International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 01 | Jan 2019 www.irjet.net p-ISSN: 2395-0072

Analysis of Landslide near Ambo City, Ethiopia, East Africa

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Abstract – *This work is contributing towards the community by suggesting very economical solution to minimize the landslide disaster. The main objectives of present study are, i) to review past and current works in regards to Numerical and experimental modeling of slope. ii) To Study the behavior of Gurfa Mountain slope, Guder for the present soil condition. iv) To suggest the mitigation methods or suggestion for the falling Gurfa Mountain slope at Guder. Methodology: For modeling of slope stability with different parameters, "GEO STUDIO – 2012 STUDENT VERSION" is used. Many parameters are varied in this analysis. Live landslide of Guder is also modeled in this tool. Results and Conclusions: i) Local landslide near Ambo city was studied in detail, and initial surveys were conducted. Soil was tested in laboratory and observed soil to be poorly graded sand (SP). ii) Prototype landslide was modeled in Geo-STUDIO, with approximate slope height, slope angle and soil properties. From the analysis, it was observed that, factory of safety obtained was very less, leading to slope failure. iii) Even though gabion wall was constructed at the landslide site, slope got failed, as height of the gabion wall was not sufficient for stabilizing it. iv) Many mitigation measures were suggested for landslide stabilization. At Guder slope, it is better to construct earth retaining wall using geogrid as reinforcement, as it is more economical than conventional retaining walls. v) As the lateral pressure from back of slope is very high, gabion walls of smaller height can't sustain the pressure.*

Key Words: Landslides, Slope Stability, Mitigation Measures, Guder Landslide

1. INTRODUCTION

The main triggering factor of slope failures is heavy rainfall. Most of the rain in Ethiopia is concentrated in July and August, during which extremely intensive and long-lasting rainfall events may occur, with subsequent high-water percolation into the ground, widespread slope wash and river-bank erosion. Infiltrating rain water plays a pivotal role in triggering landslides by increasing the total weight of the slope material, causing the water table to rise and increasing the pore pressure in fine-grained deposits. Clayey/Marly formations overlain by hard rock, fractured aquifers, such as basalt, limestone or sandstone, that may undergo sudden water table fluctuations during heavy rain, are particularly prone to gravity driven deformation and failure.

The infiltration of rain water in the fractured bedrock may be aided by the occurrence of deep desiccation cracks in the soil cover at the end of the dry season; especially after low spring rainfall. Earthquakes are recurrent events in Ethiopia, especially along the Rift system, where magnitudes greater than 5 are not rare. Widespread evidence of seismic triggering of landslides, mostly first generated rapid movements such as rock falls, rock slides, and debris-mud flows, is provided by the historical record of earthquakes and related surface effects. The increasing impact of human activities, such as intensive agriculture, quarrying, road construction, urbanization, land use changes, etc., is also responsible for slope instability and landslide hazard. Particularly prone to the initiation of slope movements seems to be the first stage of vegetation regrowth after deforestation.

In case of heavy rain, the presence of woodcutting clearings and irrigation ditches on intensively cultivated slopes may increase the infiltration of rain water and the occurrence of landslides. The construction of houses, roads, bridges, and culverts on such sites may increase slope instability by adding weight to incipient landslides or modifying the slope profile. The leakage of water into the ground from aqueducts and pipelines may also trigger mass movements.

1.1 Scope of the study

In the past history of Ethiopia, it has been observed that many landslides have occurred. There has been a huge loss for the community in terms of number of deaths, loss in properties, and disturbance in lifestyle due to landslides from many years. Many studies have been carried out on landslides after occurrence. But no study has been carried out, to overcome the problem for the occurrence of landslide. This research is contributing towards the community by suggesting very economical solution to minimize the landslide disaster.

1.2 Objectives of the study

The general objective of this work is to model slope using numerical method and give mitigation measures for slope instability.
Some specific objectives of study are,

- To review past and current works in regards to Numerical and experimental modeling of slope.
- To Study the behavior of Gurfa Mountain slope, Gudar for the present soil condition.

- To suggest the mitigation methods or suggestion for the falling Gurfa Mountain slope at Gudar.

