Soil Testing and Analysis on Two Different Soil Samples

By:

Utkarsh Sood: 101631

Supervisor: Mr. Chandra Pal Gautam

May-2015

Submitted in partial fulfillment of the Degree of

Bachelor of Technology

DEPARTMENT OF CIVIL ENGINEERING
JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY
WAKNAGHAT-173234 DIST. SOLAN, HIMACHAL PRADESH

CONTENTS

CERTIFICATE

This is to certify that the work entitled, **"Soil Testing and Analysis on Two Different Soil Samples"** submitted by **Utkarsh Sood** in partial fulfillment for the award of degree of Bachelor of technology in Department of Civil Engineering, Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Prof. Dr. Ashok Kumar Gupta

Professor and Head

Department of Civil Engineering

JUIT

Mr. Chandra Pal Gautam

Assistant Professor

(Project Supervisor)

Department of Civil Engineering

JUIT

ACKNOWLEDGMENT

I would like to express outmost gratitude to **Dr. Ashok Kumar Gupta,** (HOD Department of Civil Engineering)Jaypee University of Information technology for providing me the opportunity to do this project and learn various techniques.

I am very fortunate to be blessed with the guidance and encouragement of **Mr. Chandra Pal Gautam** and other teachers.

I would like to express special gratitude and thanks to lab assistant Mr. Manvendra Singh for giving me such attention and time.

Utkarsh Sood

SUMMARY

Experimental work done:

- Excavation and collection of two different soil samples from Punjab and Himachal respectively.
- Set of experiments performed on both the samples separately.
- Calculations and record of observations.
- Computation of results for both the samples.
- Tabular comparison of both samples.

Chapter 1

Introduction

Geotechnical Engineering and Foundation Engineering are disciplines covered in civil or structural engineering programs and they involve how small, medium or large-scale manmade structures are supported by and interact with soil. It includes knowledge of soil mechanics and numerical analyses along with material and soil testing. The tests on soil may be done In-Lab or onsite i.e. in-situ or ex-situ.

Soil testing and analyses is a part of geotechnical engineering and foundation engineering which is concerned with the engineering behavior of earth materials, especially soil. Geotechnical engineering is important in civil engineering, but also has applications in military, mining, petroleum and other engineering disciplines that are concerned with construction occurring on the surface or within the ground. Geotechnical engineering uses principles of soil mechanics and rock mechanics to investigate subsurface conditions and materials; determine the relevant physical/mechanical and chemical properties of these materials; evaluate stability of natural slopes and man-made soil deposits; assess risks posed by site conditions; design earth works and structure foundations; and monitor site conditions, earthwork and foundation construction.

A typical geotechnical engineering project begins with a review of project needs to define the required material properties. Then follows a site investigation of soil, rock, fault distribution and bedrock properties on and below an area of interest to determine their engineering properties including how they will interact with, on or in a proposed construction. Site investigations are needed to gain an understanding of the area in or on which the engineering will take place. Investigations can include the assessment of the risk to humans, property and the environment from natural hazards such as earthquakes, landslides, sinkholes, soil liquefaction, debris flows and rock falls.

Ground Improvement refers to a technique that improves the engineering properties of the soil mass treated. Usually, the properties that are modified are shear strength, stiffness and permeability. Ground improvement has developed into a sophisticated tool to support foundations for a wide variety of structures. Properly applied, i.e. after giving due consideration to the nature of the ground being improved and the type and sensitivity of the structures being built, ground improvement often reduces direct costs and saves time.

A geotechnical engineer then determines and designs the type of foundations, earthworks, and/or pavement sub grades required for the intended man-made structures to be built. Foundations are designed and constructed for 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.

Foundations built for above-ground structures include shallow and deep foundations. Retaining structures include earth-filled dams and retaining walls. Earthworks include embankments, tunnels, dikes and levees, channels, reservoirs, deposition of hazardous waste and sanitary landfills.

Geotechnical engineering is also related to coastal and ocean engineering. Coastal engineering can involve the design and construction of wharves, marinas, and jetties. Ocean engineering can involve foundation and anchor systems for offshore structures such as oil platforms.

History of use of soils for various purposes:

Humans have historically used soil as a material for flood control, irrigation purposes, burial sites, building foundations, and as construction material for buildings. First activities were linked to irrigation and flood control, as demonstrated by traces of dykes, dams, and canals dating back to at least 2000 BCE that were found in ancient Egypt, ancient Mesopotamia and the Fertile Crescent, as well as around the early settlements of Mohan jo Daro and Harappa in the Indus valley. As the cities expanded, structures were erected, supported by formalized foundations; Ancient Greeks notably constructed pad footings and strip-and-raft foundations. Until the 18th century, however, no theoretical basis for soil design had been developed and the discipline was more of an art than a science, relying on past experience.

Several foundation-related engineering problems, such as the Leaning Tower of Pisa, prompted scientists to begin taking a more scientific-based approach to examining the subsurface. The earliest advances occurred in the development of earth pressure theories for the construction of retaining walls. Henri Gautier, a French Royal Engineer, recognized the "natural slope" of different soils in 1717, an idea later known as the soil's angle of repose. A rudimentary soil classification system was also developed based on a material's unit weight, which is no longer considered a good indication of soil type.

The application of the principles of mechanics to soils was documented as early as 1773 when Charles Coulomb (a physicist, engineer, and army Captain) developed improved methods to determine the earth pressures against military ramparts. Coulomb observed that at failure, a distinct slip plane would form behind a sliding retaining wall and he suggested that the maximum shear stress on the slip plane, for design purposes, was the sum of the soil cohesion, c, and friction $\sigma \tan(\phi)$, where σ is the normal stress on the slip plane and ϕ is the friction angle of the soil. By combining Coulomb's theory with Christian Otto Mohr's 2D stress state, the theory became known as Mohr-Coulomb theory. Although it is now recognized that precise determination of cohesion is impossible because c is not a fundamental soil property, the Mohr-Coulomb theory is still used in practice today.

In the 19th century Henry Darcy developed what is now known as Darcy's Law describing the flow of fluids in porous media. Joseph Boussinesq (a mathematician and physicist) developed theories of stress distribution in elastic solids that proved useful for estimating stresses at depth in the ground; William Rankine, an engineer and physicist, developed an alternative to Coulomb's earth pressure theory. Albert Atterberg developed the clay consistency indices that are still used today for soil classification. Osborne Reynolds recognized in 1885 that shearing causes volumetric dilation of dense and contraction of loose granular materials.

Modern geotechnical engineering is said to have begun in 1925 with the publication of Erdbaumechanik by Karl Terzaghi (a mechanical engineer and geologist), considered by many to be the father of modern soil mechanics and geotechnical engineering, Terzaghi developed the principle of effective stress, and demonstrated that the shear strength of soil is controlled by effective stress. Terzaghi also developed the framework for theories of bearing capacity of foundations, and the theory for prediction of the rate of settlement of clay layers due to consolidation. In his 1948 book, Donald Taylor recognized that interlocking and dilation of densely packed particles contributed to the peak strength of a soil. The interrelationships between volume change behavior (dilation, contraction, and consolidation) and shearing behavior were all connected via the theory of plasticity using critical state soil mechanics by Roscoe, Schofield, and Wroth with the publication of "On the Yielding of Soils" in 1958. Critical state soil mechanics is the basis for many contemporary advanced constitutive models describing the behavior of soil.

Geotechnical centrifuge modeling is a method of testing physical scale models of geotechnical problems. The use of a centrifuge enhances the similarity of the scale model tests involving soil because the strength and stiffness of soil is very sensitive to the confining pressure. The centrifugal acceleration allows a researcher to obtain large (prototype-scale) stresses in small physical models. [1]

Civil engineering problems related to soils:

The proper functioning of the structure depends critically on the success of the foundation element resting on the subsoil. Since the soil is in direct contact with the structure, it acts an a medium of load transfer and hence for any analysis of forces acting on such structure, one has to consider the aspect of various features the soil exhibits. The soil is the most important yet most neglected in a construction project. All structures, buildings, roads, bridges, dams and even life itself is based on the soil. The soil is the natural foundation that supports all structures and investment.

Soil test helps to determine varying physical and chemical characteristic of soil, which can vary from place to place and from layer to layer even within the limits of the proposed structure. Soil characteristics can change considerably within a small area. Weather, climatic changes, and site management can in the future affect the bearing qualities of the soil, if the foundation is not designed properly to the bearing capacity of the soil, then they will fail and so will the building. This is as important as the entire project itself that may cause long term complications and may result to loss of life and property, endanger residents, tenants and damage other neighboring properties. The extent of exploration depends on whether the area is built up or not and size of the structure.

The soil investigation help to determine the following: bearing capacity of the soil which determine the load sustenance capability of the soil, rate of settlement of the soil which affect the rate at which any structure placed on it settles, to select a type and depth of foundation, to select suitable construction technique , to predict and resolve probable foundation problems, to determine if the land can be subjected to subsidence and cause sinking of the building, to determine water table which affects humidity within the foundation and greatly affects the character of a soil which varies considerably with water content, mineral or chemical component of the soil that might affect the choice of construction materials. For example if the soil found to contain sulphur it can attack our foundation, therefore sulphur resisting cement must be used in the foundation in such soil.

Whether we are working in peat, gravel, clay, silt, sand, or loam soil, understanding the soil properties of your site help you make good construction decisions leading to success of the project. The structural engineers can efficiently and accurately design the structural elements required based on the results of the soil test analysis so that for long term viability and soundness of the project. The result also helps to determine whether there is need for soil stabilization and the foundation depth to attain the required bearing capacity.

How to make sure land is suitable for home site's planned use:

Potential problems and costly mistakes can be avoided by the homeowner and contractor if a study of the soil and site characteristics at the site is made before construction begins or before a house is purchased.

Are the soil properties favorable for establishing and maintaining lawns, shrubs, trees, and gardens without extensive and expensive soil modifications?

Is there a flood hazard? (Is the site on a floodplain?)

Are there soil factors that prevent or limit the soil's use for septic tank absorption fields or sewage lagoons (if public sewer system is not available)?

If you plan to install a basement, will its construction be limited by such factors as:

a. High water table, either temporary or permanent?

b. Depth to bedrock?

c. Drainage – surface ponding or excessive runoff?

d. Shrink-swell potential of subsoil?

e. What is the slope surrounding the building site? Will the site be stable? Will there be excessive water runoff?

f. What are the erosion conditions and landslide potential? Previous erosion may have caused gullies and/or have limited the depth of topsoil, requiring leveling and filling. Erosion will give a clue about the stability of soil on a slope uphill from the house.

Understanding the nine critical soil and site factors will help determine if there are any limitations for the planned uses of your home site. These nine site and soil properties are critical to evaluate for home site selection: (A)surface texture, the amount of sand silt and clay in the soil; (B) permeability, the rate at which water enters and passes through the soil; (C) depth of soil to bedrock, including both topsoil and subsoil; (D) slope, steepness and length of the slope; (E)erosion hazard, the amount of topsoil currently on the site and the potential for future losses; (F) surface runoff, the rate at which water flows off the site based on slope, drainage and texture; (G), shrink-swell of the soil, which involves changes in volume based on soil wetness; (H) water table, the depth at which water occurs in the soil both seasonally or permanently; and (I) flood hazards, the frequency that water from storm runoff inundates the site.

Typical planned uses for a home site are gardening and landscaping, foundation and basement construction, on-site wastewater system, and soil stability. Soils are judged for home sites or building sites by the properties that may limit or prohibit a planned use. A favorable soil property may pose "no or slight limitations" to home site development, but if it creates unfavorable conditions that require correction or a modification of the building plans, the limitation is categorized as "moderate," "severe," or "very severe," depending on the severity of the condition. The final evaluation of a building site depends on the limitations of the individual soil properties. The soil property with the most severe limitations automatically classifies the site in the same category. For example, if all soil properties are rated as “slight” but one is “severe,” the site evaluation for that use is also classified as severe. Hence, the building site is judged by its most limiting soil property. [2]

Soil and site factors:

- Surface Texture:

The texture of a soil is determined by the relative proportion of sand, silt, and clay particles on the site. Texture is most easily determined by rubbing the soil between your fingers and feeling for a slick, floury, or gritty feeling.

