Analysis of Landslide at Gudar-Gedo Road and Proposal of Mitigation Measures

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Abstract- landslides are common problem in hilly or mountainous area. The various causes affect the landslides, namely, soil properties, geological properties and meteorological properties. The present study deals with the study of landslide occurred in GUDAR and GEDO road section at GUDAR place – in Oromia region of Ethiopia. Therefore, this study particularly aimed at investigating geotechnical characteristics, type of soil and their role in landslide initiation, slope stability analysis and to recommend possible remedial measures.

Indexed Terms- Geotechnical Characteristics, Landslide, Mitigation Measures, Slope Stability Analysis

I. INTRODUCTION

Slope stability analysis is a vital tool for the design and construction of slopes. This analysis is performed to assess the safe design of slope and the equilibrium conditions. Improper slope analysis and design might cause slope failure which has been acknowledge as one of the most frequent disaster that can lead to great loss of properties and life. Thus, the initial soil investigation has to be done properly in order to achieve the actual soil condition particular location.

In hilly areas landslide are main concern where movements of existing or planned slopes could have an effect on the safety of people and property. One of the causes of the incorrect assessment of slope stability may be inaccurate determination of the geological structure of the slope.

Landslide-induced hazards are the most destructive natural phenomena that cause property damages, including failures of engineering structures, human sufferings, environmental degradation and loss of fertile agricultural farm lands.

The developments in soil and rock mechanics play an important role in the evolution of slope stability analyses in geotechnical engineering. The increasing demand for the engineered cut and fill slopes in construction projects has enhanced the needs for deepened understanding on the analytical methods, investigation tools and stabilization methods in order to solve slope stability problems.

A slope is defined as a surface of which one end or side is at higher level than another; a rising or falling surface. An earth slope is an unsupported, inclined surface of a soil mass. The failure of a mass of soil located beneath a slope is called as slide. It involves a downward and outward movement of the entire mass of soil that participates in the failure. The failure of slopes takes place mainly due to, the action of gravitational forces, and Seepage forces within the soil. They may also fail due to excavation or undercutting of its foot, or due to gradual disintegration of the structure of the soil. Slides may occur in almost every conceivable manner, slowly or suddenly, and with or without any apparent provocation

The movement of mass of a soil in a downward direction of a slope is called a slide or a slope failure. The failure of a natural slope is a common geological phenomenon occurring whenever an imbalance takes place between shear strength and shear stress in the ground. The first sign of an imminent landslide is the

appearance of surface cracks in the upper part of the slope, perpendicular to the direction of the movement. The instability is either due to increase in seepage pressure, due to excavation of slope toe material, due to increase of shear stress from surface loading as a result of construction or train traffic. The slip may occur through the fill, through the base or through foundation

The GUDAR – GEDO road section at GUDAR place – in Oromia region of Ethiopia. It passes through steep slopes and highly dissected topography, adverse geological formations, complex structural features and dense to sparse vegetation cover. The route is highly affected by surface water erosions as well as slope instabilities. It is generally characterized by poor and at times with no construction of retaining structures and inadequate surface drainage systems like ditches and culverts. It is common to observe debris/earth slides, scouring of road sections, rock fall, and rockslides. Due to landslide problem in this area, damage of the road (asphalt), hamper traffic, rarely car accident, repeated failures leading to repeated, blocked at three different places and as a result traffic has been hampered for the several days, ditches eroded and culverts are blocked this leads to further erosions and initiate slope failures.

The above problems have been causing both direct and indirect impacts. The direct impacts are cost of reconstruction for the destroyed infrastructure and for resettlement of the displaced communities while the indirect impacts are disruption of economic activities and other social services.

Landslides have widespread distribution in Ethiopia and result in different hazard level and extents often occur in hilly and mountainous terrains and they were triggered by different influencing factors, such as rugged morphology, physically weak lithologies, very scarce land cover (barren land), poor land use practices and wide distribution of surface and groundwater associated with seasonal floods. In many parts of Ethiopian highlands landslide-induced hazards are the most destructive natural phenomena that cause property damages, including failures of engineering structures, human sufferings, environmental degradation and loss of fertile agricultural farm lands.

