RAINFALL INDUCED LANDSLIDE TRIGGERING THRESHOLD LEVEL ASSESSMENT BY LABORATORY SCALE DOWN MODEL USING SENSOR NODES

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ABSTRACT

Rainfall triggered landslide disaster frequently happens in the slopes during substantial precipitation. Water infiltration arises in the slopes due to rainfall, which changes the moisture content of the soil slope gradient and decreases its stability and landslide occurs. Landslide causes damages in the environments, prediction and forecasting is essential to reduce the property losses and to avoid loss in human lives. This paper proposes the laboratory experimental method for measurement of change in moisture content to identify the triggering condition of slope failure using different types of sensors. The experiment is used to determine the instigation process of rainfall triggered landslide. The study showed that, the slope failures were triggered by gradual increase of the soil moisture content. This analysis would support to develop Wireless Sensor Network (WSN) for continuous monitoring of slope to predict rainfall induced landslide before it occurs.

Keyword: - *Rainfall-induced landslide, scale down slope model, pore pressure sensor, movement sensor*

1. INTRODUCTION

Rainfall triggered landslide disaster is one of the natural hazards makes loss of human life and properties. it occurs in short span of time because of prolonged rainfall. Variation in Groundwater table is plays vital role to slope failures, particularly in areas with mountainous and extreme rainfalls. Penetration of rain water on the leaky soil slope surface, it activates the slope let-down[1]. Slope failures could occur in various slope conditions of the terrain. Slope failure of soil can be caused by numerous various reasons, such as rainfall triggering, intrusion and/or soil erosion by surface water overflow water, dam or reservoir break and slope instability. Most of the landslides occur due to soil slope failure, the first case shallow landslides Within all these landslide or slope failure possibilities, the first two typical process are most common. In the first case, inundation rainfall triggers directly induced shallow landslides which may transform into debris flows. There is the need of a real time system to continuously monitor the hazard zone and predict the triggering time of the slope failure. This could help to make Early warring of the disaster to prevents loss of human lives and properties [2].

Pore pressure sensor was placed subsurface flow along the soil bedrock interface, also it was used to predict rainfall induced shallow slope failures and debris flow initiation[3]. WSN is the promising technology for real time monitoring and early waring the landslide disaster but it requires the complete understanding of landslide triggering factors such as rainfall, soil pressure, slope movement etc., early study of slope behaviour due to changes in its conditioning factors is very important to develop efficient sensor network for the real time monitoring and this could be achieved by developing small scale slope model.

Nilgiri district of Tamil Nadu, India has hilly terrain with elevations ranging between 276m and 2633m, with an average elevation of 1441m and a standard deviation of 576m. heavy rainfall and deforestation in Nilgiri Mountain regions utilized for urban growth have a tendency to promote slope uncertainty leading to the generation of landslides which damages former fields, roads, properties and there is the need of hazard mitigation [4], [5]. .

In this research, the laboratory experiment was set up in the dimension of 7m*3m*1.5m. The model was fixed with the soil slope of 15° and 30° respectively. The landslide setup was filled with soil, the water was poured as an artificial rainfall over soil surface deployed the sensors in the LHZ area in the depth of 100cm. The signal analysis results indicated that there is a specific time period, a few seconds before failure, which, according to its frequency and energy content, can be defined as a landslide precursor activity

2. RELATED WORK

Landslides are triggered by several factors such as slope of soil, rainfall intensity, land use land cover, and the vibration around the soil slopes. Precise monitoring is important that can acquire and distribute the remote sensing data of hill slope let-down in real-time exactly [6]. The development of a laboratory-based scale-down model for rainfall-triggered slope failures needs a complete understanding of the landslide initiation process. Most of the researchers recommended that the incidences of slope failures that are triggered by additional pore pressure of soil[7].Also, laboratory test results of several researchers discovered that the residual pore-water pressures of the soil during rainfall directly led to landslides of the upstream slope [8].

The pore pressure of groundwater can be measured using Piezometers within a geological structure, so as to give an indication of the amount of stress and strain accumulated. Vibrating wire, pneumatic and standpipe piezometers are the most commonly used borehole piezometers. The list of authors was adopted sensors for landslide monitoring is explained in Table-1.

