EARLY DETECTION OF LANDSLIDES

A

MAJOR PROJECT REPORT

submitted in partial fulfillment of the requirements for the award of the Degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

Of

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to

DEPARTMENT OF CIVIL ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT SOLAN-173234,

HIMACHAL PRADESH, INDIA

May, 2023

STUDENT'S DECLARATION

I hereby state that the project report titled "**Early Detection of Landslides**"submitted in partial fulfilment of the requirements for the Bachelor of Technology degree in Civil Engineering at the **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work conducted under the supervision of **Dr. Saurabh Rawat.** This work has not been submitted for any other degree or credential consideration. I am fully responsible for the contents of my project report.

Signature of Student	Signature of Student
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Date:	Date:

CERTIFICATE

This is to certify that the work presented in the project report titled "**Early Detection of Landslides** " submitted to the Department of Civil Engineering, **Jaypee University of Information Technology**, Waknaghat in partial fulfilment of the requirements for the award ofthe degree of Bachelor of Technology in Civil Engineering is an authentic record of work carried out by **Paras Jaswal (191612) and Rijul Thakur (191610)** during a period from February, 2022 to May, 2023 under the supervision of **Dr. Saurabh Rawat** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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ABSTRACT

Landslides are the cause of damage to buildings, property, and human life. Landslides are the major threat to human life every year many people lost their lives due to landslides. Early detection of landslides is essential to reduce the impact of landslide to human life and property. We can save many lives if it will be feasible to identify landslides before they happen. This document offers a summary of landslip early detection method. The project report presents that land slopes of different angles are made using soil and sensors like soil and moisture sensor, ultra-sonic sensor, vibration sensors and accelerometer & gyroscope sensors are used to capture or know the behavior of the soil before or after the landslide took place. In this study, we utilized software to construct land slopes of various angles with the same dimensions as of physical slopes. We checked the factor of safety for the slopes and applied the pore-water pressure on the slopes to determine the landslide zone area and generate contour maps of pore-water pressure. The results of this study provide insights into the potential landslide zones for slopes of different angles and the corresponding pore-water pressure distribution. The software used in this study offers a cost-effective and efficient approach to studying landslides. The findings of this study can also aid in the development of effective strategies to mitigate the impact of landslides on human life and property. The study demonstrates the potential of software to provide valuable information for understanding and managing landslides. The report also discusses early detection's difficulties and proposed solutions to these difficulties. The discussion of potential future approaches for early landslide detection research brings the work to a close. In general, landslides may be detected early, which could save lives and lessen the financial toll these natural disasters take.

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CHAPTER - 1

INTRODUCTION

1.1. General

Landslides are the disaster that can cause damage to buildings, property, and human life. Landslides are the major threat to human life every year many people lost their lives due to landslides. Landslide is the downward movement of rock, debris, or soil under the influence of gravity. This downward motion may happen quickly or gradually over time. Due to global warming the environmental changes can be seen which led to excessive rainfall which causes landslides. Rainfall is one of the major cause of landslides. However, with increased human settlement in unstable terrain, landslides pose a more serious threat to humans than ever before, causing an estimated 5000 fatalities each year. Landslides occur when the downward forces, including the force of gravity, exceed the cohesive forces holding the landmass together, and a failure of the slope-forming material results.

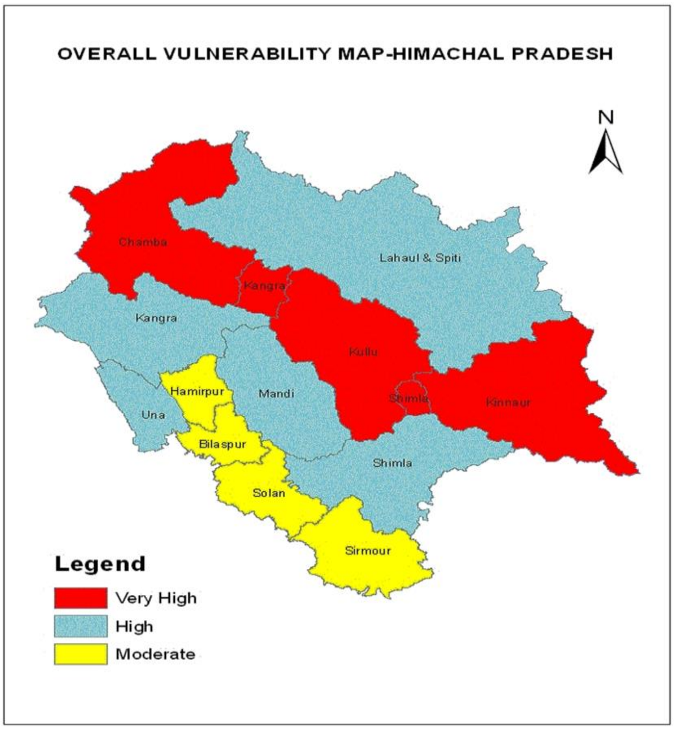

Fig.1 (vulnerability map of Himachal Pradesh)

As we can see in fig. 1 in Himachal Pradesh, high and extremely high landslip risk zones cover

over 90% of the land area. Therefore, probability of happening of landslide is very high. Landslides pose a serious threat to society and have a negative impact on the environment, economy, and human lives. As a result, we require early warning systems that alert us of landslides before they occur. To lessen the effects of landslides and prevent loss of life and property, early detection is essential. It will be beneficial to know in advance of a land slide so that we can take greater precautions and implement mitigation measures.

Landslides can occur unexpectedly, frequently with no prior warning, and they can cause serious harm to infrastructure, loss of property, and fatalities. Early landslip detection can be extremely important for lessening their effects and minimizing loss of life and property. Authorities can take the necessary precautions to protect people in danger by anticipating the possibility of landslides. People may need to be evacuated from dangerous regions, transit lines may need to be rerouted, or infrastructure may need to be strengthened to withstand landslides better.

Several factors contribute to a landslide occurrence: -

Geological factors include brittle, sensitive, and sheared rock, the presence of joints and fissures, and variations in the permeability or stiffness of the rock that makes up the slope.

Morphological factors include tectonic uplift, glacial rebound, and erosion of the hill slope or toe;

Anthropogenic factors such as mining, deforestation and excavation of the hill slope or toe.

In steep terrain, landslides frequently happen, resulting in both fatalities and injuries. Monitoring soil movement and promptly alerting people when it becomes significant is crucial to reduce the number of fatalities among humans. However, landslides are common, and the cost of current landslide monitoring and warning technology prevents their widespread implementation at a number of landslide locations.

1.2. Causes of landslides

- ✓ Heavy rains
- ✓ Earthquakes
- ✓ Volcano eruptions
- ✓ Floods
- ✓ Rapid snow melt
- ✓ Ground water changes
- ✓ Quarrying

Landslides can be caused by a variety of natural and human-induced factors. Some common causes of landslides include: -

Heavy Rainfall: Landslides may occur when the soil is saturated by heavy rain and it becomes unstable.

Earthquakes: Landslides are pushed on by earthquakes because they shake the ground and make rock and soil unstable.

Volcanic Activity: Landslides can result during volcanic eruptions because the rocks surrounding it and soil become unstable.

Changes in Water Level: Changes in water level, such as river or coastal erosion, can also lead to landslides.

Human Activities: Landslides are more likely to occur as a result of human activities including mining, deforestation, irrigation, and construction that changes the natural environment.

Geology and Topography: An area's susceptibility to landslides can depend on the local rock and soil types. Landslides, for instance, are more likely to occur in places with steep slopes and loose soil.

Wildfires: During wildfires, earth can become unstable and suffer damage, increasing the likelihood of landslides.

Many times, landslides are caused by a combination of factors rather than a single cause. Landslides are the result of several factors which affects the environment these factors can be natural or man- made or the result of the human activities.

1.3. Types of Landslides

1) **Lateral spreading** takes place when the soil mass expands laterally and this expansion causes tensional gaps in the soil mass.

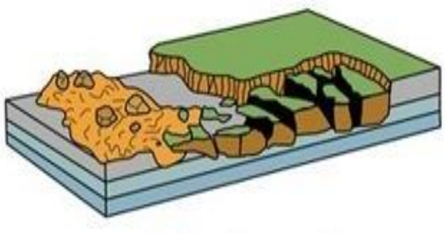

Fig.2 (Lateral Spread)

2) **Rotational Landslides** slides move along a curved, concave surface of rupture.

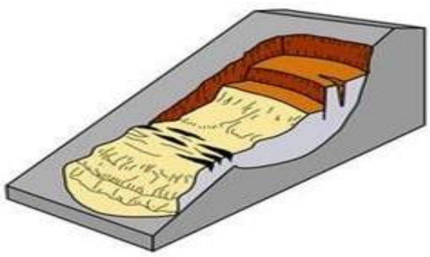

Fig.3 (Rotational Landslides)

3) C**reep** is the material moving slowly downward under the influence of gravity Usually, it happens over broad areas.

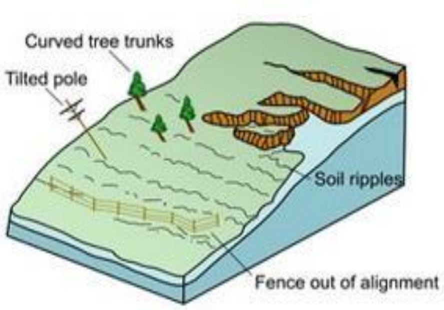

Fig.4 (Creep)

4) **Translational slides** occurs when the surface under failure is roughly flat or slightly undulating.

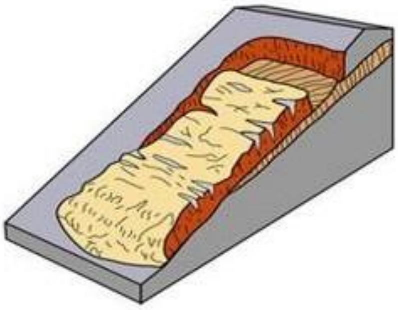

Fig.5 (Translational landslide)

5) **Rock toppling** happens when one or more rock units revolve about their bases before collapsing**.**

Fig.6 (Topple)

6) **Rock Fall: -** stones that have been freed from their bedrock and are falling down a cliff at a sharp angle.

Fig.7 (Rock Fall)

7) **Debris flow: -** collapsed, unconsolidated debris moving downward, usually following a stream channel.

Fig.8 (Debris Flow)

Due to heavy rainfall in Himachal Pradesh in 2017, the Paddhar landslip was caused by water. 46 people died as a result of the displacement of about 300 000 m3 of debris across 950 meters (courtesy of the Himachal Pradesh State Disaster Management Authority).

1.4. Chapter Outlines

The report is consisting of total five chapters. In detail about all five chapters outline is given below:

Chapter 1: - Introduction

This chapter gives us introduction about landslides, it tells us about its causes and types. It also tells us about the usage of the study of early detection of landslides.

Chapter 2: - Literature Review

This chapter gives the brief review of the literature on early detection of landslide performed by different researchers. All the literature published on early detection of landslide is summarized. The research work done on early detection of landslide is being discussed.

Chapter 3: - Methodology

In this chapter the types of testing to be done for the early detection of landslides are discussed. Two types of lab scale physical models, dynamic and static models are explained and discussed.

Chapter 4: - Result Discussion

This chapter shows the result, which contains the readings of sensor that we have installed in the slope which we have constructed manually. The factor of safety of slopes is also checked using software result of which are shown in this chapter. This chapter also contains the pore-water pressure contour maps and the sliding area of slopes of different angles.

