10	29.30	67.60	60	CH	A-7-5(20)
	3m	28.4	2.72	78	33	45	0.00	4.70	42.53	52.77	75	CH	A-7-5(20)
TP3	1.5m	33.0	2.68	99	32	67	0.00	3.70	43.17	53.13	125	CH	A-7-5(20)
	3m	39.6	2.69	93	38	55	0.00	4.40	37.79	57.81	90	CH	A-7-5(20)
TP4	1.5m	41.0	2.78	112	34	78	0.00	1.90	36.80	61.30	85	CH	A-7-5(20)
	3m	41.0	2.75	107	47	60	0.00	1.10	36.12	62.78	135	MH	A-7-5(20)
TP5	1.5m	30.2	2.51	112	37	75	15.30	2.60	23.30	58.80	95	CH	A-7-5(20)
	3m	35.1	2.66	113	47	66	8.40	1.90	31.70	58.00	155	MH	A-7-5(20)
TP6	1.5m	37.4	2.78	110	32	78	14.50	2.80	22.77	59.93	115	CH	A-7-5(20)
	3m	38.0	2.73	109	34	75	2.70	2.00	35.70	59.60	120	CH	A-7-5(20)
TP7	1.5m	31.1	2.69	73	42	31	4.10	11.10	54.39	30.41	50	MH	A-7-5(20)
	3m	31.2	2.67	64	34	30	5.00	13.20	53.81	27.99	35	MH	A-7-5(20)
TP8	1.5m	32.0	2.74	99	40	59	3.80	1.20	43.14	51.86	95	CH	A-7-5(20)
	3m	35.1	2.75	62	30	32	3.80	12.00	35.76	48.44	45	CH	A-7-5(20)
TP9	1.5m	37.8	2.72	101	33	68	4.00	3.40	39.90	52.70	105	CH	A-7-5(20)
	3m	40.7	2.74	114	40	74	4.00	3.40	39.90	52.70	100	CH	A-7-5(20)
TP10	1.5m	40.7	2.69	110	34	76	0.00	2.70	38.30	59.00	115	CH	A-7-5(20)
	3m	42.1	2.70	105	33	72	0.00	6.30	36.70	57.00	105	CH	A-7-5(20)

Engineering Properties of Soils and their test results														
				Atterber limit test(%)			Percent ammount of particle					Soil Classification	
Test Pits		Natural MC	Specific Gravity(G)	LL	PL	PI	Gravel	Sand	Silt	Clay	Free swell(%)	USCS	AASHTO
TP1	1.5m	32.4	2.79	68.9	32.4	36.5	0.80	16.70	18.7	63.7	47.5	CH	A-7-5
	3m	31.9	2.74	71.3	34.0	37.3	0.00	14.20	21.6	64.2	52.5	CH	A-7-5
TP2	1.5m	32.7	2.81	71.3	34.0	37.3	0.01	8.20	23.3	68.5	50.0	CH	A-7-5
	3m	33.6	2.78	69.1	32.7	36.4	0.00	7.90	19.9	72.2	52.5	CH	A-7-5
TP3	1.5m	32.9	2.82	70.8	33.0	37.8	0.70	13.30	28.3	57.7	40.0	CH	A-7-5
	3m	31.1	2.76	71.5	33.3	38.2	0.00	8.30	19.4	72.3	52.5	CH	A-7-5
TP4	1.5m	32.4	2.70	69.3	32.4	36.9	0.40	14.60	29.3	55.7	45.0	CH	A-7-5
	3m	31.5	2.74	73.4	34.1	39.3	0.00	5.20	22.8	72.0	48.0	CH	A-7-5
TP5	1.5m	30.8	2.73	71.0	33.1	37.9	0.00	2.80	34.1	63.1	53.0	CH	A-7-5
	3m	31.9	2.74	71.0	33.1	37.9	1.80	5.30	30.1	62.9	55.0	CH	A-7-5
TP6	2m	33.2	2.74	68.8	31.0	37.8	0.30	5.60	27.7	66.4	42.5	CH	A-7-5
TP7	2m	32.9	2.73	72.1	32.7	39.4	0.10	4.70	31.5	63.7	53.0	CH	A-7-5
TP8	2m	33.2	2.76	72.1	32.3	39.8	0.30	7.50	22.8	69.4	45.0	CH	A-7-5
TP9	1.5m	32.9	2.76	68.8	31.8	37.0	0.00	2.80	24.7	72.5	50.0	CH	A-7-5
	3m	33.7	2.81	70.3	32.1	38.2	0.00	3.60	23.6	72.8	55.0	CH	A-7-5
TP10	1.5m	31.8	2.79	70.7	32.7	38.0	0.10	3.70	25.0	71.3	52.5	CH	A-7-5
	3m	32.9	2.78	69.5	31.8	37.7	0.00	6.70	19.5	73.8	47.5	CH	A-7-5