There are numerous methods currently available for performing the slope stability analysis. The majority of these methods may be categorized as limit equilibrium method. The limit equilibrium method is widely used due to its simplicity. There are numerous limit equilibrium methods available for evaluation of slope stability, such as Ordinary Method, Bishop Simplified Method, Janbu Simplified Method, Janbu Corrected Method, Spencer's Method, Crop's of Engineers Method, Morgenstern and Price's Method, Lowe-Karafiath Method and Generalized Limit Equilibrium Method (GLE). The most widely used limit equilibrium method of analysis for slope stability is the Bishop's Simplified Method (Chitra and Gupta, 2016).

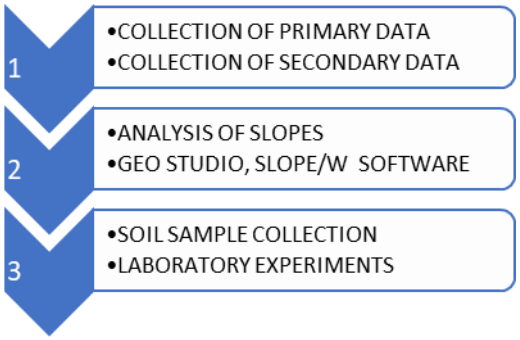
This research attempted to: investigate: the geotechnical condition of the site, analyse stability of the landslide affected area, and recommend possible mitigation measure that may help to alleviate the observed problem.

- OBJECTIVES

The specific objectives of the study are:

1. To determine and characterize the geotechnical properties of soils /rocks in the landslide prone area.
2. To identify the main cause of slope failure along GUDAR-GEDO road section.
3. To determine slope condition and analyse the stability of the slope using Geo studio Software
4. To propose the remedial measures in order to minimize landslide risks at the study area.

II. METHODOLOGY



III. EXECUTION OF THE WORK

- STUDY AREA:

The area is near GUDAR town, the journey around 5 km from GUDAR town towards GEDO, which passes through a hilly area reach to the research area. The area is at 8°58′ N and 37°44′ E, the location is about to 2228 m above sea level. The landslide area is with very loose soil with longitudinal hexogonal shape rock fragmentation**.**

The below fig shows the actual site of landslide area.

- DATA COLLECTION PROCEDURES

The data collection for the completion of this research were: (1) reviewing previous studies and literatures on research title related, (2) Interviewing (3) Measuring and reading the size and location of the landslide affected area and conducting field test (4) Geotechnical investigation of soils (5) Slope stability analysis using limit equilibrium method.

- SOFTWARE AND INSTRUMENTS USED FOR SLOPE STABILITY ANALYSIS

The software Geo-studio 2012, MS word and Excel and device mobile camera and GPS were used for the study. Geo-studio 2012 was used to delineate the study area and numerically analysis the slope stability against the landslide respectively; MS word and Excel were used to analyse laboratory and display research data; mobile camera and Garmin GPS were used for documentation and determine the location of landslide affected area respectively.

- METHOD OF SLICES USING SLOPE/W SOFTWARE

The slope model was analysed using SLOPE/W software with the aim of giving the state of the slopes with their factor of safety using Limit Equilibrium Method (LEM).The software computes the factor of safety (FOS) for various shear surfaces (SS), for example circular and non-circular. However, only the circular SS was automatically searched. The method of slices was considered in relation to its application to SLOPE/W and traditional methods of analysis. According to Abramson et al. (2002) slices method is widely used by much computer software because it can accommodate geometry of complex slope, different soil conditions and influence of external boundary loads. Conventionally, the weight of soil lying at a particular point should influence the stress acting normal to that point on sliding surface.

Theoretically, the basic principle of slices method is the potential slide mass, which is subdivided into several vertical slices and the equilibrium of individual slice can be evaluated in terms of forces and moments. This would allow easy estimation of the allowable safety factor of a slide mass. In this study, three soil layers for site1 and site2 obtained from shear strength test, with different strength parameters were used for slope stability analyses. These same shear strength parameters were used in dry conditions. Similarly, unit weight of soils for each site above the groundwater table (GWT) considered. The input parameters used in the study are shown in appendix B.

