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Mitigation of Micro and Macro Landslides – A CaseStudy

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ABSTRACT:
Mass wasting or landslide under the influence of human activities in increasing very rapidly causing serious concern. Landslides not only impacting catastrophic destruction of human life and property to the greatest extent leading to increase in carbon footprint. Macro and Micro landslides were frequently occurring in Kodagu district, Karnataka, India. Over a couple of years due to excessive rain, loss of vegetative cover to name a few. In the present experimental study, undisturbed representative samples were collected from the six strategic landslide's locations (micro and macro). In-situ and laboratory test were conducted as per BIS specifications to determine In-situ density, index properties, permeability, shear parameters for different drainage soil samples for failure modes. Landslide failures at different sites were compared through the results obtained from numerical modelling. The analysis provides useful solutions to the causes of failure and preventive maintenance to be established in order to limit micro and macro landslides to a minimum state there by contributing to the societal requirements.

Keywords: *Catastrophic causes, Landslides, micro and macro, Societal.*

1 Introduction

One of the main geological processes that pose a risk to human life and property directly is the landslide. The definition of a landslide is the mass movement of a rock, debris, or earth in a slope caused by gravity **[1]**. The speed of the sediment migration may vary. While some mass movement processes, like soil creep, are the slowest and most diffuse, others, like landslides, can move at high speeds, distinct, and have boundaries that could be easily seen, frequently in the shape of shear surfaces **[5]**.

Sometimes movement occurs in a single landslide and large landslides occur due to the temporal and spatial relationships, there analysis frequently calls for a thorough interpretation of geological sections and/or cores and landforms. Landslides happen when short-term stress from earthquakes or landslides exceeds the shear strength (resistance to shearing) of the materials that make up the slope due to gravitational and other shear stresses. Landslides can also be triggered by a number of processes that make a slope's shear strength lessened.

1.1 Mitigation of the hazards of landslide on humans

In most parts of the world, especially in areas that have seen substantial population and economic growth, landslides constitute a recurring risk to people. These risks were primarily reduced by taking precautions including limiting land use, limiting population density in vulnerable locations, setting up early warning systems and erecting retaining walls and piles. Direct methods of preventing landslides include altering the geometry of slopes, utilising chemical reinforcement to strengthen slope material, building retaining walls, grouting rock joints, rerouting debris routes, and using underwater drainage.

1.2 Effect of landslide on human beings

Landslide causes property damage, injuries, death and adversely affects varieties of resource like, water supply; dams, sewage disposal system, forest, fisheries and road ways could be affected over years after landslide event. The depressive economic effect of landslide includes the cost of repairing structure, decrease in value of property, interruption of transportation paths, medical cost in the event of injuries and indirect cost, such as lost timber and fish stocks. Water availability, quality and quantity can be affected by landslides.

Landslides are catastrophic events with geological, atmospheric and hydrological origins. Environmental factors influenced to cause these sudden events that damages property and life. The event is considered to be a disaster on the basis of magnitude of situation, number of victims involved, short of medical care in terms of space, equipment time factors (Suddenness of an event), Human basic needs like food, shelter and clothing etc.

2 LANDSLIDES IN STUDY AREA (KODAGU DISTRICT, KARANTAKA)

Highest rainfall occurs in the month of August. The southwest monsoon is the major factor for heavy rain fall. But in August 2018 the rainfall recorded beats every record of past years. Such rainfall that Kodagu last received in 87 years back in 1931. The rainfall recorded during 2018 to 2019 is highest ever which was recorded and 118 years ago. On July 9, 2018, there was mild shudder in the of the southern region of Kodagu which had core diameter (epicentre) of 10 km down the ground in the regions Sampaje to Madikeri.
In the month of August rainfall recorded was about 1675mm in which 768mm was recorded from 15th to 17th August.
The rainfall received in 72 hours witnessed more number of landslides and floods in Madikeri and Somwarpet taluks. Due to shifting of water streams the places where left unrecognised. There were many unconditional hills and streams formed due to landslides and floods. Many people have lost their living which made them to shift to other regions for their living.