Clayey (fine): Severe limitations for all uses. Soil is sticky when wet, hard when dry, and difficult to work when used for flower beds, shrubs, and gardens. They may be droughty and require frequent watering for plant growth. Special planning and design are required for foundations.

Loamy (medium): No to slight limitations for all uses. Loamy soils are floury and provide the best texture for landscaping and gardening. Loamy soil is easy to excavate and absorbs wastewater well. Care should be exercised during construction to be sure the surface soil is not covered by less desirable material.

Sandy (coarse): Moderate limitations for all uses. Soils are gritty and may require stabilization with organic material and/or loamy topsoil to improve moisture- and nutrient-holding capacity for desired plant growth. Erosion from water and wind may be a problem during construction. Sandy soil is easy to excavate and absorbs wastewater well.

- Permeability:

Permeability measures the rate at which water moves through soil and is an important factor when deciding between a septic tank system or another type of on-site wastewater treatment system. Soil percolation tests are required before making further plans.

Rapid: Slight limitations for foundations with basements, moderate limitations for lawns and gardens, and very severe limitations for septic systems and sewage lagoons. Permeability is >2.0 inches per hour. Septic systems may not adequately filter effluent under rapidly permeable conditions, which creates a very severe limitation.

Moderate: Moderate limitations for sewage lagoons and no to slight limitations for all other uses. Permeability ranges are 0.60 to 2 inches per hour.
Slow: Severe limitations for septic tank systems, moderate for foundations with basements and for lawns and gardens, and no to slight for sewage lagoons. Water movement can range from 0.06 to 0.60 inches per hour. Problems are generally similar to the very slowly permeable soils, but the modifications required for use are not as great.

Very Slow: Very severe limitations for septic systems, no to slight limitations for sewage lagoons, severe limitations for foundations with basements and for lawns and gardens. Water movement is generally <0.06 inches per hour. This requires a very large_field of lateral drains or costly modifications. Septic systems are generally not recommended. Shrink-swell potential is often high.

- Soil Depth:

Depth of soil includes topsoil and subsoil. Severity of limitations for depth varies greatly for different uses in home sites; therefore, Table 1 is useful as a guide for evaluating soil depth for alternate uses.

Table 1: Homesite use limitations by soil depth class.

CLASSES *Soil Depth to Bedrock*	*Foundations with Basement*	*Lawns & Gardens*	*Septic System*	*Ponds & Lagoons*
Very Deep: ≥72"	No-slight	No-slight	No-slight	No-slight
Deep: 36 to <72"	Moderate	No-slight	Moderate	Moderate
Mod. Deep: 20 to <36"	Severe*	No-slight	Severe	Severe
Shallow: 10 to <20"	Very severe	Severe	Very severe	Very severe
Very Shallow: <10"	Very severe	Very severe	Very severe	Very severe

- Slope:

Refers to the general slope steepness and length of slope. Slope is important to erosion, water runoff, and site stability. Table 2 will aid in home site interpretation of the slope condition.

Table 2: Homesite use limitations by slope class.

CLASSES	*Range*	*Foundations with Basement*	*Lawns & Gardens*	*Septic System*	*Ponds & Lagoons*
Nearly Level	0 to <3%	No-slight	No-slight	No-slight	No-slight
Gently Sloping	3 to <8%	No-slight	Moderate	No-slight	Moderate
Mod. Sloping	8 to <15%	Moderate	Moderate	Moderate	Severe
Strongly Sloping	15 to <25%	Severe	Severe	Severe	Very severe
Steep	25 to <35%	Very severe	Very severe	Very severe	Very severe
Very Steep	≥ 35%	Very severe	Very severe	Very severe	Very severe

- Erosion Hazard:

Current erosion on the site indicates the availability of topsoil and the future potential of soil loss after construction.

If the topsoil is less than 6 inches in thickness, problems with establishment and growth of plants for landscaping and gardens are likely.

No/slight erosion: Topsoil is greater than 6 inches. No to slight limitations for any use. Moderate erosion: Topsoil is between 4 to 6 inches. No gullies are present. Severe erosion: Topsoil is less than 3 inches thick. Occasional gullies may be present. Severe limitations for lawns and gardens; moderate for all other uses. Very Severe erosion: Topsoil is less than 3 inches thick and non-existent in some areas. Deep furrows and gullies may be present and actively eroding. This condition will require extensive filling and leveling, extra cost for septic systems, extensive modifications for landscaping, etc. Erosion control measures should be carried out during construction. Severe limitations for all uses.

- Surface Runoff:

Water runoff is an important factor in connection with slope, drainage, permeability, and erosion. Special attention needs to be given to water flowing from surrounding areas and from upslope of the home site. Runoff from adjacent areas onto planned or established home sites can cause ponding and water accumulation around the home site, wet or flooded basements, or instability of slopes and soils.

Rapid: Severe limitations for lawns and gardens. No to slight limitations for foundations with basement and for septic systems

Moderate: No to slight limitations for any use.

Slow: Severe limitations for foundations with basements and for septic systems. No to slight limitations for other uses.

- Shrink-Swell:

Many clays swell when they absorb water and shrink when they dry. The red clays of the central and western counties of West Virginia have a high shrink-swell potential, swelling to over twice their dry volume and causing very severe land use limitations. They tend to be prone to erosion and slide downhill on sloping sites. Swelling pressure of such clays may cause damage to foundations and retaining walls, and cause restricted drainage and limited permeability. Keep in mind, however, that not all clays (fine-textured soils) demonstrate equal shrink-swell.

Low: No to slight limitations for all uses. Coarse-textured soils.

Moderate: Moderate limitations for all uses. Medium-textured soils. High: Severe limitations for foundations with basements, septic systems, and lawns and gardens. No to slight limitations for sewage lagoons.

- Water Table

The presence and depth of a water table can cause limitations that restrict the soil for certain uses. A water table within the depth of basement construction or septic tank/drain field installation may result in a wet basement or inadequate waste water unless special precautions are taken. Water table must be evaluated on the basis of both depth and permanence, requiring measurements during different seasons of the year. Soils with no water table have a bright uniform color (brown, yellow, and red), and those with a water table are often pale or have a washed-out grayish color. Mottling of the soil (mixed yellow, orange, red, and gray spots) is an indication of a shallow water table for at least part of the year. Sometimes mottling looks like rust spots.

- Flood Hazards

Flooding may not occur on an area for many years, but then a serious rainstorm can flood homes that were built during drier periods. Urban development in a watershed may increase runoff by up to 70% in streams, greatly increasing flood hazards. Soils can give an indication, but long-term rainfall and flooding records must be studied to determine the true condition. Position on the landscape and proximity to nearby streams are good indicators of frequency of flooding. [3]

Thus soil testing and analysis is very vital before starting any project large or small scale or even before certain personal investments even for common people. In this project we have tried to compute and tabulate results on two different verities of soil by conducting a series of tests.

Chapter 2

Aim and objective

Objectives:

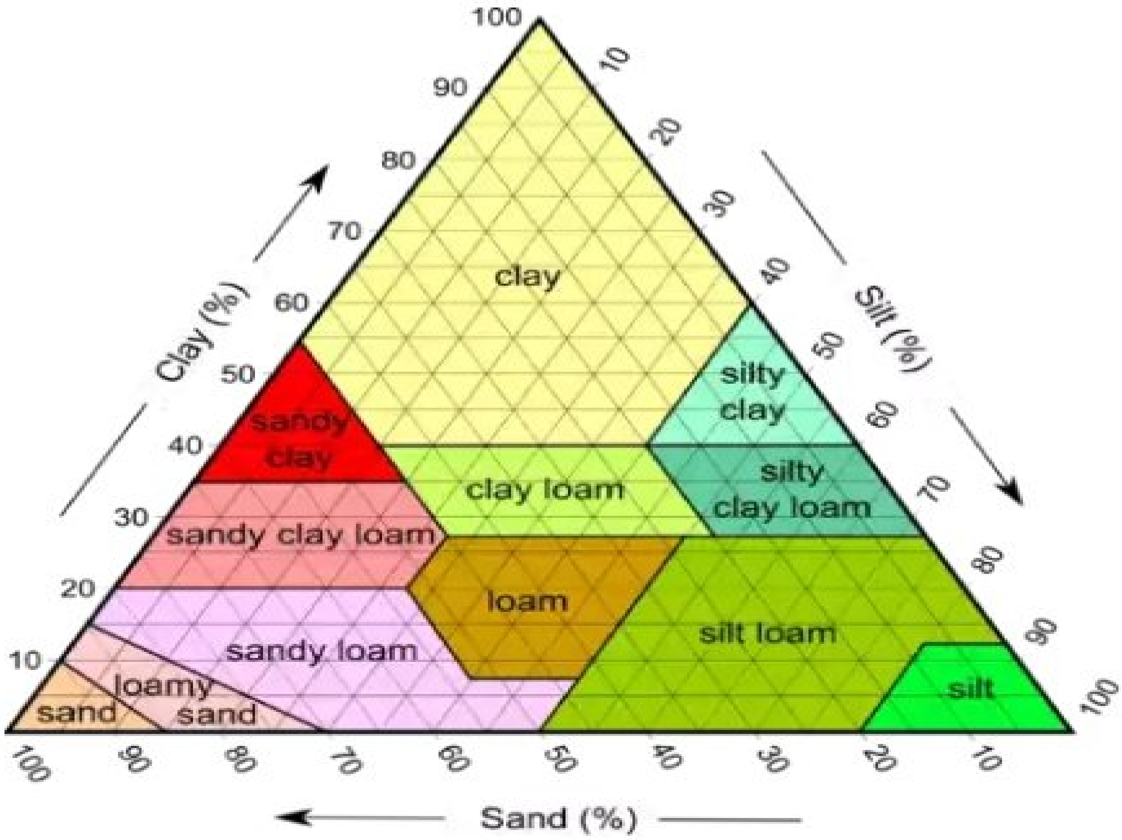
1. Literature review
2. Collection of soil samples
3. Test on samples
    - Sieve analysis
    - Moisture content
    - Liquid limit
    - Plastic limit
    - Shrinkage limit
    - Dry and bulk density measurement by sand replacement technique
    - Dry and bulk density measurement by core cutter method
    - Soil compaction (Standard Proctor Test)
    - Undrained triaxial compression test
    - Another similarities or differences between soil samples
4. Comparison of results

Chapter 3

Literature Review

Classification of soils:

Engineers classify soil according to their engineering properties as the relate to the use for foundation support or building material. The most common engineering classification system for soils in North America is the Unified Soil Classification System (USCS). The USCS has three major classification groups: (1) coarse-grained soils (e.g. sands and gravels); (2) fine-grained soils (e.g. silts and clays); and (3) highly organic soils (referred to as "peat"). The USCS further subdivides the three major soil classes for clarification. It distinguishes sands from gravels by grain size, and further classifying some as "well-graded" and the rest as "poorly-graded". Silts and clays are distinguished by the soils' Atterberg limits, and separates "high-plasticity" from "low-plasticity" soils as well. Moderately organic soils are considered subdivisions of silts and clays, and are distinguished from inorganic soils by changes in their plasticity properies (and Atterberg limits) on drying. The European soil classification system (ISO 14688) is very similar, differing primarily in coding and in adding an "intermediate-plasticity" classification for silts and clays, and in minor details. Other engineering soil classification systems in the United States include the AASHTO Soil Classification System and the Modified Burmister system. A full geotechnical engineering soil description will also include other properties of the soil including color, in-situ moisture content, in-situ strength, and somewhat more detail about the material properties of the soil than is provided by the USCS code. The USCS and additional engineering description is standardized in ASTM D 2487. Soil science Soil texture triangle showing the USDA classification system based on grain size For soil resources, experience has shown that a natural system approach to classification, i.e. grouping soils by their intrinsic property (soil morphology), behavior, or genesis, results in classes that can be interpreted for many diverse uses. Differing concepts of pedogenesis and differences in the significance of morphological features to various land uses can affect the classification approach. Despite these differences, in a well-constructed system, classification criteria group similar concepts so that interpretations do not vary widely. This is in contrast to a technical system approach to soil classification, where soils are grouped according to their fitness for a specific use and their edaphic characteristics. Natural system approaches to soil classification, such as the French Soil Reference System (Référentiel pédologique français) are based on presumed soil genesis. Systems have developed, such as USDA soil taxonomy and the World Reference Base for Soil Resources, which use taxonomic criteria involving soil morphology and laboratory tests to inform and refine hierarchical classes. Another approach is numerical classification, also called ordination, where soil individuals are grouped by multivariate statistical methods such as cluster analysis. This produces natural groupings without requiring any inference about soil genesis. In soil survey, as practiced in the United States, soil classification usually means criteria based on soil morphology in addition to characteristics developed during soil formation. Criteria are designed to guide choices in land use and soil management. As indicated, this is a hierarchical system that is a hybrid of both natural and objective criteria. USDA soil taxonomy provides the core criteria for differentiating soil map units. This is a substantial revision of the 1938 USDA soil taxonomy which was a strictly natural system. Soil taxonomy based soil map units are additionally sorted into classes based on technical classification systems. Land Capability Classes, hydric soil, and prime farmland are some examples. In addition to scientific soil classification systems, there are also vernacular soil classification systems. Folk taxonomies have been used for millennia, while scientifically based systems are relatively recent developments.

