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Landslide Early Warning System By Analyzing Soil Moisture And Land Movement

[1]Roshan Tom, [2]Alvin Johny, [3]Raniya Jasdeen, [4]Sara Mehrin, [5]Ms. D. Dalmiya Rajan

[1]Student, [2]Student, [3]Student, [4]Student, [5]Assistant Professor
[1]Civil Engineering,
[1] St. Joseph's College of Engineering and Technology, Palai, Kottayam, India

***Abstract*: The high rate of rainfall is the main trigger factor in many cases of landslides. However each type of soils has unique characteristics and behaviour concerning the rainfall infilteration. Therefore, early warning system of landslide will be more accurate by monitoring the changes of ground water conditions. The monitoring of ground water changes is designed by using soil moisture sensor. To determine the soil characteristic and behaviour with respect to water content that induce landslides, an experiment involving small-scale landslide model is conducted. The increase of soil water content will lead to the rise of the pore pressure and soil weight which could cause soil vulnerability to the movement. The soil movement sensor utilizes a sliding potentiometer that converts distances into stresses and a humidity sensor. The results obtained through the simulation that the system is able to measure the movement of soil, soil moisture, and provide early warning through sirens.**

KEYWORDS: Soil Moisture Sensor, Gyroscope, Experimental Model

INTRODUCTION

Landslide is a disaster with highest prevalence around the world. Global climate change, population increase and economy development had led to rising trend of landslide frequency and pose hazard to the population. Landslides or land movements in some cases do not occur spontaneously, but there are indications such as land movement. To reduce losses caused by landslides, an early warning system is required. The above signs can actually be converted into an early warning system that is expected to assist in monitoring the indication of landslides. According to historical data of landslide, rainfall became the main trigger for many landslides. As the intensity and duration of rainfall increase, infiltration of water into the soil rises. This situation has affected for increasing its weight and pores. When the water steadily enters the impermeable soil which acts as a sliding plane, the ground becomes unstable and the weathering caused ground movement. The change of water content in the soil account for the difference in soil properties, reducing soil strength and matrix suction. Usually, rainfall is measured using rain gauge, but it requires the specific rainfall threshold values for either regional or local areas.

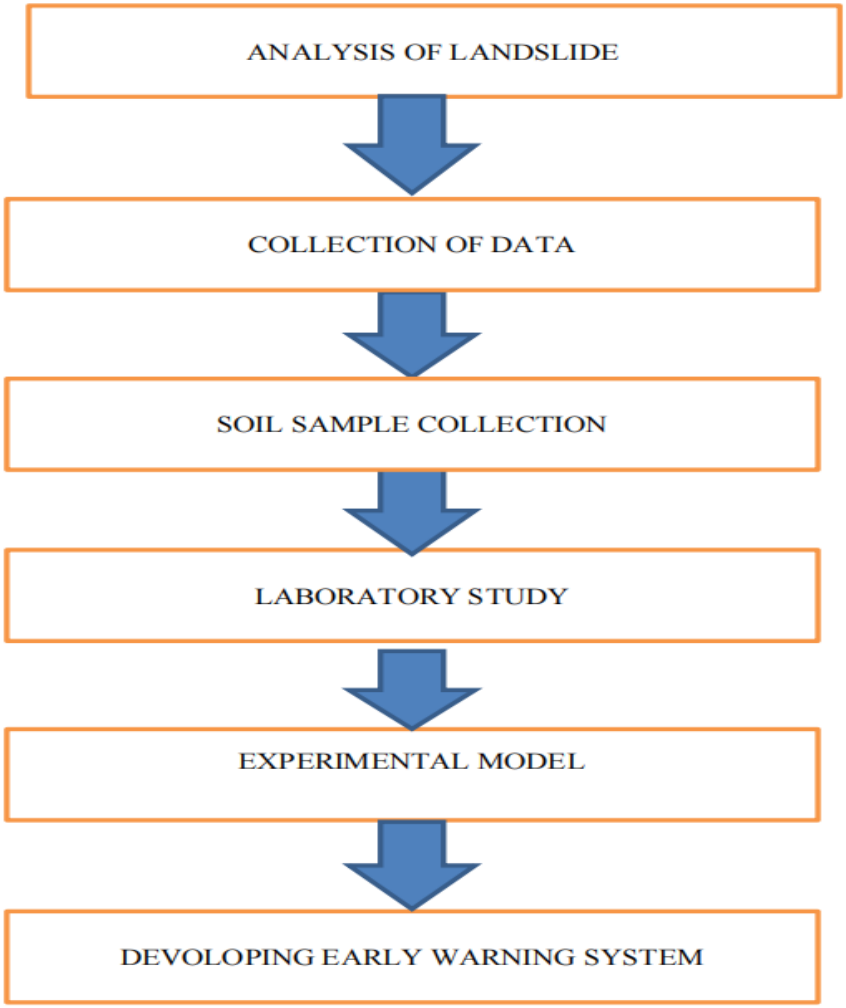
Various landslide monitoring systems have been developed using various sensors. Monitoring of landslide potential is also done through condition of water content in soil with resistivity method. Parameters used are water content, water potential and resistivity measurement used in predicting sensors. From several studies conducted there are the main parameters that are used as an indication as landslide that is the shifting of soil, ground water content. In this research using extensiometer sensor that is potentiometer and soil moisture sensor. This identic combines the use of sensors for the measurement of continued ground movement. This study uses a low cost sensor which can be conveniently used.

