SLOPE STABILITY ANALYSIS USING ARTIFICIAL NEURAL NETWORK

A

Project Report

Submitted in partial fulfillment of the requirement for the award of the Degree of

"Bachelor of Technology in Civil Engineering"

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CERTIFICATE

We hereby declare that the work presented in the project titled, 'Slope stability analysis using Artificial Neural Network (ANN) ' submitted to Department of Civil Engineering, North Eastern Regional Institute of Science and Technology, Nirjuli, for the award of 'Degree in Civil Engineering' is an authentic record of our work carried out under the guidance and supervision of Dr. Dipika Devi, Associate Professor, North Eastern Regional Institute of Science and Technology. The work presented has not been submitted to any other university or institution.

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We also deeply express our sincere regards to our "Head of the Department" Sir Prof. Dr. AJAY BHARTI for encouraging us and allowing us to present our project on the topic or subject, "**Slope Stability Analysis using Artificial Neural Network**" for the partial fulfillment of the requirement for the award of the Degree of Bachelor of Technology in Civil Engineering.

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We take this opportunity to thank all our honorable lecturers who have directly or indirectly helped with our project. We also pay our due respect, love & concern to our parents and all the other family members and friends for their love and encouragement throughout our careers. And last but not the least we express our thanks to our project partners for their cooperation and support and dedication.

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ABSTRACT

Analysis of slopes for stability and safety is a major area of concern in civil engineering. This is the reason that so many analysis techniques have been developed so far. Stability of natural slopes and man-made slopes such as roads/railways embankment, hydraulically constructed dams, earth dams etc. is a major issue in geotechnical engineering. The traditional way of slope stability analysis involves the determination of factor of safety for a slope to take safety precautions against any instability. Various researchers worked to develop a new method in which probability of failure or reliability of a slope is calculated. Thus, basically two different approaches of slope stability analysis are available with us– deterministic approach and reliability approach.

Artificial Neural Networks (ANN), usually called neural networks, are very sophisticated modeling techniques which are capable of modeling extremely complex functions. They are used for predicting the outcome of two or more independent variables. Predicting the stability of slopes is a very challenging task for Geotechnical Engineers. They must pay particular attention to geology, ground water and shear strength of the soils in accessing slope stability.

CANDIDATES DECLARATION

We hereby declare that our project entitled, “Slope Stability Analysis using Artificial Neural Network” submitted to the Civil Engineering Department of the North Eastern Regional Institute Of Science & Technology (NERIST), is a record of original work done by us under the guidance of Dr. (Mrs.) DIPIKA DEVI, Associate Prof., Department Of Civil Engineering, NERIST, and this project report is submitted in partial fulfillment of the requirement for the award of the Degree of Bachelor of Technology in Civil Engineering.

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CHAPTER-1: INTRODUCTION

1.1 General:

An exposed ground surface that stands at an angle (β) with the horizontal is called slope.

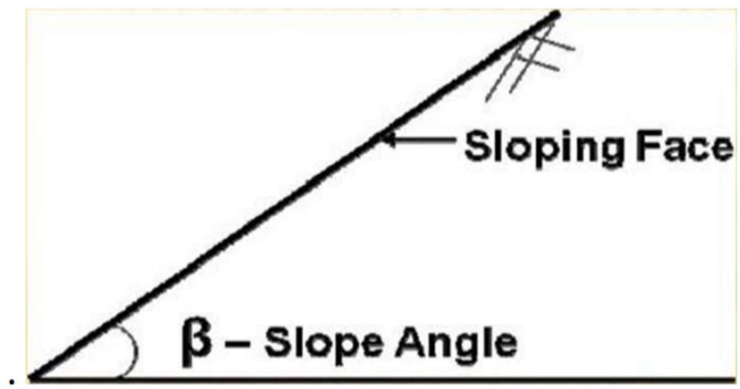


Figure-1: components of a slope

Slope may be artificial, that is man-made, as in cuttings and for highways and rail, roads, earth-dams, temporary excavations, landscaping operations for development of sites, etc. Slopes may also be natural, as in landslides and valley, coastal and river cliffs, etc.

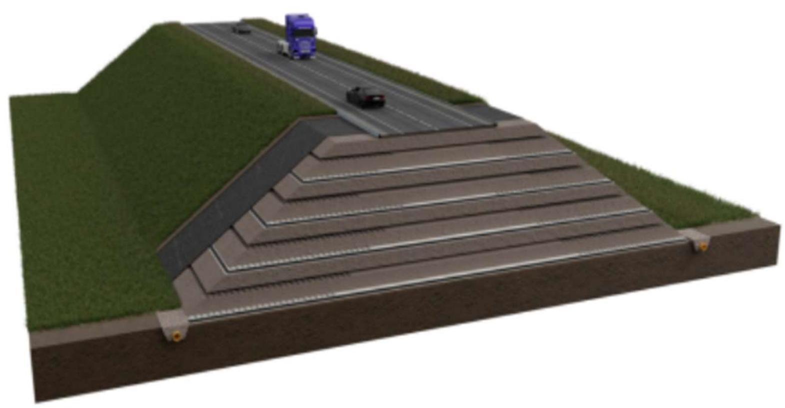


Figure-2: embankments for Highways

Figure-3: embankments for earth-dams

Figure-4 : River cliffs

Figure-5: Valley

Landslides are one of the widespread natural hazards which typically occur in the mountainous regions of the world. In recent years, the frequency of landslides has increased causing serious loss to human lives and property. India is one of the countries that is severely prone to landslides, especially in the Himalayan region and the Western Ghats. The Himalayan Mountain chain is one of the most tectonically active and fragile regions of the world. Landslides frequently occur in Northern Indian region of the Himalayas, passes including the states of Jammu and Kashmir, Uttarakhand, Himalaya Himachal Pradesh, Sikkim, and Arunachal Pradesh.

1.2 Objectives: -

- To select the site and identify the type of soil.
- To analyze the slope and study its stability using traditional methods.
- To create and verify the ANN Model and analyze the slope stability using the data.

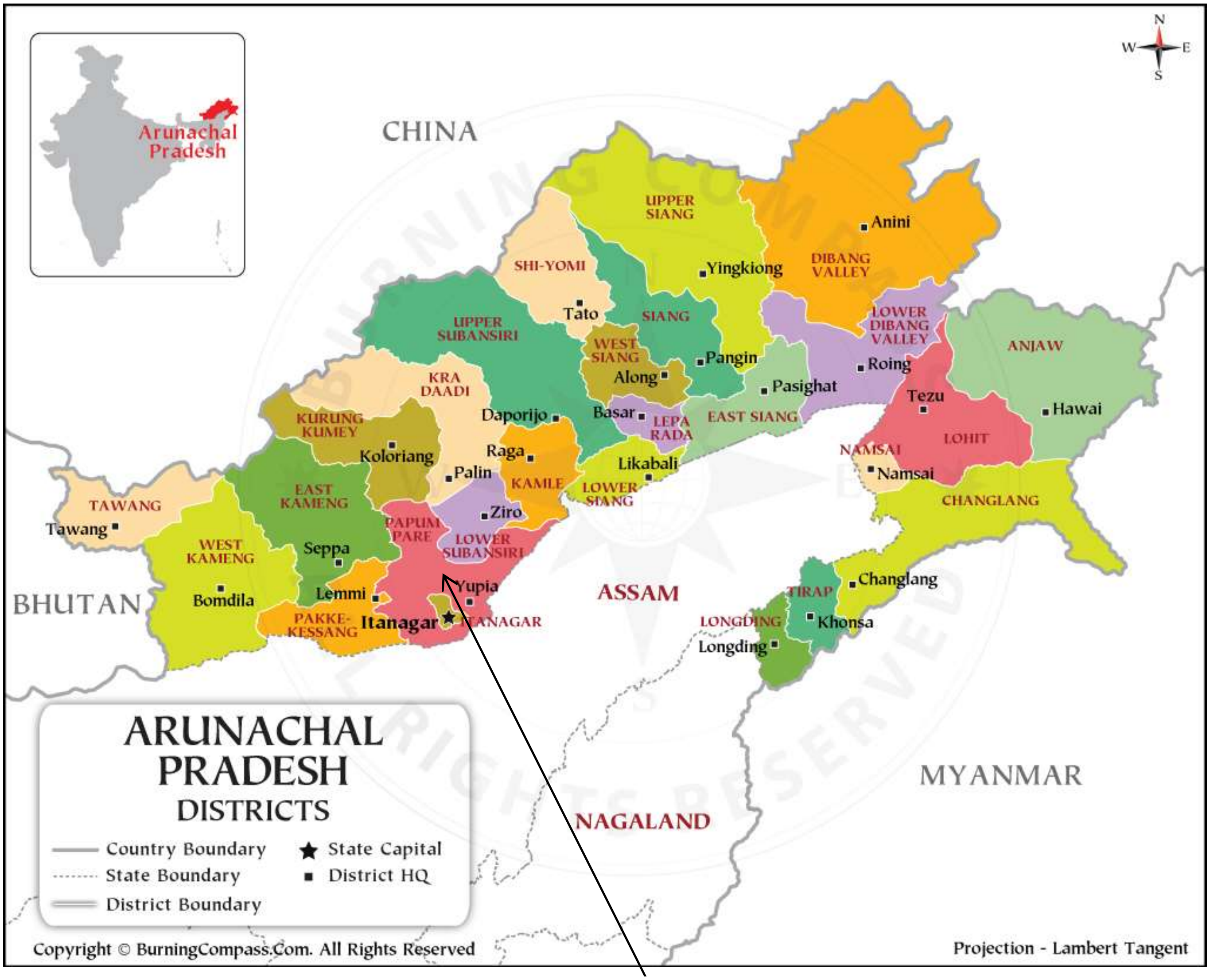


Figure-6 : map of Arunachal Pradesh along with GPS Location of site

GPS LOCATION :- 27°07'43.8"N 93°44'07.2"E

Figure 7: Test site photo

Figure 8: Test site photo

1.2 Failure of Slopes:

Slope failures occur when driving forces overcome resisting forces. The driving force is typically gravity, and the resisting force is the slope material's shear strength.