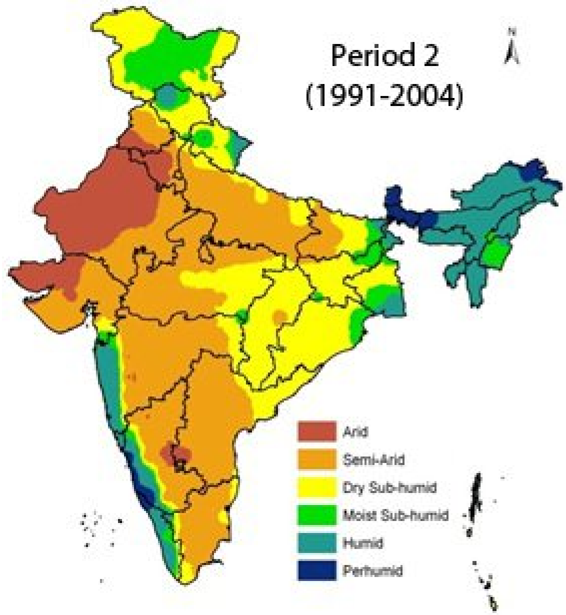


This figure here shows us different varieties of soil giving us a brief idea about the sand, silt and clay %age also.

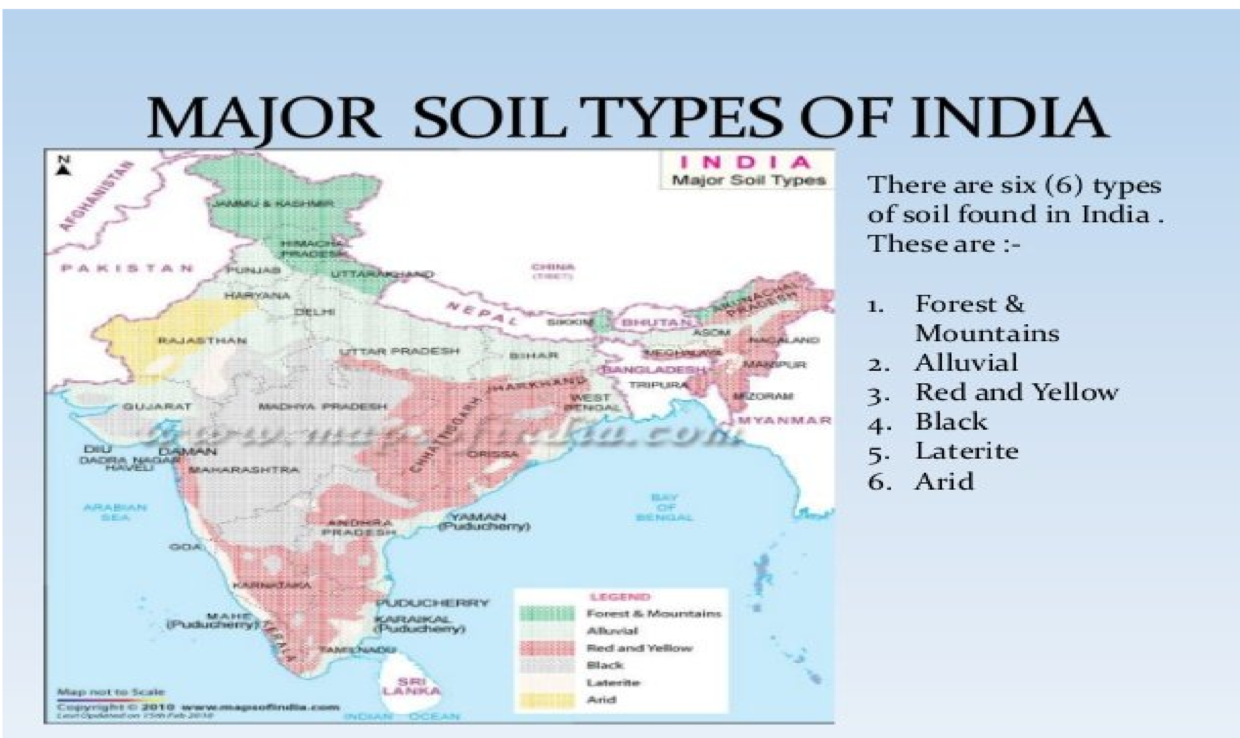
Soil types in India:

The major soil deposits of India are categorized into six types:

1. Alluvial soils
2. Desert soils
3. Black cotton soils
4. Laterite soils
5. Mountain soils
6. Red soils



The figure here shows various soil type distributions in India in terms of humidity.



The figure above gives us the information on various soil type distributions according to type and color across India.

According to these figures we have taken two samples, the first one lies in category of alluvial soil from Punjab while the other one is from Himachal Pradesh which falls in the category of mountain soils. [4]

Atterberg limits:

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. As a dry, clayey soil takes on increasing amounts of water, it undergoes dramatic and distinct changes in behavior and consistency. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state, the consistency and behavior of a soil is different and consequently so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behavior. The Atterberg limits can be used to distinguish between silt and clay, and it can distinguish between different types of silts and clays. These limits were created by Albert Atterberg, a Swedish chemist. They were later refined by Arthur Casagrande. These distinctions in soil are used in assessing the soils that are to have structures built on. Soils when wet retain water and some expand in volume. The amount of expansion is related to the ability of the soil to take in water and its structural make-up (the type of atoms present). These tests are mainly used on clayey or silty soils since these are the soils that expand and shrink due to moisture content. Clays and silts react with the water and thus change sizes and have varying shear strengths. Thus these tests are used widely in the preliminary stages of designing any structure to ensure that the soil will have the correct amount of shear strength and not too much change in volume as it expands and shrinks with different moisture contents.

As a hard, rigid solid in the dry state, soil becomes a crumbly (friable) semisolid when a certain moisture content, termed the shrinkage limit, is reached. If it is an expansive soil, this soil will also begin to swell in volume as this moisture content is exceeded. Increasing the water content beyond the soil's plastic limit will transform it into a malleable, plastic mass, which causes additional swelling. The soil will remain in this plastic state until its liquid limit is exceeded, which causes it to transform into a viscous liquid that flows when jarred.

Shrinkage limit:

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The test to determine the shrinkage limit is ASTM International D4943. The shrinkage limit is much less commonly used than the liquid and plastic limits.

Plastic limit:

The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. The procedure is defined in ASTM Standard D 4318. If the soil is at moisture content where its behavior is plastic, this thread will retain its shape down to a very narrow diameter. The sample can then be remoulded and the test repeated. As the moisture content falls due to evaporation, the thread will begin to break apart at larger diameters. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3.2 mm (about 1/8 inch). A soil is considered non-plastic if a thread cannot be rolled out down to 3.2 mm at any moisture.

Liquid limit:

Casagrande cup in action

Casagrande cup

The liquid limit (LL) is conceptually defined as the water content at which the behavior of a clayey soil changes from plastic to liquid. However, the transition from plastic to liquid behavior is gradual over a range of water contents, and the shear strength of the soil is not actually zero at the liquid limit. The precise definition of the liquid limit is based on standard test procedures described below.

The original liquid limit test of Atterberg's involved mixing a pat of clay in a round-bottomed porcelain bowl of 10–12 cm diameter. A groove was cut through the pat of clay with a spatula, and the bowl was then struck many times against the palm of one hand. Casagrande subsequently standardized the apparatus and the procedures to make the measurement more repeatable. Soil is placed into the metal cup portion of the device and a groove is made down its center with a standardized tool of 13.5 millimeters (0.53 in) width. The cup is repeatedly dropped 10 mm onto a hard rubber base at a rate of 120 blows per minute, during which the groove closes up gradually as a result of the impact. The number of blows for the groove to close is recorded. The moisture content at which it takes 25 drops of the cup to cause the groove to close over a distance of 13.5 millimeters (0.53 in) is defined as the liquid limit. The test is normally run at several moisture contents, and the moisture content which requires 25 blows to close the groove is interpolated from the test results. The Liquid Limit test is defined by ASTM standard test method D 4318. The test method also allows running the test at one moisture content where 20 to 30 blows are required to close the groove; then a correction factor is applied to obtain the liquid limit from the moisture content.

Another method for measuring the liquid limit is the fall cone test, also called the cone penetrometer test. It is based on the measurement of penetration into the soil of a standardized cone of specific mass. Although the Casagrande test is widely used across North America, the fall cone test is much more prevalent in Europe due to being less dependent on the operator in determining the Liquid Limit.[5]

Derived limits-

The values of these limits are used in a number of ways. There is also a close relationship between the limits and properties of a soil such as compressibility, permeability, and strength. This is thought to be very useful because as limit determination is relatively simple, it is more difficult to determine these other properties. Thus the Atterberg limits are not only used to identify the soil's classification, but it allows for the use of empirical correlations for some other engineering properties.

Plasticity index:

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay.

Liquidity index:

The liquidity index (LI) is used for scaling the natural water content of a soil sample to the limits. It can be calculated as a ratio of difference between natural water content, plastic limit, and liquid limit: LI= (W-PL) / (LL-PL) where W is the natural water content. [6]

We have tried to compute all the atterberg limits along with various other tests on two samples in this project work and compare the results which these two varieties of soil exhibit.

Chapter 4

Materials and Methods

Materials:

Two samples were taken to perform a series of experiments on them and compile the respective properties the two set of samples exhibited.

Sample 1- Soil sample taken from Punjab; it is a sample of medium fine sand.

Sample 2- Soil sample taken from Himachal Pradesh; it is a sample of fine silt.

Figure 1 *Soil from Punjab*

Figure 2 *Soil from Himachal*

- 10 kg soil for both samples was taken.
- Oven dry large quantity of both samples to start conducting tests.

Methods:

1. **Sieve Analysis on soils**

A sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called gradation) of a granular material.

The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.

Types of sieve analysis:

There are different methods for carrying out sieve analyses, depending on the material to be measured.

Throw-action sieving

Here a throwing motion acts on the sample. The vertical throwing motion is overlaid with a slight circular motion which results in distribution of the sample amount over the whole sieving surface. The particles are accelerated in the vertical direction (are thrown upwards). In the air they carry out free rotations and interact with the openings in the mesh of the sieve when they fall back. If the particles are smaller than the openings, they pass through the sieve. If they are larger, they are thrown upwards again. The rotating motion while suspended increases the probability that the particles present a different orientation to the mesh when they fall back again and thus might eventually pass through the mesh.

Modern sieve shakers work with an electro-magnetic drive which moves a spring-mass system and transfers the resulting oscillation to the sieve stack. Amplitude and sieving time are set digitally and are continuously observed by an integrated control-unit. Therefore sieving results are reproducible and precise (an important precondition for a significant analysis). Adjustment of parameters like amplitude and sieving time serves to optimize the sieving for different types of material. This method is the most common in the laboratory sector

Horizontal sieving

In a horizontal sieve shaker the sieve stack moves in horizontal circles in a plane. Horizontal sieve shakers are preferably used for needle-shaped, flat, long or fibrous samples, as their horizontal orientation means that only a few disoriented particles enter the mesh and the sieve is not blocked so quickly..

