Analysis of Geological Structures for Road Cut Failures: A Case Study Along Balangoda – Haputale Main Road

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Abstract: This study is focused on the causes for the road cut failures and suggest a methodology to design road orientation to minimize cut failures considering geology of the rock present in the area. In the past few years, several road cut failures have been recorded in Sri Lanka and there are development plans to construct expressways in hilly areas of the country. Hence, this study is important to minimize and control road cut failures while designing road orientation in a scientific manner. Several of studies were carried out to find the relationship between rock properties of the slope and occurrence of cut failures. This study helps to create a forecasting model for different scenarios. In this study, in order to validate the outcomes, some software were used. "DipAnalyst 2.0" is one of them and is a slope stability analysis software, which is designed to perform kinematic analysis for rock slopes and also calculating factor of safety values for plane and wedge failures based on the limit equilibrium theory. In this study, we identified that rock of the study area mainly dip towards the road (dip direction is parallel to the road direction). It is the main cause for lot of failures.

Keywords: Road Cut Failures, Geological Structures, Road Design, Optimum Road Orientation

1. Introduction

Slope failures along hill cut road slopes are the major nuisance for commuters and highway planners as they put the human lives at huge risk, coupled with immense monetary losses [1]. This study is designed to fulfill timely need of scientific method to analyse road cut failures. Through this study's main goal is to build a relationship between structural features of a rock mass and possibility to occur failure. Balangoda – Haputale road is one of the roads, where many cut failures occured during the past few years. Hence, this road is selected for this study. Balangoda – Haputale area is located in a special geological area.

Balangoda – Haputale road was constructed in the boundary of one of the major terrains: The Highland Complex. The Highland Complex (HC) is composed of inter banded metamorphic rocks. It is broad and running across the center of the island from southwest to northeast. Further, it is composed of Granulite facies rocks, Charnokitic rocks, Charnokitic gneiss, Marble, Quartzite and Quartzofeldspathic gneiss [2].

After collecting field data from this area, same data were analysed both manually and using software. The relationship between those road cut failures and the geological formation of the existing bed rocks can be interpreted by knowing about the rocks (fractures, gouges, joints, faults

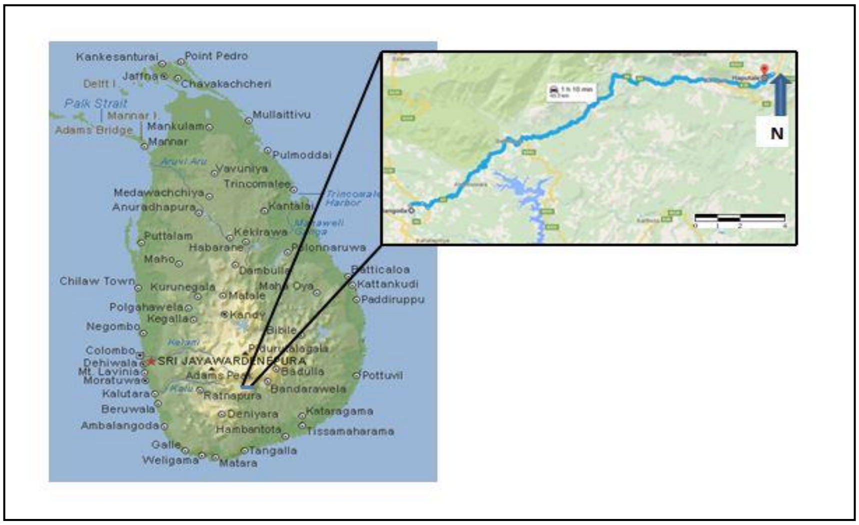

Figure 1: Study Area, Balangoda – Haputale main road

and discontinuities). Imaginations of 3D model of all of these rock formations can easily be constructed using dip and strike of these formations. Early days stereographic projections were used to perform similar analysis, which was a time consuming method.

The main objective of this study is to present a set of recommendations to choose the most suitable road orientation for a particular area in a hilly terrain.