OBJECTIVES

- To analyse various reasons for occurrence of a landslide in a selected area.
- To study different characteristics of the soil collected in lab.
- To analyse the threshold capacity of the soil and the maximum movement that the soil can undergo using sensors.

- To develop an early warning system based on the obtained results.
- To develop a working model that demonstrates its use.

METHODOLOGY



- Visit a landslide prone area and analyze the exact reasons behind the occurrence of landslides (Kanjar village near thodupuzha).
- Collect soil sample and test the soil sample in Geotechnical laboratory to find the parameters of the soil.
- Using a soil moisture sensor and a gyroscope , find out the maximum water the soil can carry and the maximum movement the soil can undergo before it slides.
- Set up an early warning system with these obtained values.

DATA COLLECTION

The village named Kanjar near Thodupuzha of Idukki district where landslide occurred on August 2022 was selected as the place for project study. The place was visited and details about landslide were collected from the residents and the Panchayat Office, Kanjar.

LABORATORY TESTS CONDUCTED

1. **Pycnometer Test**
   The Pycnometer is used for determination of specific gravity of soil particles of both fine grained and coarse grained soils. The determination of specific gravity of soil will help in the calculation of void ratio, degree of saturation and other different soil properties.

Pycnometer Test

2. **Direct Shear Test**
   The Direct Shear Test is an experimental procedure conducted in geotechnical engineering practice and research that aims to determine the shear strength of soil materials. Shear strength is defined as the it is t maximum resistance that a material can withstand when subjected to shearing. Generally, the Direct Shear Test is considered one of the most common and simple tests to derive the strength of a soil and can be performed on undisturbed or remoulded samples.

Direct Shear Apparatus

3. **Standard Proctor Test**
   Compaction test of soil is carried out using Proctor's test to understand compaction characteristics of different soils with change in moisture content. Compaction of soil is the optimal moisture content at which a given soil type becomes most dense and achieve its maximum dry density by removal of air voids. Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the water content and the dry density.

Standard Proctor Test Sample

EXPERIMENTAL MODEL

Based on the informations gathered from the datas collected from kanjar village, an experimental model is constructed on the laboratory to implement the early warning system. It is conducted to know the threshold limit of the soil. This threshold limit can be used for the warning system as a set point . this experiment is conducted on a small scale glass box which shows the failure of the slope that has been constructed in it. Landslide was simulated by continuous flow of water in the form of rain from above. Soil collected from kanjar village, where the landslide occurred was used for this experiment. We took
the slope value 58 degree. Rain was induced in a cloud burst format for the experiment.