Engineering Properties of Soils and their test results														
				Atterber limit test(%)			Percent ammount of particle				Free swell	Soil Classification	
Test Pits		Natural MC	Specific Gravity(G)	LL	PL	PI	Gravel	Sand	Silt	Clay		USCS	AASHTO
TP1	1.5m	33.9	2.72	73	33	40	0.35	2.84	29.31	67.50	80	CH	A-7-5
	3m	58.99	2.78	80	34	46	0.00	2.37	47.92	49.71	100	CH	A-7-6
TP2	1.5m	22.01	2.69	47	30	17	4.04	23.44	48.74	23.78	50	ML	A-7-5
	3m	24.27	2.70	43	29	14	1.68	34.11	55.44	8.77	55	ML	A-7-6
TP3	1.5m	30.02	2.81	66	28	38	0.11	14.03	42.41	43.45	70	CH	A-7-6
	3m	31.14	2.70	32	17	15	17.88	38.74	27.81	15.57	60	SC	A-6
TP4	1.5m	37.47	2.65	56	31	25	2.42	15.39	47.08	35.11	50	MH	A-7-5
	3m	23.62	2.62	44	29	15	0.43	33.23	48.53	17.81	50	ML	A-7-5
TP5	1.5m	32.85	2.78	77	34	43	1.31	7.91	41.72	49.06	95	CH	A-7-5
	3m	30.93	2.72	64	34	30	0.11	8.74	47.04	44.11	85	MH	A-7-5
TP6	1.5m	43.04	2.77	73	43	30	0.17	4.84	46.53	48.46	90	MH	A-7-5
	3m	46.96	2.74	60	28	32	1.45	7.39	47.23	43.93	85	CH	A-7-6
TP7	1.5m	31.49	2.73	70	32	38	0.03	7.26	36.24	56.47	80	CH	A-7-6
	3m	43.64	2.80	56	39	17	2.11	28.36	55.90	13.63	50	MH	A-7-5
TP8	1.5m	43.64	2.81	72	32	40	0.01	2.44	45.15	52.40	85	CH	A-7-5
	3m	40.48	2.77	48	22	26	0.05	17.27	35.08	47.60	70	CH	A-7-6
TP9	1.5m	25.55	2.78	47	25	22	1.46	20.70	43.07	34.77	45	CH	A-7-6
	3m	28.47	2.72	45	20	25	1.91	34.07	30.00	34.02	35	CH	A-7-6
TP10	1.5m	27.69	2.79	62	29	33	0.00	6.86	42.91	50.23	95	CH	A-7-6
	3m	20.11	2.81	41	30	11	24.63	37.02	27.28	11.07	50	SM	A-7-5
TP11	1.5m	33.8	2.71	58	29	29	0.00	15.40	39.55	45.05	75	CH	A-7-5
	3m	26.87	2.76	41	19	22	0.82	36.32	32.70	30.16	50	CH	A-7-6

Engineering Properties of Soils and their test results														
				Atterber limit test(%)			Percent ammount of particle					Soil Classification	
Test Pits		Natural MC	Specific Gravity (G)	LL	PL	PI	Gravel	Sand	Silt	Clay	Free swell	USCS	AASHTO
TP1	1.5m	28.24	2.63	82	39	43	0.68	14.76	60.48	24.08	50	MH	
	3m	25.87	2.68	76	40	36	9.35	15.63	51.07	23.95	45	MH	
TP2	1.5m												
	3m												
TP3	1.5m	31.56	2.69	63	32	31	0.46	19.12	69.15	69.15	35	MH	
	3m	5.29	2.64	29	18	11	4.98	95.03	0.00	0.00	25	SP	
TP4	1.5m	31.62	2.65	74	42	32	0.09	9.23	80.65	10.03	60	MH	
	3m	35.85	2.70	71	40	31	2.15	9.73	65.33	22.70	50	MH	
TP5	1.5m	25.94	2.64	82	49	33	3.72	13.69	54.97	27.62	55	MH	
	3m	32.18	2.67	85	50	35	0.00	11.17	58.77	30.06	45	MH	
TP6	1.5m	21.58	2.66	65	34	31	0.00	21.02	67.26	11.72	40	MH	
	3m	24.97	2.63	66	39	27	18.77	31.67	36.83	12.73	35	MH	
TP7	1.5m	24.96	2.65	77	41	36	0.00	5.77	70.62	23.61	20	MH	
	3m	23.88	2.67	49	30	18	0.00	6.11	66.26	27.63	50	ML	
TP8	1.5m	17.68	2.66	49	33	17	0.13	14.79	60.42	24.66	40	MH	
	3m	28.82	2.65	65	45	20	0.07	8.44	73.35	18.14	20	MH	
TP9	1.5m	27.77	2.62	72	49	27	6.22	13.86	50.27	29.65	40	MH	
	3m	29.49	2.63	87	48	40	4.04	11.97	56.20	27.79	40	MH	
TP10	1.5m	26.02	2.64	67	42	24	0.00	11.86	56.63	31.51	50	MH	
	3m	17.27	2.63	64	44	20	0.00	13.03	59.17	27.80	40	MH	

APPENDIX B:

Test Pit	Location	Northing	Easting	Elevation (m)
TP-1	Around Adama University (Gichi)	531856.00	945678.00	1653
TP-2	Kebele-12(Municipality)	529976.00	944650.00	1615
TP-3	Kebele-09 (Ketara)	528655.00	943297.00	1612
TP-4	Kebele-01 (Kechema)	529233.00	945691.00	1641
TP-5	Kebele-03 (Boku)	530258.00	941824.00	1598
TP-6	Kebele-05 (Cheffe)	527055.00	943485.00	1643
TP-7	Kebele-14 (Dibibisa)	531379.00	944277.00	1604
TP-8	Kebele-02 (Migira)	530640.00	942118.00	1603
TP-9	Kebele-04 (Sole)	530683.00	946375.00	1634
TP-10	Kebele-03 (Dabe)	531303.00	939312.00	1633

