Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 07, July-2021

Review Paper on Numerical Evaluation of Risk Assessment and Mitigation of Lanslides in Kerala

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***Abstract*— The unprecedented flood situation in Kerala during the period 2018-2019, was a result of unusually high amount of rainfall as well as the heavy discharge from dams. Massive landslides in several hilly areas were also triggered by torrential rain leading to deaths and severe destruction of property. In order to minimize the degree of instability in slopes, various slope stabilization methods should be adopted by analyzing the slopes using appropriate methods. This paper gives a brief review on the causes of landslides occurred in Kerala. This paper presents a brief survey of analysis of slopes and provides a relative comparison of different slope stabilization methods adopted so far.**

Keywords—Slope stabilitry, FEM, Numerical study, Landslides.

I. INTRODUCTION

Landslides are the down slope movement of masses of rock, debris and soil under the influence of gravity. Landslides can be caused by one or more combination of many factors. Some of the major triggering factors responsible for landslides are increased unit weight by soil wetting, intense rainfall, steepened slopes either by excavation or by erosion, earthquakes, added external loads, shock loads, freezing and thawing action, increased pore pressure, soil piping & anthropogenic activities. These landslides not only cause damage to properties but also cause loss of lives.

India has been vulnerable to all kinds of calamities for long time and every state is prone to disasters in varying degrees. Due to the geographical location, population, weather conditions and unsustainable land use, Kerala state is also prone to many natural and human induced disasters. Among them, landslides especially debris flow is most common. The major hazards were reported along the Western Ghats in Wayanad, Calicut, Idukki and Kottayam districts.

Slope stabilization can limit the amount of erosion and potential for landslides to a certain extend. It is a system of design measures used to minimize erosion from disturbed surfaces. Slope stability is defined as the process of calculating and assembling how much stress a particular slope can manage before falling. Some of the slope stabilization techniques are, planting natural vegetation, changing slope geometry, buttressing & shear keys, provision of proper drainage, reinforced slopes & retaining walls, soil nailing & micro piles.

Slope stability analysis can be performed by different means including Finite Element Methods and Limit Equilibrium Methods. The stability of slopes is essentially controlled by ratio between available shear strength and acting shear stress, which can be expressed in terms of Factor Of Safety. GeoStudio, Slope/W, Seep/W, Plaxis 2D & 3D, Slide, SV-Slope & GEO5 are some of the commonly used software for the analysis of slope.

The entire paper is divided as follows: Section I gives brief introduction, Section II gives survey of FEM analysis of slopes and the stabilization methods adopted and Section III conclusion followed by references.

II. RELATED WORKS

Hymavathi Jampani & Navya Bhupathi [1] analysed the slope stability of 3 different soil types using Limit Equilibrium Method. Based on the results they suggested appropriate slope stabilization techniques for selected soil types. In their study, initially they analyzed a slope of 30m height & inclination 50^0 using SLOPE/W of GEOSTUDIO. Geostudio is limit equilibrium method based software. Then they used three different soils which are GW (well graded gravel), CL-ML (low plasticity silty clay) & CH (high plasticity clay) in their analysis to select the best stabilization technique for a particular soil. At first, slope is analyzed without any external destabilizing forces. Later, it was analyzed by considering the water table surcharge effect and seismic loading. From that they arrived at a result that surcharge has very low effect in comparison with earthquake and water table effect. The effect of water table is more dominant in case of gravel followed by silty clay & is little in case of clay. It was also observed that decrease in the FOS is more in gravel when compared with clay & silty clay when slope is subjected to surcharge, water table & seismic load. Next part of their research comprised of analyzing the effect of factors depending on soil berming & soil nailing. At last from the obtained results, they concluded that soil nailing is

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 07, July-2021

the best stabilization technique for gravel & combination of both berming & soil nailing is more effective in clayey soil rather than using them alone.

Preji P & Biju Longhinos [2] analyzed the landslide susceptibility in Sastha valley of Periyar river basin, Idukki district, Kerala. They conducted a reconnaissance survey & collected undisturbed soil samples from the selected location. After the experimental investigations they inferred that the soil samples soil samples are showing high value of cohesion at field condition. Also the presence of water reduced the inter-particle forces between the particles which in turn reduced the cohesion between them. Later they conducted stability analysis using SLOPE/W & SEEP/W softwares in both steady & transient conditions. After that they validated the results from software using explicit equation. Also using GIS-TISSA model, they analyzed the Factor Of Safety of slopes in the study area. Finally they prepared landslide zonation map of the selected area from both field investigation & GIS-model. From the obtained results they concluded that the unsustainable land use in that area lead to landslides. Also in order to identify the locations vulnerable to landslide, the zonation map based on field investigation & GIS model can be used.