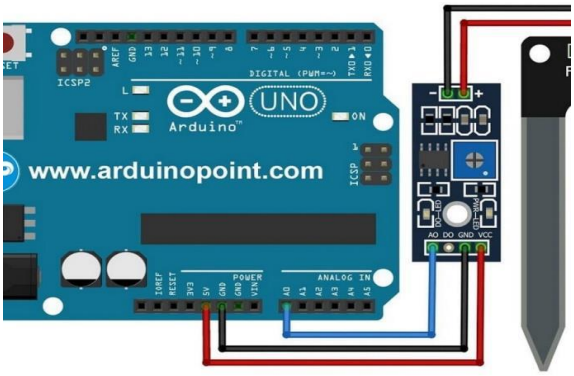

Experimental Model

SENSORS USED

- **Soil Moisture Sensor**

  Soil moisture sensors measure the volumetric water content in soil. Since the direct gravimetric measurement of free-soil moisture requires removing, drying, and weighing of a sample, soil moisture sensors measure the volumetric water content indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content. The relation between the measured property and soil moisture must be calibrated and may vary depending on environmental factors such as soil type, temperature, or electric conductivity. Reflected microwave radiation is affected by the soil moisture and is used for remote sensing in hydrology and agriculture. Portable probe instruments can be used by farmers or gardeners. Soil moisture sensors typically refer to sensors that estimate volumetric water content. Another class of sensors measure another property of moisture in soils called water potential; these sensors are usually referred to as soil water potential sensors and include tensiometers and gypsum blocks.

Circuit Connection



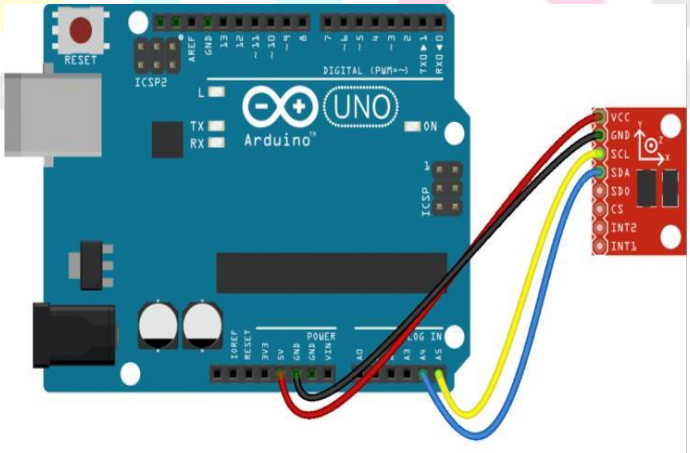
Program Code

```
const int sensor_pin = A1; /* Soil moisture sensor O/P pin */
void setup()
{
Serial.begin(9600);
/* Define baud rate for serial communication */
}
void loop()
{
float moisture_percentage;
int sensor_analog;
sensor_analog = analogRead(sensor_pin);
moisture_percentage = ( 100 - ( (sensor_analog/1023.00) * 100 ) );
Serial.print("Moisture Percentage = ");
Serial.print(moisture_percentage);
Serial.print("%\n\n");
delay(1000);
}
```

- **Gyroscope Sensor**

Gyroscope sensor is a device that can measure and maintain the orientation and angular velocity of an object. These are more advanced than accelerometers. These can measure the tilt and lateral orientation of the object whereas accelerometer can only measure the linear motion. Gyroscope sensors are also called as Angular Rate Sensor or Angular Velocity Sensors. These sensors are installed in the applications where the orientation of the object is difficult to sense by humans. Measured in degrees per second, angular velocity is the change in the rotational angle of the object per unit of time.

