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Physical Modeling of Rainfall and Induced Landslide

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ABSTRACT- Rainfall and Snowfall induced landslides are one of the most common and damaging natural hazards on Jammu and Kashmir region that not only degrade land in hilly areas but additionally causing deaths and destruction on natural slopes and cause tremendous losses. These slope failures usually influence by rain intensities which vary with time that is extremely common in Jammu Kashmir highway. The intensity and time duration of rainfall over a catchment area decide the property and magnitude of the landslide occurred by the rainfall. Deep slope failure mostly occurred by long duration rain over a catchment area, whereas shallow failure is related to very short-term rain with high intensity. The study shows that slope geometry and rainfall intensity are the major affecting parameter which generally cause landslide by the action of depletion of water through the soil pores which leads to the development of lubrication effects between soil particles and hence reduction in shear strength parameter of soil particles. It also indicates that permeability and density of the soil also playing an important role in slope failure mechanism.

KEYWORDS- Rainfall, Snowfall, Landslide, Destruction, Failure, Catchment area.

I. INTRODUCTION

Landslide are part of a general erosion or surficial process known as mass wasting which is simply the downslope movement of surface of material due to gravity.
Thus the rate of landslide can be increased due to the action of rain water and melting of snow which is the main study part of this report The geo mechanical modelling of failure and post failure stages of rainfall induced shallow landslides represents a fundamental issue to the proper assessment of failure conditions and recognises the potential for long travel distances of the failed soil masses[1]. The main cause of the landslides is due to the processes like rainfall erosion and earthquakes and also by human actions like construction and agriculture. The effect of the landslide includes loss of life, damage of infrastructure, damage to land and also loss of natural resources. The different infrastructural damage occurred by the different landslides [2].

II. OBJECTIVES

- To study the slope failure mechanism of Sadhna slope in Kupwara Tanghdar Highway by physical modelling.
- Design a rainfall generator to reduce the flow of water for generating the desired rainfall intensity with known discharge to introduce desired rainfall depth on slope.
- To prepare a physical model of slope in laboratory and study its behaviour underrainfall.

III. LITERATURE REVIEW

Mostly failures of the slopes occurs frequently all over the world during the rainfall and snowfall. It is mostly caused by disturbances in the natural stability of a slope. Mudslides develop when water rapidly accumulates in the ground and results in a surge of water saturated rock, earth, and debris
Abhirup Dikshit et al. has done a research on rainfall induced landslide studies in Indian Himalayan region. According to the research done above landslides are one of the most recurring and devastating natural disasters and have affected several hilly region across the world. Indian Himalayan region is no exception to landslide affecting key economic sectors such as agriculture and transportation and also leads to loss of lives. According to the world landslide dataset, most of the landslides in this region are rainfall triggered [3].
The region is prone to 15% of the global rainfall triggered landslides. They are the most frequent naturally occurring hazards that affect people and their livelihood worldwide. Its frequency in the Himalayan context is large when compared with global events. This review paper is attempted to understand the assess, and mitigate landslide scenarios in the Indian Himalayan region.
Kumar et al. has done his research in 2017 in which he described rainfall triggered landslide in 2009 at Marappalam area of Nilgiris district, Tamil Nadu, India. In this study some field work is done one of them is Topographical survey where we can check the geometry of Marappalam slope which includes slope angle, elevation, run-out distance, and breadth of the landslide. To find the properties of the soil and rock Borehole and geophysical investigations were done [4]. The nalgris district in western ghats of india is one of the severe to high landslide hazard prone areas of India. Data on landslides from1824 to 2014 were collected and a spatial database on landslides was created [5].
The tests which were done in the laboratory on soil and rock samples. These different laboratory tests which were done on soil like specific wet sieve analysis, gravity test mechanical sieve analysis, hydrometer analysis; Atterberg limits tests liquid limit and plastic limit and hydraulic conductivity test. The types of tests which were done like uniaxial compressive strength test, tensile strength test and point load index strength test were done on rock samples.. The x-ray diffraction analysis were used to identify the mineral composition of soil and rocks.