2. Landslide near Ambo, Ethiopia

2.1 Landslide site details

The site is located at Guder Gorfa Mountain, near Ambo on the way to Nekemte. The site is located with Longitude as $8^0 97'35.7''$N and latitude as $37^0 74'64''$E. The site is located at a distance of 16 km from Ambo and 4 km from Guder. Initially, slope was stabilized with gabion walls. But, because of less height of gabion walls and more lateral pressure from backside, gabion walls failed. The Location of Landslide showed in Google Earth is as follows,

Fig -1: Location of Landslide site in Google Earth

The initial survey was carried out, at the site to get details such as, height and angle of slope. Details of slope were measured (details are shown in following table)

Table -1: Details of Slope at Guder

Parameters	Values
Slope Length	110 m
Horizontal Distance from edge to tip of slope	82 m
Height of the slope calculated	100 m
Width of the road	10 m
Angle of Slope (Degrees)	55^0

Fig -2: Photographic view of landslide from front side

2.2 Soil and Rock details at site

Upper soil of slope was collected and taken to laboratory for testing. Initial index tests were carried out to understand the classification of soil. Rock was found out to be soft weathered rock which was not stable at site.

In the Geotechnical laboratory of IOT, Ambo University, sieve analysis was carried out as per ASTM D6913-Standard Test Methods for Particle Size Distribution, and classification was done.

Table -2: Result of Grain size analysis

Retained Weight			Cumulative Weight		
sieve size (mm)	retained wt (g)	Retained %	Cumulative wt (g)	Cumulative (%)	Passing %
4.75	400.00	40.00	494.00	40.00	60.00
2.36	390.00	39.00	884.00	79.00	21.00
1.18	51.00	5.10	935.00	84.10	15.90
0.6	41.00	4.10	976.00	88.20	11.80
0.425	10.00	1.00	986.00	89.20	10.80
0.3	5.00	0.50	991.00	89.70	10.30
0.15	4.00	0.40	995.00	90.10	9.90
0.075	3.00	0.30	998.00	90.40	9.60
pan	2.00	0.20	1000.00	90.60	9.40

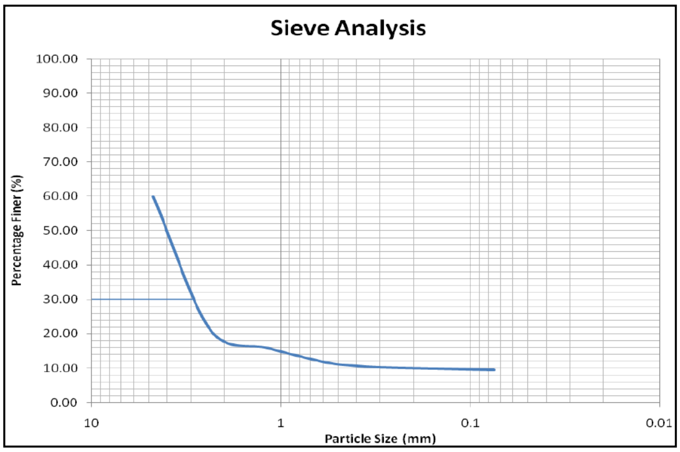

Fig -3: Grain Size Distribution Curve

The values of D_{10}, D_{30} and D_{60} are respectively 0.4, 3 and 4.75.

$Cu = D_{60} / D_{10} = 4.75 / 0.4 = 11.87$.
$Cc = (D_{30})^2 / D_{10} \times D_{60} = (3)^2 / 0.4 \times 4.75 = 4.74$.
So, from the above results it is clear that, soil is poorly graded sand (SP), Because, Cc is not lying between 1 and 3; Cu is greater than 6.

2.3. Numerical Modelling of Landslide

Slope was modeled using GeoSTUDIO 2012, for the slope stability analysis. Details of slope were taken after initial survey at site and experimental studies. Details of data taken for modeling are shown in table below.

Table -3: Parameters adopted in slope modeling of Guder

Parameters	**Values**
Slope Length	110 m
Horizontal Distance from edge to tip of slope	82 m
Height of the slope calculated	100 m
Width of the road	10 m
Angle of Slope (Degrees)	**55^0**
Inner Profile	**Soft Weathered Rock**
Outer Profile	**Poorly Graded Sand (SP)**

Model was carried by using ordinary limit equilibrium analysis. In this analysis, lot of slip surfaces were drawn, and out of all, critical slip surface with minimum factor of safety was considered. Factor of safety with less than 1.5, is considered to be more critical. From the present analysis, it was observe that factor of safety is 0.479, which is very critical for failure. The main reason for this failure is because of type of soil presents there, also human activities at the toe of slope.

