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Analysis of Climate Changes and Slope Instability Factors Triggered by Natural Rainfall

Associate Prof. Dr C P Ramesh
Department of Civil,
Jain University,
Ramanagar, India
cp.ramesh@jainuniversity.ac.in

Assistant Prof. B S Girish
Department of Civil,
RV College of Architecture,
Bengaluru, India
girishbs.rvca@rvei.edu.in

Abstract- Rainfall-triggered slope instability is generic in tropical regional countries, i.e everywhere soil on the hillside is usually unsaturated, having greater resistance than the saturated state due to the suction of the matrix. This paper aims to check the pore pressure (PWP), slant rain infiltration and equivalent consequence of slope stability in various sections of India. By raining on the sloped surface of the region, SEEP/W parameter is considered, where, boundary condition flux and transient seepage analysis are to be performed to check slope stability. For the Slope stability analysis, we checked with various slopes and extreme rain intensity for a period 2015 – 2025, where the rain analysis is carried out with a week date and time. From the analysis, the paper is concluded that, due to change in climatic issues, slopes in the regions are quite stable but rain fall prediction is failed under weather forecasting, so the factor of safety is 1.0013 in the period of the range 2015-2050, similarly the value of FOS is 0.9935 and 0.9989 is respectively, for the period 2051-2075 and 2076-2100.

Keywords- Climate, FOS, SEEP, LEM, FEM, FDM.

I. INTRODUCTION

Land slides or slope failure is a normal process in all over the world; it endangers human lives and causes property damage. Slope subsidence caused by various factors, together with slope steepening, earthquakes, surface erosion, precipitation infiltration, deforestation, and so on. Precipitation infiltration is the most prevalent cause of landslides, especially in tropical areas, among all of these variables.

This is due to the fact that rainfall in tropical locations lasts longer, and the bedrock soil cover in hilly places is frequently residual soil with high suction value above the water table. In general, impact of rainfall caused towards to landslide it is a common hazard in hill station area. According to previous estimates, 15 percent of India's landmass is vulnerable to landslides of up to 0.49 million square kilometers [1].

Deep landslides and shallow landslides are two types of slope settlements. Deep landslides entail movement of the surface mantle and bedrock at higher depths, whereas shallow landslides only move a few meters, because of Deoloteen landslides are vulnerable to the extremes of the hydrological cycle and extended drought, which hindered groundwater filling, most landslides are superficial in nature.

Landslides in general are superficial in nature because Deoloteen landslides are sensitive to the extremes of the hydraulic cycle and prolonged drought, which prevented groundwater refill and thus caused the cessation of this type. Because of the increase in temperature over time, rain models will no longer be the same and will become more intense and less frequent.

1. Objectives of the paper:

- Analysis of transient seepages in the slope region, at rain infiltration;
- Examine the slope stability corresponding to transient infiltrations.
- Verify the impact of climatic changes on slope stability, due to global warming condition.

II. LITERATURE REVIEW

For slope stability analysis, many researchers are used variety of rain fall insinuation models as well as boundary equilibrium analyses, so that researchers have been referred and utilized the study and impact of precipitation infiltration on slope stability [2].

Precipitation intensity and soil parameters are the key elements impacting slope stability, according to previous studies, while pure slope mathematics and the initial water table are secondary considerations [5].

Researchers used many approaches for Numerical simulations employing LEM (limited equilibrium technique), FEM (finite component method), FDM (finite distinction method, BEM (boundary element method), NN (Neural Networks), and other methodologies were used to investigate the failure process of slopes owing to rain water infiltration. Because stress distributions and slope displacement are addressed in these techniques, which are not accelerated by LEM, FEM and FDM provide the most accurate findings [6].

With respect to all techniques a LEM is one of the most commonly practiced techniques for the analysis of slope stability for feasibility examination. Slope stability was studied using TRIGRS (transient precipitation infiltration and grid-based regional slope stability) and Geostudio for SEEP/W and SLOPE/W programs.

The Geostudio 2018 R2 SEEP/W and SLOPE/W techniques is meant for the analysis of water flowing and slope stability purposes, where momentary precipitation insinuation analysis issues are to be considered on geometry usages [7].

