Slope Stability Analysis of Langdeibung Area Along Imphal-Jiribam National Highway (NH-37) Using Geoslope

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1 Introduction

Slope stability analysis is done to evaluate the equilibrium conditions and the safe design of a natural or man-made slope [1]. The slope of an inclined surface measures its resistance to failure by sliding or collapsing. Loss of lives and property may result from slope failure. Therefore, it is crucial to verify the stability of the suggested slopes. A safe and effective slope design is now achievable because of advancements in stability analysis and contemporary soil testing techniques. The various techniques for evaluating the stability of slopes and their limits should be thoroughly understood by the geotechnical engineer. The main objectives of slope stability analysis are finding weak spots, examining potential failure mechanisms, determining how sensitive a slope is to different triggers, building the finest slopes in terms of safety, dependability, and cost, and creating potential corrective procedures are the key goals of slope stability analysis [2]. Here the study is done on the finite slope analysis. The following are some common techniques for analysing finite slopes:

1. Morgenstern-Price method 2. Spencer Method 3. Bishop Method 4. Janbu Method 5. Ordinary Slices Method 6. Sarma Method.

The study area is done for a hill slope located at Langdeibung of Senapati District, Manipur, India. A portion of the slope in this location has developed a crown, which is a warning indication of a potential landslide. This is because of the slope's angle, the soil's characteristics, and the lack of vegetation in that particular area. Geoslope software is used to do slope stability analyses using Morgenstern Price's limit equilibrium method. Modern limit equilibrium tools like GeoSlope help manage complexity

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in analyses. Today, it is possible to handle complex stratigraphy, pore-water pressure conditions that are wildly inconsistent, a variety of linear and nonlinear shear strength models, virtually any slip surface shape, concentrated stresses, and structural reinforcement. In addition, limit equilibrium formulations based on the method of slices are increasingly being used to analyse the stability of structures such as tie-back walls, slopes reinforced with nails or fabric, and even the sliding stability of structures subjected to significant horizontal loading, such as that caused by ice flows. We aim to investigate the slope stability analysis using Morgenstern Price's method with the help of Geoslope software to find out the critical factor of safety.

1.1 Study Area

The study area is located along NH-39 in Langdeibung, Senapati district, Manipur. Rocky, steep terrain characterises the entire area. The hill ranges generally follow an NNE-SSW pattern, though this can occasionally switch to N–S or NE–SW. The main features in the area are hill ranges and river valleys. A large portion of the land is covered by structural and denudational hills that are aligned parallel to sub-parallel. The region experiences a mild, humid subtropical monsoon climate, with annual rainfall ranging from 671 to 1454 mm and temperatures ranging from 3 to 34 °C.

1.2 Geological Setting

A sequence of the Disang and Barail group of rocks and Quarternary alluvium make up the research region, which is situated in the northernmost section of the arcuate Arakan Yoma-Chin highlands. Disangs are tectonically deformed, dark grey, splintery shales intercalated with siltstones and fine-grained sandstones. Barails underlying Disangs are made up of huge to thick, strongly jointed sandstone strata that are frequently interbedded with shales. Individual sandstone strata range in thickness from 60 cm to more than a metre, whereas shale beds are between 1 and 2.5 cm thick [3]. The frequency and quantity of the arenaceous material are noticeably increasing in the direction of the north. A series of alluvium that is representative of quaternary deposits are characterised by the predominance of silty and clayey material and, occasionally, sandy to pebbly in texture. In Table 1, each unit's litho-character and simplified stratigraphic succession are shown.

Table 1 Stratigraphic succession of the study area [4]

Litho unit	Age	Description
Alluvium	Quaternary-holocene to pleistocene	Clay, silt, sand, pebble and boulder deposits
Unconformity		
Barails	Oligocene to upper eocene	Massive to thickly bedded sandstone. Alternations of shale and sandstone. Flyash sediments of turbidite character
Gradational contact		
Disangs	Eocene to upper cretaceous	Dark grey to black, splintery and earthy coloured shales, siltstones and sandstones showing occasionally rythmite characters
Unconformity		
Basement complex: Unseen		

2 Methodology

The methodology followed for the analysis of the stability of slope is:

a. Marking the project site (Langdeibung) using polygon tool from Google Earth Pro.
b. To extract DEM data for the project site from Global Mapper using the mark area of the site from Google Earth Pro.
c. To generate elevation profile graph in QGIS using extracted DEM data from Global Mapper.
d. Transferring the elevation profile data to GeoStudio.5. Creation of the elevation slope of the project site in GeoStudio.
e. Analysis of Factor of Safety in GeoStudio.