Tapping sieving

A horizontal circular motion overlies a vertical motion which is created by a tapping impulse. These motional processes are characteristic of hand sieving and produce a higher degree of sieving for denser particles (e.g. abrasives) than throw-action sieve shakers.

Super sonic sieving

The particles are lifted and forcibly dropped in a column of oscillating air at a frequency of thousands of cycles per minute. Sonic sievers are able to handle much finer dry powders than woven mesh screens.

Wet sieving

Most sieve analyses are carried out dry. But there are some applications which can only be carried out by wet sieving. This is the case when the sample which has to be analyzed is e.g. a suspension which must not be dried; or when the sample is a very fine powder which tends to agglomerate (mostly < 45 µm) – in a dry sieving process this tendency would lead to a clogging of the sieve meshes and this would make a further sieving process impossible. A wet sieving process is set up like a dry process: the sieve stack is clamped onto the sieve shaker and the sample is placed on the top sieve. Above the top sieve a water-spray nozzle is placed which supports the sieving process additionally to the sieving motion. The rinsing is carried out until the liquid which is discharged through the receiver is clear. Sample residues on the sieves have to be dried and weighed. When it comes to wet sieving it is very important not to change to sample in its volume (no swelling, dissolving or reaction with the liquid).

Air Circular Jet Sieving

Air jet sieving machines are ideally suited for very fine powders which tend to agglomerate and cannot be separated by vibrational sieving. The reason for the effectiveness of this sieving method is based on two components: A rotating slotted nozzle inside the sieving chamber and a powerful industrial vacuum cleaner which is connected to the chamber. The vacuum cleaner generates a vacuum inside the sieving chamber and sucks in fresh air through the slotted nozzle. When passing the narrow slit of the nozzle the air stream is accelerated and blown against the sieve mesh, dispersing the particles. Above the mesh, the air jet is distributed over the complete sieve surface and is sucked in with low speed through the sieve mesh. Thus the finer particles are transported through the mesh openings into the vacuum cleaner.

Types of gradation:

A Dense gradation

A dense gradation refers to a sample that is approximately of equal amounts of various sizes of aggregate. By having a dense gradation, most of the air voids between the materials are filled with particles. A dense gradation will result in an even curve on the gradation graph.

Narrow gradation

Also known as uniform gradation, a narrow gradation is a sample that has aggregate of approximately the same size. The curve on the gradation graph is very steep, and occupies a small range of the aggregate.

Gap gradation

A gap gradation refers to a sample with very little aggregate in the medium size range. This results in only coarse and fine aggregate. The curve is horizontal in the medium size range on the gradation graph.

Open gradation

An open gradation refers an aggregate sample with very little fine aggregate particles. This results in many air voids, because there are no fine particles to fill them. On the gradation graph, it appears as a curve that is horizontal in the small size range.

Rich gradation

A rich gradation refers to a sample of aggregate with a high proportion of particles of small sizes.

Types of sieves:

Woven wire mesh sieves

Woven wire mesh sieves are according to technical requirements of ISO 3310-1. These sieves usually have nominal aperture ranging from 20 micrometers to 3.55 millimeters, with diameters ranging from 100 to 450 millimeters.

Perforated plate sieves

Perforated plate sieves conform to ISO 3310-2 and can have round or square nominal apertures ranging from 1 millimeter to 125 millimeters. The diameters of the sieves range from 200 to 450 millimeters.

American standard sieves

American standard sieves also known as ASTM sieves conform to ASTM E11 standard. The nominal aperture of these sieves range from 20 micrometers to 200 millimeters, however these sieves have only 8 and 12 inch diameter sizes.

Limitations of sieve analysis:

Sieve analysis has, in general, been used for decades to monitor material quality based on particle size. For coarse material, sizes that range down to #100 mesh (150μm), a sieve analysis and particle size distribution is accurate and consistent.

However, for material that is finer than 100 meshes, dry sieving can be significantly less accurate. This is because the mechanical energy required to make particles pass through an opening and the surface attraction effects between the particles themselves and between particles and the screen increase as the particle size decreases. Wet sieve analysis can be utilized where the material analyzed is not affected by the liquid - except to disperse it. [7]

List of sieves used in the experiment (from top to bottom):

- 10mm
- 4.75mm
- 2mm
- 1mm
- 600 microns
- 425 microns
- 300 microns
- 212 microns
- 150 microns
- 75 microns
- Pan

The sieves are put in sequence mentioned above and 1 kg soil is put in the top sieve. The lid is closed and the arrangement is put on the sieve shaker which is kept on for 15 minutes. At the end the retaining soil on each sieve is weighed and calculations are made for both the samples separately. The image below shows the sieve analysis arrangement over a sieve shaker in the laboratory.

Figure 3 *Sieve Shaker*

2. **Moisture content determination:**

The amount of moisture found in soil varies greatly with the type of soil, the climate and the amount of humus in that soil. The types of organisms which can survive in an area are largely determined by the amount of water available to them, since this water acts as a means of nutrient transport and is necessary for cell survival. This method for measuring the moisture content of soil involves comparing the weight of a soil sample before and after it has been dried in an oven. From this information, the percent of moisture can be calculated.

Materials: Large beaker (or evaporating dish), Soil (150 grams), Oven (temperature range should be such that readings near 100˚C are accurate)

Procedure:

- Sieve about 200 g of soil sample through a 425 micron sieve.
- Take an empty dish and note the weight.
- Now put some water in the sample without measuring.
- Mix the water well and put sample in the dish.
- Weigh the dish and wet soil now.
- Keep the dish in oven for 24 hours at about 100˚C.
- Take out the dish and record weight of dish and wet soil.
- Calculate the moisture content.
- Repeat procedure for second sample also.

Figure 4 *Weighing dish for moisture content*

3. Liquid limit:

The liquid limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dried soil, at the boundary between the liquid and plastic states of consistency. The moisture content at this boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together, for a distance of ½ in. (12.7 mm) along the bottom of a groove of standard dimensions separating the two halves, when the cup of a standard liquid limit apparatus is dropped 25 times from a height of 0.3937 in. (10 mm) at the rate of two drops/second.

It is preferable that soils used for liquid limit determination be in their natural or moist state, because drying may alter the natural characteristics of some soils. Organic soils in particular undergo changes as a result of oven-drying or even extended air-drying. Other soils containing clay may agglomerate, lose absorbed water which is not completely regained on rewetting, or be subject to some chemical change.

Appratus:

- Cassagrande's apparatus
- Dishes
- Cassagrande's grooving tool
- Weighing machine
- Oven

Procedure:

- A 425 micron sieve is used to sieve 200 g sample of soil.
- Take some of the sample in an evaporating dish and add some known quantity of water.
- Mix the soil and water well.
- Take three empty containers and weigh them.
- Now put the mix in Cassagrande's apparatus in a leveled height.
- Groove the soil sample from b/w using the grooving tool

- Turn on the machine and count number of blows it takes to join the sample grooved from between again.
- Now take the sample and put it in one empty container and record weight.
- After recording weight put the dish with soil in oven for 24 hours and heat at 110˚C.
- Add more water to the sample and record it.
- Repeat procedure for second sample and then for third by adding another known amount of water.
- Next day take out all three samples and record weight again.
- Calculate moisture content for all three samples of the soil.
- Plot graph b/w moisture content and no. of blows.
- Compute the flow index and toughness index of soil.
- Repeat whole process up to computation of indices for the second sample of soil too.

Figure 5 *Soil pat and grooving tool*

4. **Plastic limit:**

Use 425 microns sieve to sieve 100 g sample. We add some water to the sample and try to roll it into threads of about 5 cm length and 3 mm dia. Until the soil tends to crumble below that diameter. The set of changes that occur in a soil between plastic and liquid limit is called as plasticity of the soil. When the threads are rolled, after that we keep the threads in an empty dish and weigh it and record the weight. The dish is then kept in the oven for 24 hours to record moisture content after 24 hours. Plasticity index of the soil is then calculated. No special apparatus is needed for this test.

5. **Shrinkage limit:**

Reference Standards:

IS: 2720(Part 6)-1972 Methods of test for soils: Determination of shrinkage factor.

Equipment & Apparatus:

- Oven
- Balance
- Sieve
- Mercury
- Desiccator

The soil passing 425 micron sieve is used in this test.

Procedure

1. 100 gm. of soil sample from a thoroughly mixed portion of the material passing through 425 micron IS sieve is taken.
2. About 30 gm. of above soil sample is placed in the evaporating dish and thoroughly mixed with distilled water to make a paste.
3. The weight of the clean empty shrinkage dish is determined and recorded.
4. The dish is filled in three layers by placing approximately 1/3rd of the amount of wet soil with the help of spatula.
5. Then the dish with wet soil is weighed and recorded immediately.

6. The wet soil cake is air dried until the color of the pat turns from dark to light. Then it is oven dried at a temperature of 105^0 C to 110^0 C for 12 to 16 hours. The weight of the dish with dry sample is determined and recorded. Then the weight of oven dry soil pat is calculated (W_0).
7. The shrinkage dish is placed in the evaporating dish and the dish is filled with mercury, till it overflows slightly. Then it is be pressed with plain glass plate firmly on its top to remove excess mercury. The mercury from the shrinkage dish is poured into a measuring jar and the volume of the shrinkage dish is calculated. This volume is recorded as the volume of the wet soil pat (V).
8. A glass cup is placed in a suitable large container and the glass cup removed by covering the cup with glass plate with prongs and pressing it. The outside of the glass cup is wiped to remove the adhering mercury. Then it is placed in the evaporating dish which is clean and empty.
9. Then the oven dried soil pat is placed on the surface of the mercury in the cup and pressed by means of the glass plate with prongs, the displaced mercury being collected in the evaporating dish.
10. The mercury so displaced by the dry soil pat is weighed and its volume (V_o) is calculated by dividing this weight by unit weight of mercury.

Figure 6 *Oiling of shrinkage dish*

Figure 7 *Sample filled in shrinkage dish*

Figure 8 *Glass dish and sample*

Figure 9 *Using mercury to calculate volume*

6. **Sand replacement technique:**

Reference:

IS-2720-Part-28-Determination of dry density of soils in place, by the sand replacement method

Apparatus:

1. Sand pouring cylinder
2. Calibrating can
3. Metal tray with a central hole
4. Dry sand (passing through 600 micron sieve)
5. Balance
6. Moisture content bins
7. Glass plate
8. Metal tray
9. Scraper tool

Theory and Application:

Determination of field density of cohesion less soil is not possible by core cutter method, because it is not possible to obtain a core sample. In such situation, the sand replacement method is employed to determine the unit weight. In sand replacement method, a small cylindrical pit is excavated and the weight of the soil excavated from the pit is measured. Sand whose density is known is filled into the pit. By measuring the weight of sand required to fill the pit and knowing its density the volume of pit is calculated. Knowing the weight of soil excavated from the pit and the volume of pit, the density of soil is calculated. Therefore, in this experiment there are two stages, namely

1. Calibration of sand density
2. Measurement of soil density

Procedure:

Stage-1 (Calibration of Sand Density)

1. Measure the internal dimensions (diameter, d and height, h) of the calibrating cyllinder and find its internal volume, $V_c = \pi d^2 h/4$.
2. Fill the sand pouring cylinder (SPC) with sand with 1 cm top clearance (to avoid any spillover during operation) and find its weight (W_1)
3. Place the SPC on a glass plate, open the slit above the cone by operating the valve and allow the sand to run down. The sand will freely run down till it fills the conical portion. When there is no further downward movement of sand in the SPC, close the slit.
4. Find the weight of the SPC along with the sand remaining after filling the cone (W_2)
5. Place the SPC concentrically on top of the calibrating can. Open the slit to allow the sand to run down until the sand flow stops by itself. This operation will fill the calibrating can and the conical portion of the SPC. Now close the slit and find the weight of the SPC with the remaining sand (W_3)