Slope failures must be pushed to be discovered in advance to limit the harmful repercussions. Many scholars looked into the issue of slope instability, but most of them used a stationary approach to obtain rainfall data. Rainfall extremes alter throughout time as a result of the ever-changing environment, resulting in a lot of heavy rainfall resting for an extended period, necessitating analysis-supported nonstationary techniques [8].

Above research studies are so important because it might be very useful to analyze potentially unstable slopes, so it prone to failure owing to changes in surface flux rates over time, potentially lowering the danger of loss of life and property damage.

On a sociological and economic level, this will benefit the United States of America. As a result, a constantly changing statistics of extremes are considered during this study by analyzing the soundness of slopes under current and future circumstances by considering 95 score precipitation intensity and most rainfall intensity for three time periods: 2015–2050, 2051–2075, and 2076–2100, and these data are extracted from the CMIP5 climate model, which is then analyzed for flowing and stability of slopes by the SEEP/W and SLOPE/W programs.

III. METHODOLOGY

In our approach we use various stages to study analysis, i.e.

- Actual raining dataset and extraction
- Rainfall analysis,
- Seepage analysis,
- Stability analysis

In this research paper, we consider shifting statistics of rainfall extremes on analysis of slope stability for present and future state rainfall by evaluating rainfall patterns for three time periods: 2015–2050, 2051– 2075, and 2076–2100. The slopes are tested at maximum rainfall intensity (to ensure slope stability during extreme rainfall occurrences) and at 95 % rainfall intensity, where (i =mean rainfall intensity + 2 x standard deviation)

1. Seepage Analysis:
SEEP/W program Geostudio software is used for unsaturated or saturated transient seepage analysis, where we analyze the data for five days with 24Hr rainfall duration as a present initial condition for the analysis to represent the location and ground water table, so that seepage analysis will perform in more realistic pattern.

The rainfall intensity value is an ensemble mean, and futures with no climate action are chosen for the analysis. The precipitation of rainfall will evaluate and promote a set of simulation model to assess the rainfall statistics for past, present and future climate change projection on rainfall intensity. Due to precipitation penetration, the Himalayas, Western Ghats, Nilgiris, and the North eastern regions in Asian countries are most susceptible to landslides bearing on mind overall slope geometry, we used Tamilnadu state, Niligiries, is one of the research locations, because it is one of the highest hill station regions, that’s why we have to choose, for our research investigation in this paper:

Around the Asian countries, where Nilgiri is one of the beautiful hill stations with in the Tamilnadu state, India. Nilgiris coordinates with the location between 10 - 38 and 11- 49 North Latitude and between 76.0 and 77.15 East Longitude. The district covers an area of 2452.50 sq. km. It has a subtropical climate, which results in a lot of rain in this area, and landslides caused by the excessive rain have disrupted people's life. The soil on Nilgiries hill slopes is predominantly low sponginess clay (CL), and this study takes into account two completely distinct slope angles (Fig. 3) into thought with soil hydraulic and strength properties, shown in table 1.

The SWCC and HCF of the soil have an impact on precipitation infiltration inside the soil mass, as demonstrated in Fig. 2 for Nilriri soil. In the past, tectonic processes, varied earth science circumstances, and structural distortions on the main boundary thrust (MBT) caused tremendous destruction in the Lesser Himalayan region due to displacement of soil/rock slopes and LED.

Certain soil/rock varieties that absorb a lot of moisture have been discovered to be very easy to distort. Rock types such as quartzite, limestone, slates, loose sandstone, gneiss, schist, phyllite, and others are worn up to a certain depth in Uttarakhand's mountainous terrain, resulting in sandy soils, sandy soil, and silt loam.

A stretch of the Western Ghats has been impacted by rain-induced landslides in Tamilnadu's, Nilgiri district. It is located in the intersection of the states of Karnataka, Kerala, and Tamil Nadu (Fig. 1). The heights of this mountainous district range from 1000 m to 2633 m above MSL (Mean Ocean Level).