2.1 Upshot for landslides in Kodagu District

Landslides in Kodagu have huge consequences on livelihood, property, animals, plants and so on. Occurrence of landslides different sectors of economy have failed to conduct themselves as before. **Table 1** depicts the losses which had happened in month of August 2018 in Kodagu district that shows causalities with their volume associated with overall cost **[3]**.

Table 1. The consequences of landslide occurred in Kodagu

Sl.no	Particulars	Causalities and Volume	Overall cost (lakh)
1	Human life	20 members	
2	Cattles	144	Rs.25.00
3	Public property		Rs.1.41
4	Crops	130633.88 hectors	Rs.50.67
5	Damages of residential houses	3916 houses	
6	Complete destructions of houses	840 families	

Source: District Commissioner office, Kodagu district **[9]**.

3 REASONS BEHIND DISASTER IN KODAGU

3.1 To enhance tourism growth and infrastructure development increase in deforestation

The hilly regions in Kodagu are much stable when they were covered with thick green cover. Due to the construction of resorts, jungle camps and homestays many tress along the hills slopes and forest region where brought down from past few years. By cutting down trees and hill tops the stability of slopes got decreased and causes soil erosion, with this soil will hold more water and movement of sediments takes place causes landslide and floods in rainy season. The eroded soil gets stagnated in the rivers and ponds which changes the morphology of the river to divert its path causes flooding in Madikeri.

3.2 Unauthorized mining activities

Sand mining activities decreases the strength of soil which causes landslides in and around those areas. Along the ridges of river Cauvery witness unauthorized sand mining which weakens embankments to bear heavy flow when the river swells up.

3.3 Massive deforestation in Kodagu

The activities including cut down of hill tops and breaking of rocks causes loosening of the soil and the heavy rainfall has acts as spur for erosion. The Department of Forest Survey of India's states, Kodagu had lost about 88 km^2 of forest since 2007, while the protection of dense forest has been done and the got risen dramatically, moderately in dense and open forest; private property have reduced to 654km^2 since 2015. As mentioned by researchers there has been planation of silver oak which causes erosion. Studies have shown in past three decades there has been decrease in 30% of dense cover. According to Global Forest Watch, between 2000-2017, Kodagu district have lost approximately 2908 hectares of tree cover.

3.4 Rise in water level:

Heavy rainfall is the main reason for increase in ground water level which fluctuates water table. As told by residents of Karike sounds heard is due to groundwater flow.

3.5 Setting up of massive ponds

For irrigation purposes rainwater stored in massive ponds is used by the owners of coffee estate in Kodagu. Massive waterfall and heavy pressure due to heavy rainfall is resisted by ponds, resulting in massive landslides along the downstream.

3.6 Reducing vegetation along slopes

Heavy rainfall, percolates into the slopes; it causes erosion of soluble salts of mineral in the rock mass, which creates fracture disturbing arrangement of soil particles causes landslides.

3.7 Minor earthquake in some regions

Indian Meteorological Department had no proper proof of minor earthquake which hit Kodagu region. According to the Karnataka State Natural Disaster Management Centre (KSNDMC), an earthquake measuring 3.4 on the Richter Scale occurred on August 9 in the southern Kodagu region, with the epicentre located 10 kilometres beneath the surface between Madikeri and Sampaje.

3.8 Construction of road in unscientific manner

Constant use of vibrators and rock drillers for construction of road along hill slopes causes instability in hilly regions which causes landslides in the sensitive regions of Kodagu district.