Serial No	Designation	Depth(m)	Specific Gravity Using		Water used for testing
			Method-A	Method-B	
1	TP-1-1	0.80-1.40	2.56	2.55	Tap water
2	TP-1-2	1.40-3.00	2.62	2.65	〃
3	TP-2-1	0.80-1.50	2.52	2.52	〃
4	TP-2-2	1.50-3.0	2.57	2.66	〃
5	TP-3-1	0.00-1.00	2.53	2.47	〃
6	TP-3-2	1.0-3.0	2.61	2.66	〃
7	TP-4-1	0.30-2.0	2.52	2.45	〃
8	TP-4-2	2.0-3.0	2.55	2.70	〃
9	TP-5-1	0.00-0.80	2.46	2.48	〃
10	TP-5-2	0.80-3.0	2.57	2.60	〃
11	TP-6-1	0.3-1.10	2.59	2.61	〃
12	TP-6-2	1.10-3.0	2.62	2.69	〃
13	TP-7-1	0.00-1,10	2.48	2.47	〃
14	TP-7-2	1.10-2.60	2.62	2.67	〃
15	TP-8-1	0.60-1.45	2.46	2.53	〃
16	TP-8-2	1.45-2.30	2.63	2.69	〃
17	TP-9-1	0.60-1.85	2.46	2.40	〃
18	TP-9-2	1.85-3.0	2.56	2.56	〃
19	TP-10-1	0.00-2.0	2.57	2.64	〃
20	TP-10-2	2.00-3.00	2.57	2.53	〃

Test pit	Depth	Liquid limit (%)		Ratio
		Oven dried	Air dried	
TP-03-2	1.0-2.8@2.60	60	73	82
TP-07-2	1.10-2.60	33	35	94
TP-08-2	1.45-2.30	31	31	100
TP-09-1	0.6-1.85	47	52	90
TP-09-2	1.85-3.0	56	57	98

Serial No	Designation	Depth(m)	Test condition	Free swell (%)	Water used for testing
1	TP-1-1	0.80-1.40	Oven dry	18	Tap water
2	TP-1-2	1.40-3.00	Oven dry	20	,,
3	TP-2-1	0.80-1.50	Oven dry	30	,,
4	TP-2-2	1.50-3.0	Oven dry	50	,,
5	TP-3-1	0.00-1.00	Oven dry	50	,,
6	TP-3-2	1.0-3.0	Oven dry	50	,,
7	TP-4-1	0.30-2.0	Oven dry	19.5	,,
8	TP-4-2	2.0-3.0	Oven dry	20	,,
9	TP-5-1	0.00-0.80	Oven dry	50	,,
10	TP-5-2	0.80-3.0	Oven dry	30	,,
11	TP-6-1	0.3-1.10	Oven dry	28	,,
12	TP-6-2	1.10-3.0	Oven dry	30	,,
13	TP-7-1	0.00-1,10	Oven dry	30	,,
14	TP-7-2	1.10-2.60	Oven dry	25	,,
15	TP-8-1	0.60-1.45	Oven dry	30	,,
16	TP-8-2	1.45-2.30	Oven dry	40	,,
17	TP-9-1	0.60-1.85	Oven dry	30	,,
18	TP-9-2	1.85-3.0	Oven dry	50	,,
19	TP-10-1	0.00-2.0	Oven dry	30	,,
20	TP-10-2	2.00-3.00	Oven dry	20	,,

Serial No	Designation	Depth(m)	MDD (g/cm3)	OMC (%)
1	TP-1-1	0.80-1.40	1.53	17.5
2	TP-1-2	1.40-3.00	-	-
3	TP-2-1	0.80-1.50	1.29	33
4	TP-2-2	1.50-3.0	1.47	23.5
5	TP-3-1	0.00-1.00	1.27	32
6	TP-3-2	1.0-3.0	1.37	26.75
7	TP-4-1	0.30-2.0	1.37	28.2
8	TP-4-2	2.0-3.0	1.52	23.5
9	TP-5-1	0.00-0.80	-	-
10	TP-5-2	0.80-3.0	1.33	31
11	TP-6-1	0.3-1.10	1.35	27
12	TP-6-2	1.10-3.0	1.62	20.2
13	TP-7-1	0.00-1,10	1.37	22.5
14	TP-7-2	1.10-2.60	1.47	26
15	TP-8-1	0.60-1.45	1.44	25.8
16	TP-8-2	1.45-2.30	1.44	29.25
17	TP-9-1	0.60-1.85	1.2	33.5
18	TP-9-2	1.85-3.0	1.26	36.5
19	TP-10-1	0.00-2.0	1.38	29.5
20	TP-10-2	2.00-3.00	1.44	22.5

Serial No	Designation	Depth(m)	Percent amount of particle size				LL (%)	PI (%)	Classification According to USCS
			Gravel	sand	silt	clay			
1	TP-1-1	0.80-1.40	24.78	52.23	17.62	5.37	28.50	0.00	SM
2	TP-1-2	1.40-3.00	6.08	44.85	34.18	15.49	37.50	13.18	SM
3	TP-2-1	0.30-1.50	0.00	27.23	49.76	23.02	48.10	17.18	ML
4	TP-2-2	1.50-3.0	0.64	14.48	54.31	30.57	47.8	13.04	ML
5	TP-3-1	0.00-1.00	9.54	33.59	28.70	28.17	49.00	24.95	CL
6	TP-3-2	1.0-3.0	0.00	30.29	39.18	30.54	72.8	33.94	MH
7	TP-4-1	0.30-2.0	0.00	40.84	47.25	11.91	41.8	9.50	ML
8	TP-4-2	2.0-3.0	0.00	40.84	47.25	11.91	39.1	9.04	ML
9	TP-5-1	0.00-0.80	2.03	20.91	60.72	16.33	47.4	15.29	ML
10	TP-5-2	0.80-3.0	0.00	23.34	59.47	17.18	46.50	13.36	ML
11	TP-6-1	0.3-1.10	0.15	29.97	52.54	17.34	48.10	17.18	ML
12	TP-6-2	1.10-3.0	13.80	47.14	31.19	5.87	28.70	8.14	SM
13	TP-7-1	0.00-1,10	0.00	33.00	52.01	14.99	41.3	10.91	ML
14	TP-7-2	1.10-2.60	1.22	36.80	47.18	14.80	34.65	7.00	ML
15	TP-8-1	0.60-1.45	0.80	24.00	60.78	14.42	41.8	11.14	ML
16	TP-8-2	1.45-2.30	0.00	36.34	49.90	13.76	30.8	6.98	ML
17	TP-9-1	0.60-1.85	0.61	31.52	36.25	31.62	52.40	17.77	MH
18	TP-9-2	1.85-3.0	0.00	17.98	62.14	19.88	57.40	26.00	MH
19	TP-10-1	0.00-2.0	4.86	33.47	44.11	17.56	40.00	10.00	ML
20	TP-10-2	2.00-3.00	1.22	54.60	33.15	11.02	30.28	4.97	SM