IV. MATERIALS AND METHODOLOGY

In this chapter the materials and methodologies which is used for research to ensure the achieve the main objectives of this study. The particular region with natural slope failure which is effected by rainfall and snowfall is used for this study. Rainfall and snowfall data from nearest station, to the study areas is taken into consideration in the analysis. Different Laboratory tests are performed by which we can found the different properties of the soil.

Soil stability can be major problem during the construction of surface facilities. Cutting into existing ground disturbs the mechanics of the surrounding area, which can result in landslides and rock fall. This practical reference gives us the comprehensive information for the slope stability [6]. Flow like landslides triggered by rainfall are very prominent in Nepal, Shikoku and japan. In July 2002 many landslides occurred in southern hills because of rainfall. About 18 people died who lived at the foot of the hill. Much damage occurred to roads and housed because of landslides and debris flow in the small streams [7].

As the location of the study is NH-701 which connects Tanghdar to district Kupwara, India. Sadhna area in Kupwara district is most susceptible area for landslide. The landslide on the NH-701 is caused by rainfall and snowfall and is as shown as Figure 1.

Figure 1: The NH – 701 Road

A. Description of Slope

By these landslides loss of property and life occurs. Also people suffer a lot while travelling during emergencies. Sadhna top is located at an altitude of 11000 feet above sea level and 80 km long kupwara tanghdar road receives more than 12 to 15 feet of snow every year in winter which cuts off the road connection of karnah from district headquarter of kupwara and other parts of valley. A picture of landslide by rainfall and snowfall is shown in Figure 2.

Figure 2: Landslide on Sadhna road

Around 6 kilometer stretch of this road around sadhna top is avalanche prone and very dangerous for commuting during winters as well as in summers. The frequent accidents, landslides, snow avalanches and rolling stones. Most of the persons were died on sandna top due to accidents which is caused by the snow avalanches during the past 8 years. Thus the dangerous kupwara tanghdar road gets blocked due to thick blanket of snow on sadna pass.

B. Materials and Methods

Sieve analysis of the soil is shown in Table 1.

Table 1: Sieve analysis of DTU soil

Sieve size , mm	**Retained weight, gm**	**% Weight Retained**	**Cumulative % retain**	**% Finer**
4.75	29.9	5.7	5.89	94.01
2.46	59.92	11.8	17.9	82.01
1.18	85.9	17.0	34.7	66
0.7	39.01	6.9	41.88	58.01
0.5	56.9	10.7	52.8	45.6
0.16	77.9	16.1	70.3	31.1
0.075	83.9	16.4	85.91	14.2
Less than 0.75	68.8	14.2	99.98	0

The particle size distribution curve for the soil is shown in figure 3.

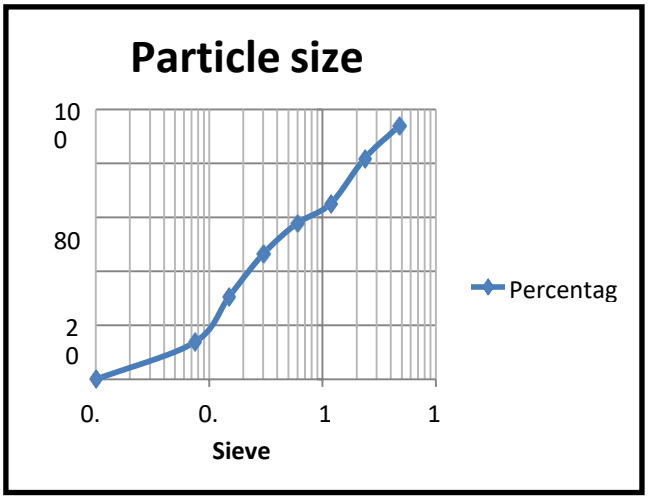

Figure 3: Particle size distribution curve for the soil

From the above results, we can conclude that soil available in the laboratory includes 78% sand and 22% silt and clay, thus we can say the soil is sandy in nature. Thus main part of area is silty from 20.01 to 38.22, sand 61.10% and clay 1.4 to 5.91%. Thus we can say clay and slit nearly 40% and sand as 60%. For the resemblance condition 40% clay and 10% sand is mixed with DTU soil. Also stones as well as boulders existed also there in the study area in debris material.