The project is classified into two parts, the first part falls under the extraction of DEM format from Global Mapper using the marked area of Google Earth's polygon tool along with the preparation of data from the DEM in QGIS and the second part is the analysis of slope stability from the data prepared in QGIS using GeoStudio. The use of Google Earth and Global Mapper is to ease the extraction of elevation data for the project.

Google Earth is primarily used to mark the project location since it is simpler to mark the specific area as shown in Fig. 2. Transferring the KMZ file for the marked area to Global Mapper. The necessary DEM file for Global Mapper can be simply extracted using the online sources tool. The indicated area's KMZ file from Google Earth can be utilised as a reference layer.

Two types of DEM data are available worldwide in Global Mapper:

1. SRTM Worldwide Elevation Data (1-arc-second Resolution, SRTM Plus V3)
2. ASTER GDEM v2 Worldwide Elevation Data (1 arc-second Resolution)

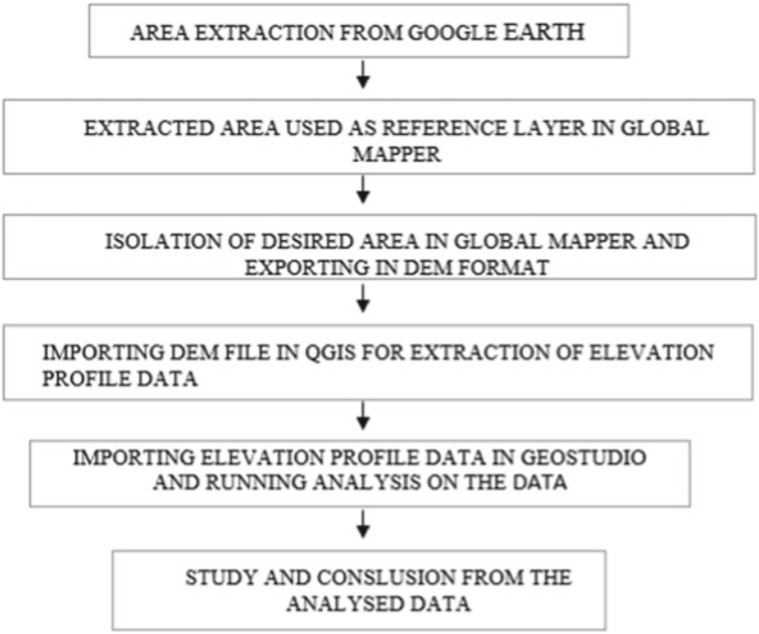

Fig. 1 Flow chart for the project

In Global Mapper, the SRTM Worldwide Elevation Data is used as a map model for elevation as shown in Fig. 3. Using the KMZ file as reference layer, the SRTM data for the project site can be extracted. The SRTM data available worldwide in Global Mapper is 1-arc-second resolution, which means that the size of the pixel in making the elevation data is 30 m. It is to be noted that the smaller the resolution (say 5, 10 m), the more accurate the data and vice versa. The flowchart for the project is shown in Fig. 1 (Fig. 2).

3 Results

The DEM data of the chosen layer from Global Mapper, displayed in Fig. 3, is imported into QGIS, where a 10 m contour is created as indicated by the blue line in Fig. 4. Drawing a profile elevation in the west-to-east direction produces elevation profile data in the form of elevation-distance in an excel spreadsheet. To determine the factor of safety, the data is sent to GeoStudio for a slope stability analysis.

Geostudio is used to import the elevation profile data exported from QGIS for additional analysis. A piece of software called Geostudio is used to examine the stability of various 1D, 2D, and 3D geometries and structures. In order to handle complex analyses of slope stability, pore-water pressure, earthquake, wind load and