Serial No	Designation	Percent passing on sieve			LL (%)	PI (%)	Group index	Group classification	Usual types of significant constituent materials	General rating as sub-grade materials
		No. 10	No. 40	No. 200						
1	TP-1-1	65.67	49.97	28.27	28.50	0.00	0	A-2-4	Silty or clayey gravel and sand	Good!
2	TP-1-2	90.78	80.71	57.86	37.50	9.44	8(max)	A-4	Silty soils	Fair!
3	TP-2-1	99.39	96.53	80.61	48.10	17.18	20(max)	A-7-5	Clay soils	Poor!
4	TP-2-2	99.07	97.79	94.20	47.8	13.04	20(max)	A-7-5	Clay soils	Poor!
5	TP-3-1	87.55	82.02	61.55	49.00	24.95	20(max)	A-7-6	Clay soils	Poor!
6	TP-3-2	99.39	96.53	80.61	72.8	33.94	20(max)	A-7-6	Clay soils	Poor!
7	TP-4-1	98.60	89.80	67.20	41.8	**9.50**	12(max)	A-5	Silty soils	Fair!
8	TP-4-2	94.65	89.91	77.97	39.1	9.04	8(max)	A-5	Silty soils	Fair!
9	TP-5-1	95.73	91.87	84.76	47.4	15.29	20(max)	A-7-5	Clay soils	Poor!
10	TP-5-2	99.57	96.39	82.69	46.50	13.36	20(max)	A-7-5	Clay soils	Poor!
11	TP-6-1	99.45	95.86	82.51	48.10	17.18	20(max)	A-7-5	Clay soils	Poor!
12	TP-6-2	82.00	74.00	44.40	28.70	8.14	8(max)	A-4	Silty soils	Fair!
13	TP-7-1	99.39	92.06	71.08	41.3	10.91	20(max)	A-7-5	Clay soils	Poor!
14	TP-7-2	96.54	88.62	71.95	34.65	7.00	8(max)	A-4	Silty soils	Fair!
15	TP-8-1	98.80	92.60	75.20	41.8	11.14	20(max)	A-7-5	Clay soils	Poor!
16	TP-8-2	90.59	84.98	70.36	30.8	6.98	8(max)	A-4	Silty soils	Fair!
17	TP-9-1	96.11	85.66	71.31	52.40	17.77	20(max)	A-7-5	Clay soils	Poor!
18	TP-9-2	99.63	97.42	90.80	57.40	26.00	20(max)	A-7-6	Clay soils	Poor!
19	TP-10-1	93.66	87.32	69.77	40.00	10.00	8(max)	A-4	Silty soils	Fair!
20	TP-10-2	95.52	80.65	48.27	30.28	4.97	8(max)	A-4	Silty soils	Fair!

Test Pit Designation	Depth (m)	Natural Moisture Content (%)	Total Unit weight in (γ) kPa	Pressure P kPa	Void ratio e_f	Coefficient of Consolidation C_v 10^{-3} cm^2/sec	Compression Index C_c	Over-burden pressure Po (kPa)	Pre-consolidation pressure Pc (kPa)	Over-consolidation ratio (OCR)
				5	1.270	-				
				50	1.231	-				
				100	1.193	2.79				
TP-03-2	3	38	14.7	200	1.114	9.05	0.360	43.3	103	2.4
				400	1.007	9.05				
				800	0.889	1.87				
				1600	0.775	0.883				
				5	1.150	-				
				50	1.003	-				
				100	0.919	9.81				
TP-04-2	3	21	13.8	200	0.841	14.1	0.327	40.6	60	1.5
				400	0.763	9.05				
				800	0.687	7.48				
				1600	0.610	6.28				

Test Pit Designation	Depth (m)	Natural Moisture Content (%)	Total Unit weight in γ (kPa)	Pressure P kPa	Void ratio e_f	Coefficient of Consolidation C_v 10^{-3} cm^2/sec	Compression Index C_c	Over burden pressure Po (kPa)	Pre-consolidation pressure Pc (kPa)	Over consolidation ratio (OCR)
TP-05-2	3	32	13.4	5	1.222	-	0.335	39.4	50	1.3
				25	1.211	-				
				50	1.169	-				
				100	1.077	9.050				
				200	0.974	11.70				
				400	0.858	9.050				
				800	0.761	5.350				
				1600	0.659	4.610				
TP-09-2	3	27	14.0	5	1.326	-	0.399	41.2	70	1.7
				50	1.119	-				
				100	0.999	-				
				200	0.879	0.513				
				400	0.739	1.340				
				800	0.625	0.883				
				1600	0.529	0.427				