When assessing a slope's stability look for indications that physical processes are decreasing shear strength. These include the following:

a) Weak, weathered bedrock, jointed rock, or bedrock that dips parallel to the slope can decrease stability.
b) Droughts, wildfires, and humans can remove vegetation from the slope, decreasing stability.
c) Water in rock joints or in soils can decrease slope stability.
d) Rivers can erode the bottom of the slope, called the toe, decreasing stability. This can occur over time through normal stream action or catastrophically during flood events.
e) Humans modify stability through actions such as excavation of the slope or its toe, loading of the slope or crest, surface or groundwater manipulation, irrigation, and mining.
f) Steeper slopes tend to have greater risks for instability.
g) Soils have variable amounts of shear strength, dependent on factors such as soil texture, pore water, and particle cohesion.
h) Water works in many ways to reduce shear strength. For example, pore water pressure in soils decreases shear strength, and saturated soils are more likely to lead to slope failure. Perched water tables, groundwater seeps, and excessive precipitation are some examples of water sources that may lead to slope failure in certain conditions.

Figure-9: photo of landslide at Balipara-Charduar-Tawang (BCT) road.

Many things can impact the stability of a slope. Just like with stream crossings, all geomorphic factors affecting slope stability should be considered when determining the risk of slope failure.

After the geomorphic factors for each slope crossing have been adequately assessed, these indicators can be fed into our geomorphic framework of slope stability to determine how likely slope failure is at a particular location.

1.3 Types of Slope:

Slopes may be of two types: Infinite slope and Finite slope. If a slope represents the boundary surface of a semi-infinite soil mass, and the soil properties for all identical depths below the surface are constant, it is called an Infinite slope. If the slope is of limited extent, it is called a Finite slope. Slopes extending to infinity do not exist in nature. The examples of finite slopes are the inclined faces of earth dams, embankments, and cuts etc.

1.3.1 Stability of Finite slopes:

Failure of finite slopes occurs along a surface which is a curve. In stability computations, the curve representing the real surface of sliding is usually replaced by an arc of a circle or logarithmic spiral. Two basic types of failure of a finite slope may occur: (i) slope failure, (ii) base failure.

If the failure occurs along a surface of sliding that intersects the slope at or above its toe, the slide is known as slope failure (or face failure) as shown in Fig-8(d).

If the failure surface passes through the toe, it is known as toe failure (as shown in Fig-8(c)). This occurs when the slope is steep and homogeneous.

If the failure surface passes below the toe portion, it is known as base failure. This generally occurs when the soil below the toe is relatively weak and soft (as shown in Fig-8(b)).

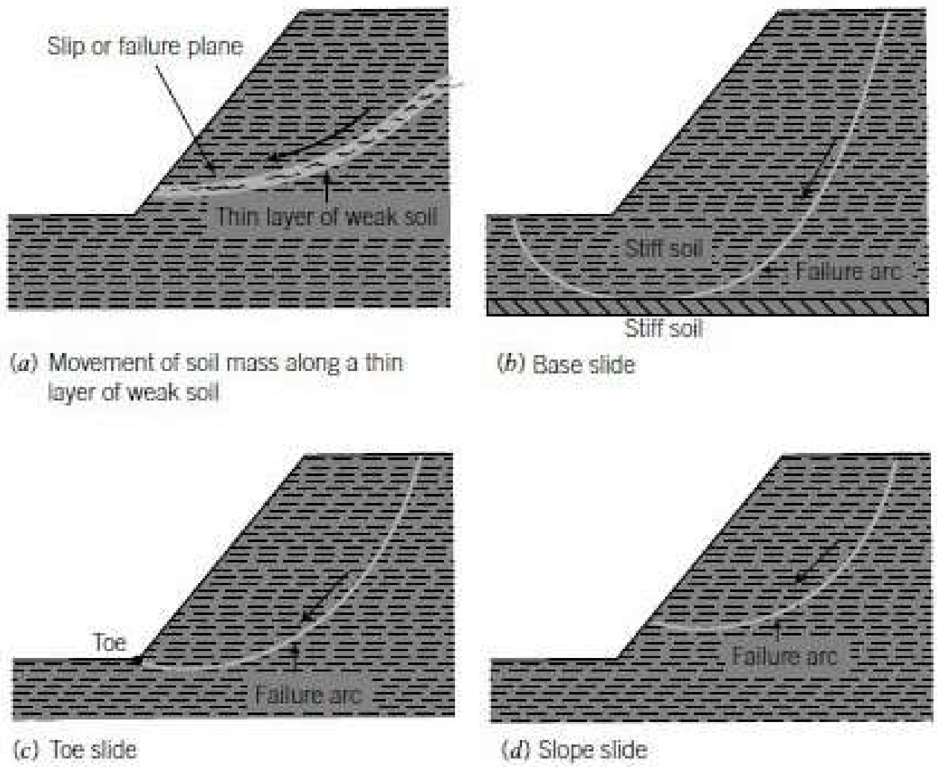


Figure-10: modes of failure for finite slopes

Methods of analysis of finite slopes are: -

a) Culmann's Method of plane failure surface.
b) The Swedish circle Method (Slip circle Method).
c) The Friction circle Method.
d) Bishop's Method.

a) Culmann considered a simple failure mechanism of a slope of homogeneous soil with plane failure surface passing through the toe of the slope.

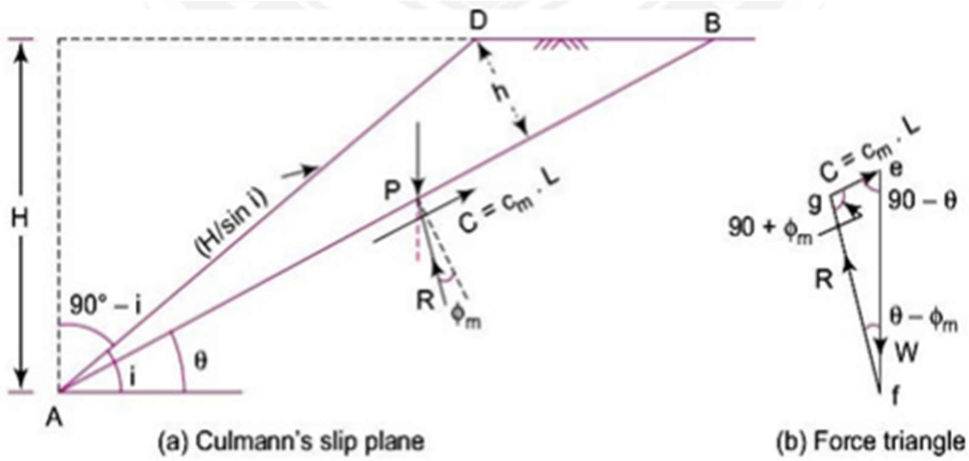


Figure- 11: Culmann’s slip plane and Force triangle

Factor of safety, F = $\frac{\tau_f}{\tau} = \frac{cL + W\cos\theta\tan\varphi}{W\sin\theta}$

Culmann’s method is suitable for very steep slopes.

b) The method, developed by Swedish engineers assumes that the surface of sliding is an arc of a circle. Two cases arise as follows:

- Analysis of purely cohesive soil [($\emptyset_u = 0$) analysis]:

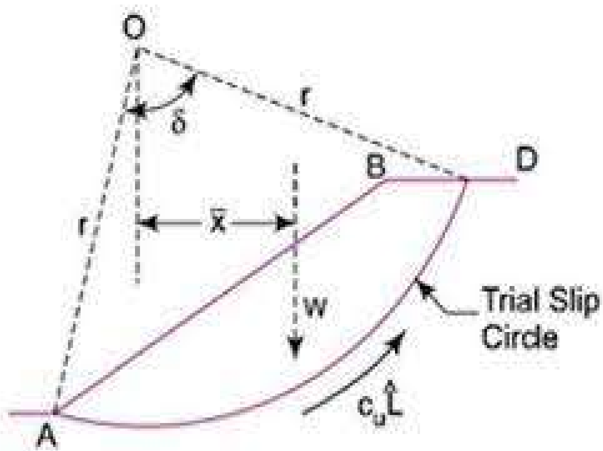


Figure-12: ($\phi_u = 0$) Analysis.

Factor of safety, $F = \frac{C_u}{C_m} = \frac{C_u \widehat{L}\ .\ r}{W.\bar{x}}$ where,

$'C_m'$ is the mobilized shear resistance of soil ($\emptyset_u = 0$) and $'C_u'$ is the unit cohesion.

- Analysis of soil possessing both cohesion and friction [(c-ϕ) analysis]:

To test the stability of the slope of a c- ϕ soil, trial slip circle is drawn, and the material above the assumed slip surface is divided into a convenient number of vertical strips or slices. The forces between the slices are neglected, and each slice is assumed to act independently as a column of soil of unit thickness and of width ‘b’.