By material similarity, the similar ratio of cohesion, inner friction angle, modulus of Elasticity, and Poisson's ratio are taken similar to prototype, as $C_c = C_\varphi = C_E = C_\mu = 1$. Thus the figures of different materials like clay, stone and boulders are shown in Figure 4 and Figure 5.

Figure 4: Clay

Figure 5: Stone and Boulders

C. Laboratory Investigation

Thus, the different laboratory investigation is done to determine the properties of soil for stability of the slope.

D. Water Content

Firstly, the weight of empty container is calculated and noted as M1 and then sample of soil is placed in the container and again weighted which is noted as M2. The container is kept in oven at suitable temperature for some time for drying process. Thus the inorganic soil is kept between the temperature level of 106°C to 111°C and is dried up to 24 hours. Thus this dry soil is weighted and is noted as M3.

E. Particle Size Distribution

The engineering properties of soils especially coarse grained soil depends upon the shape of particles. It is more difficult to measure the shape than the size, the shape of the particles does not get the required attention. The particle size distribution of the granular materials or particles dispersed in fluid is a list of values. . By the particle size analysis the proportion of particles sizes which are in dry sample is finded.

F. Triaxial Test

A triaxial test is a common method to measure the mechanical properties of many solids like rock and soil, and other granular materials. Triaxial test is used to determine the shear strength of discontinuity. The triaxial test is executed on a cylindrical soil sample which has a length to diameter ratio of about 2.

G. Unit Weight

For all types of soil with all methods of compaction, increasing the amounts of compaction, that is, the energy applied per unit weight of soil, results in an increase in the maximum dry unit weight and a corresponding decrease in the optimum moisture content

The different types are discussed as:

- Standard Compaction Test
- Modified Compaction Test

H. Permeability of Soil:

Permeability of the soil is also the ability of the soil which permit the flow of the fluid through its void. Permeability of fine grained soil is less than the Permeability of coarse grained soil. The permeability range for different soil is shown in Table 2

Table 2: Permeability range for different soil

Types of soil	Permeability (K)
Gravel	> 1
Sand	$1 - 10^{-3}$
Silt	$10^{-3} - 10^{-7}$
Clay	$< 10^{-7}$

I. Falling Head Method

The falling head test is common laboratory test which is used to determine the permeability of a fine grained soils with intermediate and less permeability such as slits and clays. The soil sample is kept in a vertical cylinder of a cross sectional area. In the falling head permeability test the water runs through a short sample of soil which is connected to a stand pipe which helps in measuring the volume of water passing in it. Thus the diameter of the standpipe depends on the permeability of the soil tested. The falling head test is shown in Figure 6.

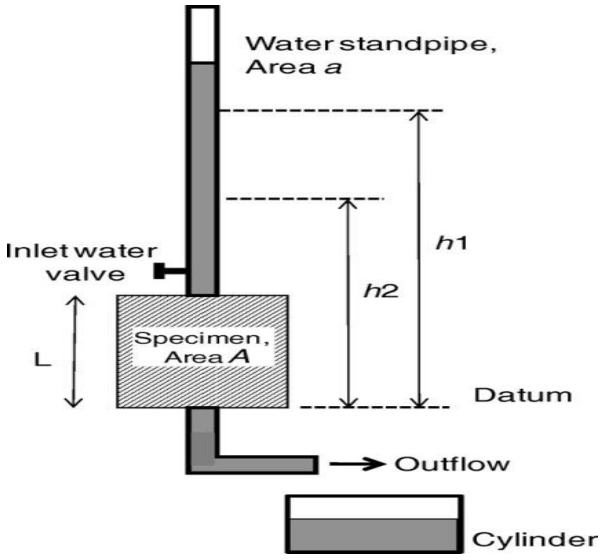

Figure 6: Falling head test

J. Rainfall Generator

To understand the characteristics of the rainfall an artificial generator which provides artificial rainfall is to be designed. Rainfall generator consists of water supply tank, submersible pump, pressure regulating valve which controls the pressure of pump, pressure meter which measures the water flow pressure and also a nozzle which generates a raindrop. To simulate the different rainfall intensity using control valve for that. The diagram is shown in Figure 7.

