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# FEM Modelling of Mitigation of Rain Triggered Landslide

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***Abstract: Our world is in the path of development. Several activities are ongoing which contributes to the development. But some of these activities interfere the nature and climate very badly.Sudden and unexpected climate change is a result of such man made activities. For the recent two years Kerala state has faced severe flood during rainy season. But the fact is that our state doesnot received much rainfall during monsoon. These are result of unsustainable human activities. On August 2019 , Kavalappara (Malappuram) and Puthumala (Wayanad), located on either side of ecologically sensitive Western Ghats , faced severe landslide which cause loss of several lives and damage to property. Kavalappara is the area considered for this study. The slope lost its naturality due to human interference for plantations activities. Along with that continous rain also triggered the disaster ; hence it is a rain triggered landslide. Rain is an external factor that triggers landslide, which is threat to entire humanity. There arise the need of adopting some measures to slope modification. There is no sure that landslide can be avoided completely, but to some extent we can mitigate the risk and reduce impact of landslide. Here PLAXIS software is used for the stability analysis .It is a FEM (Finite Element Method) modelling.***

***Keywords: FEM, PLAXIS, rain triggered landslide***

## I. INTRODUCTION

Landslide is the movement of rock earth or debris down a sloped section of land. The primary cause of a landslide is the influence of gravity acting on weakened materials that make up a sloping area of land. Landslides are triggered by rain , earthquake , volcanoes or other factors that make the slope unstable. The other factors that influence landslides are geology , morphology and human activity. Geology refers to characteristics of the material itself. The earth or rock might be weak or fractured , or different layers may have different strengths and stiffness. Morphology refers to the structure of the land. For example , slopes that lose their vegetation to fire or drought are more vulnerable to landslides. Vegetation holds the soil in place, and without the root system of trees, bushes and other plants , the land is more likely to slide away. Human activity such as agriculture and construction can increase the risk of a landslide. Irrigation , deforestation, excavation and water leakage are some of the common activities that can cause destabilize or weaken a slope. Kavalappara ( Nilambur , Malappuram District, Kerala ) is selected as location for this study as the place faced landslide on August 2019. Malappuram metrorological subdivision got 189.4 mm rain from August 1 to August 7 which is 66% more than the normal 114.3mm. On August 8, the Nilambur rain guage station , the one nearest to Kavalappara , recorded highest rainfall of that day in kerala.Landslide occurs on August 8 2019.

## II. RAIN TRIGGERED LANDSLIDE AND MITIGATION MEASURES

The landslide that occur due to rainfall is rain triggered landslide. Rainfall is the key triggering factor however slope geometry etc like ground conditions should also be considered. Rainfall is the influencing factor. But its intensity and duration is the important factors. High intensity rainfall for short period doesnot raise any risk but high or low intensity rainfall that last for a long duration (days or weeks) possess high risk of landslide. When rainfall increases, if not proper drainage is provided , water will percolate. i.e. seepage increases in slope. This will in turn increase the dead weight of slope. At the same time pore water pressure increases. Thus the shear strength of slope get reduced. Also when the soil get completely saturated the attractive force that hold the soil particles get weakened i.e the cohesion get reduced and in such situation gravity will be the exceeding force. Thus the slope become unstable and downward movement of soil mass occur which is the phenomenon known as landslide that is induced due to rainfall.We cannot avoid landslide completely , but can reduce the risk and impact to some extent by adopting measures. Some measures are discussed below.

### *A. Re profiling*

In this method the slope geometry is modified . Slope angle is an important factor that determines the stability of slope. Slope angle can be determined by surveying. Most of the natural hills are stable with safe slope angle. But due to human intervention sometimes this slope angle get affected and slope become unstable. Also manmade slope will not be stable due to unsafe angle. So by surveying of hill, geometry can be obtained and the slope stability can be analysed in PLAXIS. The slope should be modified with safe slope angle. By this method it is possible to reduce the steepness of hill.

### *B. Erosion Control Technique*

Due to rainfall, surface runoff on slope or hill increases. This increase the chance of erosion of surface material , which inturn tends to weaken the slope by removing material and triggering excess pore pressures due to the water flow. In such situation , can adopt some methods to control erosion which make only low environmental impact.

Geomats :These are anti-eroding biomats or bionets. Geomats are purpose made synthetic products. These provide protection for slope from surface erosion. It also protect from the impact of raindrops.