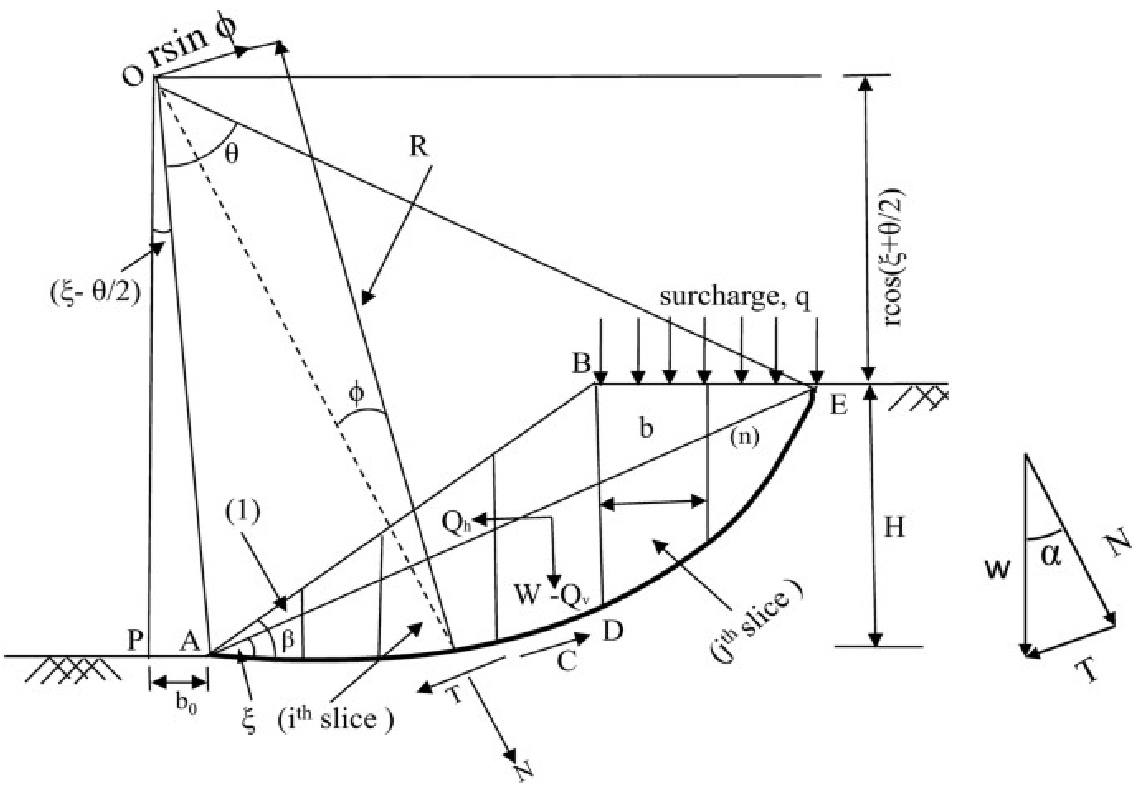


Figure 13: Slip circle method: (c- ϕ) analysis

Factor of safety, $F = \frac{M_R}{M_D} = \frac{c\,\hat{L} + \tan\phi \sum N}{\sum T}$

M_D is the driving moment (= $\sum T * r$).

M_R is the resisting moment.

c) This method uses a total stress-based limit equilibrium approach. In this method the equilibrium of the resultant weight `w', the reaction `p' due to frictional resistance and the cohesive force `c' are considered.

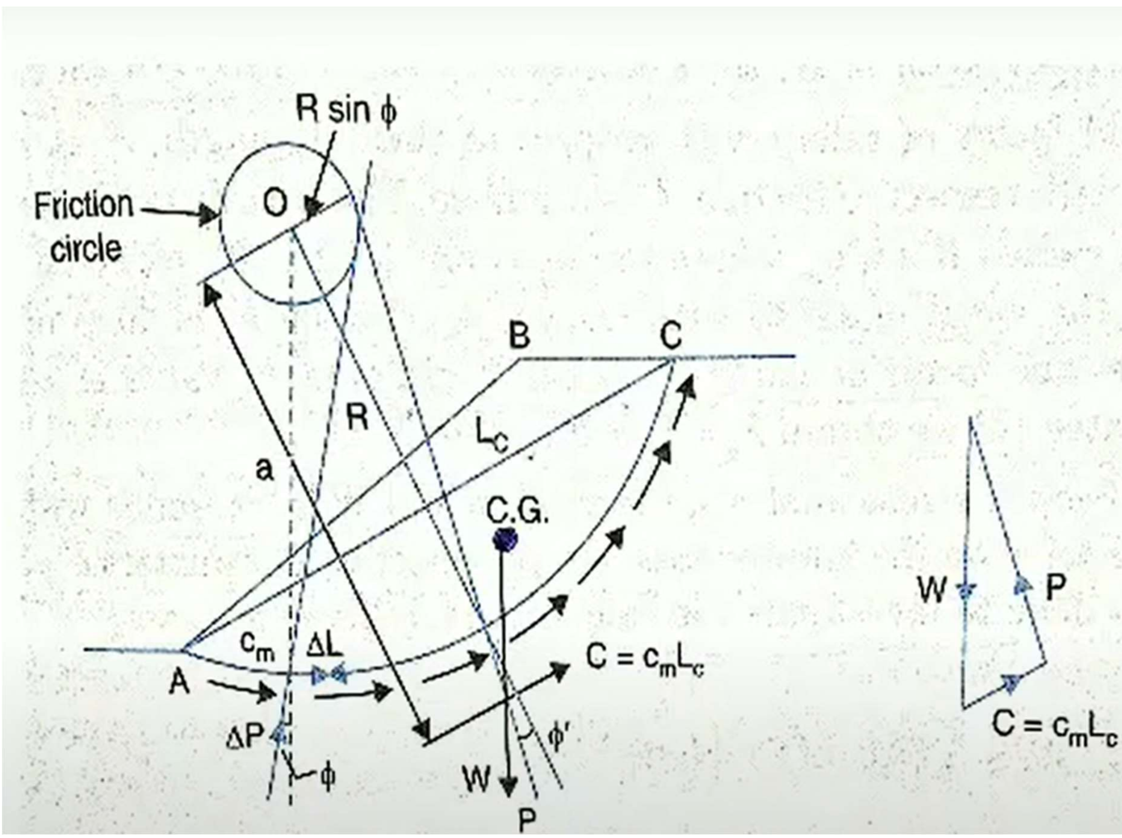


Figure-14: Friction circle analysis and force triangle.

Factor Of Safety (F_c) = $\frac{C_U}{C_m}$ where,

'C_U' is the cohesion value that we obtain from lab.

1.3.2 Stability of Infinite slopes:

- Case-1: COHESIONLESS SOIL.

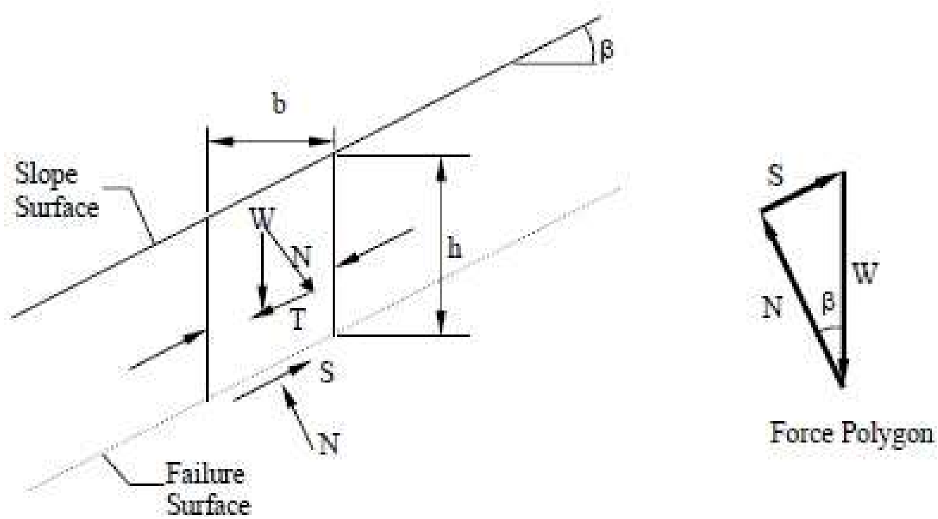


Figure-15: Forces acting on an element in case of cohesionless soil

The normal (N) and tangential (T) force components of W are determined as follows:

N = W$\cos\beta$

T = W$\sin\beta$

Available shear strength along the failure plane is given by,

$$S = N \tan\emptyset$$

The factor of safety (FS) is defined as the ratio of available shear strength to strength required to maintain stability. Thus, the F.S will be given by,

$$F.S = \frac{S}{T} = \frac{N\tan\emptyset}{W\sin\beta} = \frac{W\cos\beta\ \tan\emptyset}{W\ \sin\beta} = \frac{\tan\emptyset}{\tan\beta}$$

- Case-2: COHESIVE SOIL [$(C-\varphi)$ soil]

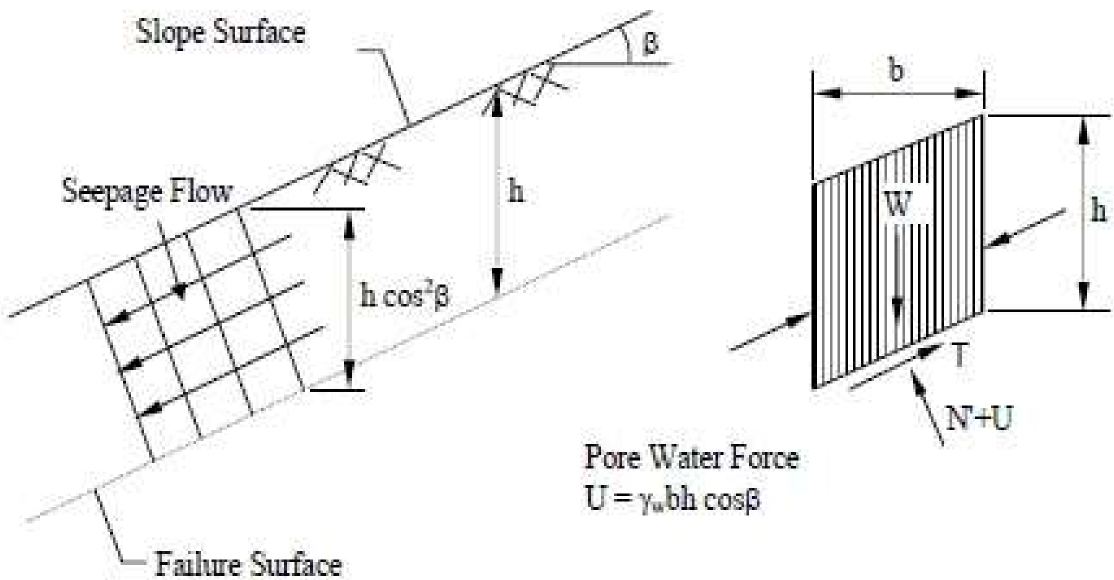


Figure-16: Forces acting on an element in case of cohesive soil

The pore-water pressure acting on the bottom of the typical section is:

$$u = \gamma_w H (\cos\beta)^2$$

where 'H' is any depth less than or equal to the depth of saturation and b is a unit width.