Figure 10 *Cutting of soil sample*

Stage-2 (Measurement of Soil Density)

1. Clean and level the ground surface where the field density is to be determined
2. Place the tray with a central hole over the portion of the soil to be tested.
3. Excavate a pit into the ground, through the hole in the plate, approximately 12 cm deep (same as the height of the calibrating can). The hole in the tray will guide the diameter of the pit to be made in the ground.
4. Collect the excavated soil into the tray and weigh the soil (W)
5. Determine the moisture content of the excavated soil.
6. Place the SPC, with sand having the latest weight of W_3, over the pit so that the base of the cylinder covers the pit concentrically.
7. Open the slit of the SPC and allow the sand to run into the pit freely, till there is no downward movement of sand level in the SPC and then close the slit.
8. Find the weight of the SPC with the remaining sand (W_4)

Precautions:

- If for any reason it is necessary to excavate the pit to a depth other than 12 cm, the standard calibrating can should be replaced by one with an internal height same as the depth of pit to be made in the ground.
- Care should be taken in excavating the pit, so that it is not enlarged by levering, as this will result in lower density being recorded.
- No loose material should be left in the pit.
- There should be no vibrations during this test.
- It should not be forgotten to remove the tray, before placing the SPC over the pit. [8]

7. Core cutter method:

Reference:

IS-2720-Part-29-Determination of dry density of soil in place by the core-cutter method

Apparatus:

1. Cylindrical core cutter
2. Steel rammer
3. Steel dolly
4. Balance
5. Steel rule
6. Spade or pickaxe
7. Straight edge
8. Knife

Figure 11 *Placing of core cutter*

Procedure:

1. Measure the height (h) and internal diameter (d) of the core cutter and apply grease to the inside of the core cutter
2. Weigh the empty core cutter (W_1)
3. Clean and level the place where density is to be determined.
4. Drive the core cutter, with a steel dolly on its top, into the soil to its full depth with the help of a steel rammer.
5. Excavate the soil around the cutter with a crow bar and gently lift the cutter without disturbing the soil in it.
6. Trim the top and bottom surfaces of the sample and clean the outside surface of the cutter.

7. Weigh the core cutter with soil (W_2)
8. Remove the soil from the core cutter, using a sample ejector and take representative soil sample from it to determine the moisture content.

Precautions:

1. Core cutter method of determining the field density of soil is only suitable for fine grained soil (Silts and clay). This is because collection of undisturbed soil sample from a coarse grained soil is difficult and hence the field properties, including unit weight, cannot be maintained in a core sample
2. Core cutter should be driven into the ground till the steel dolly penetrates into the ground half way only so as to avoid compaction of the soil in the core.
3. Before lifting the core cutter, soil around the cutter should be removed to minimize the disturbances.

8. Standard proctor test (Soil Compaction Test):

In the construction of high load structures such as dams, paved roadways and construction projects that rely on the stability of embankments; soil compaction is used to increase soil strength. Loose soil can be compacted by using mechanical equipment to remove air-voids, thereby densifying the soil and increasing it's dry unit weight. There are a variety of different benefits to soil compaction, including: prevention of soil settlement and frost damage, increased ground stability, reduced hydraulic conductivity and mitigating undesirable settlement of structures, such as paved roads, foundations and piping.

Standard Proctor Compaction Test: Standard Proctor Compaction Testing can be performed in a lab. The testing first determines the maximum density achievable for the soil and uses it as a reference for field testing. It also is effective for testing the effects of moisture on the soil's density. For soil with higher densities a Modified Proctor Compaction Test which uses higher values will be necessary.

Apparatus:

- 1/30 cubic ft. mold
- 5.5 lb. hammer
- 12" drop
- 3 layers of soil
- 25 blows

Procedure:

1. Obtain layered soil sample (via our VTK Soil Sampler if equipped)
2. Determine the weight of the Proctor mold with the base and the collar extension
3. Assemble the compaction tool.
4. Place soil in the mold in 3 layers.
5. Compact the soil with 25 well distributed blows of the hammer.
6. Carefully detach the collar extension and base without distributing the soil.
7. Determine the weight of the Proctor mold and the soil.
8. Oven dry the soil for 12 hours to determine the moisture content.
9. Compute the O.M.C and graph b/w moisture content and dry unit weight.

Figure 12 *Soil compaction apparatus*

9. **Unconfined compression test:**

Need and scope of the test:

The standard consolidated undrained test is compression test, in which the soil specimen is first consolidated under all round pressure in the triaxial cell before failure is brought about by increasing the major principal stress.

It may be performed with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

Planning and organization:

Knowledge of Equipment

A constant rate of strain compression machine of which the following is a brief description of one is in common use. A loading frame in which the load is applied by a yoke acting through an elastic dynamometer, more commonly called a proving ring which used to measure the load. The frame is operated at a constant rate by a geared screw jack. It is preferable for the machine to be motor driven, by a small electric motor. A hydraulic pressure apparatus including an air compressor and water reservoir in which air under pressure acting on the water raises it to the required pressure, together with the necessary control valves and pressure dials. A triaxial cell to take 3.8 cm dia. and 7.6 cm long samples, in which the sample can be subjected to an all round hydrostatic pressure, together with a vertical compression load acting through a piston. The vertical load from the piston acts on a pressure cap. The cell is usually designed with a non-ferrous metal top and base connected by tension rods and with walls formed of perspex.

Apparatus for preparation of the sample:

a) 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.

b) Rubber ring.

c) An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side.

d) Stop clock.

e) Moisture content test apparatus.

f) A balance of 250 gm capacity and accurate to 0.01 gm.

Experimental Procedure:

1. The sample is placed in the compression machine and a pressure plate is placed on the top. Care must be taken to prevent any part of the machine or cell from jogging the sample while it is being setup, for example, by knocking against this bottom of the loading piston. The probable strength of the sample is estimated and a suitable proving ring selected and fitted to the machine.

2. The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.

3. When the sample is setup water is admitted and the cell is fitted under water escapes from the bead valve, at the top, which is closed. If the sample is to be tested at zero lateral pressure water is not required.

4. The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.

5. The handle wheel of the screw jack is rotated until the underside of the hemispherical setting of the proving ring, through which the loading is applied, just touches the cell piston.

6. The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the begging of the test.

7. Strain and stress are computed through a series of readings and a graph is plotted. [9]

Chapter 5

Results

In this chapter we will refer Sample 1 as the sample of soil from Punjab and Sample 2 as the sample of soil from Himachal Pradesh. The results for both are computed simultaneously for each test performed.

1. **Sieve analysis:**

Sieve Analysis formulae:

- % retained on a particular sieve = (wt. of soil retained on that sieve) / (total wt. of soil taken)*100
- Cumulative % retained = (sum of % retained on all sieves of larger sizes and the % retained on that particular sieve)
- %age finer than the sieve under reference = 100% - cumulative % retained

Total weight of sample taken for sieve analysis = 1 kg

Weight of soil recovered after testing = 999 gm; as one gram is lost in testing**.**

- **Sample 1** :

Sieve size	**Sample retained (gm)**
10 mm	69.5
4.75 mm	112.0
2 mm	107.5
1 mm	148.0
600 microns	184.0
425 microns	152.0

300 microns	26.0
212 microns	110.0
150 microns	78.0
75 microns	3.0
Pan	9.0
Total	999

% retained on sieve	**Cumulative % retained**	**% finer than**
6.95	6.95	93.05
11.2	18.15	81.85
10.75	28.9	71.1
14.8	43.7	56.3
18.4	62.1	37.9
15.2	77.3	22.7
2.6	79.9	20.1
11	90.9	9.1
7.8	98.7	1.3
0.3	99	1
0.9	99.9	0.1

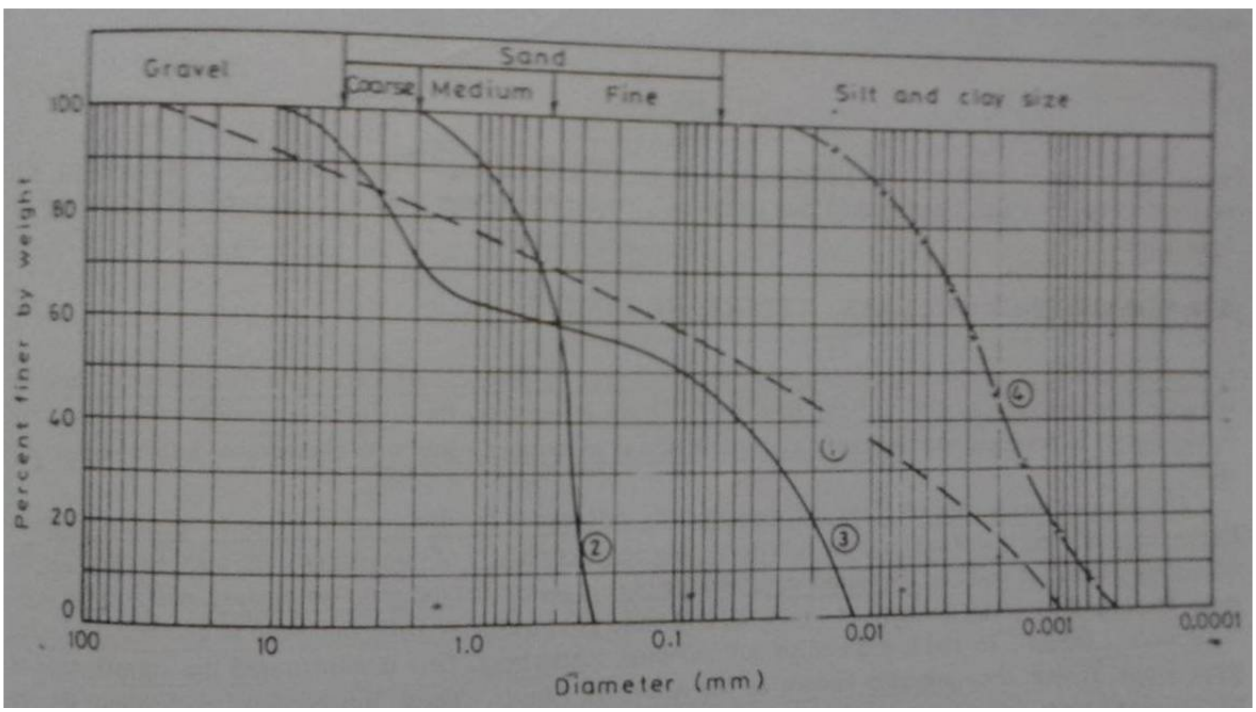
- **Sample 2:**

Sieve size	**Sample retained (gm)**

10 mm	80.0
4.75 mm	125.0
2 mm	113.6
1 mm	136.0
600 microns	164.0
425 microns	136.0
300 microns	45.0
212 microns	119.0
150 microns	69.0
75 microns	4.0
Pan	7.2
Total	998.8

% retained on sieve	**Cumulative % retained**	**% finer than**
8	8	92
12.5	20.5	79.5
11.3	31.8	68.2
13.6	45.4	54.6
16.4	61.8	38.2
13.6	75.4	24.6
4.5	79.9	20.1
11.9	91.8	8.2

6.9	98.7	1.3
0.4	99.1	0.9
0.72	99.82	0.18



Graph 1 *Grain size distribution curves for the samples*

Sample 1- medium fine sand.

Sample 2- fine silt.