- GEOTECHNICAL ANALYSIS

Preliminary geotechnical classification and identification tests such as moisture content, bulk density, specific gravity, grain size distribution, liquid limit, plastic limit, and plasticity index and shear strength tests were carried out on the soil samples based on According to ASTM, Each geotechnical test was performed thrice on the same soil sample under the same condition in order to determine the reliability of the geotechnical test results.

- SAMPLING PREPARATION FOR LABORATORY ANALYSIS

The soil samples taken to the laboratory for investigation of some geotechnical characteristics and slope stability analysis of the affected area were: (i) the disturbed collected samples at different depths were air dried 3 – 4 days and oven dried at ±105C° for 16 to 24 hr before carrying out laboratory test. (ii) The undisturbed collected samples using cylinder tube and tied to plastic bag to prevent moisture loss was but not used for direct shear strength and in situ natural moisture content determination. Natural moisture

contents and shear strength were determined immediately, after the samples brought to the laboratory. After air or oven dried each sample were weighted for the required laboratory test and the test was carried out in accordance with ASTM standard.

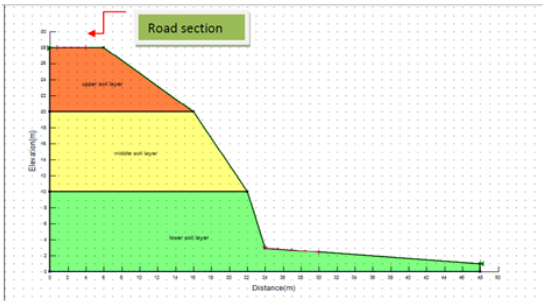
- LABORATORY ANALYSIS

To identify and characterize the problem nature of the slope material for slope stability, a range of laboratory analysis were carried out. Among those Atterberg limits (liquid and plastic limits), Specific gravity and particle size distribution were conducted for geotechnical classification whereas shear strength parameters and bulk density for slope stability analysis. The following below were laboratory tests analysed for investigation of geotechnical characteristics and slope stability analysis.

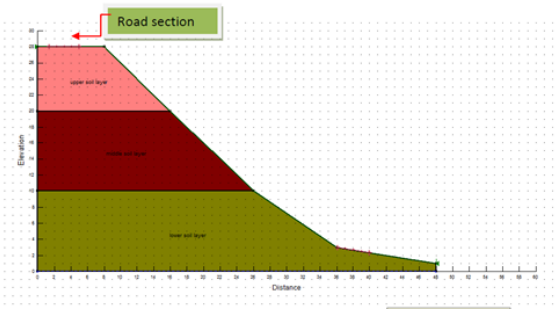
- INPUT DATA FOR SLOPE STABILITY ANALYSIS ON SITE

Condition	Soil profile	Slope angle (^{0})	Unit weight (kN/m^3)	Cohesion (kN/m^2)	Angle of internal friction (*)	Ground water conditions
1	Upper soil layer	54.25	15.03	25.37	24.23	At great depth
1	Middle soil layer	54.25	15.81	44.42	25.24	At great depth
1	Lower soil layer	54.25	17.78	49.47	26.52	At great depth
2	Upper soil layer	39.81	15.03	25.37	24.23	At great depth
2	Middle soil layer	39.81	15.81	44.42	25.24	At great depth
2	Lower soil layer	39.81	17.78	49.47	26.52	At great depth