Steel wire mesh :It is a cost effective method. After the slope get leveled and compacted , the surface can be covered by steel wire mesh. It is fastened and tensioned to slope. It will protect the slope from surface erosion.

Vegetative cover :Presence of greenery has a vital role in avoiding the chance of landslide. Presence of grass and trees will help to hold the soil particles close together. Also it reduces the chance of erosion. Thereby chance for landslide get reduced. Grasses shrubs etc are more preferred on hillside.

### *C. Drainage Techniques*

When rainfall increases, surface runoff increases as well as chances for seepage flow cannot be avoided. It will increase the pore water pressure which decrease the shear strength of soil and mass become unstable. Introducing a proper drainage system reduce the water level inside an unstable slope, that leads to reduce pore water pressure and increase the shear strength of slope. Water from slope has two sources mainly ;surface water and ground water. Rainwater increases surface water and also due to infiltration water table get rised. So drainage should be improved along the slope.It can be achieved by surface drainage and sub-surface drainage systems. There are some common methods for this.

Surface drainage :It can be done by making a network of ditches along the slope. This network of ditches tends to converges to carry surface water away from the instable slope.

Sub surface drainage :Sub surface drainage is the removal of water from root zone. it is accomplished by horizontal drains , drainage galleries , deep drainage trenches , etc. These method are costly that surface drainage but more effective.

Sub surface drains is also very effective method for lowering the water table. By that can reduce the risk of slope failure.

### *D. Common Methods*

By providing reinforcements elements into the ground, slope stabilization can be achieved . this is common method adopted. when reinforcing elements are given, external force act on it and mechanical strength is increased. some of the methods are follows :

Anchors :This is a common method adopted for slope stabilization. An unstable slope can be stabilized by providing active force to the unstable mass. These force increase the normal stress and thereby resistance to friction along the creeping surface also increases. Anchors are linked at the surface to each other by a beam frame and this beam frame is protected using geofabrics ,in order to prevent erosion from removing the ground underlying the beam frame.

Soil nailing :This is a common method used to stabilize natural as well as man made slope. This is based on the fundamental principle in construction engineering ; mobilizing the intrinsic mechanical characteristics of the ground , such as cohesion and the angle of internal friction, so that the ground actively collaborates with the stabilization work. Nailing similer to anchors also induces friction and stability within hillslope.

Reinforcement method are very common method for slope stabilization. To make the mitigation measures cost effective, combinations of these methods can be also done( For eg, steel wire mesh and anchors can be provided for a slope ). Anyway the mitigation measure should suit the soil type , geographical factors etc. therefore the mitigation measure should be selected and adopted only after having a detailed study on slope geometry, soil characteristics etc

## III.FINITE ELEMENT MODELLING FOR SLOPE STABILITY ANALYSIS

The Slope stability defined as the resistance of an inclined surface to failure by sliding or collapsing. The stability of the slope cannot be determined perfectly because of many factors that can effects the stability from time to time. Therefore, the stability of the slopes can be analyzed with many ways such as infinite slope analysis, finite element analysis, block analysis, planar surface analysis and circular surface analysis.

Nowadays, Finite element method has been increasingly used in slope stability analysis. When the slope geometry and subsoil conditions have been determined, the stability of a slope maybe assessed using computer analysis. Most of the computer programs used for slope stability analysis are based on the limiting equilibrium approach for a two dimensional model. This analysis was conducted using two-dimensional finite element program, PLAXIS.

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### *A. PLAXIS Software*

PLAXIS is a finite element package that has been developed specifically for the analysis of deformation and stability in geotechnical engineering projects. The simple graphical input procedures enable a quick generation of complex finite element models, and the enhanced output facilities provide a detailed presentation of computational results. The calculation itself is fully automated and based on robust numerical procedures. The safety factor is evaluated using gravity loading and phi-c reduction procedure. Mohr-Coulomb soil parameters and different levels of global coarseness were examined to know its effect to the computed factor of safety. By slope stability analysis using Plaxis software one can obtain the FOS and displacement of the slope under consideration.