Fig. 2 Marked area for the project site

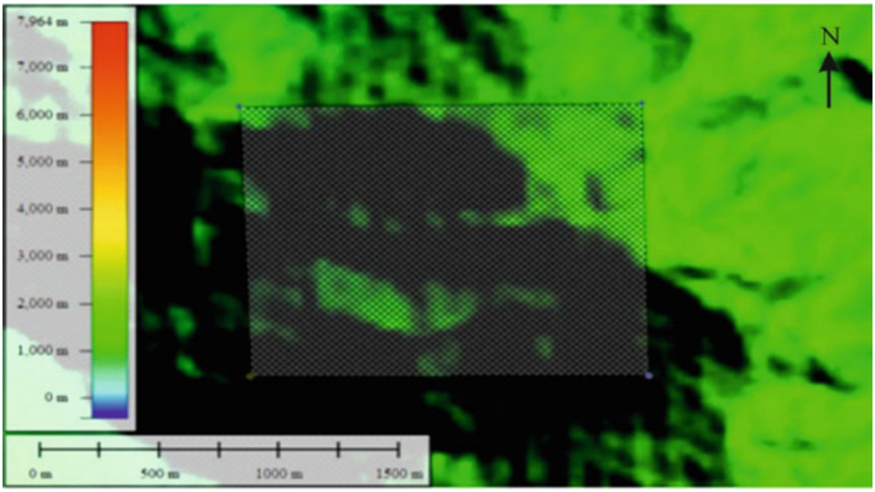

Fig. 3 Marked area of the project site along with elevation data

direction, etc., Geostudio is a limit equilibrium software. The objective of the slope stability analysis is to determine whether the area is stable or not. This is done by finding out the FOS for the area. The stability analysis for these finite slopes includes methods such as the Morgenstern-Price method, Bishop method, Spencer method, Janbu method, Ordinary Slices method, and Sarma method where the Morgenstern-Price method is used as a method of analysis for this project. A portion of the elevation profile data extracted from QGIS is shown in Fig. 4.

The line created to generate the data as illustrated in Table 2 is used to determine the distance and elevation for the elevation profile data. For ease of analysis, the

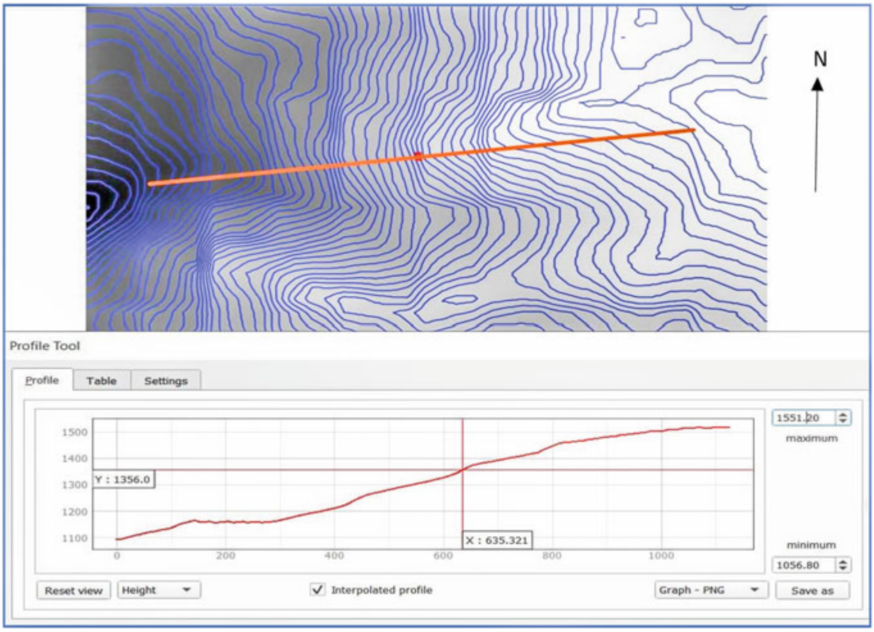

Fig. 4 Extraction of elevation profile graph in QGIS

elevation from mean sea level is ignored and the lowest elevation for the data is equalised from 0. The profile section generated from GeoStudio w.r.t. the distance and elevation data, is shown in Fig. 5.

The shape and size of the hill from Fig. 5 is obtained by plotting the actual value of the data and not a scaled down value.

As the hill's elevation changes from highest to lowest in a left-to-right direction in Fig. 6, the slip surface for the analysis is taken from left to right. A slip surface is one where there is a chance that the ground or other debris will fail. The number of important slip surfaces is assumed as one, and the entry and exit type slip surface is chosen. Where the factor of safety is lowest is where the crucial slip surface will appear.

The soil found in the area consists of shale, sandstone, alluvial, etc. Specific gravity of the area is around 2.36, and the natural water content of the area is 9.08%. The unit weight of the soil is 23.6 kN/m^3 with 7 kN/m^3 (kPa) as the cohesive stress and the angle of internal friction (phi) as 29°. The bed rock begins around 2 m below the topsoil. Figure 7 displays the topsoil and bedrock materials along with their corresponding colours. Since the thickness of the topsoil is so much thinner than the thickness of the bedrock, it will be difficult to see the colour of the topsoil in a cross section of the hill slope.