2. **Moisture content:**

- **Sample 1:**

Weight of empty container = 20 g (w1)

Weight of container + wet soil = 173 g (w2)

Weight of cont. + dry soil = 160 g (w3)

So, wt. of dry soil = w3-w1 = 140 g

Mass of moisture = w2-w3 = 13 g

Water content = W = (w2-w3) / (w3-w1)*100%

= 1300/140 = 9.29%

- **Sample 2:**

Weight of empty container = 19.5 g (w1)

Weight of container + wet soil = 97 g (w2)

Weight of cont. + dry soil = 70 g (w3)

So, wt. of dry soil = w3-w1 = 50.5 g

Mass of moisture = w2-w3 = 27 g

Water content = W = (w2-w3) / (w3-w1)*100 = 27/50.5 *100 % = 52.42%

3. **Liquid limit:**

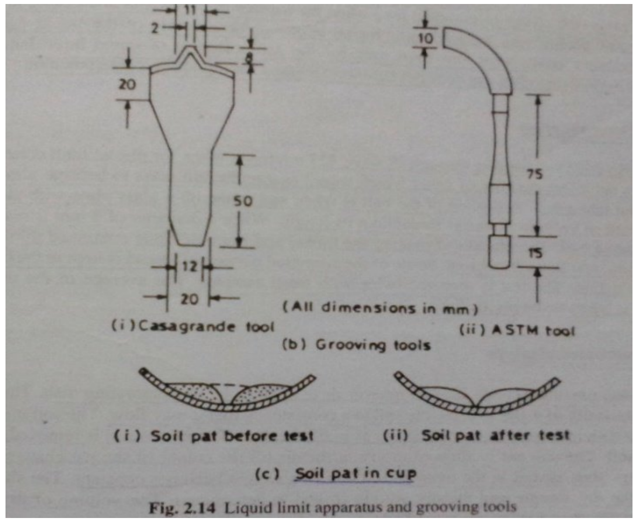
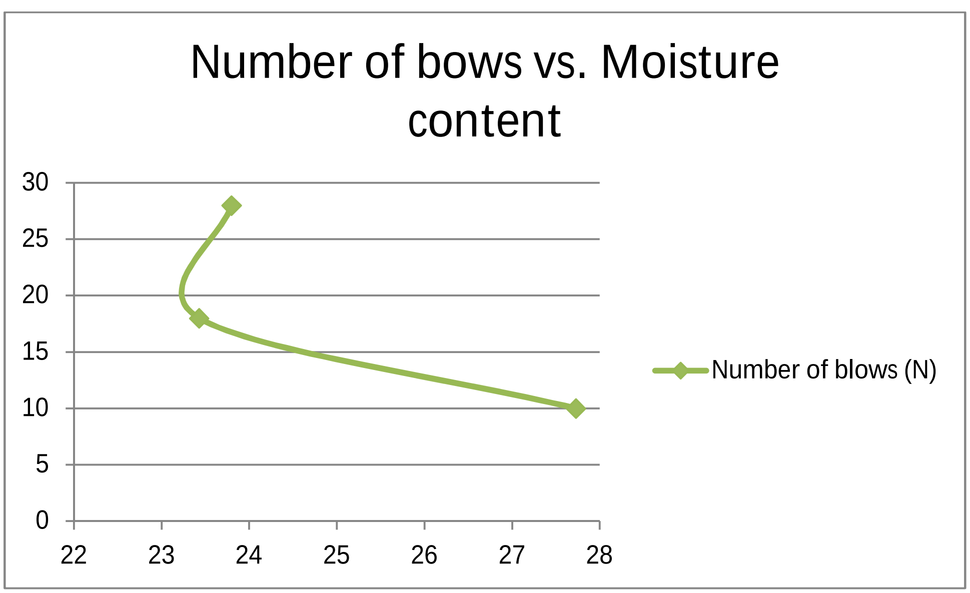


Figure 13 *Grooving tool dimensions*

- **Sample 1:**

Serial number	Water added (ml)	Number of blows (N)	Moisture content (%)
1	40	10	27.73
2	20	18	23.43
3	15	28	23.80



Graph 2 *The graph between moisture content and number of blows*

Flow index:

Wl = wn (N/25) =15(28/25) =16.8   IS: 2720 part 5-1970

Relative consistency IC = 0 since Ip = 0 as IC= (wl-wn)/Ip

Liquidity index IL= 1-IC = 1

Flow index IF= (w1-w2) / {log (n2/n1)}

IF= (20-15) / {log (28/18)} =26.05

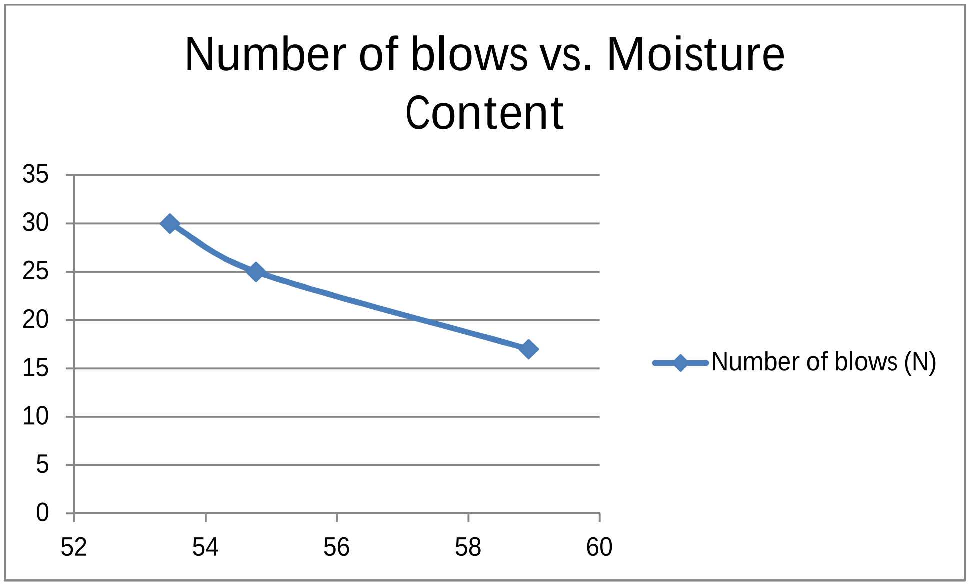
Flow index indicates the loss in shearing strength upon increase in water content. This soil possesses lower shear strength.

Toughness index IT=IP/IF = 0

Toughness index gives an idea about shear strength of a soil at plastic limit. When IT<1 soil is easily crushed.

Sample 2:

Serial number	Water added (ml)	Number of blows (N)	Moisture content (%)
1	15	30	53.46
2	19	25	54.77
3	25	17	58.92



Graph 3 *The graph between moisture content and number of blows*

Flow index:

Wl = wn (N/25) =25(17/25) =17.0   IS: 2720 part 5-1970

Relative consistency Ic = 0 since Ip = 0 as Ic = (wl-wn)/Ip

Liquidity index IL= 1-IC = 1

Flow index IF= (w1-w2) / {log (n2/n1)}

IF= (19-25) / {log (17/25)} =35.82

Flow index indicates the loss in shearing strength upon increase in water content. This soil possesses lower shear strength.

Toughness index IT=IP/IF = 0

Toughness index gives an idea about shear strength of a soil at plastic limit. When IT<1 soil is easily crushed.

4. **Plasticity Index:**

Plasticity index IP	Soil description
0	Non-Plastic

Less than 7	Low-Plastic
7-17	Medium-Plastic
Greater than 17	Highly-Plastic

- **Sample 1**: The sample we have here is very sandy and contains near about 80% sand and very less clay. Thus we may conclude that the plasticity of this sample is very close to zero. Thus IP = 0 = Non Plastic.
- **Sample 2**: The sample we have here is very sandy and contains near about 65% sand and very less clay. Thus we may conclude that the plasticity of this sample is very close to zero. IP = 0 = Non-Plastic.

Figure 14 *Soil could not be rolled into threads*

5. **Shrinkage Limit:** Maximum Water content at which a reduction in water content will cause decrease in vol. of this soil mass.

Sample 1:

100 g of soil sample is sieved through 425 micron sieve.

Wt. of air dry shrinkage dish = 24.5 g

Wt. of shrinkage dish + wet soil = 68 g

Wt. of shrinkage dish + soil after 3 hours = 67.5 g

Wt. of glass dish = 36.5 g , Wt. of tray = 312.5 g

Wt. of mercury = 457 g

Wt. of glass dish + mercury + tray (remaining) = 493.5 g

Wt. of mercury displaced = 257 g

Unit wt. of hg = 13.55

V0 = wt. of hg displaced/unit wt. of hg

Vol. of soil (wet) = π/4{4.5^2 * 1.5}

= 23.86 cm^3= V

Vol. of soil dry = 257/13.6 = 18.89 cm^3

Water content = 11.5/32 = 35.9 %= W

Shrinkage Limit = Ws= W-{(V-Vo)/W0}*100

= 20.37 %

- **Sample 2:**

100 g of soil sample is sieved through 425 micron sieve.

Wt. of shrinkage dish = 24.5 g

Wt. of shrinkage dish + wet soil = 65 g

Wt. of shrinkage dish + dry soil = 56.5 g= W0

Wt. of shrinkage dish + soil after 3 hours = 64 g

Wt. of glass dish = 36 g, Wt. of tray = 313.5 g

Wt. of tray + weighing dish + hg =1059.5 g

Wt. of mercury = 710 g

Wt. of glass dish + mercury + tray after dipping sample = 477 g

Wt. of mercury displaced = 233 g

Vol. of soil (wet) = π/4{4.5^2 * 1.5}

= 23.86 cm^3 = V

Vol. of soil dry = 233/13.6 = 17.13 cm^3

Water content = 08.5/32 = 26.56 %= W

Specific gravity of hg w.r.t water = 13.55

Thus V0 = wt. of mercury displaced/13.55 = 233/13.55= 17.20

Shrinkage Limit = Ws = W- {(V-V0)/W0} *100

= 26.44

6. **Determination of field densities (bulk and dry) using Sand Replacement technique:**

- **Sample 1:**

Wt. of cylinder = 6.2 kg

Wt. of cone = 0.38 kg

Total weight = 6.2-0.38 = 5.82 kg

Vol. of cylinder = 1177.5 cm^3 (10 cm dia. & 15 cm ht.)

Wt. of sand in cylinder = 7.8-5.82-0.38 = 1.63 kg

Bulk density (sand) = 1.63*1000/1177.5 = 1.38 g/cc

Field observation – Wt. of wet soil from pit = 1.29 kg

Wt. of cylinder + sand (after pouring) = 6.15 kg

Wt. of sand in hole = 7.8-6.15-0.38 kg = 1.27 kg

Bulk density ρ = 1.27*1000/1177.5 = 1.46 g/cc

For water content:

Wt. of container = 19.5 g

Wt. of container + soil = 126 g

Wt. of container + dry soil = 118 g

Water content = 8 g

Moisture content = 8.12 %

Dry density = ρd = ρ / (1+w) = 1.46 /1+0.0812 = 1.35 g/cc

Dry unit weight = λd = λ / (1+w) = 1.38 * 9.81 = 13.53 kN/m^3

- **Sample 2:**

Wt. of cylinder = 6.2 kg

Wt. of cone = .38 kg

Total weight = 6.2-0.38 = 5.82 kg

Vol. of cylinder = 1177.5 cm^3 (10 cm dia. & 15 cm ht.)