Chapter 5:- Conclusion

This chapter represent about overall summary of the study that has been carried out and tells us about the conclusion of the work that has been carried out. It also tells us about the future scope of the study that has been carried out in this report

CHAPTER-2

LITERATURE REVIEW

2.1 General

The following chapter deals with the previous studies that has been carried out for the early detection of landslides. Academic journals, books, conference proceedings, and internet databases all fall under this category. The detail summary of these previous studies is given below :-

Chaturvedi et al.(2014) studied the high relief, brittle, tetanized, and heavily worn rocks, glacial debris, and human-made activities like road building and step agriculture, landslides are frequent in the Himalaya. Long-lasting or intenserainfall is the key factor that initiates landslides. In the Himalaya, landslides result in approximately 200 fatalities and losses of Rs. 550 crores per year. Therefore, determining Landslide Risk is essential. An efficient approach for determining landslide vulnerability at theregional level is remote sensing and GIS. The Chamoli- Joshi Math region is the focus of the current research investigation. Input data for this study include satellite data, toposheets, digitalelevation model data, field observations, and satellite-based rainfall data. Thematic layers related to lithology, fault, lineament, drainage, slope angle, slope aspect, land use/land cover, soil texture, and soil depth are produced by manual remote sensing-based interpretations. Thesethematic layers are then combined based on predetermined weights and rankings that are generated using map algebra in a GIS context to create maps of landslide susceptibility. Afterfield validation, the results demonstrate that this method for assessing susceptibility is fairly exact and accurate. To alert local authorities and communities to the risk as soon as possible, alandslide susceptibility map that combines empirical rainfall thresholds with spatial probabilities of landslides can be employed. Future research on risk perception in the area of interest will make use of the developed landslide susceptibility maps.

Towhata et al.(2005) had done the installation of retaining walls and ground anchors are traditional methods for stabilizing unstable slopes in order to prevent rainfall-induced landslides. The installation of retaining walls and ground anchors are traditional methods for stabilizing unstable slopes in order to prevent rainfall- induced landslides. To accomplish this, model testing and triaxial laboratory tests have been carried out to comprehend the behaviour of soil before failure. In order to confirm the results of the model tests, numerical analyses on ground water percolation and the decline of the safetyfactor during rainfall were carried out on a sandy slope. A small device that can detect minutemovement and changes in moisture content prior to a slope failing is recommended for humanusage, and it can send out warnings over the internet.

Thakur et al.(2019)Landslides pose a serious threat to society and have a negative impact on the environment, the economy, and human lives. Theimplementation of difficult and expensive steps is frequently necessary to mitigate the possibledetrimental effects of landslides. This is frequently true when building and maintaining linear infrastructures in landslide-prone locations, such as road, pipeline, and rail networks. Monitoring landslide triggering factors and delivering early warnings is one of the often-used strategies for reducing the negative effects. It is necessary to design a landslide monitoring andearly warning system for both regional and local sizes because the linear infrastructures and the landslide triggering factors (such as major weather systems and local man-made triggers) operate at various spatial scales**.** The Norwegian approach for early warning of landslides caused by harsh weather on a regional scale is briefly introduced in this study and has proven to be successful. The standard for giving an early warning is based on the soil's saturation leveland the amount of water being supplied to it through precipitation and snowmelt. On the otherhand, it can be difficult and expensive to monitor a single slope at the local level. Indian Institute of Technology Mandi created a low-cost landslide monitoring and early warning system in order to provide landslide monitoring systems of single slopes at a cheap price. Thesedevices are in place and monitoring more than fifteen landslide spots in the Mandi district of Himachal Pradesh, India. A recent case study where these systems assisted in warning peopleand transportation of an imminent landslide is also covered in this paper.

Ramesh, Vinodini, M.(2014)**-** This paper also discusses arecent case study where these technologies assisted One of the most promising new technologies is alert wireless sensor networks, which enables real-time monitoring of hostile and isolated areas that are vulnerable to calamities. This investigation, which focuses on landslide detection, confirms wireless sensor networks' potential for disaster mitigation. In Idukki, a district in the southwest of

Kerala State, India, a severely landslide prone area, a fullyfunctional system made up of 50 geological sensors and 20 wireless sensor nodes wasdeployed. For the past three years, the wireless sensor network system has collected a ton ofdata, including correlated sensor data values on rainfall, moisture, pore pressure, and movement, as well as other geological, hydrological, and soil properties, which has helped to provide a better understanding of the landslide scenario. Using wireless sensor networks, a novel three level landslide warning system was created (Early, Intermediate and Imminent). This system has demonstrated its reliability by giving the neighborhood a true warning amid torrential downpours in the monsoon season of July 2009. This system's implementation makesadvantage of cutting-edge data aggregation techniques for field deployment power optimization. Here is a study about unexpected difficulties encountered during the field deployment of wireless sensor networks and the creative solutions developed to deal with suchdifficulties.

Pathania et al. (2020):- In hilly areas, landslides are common disasters. Each year, these catastrophes result in several fatalities and injuries. It is crucial to monitor landslides and promptly alert people to looming disasters in light of these injuries and fatalities. Additionally, it's critical to foresee soil movement patterns so that inhabitants can leave the area in advance. The currently available technologies monitor landslides at a very high cost and fail to forewarn people or forecast soil changes. The main goal of this study is to provide details on the creation, implementation, and assessment of a new, low-cost IoT-based landslide monitoring, warning, and prediction system. In this study,a new subsurface system that may send SMS warnings in real time in the event of substantial subsurface movements was designed and put into use. Using sequential minimum optimizationand auto regression machine-learning models, we also performed predictive analytics on the data gathered from the system. The proposed system's key benefit is that it is inexpensive andoperates on the same movement detecting principle as already-existing technology. Because of its inexpensive cost, this system can be widely deployed to track landslides and alert people intime. We talk about the effects of installing this technology in various landslide-prone regionsof the world.

Vasudevan, N., Ramanathan, K. (2016):- Landslides, which are defined as large-scale movements of rock, debris, or soil down a slope, are a common occurrence that result in major property damage and an estimated 5000 fatalitiesannually. They take place in a variety of environmental settings and are brought on by the interaction of numerous natural and manmade variables. Landslides mostly happen in the Western Ghats of South India and the Himalayas of North India. The findings of field investigations conducted at six landslide locations in North, Northeast, and South India are presented in this publication. We offer justifications for why several landslides happened at each of the locations. In order to more accurately identify landslide-prone areas and enable early detection of landslide events, our goal is to develop a deeper understanding of the causes and antecedents of landslides.

Yang et al. (2021):- Landslide processes are a result of interactions between the environmental factors that cause them and their triggers. New insightsfor landslide prevention and mitigation can be gained by comprehending the variations in landslide movement mechanisms and features. In Hualong County, China, three neighboring landslides with distinct movement patterns were set off between August and September of 2018. The Xiongwa (XW) landslides 1 and 2 have undergone multiple deformations and show significant heterogeneity, according to a combination of surface and subsurface characteristics,whereas the Xiashitang (XST) landslide is a typical retrogressive landslide, and its material hasmoved downslope along a shear surface. The displacement mechanisms of these three landslides were detected using Differential in SAR (Din SAR) and Time-series Interferometric Synthetic Aperture Radar (In SAR) approaches. Time-series In SAR can be used to clearly identify the pre-failure displacement signals of a slow-moving landslide (the XST landslide). However, time-series In SAR can easily disregard these unexpected landslides, which are a common catastrophic natural hazard around the world. We were able to confirm that the threelandslides were significantly influenced by effective antecedent precipitation. In this study, the deformation of an existing landslide itself can also cause new nearby landslides. These results show that landslide early warnings remain difficult due to the complexity of landslide processes and mechanisms. In order to reduce the risk of landslides, more pertinent field investigations and detection should be made. We must learn to deal with natural disasters.

Abeykoon et al. (2018**):-** Real-time landslide monitoring is a useful method for reducing landslide hazards, particularly when there are few options for structural countermeasures. One of the main elements causing slope instability is regarded to be rainfall infiltration. Since landslides can be detected early and their negative effects reduced, real-timemonitoring of parameters such as rainfall, volumetric water content, and surface deformations/displacements in the soil is necessary. For the purpose of early detection of potential slope failure, this study uses inexpensive, easily installed miniature ground inclinometers with MEMS (Micro Electro Mechanical Systems) tilt sensors, volumetric watercontent sensors, temperature sensors, a rain gauge, and a wireless data transmission unit (DTU).The DTU automatically transfers data from sensor units via mobile network to an internet server and refreshes a web interface for the purpose of determining slope instability after receiving it at a higher data collection frequency from the sensor units. The monitoring program, which has been running for more than two years in the Lake Barron Catchment, Melany plateau, Australia, successfully recorded both mass movements brought on by rainfallas well as the creep movement of the slope with wetting and drying cycles. In the present study,surface deformation and rainfall data generated by the real-time monitoring system were analyzed, and results were validated using findings from previous studies. As a result, it was determined that a combination of rainfall data, I-D threshold equations, and ground tilting ratewas a more effective way to anticipate potential slope failure. In addition, this study recommends that caution be issued at tilting rates of 0.010 /hr and warnings be issued at tiltingrates of 0.10 /hr while taking rainfall data into account.

2.2. Summary of Literature Review

- The criteria for issuing early warning are based on degree of saturation of soil and the supply of water to it through rainfall and snow melting.
- The existing technologies monitor landslides at a very high cost and do not warn people and predict soil movements ahead of time.
- Indian Institute of Technology Mandi has developed a IOT based landslide monitoring and early warning system. But it issues warning just before, the movement of soil starts which gives very less time for evacuation.

Table2.1 Literature Review

SR. NO.	AUTHORS	TITLE	JOURNAL NAME
1	Chaturvedi et al. (2014)	Remote Sensing Based Regional Landslide Risk Assessment	International Journal of Emerging Trends in Electrical and Electronics (IJETEE – ISSN: 2320-9569)
2	Towhata et al. (2005)	On Early Detection and Warning against Rainfall Induced Landslides	In: Sassa, K., Fukuoka, H., Wang, F., Wang, G. (eds) Landslides. Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-28680-2_16
3	Thakur et al. (2019)	Early Warning of Water-Triggered Landslides	Indian Geotechnical Conference 2019
4	Ramesh, Vinodini, M. (2014)	Design, development, and deployment of a wireless sensor network for detection of landslides	Ad Hoc Networks 13 (2014): 2-18.

5	Pathania et al. (2020)	A Low Cost, Sub-Surface IoT Framework for Landslide Monitoring, Warning, and Prediction	In Proceedings of 2020 International conference on advances in computing, communication, embedded and secure systems
6	Vasudevan, N., Ramanathan, K. (2016)	Geological factors contributing to landslides	Earth and Environmental Science (Vol. 30, No. 1, p. 012011). IOP Publishing.
7	Yang et al. (2021)	Landslide Characteristics and Evolution	Remote Sensing 13, no. 22 (2021): 4579.
8	Abeykoon et al. (2018)	Real-time monitoring and wireless data transmission to predict rain-induced landslides in critical slopes.	Australian Geomechanics Journal, *53*(3), pp.61-76.

2.3. Objectives of the study

I. To identify landslides using Artificial Intelligence for slope angles 60°, 70°, 80°,90°.

II. To suggest Remedial measure for the observed type of landslide.

The methodology, material and setup used for the following work is described in the next chapter.