Test Pit Designation	Depth (m)	Pressure P kPa	Void ratio e_f	Coefficient of consolidation C_v 10^{-3} cm^2/sec	Coefficient of compressibility a_v 10^{-5} cm^2/KN	Coefficient of permeability k 10^{-8} cm/sec
TP-03-2	3.0	100	1.193	2.79	78.50	9.98
		200	1.114	9.05	66.72	28.57
		400	1.007	9.05	40.00	18.04
		800	0.889	1.87	30.00	2.97
		1600	0.775	0.883	12.45	0.62
TP-04-2	3.0	100	0.919	9.81	107.81	55.12
		200	0.841	14.1	70.00	53.60
		400	0.763	9.05	50.00	25.67
		800	0.687	7.48	10.00	4.43
		1600	0.610	6.28	3.55	1.38
TP-05-2	3.0	100	1.077	9.05	130.00	56.66
		200	0.974	11.7	88.00	52.16
		400	0.858	9.05	40.00	19.48
		800	0.761	5.35	20.00	6.08
		1600	0.659	4.61	10.35	2.88
TP-09-2	3.0	100	0.999	-	-	-
		200	0.879	0.513	99.5	2.72
		400	0.739	1.34	50	3.85
		800	0.625	0.883	15	0.82
		1600	0.529	0.427	10.64	0.30

Test Pit Designation	Depth (m)	Effective stress s' (KN/m²)	Total compression ΔH (mm)	Relative settlement s' = ΔH/H	Modulus of compressibility KN/m²
TP-03-2	3.0	5	0.000	0.000	4910
TP-03-2	3.0	50	0.352	0.018	4910
TP-03-2	3.0	100	0.689	0.034	4910
TP-03-2	3.0	200	1.408	0.070	4910
TP-03-2	3.0	400	2.366	0.118	4910
TP-03-2	3.0	800	3.431	0.172	4910
TP-03-2	3.0	1600	4.454	0.223	4910
TP-04-2	3.0	5	0.000	0.000	7512
TP-04-2	3.0	50	1.324	0.066	7512
TP-04-2	3.0	100	2.080	0.104	7512
TP-04-2	3.0	200	2.779	0.139	7512
TP-04-2	3.0	400	3.483	0.174	7512
TP-04-2	3.0	800	4.171	0.209	7512
TP-04-2	3.0	1600	4.860	0.243	7512
TP-05-2	3.0	5	0.000	0.000	4651
TP-05-2	3.0	25	0.139	0.007	4651
TP-05-2	3.0	50	0.516	0.026	4651
TP-05-2	3.0	100	1.349	0.067	4651
TP-05-2	3.0	200	2.272	0.114	4651
TP-05-2	3.0	400	3.315	0.166	4651
TP-05-2	3.0	800	4.191	0.210	4651
TP-05-2	3.0	1600	5.104	0.255	4651
TP-09-2	3.0	5	0.000	0.000	3680
TP-09-2	3.0	50	1.863	0.093	3680
TP-09-2	3.0	100	2.939	0.147	3680
TP-09-2	3.0	200	4.019	0.201	3680

Test Pit Designation	Depth (m)	υ kN/m2	w	Modulus of compressibility, Es KN/m²
TP-03-2	3.0	850	1.0	850(σ′)
TP-04-2	3.0	437	1.0	437(σ′)
TP-05-2	3.0	536	1.0	536(σ′)
TP-09-2	3.0	2396	1.0	2396(σ′)

Sample No.	TP-03-2	TP-04-2	TP-05-2	TP-09-2
Depth (m)	3.0	3.0	3.0	3.0
σ'	Es kN/m2	Es kN/m2	Es kN/m2	Es kN/m2
0	0	0	0	0
100	85000	43700	53600	239600
200	170000	87400	107200	479200
300	255000	131100	160800	718800
400	340000	174800	214400	958400
500	425000	218500	268000	1198000
600	510000	262200	321600	1437600
700	595000	305900	375200	1677200
800	680000	349600	428800	1916800
900	765000	393300	482400	2156400
1000	850000	437000	536000	2396000
1100	935000	480700	589600	2635600
1200	1020000	524400	643200	2875200
1300	1105000	568100	696800	3114800
1400	1190000	611800	750400	3354400
1500	1275000	655500	804000	3594000
1600	1360000	699200	857600	3833600

APPENDIX C:

Some important tables from Behailu Hunde's theses. Ambo town

Sample description	Location	GPS Data (UTM)		
		Easting	Northing	Elevation(m)
TP-1	Awura Godana	0375750	0992890	2140
TP-2	Ambo Hospital #2	0371902	0993733	2081
TP-3	Kes Amba	0373732	0992359	2106
TP-4	Kidane Mihret	0373351	0992489	2117
TP-5	Catholic church	0373872	0991665	2133
TP-6	Kisose	0376221	0993351	2152
TP-7	Bole	0375580	0993272	2135
TP-8	Stadium	0374783	0992998	2128
TP-9	Cheri	0374765	0993261	2119
Tp-10	Awaro	0378409	0991058	2108

Location	Depth	Color	Free swell (%)
Awra Godana	1.5	Black	115
	3	Black	110
Ambo Hospital#2	1.5	Reddish brown	60
	3	brown	75
Kes Amba	1.5	Black	125
	3	Gray	90
Kidane Mihret	1.5	Gray	120
	3	Yellowish gray	85
Catholic Church	1.5	Black	135
	3	Gray	95
Kisose	1.5	Black	155
	3	Gray	115
Bole	0.8	Black	120
	1.5	Yellowish brown	50
	2.5	Yellowish brown	35
Stadium	1.5	Gray	95
	3	Reddish brown	45
Cheri	1.5	Black	105
	3	Gray	100
Awaro	1.5	Black	115
	3	Black	105