Wt. of sand in cylinder = 7.56-5.82-0.38 = 1.74 kg

Bulk density (sand) = 1.74*1000/1177.5 = 1.47 g/cc

Field observation – Wt. of wet soil from pit = 1.32 kg

Wt. of cylinder + sand (after pouring) = 6.18 kg

Wt. of sand in hole = 7.76-6.18-0.38 kg = 1.2 kg

Bulk density ρ = 1.2*1000/1177.5 = 1.02 g/cc

For water content:

Wt. of container = 20 g

Wt. of container + soil = 115 g

Wt. of container + dry soil = 106 g

Water content = 9 g

Moisture content = 10.46 %

Dry density = $\rho d = \rho / (1+w) = 1.46 / 1+0.1046 = 1.32$ g/cc

Dry unit weight = $\gamma d = \gamma / (1+w) = 1.32 * 9.81 = 12.94$ kN/m^3

Figure 15 *Hole being dug in field*

7. Determination of field densities using Core Cutter method:

- **Sample 1:**

Wt. of core cutter W1 = 996 g

Wt. Of core cutter and wet soil = 3.06 kg

Mass of soil = 2.064 kg

Vol. of core cutter = πr^2 h (r=5, h=13)

=1021.6 cm^3

Bulk density = Wsoil (wet)/v = 2.02g/cc

Wt. of container= 20 g

Wt. of cont. + wet soil = 105 g

Wt. of cont. + dry soil = 97 g

Moisture content = 10.38 %

Dry density = ρd= ρ / (1+w) = 2.02 / (1+0.1038) = 1.83 g/cc

Dry unit wt. = λd = 1.83* 9.81 = 17.95 Kn/m^3

- **Sample 2:**

Wt. of core cutter W1 = 996 g

Wt. Of core cutter and wet soil = 3.05 kg

Mass of soil = 2.054 kg

Vol. of core cutter = $\pi r^2 h$ (r=5 , h=13)

=1021.6 cm^3

Bulk density = W soil (wet) / v = 2.98g/cc

Wt. of container= 20 g

Wt. of cont. + wet soil = 100 g

Wt. of cont. + dry soil = 92 g

Moisture content = 11.11 %

Dry density = ρd= ρ / (1+w) = 2.98/(1+0.1111)= 2.68 g/cc

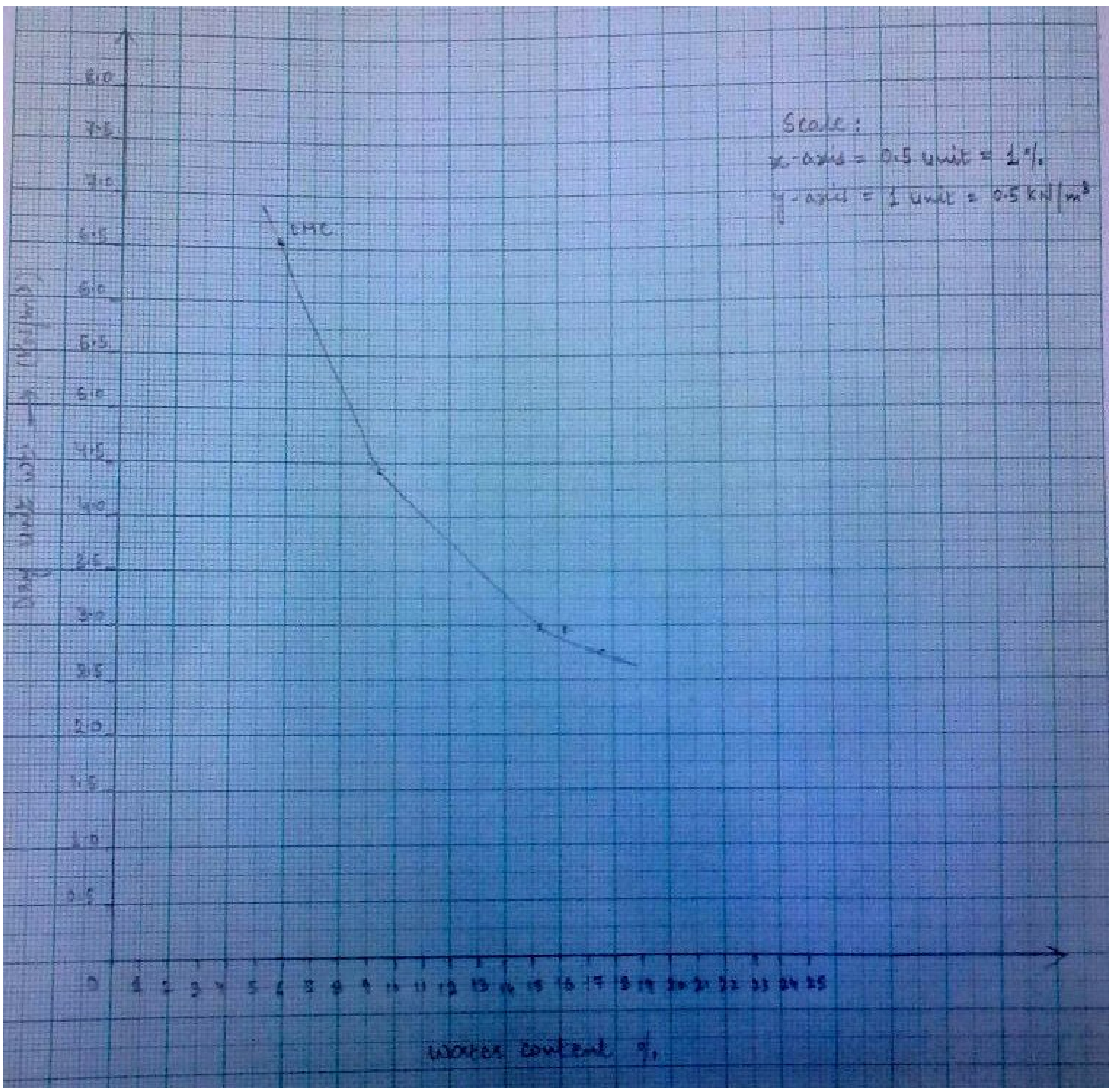
Dry unit wt. = γd = 2.68* 9.81 = 26.29 Kn/m^3

8. Standard Proctor test (Soil Compaction):

- **Sample 1:**

Weight of wet soil (g)	**Moisture content (%)**	**Γ_t**	**Γ_d (kN/m$^{3)}$**

1509.5	5.89	45.27	6.57
1560.5	9.47	46.80	4.47
1645.8	15.45	49.35	3.0
1673.7	17.41	50.19	2.73
1655.0	16.10	49.65	2.90



Graph 4 *A graph between moisture content and dry unit weight*

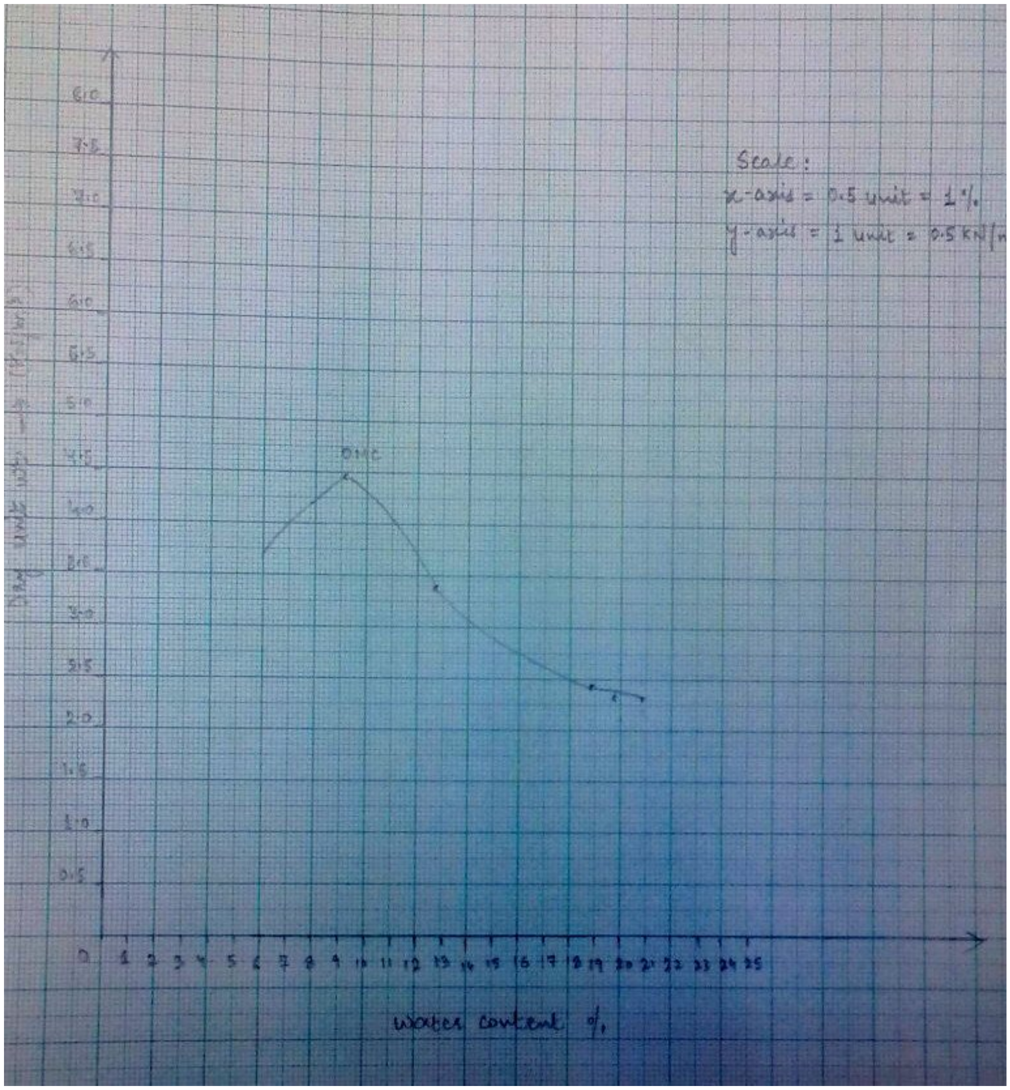
The optimum moisture content is the moisture content which forms the highest peak in the graph.

Here the O.M.C = 5.89%

- **Sample 2:**

Weight of wet soil(g)	**Moisture content (%)**	**Γ_t**	**Γ_d (kN/m$^{3)}$**
1516.8	9.12	45.48	4.49
1569.0	12.87	47.07	3.39
1652.9	18.91	49.56	2.49
1680.9	20.92	50.40	2.30
1665.8	19.84	49.95	2.40

Figure 16 *Performing soil compaction*



Graph 5 *A graph between moisture content and dry unit weight*

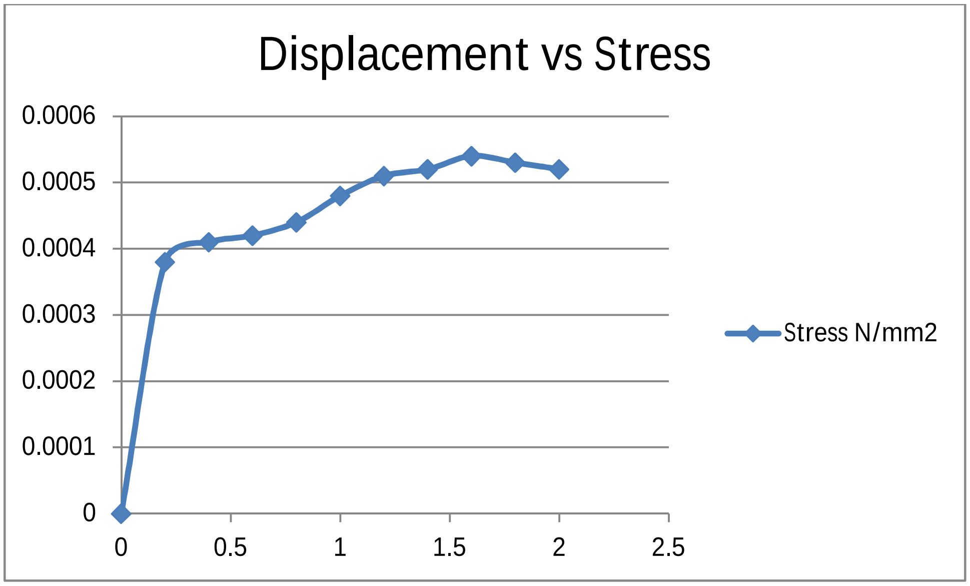
The optimum moisture content is the moisture content which forms the highest peak in the graph.