The available frictional strength, S, along the failure plane will depend on φ' and the effective normal force, N' =N-U, where N is the total normal force. The equation for S is:

$$U = \gamma_w \, B \, H \cos\beta$$

$$W = \gamma_{sat} * B * H$$

Factor Of Safety, F.O.S = $\dfrac{c+(\gamma_{sat}-\gamma_w)*\tan(\varphi)*(cos\beta)^2 * H}{\gamma_{sat}* \cos\beta * \sin\beta * H}$

CHAPTER-2: LITERATURE REVIEW

1) Xuzhen et al (2020) studied Machine learning aided stochastic reliability analysis of spatially variable slopes. Within this framework, a small number of traditional random finite-element simulations are conducted. The samples of the random fields and the calculated factor of safety are, respectively, treated as training input and output data, and are fed into machine learning algorithms to find mathematical models to replace finite-element simulations.

2) Chakraborty and Goswami (2015) analyzed Slope Stability prediction using Artificial Neural Network. Artificial neural networks (ANN), usually called neural networks, are very sophisticated modeling techniques which are capable of modeling extremely complex functions. They are used for predicting the outcome of two or more independent variables. Predicting the stability of slopes is a very challenging task for geotechnical engineers.

3) Kaur and Sharma (2016). Analysis of slopes for stability and safety is a major area of concern in civil engineering. This is the reason that so many analysis techniques have been developed so far. The traditional way of slope stability analysis involves the determination of factor of safety for a slope to take safety precautions against any instability. Thus, basically two different approaches of slope stability analysis are available – deterministic approach and probabilistic (or reliability) approach. In this paper past trends in slope stability analysis are discussed with the evolution of each method. A brief review of available methods has also been presented here along with the advantages and limitations of their use.

4) Meng & Mattson (2021). To enable assess slope stability problems efficiently, various machine learning algorithms have been proposed recently. However, these developments are restricted to two-

dimensional slope stability analyses (plane strain assumption), although the two-dimensional results can be very conservative. In this study, artificial neural networks are adopted and trained to predict three-dimensional slope stability and a program, Slope Lab has been developed with a graphical user interface. The model has been trained with a dataset from slope stability charts for fully cohesive and cohesive-frictional soils.

5) Zhou (2019) expounded the natural factors that affect slope stability and the application principle of Artificial Neural Network in the slope stability analysis. The advantages and disadvantages of general neural network and BP network are analyzed, and the corresponding countermeasures were put forward. ANN is set up by humans and carries out information processing through continuous or intermittent external input to make state responses. With the development of science and technology, people pay increasing attention to artificial intelligence research, and artificial neural network research is deeper.

6) Pradhan and Lee (2008) presented a study on landslide hazard and risk analysis using remote sensing data, GIS tools and artificial neural network model. Landslide locations were identified in the study area from interpretation of aerial photographs and from field surveys. Topographical and geological data and satellite images were collected, processed, and constructed into a spatial database using GIS and image processing

7) Khandelwal et al (2022) A stability prediction system that can analyze the slope under both the condition of the soil or rock surface is missing. In this study, artificial neural network technology has been utilized to predict the stability of jointed rock and residual soil slope of the Himalayan region.

CHAPTER-3: METHODOLOGY

3.1 PRELIMINARY INVESTIGATION OF SOIL:

The preliminary investigation was carried out to find out the index and engineering properties of the soil by using the following methods.

3.1.1 Grain-size Analysis:

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, airfield etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are generally used. The method is applicable to dry soil passing through 4.75 mm size sieve less than 10 % passing through 75-micron sieve.

Percentage retained on any sieve = $\frac{weight\ of\ soil\ retained}{Total\ weigh} * 100\%$

Cumulative percentage retained is equal to the sum of percentages retained on any sieve for all coarser sieves.

<u>Apparatus for Grain-size analysis: -</u>

- IS Sieves (10mm, 4.75mm, 2mm, 1mm, 600 μ, 425 μ, 300 μ, 150 μ, and 75 μ).
- Sieve shaker (Mechanical shaker).
- Oven.
- Trays.
- Weighing balance with accuracy of 0.1% of the mass of the sample.

Figure 17: IS Sieves.

Procedure for Grain-size analysis: -

1). For soil samples of soil retained on 75 micron I.S sieve

(a) The proportion of soil sample retained on 75 micron I.S sieve is weighed, and recorded weight of soil sample is as per I.S 2720.

(b) I.S sieves are selected and arranged in the order as shown in the table.

(c) The soil sample is separated into various fractions by sieving through above sieves placed in the above-mentioned order.

(d) The weight of soil retained on each sieve is recorded.

(e) The moisture content of soil if above 5% it is to be measured and recorded.

2). No particle of soil sample shall be pushed through the sieves.

3.1.2 Liquid limit test:

Liquid limit is the water content where the soil starts to behave as a liquid.

In the static cone penetrometer method, the liquid limit is taken as the moisture content at which a standard 30-degree, 80 g cone will penetrate the soil sample 20 mm in approximately 5 sec. The Cone Penetration Test (CPT) is one of the most used site investigation tools in the field of geotechnical engineering for the classification and characterization of soils. The liquid limit of the soil corresponds to the water content of a paste which would give 20 mm penetration of the soil.

<u>Apparatus Required: -</u>

- Cone Penetrometer conforming to IS :11196-1985.
- Weigh Balance, sensitive to 0.01g.
- Containers, non-corrodible and airtight for moisture determination.
- Hot Air Oven, thermostatically controlled, capable of maintaining temperature of 105° to 110° C.

Figure-18: cone penetrometer

Procedure for Cone Penetration test to determine liquid limit of the soil sample: -

1. Take about 150 g of soil sample, passing from 425 micron, and work it well into a paste with addition of distilled water. In the case of highly clayey soils, to ensure uniform moisture distribution, it is recommended that the soil in the mixed state is left for sufficient time (24 hours) in an air-tight container.
2. The wet soil paste shall then be transferred to the cylindrical cup of cone penetrometer apparatus, ensuring that no air is trapped in this process. Finally, the wet soil is levelled up to the top of the cup and placed on the base of the cone penetrometer apparatus.
3. The penetrometer shall be so adjusted that the cone point just touches the surface of the soil paste in the cup clamped in this position. The initial reading is either adjusted to zero or noted down as is shown on the graduated scale. The vertical clamp is then released allowing the cone to penetrate the soil paste under its own weight. The penetration of the cone after 5 seconds shall be noted to the nearest millimeter.
4. If the difference in penetration lies between 14 and 28 mm, the test is repeated with suitable adjustments to moisture either by addition of more water or exposure of the spread paste on a glass plate for reduction in moisture content.
5. The test shall then be repeated at least to have three sets of values of penetration in the range of 20 to 28 mm. The exact moisture content of each trial shall be determined.

3.1.3 Standard Proctor test:

The objectives of compaction are:

- To increase soil shear strength and therefore its bearing capacity.
- To reduce subsequent settlement under working loads.
- To reduce soil permeability making it more difficult for water to flow through

To assess the degree of compaction, it is necessary to use the dry unit weight, which is an indicator of compactness of solid soil particles in a given volume. The laboratory testing is meant to establish the maximum dry density that can be attained for a given soil with a standard amount of compactive effort.

1) Bulk Density, $\rho = \frac{(M_2 - M_1)}{V}$

2) Dry Density, $\rho_d = \frac{\rho}{(1+w)}$

3) Dry density for zero air voids line, $\rho_d = \frac{G * \rho_w}{[1+\left\{\frac{wG}{S}\right\}]}$

'M_1'is the mass of mould used for Proctor test.

'M_2'is the combined mass of mould and compacted soil.

'M' is the mass of wet soil.

'V' is the volume of mould.

'ρ_w' is the density of water.

'G' is the specific gravity of soils.

'w' is the water content.

'S' is the degree of saturation.

Apparatus Required: -

i. Proctor mould having a capacity of 944 cc with an internal diameter of 10.2 cm and a height of 11.6 cm. The mould shall have a detachable collar assembly and a detachable base plate.
ii. Rammer: A mechanical operated metal rammer having a 5.08 cm diameter face and a weight of 2.5 kg. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall of 30 cm.
iii. Sample extruder, mixing tools such as mixing pan, spoon, towel, and spatula.

iv. A balance of 15 kg capacity, Sensitive balance, Straight edge, Graduated cylinder, Moisture tins.

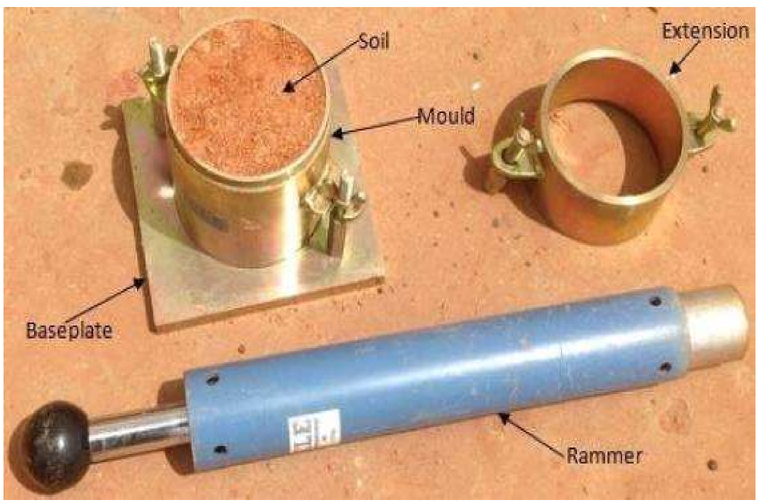


Figure-19: standard proctor test apparatus.