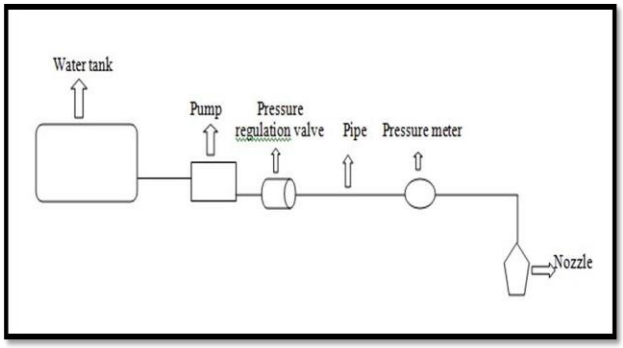

Figure 7: Schematic diagram

V. RESULTS AND DISCUSSION

A. Laboratory Results

Thus to find the properties of the soil for the analysis of the soil stability the laboratory investigation has been done. By performing different tests the different physical and engineering properties of soil are obtained. The results of the different tests which were performed are discussed in the Table 3 and Table 4.

Table 3: Soil properties

	Moisture content 'w'	bulk Density in gm/cc
Soil	5.92 %	1.75
Clay	6.32 %	1.43
Sand	9.04 %	1.5

Table 4: Properties of Experimental Soil

Bulk unit weight at 5% water content (KN/m^3)	13.94
Dry unit weight (KN/m^3)	13.4
Saturated unit Weight (KN/m^3)	17.2
Specific gravity	2.65
Coefficient of permeability(m/hr)	0.0025
Cohesion (kg/cm^2)	9.6
Angle of internal friction (φ°)	31

B. Test Result:

The slope with 10 mm rainfall depth is shown below:

At 10mm rainfall depth- Thus the rainfall percolation occurs quickly at 10mm rainfall depth and the result is shown in Figure 8.

Figure 8: Outcome at 10 mm depth

- The test is conducted further at 20mm, 30mm, 40mm , 50mm , 60mm , 70 mm , and 80mm and the result is shown in Figure 9.

Figure 9: Outcome at 80 mm depth

VI. DISCUSSION

From the above study at 80 mm rainfall the slice failure occurred as the erosion failure starts at 30mm rainfall depth As per the above results the probable initiation mechanism is developed.

- When the high rainfall occurs, the rainwater enters into the soil layer and creates water level which enlarges the pore water pressure. Thus the lower layer of soil gets fully saturated
- The rainfall intensity is more than the hydraulic conductivity (k) of the soil. Erosion occurs due to the flow of intensive rainfall which converts into run off water at 30mm.
- At 40mm rainfall depth, more erosion occurs. Thus due to the intensive rainfall which leads the erosion and sliding failure takes place. Due to the increase in pore-water pressure which surpasses the critical value, which leads a shallow landslide occurred at 80mm rainfall depth. The factor of safety is less FS=0.66.

VII. CONCLUSION

This study provides the scientific and theoretical information about monitoring, prevention, early warning system and to control the rainfall induced landslide. Thus, in my study a physical model test on rainfall-induced landslides has been done. A self-made artificial rainfall system. In my study, the soil materials are simulated by martial similarity theory from study site which is situated in Sadhna Road of kupwara as this site has continuous slope failure in history.

In my study which show that the methods used are effective method to monitor the infiltration process of pore water. Sliding mechanism of slope and factors inducing slope failure has been studied in this thesis. Start-up conditions of slope failure are as follows:

- The intensity of rainfall is about 295 mm/hr. and rainfall

of 10mm depth is introduced each time;

- Surface erosion is more likely to occur initially than the internal landslide,

The main factor for causing shallow landslides on the sadna slope is the high rainfall

VIII. FUTURE SCOPE

Thus, in this study there are also some limits due to the size of landslide prototype is very high as the size of the laboratory model is limited in terms of feasibility of the tests. In this research all these limitations are supposed to be improved. The results show rainfall-induced landslides mechanism, and still need to be verified in the engineering practice. Thus this study mainly provides a scientific and theoretical information for early warning, monitoring, prevention, and control of the rainfall-induced landslide to prevent loss of health, wealth and life.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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