Here the O.M.C = 9.12%

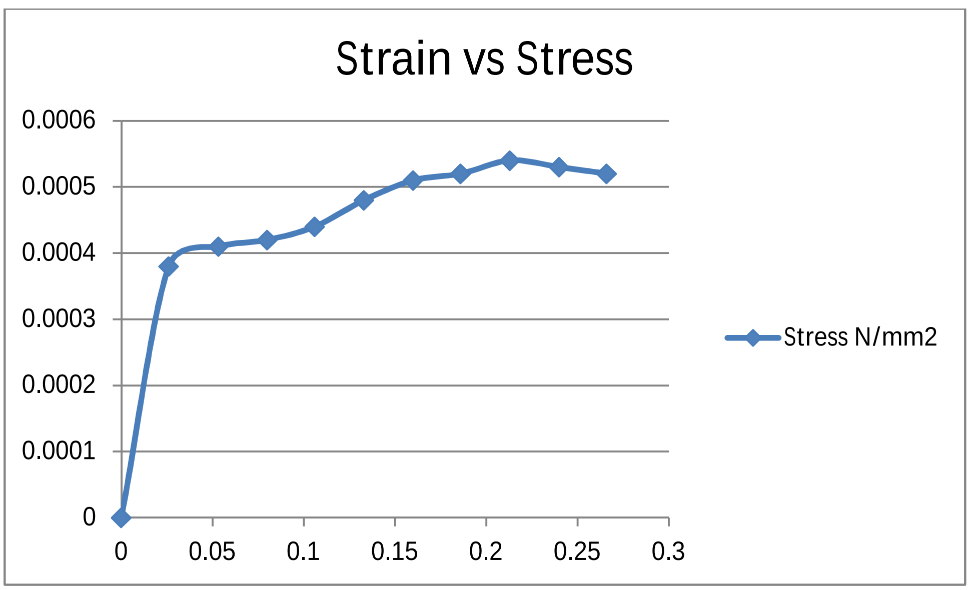
9. **Unconfined Compression test:**

- **Sample 1:**

Dial gauge reading	Proving ring reading	Deformation mm	Strain	%Strain	Corrected area mm^2	Load kN	Stress N/mm^2
0	0	0	0	0	1120.20	0	0
20	3.1	0.2	0.0260	2.66	1150.10	0.4433	0.00038
40	3.4	0.4	0.0533	5.33	1182.89	0.4862	0.00041
60	3.6	0.6	0.0800	8.00	1217.60	0.5148	0.00042
80	3.9	0.8	0.1060	10.66	1253.02	0.5577	0.00044
100	4.4	1.0	0.1330	13.33	1290.04	0.6292	0.00048
120	4.8	1.2	0.1600	16.00	1335.57	0.6864	0.00051
140	5.1	1.4	0.1860	18.60	1376.16	0.7293	0.00052
160	5.4	1.6	0.2130	21.33	1423.37	0.7722	0.00054
180	5.7	1.8	0.2400	24.00	1513.78	0.8151	0.00053
200	6.0	2.0	0.2660	26.66	1526.15	0.8580	0.00052



Graph 6 *Graph between displacement and stress*

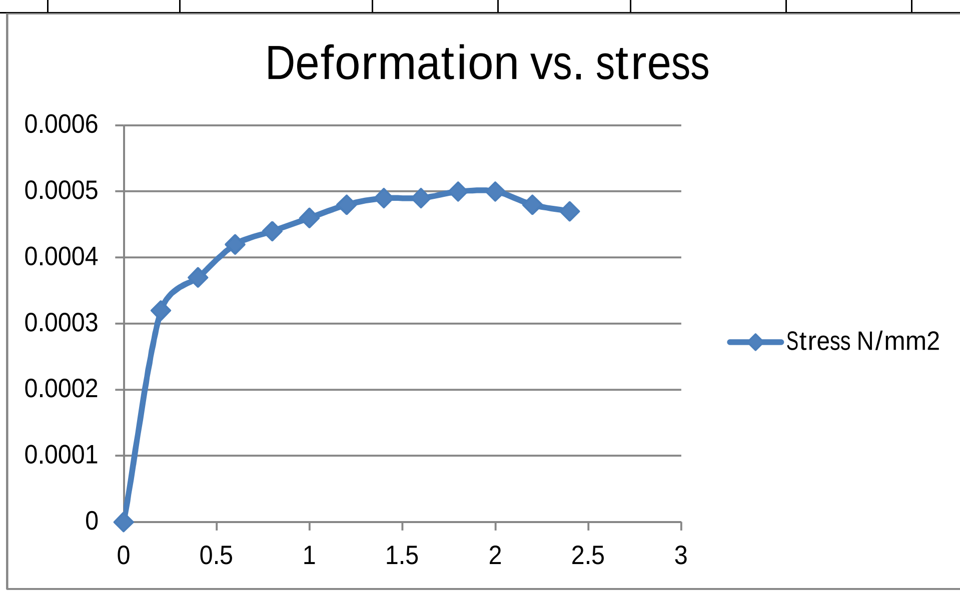


Graph 7 *Graph between Strain and stress*

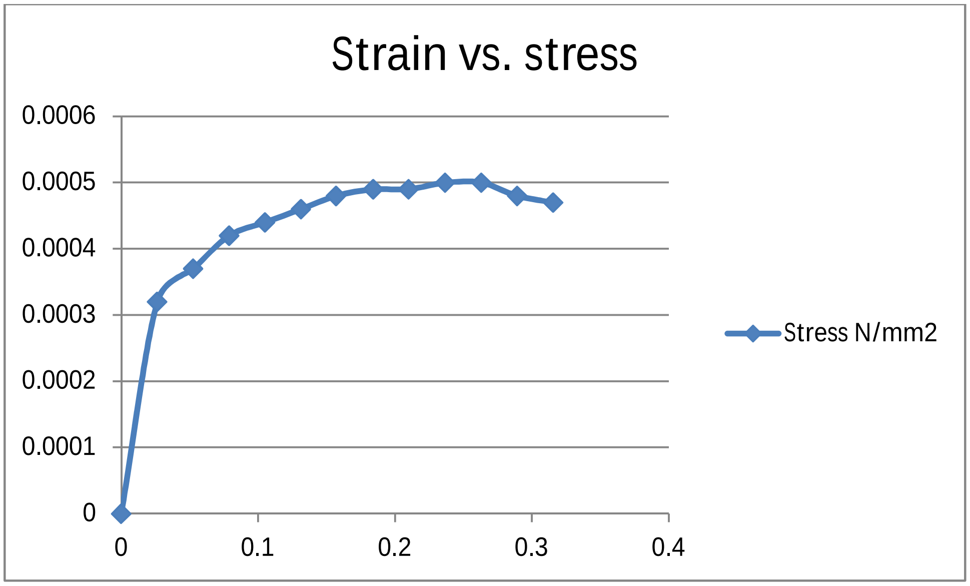
- **Sample 2:**

Dial gauge reading	Proving ring reading	Deformation mm	Strain	%Strain	Corrected area mm^2	Load kN	Stress N/mm^2

0	0	0	0	0	1134.11	0	0
20	2.8	0.2	0.0263	2.63	1164.74	0.4004	0.00032
40	3.1	0.4	0.0526	5.26	1197.07	0.4433	0.00037
60	3.4	0.6	0.0789	7.89	1231.25	0.5291	0.00042
80	3.9	0.8	0.1051	10.51	1267.16	0.5577	0.00044
100	4.2	1.0	0.1314	13.14	1305.00	0.6006	0.00046
120	4.6	1.2	0.1570	15.70	1345.32	0.6578	0.00048
140	4.8	1.4	0.1842	18.42	1389.84	0.6864	0.00049
160	5.0	1.6	0.2100	21.00	1435.58	0.7150	0.00049
180	5.2	1.8	0.2367	23.67	1484.43	0.7436	0.00050
200	5.4	2.0	0.2632	26.32	1540.91	0.7722	0.00050
220	5.7	2.2	0.2894	28.94	1595.98	0.8151	0.00048
240	6.0	2.4	0.3157	31.57	1657.32	0.8580	0.00047



Graph 8 *Graph between deformation and stress*



Graph 8 *Graph between strain and stress*

Figure 17 *Extraction of sample and setting the sample to perform test*

10. Tabular comparison of both the soils:

Name of experiment:	**Result of Sample 1: (Punjab Sample)**	**Result of Sample 2: (Himachal Sample)**
Sieve Analysis	Soil is found to be medium fine sand.	Soil is found to be fine silt.
Moisture Content	9.29%	52.42%
Liquid limit	Flow index = 26.05 % Toughness index = 0	Flow index = 35.82 % Toughness index = 0

Plastic limit	IP = 0 = Non Plastic	IP = 0 = Non Plastic
Shrinkage limit	20.37%	26.44 %
Sand replacement method	ρ = 1.46 g/cc, ρd = 1.35 g/cc, γd = 13.53 kN/m^3	ρ= 1.02 g/cc, ρd = 1.32 g/cc, γd = 12.94 kN/m^3
Core cutter method	ρ= 2.02 g/cc, ρd = 1.83 g/cc, γd = 17.95 kN/m^3	ρ= 2.98 g/cc, ρd= 2.68 g/cc, γd= 12.94 kN/m^3
Soil Compaction test	O.M.C= 5.89 %	O.M.C= 9.12%
Unconfined compression test	Unconfined compressive strength= 0.00054 kN/m^3	Unconfined compressive strength =0.00050 kN/m^3

11. Other comparisons made between the two samples are:

Soil property/Behavior	Sand	Silt
Water holding capacity	Low	medium to high
Aeration	Good	Medium
Drainage rate	High	slow to medium
Soil organic matter level	Low	medium to high
Compactibility	Low	Medium
Shrink/swell potential	very low	Low
Sealing of ponds, dams and landfills	Poor	Poor

Discussion and Conclusion

- **Discussion:**

The main objective of the project was to collect two different varieties of soil and perform various laboratory and field tests on these samples to compute results and check various features that these soils exhibit when put to test. The results were carried out using various tests and techniques which have been compiled and discussed in detail in the earlier chapters. The basic reason of conducting these tests was to compare the two samples of soil and discuss the various properties these soils exhibit and hence come out with one sample between these two which proves to be better for large scale construction purposes.

Soil which lies below a building, institution or any such constructional areas which have to be developed, needs to be tested and analyzed before carrying out the constructional process. Soil testing and analyses in made compulsory for even small scale constructions in some parts of United States and is being followed by many others also. Thus carrying out the soil testing and computing the results has now become a very vital aspect even for smaller constructions. Soil below a foundation bears a lot of loading from the construction above and thus should not fail or collapse else it can cause serious damage to the foundation, the building above or even cause loss of life. To avoid these dangers, soil testing and analysis is very important.

- **Conclusion:**

Comparison of results has been done between the two samples which gives us a clue about both the samples and tells us which sample is much more suitable for large scale constructions. We shall now conclude with some major parameters which helped us to know which sample between the two should be considered prominent.

The Punjab sample possesses:

i. Low moisture content
ii. Low flow index
iii. Low shrinkage limit

iv. High field density values
v. High unconfined compressive strength

The moisture content of this sample is 9.29 % and the Optimum moisture content for this sample is 5.89% which can be achieved easily by good compaction techniques. If we compare this with the other sample, we find that moisture content value and Optimum moisture content values lie very far off which would cause problem in compaction in regard to construction purposes. Also, the Punjab sample possesses low shrinkage limit value i.e. 20.37 % and has a low flow index of 26.05% than the other sample which is also a good sign for heavy constructions that would be supported by this soil type. When we talk about the field densities, this soil type has higher values of field densities in both the sand replacement and core cutter methods except the value of dry density (ρd) in core cutter method. The dry unit weight (γd) in both the methods gives a greater value than the other sample. This also tends us to believe that this sample is more suited for constructional purposes. The unconfined compression test value of the Punjab sample is 0.00054 kN/m^3 which is also higher than the other sample.

References:-

1. Walworth James, College of Agriculture and Life Sciences, University of Arizona (Tucson, AZ), July 2006.
2. Dr. Donald S. Loch, Department of Primary Industries and fisheries, Redlands research station, Cleveland, May 2001.
3. http://www.wikipedia.org/wiki/soilsitefactors.
4. Public welfare department, Himachal Pradesh, No. PW, E-in-C(QC & D) Lab Empanelment/2013-2227-2308.
5. K.C Shines, J.V Burton, M.L Papp, Lockhead engineering and Sciences Company Inc. Las Vegas Nevada 89119, 2010.
6. L.J Blume, Exposure Assessment Research Division Environment Monitoring systems laboratory, California, 2010.
7. W.O Thom, K.L Wells, L.W Murdock, Cooperative extension service, University of Kentucky, College of Agriculture, U.K, 1998
8. http://www.globososo.com/grain-size-distribution/soil-testing-techniques.pdf.
9. http://www.hos.ufl.edu/publications/interpretationofsoil-zotarelli.pdf.