Procedure for Standard Proctor test: -

1. Take a representative oven-dried sample, approximately 5 kg in the given pan. Thoroughly mix the sample with sufficient water to dampen it with approximate water content of 4-6 %.
2. Weigh the proctor mould without base plate and collar. Fix the collar and base plate. Place the soil in the Proctor mould and compact it in 3 layers giving 25 blows per layer with the 2.5 kg

rammer falling through. The blows shall be distributed uniformly over the surface of each layer.

3. Remove the collar; trim the compacted soil even with the top of mould using a straight edge and weigh.
4. Divide the weight of the compacted specimen by 944 cc and record the result as the bulk density (ρ_{bulk}).
5. Remove the sample from mould and slice vertically through and obtain a small sample for water content.
6. Thoroughly break up the remainder of the material until it will pass a no.4 sieve as judged by the eye. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points and repeat the above procedure for each increment of water added. Continue this series of determination until there is either a decrease or no change in the wet unit weight of the compacted soil.

3.1.4 Triaxial test:

A triaxial shear test is a common method to measure the mechanical properties of many deformable solids, especially soil (e.g., sand, clay) and rock, and other granular materials or powders. A. Casagrande developed the triaxial test. It is the most versatile of all the shear stress. Drainage conditions can be controlled, whatever be the type of the soil. In the triaxial test, pore water measurements can be made accurately. Volume changes can also be measured. There is no rotation of the principal stresses during the test. The failure plane is not forced. The specimens can fail only on any weak plane or can simply bulge. The stress distribution on the failure plane is uniform. From the triaxial test data, it is possible to extract fundamental material parameters about the sample, including its angle of shearing resistance, apparent cohesion, and dilatancy angle. These parameters are then used in computer models to predict how the material will behave in a larger-scale engineering application.

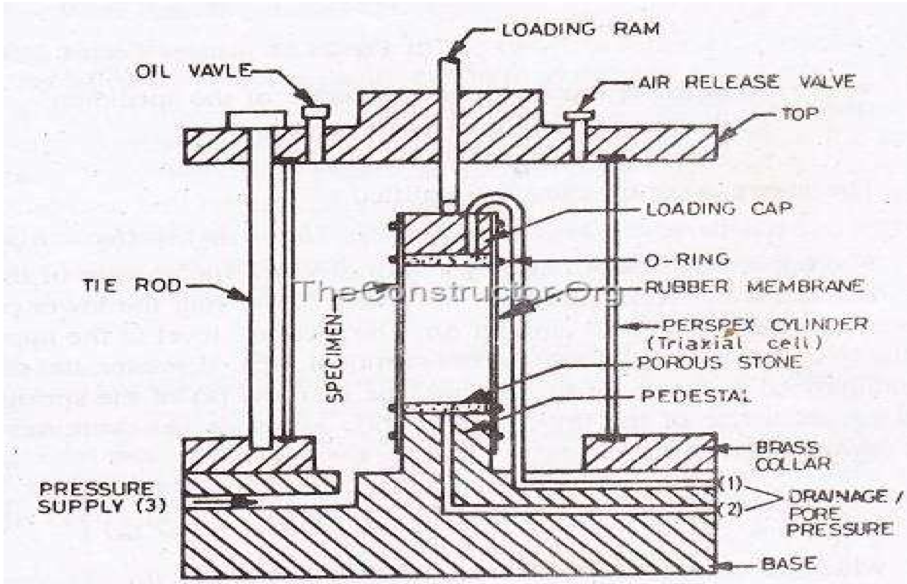


Figure-20: Triaxial test apparatus. 1

An example would be to predict the stability of the soil on a slope, whether the slope will collapse or whether the soil will support the shear stresses of the slope and remain in place. Triaxial tests are used along with other tests to make such engineering predictions. The test is carried out on a cylindrical specimen of soil, usually having a length to diameter ratio of 2.

Three types of triaxial tests can be conducted with different combinations of drainage conditions in the two stages of the tests:

(i) Unconsolidated Undrained (UU) Triaxial Test:

In the UU triaxial test, the drainage line valve is kept closed during the two stages. As a result, the pore water of the soil remains in the soil and, hence, the soil remains unconsolidated. Finally, the sample is tested to failure under undrained conditions, i.e., without allowing the pore water pressure to dissipate. If the pore water pressures are measured, the test is denoted as UU test.

(ii) Consolidated Undrained (CU) triaxial Test:

In the CU triaxial test, the drainage line valve is kept open during the first stage and then closed during the second stage. As a result the pore water drains out of the soil and pore water pressure will dissipate and, hence, the soil will eventually be consolidated. Finally, the sample is tested to failure under undrained conditions by closing the drainage line valve. If the pore water pressures are measured, the test is denoted as CU test.

(iii) Consolidated Drained (CD) Triaxial Test.

In the CD triaxial test, the drainage line valve is kept open during the two stages and. As a result, the pore water drains out of the soil and pore water pressure will dissipate and, hence, the soil will eventually be consolidated. Finally, the sample is tested to failure under drained conditions by opening the drainage line valve and the allowing dissipation of pore water pressure.

Apparatus required: -

- Triaxial Shear Test Apparatus.
- Triaxial Shear Test Setup.
- 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.
- Rubber Ring.
- Open ended cylindrical section.
- Weighing balance.

Procedure: -

(1) A cylindrical specimen of soil having size length to diameter as 78 mm by 36 mm is placed on a saturated porous disc resting on the pedestal of the triaxial cell.

(2) The specimen is encased in a rubber membrane and sealed to the pedestal using rubber O-rings.

(3) The triaxial cell is filled with water at the required cell pressure, σ_c, with the drainage line valve closed.

(4) The cell pressure is held constant, and the pore water pressure measurement device can be attached to the specimen through the pressure connections.

(5) Additional axial stress, called the deviator stress (σ_d), is then applied through the ram gradually with the drainage line valve kept close, and measured with a proving ring until 15% axial strain was reached.

(6) The above steps are repeated using a different sample.

For an undrained test, the volumetric change (ΔV_0) is zero and the cross-sectional area (A) of the specimen at any stage during shear is given by:

$$A = A_0 / (1 - \epsilon_l)$$

where, A_0 = cross sectional area of original sample

ϵ_l = axial strain in the sample

The minor principal stress (σ_3) is equal to the cell pressure (σ_c). The major principal stress (σ_1) is equal to the sum of the cell pressure and the deviator stress. Thus,

$$\sigma_1 = \sigma_3 + (\sigma_1 - \sigma_3) = \sigma_3 + \sigma_d$$

The deviator stress at failure (σ_1 - σ_3) is known as the compressive strength of the soil.

3.2 ANN ARCHITECTURE AND TRAINING ALGORITHM:

Artificial Neural Network (ANN) usually called neural networks, are very sophisticated modelling techniques which are capable of modelling extremely complex functions. They are used for predicting the outcome of two or more independent variables.

In this project, 110 slope cases having different geometrical and slope parameters will be selected whose various soil parameters are knowns. These slope parameters will be used to analyze the various slopes using Bishop's Simplified Method to find the FOS. Out of these, 100 cases will be used to develop the prediction model using ANN. In the proposed model, several important parameters including, height of the slope (H), cohesion (C), angle of internal friction (φ), angle of the slope (β) and unit weight of soil (γ) will be used as input parameters whereas the FOS will be use as the target value. The computational method for the training process was a back propagation learning algorithm. The prediction model will be validated by comparing the results with the remaining 10 cases. The ANN model will be prepared in MATLAB.

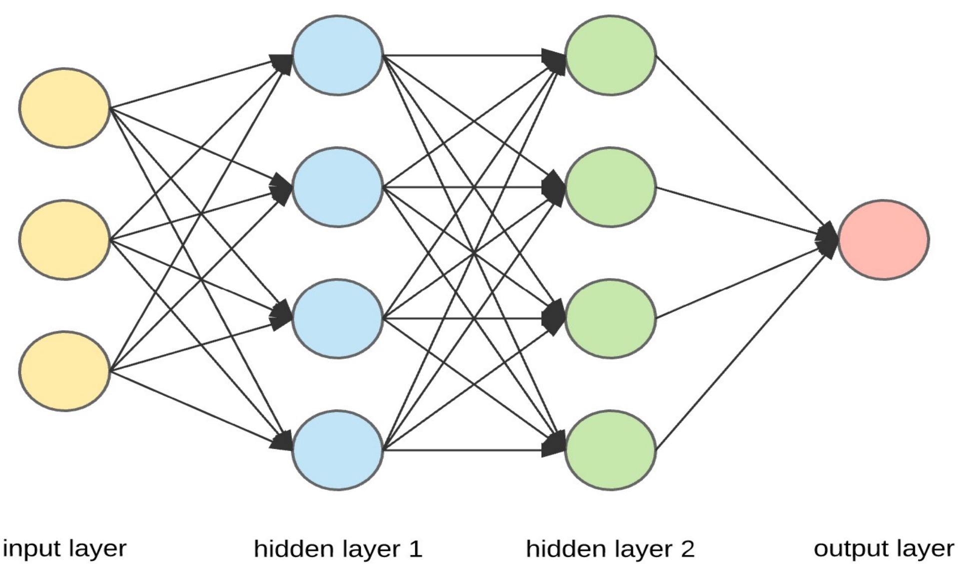


Figure 20: Network architecture diagram in ANN

A typical neural network structure used in this study is shown in Fig-21. As shown in figure, the ANN structure consists of an input layer, one hidden layer, and an output layer. Each layer has its corresponding neurons and weight connections. It has been shown that ANNs with one hidden layer can approximate any function given that sufficient degrees of freedom are provided. The input represents the random variables X in the input layer. The output consists of a single neuron representing the response surface. To determine the determine this number. It is normally determined by a trial-and-error process, so this number will be optimized during the training process. The initial number is picked by guesswork and experience. If the network has trouble learning, further neurons can be added to the hidden layer and the process is repeated until the performance of the trained model is acceptable.