2. Material and Methods

Mainly our research project was based on road cut failures. We had to select better areas containing of cut failures along the main road where there were disturbances to day to day activities, vehicles and people.

2.1 Planing and colleting of field data

Along the road from Balangoda – Haputale, 54 locations were identified where the rock outcrop exposed due to road cut. In these locations geological features of the rock such as dip, strike, and slope angle, slope direction, joint, joint intensity and etc. were recorded.

2.2 Analysis of data

First part of the analysis is to confirm the suitability of the "DipAnalyst 2.0" software's kinematic analysis process to rock types in the study area.

It was important to find the accuracy of the software because all the designing, predictions are based on the software. This was done by comparing real situation or actual conditions with the output results given by the software. Here percentage of accuracy was measured by number of items of actual cut failures in the field and how many results match with these actual results. The accuracy for the plane failure was also calculated to check the reliability of the software; how many locations and conditions for plane failure were satisfied in the field and the output data from the software at the locations where actually cut failures had taken place.

After confirmation of its suitability, the software can then be used to analyse further details.

The main target was to present the most suitable scientific method to identify possibility of cut failures during the designing stage.

When designing the road we can easily change road direction and slope angle based on other parameters. Hence, using software most suitable road orientation and slope angle can be determined easily.

In order to gain the best slope angle, slope angle value was changed while cut slope direction was unchanged. For some specific slope angle value, the number of failure plane set became zero. It was taken as the best slope angle value. Likewise, to gain the best cut slope direction, slope angle was unchanged and the cut slope direction values were varied until failure set became zero [3].

Final step was to consider joint patterns, for some region along the road overall joint direction and overall road direction was plotted. Hence, got the joints parallel or perpendicular to the road direction. This representation was used to predict whether joints are caused for cut failures or not.

3. Results

According to the main objectives of the project, results are also present under three main headlines.

3.1 Check the accuracy of software comparing with actual condition

Total number of locations considered in the analysis = 54

Table1: Comparing with actual condition

Situation of Failure (Deviation)		Number of Locations	Percentage (%)
Real observation	Software		
Less	No	4	7.4
High	No	7	12.9
No	Yes	4	7.4
Total deviation		15	27.8

3.2 Find out most suitable slope direction and slope angle for each location

Example location
Original details of L16
Northing - 179655
Easting - 220593
Slope direction - 115
Slope angle - 90
Dip angle – 10
Bearing - 120
Friction angle - 38
Observation - rock fall

Joint details
No 1 –Dip - 80 SW
Bearing - 120
No 2 –Dip – 90
Bearing – 10

Failures from software
Plane set – 2
Wedge set – 1

Results from software

Table 2: Fixed cut slope direction value and change slope angle

Slope angle	90^0	80^0	70^0
No of plane failure set	2	0	0
No of wedge failure set	1	0	0