The slope after analysis is shown in Fig. 8, with the most important portion of the slope highlighted in red and coloured green. The slope's critical factor of safety is discovered to be 1.026, which is just a little bit above the permissible level.

Table 2 Data showing distance and its corresponding elevation (altogether there are 126 points taken)

Distance (m)	0	8	15	23	32	44	57	66	75	84	95	105	116	129	144	159	175	189	205	219	227	235	241
Elevation (m)	451	451	449	449	447	445	444	443	441	439	438	437	435	433	433	431	429	427	425	425	423	421	420

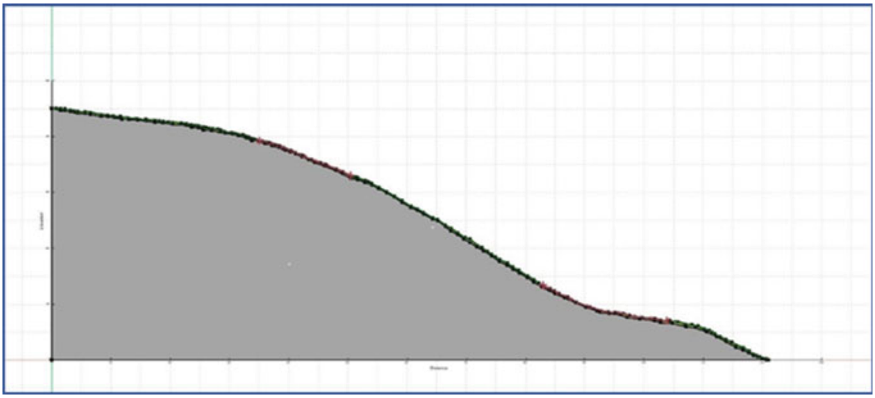

Fig. 5 Generated slope from the elevation profile data in GeoStudio

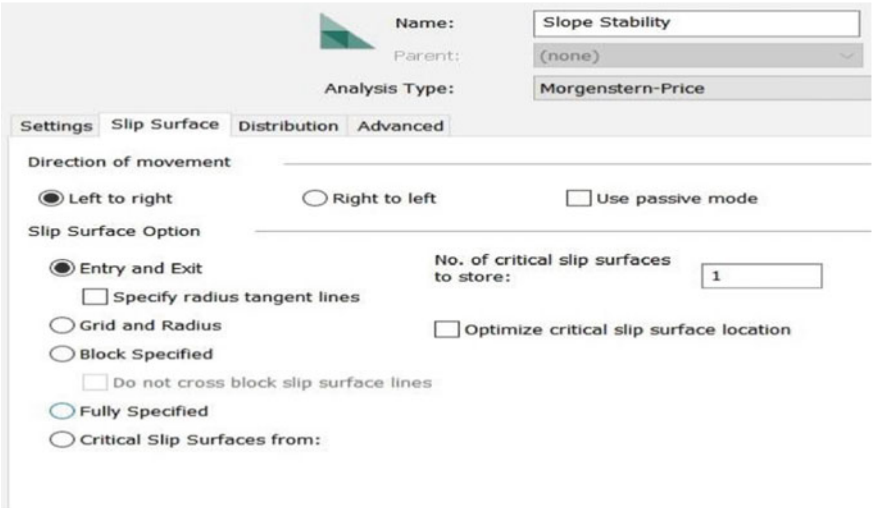

Fig. 6 Image showing analysis type along with options for slip surface

The comparison between the data from the elevation profile graph, where the area of the crucial factor of safety is surrounded by a black colour eclipse, and the Google Earth image, where the critical factor of safety is located, is shown in Fig. 9. Through it, the NH-53 passes. The area looks to be developing a crown, which is a warning sign for a potential landslide, according to the Google Earth image. Additionally, the soil doesn't appear to have any vegetation to hold it down.