CHAPTER - 3

MATERIAL, SETUP AND METHODOLGY

3.1. General

This chapter depicts the setup, material and methodology used for carrying out this study.

This includes the types of physical modal or tests need to perform and work need to be done in order to achieve the result for the study.

3.2. Project Description

Landslides are the cause of damage to buildings, property, and human life. An estimated 5000 people die each year as a result of mass movements of rock, debris, or soil down a slope, which are a worldwide phenomenon. They arise under various environmental conditions and are an outcome of the interaction of variousnatural and man-made causes. Landslides mostly happen in India's Himalayas in the north and Western Ghats in the south.

The purpose of this project is to develop a system for early detection of landslides so that it can warn people before a landslide happens. The purpose of this study is to develop a portable and easily available landslide detection system which can be installed easily anywhere for detection purpose. Early landslip detection can be extremely important for lessening their effects and minimizing loss of life and property. Authorities can take the necessary precautions to protect people in danger by anticipating the possibility of landslides.

3.3. LAB SCALE PHYSICAL MODEL

- Static actions
- Dynamic/seismic actions

3.4. Static Model: - Controlled experiments with realistic simulations of the landslide process are essential for improving our understanding and management of landslides. Static operations use controlled rainfall to start landslides and track the progress of the landslide process in order to do this. In order to recreate the conditions that cause landslides, tests like these include purposefully applying rain on a slope. Researchers can examine the effects of several factors, including the slope angle, soil type, and cover of vegetation, on the landslip process by adjusting the volume and timing of rainfall. Researchers may monitor and measure the movement, soil pressures, and pore pressures of the landslip body using photogrammetric equipment and a complex sensor network, which improves the quality of these studies. These studies' results can provide important details about the mechanisms of landslides, such as the significance of soil type, slope angle and soil saturation. The invention of improved early warning systems and landslip mitigation techniques can then be done using the information provided.

In conclusion, static activities using managed precipitation and high-tech monitoring tools offer a useful tool for researching the causes underlying landslides. To lessen the effects of landslides on property, infrastructure, and human life, this research can help develop earlier warning systems and mitigating techniques.

3.5. Dynamic Model: - Seismic activities will be produced to enable a landslide to begin when there is shaking from an artificial earthquake when an earthquake is the landslide-triggering element. In these tests, an artificial seismic event is produced to mimic the trembling that an earthquake might produce. Researchers can investigate the process and get information on the components that trigger landslides because this shaking can cause landslides. In-depth information on the displacement of the landslip body, pore pressures, and soil pressures throughout the landslide process can be obtained with the use of advanced monitoring equipment, such as accelerometers and seismometers. The use of seismic activities to study landslides is an important area of research that has the potential to improve our understanding of landslides and enhance our ability to predict and mitigate their impact. By combining advanced monitoring equipment with artificial seismic events, researchers can gain valuable insights into the underlying mechanisms that trigger landslides and develop tools and models to reduce their impact on communities and infrastructure.

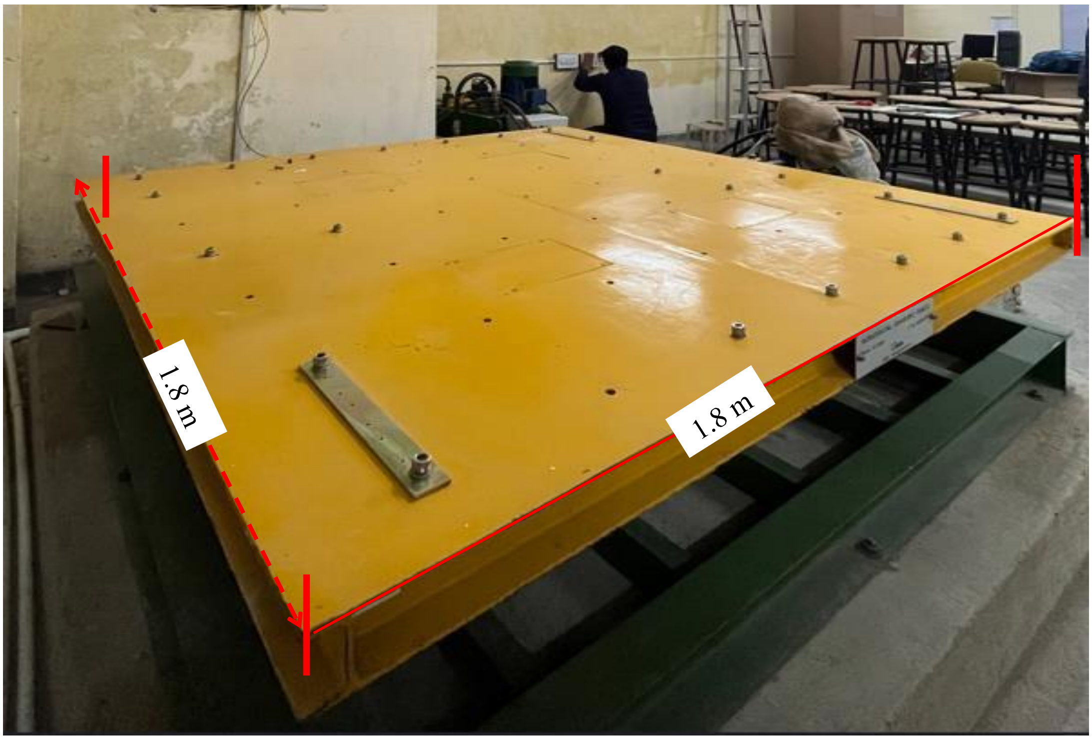

Fig.9 (Shaking Table)

Shaking table (shown in fig.9) is a mechanical device that simulates seismic activity by generating vibrations in a controlled and repeatable manner. The table typically consists of a large platform that can be moved in multiple directions, such as up and down, side to side, and back and forth. This movement is achieved using hydraulic or electric actuators that apply forces to the platform.

To simulate seismic activity, the shaking table is programmed to generate different types of waveforms that represent the ground motion during an earthquake. These waveforms can vary in frequency, amplitude, and duration, depending on the specific testing requirements. The shaking table can also be used to generate complex waveforms that simulate the interaction between different types of seismic waves. during dynamic testing, structures and equipment are placed on the shaking table and subjected to simulated earthquakes. The response of these structures is measured through sensors that are placed at strategic locations, such as at the base or at critical points within the structure. The data collected from these sensors is analyzed to evaluate the performance of the structure under simulated seismic activity.

3.6. SENSORS USED FOR COLLECTION OF DATA

1) **Soil and Moisture Sensor: -** The amount of water in the soil can be determined or monitored using soil moisture sensors. These sensors may be portable, like handheld probes, or immovable. Portable soil moisture probes have a wider monitoring range than permanent sensors, which are installed in the field at precise depths and locations.

Fig.10 (Soil Moisture Sensor)

2) **Acceleration and Gyroscope Sensor: -** The rate at which an object's velocity varies is monitored using accelerometers, which are electromechanical devices. In other words, it describes machinery that responds to vibrations caused by movement. A gyroscope is a device for monitoring rotational changes or maintaining balance. Its foundation is the concept of preserving angular momentum.

Fig.11 (Acceleration and gyroscope Sensor)

3) **Vibration Sensor: -** A vibration sensor is a device that measures both the frequency and intensity of vibration in a certain machine, system, or piece of equipment. These metrics can be used to spot asset imbalances or other problems, as well as forecast upcoming breakdowns.

Fig.12 (Vibration Sensor)

4) **Ultra-sonic Sensors: -** An ultrasonic sensor uses ultrasonic sound waves to detect the distance to a target object and then transforms the sound's reflection into an electrical signal. Compared to audible sound, ultrasonic waves move more swiftly.

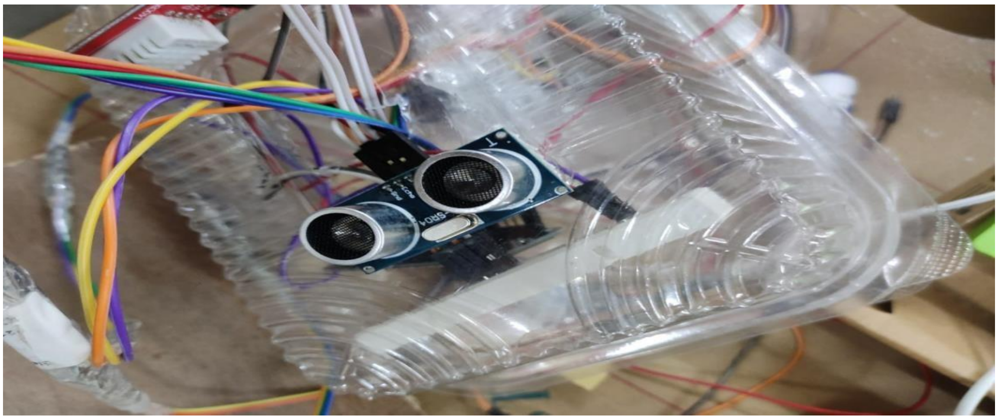

Fig.13 (Ultra-sonic Sensors)

3.7. PROPERTIES OF SOIL SAMPLE

Table 3.1 shows the of the soil that we have used in construction of slopes of different angles. We built slopes that are a good representation of natural slopes and may be used to examine the mechanisms of landslides by studying the qualities of the soil.

Table 3.1 Fundamental properties of soil sample

SR.NO.	PROPERTY	VALUE
1	specific gravity, G_s	2.72
2	D_{30} (mm)	0.21
3	Average grain size D_{50} (mm)	0.25
4	D_{60} (mm)	0.28
5	Effective size D_{10} (mm)	0.16
6	Coefficient of curvature, C_c	1
7	Coefficient of uniformity, C_u	1075
8	Minimum dry unit weight, γd(max) (kNm2)	13.13
9	Maximum dry unit weight, γd(max) (kNm2)	16.87
10	Friction angle from the direct shear test, Φ (°)	37.9°
11	Relative density, (R_D)	86.4%

3.8. SLOPES OF DIFFERENT ANGLES

Fig.14 (Land slope constructed of 60° angle)

Figure 14 shows a slope with a 60° angle that is constructed using the soil characteristics listed in Table 3.1. To assure the precision of the results, the slope has been built in four layers that have all been perfectly levelled. The slope measures 50 cm in height, 65 cm in base length, and 54 cm in width. The length is 54 cm and the width is 22 cm at the slope's top. The slope is built in layers to ensure that the soil parameters are constant along the slope and to provide a more controlled testing environment. This is crucial because changes in soil qualities might have an impact on the slope's stability and landslip risk. By constructing the slope at a 60° angle, we can study the effects of slope angle on the landslide process. This is an important variable to consider because steeper slopes are typically more prone to landslides. By measuring the displacement, pore pressures, and soil pressures during the land sliding process, we gain valuable insights into how slope angle affects the likelihood and severity of landslides.

Fig.15 (Land slope constructed of 70° angle)

Figure 15 shows a slope with a 70° angle that is constructed using the soil characteristics listed in Table 3.1. To assure the precision of the results, the slope has been built in four layers that have all been perfectly levelled. The slope measures 50 cm in height, 65 cm in base length, and 41 cm in width. The length is 41 cm and the width is 30 cm at the slope's top. The slope is built in layers to ensure that the soil parameters are constant along the slope and to provide a more controlled testing environment. This is crucial because changes in soil qualities might have an impact on the slope's stability and landslip risk. By constructing the slope at a 70° angle, we can study the effects of slope angle on the landslide process. This is an important variable to consider because steeper slopes are typically more prone to landslides. By measuring the displacement, pore pressures, and soil pressures during the land sliding process, we gain valuable insights into how slope angle affects the likelihood and severity of landslide.