Table 5.2 USCS classification for soils of the study area

Location	Depth	Wl (%)	Pl (%)	Classification
Awura Godana	1.5	114	83	CH
	3	109	73	CH
Ambo Hospital	1.5	76	42	CH
	3	78	45	CH
Kes Amba	1.5	99	67	CH
	3	93	38	CH
Kidane Mihret	1.5	112	78	CH
	3	107	60	MH
Catholic church	1.5	112	75	CH
	3	113	66	MH
Kisose	1.5	110	78	CH
	3	109	75	CH
Bole	0.8	107	75	CH
	1.5	73	31	MH
	2.5	64	30	MH
Stadium	1.5	99	59	CH
	3	62	32	CH
Cheri	1.5	101	68	CH
	3	114	74	CH
Awaro	1.5	110	76	CH
	3	105	72	CH

S/N	Activity	Soil type
1	<0.75	In active
2	0.75-1.25	Normal
3	>1.25	Active

Consistency	q_u (kN/m²)
Very soft	<25
Soft	25-50
Medium	50-100
Stiff	100-200
Very stiff	200-400
Hard	>400

Location	Test pit	Depth (m)	UCS (kN/m²)	W (%)	Consistency
Hospital #2	TP-2	3	545.00	28.40	Hard
Kidane Mihret	TP-4	1.5	127.53	41	Stiff
		3	151.09	41	Stiff
Kisose	TP-6	1.5	128.53	37.4	Stiff
		3	179.18	38	Stiff
Stadium	TP-8	1.5	530.22	32	Hard
		3	385.00	35.1	Very stiff
Cheri	TP-9	1.5	147.43	37.8	Stiff
		3	112.00	40.7	Stiff

Test pit	Depth (m)	Total unit weight (kN/m^3)	Over burden pressure (kPa)	Compression index	Preconsolidation pressure (kPa)	Swelling pressure (kPa)	Over consolidation ratio
TP-4	3	16.5	49.5	0.355	150	100	3.03
TP-9	3	19.2	57.6	0.358	225	80	3.90

Table 6.4 consolidation coefficients of soils of the study area

Location	Depth (m)	Pressure (kPa)	Void ratio	Coefficient of consolidation, Cv (10^{-3}cm^2/sec)
TP-4	3	50	1.36	1.22
		100	1.33	1.42
		200	1.28	1.63
		400	1.2	1.06
		800	1.12	0.93
		1600	1.01	0.5
T9-9	3	50	1.31	2.14
		100	1.29	2.65
		200	1.24	1.21
		400	1.18	1.06
		800	1.09	0.98
		1600	0.98	0.88

APPENDIX D:

Some important tables from Wubshet Hirphasa's theses. Burayu town

Table 4.1: Global coordinates of sampling areas

Test Pit	Location	Northing	Easting	Elevation(m)
TP-1	Gefersa Buryau	457922	1004419	2524
TP-2	Buryau keta	462512	1004200	2547
TP-3	Gefersa Guji	460044	1001363	2615
TP-4	Gefersa Guji	456788	1000991	2627
TP-5	Gefersa Nono	461502	997341	2647
TP-6	Gefersa Nono	458443	998377	2637
TP-7	Melka Gefersa	465636	998303	2536
TP-8	Melka Gefersa	464349	997057	2500
TP-9	Leku keta	465229	1001703	2595
TP-10	Leku keta	462950	1000055	2619

Table 4.6: Free swell test results

Test Pit	Depth	Free Swell (%)	Test Condition
TP-1	1.5m	47.5	Oven Dry
	3.0m	52.5	"
TP-2	1.5m	50	"
	3.0m	52.5	"
TP-3	1.5m	40	"
	3.0m	52.5	"
TP-4	1.5m	45	"
	3.0m	48	"
TP-5	1.5m	53	"
	3.0m	55	"
TP-6	2.0m	42.5	"
TP-7	2.0m	53	"
TP-8	2.0m	45	"
TP-9	1.5m	50	"
	3.0m	55	"
TP-10	1.5m	52.5	"
	3.0m	47.5	"

Table 4.10: Activity of the soil in the study area

Test Pit	Depth	PI	Clay fraction %	A=PI/C	Remark
TP-1	1.5m	36.5	55.62	0.66	Inactive
	3.0m	37.3	55.72	0.67	Inactive
TP-2	1.5m	39.5	59.25	0.67	Inactive
	3.0m	36.4	62.80	0.58	Inactive
TP-3	1.5m	37.8	47.03	0.80	Normal
	3.0m	38.2	62.22	0.61	Inactive
TP-4	1.5m	36.9	44.92	0.82	Normal
	3.0m	39.3	61.57	0.64	Inactive
TP-5	1.5m	37.9	53.91	0.70	Inactive
	3.0m	35.5	54.09	0.66	Inactive
TP-6	2.0m	37.8	58.99	0.64	Inactive
TP-7	2.0m	39.4	53.15	0.74	Inactive
TP-8	2.0m	39.8	60.63	0.66	Inactive
TP-9	1.5m	37.0	63.35	0.58	Inactive
	3.0m	38.2	62.29	0.61	Inactive
TP-10	1.5m	38.0	62.31	0.61	Inactive
	3.0m	37.7	63.60	0.59	Inactive

Test Pit	Depth (m)	OMC (%)	MDD (g/cm3)
TP-1	3.0m	30.4	1.33
TP-2	3.0m	30.5	1.31
TP-3	3.0m	33.8	1.38
TP-5	3.0m	35.0	1.37
TP-7	2.0m	32.1	1.32
TP-9	3.0m	31.9	1.35

Table 4.12: Unconfined Compressive Strength of soils of the study area

Test Pit	**Depth (m)**	**Water content (%)**	**UCS (kN/m^2)**	**Liquidity Index (L_I)**	**Consistency***
TP-3	3.0m	31.1	465.18	-0.06	Hard
TP-4	3.0m	31.4	372.82	-0.07	Hard
TP-5	3.0m	31.9	328.88	0.04	Hard
TP-9	3.0m	33.7	306.68	0.04	Hard