4 Study area

The Kodagu district is surrounded by dense green vegetation, plantations, and cultivated valleys on the eastern and western sides of the Western Ghats. Geographically, Kodagu is located in the southwest corner of the Western Dharwar Cro-ton and borders the state of Karnataka to the southwest (WDC). It occupies an average area of 4102 square kilometers in the Western Ghats and is bordered by Dakshina Kannada district in north-west, Hassan district in north, Mysore district in east, Kannuru district of Kerala in southwest and Wayanadu district of Kerala in south. The research region is located on toposheet number 48 P/6, P/7, P/10, P/11, P/14, P/15, and 57D/2 of the 1:50 000 Survey of India, between north latitude 12040'55' and 120 29' 11' and east longitude 750 46' 4' and 760 42' 25'. The research area (Fig. 3) is in the Coorg district and has a total size of roughly 311.57 km² (120.30 mi²). The chain of hill ranges covered in plantations, forests, and farmed valleys is the subject of the inquiry.

Figure.1. Macro landslides **[2]**

Figure.2. Micro landslides **[4]**

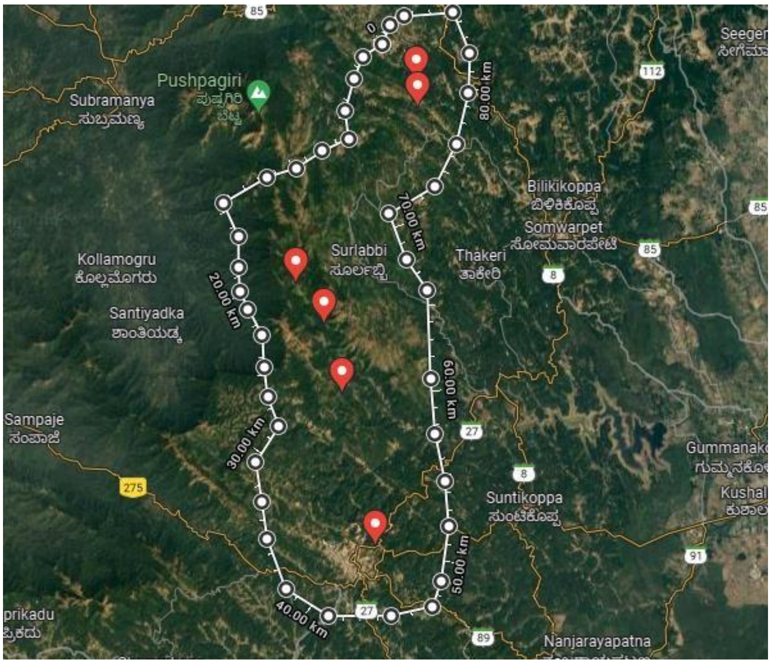


Figure.3. Map of study area of 4102 sq.km (Total area: 311.57 km² (120.30 mi^2))

Figure.4. Photographs of Landslides

Table 2. Shows the location and type of landslide occurred in study area.

Sl.no	Location	Landslide type	Latitude	Longitude
1	Mageri	Macro	12°40'33.2"N	75°46'14.3"E
2	Kundalli	Micro	12°39'44.7"N	75°46'18.7"E
3	Hammiyala	Micro	12°34'14.2"N	75°42'22.7"E
4	Between Hammiyala and Mukkodlu	Micro	12°32'56.1"N	75°43'18.1"E
5	Mukkodlu	Macro	12°30'46.1"N	75°43'51.5"E
6	Madkeri	Macro	12°25'58.4"N	75°44'56.1"E

5 METHOD

5.1 Soil parameters adopted for this study

The representative soil samples were obtained from 6 strategic locations of micro and macro landslides for detailed laboratory analysis. The weathered surface of landslides in those locations were removed, to obtain fresh samples outcrop was horizontally dug. The effective depth of soil samples was determined using a core cutter, soil auger, a surveying tape, depths of recent landslides and slope remodelling. The soil samples were collected from the scars of landslides. In order to provide additional record, longitudinal and latitude of the landslide areas and photographs were clicked during field visits. Further, insitu density test were conducted (core cutter method) at the locations. Undisturbed samples were obtained from the locations to obtain shear parameters and permeability characteristics, index properties of representative soil sample were determined as per BIS specification. The soil classification was done based on **[7]**. Shear parameters were obtained from unconfined compression test conducted on undisturbed sample obtained from different locations according to **[7]**. A falling head permeability test was conducted to obtain coefficient of permeability of collected representative soil samples according to **[8].**

Table (3) and **(4)** shows the index properties and shear parameters of the soil samples

Soil index properties which help in identification and classification of soils for engineering purposes **[6]**. The index properties of a soil, such as the grain-size distribution, plasticity, compressibility, and shear strength are evaluated by proper laboratory testing. Permeability is determined by finding the depth of penetration or the amount of liquid passing through the sample.