Fig.16 (Land slope constructed of 80° angle)

In Figure 16 a slope of angle 80° can be seen that is constructed using the soil characteristics listed in Table 3.1. To assure the precision of the results, the slope has been built in four layers that have all been perfectly levelled. The slope measures 50 cm in height, 65 cm in base length, and 41 cm in width. The length is 41 cm and the width is 38 cm at the slope's top. The slope is built in layers to ensure that the soil parameters are constant along the slope and to provide a more controlled testing environment. This is crucial because changes in soil qualities might have an impact on the slope's stability and landslip risk. By constructing the slope at a 80° angle, we can study the effects of slope angle on the landslide process. This is an important variable to consider because steeper slopes are typically more prone to landslides. By measuring the displacement, pore pressures, and soil pressures during the land sliding process, we gain valuable insights into how slope angle affects the likelihood and severity of landslide. Different angles of slope have different factor of safety.

Fig.17 (Land slope constructed of 90° angle)

Figure 15 shows a slope with a 90° angle that is constructed using the soil characteristics listed in Table 3.1. To assure the precision of the results, the slope has been built in four layers that have all been perfectly levelled. The slope measures 50 cm in height, 65 cm in base length, and 40 cm in width. The length is 40 cm and the width is 40 cm at the slope's top. The slope is built in layers to ensure that the soil parameters are constant along the slope and to provide a more controlled testing environment. This is crucial because changes in soil qualities might have an impact on the slope's stability and landslip risk. By constructing the slope at a 90° angle, we can study the effects of slope angle on the landslide process. This is an important variable to consider because steeper slopes are typically more prone to landslides. By measuring the displacement, pore pressures, and soil pressures during the land sliding process, we gain valuable insights into how slope angle affects the likelihood and severity of landslide. The factor of safety of the land slope is also affected or changed with the change in the angle.

3.9. SENSORS INSTALLED FOR TESTING

The sensors are installed in soil to monitor the characteristics and properties of soil as we can see in the figure18. The sensors include moisture sensors, ultrasonic sensors, accelerometer and gyroscope sensors, and vibration sensors. These sensors are used to collect data that can be analyzed to detect early signs of landslides. Moisture sensors are used to measure the amount of water present in soil. They can be used to determine the moisture content of the soil, which can be an important factor in the occurrence of landslides.

Fig.18 (Sensors installed in the slope)

If the soil is too wet, it can become unstable and more prone to landslides. Ultrasonic sensors are used to measure the distance between the sensor and the soil surface. This data can be used to detect changes in the soil profile, such as erosion or subsidence, which can be indicative of an impending landslide. Accelerometer and gyroscope sensors are used to measure the acceleration and rotation of the soil. These sensors can detect small movements in the soil, which can be an early sign of a landslide. They can also be used to monitor the stability of slopes and hillsides. Vibration sensors are used to detect ground vibrations caused by earthquakes, landslides, and other natural phenomena. These sensors can detect changes in the frequency and amplitude of vibrations, which can be an early warning sign of a landslide. The data collected from these sensors is processed and analyzed using various techniques, such as machine learning algorithms and statistical analysis. By monitoring the characteristics and properties of the soil using these sensors, it is possible to detect early signs of landslides and take preventative measures to avoid or mitigate their effects.

CHAPTER - 4

RESULT AND DISCUSSION

4.1. General

Using lab scale physical model and software the work study is carried out. As a result, the readings of sensor installed in soil are collected and pore-water pressure contour maps are represented below:-

4.2. SENSOR READINGS

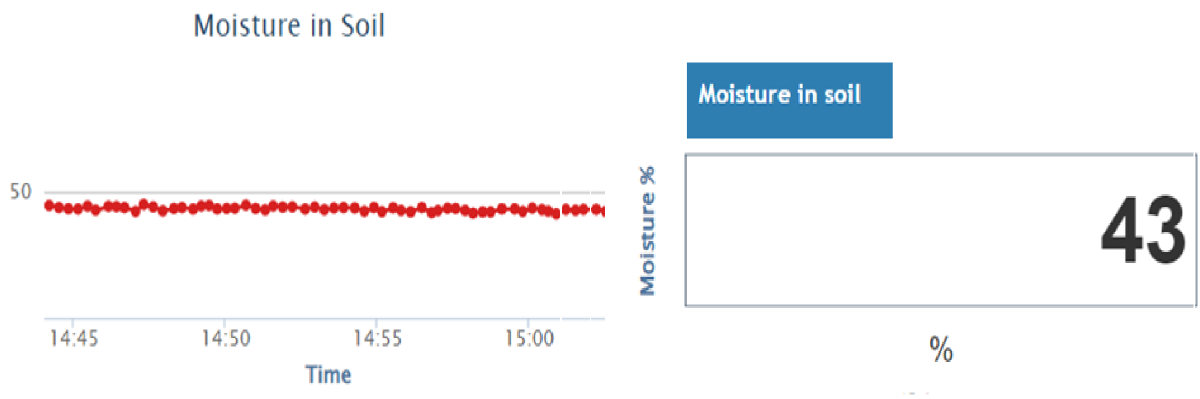

Fig.19 (Moisture in soil)

Readings shown or collected by the soil and moisture sensor installed in the soil are shown in the figure19 which shows 43 percent moisture content of the soil after the slope is being constructed . Information regarding the soil's moisture content over time is shown in the graph. The graph's data points show the moisture levels at intervals of 15 minutes. The proportion of the soil's moisture content is shown on the graph's y-axis, With the earliest time on the left and the latest time on the right, the x-axis depicts the time span. Depending on the soil's moisture level, the graph may have a curve, a straight line, or a fluctuating pattern. The moisture sensor continuously monitors the moisture level in the soil and generates data at regular intervals, which is represented on the graph. This data can be useful to monitor the value at which soil erosion or landslide took place which will be helpful in preventing the soil erosion before it happens.

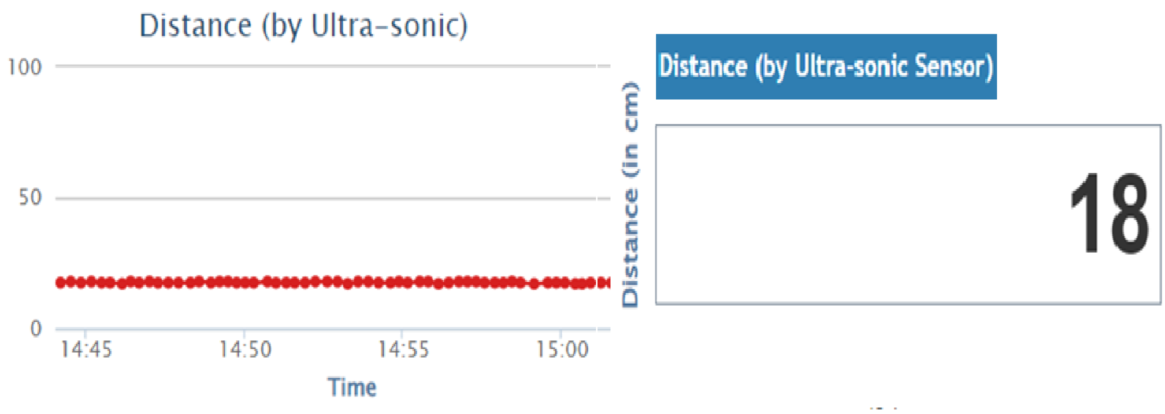

Fig.20 (Distance reading of ultra-sonic sensor)

Figure 20 displays readings of ultrasonic sensor in the form of a graph, which is installed on the slope, as shown in Figure 18. The ultrasonic sensor measures the distance between the sensor and the slope's surface, which can be used to analyze the soil particles of the slope in a better way. The graph in Figure 20 shows the variation of the distance between the sensor and the slope surface over time. The y-axis represents the distance measured in centimeters, while the x-axis represents time. The graph can show a straight line or a curve, depending on the slope's surface and the sensor's position.

The ultrasonic sensor sends out a sound wave that bounces off the slope's surface and returns to the sensor. The time it takes for the sound wave to return to the sensor is used to calculate the distance between the sensor and the slope's surface. This process is repeated at regular intervals to collect data on the slope's surface. Analyzing the data collected by the ultrasonic sensor can provide valuable information about the soil particles of the slope. For example, if the distance between the sensor and the slope's surface decreases over time, it could indicate that the soil particles are becoming more compacted. Alternatively, if the distance increases, it could indicate that the slope is experiencing erosion or that the soil particles are becoming loose. Overall, the data collected by the ultrasonic sensor can be used to make informed decisions about soil management practices, such as slope stabilization or erosion control, to ensure the long-term sustainability of the slope and the surrounding environment.

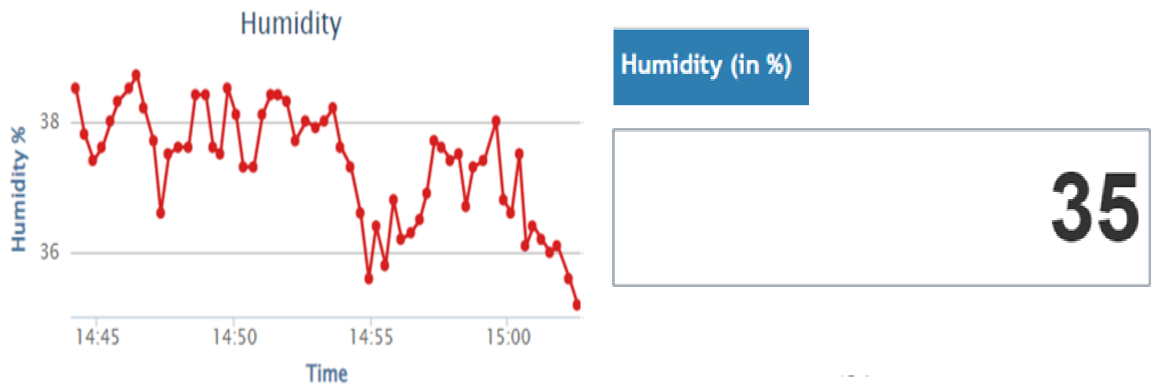

Fig.21 (Humidity percentage of soil)

The soil and moisture sensor's findings, which provide the percentage of soil humidity, are shown in Figure 21. The graph displays the average humidity % value as well as the fluctuation in soil humidity over time. The graph's data points show the humidity percentage for a 15-minute average. The graph's y-axis displays the percentage of soil humidity, and the x-axis shows the time intervals. Depending on the soil humidity level, the graph may have a curve, a straight line, or a fluctuating pattern. The graph shows the data that is generated at regular intervals by the soil and moisture sensor, which continuously checks the soil's humidity %. This information can be useful to prevent soil erosion. The graph in Figure 21 can help to identify any changes in soil management practices. The average humidity percentage value can provide an overall understanding of the soil moisture levels during the period of observation.