Slope Profile at Natural Condition for Site

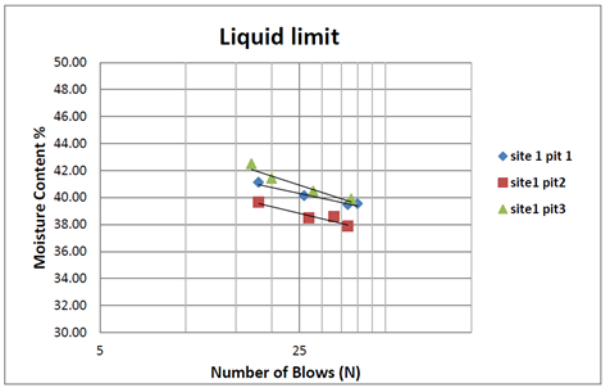


Slope Profile at Modify Condition for Site

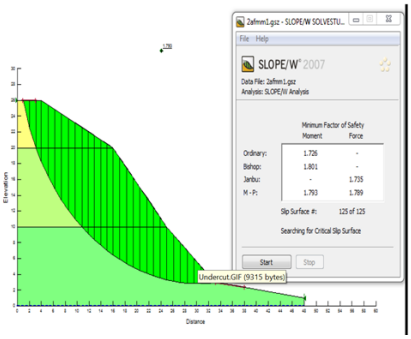


Size Distribution Curves for the Soil Samples

Liquid Limit Test Results by Casagrande Cup Method of Site



The Critical Slip Surface; CSS and FOS For Modify Slope of Site



IV. RESULTS AND CONCLUSION

In general, the present study area slope instability is the main problem of the study area. The laboratory and field test result, characteristics and type of soil, geology, physiography, and hydrological condition and also their effect on slope instability are found out. Additionally, software results present the state of the slope at three different distances from failure surface, FOS of natural slope and modified slope angle and also based on FOS result remedial measures proposed. The following below are proposed mitigation measures.

- Methods Proposed to Minimize the Effects of Landslide in the Study Area

Depending on the result of FOS of the slope of the study area, the following methods are proposed to prevent or minimize the effects of landslide in the study area.

- Geometry modification

The slope of the study area is steep and this causes increase in tangential gravity force as a result, maximum value of shear stress which leads slope instability. Therefore, removing all or part of the earth driving landslide to modify slope geometry which is the most efficient way of increasing the factor of safety of a slope. The geometry of the slope can be modified by grading a slope angle to a uniform flatter angle, removing the material from the driving the landslide area.

- Providing Drainage

The study area was located almost on sloped area and no drainage provided for taking erosion during intense rainfall, this makes the slope unstable against sliding. To minimize these problems providing surface drainage along East to West and North to South at the upper side of slide area and controlling the runoff from upper course will minimize the continuity of landslide at the GUDAR-GEDO road.

- Providing Engineering Structure

Providing engineering structures such as gabion retaining wall for damaged area by landslide for GUDAR-GEDO road section Thus, constructing gabion along one side of the slope to guide the soil movement and providing embankments along failed slope, with the size determined by the selection of gradient that produces a stable slope. In addition, and alternatively benching of upslope, maintenance of subsurface drainage, road side surface ditch is considered too.

CONCLUSION

Erosion and steep slope was suspected as the main cause of the landslide that occurred in study area of GUDAR-GEDO road section. The results from gradation curve which gave 1.62-1.97 % clay and silt, 43.56-65.37 % sand and 31.28-54.16 % gravel for the samples. In addition, from the site investigation, the terrain is rugged in nature and the slope is steep which can facilitate landslide by gravity. The results from the Atterberg limit test shows the liquid limit (LL) and plastic limit (PL) of the landslide materials range 38.97 to 41.15% and 27.80 to 30.61% for site1 and 26.94 to 29.68% and 19.13 to 24.33% for site2 respectively. The specific gravity value tells as the soil falls in the range specific gravity of gravel soil. The result from moisture content tests obtained for the soils range between 6.34 to 14.16 %. The density and unit weight test result shows the soil of the study area categorized under coarse-grained soils. From the results of samples which are taken from selected test pits and according to the unified soil classification system (USCS) and American Association of State Highway Transportation Officials (AASHTO) the main soil groups are gravel of low to medium plasticity with a group symbol GW and GP-GC and A-2-7 and A-2-6 respectively. The result from direct shear test obtained for the soils, the angle of internal friction (ϕ) of soils varies from 17.16o to 27.93o and the cohesion (C) 25.37KN/m2 to 73.65KN/m2 respectively. These parameters are used in the slope stability analysis.

The FOS values for natural slope 1.203 and 1.372 and for modify slope 1.68 and1.793 of site1 and site2 respectively. From FOS result it can be understood that the slope of the study area classified as marginal stable. Marginal stable slope or1< FOS<1.5 obtained may be due to slope steepness, many crack, rainfall (erosion) and absence of drainage and structure. The FOS in gentle slope which is much greater than that of steep slope depicts as geometry modification used for prevention or remedial measure for landslide in the

study area. The landslide type of the study area is base failure which is one type of a plane slide or a rotational slide. The failure become toe (slope)

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