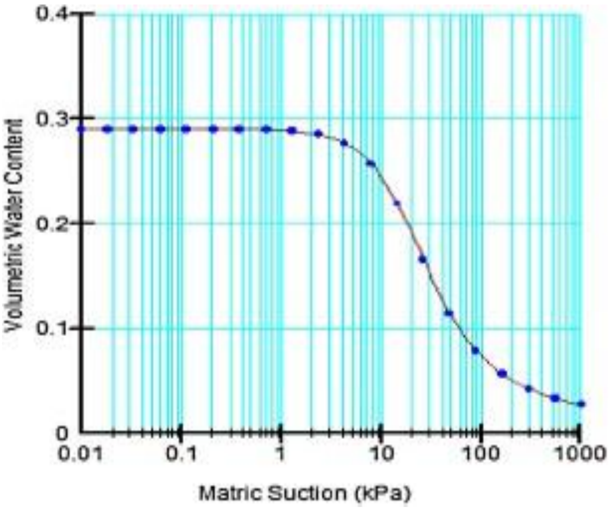
This district's topography is undulated, with slope angles ranging from 150 to 60 degrees. These bedrocks were generally underlain by burnt sienna and xanthous soil (residual soils generated by strong weathering) with thicknesses varying from one to thirty meters.

This study analyses a sandy silt slope with hydraulic (SWCC and HCF displayed in Fig. 2) and strength properties presented in Table three. A basic slope profile of 20 m height and 35 slope angle (Fig. 3) is utilized to investigate ooze caused by precipitation and its impact on slope stability.

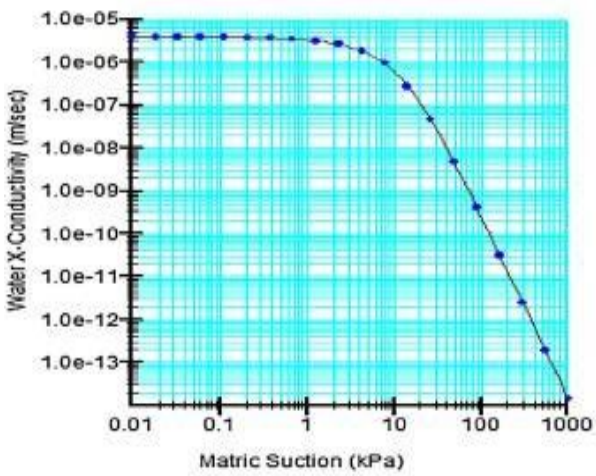
(a)

(b)

Fig 1. Nilgiri, Tamilnadu's geographical location (Source: Google Maps).



(a)



(b)

Fig 2. SWCC and HCF for Nilgiri hills sandy silt soil (Tamilnadu).

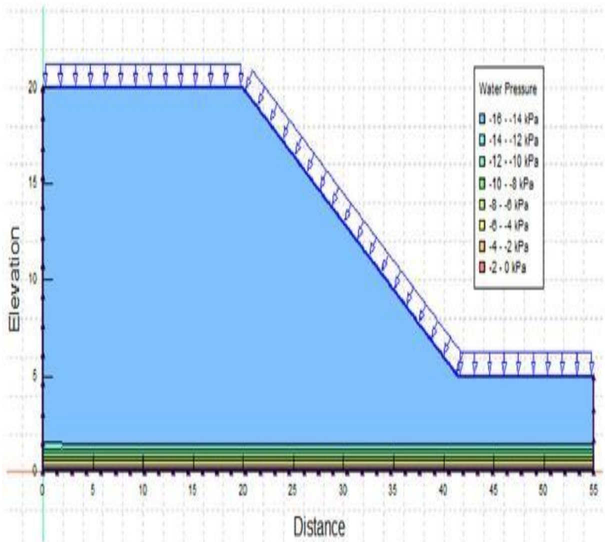


Fig 3. General slope profile of Nilgiries, Tamilnadu region.

The transient SEEP/W program is based on Darcy's law which is represented as follows:

q = ki ---------------- (1)

Where
q - is specific discharge,
i - refers to hydraulic gradient and k - is hydraulic conductivity of soil.