Circuit connection



Program Code

```
#include <Wire.h>
#include <L3G.h>
L3G gyro;
void setup()
{
Serial.begin(9600);
Wire.begin();
if (!gyro.init())
{
Serial.println("Failed to autodetect gyro type!");
while (1);
}
gyro.enableDefault();
}
void loop()
{
gyro.read();
Serial.print("X: ");
Serial.print(gyro.g.x);
Serial.print(" Y: ");
Serial.print(gyro.g.y);
Serial.print(" Z: ");
Serial.println(gyro.g.z);
delay(200);
}
```

LAB RESULTS

1. **Pycnometer Test**
   From this test, we have obtained the specific gravity value of the soil that collected from site.
   Specific gravity = 2.57 Kg/m3
   The specific gravity of a soil, which is 2.57, can provide some insight into its physical characteristics. Here are a few possible characteristics of a soil with a specific gravity of 2.57.

2. **Direct Shear Test**
   Based on the test conducted, following values are obtained:
   Angle of internal friction = 19 degrees
   Cohesion = 0.36 kpa
   The angle of internal friction is a measure of the resistance of the soil to shearing, or sliding along a plane. It represents the angle at which the soil will begin to slide under its own weight, and it is typically expressed in degrees. In this case, the soil has an angle of internal friction of 19 degrees, which is relatively low and indicates that the soil is relatively weak. The cohesion of the soil is a measure of its ability to hold together under stress, even in the absence of shear. It represents the force that must be applied to the soil to cause it to fail. In this case, the soil has a cohesion of 0.36 kPa, which is also relatively low and further indicates that the soil is weak and prone to failure.

   Based on the results , a graph is plotted between shear stress and normal stress.

Shear Stress vs Normal Stress Graph

3. **Standard Proctor Test**
   Based on the test results, the Optimum Moisture Content (0MC) of the soil that collected from the site is obtained.
   OMC (Optimum Moisture Content) = 17%
   If the OMC of a particular soil is 17%, it means that when the soil is compacted to the maximum possible density using the standard compaction test, it has the highest level of compactibility and the lowest level of permeability when its moisture content is at 17% of its dry weight. A soil with an OMC that is considered optimal for its intended use can still be susceptible to landslides under certain conditions, such as heavy rainfall or seismic activity.

CONCLUSION

From the working of the experimental model we can conclude that soil collapses at a moisture content of 35% .The buzzer was set to ring at 30% moisture content so as to give a prior alarm before the failure of the slope. The buzzer worked correctly according to value set and gave an alarm before the failure of the slope during our working model test. The given project here thus helps us in knowing the landslide possibilities in a mountainous regions. The intention of this project is to record the soil moisture and formation of cracks in the soil stratum due to soil movement which gives us the threshold value which can be used as an early warning for landslides. These recorded data could be provided to local governing bodies for proper evacuation and mitigation measures. This helps in the reduction of economic loss and loss of lives. So from this project we will try to bring about changes in the current landslide detection systems. From all the journals we referred, we have come to a conclusion that the combination of accelerometer and soil moisture sensor along with other sensors could be used in the process of determining a landslide and thus help in developing an early warning system.

FUTURE SCOPE OF STUDY

- Future implementation of the project can be done by developing the soil moisture sensor and gyroscope with IoT (Internet of things).
- This provides a means to use this sensors without wired connections which is one of the major drawbacks of the project.
- Implementing this in a region consulting with landslide susceptibility maps will help to provide more accurate monitoring.

IMPLEMENTATION

This project can be implemented in a real situation by the following means.
1. Providing two soil moisture sensors and a 3 axis gyroscope as a module to be placed 1.5 – 2 meters deep in the location.
2. Such modules could be placed at a distance of 500 meters to 1 km from each other in the red zone location. This is done so as to accommodate the recent trends of cloud burst in specific areas only.

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