CHAPTER-4: RESULT AND ANALYSIS:

4.1 Grain-size Analysis: -

Sample Details: -

Weight of Sample taken for Sieve Analysis = 500gms.

S. No.	I.S. Sieve No	Weight retained in gms	Cumulative weight retained in gms	Percent (%) weight retained	Percent (%) weight passing
1	10 mm	150.91	150.91	30.18	69.81
2	4.75mm	125.13	276.04	55.22	44.78
3	2mm	60.29	336.33	67.28	32.72
4	1mm	47.27	383.6	76.74	23.26
5	600 µ	30.46	414.06	82.83	17.17
6	425µ	22.63	436.69	87.36	12.64
7	300µ	23.81	460.5	92.12	7.88
8	150µ	29.99	490.49	98.12	1.88
9	75µ	4.59	495.08	99.04	0.96
10	PAN	4.83	499.90	100	0

Table - 4.1 1: Sieve analysis datasheet

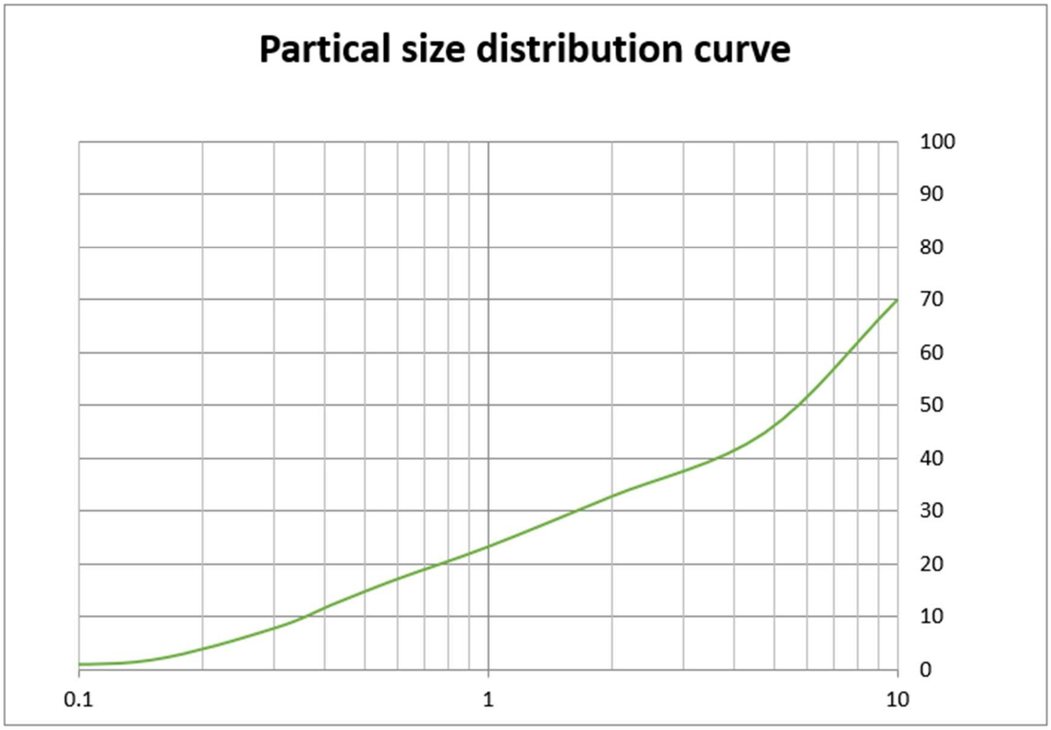


Figure 21: Particle-size distribution curve

The above graph shows, as the particle size increases the percentage finer also increases. From the graph the values of D10, D30, D60 was found to be 0.355672269, 1.712473573, and 7.942369157and then the uniformity coefficient and curvature coefficient was found to be 22.3305831 and 1.038120296. From the above results the soil is a well-6 graded soil.

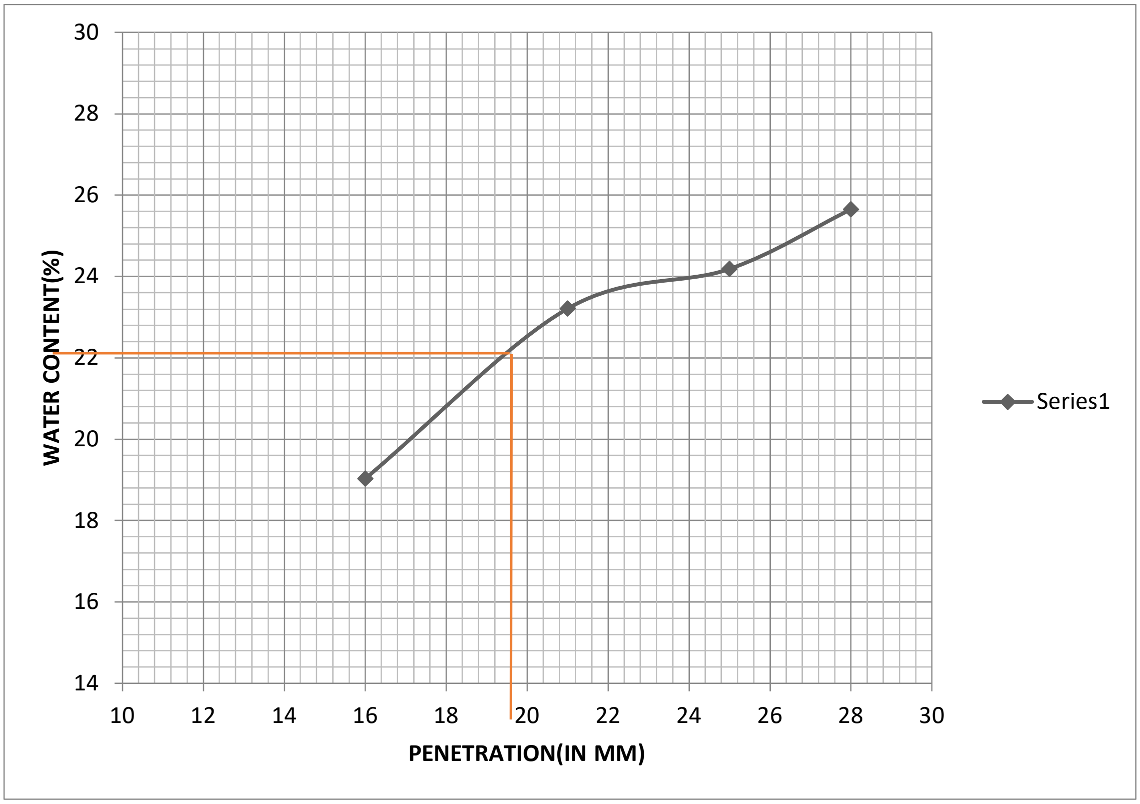
4.2 Liquid limit test: -

container no.	1	2	3	4	5	6	7	8
wt. of container + lid w1	10.05	9.64	8.94	8.59	6.28	6.79	4.2	6.2
Wt. of container + lid + wet sample, W2	48.69	45.94	49.32	44.49	41.81	44.42	32.85	33.88
Wt. of container + lid + dry sample, W3	40.75	38.69	41.65	37.78	34.89	37.09	28.22	29.5
Wt. of dry sample = W3 – W1	30.7	29.05	32.71	29.19	28.61	30.3	28.65	27.68
Wt. of water in the soil = W2 – W3	7.94	7.25	7.67	6.71	6.92	7.33	4.63	4.38
Water content (%) = (W2 – W3) / (W3 – W1) ´ 100	26.4	24.95	23.44	22.98	24.18	24.19	19.27	18.79
AVERAGE WATER CONTENT (%)	W1	=	23.025					

Table-4.2 1: Liquid limit datasheet

SL. NO	WATER CONTENT (%)	PENETRATION(IN MM)
1.	19.03	16
2.	23.21	21
3.	24.185	25
4	25.65	28

Table- 4.2 2 : Depth of penetration for different water content.



From the above experiment, the Liquid limit was found to be 22.374.

Determination number	1	2	3
Container number	I	II	III
Weight of container, g	25.55	24.65	25.40
Weight of container + Wet soil, g	29.40	27.60	29.35
Weight of container + Oven dry soil, g	28.30	26.90	28.50
Weight of water, g	1.10	0.70	0.85
Weight of oven dry soil, in g	2.75	2.25	3.10
Water content (%)	40.00	31.19	27.42

Table- 4.2 3 : Plastic limit datasheet

From the above experiment, the Plastic limit was found to be 32.84%

4.3 Triaxial test: -

Readings recorded and other evaluated values in the Triaxial test are given in the following tables.