Table 3. Index properties of the soil adopted for study:

Properties → / Location ↓	Specific Gravity	Bulk Density (kN/m^3)	Dry Density (kN/m^3)	Soil Classification	Soil grain size distribution		
					Gravel (%)	Sand (%)	Silt + Clay (%)
1	2.65	18.13	13.9	ML	5	43	52
2	2.68	17.87	13.93	MH	6	28	66
3	2.66	18.27	14.97	MH	12	24	64
4	2.69	18.65	15.04	MH	3	32	65
5	2.71	18.13	13.9	CL and ML	0	34	66
6	2.68	17.77	12.87	ML	8	38	54

Table 4. Geotechnical parameters of the soil adopted for study

Properties → / ↓ Location	Shear Angle (φ)	Cohesion 'c' (N/mm^2)	Permiability (mm/s)
1	36^0	8.92	6.69×10^{-3}
2	32^0	10.69	8.97×10^{-6}
3	26^0	12.8	2.81×10^{-3}
4	30^0	30.31	5.15×10^{-4}
5	36^0	8.92	4.16×10^{-5}
6	28^0	9.61	5.79×10^{-4}

5.3 Stability analysis

Analytical approach: Analytical method of slope stability method (Swedish circle method) was analyzed. Factor of safety is the ratio of resisting moment (M_R) to overturning moment (M_O), as given by equation 1

$$FS = \frac{c\ La + \tan\varphi\ \Sigma N}{\Sigma T} \qquad (1)$$

In order to have a comprehensive detailed analysis regarding the types of failure which is paramount importance from the safety of the study area GeoStudio software was used.

GeoStudio Software:

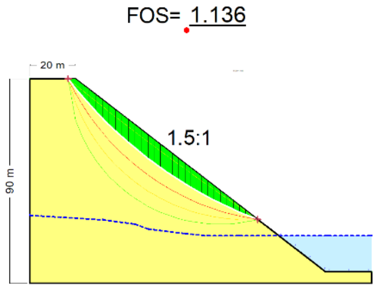
GeoStudio is integral geotechnical analysis software which suits for analysing slope stability, flow of groundwater, mass of heat transfer in soil and rock. The most popular method for analysing retaining structures is the limit equilibrium method. The approach known as limit equilibrium makes use of limit state assumptions. The earth pressures are anticipated on both the maintained and excavated sides for earth retaining structures and excavation activities.

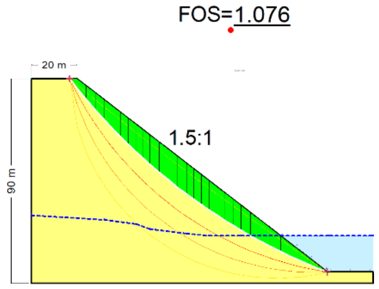
In this analysis GeoStudio 2021.4 version software is used for analysis of slope stability of landslides at six strategic locations. Table 5 shows slope of study area.

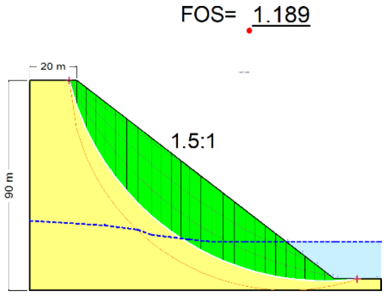
Table 5. Slope of study area.