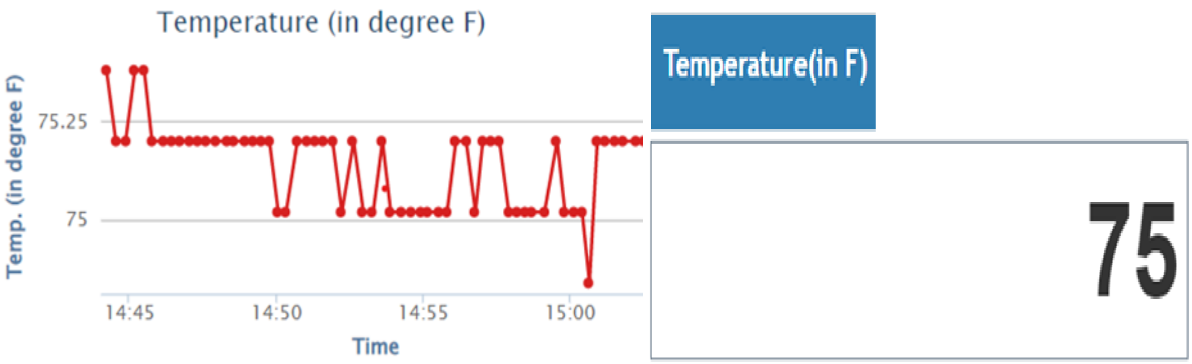

Fig.22 (Temperature in Fahrenheit)

In figure 22 the graph demonstrates how the soil's temperature changes over time with some temperature fluctuations. These variations could be caused by several variables, including variations in solar radiation, cloud cover, and soil moisture content. Another possibility is that some of the variations in soil temperature are caused by measurement mistake or data noise.75 degrees Fahrenheit is the average temperature for the entire 15-minute timeframe. The central tendency of the temperature distribution across the time period is indicated by this average number, which offers a good overview of the temperature data. It is crucial to keep in mind that because some of the fluctuations may be significant, the average number might not accurately reflect the temperature data's variability.

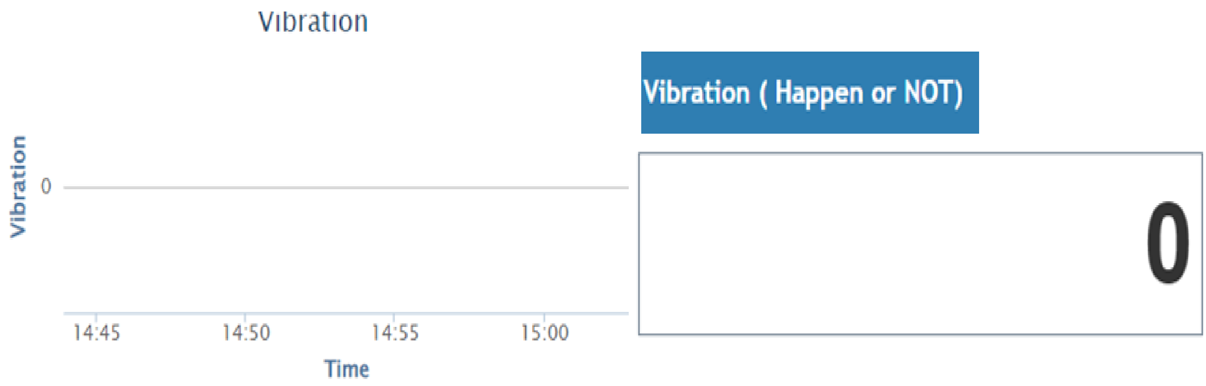

Fig.23 (Vibration Graph)

Vibration sensors are devices used to measure and monitor ground vibrations or seismic activity in the soil. The movement of soil and rock can produce vibrations that the sensors can detect, they are frequently employed to detect and monitor landslides. As shown in Figure 23, the vibration measurements recorded by the sensors are zero, there may not be any soil movement at that specific place. This may be the result of several factors, including the lack of any triggering factors, stability of the slope, or the sensor's placement. It is essential to remember that landslides can happen abruptly and unexpectedly, thus zero values may not always indicate that there is no risk of them in the area. Vibration sensors are important for early detection of landslides because they can alert users to ground movement that could cause landslides. This can play a key role in preventing or reducing the harm and fatalities caused by landslides. Early discovery can also make it possible to put suitable mitigation strategies in place, like slope stabilization, drainage management, and evacuation planning. In conclusion, vibration sensors are vital instruments for spotting and keeping an eye on landslides. Zero readings can suggest that there is not any ground movement at a specific spot, but it's important to confirm the quality and dependability of the data.

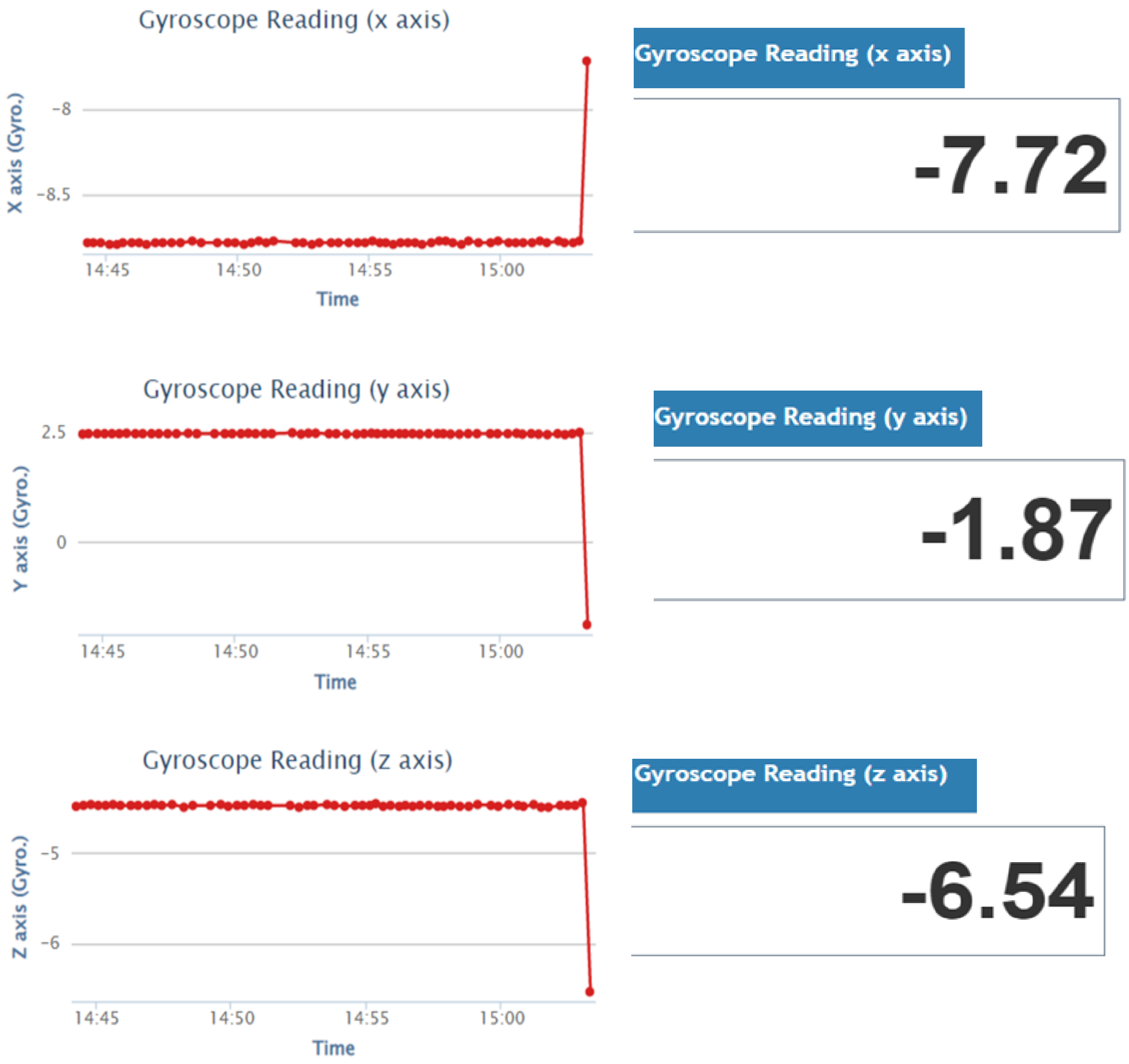

Fig.24 (Gyroscope readings)

Gyroscope sensors are devices used to measure rotational movement or angular velocity. Gyroscope can detect and measure soil movement in three dimensions-x, y, and z when implanted in the soil. As seen in Figure 24, the readings obtained by the gyroscope sensor are normally presented as a graph or as numerical values. The ability of the gyroscope sensor to detect and measure the rotational movement of the soil, which can signal the possibility of landslides, makes it a useful instrument for the early detection of landslides. Numerous factors, including the destabilization of the soil brought on by rotational movement, can induce landslides. The gyroscope sensor can identify and gauge this rotational movement, giving probable landslide action an early warning. The soil may be growing more unstable and there may be a greater risk of landslides if the readings over time reveal an increase in rotational movement. Early intervention can be started to stop or reduce the harm and fatalities brought on by landslides by keeping an eye on these tendencies. In addition, compared to other sensors that can only detect movement in one or two dimensions, the gyroscope measurements offer more thorough information on the soil movement. The volume and direction of the soil movement can be determined using this, which can help mitigation techniques like slope stabilization and evacuation planning. Gyroscope sensors can be useful tools for identifying landslides before they happen. The three-dimensional data nature offers extensive information on the soil movement, which can help mitigate damage and reduce the risk of loss of life by informing mitigation efforts.

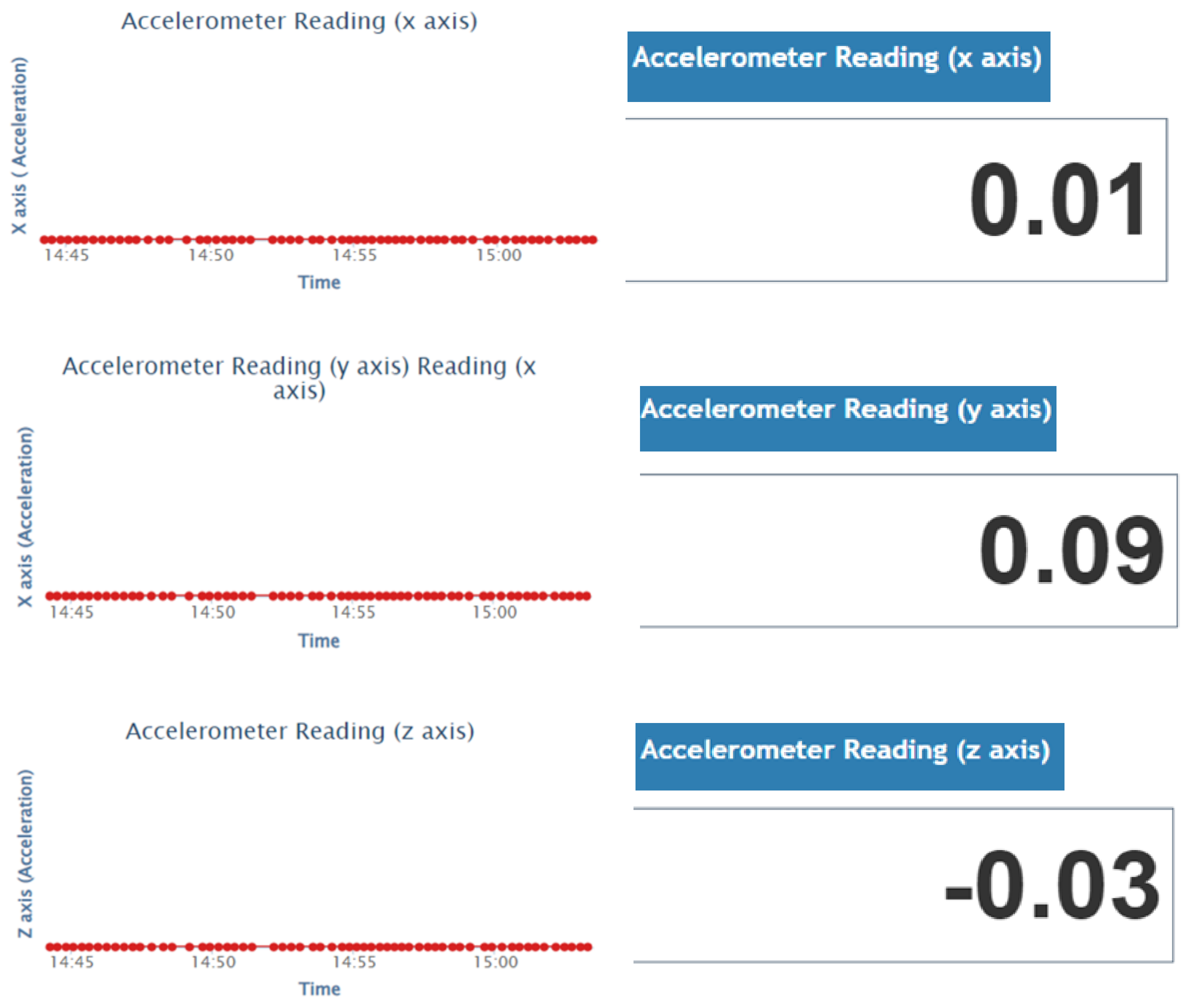

Fig.25 (Accelerometer Readings)