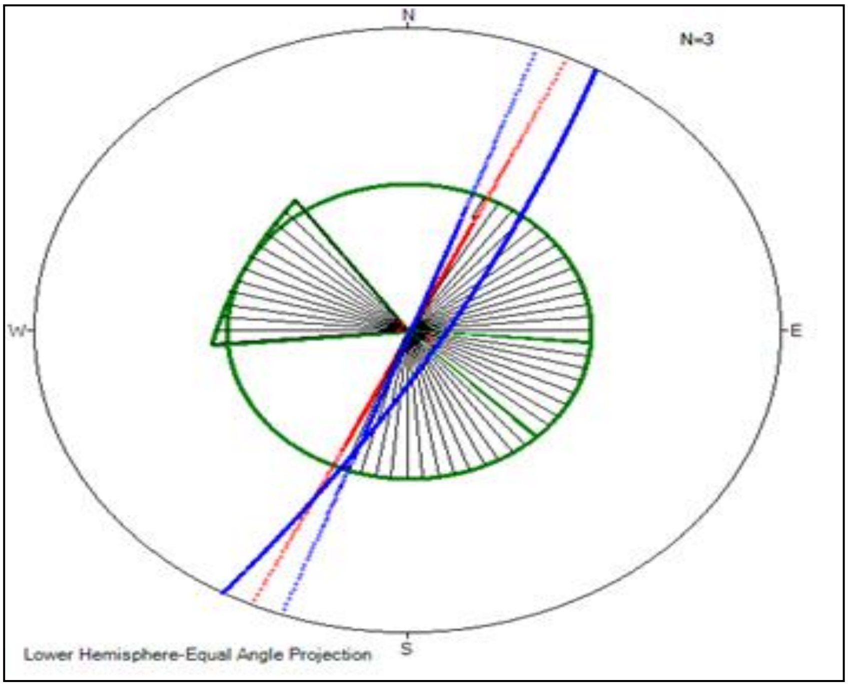

Figure 2: Stereonet of LH16

Table3 : Fixed cut slope angle value and change slope direction

Slope direction	105^0	95^0	85^0	75^0
No of plane failure set	2	2	1	0
No of wedge failure set	1	0	0	0

3.2 Analyse joint pattern and it's relation to the failure using rose diagram

When analysing joint patterns considering the slope direction/road direction, followings were observed.

In danger zones bearing of the joint set is perpendicular to road direction. It will cause failure. (Two joints sets are perpendicular to each other. It may cause wedge failure).

Stable zones show that road direction and joint bearing are nearly same either parallel to each other.

4. Discussion

The main purpose of this research project was to develop and design new road direction without any failures, in otherwords safety road during the journey along the road by using the "DipAnalyst 2.0" software. The main focus of this project was to check the places where already failures happened and places of possibility of happening a failure into the road in between Balangoda – Haputale uphill roadway in the future. At these areas, the influence of rock types, geological features and structural features of the rock not only out crops but also faced to the cut slope also were analysed.

Measurements such as dip angle, dip direction, road directions, joint measurements, spacing were measured and analysed by the software at each location of cut failures. However, in extreme cases the software results were more deviated from the actual situation, it showed no cut failure indications at some locations, however actual failures were there. It was very clear that lack of information related to failures, making of false assumptions, consideration of few variables may have caused those deviations.

There are a few elements which govern the stability of cut slopes; rock type, mineral composition, geological structures, groundwater condition, slope angle, Road direction and relationship with geological structure and weathering effect.

In this project, lack of considerations about the rock type at each place, mineral compositions, and quantity of weathering may cause some deviations of results. The groundwater conditions and surface water was not considered here. The influence of groundwater and surface water [4] is more important in this analysis, because rainfall data shows that Balangoda- Haputale area is having a long rainy season per year.

The difficulties such as reaching some locations where cut slopes had occured and getting approximate measurements have affected the results.

5. Conclusions

Currently, a number of uphill road projects are in progress. In Sri Lanka, there are number of roads constructed through hilly areas. Also several important road development projects and new projects have been planned. However, when such roads are designed, a number of facts have to be considered specially risk analysis is important. Although road cut failure is a critical issue, that cause fatal accidents, when construct roads with cut face there is no proper system to predict and locate road and its direction to avoid cut failures. When studying constructed roads their factors are decided mostly according to the economic factors. Scientific method of analyzing and predicting road cut failures using properties and structures of rock is a timely need. Hence, this research project can be considered as a well focused scientific research to minimize road cut failures in the future.

6.Recommendations

Proposals for design methodology

One of the main necessity is avoiding or reducing the current cut failures along the road. To achieve this, data should be collected at such locations and input to the software. The current situation of the place should be studied next and this will provide the best slope angle which is suitable to the particular location that would result in a minimum number of cut failures. According to the slope angle which is given by the software, the slope angle at each location should be changed with suitable measures.

When design a new road consider the regional geology and rock types, input the data into the software and design the road direction and the slope angle of cut slopes to minimize the cut failures.

These methodologies may be the better plans to reduce the cut failures and for a safety road.

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