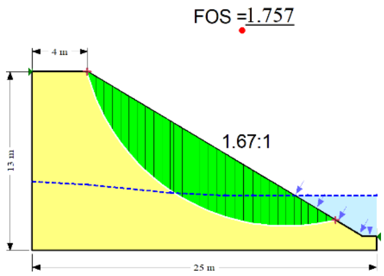
SI.No	Location name	Slope
1.	Mageri	1.5:1
2.	Kundalli	1.67:1
3.	Hammiyalla	1.33:1
4.	Between Hammiyalla and Mukodlu	1.25:1
5.	Mukodlu	1.5:1
6.	Madkeri	1.25:1

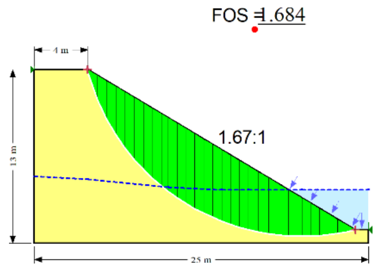
Figure 5. through 10 are showing the face, toe, base failure with factor of safety

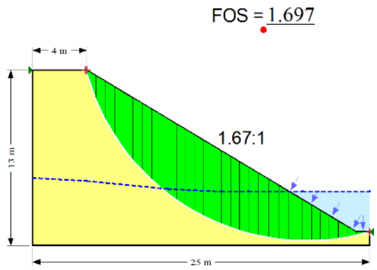
<table>
<tr><th></th><th>Face failure</th><th>Toe failure</th><th>Base failure</th></tr>
<tr><td>1</td><td>

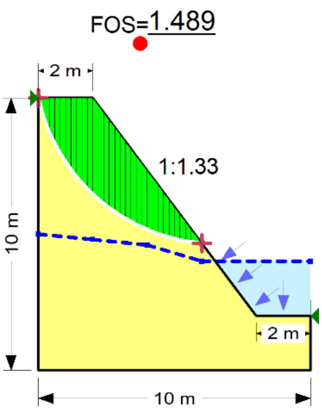
Location 1-Mageri
(FOS $_{critical}$= 1.706)
5(a)</td><td>