Sample height = 76 mm

Sample diameter = 38 mm

Sample cross sectional area A_0 = 1134 mm^2

1) Cell Pressure = 0.5 kg/cm^2:

	DEFORMATION (mm)	LOAD (kN)	STRAIN ($*10^{-3}$)	AREA (mm^2)	DEVIATOR STRESS (N/mm^2)
1.	0	0	0	1134	0
2.	0.2	0.01132	2.63157	1136.99207	0.00995
3.	0.4	0.01689	5.26315	1139.99999	0.01481
4.	0.6	0.02256	7.89473	1143.02386	0.01973
5.	0.8	0.02876	10.52631	1146.06382	0.02509
6.	1.0	0.03328	13.15789	1149.11999	0.02896
7.	1.5	0.03872	19.73684	1156.83221	0.03347
8.	2.0	0.04369	26.31578	1164.64863	0.03751
9.	2.5	0.04767	32.89473	1172.57142	0.04065
10.	3.0	0.05245	39.47368	1180.60273	0.04442
11.	3.5	0.05678	46.05263	1188.74482	0.04776
12.	4.0	0.06095	52.63157	1196.99998	0.05091

13.	6.0	0.06583	78.94736	1231.19999	0.05346
14.	8.0	0.06590	105.26315	1267.41175	0.05199
15.	10.0	0.06579	131.57894	1305.81817	0.05038
16.	12.0	0.06620	157.89473	1346.62498	0.049815

Table-4.3 1: Triaxial test datasheet

2) Cell Pressure = 1.0 kg/cm^2

	DEFORMATION (mm)	LOAD (kN)	STRAIN ($*10^{-3}$)	AREA (mm^2)	DEVIATOR STRESS (N/mm^2)
1.	0	0	0	1134	0
2.	0.2	0.01132	2.63157	1136.99207	0.00995
3.	0.4	0.01689	5.26315	1139.99999	0.01481
4.	0.6	0.02256	7.89473	1143.02386	0.01973
5.	0.8	0.02876	10.52631	1146.06382	0.02509
6.	1.0	0.03328	13.15789	1149.11999	0.02896
7.	1.5	0.03872	19.73684	1156.83221	0.03347
8.	2.0	0.04369	26.31578	1164.64863	0.03751
9.	2.5	0.04767	32.89473	1172.57142	0.04065
10.	3.0	0.05245	39.47368	1180.60273	0.04442
11.	3.5	0.05678	46.05263	1188.74482	0.04776
12.	4.0	0.06095	52.63157	1196.99998	0.05091
13.	6.0	0.06583	78.94736	1231.19999	0.05346
14.	8.0	0.06590	105.26315	1267.41175	0.05199
15.	10.0	0.06579	131.57894	1305.81817	0.05038
16.	12.0	0.06620	157.89473	1346.62498	0.049815

Table-4.3 2 : Triaxial test datasheet 2

3) Cell Pressure = 1.5 kg/cm^2

	DEFORMATION (mm)	LOAD (kN)	STRAIN ($*10^{-3}$)	AREA (mm^2)	DEVIATOR STRESS (N/mm^2)
1.	0	0	0	1134	0
2.	0.2	0.01121	2.63157	1136.99207	0.00985
3.	0.4	0.01674	5.26315	1139.99999	0.01468
4.	0.6	0.02364	7.89473	1143.02386	0.02068
5.	0.8	0.02901	10.52631	1146.06382	0.02531
6.	1.0	0.03425	13.15789	1149.11999	0.02980
7.	1.5	0.03979	19.73684	1156.83221	0.03439
8.	2.0	0.04438	26.31578	1164.64863	0.03810
9.	2.5	0.04945	32.89473	1172.57142	0.04217
10.	3.0	0.05431	39.47368	1180.60273	0.04600
11.	3.5	0.05860	46.05263	1188.74482	0.04929
12.	4.0	0.06357	52.63157	1196.99998	0.05310
13.	6.0	0.06702	78.94736	1231.19999	0.05443
14.	8.0	0.07076	105.26315	1267.41175	0.05583
15.	10.0	0.07135	131.57894	1305.81817	0.05464
16.	12.0	0.07264	157.89473	1346.62498	0.05394

Table-4.3 3 : Triaxial test datasheet 3

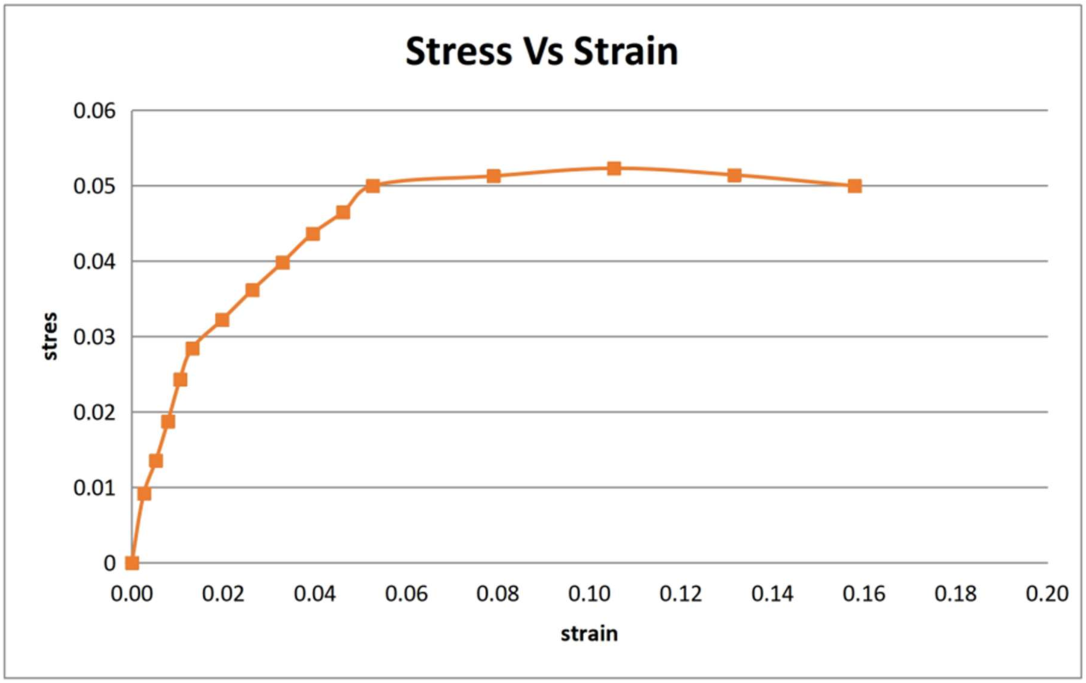


Figure 22: Stress Vs Strain for Cell pressure = 0.5 kg/cm^2

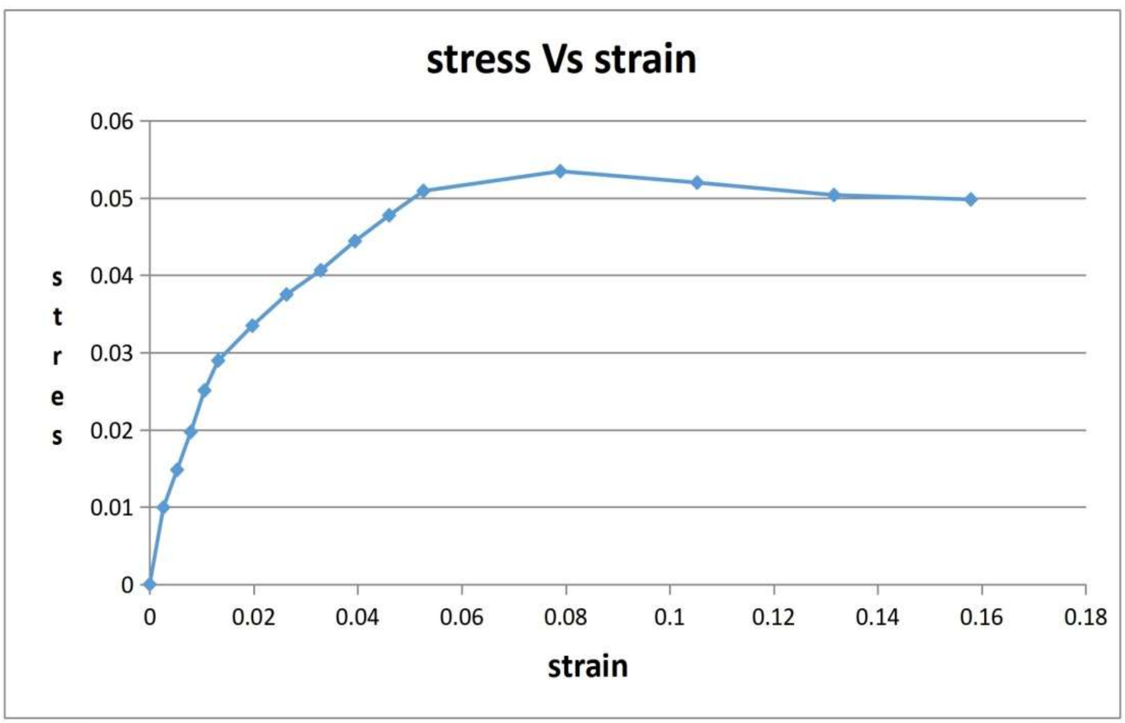


Figure 23: Stress vs Strain for Cell pressure = 1.0kg/cm^2

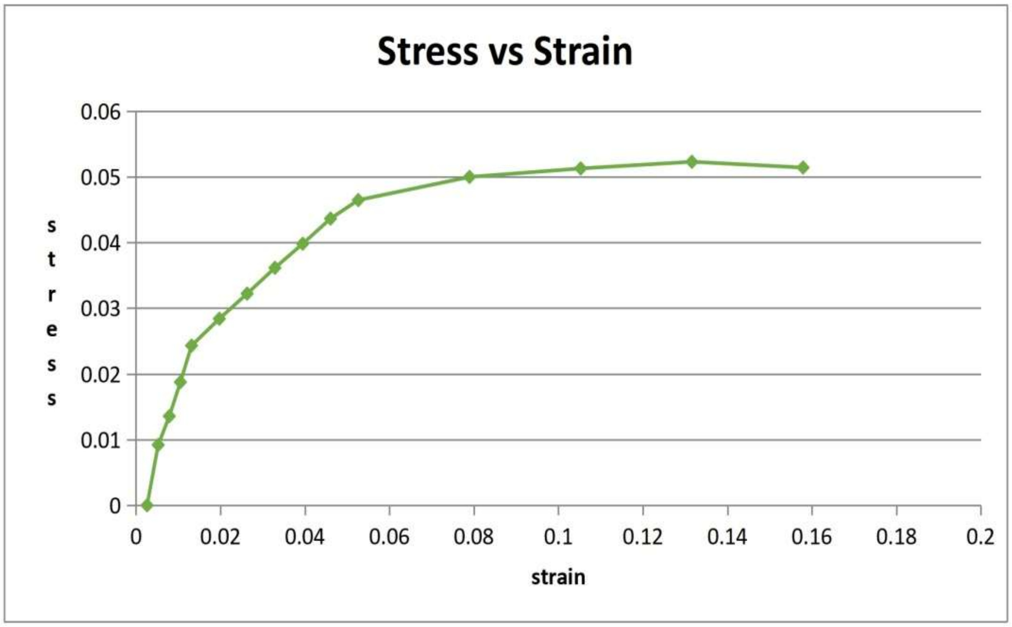


Figure 24: Stress vs Strain for Cell pressure = 1.5 kg/cm^2

To determine the shear strength parameters stress, strain and principal stresses were found out. The stress results of the series of triaxial tests at increasing cell pressure were plotted as a Modified failure envelope using p = (σl+σ3)/2 as abscissa and q = (σl-σ3)/2 as ordinate. In this diagram a best fit line was plotted within which the slope represents the value of tan Ψ while the intercept represents the value of 'a'

P	Q
0.07164	0.02614
0.12673	0.02673
0.16791	0.02791

Table-4.3 4: Modified failure envelope values.