The general governing differential equation for two-dimensional seepage is shown in equation (2), it holds both saturated and unsaturated seepage settings, with the exception that hydraulic conductivity in unsaturated conditions varies with soil water content.

$$\frac{\partial}{\partial x}\left(k_x\frac{\partial H}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_y\frac{\partial H}{\partial y}\right)+Q=\frac{\partial \theta}{\partial t} \text{ -------------- (2)}$$

Where,
H - Denotes total head,
kx and ky - denote hydraulic conductivity in the x and y directions,
Q - Denotes applied boundary flux,
h - Denotes volumetric water content, t - denotes time.

In transitory situations, the pore air pressure is assumed to be constant at atmospheric pressure. As a result, the change in volumetric water content is governed by pore water pressure (UW). As a result, the SEEP/W finite element computer program's equation is reduced and input parameters represented in table 1.

Table 1. Nilgiri Hills Soil SEEP/W and SLOPE/W Program Input Parameters.

Parameters	Value
weight per unit	20.05 kN/m3
cohesion Internal friction angle	15 kPa 27
water content in saturated volumetric	0.29
water content in residual volumetric	0.029
Saturated hydraulic conductivity	3.924 9 10–6 m/
Soil classification	Sandy silt
Height of slope	20 m
Slope angle	35°

IV. EXPERIMENTAL DETAILS

The results are expressed as a change in the water pressure distribution of soil pores over time, a change in FOS over time, and relative changes in FOS compared to the safety factor for the periods 2051- 2075 and 2076-2100. Parametric research is done based on these data to explain the relationship between pore pressure fluctuations and the related variation in safety factor with slope parameters, soil properties, and rainfall intensity, with minimum FOS value of Nilgiris shown in table 1.

1. Result of Rainfall Features:
rainfall intensity is increased over a time (considering the 95 % rainfall data), and the slope become unbalanced, so it reduces the FOS, in fact, we can expect 95 percentile rainfall intensity for the Nilgiri region, so water content in residual and saturated parameter will be is 8.68 mm/hr and 9.7 mm/hr respectively, with the corresponding factor of safety is 1.429502, 1.4864092.

As a result of these findings, the instability of slopes with rising rainfall patterns can be clearly recognized, and slopes should be analyzed using anticipated rainfall patterns rather than historical rainfall patterns, which can lead to an overestimation of FOS for future scenarios.

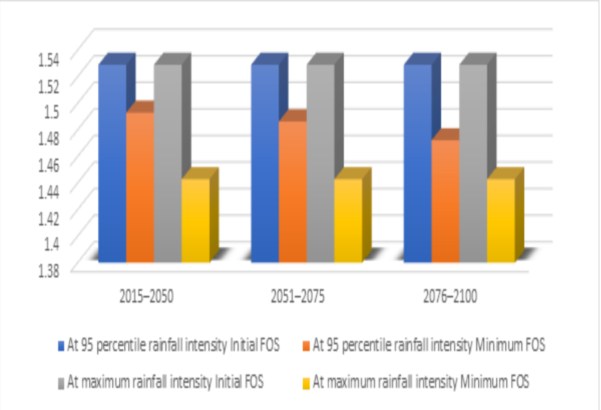


Fig 3. Minimum FOS value for Sandy silt soil in Nilgiris.

V. CONCLUSION

On drastic change in climate distortions, precipitations are become additional intense based on huge rainfall, thereby in nilgiris, where 95% of rainfall intensity, it will rise from 8.68 to 9.7 mm/h for the period 2015–2050 to 2051–2076, moreover we can predict, it then rises to 11.54 mm/h for the period 2076–2100, however intense rainfall outlines are uncertain in nature.

As rainfall intensity increases, the minimum worth of FOS decreases, owing to a reduced in admission suction, it could lead to failure in slope region, based on the values drawn, in nilgiris, the initial worth of FOS 1.529 decreases to 1.492, 1.486 and 1.472 in the period of 2015-2050, 2051–2075, and 2076–2100, respectively.

From the above result we concluded that, as intensity of rainfall increases, while minimum FOS decreases, so reduction in admission suction, which could lead to slope failure in the future.

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