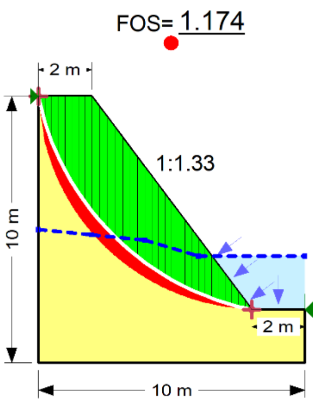
5(b)</td><td>

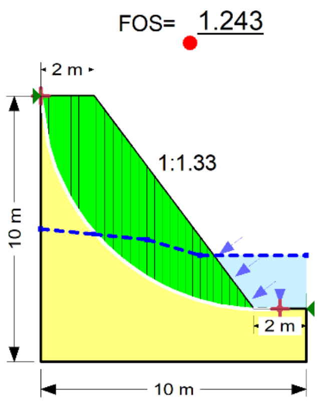
5 (c)</td></tr>
<tr><td>2</td><td>

Location 2-Kundalli
(FOS $_{critical}$= 1.684)
6(a)</td><td>

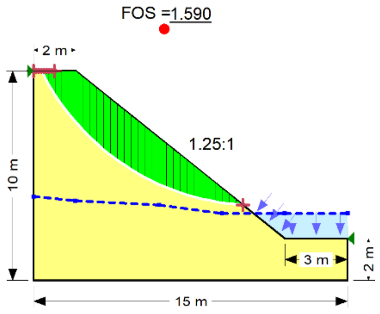
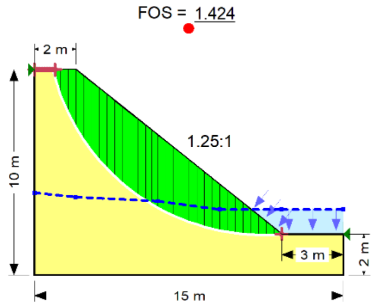
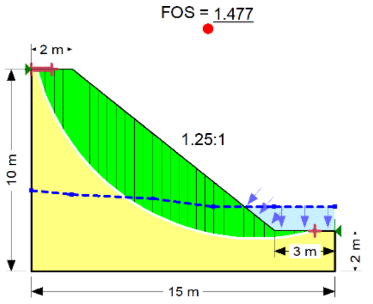
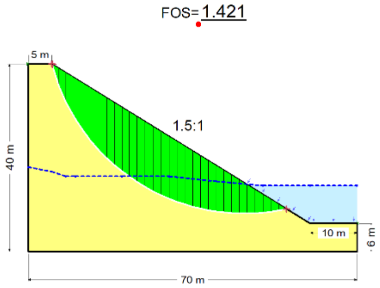
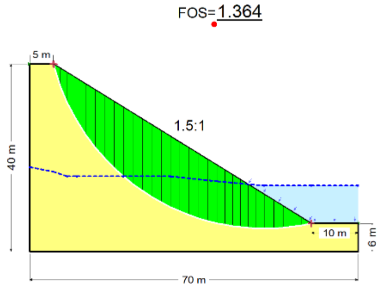
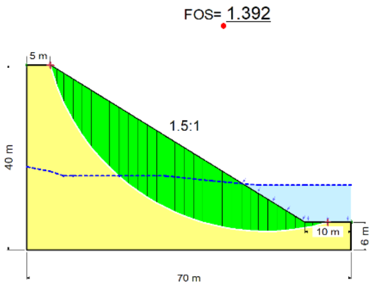
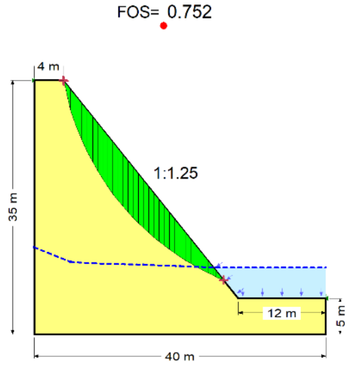
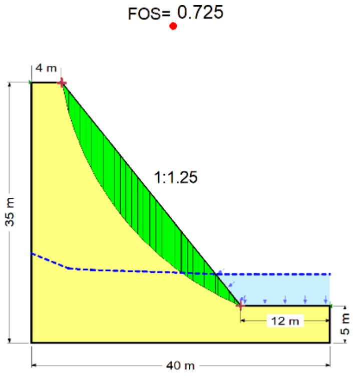
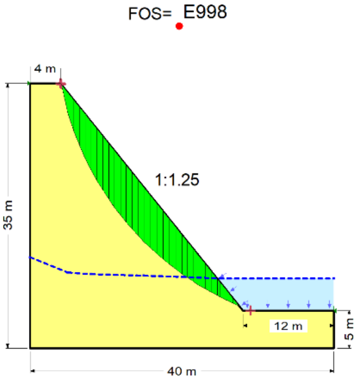
6(b)</td><td>

6(c)</td></tr>
<tr><td>3</td><td>

Location 3: Hammiyalla
(FOS $_{critical}$= 1.243)
7(a)</td><td>

7(b)</td><td>

7(c)</td></tr>
</table>

4	 **Location 4: Between Ham-miyalla and Mukkodlu** **(FOS $_{critical}$= 1.424)** **8(a)**	 **8(b)**	 **8(c)**
5	 **Location 5: Mukkodlu** **(FOS $_{critical}$= 1.364)** **9(a)**	 **9(b)**	 **9(c)**
6	 **Location 6: Madkeri** **(FOS $_{critical}$= 0.725)** **10(a)**	 **10(b)**	 **10(c)**

6 Result analysis

From figure **5(a)** through **10(c)** the following observations are made:
Toe failures as shown in figure **5(b), 6(b), 9(b)** and **10(b)** which exactly depict the actual failure which had happened at the site locations which were critical.
However, from figure **7(a)** and **8(a)** face failures were observed at the locations which were not critical, Further more toe failures are likely to happen in the future which may further causes serious damage to the life and property.