Table- 1: Sensors adopted by previous researchers for slope failure monitor

Sl. No	**Sensor**	**purpose**	**Reference**
1	Piezometer	Capable to measure pore pressure of water present in soil subsurface	[8], [10], [19], [11]–[18]
2	Movement sensor	It is useful to monitor the terrain displacement	[2], [4], [10], [15]–[17], [20], [21]
3	Laser	the soil movement by Laser beams	[6], [11]
4	Crack Meter	Monitor the crack development	[12], [14], [15], [20], [22]–[25]
5	Tiltmeter	soil slope can be monitor	[8], [15], [18], [20], [25], [26]
6	Accelerometer	Measure vibration	[2], [4], [16], [27]
7	Camera	Soil movement -monitor by Camera	[8], [15]

3. SENSORS USED FOR LANDSLIDE FORECASTING

Piezometer (Model IG 1401) comprises a solid tubular container having the Vibrating cable connected sensor. One end of the tubular container has a high velocity air entry filter or low velocity air entry filter. The other end tubular container has the sealed wire entry as shown in Figure 1. The description of the piezometer has been exemplified in Table-2.

Fig -1: Piezometer

Table -2: Piezometer specifications

STANDARD PIEZOMETER SPECIFICATION MODEL SIS-2001	
Standard Ranges:	3,5,7,10 kg/cm2, 300,500, 700 kPa
Over Range	2 × rated pressure
Resolution	0.10% F.S.
Accuracy	± 0.25% F.S
Linearity	<0.5% F.S.
Temperature Range:	−20°C to +70°C
Length × Diameter:	150 × 20 mm

A Displacement Sensor is a device that measures the distance between the sensor and an object by detecting the amount of displacement through a variety of elements and converting it into a distance specification details is shown Figure 2 and the description of the displacement sensor has been exemplified in Table-3.

Fig -2: Displacement Sensor

Table-3: Displacement Sensor Specification

Sl. no	Type	references
1	Variants	Bore Hole Extensometer, Joint meter,
2	Range	50mm(±25mm), 100mm(±50mm) Other ranges available on request.
3	Dimension	16 m Dia

4. LABORATORY SETUP

The soil was collected based urban area of conoor, nilgiri district, based on the landuse landcover map[5], [28], [29]. A steel container (box) is filled with soil as illustrated in Figure.1. The dimension of the container was the length of 152.5cm, the width of 91.5cm and a depth of 122cm. The soil was collected which has been identified by LHZ map. The soil slope was exposed to artificial rainwater with constant flow, which results in soil movement (i.e. land sliding). The depth of the container is 36 inches. A soil slope with an inclination of 45° and 35° has been built.
A test box was made-up with steel sheets and filled with soil to bring reality model of landslide artificial slope. The two type of sensors connected with data logger was used in the experiment, namely: (1) displacement sensor (for movement sensor), (2) Piezometer were installed in the test box). These sensors were mounted in the soil of test box. The sensor's output was connected with a Data recorder (Single Channel Data logger. All the sensor nodes were set to zero reading by appropriately keeping their initial location and converting the initial sensor value as zero. Both the sensors with cables were fixed with respect to slope failure and according to difference of related parameters.

The piezometer sensor was vertically placed at the middle of the soil slope and the vertical axis of the movement sensor was positioned in the path of the debris flow as shown in Figure 3. The sensors, Piezometer and displacement sensor (for movement sensor, are installed on the peak point of the soil and at the bottom of the slope surface in the box container. Every sensor hosts the embedded agents. A scale-down model was absorbed to realise landslide mechanism and its influencing factors[30], [31]. Laboratory experiments with sensors were accompanied underneath imitation circumstances of the soil to standardise the sensors instruments used for debris flow monitoring.

Water supplied by artificial rainfall pouring device to simulate actual rainstorms. The process starts with the artificial rainfall with a discharge of 0.00778 Litre/s [2]. The movement results in changes in the slope movement data, which were identified by the sensor and data collection unit. The depth of the soil practiced a moistening failure throughout the water inundation capacity leading to a soil movement downward direction of the slope, as shown in Fig. 3b, while the debris flow movement was stored as a digital data with respect to time by a data logger unit. The triggering point of the debris flow or landslide for particular soil slope was recorded by a data logger in Fig. 3c. After 72 minutes, the water initiated to escape from the bottom of landslide laboratory model, conveying small soil particles as shown in Fig. 4c; The slope failure could be identified; the entire slope suddenly moved within a second with a speed of over 10cm/s, as the vertical displacement of the slope is shown in the Fig. 3d, A complete water inundation of the saturated soil mass was prompted after the collapse of the slope failure, the data was observed and stored in data logger unit.

Fig-3. a–d Beginning procedure of slope failure movement for the laboratory test with 0% initial water content. The sensor direction is the position for the monitoring of parallel displacement.