The measurement of an object's acceleration or changes in velocity is done with the aid of accelerometer sensors. They have the ability to detect and measure soil movement in three dimensions (x, y, and z) when buried in the ground. Figure 25 illustrates how the readings from the accelerometer sensor are often shown as a graph or as numerical values. For tracking soil movement and spotting impending landslides, the accelerometer sensor can be a useful device. The results from the accelerometer can reveal details on the speed and direction of soil movement, which can help determine the likelihood of landslides. Accelerometer sensors can identify both gradual and abrupt changes in soil movement, making them ideal for landslide early warning systems. The frequency and amplitude of the soil movement can also be examined using the readings obtained by the accelerometer sensor. The possibility for landslides can be predicted using this information, which can also be used to discover patterns in the soil movement. Early intervention can be started to stop or reduce the harm and loss of life caused by landslides by keeping an eye on these tendencies. Compared to conventional sensors that simply monitor movement in one or two dimensions, the accelerometer measurements provide more thorough information on the soil movement. The volume and direction of the soil movement can be determined using this, which can help mitigation techniques like slope stabilization and evacuation planning. In result, accelerometer sensors can be useful equipment for tracking soil movement and spotting probable landslides. The measurements' three-dimensionality offers extensive data on the rate, direction, and features of soil movement, which can be used to forecast the likelihood of landslides and guide mitigation measures.

4.3. FACTOR OF SAFETY TEST RESULT FOR DIFFERENT SLOPES

A slope's stability is determined by the factor of safety. It is calculated by dividing the soil's shear strength by the soil's shear stress. If the slope's factor of safety is greater than one, the slope is stable; if it is lower than one, the slope is unstable. Geo-studio software is utilized to determine the factor of safety for various slope angles. This software enables the modelling of various slopes and the determination of their safety factor. To assure the stability of the slope, the factor of safety is examined prior to applying pore-water pressure on it. The slope is built using the same basic soil characteristics as those listed in table 3.1. These characteristics include elements that are considered when calculating the factor of safety, such as soil type, density, and shear strength. In order to ensure that the findings from the software are accurate representations of the slope, the software's geometry of the slope is modelled to be identical to the physical land slope modal. The best slope design can be found by modelling the slope in the software and testing various scenarios, such as changing the slope's angle or the soil's qualities.

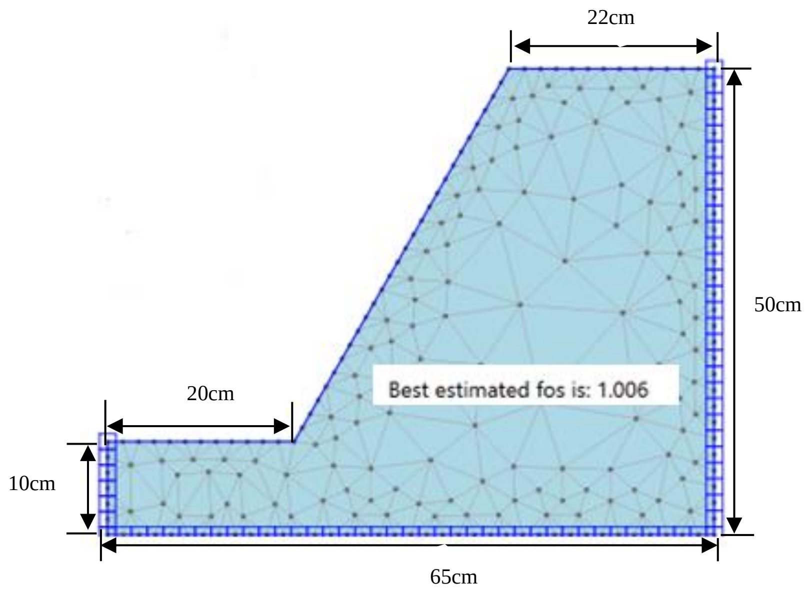

Fig.26 (Factor of safety of 60° slope)

A slope of 60°angle is made using the same materials as a physical model, with dimensions of 50 cm elevation or height, 65 cm bottom foundation, and 22 cm top base. The Geo-studio software is used to determine the factor of safety in order to guarantee the stability of the slope. As seen in figure 26, the outcome for the 60° slope is a factor of safety of 1.006. A slope's safety factor plays a crucial role in determining its stability. If the slope's factor of safety is greater than one, the slope is considered to be stable; if it is lower than one, the slope is considered unstable and may experience a landslide or other type of slope failure. When it comes to manmade slopes, the factor of safety for slopes with an angle up to 60° have safety of factor more than 1 but after angle more than 60° the factor of safety starts decreasing which means the slopes are more unstable and there is high risk of landslide which can cause damage to life and property. For the making of early detection system, it is important to collect data of about unstable slopes and also there is a need of conducted test on unstable slopes to system to work better.

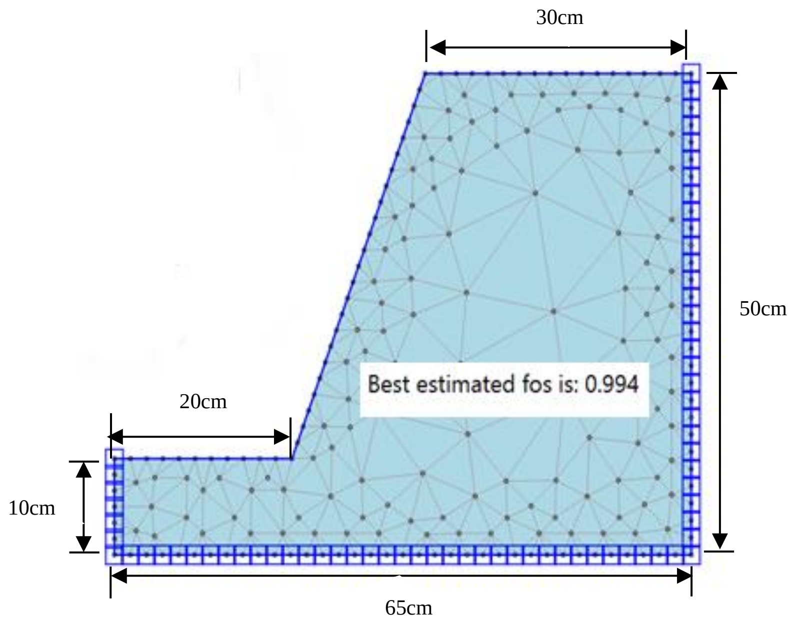

Fig.27 (Factor of safety of 70° slope)

The dimensions of the slope at an angle of 70° in Figure 27 are 50 cm in elevation or height, 65 cm for the foundation base, and 30 cm for the top base. The slope is built using the same essential soil characteristics as the physical modal, and the Geo-studio software calculates its factor of safety to be 0.994. If the factor of safety is less than 1, the slope is unstable and might be dangerous.

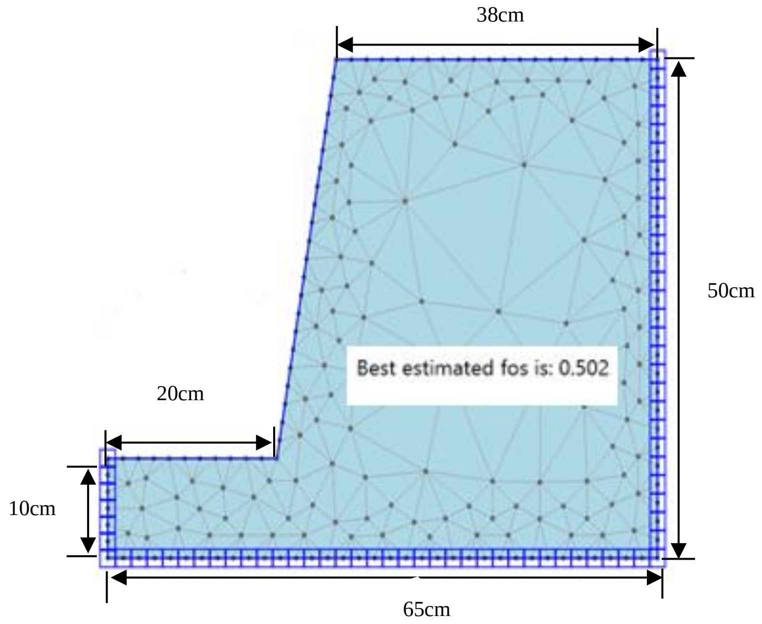

Fig.28 (Factor of safety of 80° slope)

The dimensions of the slope at an angle of 80° in Figure 28 are 50 cm in elevation or height, 65 cm for the foundation base, and 30 cm for the top base. The slope is built using the same essential soil characteristics as the physical modal, and the Geo-studio software calculates its factor of safety to be 0.502. If the factor of safety is less than 1, the slope is unstable and might be dangerous.