India is classified into different seismic zones; Our study area falls in Zone 3 i.e., it is prone to moderate damage risk zone. The seismic shaking triggers the liquefaction of saturated soils and leads to sliding, despite of very shallow slopes – a hazard that threatens gentle sloping irrigated terrains in other tectonically active regions.

According to the geotechnical investigation findings, the soils contain 6–8 per cent clay and 72–90 per cent silt and sand. The soil samples were categorised as well graded with group symbols of ML, MH, and CL according to the IS soil classification system. The soil parameters like grain size and its distribution, relative density and soil type of soil samples from location 1,2,5,6 (Mageri, Kundalli, Mukkodlu, Madikeri) are potentially liquefiable. The liquefaction screening criteria reveals that location 1,2,5,6 (Mageri,Kundalli, Mukkodlu,Madikeri) are potentially susceptible to liquefaction, whereas samples from location 3 and 4(Hammiyala and Between Hammiyala and Mukkodlu) are less vulnerable.

6.1 Mitigative measures

Based on comprehensive study the following precautions and procedures can be adopted from the risk or damage:

- The demarcation of landslides prone areas to be carefully made accordingly future development activities are made.
- Detailed mapping of necessity of rock bolts in the study area to be made.
- Unscientific slope cuts and deforestation to be avoided.
- Stabilization of existing slope by natural reinforcement like vetiver grass to be made.
- Geosynthetics and Geofabric materials can be blended with natural soil slope
- The path of natural drainage path shall not be blocked due to land development activities
- Toe drains to be provided with naturally available material for smooth drainage of rainwater and underground water.
- Water content or pore water pressure can be reduced inside the rock by suitable grouting techniques.
- Combination of rigid and flexible retaining walls to be constructed to suit the demographical Locations.
- The slope angle can be reduced by providing berms at suitable levels.
- Micro and macro piles can be driven to prevent sliding of soil mass at demographical locations.

7 Conclusion

The use of GeoStudio shows that the probable landslides likely to cause along the slip circle shown in the analysis. The unscientific slope cuts and deforestation can be avoided, and pre-existing slope can be stabilized by artificial fibres like vetiver grass or Geosynthetics and Geofabrics which can be blunts with natural soil slope. The blockage of natural drainage path shall be avoided which reduces the development of pore pressure in the soil to minimal value. Slope angle can be reduced by providing berms at suitable levels. Micro and macro piles can be driven to prevent sliding of soil mass at demographic locations.

8 References

1. Cruden, David M. "A simple definition of a landslide." Bulletin of the International Association of Engineering Geology-Bulletin de l 'Association Internationale de Géologie de l'Ingénieur 43.1 (1991): 27-29.
2. Chudý, F., Slámová, M., Tomaštík, J., Prokešová, R., & Mokroš, M. (2019). Identification of micro-scale landforms of landslides using precise digital elevation models. Geosciences, 9(3), 117.
3. Dayananda.K.C, “Analysis of August 2018 Disaster in Kodagu: An Overview”, IOSR Journal Of Humanities And Social Science (IOSR-JHSS) Volume 24, Issue 8, Ser. 4 (August. 2019)

4. Guerricchio, A., Doglioni, A., & Simeone, V. (2012). Tectonic-gravitational deep-seated failures and macro-landslides in Scilla and Punta Pezzo area (Southern Calabria-Italy). Rend Online Soc Geol Ital, 21(1), 367-369
5. Heerdegen, R. G. "Landslides: Causes, Consequences and environment. By Michael J. Crozier." (1989): 93-94.
6. IS.1498–1970. Classification and Identification of Soils for General Engineering Purposes (2000).
7. IS: 2720-13. "Methods of test for soils—Direct shear test." (1986).
8. IS: 2720 (Part 17). "Methods of test for soils, laboratory determination of permeability." (1986).
9. Report of District Commissioner office, Kodagu District