The sample under consideration is collected from Kavalappara, Malappuram, Kerala . But the slope is doesnot existing .It get completely collapsed in August 2019 rainfall. So we are creating a slope geometry . For an existing slope , we get the geometry by survey process etc. But in this case, a slope created in PLAXIS software as 15-node element. Standard fixities is provided to the slope . Here slope analysis is done for 3 different cases

| | |
|---|---|
| Material model | Mohr-Coulamb |
| Material type | Undrained |
| Soil unit weight above p.l | 16 KN/m^2 |
| Soil unit weight below p.l | 18 KN/m^2 |
| permeability | 0.2 m/day |
| Young’s modulus | 42130 KN/m^2 |
| cohesion | 38.3 KN/m^2 |
| Friction angle | 28 degree |
| Poisson’s ratio | 0.35 |

Table I Soil Parameters

1) *Case 1:* Here the created slope is analysed. First of all, define the material of the slope :soil and interfaces. The soil parameters are defined as given in the table I And mesh is generated. Then by applying initial condition, pore pressure and stress is generated. Then by phi-c reduction calculation, slope is analysed and displacement and factor of safety is generated
2) *Case 2:* The same slope by changing its geometry ( Slope angle ) is changed. Then the same soil parameters as in case 1 is defined for the slope and same procedure is followed. Displacement and factor of safety in this analysis is also noted.
3) *Case 3:* The same slope by changing its water table level is analysed by defining the same soil parameters as in table I. Then displacement and factor of safety is obtained by following the same procedure explained in case 1.

Then the output obtained in three cases are shown below

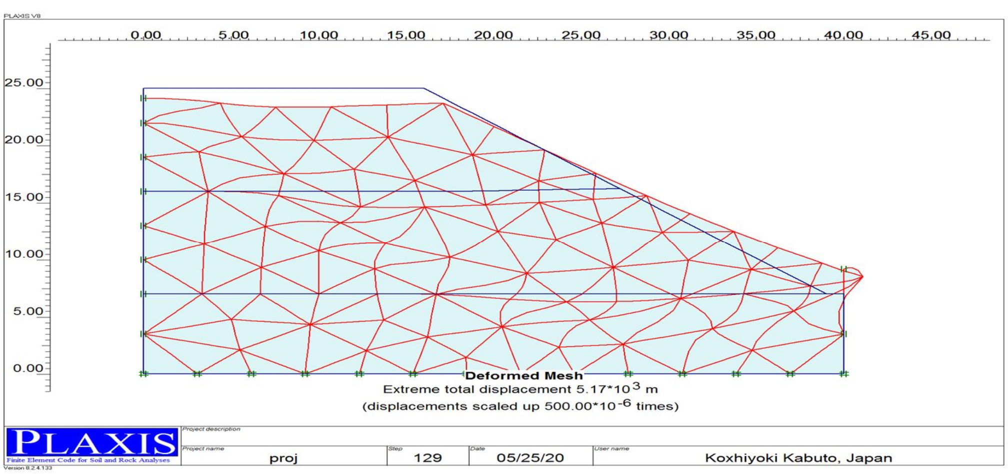


Fig 1 A (Case 1 Deformed Mesh)

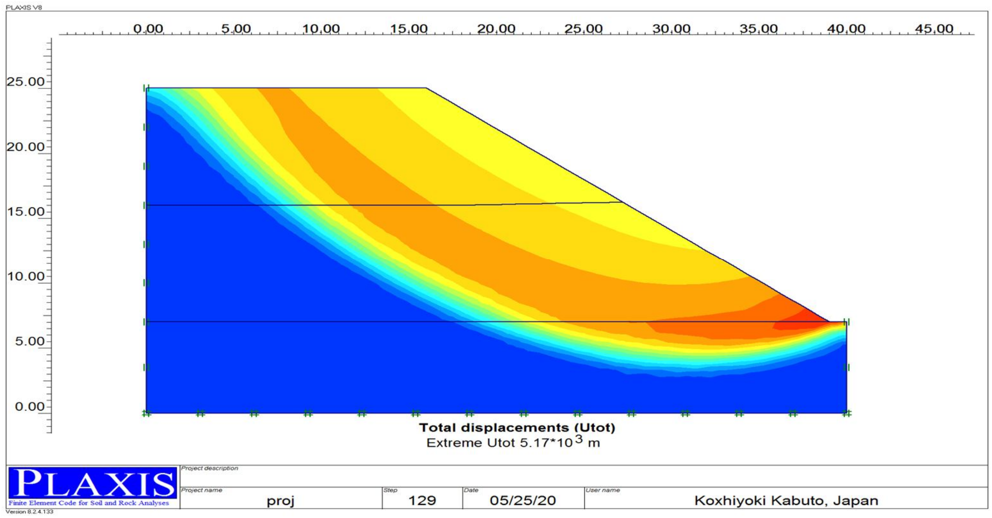


Fig.1 B (Case 1 Total Displacement )