Table 4.13: Preconsolidation and swelling pressure test results of soils of Burayu town

Test pit	Depth (m)	Total unit weight (kN/m^3)	Overburden pressure, Po (Kpa)	Compression index (Cc)	Preconsolidation Pressure, Pc (Kpa)	Swelling Pressure (KPa)	Over consolidation ratio
TP-3	3	19.8	59.4	0.099	150	20	2.53
TP-7	2	18.4	36.8	0.133	200	25	5.44

Table 4.14: Consolidation coefficients of soils of the study area

Location	Test Pit No.	Depth(m)	Pressure (kPa)	Void ratio (e)	Coefficient of Consolidation Cv ($10^{-3}cm^2/sec$)
Gefersa Guji	TP-3	3	50	0.95	2.20
			100	0.93	1.90
			200	0.90	1.69
			400	0.87	1.57
			800	0.84	1.25
			1600	0.80	1.05
Melka Gefersa	TP-7	2	50	1.01	2.49
			100	0.98	2.15
			200	0.94	1.72
			400	0.84	1.35
			800	0.72	1.03
			1600	0.59	0.84

Table 4.15: Relationship between Void ratio and coefficient of permeability

Depth(m)	Pressure (kPa)	Void ratio (e)	Coefficient of Consolidation, Cv ($10^{-3}cm^2/sec$)	Coefficient of Compressibility, a_v ($10^{-5}cm^2/KN$)	Coefficient of permeability, k ($10^{-8}cm/sec$)
3	50	0.95	2.20	36	4.06
	100	0.93	1.90	28	2.76
	200	0.90	1.69	16	1.42
	400	0.87	1.57	14	1.18
	800	0.84	1.25	10	0.68
	1600	0.80	1.05	7	0.41
2	50	1.01	2.49	56	6.94
	100	0.98	2.15	39	4.23
	200	0.94	1.72	43	3.81
	400	0.84	1.35	31	2.27
	800	0.72	1.03	20	1.20
	1600	0.59	0.84	17.5	0.92

Table 5.1: Comparison of Test Results in different parts of Addis Ababa town

Description	**Previous Research (Samuel.T,1989)**	**Previous Research (Samuel.T,1989)**	**Previous Research (Samuel.T,1989)**	**Current Research**
Soil Type	Red clay	Red Clay	Red Clay	Red Clay
Location	Kolfe	Rufael	Semen Gebeya	Burayu
Clay Content	58-70	50-70	53-68	56-74
Activity	<0.75	<0.75	<0.75	<0.75
Liquid Limit	61-75	56 -75	57-76	66-72
Plastic Limit	28-33	27-34	24-31	31-34
Plastic Index	30-43	29-41	33-47	36-40
Specific	2.66-2.73	2.66-2.74	2.70-2.77	2.70-2.82
Soil	CH	CH	CH	CH
Free Swell	15-45	30-40	15-50	40-55

Table 4.8: Classification of soil based on AASHTO

Test Pit	Depth	percent Amount Of particle size				LL (%)	PI (%)	Classification according to AASHTO	Usual types of significant constituent materials
		Gravel	Sand	Silt	Clay				
TP-1	1.5m	0.8	16.7	18.7	63.7	68.9	36.5	A-7-5	Clayey soil
	3.0m	0	14.2	21.6	64.2	71.3	37.3	A-7-5	Clayey soil
TP-2	1.5m	0	8.2	23.3	68.5	71.9	39.5	A-7-5	Clayey soil
	3.0m	0	7.9	19.9	72.2	69.1	36.4	A-7-5	Clayey soil
TP-3	1.5m	0.7	13.3	28.3	57.7	70.8	37.8	A-7-5	Clayey soil
	3.0m	0	8.3	19.4	72.3	71.5	38.2	A-7-5	Clayey soil
TP-4	1.5m	0.4	14.6	29.3	55.7	69.3	36.9	A-7-5	Clayey soil
	3.0m	0	5.2	22.8	72.0	73.4	39.3	A-7-5	Clayey soil
TP-5	1.5m	0	2.8	34.1	63.1	71.0	37.9	A-7-5	Clayey soil
	3.0m	1.8	5.3	41.7	51.2	66.1	35.5	A-7-5	Clayey soil
TP-6	2.0m	0.33	5.57	27.72	66.3	68.8	37.8	A-7-5	Clayey soil
TP-7	2.0m	0.1	4.7	31.5	63.7	72.1	39.4	A-7-5	Clayey soil
TP-8	2.0m	0.34	7.5	22.8	69.4	72.1	39.8	A-7-5	Clayey soil
TP-9	1.5m	0	2.79	24.7	72.5	68.8	37.0	A-7-5	Clayey soil
	3.0m	0	3.6	23.6	72.8	70.3	38.2	A-7-5	Clayey soil
TP-10	1.5m	0.1	3.7	25.0	71.3	70.7	38.0	A-7-5	Clayey soil
	3.0m	0	6.7	19.5	73.8	69.5	37.7	A-7-5	Clayey soil