5. RESULT AND DISCUSSION

The test was conducted by using soil type of Nilgiri district. This paper proposes the laboratory experimental method for measurement of change in moisture content to identify the threshold time of slope failure triggering condition using different types of sensors. Due to increase of water content in soil, the toe portion of the soil was fully saturated with moisture. The saturated soil of a shallow soil debris flow is initiated by motionless soil liquefaction i.e. artificial poured water over soil surface i.e. rainfall. However, the indication of static liquefaction in this test is very clear, since no sudden increase of pore pressure occurred at the soil movement. Two different type of equivalent method led to the soil instability and debris flow of the toe of the soil slope and a loss of cohesive properties of soil due to suction decrease. Slope debris flow was wash-down the soil due to leakage and increase the porosity of the soil and trigger it much more unstable that lead to collapse of the entire slope. Changes in debris soil slope in terms soil movement and pore pressure due to artificial rainfall was studied with the help of sensor nodes. The slope debris soil movement data, artificial rainwater pour data and pore water pressure data were illurstated in the Fig.4. The soil stability strength decreased by increasing the water inundation level, concluded this it is obvious that the pore water pressure is progressively increased in the linear manner with the increases in the artificial rainfall. During of landslide triggering processes, the volatility of the soil slope plays an significant role throughout monitoring process. This soil volatility was not produced by the creation of high positive pore pressures but by internal water seepage erosion and a reduction in strength. The grading and initial density of the soil sample is equal to that of the flume test soil suction through wetting causing a decline in the strength of the soil. This has also been shown by the Soil pore pressure, movement Curve given in Fig. 4. Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work

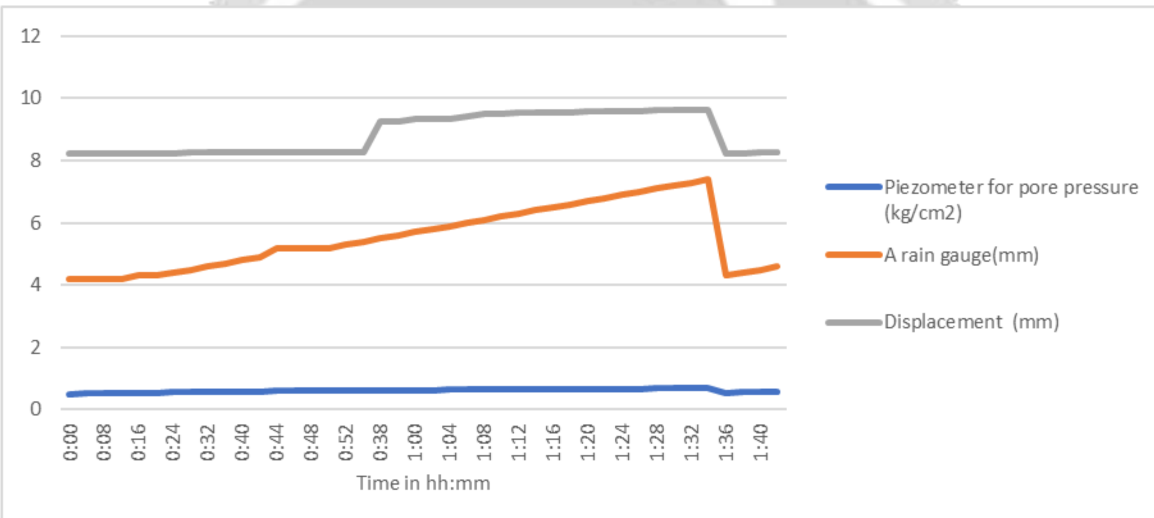

Fig- 4. Time series data of horizontal displacement. To reveal details of behaviour during the 2-s failure period, the time axis is expanded also Slope movement, rainfall and pore water pressure data.

6. CONCLUSIONS

The test results of the laboratory scale down model were exposed that the rainwater infiltration capacity of coarsely packed soil strengthens the beginning and movement of debris flows. The abrupt slope failure of the coarsely packed subsoil layer initiating to a quick debris flow can be triggered by pouring artificial rainfall, triggering soil destruction within this subsoil layer. A similar kind of slope failure may occur during a heavy rainfall of Nilgiri district on landslide prone zone, and especially in urban area with loose soil. The excess rainwater pouring over comparatively dry soils with a high initial intrusion capacity will infiltrate. Two sensors were adopted to monitor the slope condition from this study we could classify the slope changes into three different thresholding level as low, medium and high. By using these data, the landslide triggering threshold levels were fixed into low for initial stages of changes, medium for moderate level of changes and high for maximum level of changes. The experiment is used to determine the instigation process of rainfall triggered landslide. The study showed that, the slope failures were triggered by gradual increase of the soil moisture content. This analysis would support to develop Wireless Sensor Network (WSN) for continuous monitoring of slope to predict rainfall induced landslide before it occurs. Authors recommended to conduct similar kind of test for several of soil type.

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