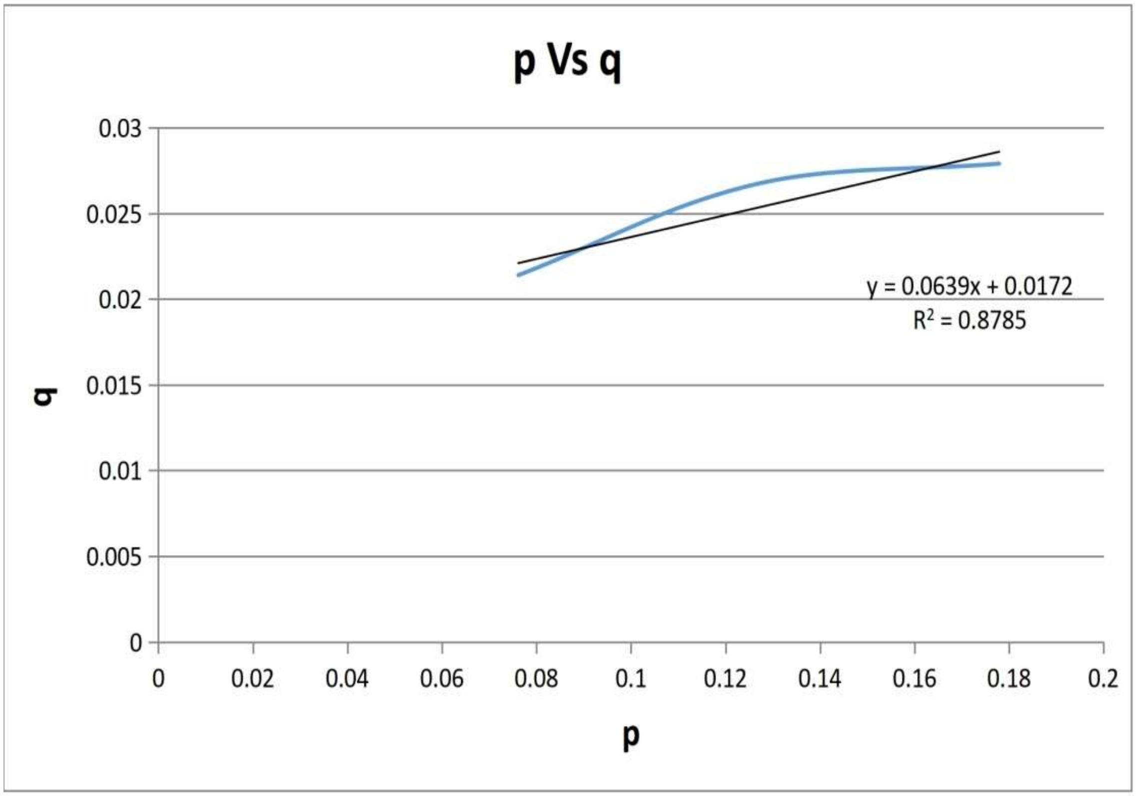


Figure-25: Failure Envelope

RESULT: -

From the above graph we obtained
Intercept on y axis (a) as 0.0172
Slope of the failure envelope = tan Ψ = 0.0639
Intercept on y-axis = a = 0.0172
Therefore, sin Φ = tan Ψ
=> sin Φ = 0.0639
=> $\Phi = \sin^{-1}(0.0639)$

=> Φ = 3.66369°
Therefore, c = a/cos Φ
=> c = 0.0172/cos (3.66369°)
=> c = 0.017235 N/mm2
=> c = 17.235 kPa

4.4 Standard Proctor test: -

Table 4.4.1 1: Standard Proctor test datasheet

water in (%)	Water content (mL):	Empty Wt. (g):	Volume of mould:	Wt. of soil + Wt. of mould (g):	Wt. of compact soil (g):	Bulk density:	Dry density:	Moisture content:
5	175	5070	1000	6857	1787	1.787	1.706	4.745
6	210	5070	1000	6897	1827	1.827	1.728	5.715
7	245	5070	1000	6949	1879	1.879	1.762	6.6
8	280	5070	1000	6981	1911	1.911	1.776	7.58
9	315	5070	1000	7021	1951	1.951	1.813	7.62
10	350	5070	1000	7067	1997	1.997	1.841	8.455
11	385	5070	1000	7101	2031	2.031	1.854	9.495
12	420	5070	1000	7143	2073	2.073	1.879	10.325
13	455	5070	1000	7196	2126	2.126	1.844	15.25
14	490	5070	1000	7182	2112	2.112	1.836	15.005
15	525	5070	1000	7171	2101	2.101	18,201	15.43

16	560	5070	1000	7162	2092	2.092	1.803	16.035
17	595	5070	1000	7154	2084	2.084	1.784	16.77

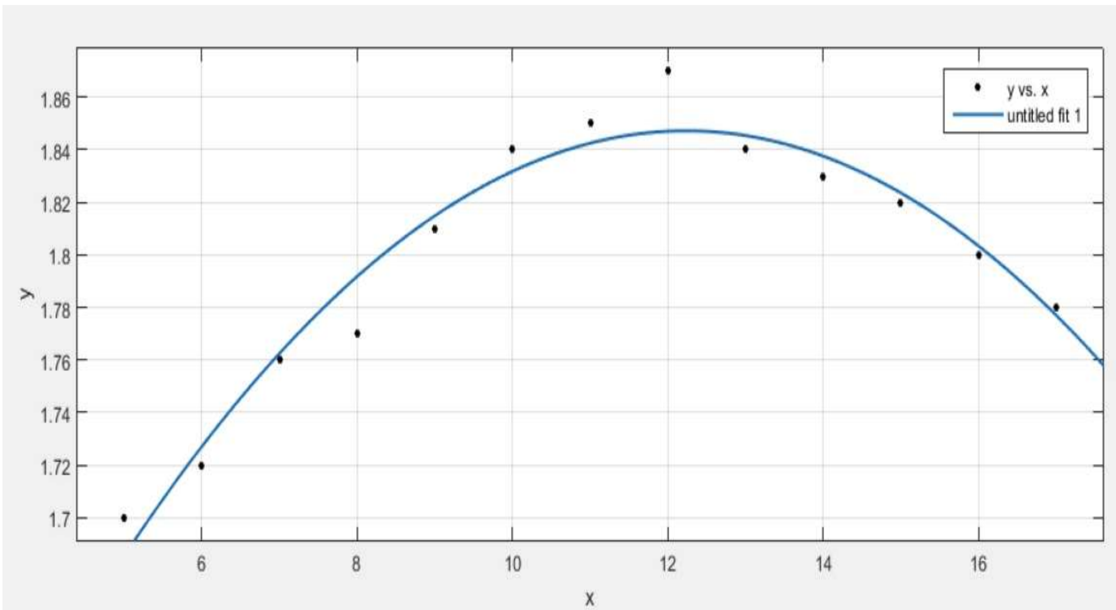


Figure 26: dry density vs moisture content graph

The above graph shows, as the water content increases the dry density increases up to a limit afterwards it decreases. The optimum moisture content and the maximum dry density were found to be 10% and 18.44 kN/m^3 calculated from graph.

CHAPTER 5: CONCLUSION

From the work done yet, the following conclusions can be made: -

- The present slope stability condition of the site visited is observed to be quite alarming in nature and need to be analyzed seriously.
- The selected site (i.e., Bage Tinali) has soil of Coefficient of uniformity = 22.3305 and Coefficient of curvature = 1.0381. The particle-size distribution test shows that the soil Is silty in nature. M.D.D and O.M.C of the soil are 18.44kN/m and 10%. Moreover, the plasticity index and the liquid limit also indicates the soil to be silty in nature.
- The ANN (i.e., Artificial Neural Network) which to be used in the study, is not yet selected yet as all the required parameters are to be tested and observed.

CHAPTER-6: REFERENCES:

- Xuzhen He, Haoding Xu, Hassan Sabetamal, Daichao Sheng (2020) "Machine learning aided stochastic reliability analysis of spatially variable slopes" [1]. *School of Civil and Environmental Engineering, University of Technology Sydney, Australia.*

- Arunav Chakraborty and Dr. Diganta Goswami (2017) "Slope Stability Prediction using Artificial Neural Network (ANN)" [2]. *International Journal Of Engineering And Computer Science ISSN:2319-7242.*

- Amritpal Kaur and Dr. R. K. Sharma (2016) "Slope Stability Analysis Techniques: A Review." [3]. *International Journal of Engineering Applied Sciences and Technology, 2016.*

- Jingjing Meng and Hans Mattsson (2021) "Three-dimensional slope stability predictions using artificial neural networks" [4]. *Department of Civil, Environmental and Natural Resources Engineering, Lulea University of Technology, Luleå, Sweden.*

- Yongsheng Zhou (2019) "Application of Artificial Neural Network in slope stability analysis." [5*]. Computer Software and Media Applications (2019) volume 2.*

- Biswajeet Pradhan and Saro Lee (2008) "Landslide risk analysis using artificial neural network model focussing on different training sites." [6]. *International Journal of Physical Sciences Vol. 4 (1), pp. 001-015, January 2009.*

- IS:2720 (part 4)-1985: Methods of test for soils, Part 4: Grain size analysis (pg. no. 6).

- IS:460 (part 1)-1978: Conforming of IS sieves.