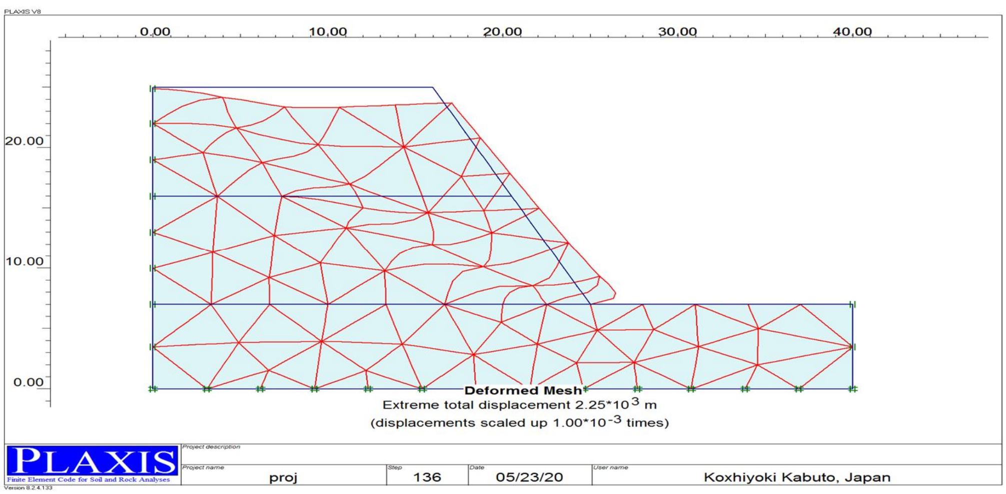


Fig 2 A (Case 2 Deformed Mesh )

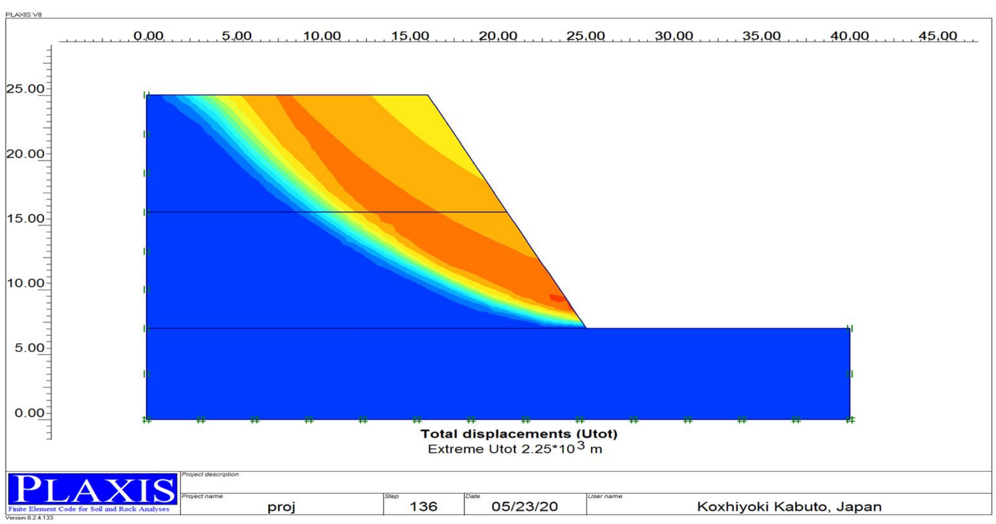


Fig 2 B (Case 2 Total Displacement )