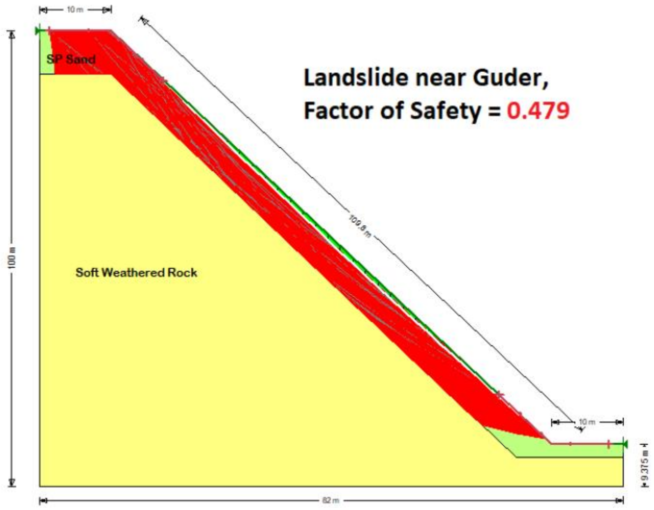

Fig -4: The Numerical model from GeoSTUDIO 2012, of Guder slope

The exact slope was modeled in Geo Studio software to simulate the Behviour of landslide. In the landfill site, toe of the slope was disturbed for mining purpose, which leads to failure of slope in a huge quantity.

Even though slope contains rock strata inside, it started failing, as the outer part of slope contains loose deposit of poorly graded sand. In the software, slope was simulated, just similar to field conditions, which got factor of safety as 0.479. This shows that slope is very critical for failure. Immediate action has to be taken for stability of the failing slope, as it can cause severe damages to adjacent road and also serious fatalities.

3. Mitigation measures for Landslide

Retaining Walls

Retaining walls are relatively rigid walls used for supporting the soil mass laterally so that the soil can be retained at different levels on the two sides. Retaining walls are structures designed to restrain soil to a slope that it would not naturally keep to (typically a steep, near-vertical or vertical slope).

Reinforced Earth wall: Reinforced earth is a composite material formed by cohesion less soil and flexible metal reinforcing strips. The earth and the reinforcement are combined through friction. The result is monolithic mass that act cohesively supporting its own weight and applied loads. Mechanically Reinforced earth wall u utilize tensile reinforcement in many different forms: from galvanized metal strips or ribbons, to HDPE geotextile mats, like those shown above right. This reinforcement increases the shear strength and bearing capacity of the backfill.

Fig -5: MSE Wall used for Slope Protection

Gabion Wall: A gabion wall is a retaining wall made of stacked stone-filled gabions tied together with wire. Gabion walls are usually battered (angled back towards the slope), or stepped back with the slope, rather than stacked vertically.

The life expectancy of gabions depends on the lifespan of the wire, not on the contents of the basket. The structure will fail when the wire fails. Galvanized steel wire is most common, but PVC-coated and stainless steel wire are also used. PVC-coated galvanized gabions have been estimated to survive for 60 years. Some gabion manufacturers guarantee a structural consistency of 50 years.

Fig -6: Gabion Wall used for Slope Protection

Vetiver grass vegetation

Vetiver grass can reduce or control soil erosion on the slopes if planted in rows across the slope. Row spacing should be 1 m and clump spacing 10-15 cm. Soil erosion protection occurs both in surface and sub-surface soils. When the vetiver clumps grow close laterally, they act as a living wall which stands against and slows down runoff, and the eroded soil is deposited behind the vegetative barrier. The vetiver grass tillers grow up through it and go on building natural terraces, and they adjust themselves to rise above these natural terraces, which still act as living walls as long as the vetiver is alive. Under the vetiver hedgerows where the soil condition is good, the root system penetrates as deep as about 3 m and expands to about 0.5 m. The root system acts as an underground curtain that tightens the soil particles like reinforced earth to protect from erosion.

Fig -7: Vetiver Grass for Slope Protection

4. Conclusions

- Local landslide near Ambo city was studied in detail, and initial surveys were conducted. Soil was tested in laboratory and observed soil to be poorly graded sand (SP).
- Prototype landslide was modeled in GeoSTUDIO, with approximate slope height, slope angle and soil properties. From the analysis, it was observed that, factory of safety obtained was very less, leading to slope failure.
- Even though gabion wall was constructed at the landslide site, slope got failed, as height of the gabion wall was not sufficient for stabilizing it.
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ACKNOWLEDGEMENT

The authors are very much thankful the local authorities of Guder area and also geological department of Ethiopia.

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