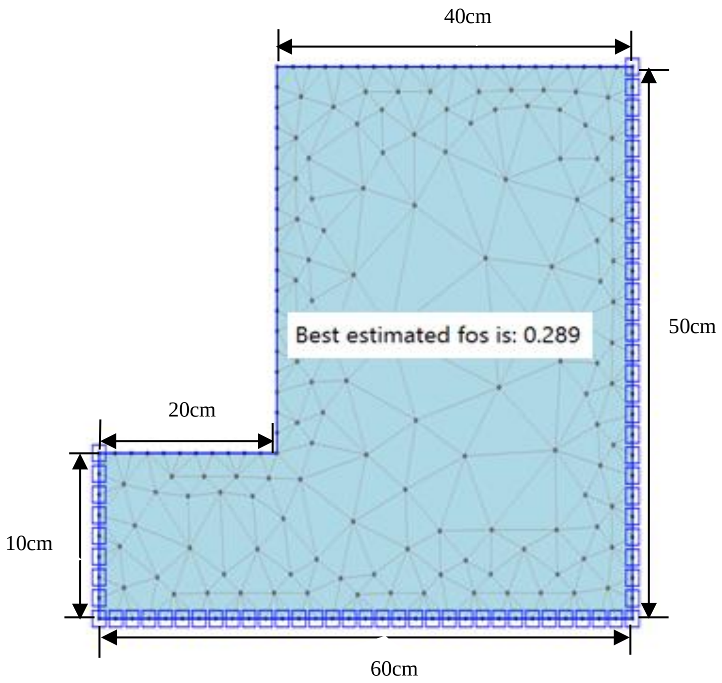

Fig.29 (Factor of safety of 90 Degree slope)

The dimensions of the slope at an angle of 80° in Figure 29 are 50 cm in elevation or height, 65 cm for the foundation base, and 30 cm for the top base. The slope is built using the same essential soil characteristics as the physical modal, and the Geo-studio software calculates its factor of safety to be 0.289. If the factor of safety is less than 1, the slope is unstable and might be dangerous. After constructing the slopes of different angles and checking factor of safety of slopes, now we will apply pore water pressure on the slope and will draw water entry and exit points on the slope the unit weight of water applied on the slope is 9.807 KN/m^3 , which will give us contour maps of pore water pressure of water at different depths of the slopes and it will also provide us land sliding area image of slope.

4.4. SLIDING OF SLOPES AND PORE-WATER PRESSURE CONTOUR MAPS

When pore water pressure is applied to a slope, it can decrease the effective stress on the soil particles, which can lower the soil's shear strength. This may finally cause the slope to break, causing landslides or slope instability. The rainfall is one of the major cause of landslides Therefore, it is important to examine how pore water pressure affects the stability of the slope.

We used the Geo-studio program to simulate the impact of pore water pressure on the slope. Based on inputs like the water entry and departure locations, unit weight of water, and other hydrological properties, the Geo-studio software may assist you in calculating the distribution of pore water pressure at various depths of the slope. The sources of water that can enter the slope, such as rainfall or groundwater flow, must be identified in order to sketch the water entry and departure locations on the slope. Based on the slope's drainage features, such as the availability of natural or man-made drainage channels, the departure spots can be identified. Once the points of entry and departure for the water have been determined, you can use the software to simulate the water flow through the soil and ascertain the distribution of pore water pressure at various slope depths. using this data, contour maps of the slope's pore water pressure may be made, allowing us to spot regions with high pore water pressure and potential land-sliding hazards, which will help in the making of an cost-effective early landslide detection system.

We can see how the pore water pressure is distributed on the slope using the contour maps, and you can identify probable failure zones in the regions with high pore water pressure. We can identify the regions that require mitigation actions by evaluating the contour maps, such as better drainage or slope stabilization techniques like retaining walls.

In conclusion, applying pore water pressure to a slope and drawing contour maps of the pore water pressure at various slope depths can aid in identifying possible land sliding locations and give important data for slope stabilization and mitigation actions.

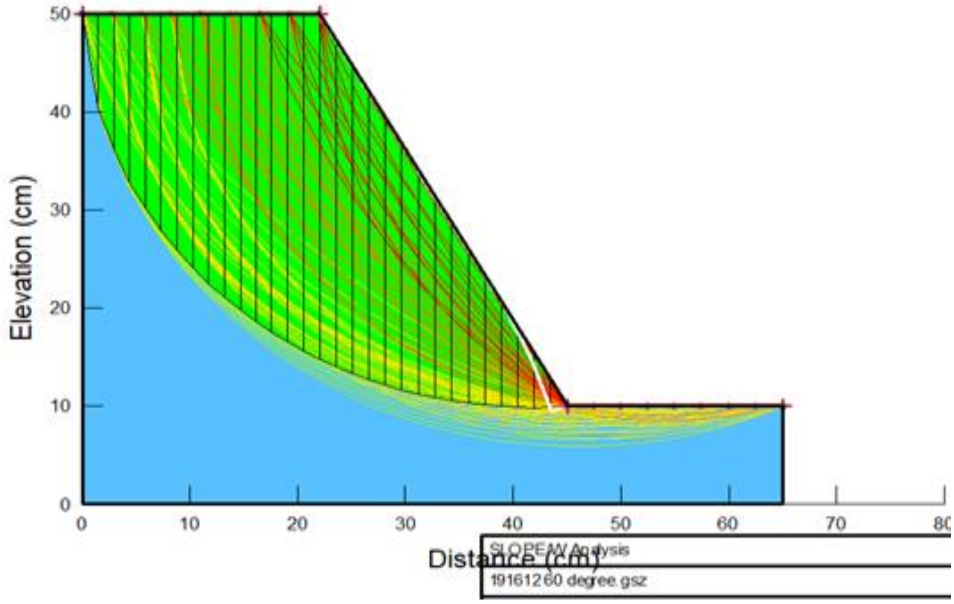

Fig.30 (Sliding Area of 60° slope)

Figure 30 given above shows the land sliding zone of 60° slope which is obtained using Geo-studio software, the pore water-pressure was applied on the slope. The unit weight of the water was 9.807 KN/m^3 . The slope is constructed of as same as dimension of physical made slopes. The slope has a dimensions of 50 cm elevation or height, 65 cm bottom foundation, and 22 cm top base.

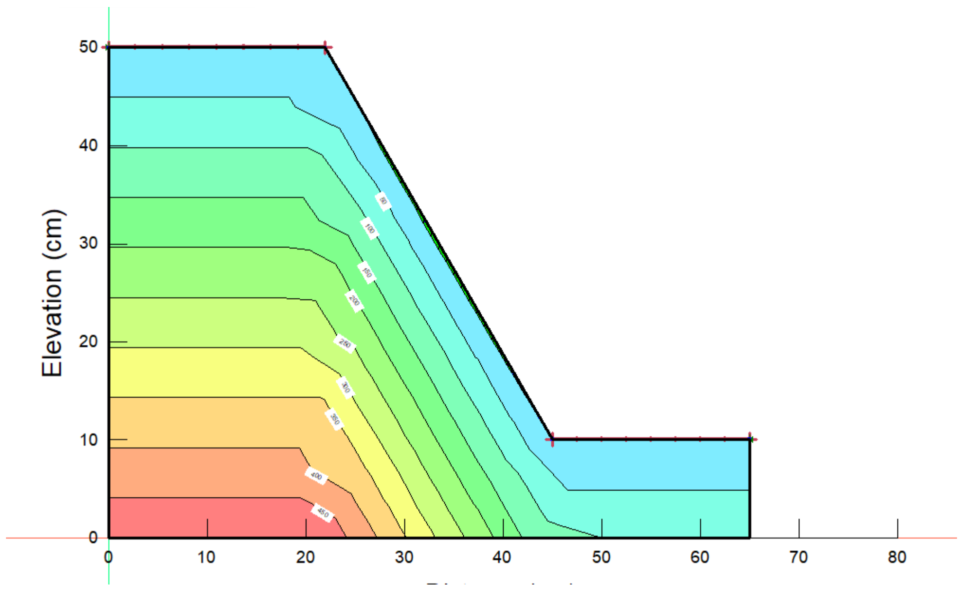

Fig.31 (pore- water pressure contour map of 60° slope)

The stability of the slope is greatly influenced by the distribution of pore water pressure on the slope, as shown in Figure 31. As we dig further into the soil, the pore water pressure values rise, which can have a substantial impact on the soil's shear strength and cause slope instability.

Comparing the data produced from the software with the readings from a sensor implanted in the slope is essential to obtaining more accurate readings of the pore water pressure. A precise and reliable reading of the pore water pressure at various depths in the slope can be obtained by installing a pore water pressure sensor in the slope. After the sensor has been mounted, readings of the pore-water pressure must be taken at various depths down the slope and contrasted with results from the program. The software's predictions are validated by this comparison, which also offers a more precise evaluation of the slope stability.

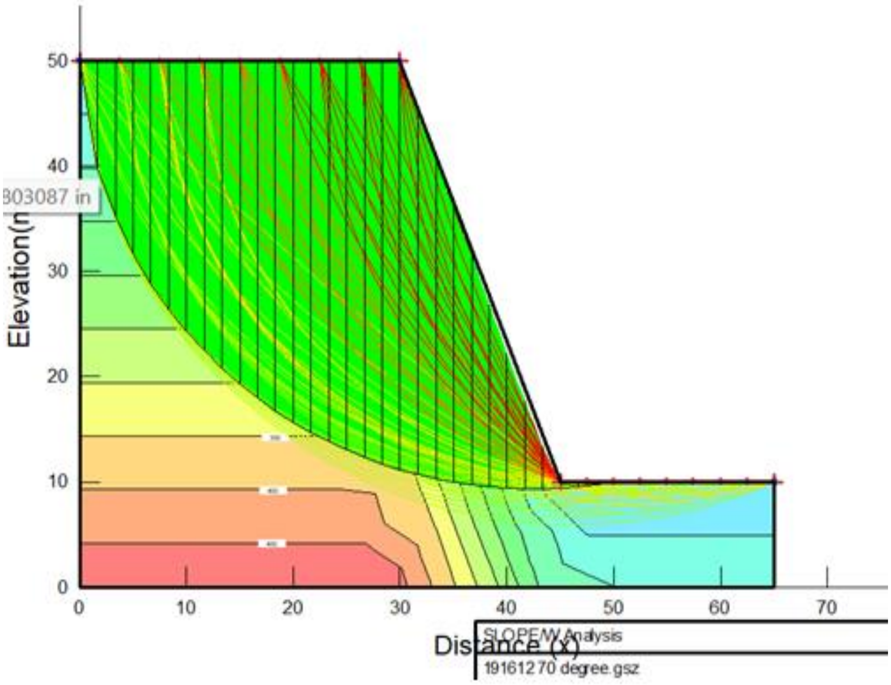

Fig.32 (Sliding Area of 70° slope)

Figure 32 given above shows the land sliding zone of 70° slope which is obtained using Geo-studio software, the pore water-pressure was applied on the slope. The unit weight of the water was 9.807 KN/m^3 . The slope is constructed of as same as dimension of physical made slopes. The slope has a dimensions of 50 cm elevation or height, 65 cm bottom foundation, and 30 cm top base.

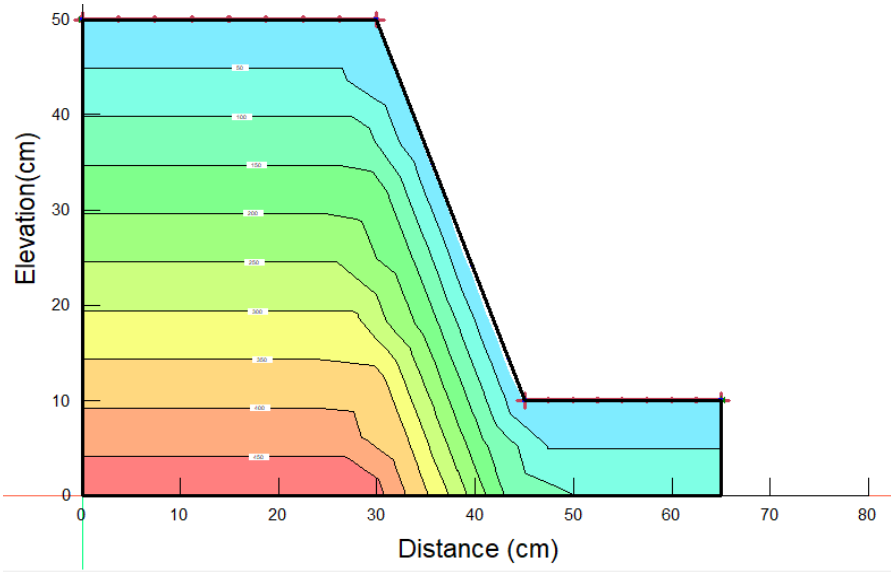

Fig.33 (pore- water pressure contour map of 70° slope)

As we go deep further into the soil, the pore water pressure values rise (shown in figure33), which can have a substantial impact on the soil's shear strength and cause slope instability. Comparing the data produced from the software with the readings from a sensor implanted in the slope is essential to obtaining more accurate readings of the pore water pressure. A precise and reliable reading of the pore water pressure at various depths in the slope can be obtained by installing a pore- water pressure sensor in the slope. After the sensor has been mounted, readings of the pore water pressure must be taken at various depths down the slope and contrasted with results from the program. The software's predictions are validated by this comparison, which also offers a more precise evaluation of the slope stability.