Sooraj et al. [3] highlighted the detailed information about the landslides occurred in the hilly areas of Kannur district in the year 2018 & 2019. Primarily they conducted a reconnaissance survey of three selected landslide locations. Further they conducted a site investigation, collection of soil samples & laboratory test. Based on the test results it was found that the soil mass over there was highly plastic clay with low shear strength. Then they modelled and analyzed the slopes by limit equilibrium method using SLIDE software. After the analysis of two selected locations, they found that the slope is stable under dry condition with a FOS of 1.352. But under heavy rainfall condition, the slope is unstable with a FOS of 1.03. For the third location also they got a FOS less than 1 under saturated condition. Finally they concluded that the instability occurred mainly due to the deforestation & modification of natural slope for developmental activities. As a remedial measure, they suggested that a sustainable method is to provide proper drainage & provide better awareness to people about the need for conservation of vegetation to avoid the soil erosion.

The unprecedented heavy monsoon rainfall from 4 August 2019 to 8 August 2019 led to several landslides along the northern slopes at Kavalappara in Malappuram district and Puthumala in Wayanad district of Kerala. *Sudheesh K.M et al* [4] provides the details regarding the causative factors of landslides along with suggestions on appropriate land use planning and deployment of real-time flood and landslide monitoring systems and building an adaptable community resilience model in high landslide prone areas. Preparatory work for this paper includes the procurement, followed by study of relevant map & geoscientific & meteorological data. The locations of landslides were marked on Survey of India Topographical sheets & studied their accessibility and contextual details. Through geoscientific methods, the causative factors & present suggestive remedial measures were found out. Major causative factors includes, structurally weakened bedrock, mismanaged water drainage, the extreme weather event, enhanced erosive power of flooded river, human interventions, reduction in cohesive strength, steep natural topography & the lack of early warning schemes for landslide. Suggested remedial measures regarding human settlement include the adoption of scientific land use practices & regular scrutiny of geoscientific and meteorological machine data essential for making informed decision. Also they suggested providing natural drainage for slope modification, improper terracing & leveling. Then construction of houses in hazardous zones should be strictly prohibited, Natural afforestation must be adopted for slope stabilization, Flood monitoring of rivers should be implemented in order to predict disaster and also a participatory approach and community resilience model for risk management need to be considered in landslide hazard zones.

Diya [5] included the study of a landslide occurred at Thodupuzha, Idukki district, Kerala. It paper includes the details of the laboratory and numerical analysis conducted in order to check stability of slopes with and without gabion walls. This project provides an insight of utilization of Gabions for slope stabilization. Initially they collected soil sample from the landslide location and experimental investigation was conducted to determine the soil parameters. Then the slope stability analysis was conducted by using FEM based software called GEO5. By inputting the soil parameters and geometric parameters like slope, inclination & height the Factor of Safety acquired from analysis is $1.13 \leq 1.5$ (1.5-standard value), which shows that the slope is unstable. When gabion structures were provided, they got a factor of safety $3.04 \geq 1.5$. Hence slope stability using gabion structures was considered as acceptable as per GEO5 software. Finally they concluded that it is economical to provide gabions in slopes which are more prone to translational landslide in their saturated state. Also provision of such structures improves their stability against minor landslides.

The main objective of *Amashi et al* [6] is to analyse typical slope by varying different soil parameters like cohesion, angle of internal friction, water table, slope angle and slope height. The study aims to assess the stability of landslides on State Highway 72, near Mahabaleshwar, Maharashtra. For the case study, the study area is chosen from the research work done by M. Ahmed et al. in 2013. Here the parametric analysis is carried out using SLOPE/W, SV-SLOPE and PLAXIS 2D software. From the analysis, it was clear that when the cohesion & internal friction increase, the FOS of soil will also increase. At the same time, when the water table level, slope height & slope angle increases, then the FOS will decrease. From the Slope stability analysis results obtained using SLOPE/W & PLAXIS 2D, it was evident that the slope was unstable under saturated condition. The remedial measure suggested in this research is Soil nailing. Then analysis is carried out using GEO5 software after providing remediation measure. The FOS obtained after providing soil nailing were around 2-3, which shows that the slope became stable after providing the remediation.

Premlet B [7] dealt with the study of various Natural disasters happened in Kerala State. The study was conducted by Kerala State Disaster Management Authority. In this

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 07, July-2021

report, we can see detailed report of landslides occurred in different regions of Kerala. They classified landslides into different types and observed that the reason for the occurrence of majority landslides in 2018 is due to debris flow, land slip & soil slide. From the landslide zonation map, they identified the critical regions for landslides considered for further studies. The selected locations are Kurichiyar Mala, Muttil Mala, Kottiyoor forest area in Wayanad. Based on their case studies, they found out that vertically cut slopes, deforestation, unsustainable construction of buildings and soil piping was the major reasons for landslides in those areas.

III. CONCLUSION

It is of utmost importance to analyze the causes of landslides occurring and to adopt suitable mitigation measures. Several authors have conducted numerical assessment using various softwares available. Among them, SLOPE and PLAXIS softwares are most reliable and give accurate results of factor of safety for slides. Slope stability analysis can be conducted using finite element method and limit equilibrium method. According to the results, factor of safety obtained using finite element method is higher than from limit equilibrium method.

ACKNOWLDGEMENT

We would like to thank the Principle of our institution for providing us the facilities and support for our wok. We express our gratitude to all the previous researchers for provided and availed research articles for the preparation of this review paper.

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