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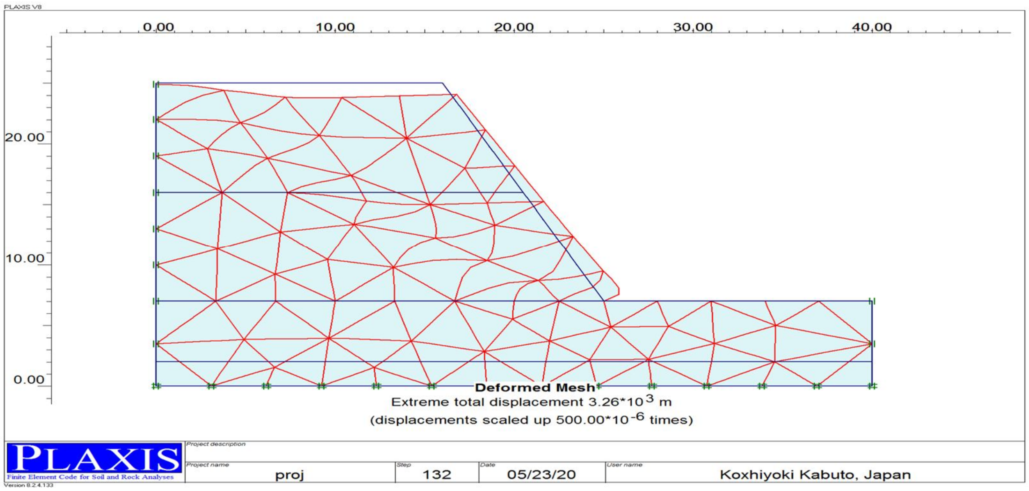


Fig 3 A (Case 3 Deformed Mesh)

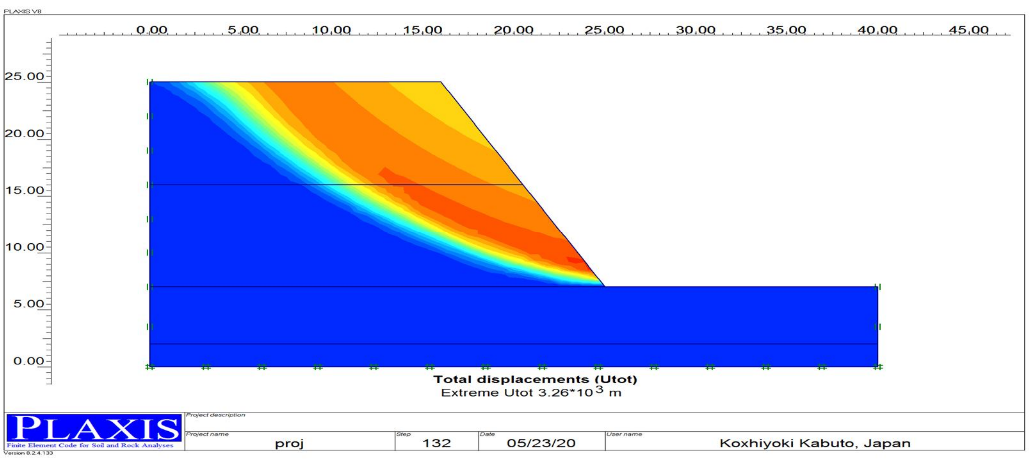


Fig 3 B (Case 3 Total Displacement )

| Case | FOS | Total displacement |
|---|---|---|
| Case 1 | 1.4 | 2.585 m |
| Case 2 | 1.38 | 2.25 m |
| Case 3 | 1.38 | 1.63 m |

Table II Plaxis Output

## IV. CONCLUSIONS

Kavalappara, located on one side ofecologically sensitive Western Ghats, close to Tamil Nadu's Nilgiri district faced landlide on August 8, 2019. Malappuram metrorological subdivision got 189.4 mm rain from August 1 to August 7 which is 66% more than the normal 114.3mm. On August 8, the Nilambur rain guage station , the one nearest to Kavalappara , recorded highest rainfall of that day in kerala. Soil parameters are analysed by various types of experiments. Laterite soil the soil type under area of investigation.

A slope is created and by applying soil parameters stability is analysed in PLAXIS software which is an Finite Element Modelling (FEM) based software. Here 3 cases are analysed. From the analysis , It is clear that slope is stable since the obtained FOS is greater than one. At same time displacement value is higher which indicates that there is a chance for slope failure. From this it is sure that rain is the factor that triggered the landslide. The loss of greenery and unsafe slope modification increased the impact to it.

Various measures can be adopted to reduce the risk of rain triggered landslide. some of them are re profiling (slope angle modification , cutting and filling) , erosion control technique (vegetation, geomats etc ) , by improving drainage and lowering water table, reinforcement method etc. When analysis had done by changing slope angle and lowering the water table, it shows decrease in displacement value of the slope The failed slope can be analysed again in PLAXIS by providing anchors, geogrids etc. Anyway slope analysis, rainfall intensity , type of soil, etc should be considered before adopting the mitigation measure.

## V. ACKNOWLEDGMENT

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