Table 4.9: Liquidity index of the study area

Test Pit	Depth	NMC (%)	Plastic Limit	Plasticity Index	Liquidity Index	Remark
TP-1	1.5m	32.4	32.4	36.5	0.00	very stiff state
	3.0m	31.9	34.0	37.3	-0.06	solid state
TP-2	1.5m	32.7	32.4	39.5	0.01	plastic state
	3.0m	33.6	32.7	36.4	0.02	plastic state
TP-3	1.5m	32.9	33.0	37.8	0.00	plastic state
	3.0m	31.1	33.3	38.2	-0.06	solid state
TP-4	1.5m	32.4	32.4	36.9	0.00	very stiff state
	3.0m	31.5	34.1	39.3	-0.07	solid state
TP-5	1.5m	30.8	33.1	37.9	-0.06	solid state
	3.0m	31.9	30.6	35.5	0.04	plastic state
TP-6	2.0m	33.2	31.0	38.7	0.06	plastic state
TP-7	2.0m	32.9	32.7	39.4	0.01	plastic state
TP-8	2.0m	33.2	32.3	39.8	0.02	plastic state
TP-9	1.5m	32.9	31.8	37.0	0.03	plastic state
	3.0m	33.7	32.1	38.2	0.04	plastic state
TP-10	1.5m	31.8	32.7	38.0	-0.02	solid state
	3.0m	32.9	31.8	37.7	0.03	plastic state

Table 4.10: Activity of the soil in the study area

Test Pit	Depth	PI	Clay fraction %	A=PI/C	Remark
TP-1	1.5m	36.5	55.62	0.66	Inactive
	3.0m	37.3	55.72	0.67	Inactive
TP-2	1.5m	39.5	59.25	0.67	Inactive
	3.0m	36.4	62.80	0.58	Inactive
TP-3	1.5m	37.8	47.03	0.80	Normal
	3.0m	38.2	62.22	0.61	Inactive
TP-4	1.5m	36.9	44.92	0.82	Normal
	3.0m	39.3	61.57	0.64	Inactive
TP-5	1.5m	37.9	53.91	0.70	Inactive
	3.0m	35.5	54.09	0.66	Inactive
TP-6	2.0m	37.8	58.99	0.64	Inactive
TP-7	2.0m	39.4	53.15	0.74	Inactive
TP-8	2.0m	39.8	60.63	0.66	Inactive
TP-9	1.5m	37.0	63.35	0.58	Inactive
	3.0m	38.2	62.29	0.61	Inactive
TP-10	1.5m	38.0	62.31	0.61	Inactive
	3.0m	37.7	63.60	0.59	Inactive

Table 4.11: Summary of Standard Compaction Test Result for selected soil sample

Test Pit	Depth (m)	OMC (%)	MDD (g/cm3)
TP-1	3.0m	30.4	1.33
TP-2	3.0m	30.5	1.31
TP-3	3.0m	33.8	1.38
TP-5	3.0m	35.0	1.37
TP-7	2.0m	32.1	1.32
TP-9	3.0m	31.9	1.35

Table 4.12: Unconfined Compressive Strength of soils of the study area

Test Pit	Depth (m)	Water content (%)	UCS (kN/m^2)	Liquidity Index (L_I)	Consistency*
TP-3	3.0m	31.1	465.18	-0.06	Hard
TP-4	3.0m	31.4	372.82	-0.07	Hard
TP-5	3.0m	31.9	328.88	0.04	Hard
TP-9	3.0m	33.7	306.68	0.04	Hard

Table 4.13: Preconsolidation and swelling pressure test results of soils of Burayu town

Test pit	Depth (m)	Total unit weight (kN/m^3)	Overburden pressure, Po (Kpa)	Compression index (Cc)	Preconsolidation Pressure, Pc (Kpa)	Swelling Pressure (KPa)	Over consolidation ratio
TP-3	3	19.8	59.4	0.099	150	20	2.53
TP-7	2	18.4	36.8	0.133	200	25	5.44

Table 4.14: Consolidation coefficients of soils of the study area

Location	Test Pit No.	Depth(m)	Pressure (kPa)	Void ratio (e)	Coefficient of Consolidation Cv ($10^{-3}cm^2/sec$)
Gefersa Guji	TP-3	3	50	0.95	2.20
			100	0.93	1.90
			200	0.90	1.69
			400	0.87	1.57
			800	0.84	1.25
			1600	0.80	1.05
Melka Gefersa	TP-7	2	50	1.01	2.49
			100	0.98	2.15
			200	0.94	1.72
			400	0.84	1.35
			800	0.72	1.03
			1600	0.59	0.84

Table 4.15: Relationship between Void ratio and coefficient of permeability

Depth(m)	Pressure (kPa)	Void ratio (e)	Coefficient of Consolidation, Cv ($10^{-3}cm^2/sec$)	Coefficient of Compressibility, a_v ($10^{-5}cm^2/KN$)	Coefficient of permeability, k ($10^{-8}cm/sec$)
3	50	0.95	2.20	36	4.06
	100	0.93	1.90	28	2.76
	200	0.90	1.69	16	1.42
	400	0.87	1.57	14	1.18
	800	0.84	1.25	10	0.68
	1600	0.80	1.05	7	0.41
2	50	1.01	2.49	56	6.94
	100	0.98	2.15	39	4.23
	200	0.94	1.72	43	3.81
	400	0.84	1.35	31	2.27
	800	0.72	1.03	20	1.20
	1600	0.59	0.84	17.5	0.92

Table 5.1: Comparison of Test Results in different parts of Addis Ababa town

Description	**Previous Research (Samuel.T,1989)**	**Previous Research (Samuel.T,1989)**	**Previous Research (Samuel.T,1989)**	**Current Research**
Soil Type	Red clay	Red Clay	Red Clay	Red Clay
Location	Kolfe	Rufael	Semen Gebeya	Burayu
Clay Content	58-70	50-70	53-68	56-74
Activity	<0.75	<0.75	<0.75	<0.75
Liquid Limit	61-75	56 -75	57-76	66-72
Plastic Limit	28-33	27-34	24-31	31-34
Plastic Index	30-43	29-41	33-47	36-40
Specific	2.66-2.73	2.66-2.74	2.70-2.77	2.70-2.82
Soil	CH	CH	CH	CH
Free Swell	15-45	30-40	15-50	40-55