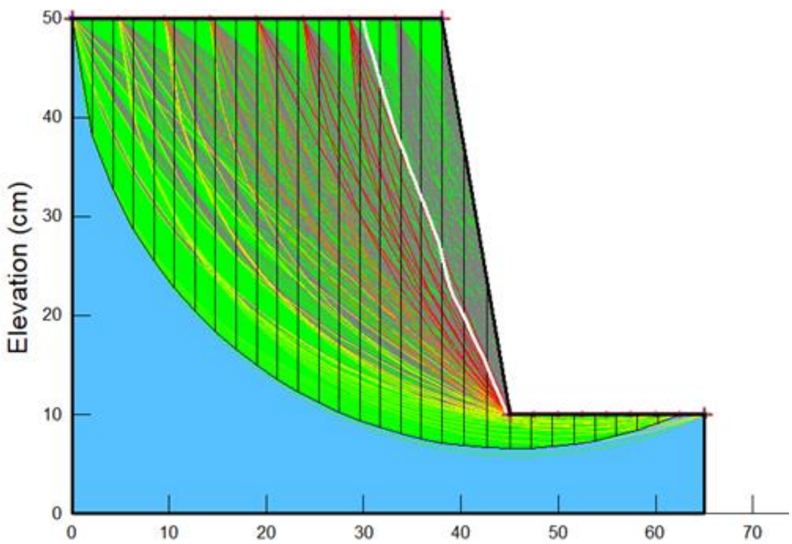

Fig.34 (Sliding Area of 80° slope)

Figure 34 shows the sliding are of 80° slope which is obtained using Geo-studio software, the pore water-pressure was applied on the slope. The unit weight of the water was 9.807 KN/m^3 .The slope is constructed of as same as dimension of physical made slopes. The slope has a dimensions of 50 cm elevation or height, 65 cm bottom foundation, and 38 cm top base.

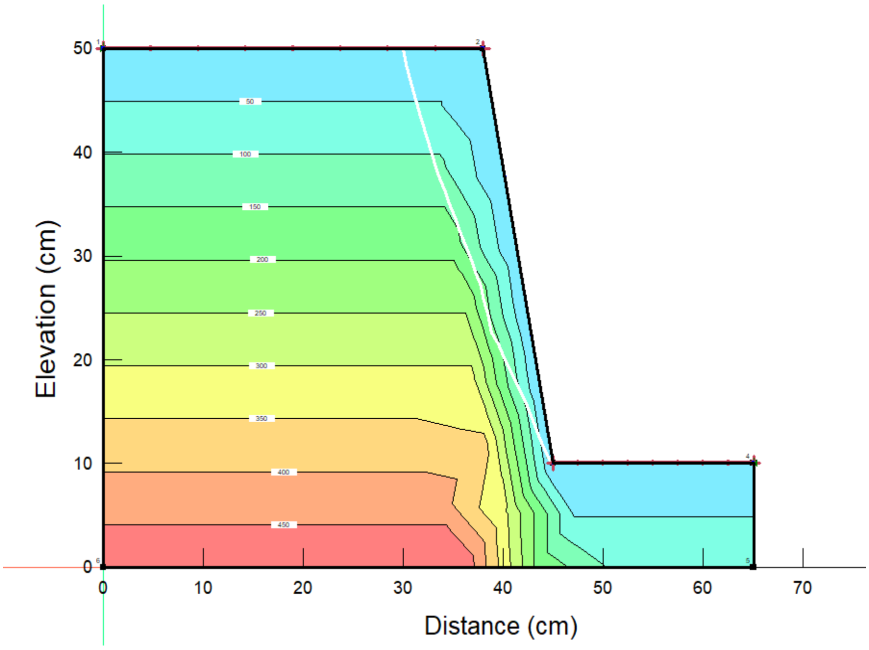

Fig.35 (pore- water pressure contour map of 80° slope)

As we go deep further into the soil, the pore water pressure values rise (shown in figure35), which can have a substantial impact on the soil's shear strength and cause slope instability. Comparing the data produced from the software with the readings from a sensor implanted in the slope is essential to obtaining more accurate readings of the pore water pressure. A precise and reliable reading of the pore water pressure at various depths in the slope can be obtained by installing a pore- water pressure sensor in the slope. After the sensor has been mounted, readings of the pore water pressure must be taken at various depths down the slope and contrasted with results from the program. The software's predictions are validated by this comparison, which also offers a more precise evaluation of the slope stability.

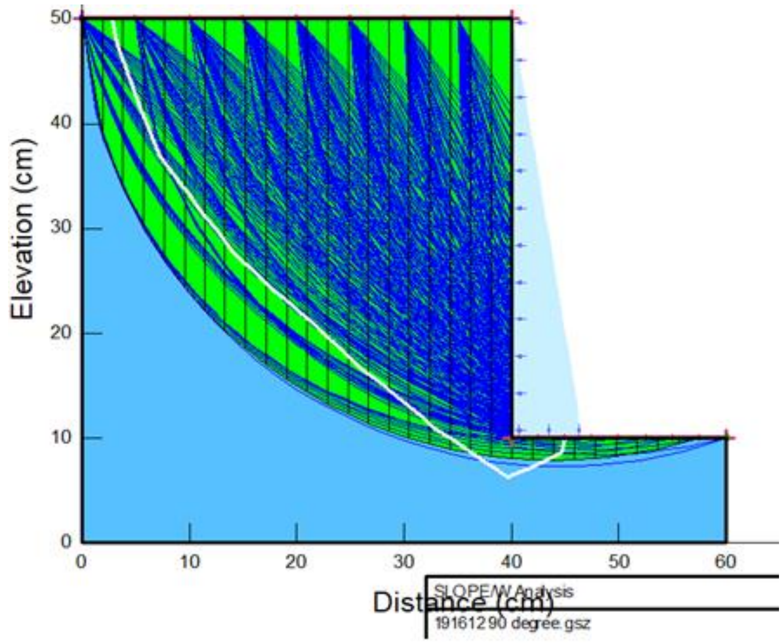

Fig.36 (Sliding Area of 90° slope)

Figure 36 shows the sliding are of 90° slope which is obtained using Geo-studio software, the pore water-pressure was applied on the slope. The unit weight of the water was 9.807 KN/m^3 .The slope is constructed of as same as dimension of physical made slopes. The slope has a dimensions of 50 cm elevation or height, 65 cm bottom foundation, and 48 cm top base.

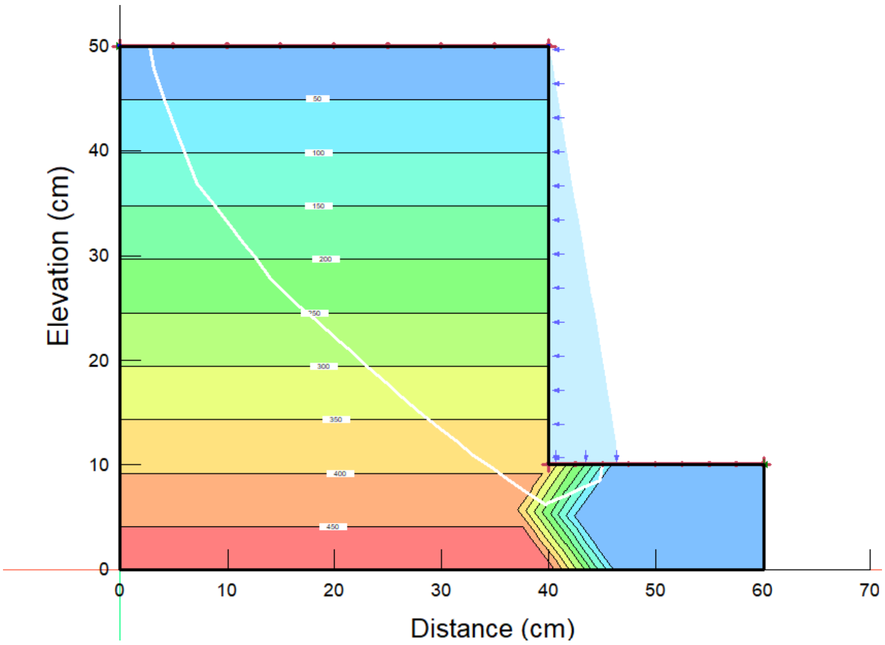

Fig.37 (pore- water pressure contour map of 90° slope)

The stability of the slope is greatly influenced by the distribution of pore water pressure on the slope, as shown in Figure 37. As we dig further into the soil, the pore water pressure values rise, which can have a substantial impact on the soil's shear strength and cause slope instability. Comparing the data produced from the software with the readings from a sensor implanted in the slope is essential to obtaining more accurate readings of the pore water pressure. A precise and reliable reading of the pore water pressure at various depths in the slope can be obtained by installing a pore-water pressure sensor in the slope. After the sensor has been mounted, readings of the pore-water pressure must be taken at various depths down the slope and contrasted with results from the program. The software's predictions are validated by this comparison, which also offers a more precise evaluation of the slope stability.

These landslips and contour maps of pore-water pressure at different angles of slopes test is done by using Geo studio software. Contour maps of different angles of slopes tells us about pore- water pressure at different levels or depth of slopes of different angles of 60°, 70°, 80° and 90°. These results need to be checked or compared by performing the physical test on the different slopes with the help of sensors at different depths as given above in the contour map then the data can be analyzed and can be used for the further process of making of early detection system.

CHAPTER-5

CONCLUSION

5.1. General

This chapter deals with conclusion that has been derived on the basis of the work and methodology that has been carried out and on the basis of the result that we got from the study we have carried out.

It can be concluded that

1) Early detection of landslides is crucial for protecting communities and infrastructure from their potentially devastating effects.
2) For us to better understand landslides and create efficient early detection and warning systems to safeguard infrastructure and populations, we must continue to invest in research and development.
3) The slopes of angle more than 60° are more unstable because factor of safety starts decreasing as the angle of slopes starts increasing.
4) The parameters like displacement, bonding of soil particles, pore-water pressure, moisture content, Vibrations can be used for early detection of landslide.

5.2. Future Scope of work

Seismic activities can be used to simulate landslides and collect detailed data on their behavior, for early detection of landslides. We have checked the pore- water pressure of the slopes using geo- studio software which could be checked manually using sensors at different depths of slope. So, that results can be verified for making a good early detection system. In future, the testing of slopes could be done in the shaking table for analyzing landslide factor earthquake. So, it will help in making a good landslide detection system which could warn people before the landslide happens.

REFRENCES

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