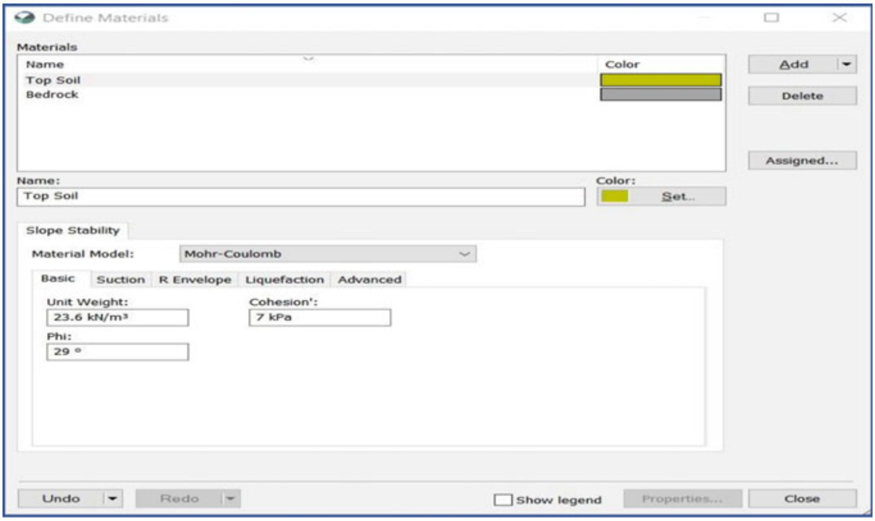

Fig. 7 Image showing defining of materials for the hill slope

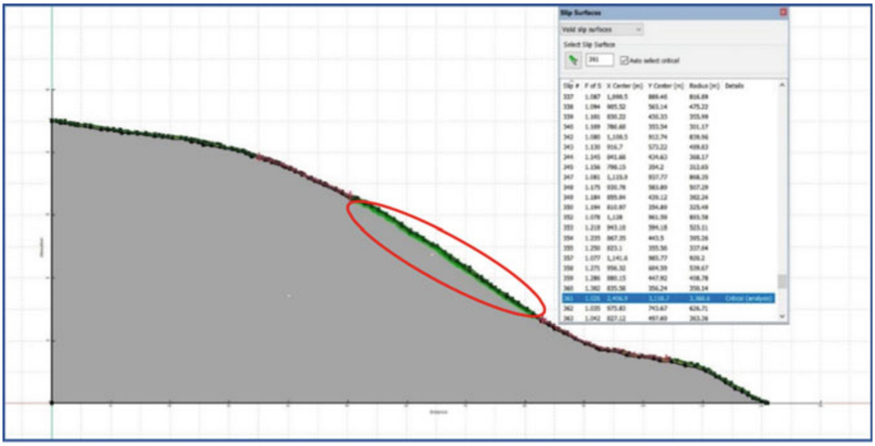

Fig. 8 Image showing the location of the area for the critical factor of safety

As per the analysis, the critical factor of safety is found to be 1.026. This value is above the most critical factor of safety which is 1. The area will be stable as long as there is no external disturbance such as excessive rainfall, earthquake, vibration from heavy loaded vehicles etc.

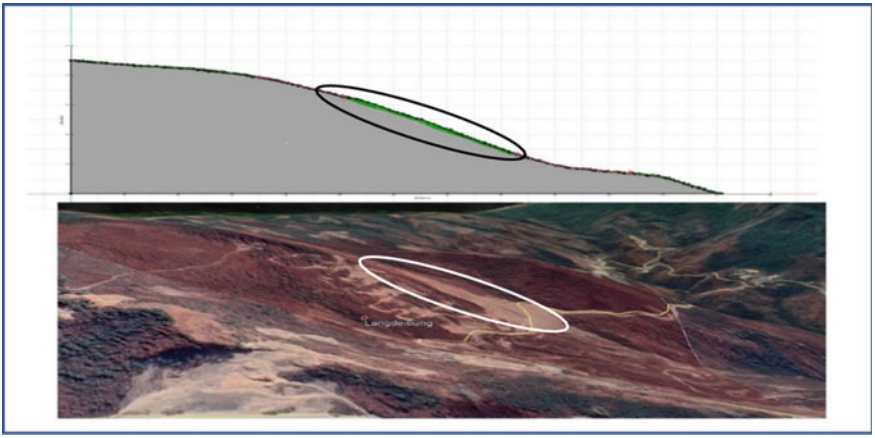

Fig. 9 Image showing comparison between hill slope in GeoStudio and image from Google Earth

4 Conclusion

The analysis for factors of safety and data extraction was carried out as a part of our project. The study for this project helps us in better understanding the knowledge about landslide and also in the field of remote sensing. The accuracy of DEM and profile elevation data can be improved if the high-quality DEM data is available to the public or the data is purchased from the government or performing drone surveying at the site. This study helps us to understand the difficulties faced when acquiring data through the process of remote sensing.

The stability of a slope can be increased by the following methods:

1. Slope flattening 2. By constructing proper drainage 3. Densification by vibrofloatation or terra probe 4. Grouting and injection of cement concrete mixture 5. Constructing sheet piles and retaining walls.

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