DETERMINATION OF GEO-HYDRO SEISMIC IMPACT ON SLOPE STABILITY AT EAST OF MALAYSIA USING LIMIT EQUILIBRIUM ANALYSIS

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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries and references, which have been duly acknowledged.

6 July 2023

Mohammad Haziq Bin Rosly
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ABSTRACT

Rainfall and earthquake have been identified as the highest contributing factors that lead to landslide occurrence worldwide. This is due to rainwater infiltration have caused the groundwater to increase and decrease creating fluctuation of groundwater level. Whereby earthquake have deteriorated the shear strength of soil due to the dynamic loading. Further to that, Ranau and Kota Belud, Sabah have been selected in this study due to the presence of both contributing factors and located within the same geological formation. GeoStudio was utilized to perform the slope stability analysis by using Slope/W and Seep/W features using soil parameter input obtained from soil investigation works and lab testing. Also, statistical analysis was conducted to develop Intensity Duration Frequency (IDF) graph using existing data for rainfall intensity calculation. The objective of this study is to identify the impact of rainfall and earthquake to factor of safety of slope at RNU1, KB1 & KB2. Based on the IDF graph developed using data obtained has shown that Ranau and Kota Belud are having dense rainfall every year with maximum rainfall intensity is ranging between 175.2 mm/hr to 220.3 mm/hr. As for earthquake, Ranau recorded the highest seismic activity with 1,093 number of events between year 2000 until 2020. While Kota Belud recorded not significant seismic event for the similar window period. From the slope stability without earthquake, and the factor of safety recorded at Kota Belud is ranging between 2.333 to 3.375 while Ranau recorded factor of safety between 2.431 to 2.572. For the slope stability with earthquake, four earthquake values were introduced are 0.03g, 0.06g, 0.09g and 0.12g. Presence of earthquake have dropped the factor of safety for the Kota Belud approximately between -16.8% to -9.6%. while for Ranau the factor of safety dropped roughly within -9.3% to -7.7%. Slope stability analysis has indicated that there is fluctuation of pore pressure during rainfall infiltration into the ground. In conclusion, combination of rainfall and earthquake resulted to catastrophic landslide that impacting the pore pressure and frictional strength respectively.

ABSTRAK

Hujan dan gempa bumi telah dikenal pasti sebagai faktor penyumbang tertinggi yang membawa kepada kejadian tanah runtuh di seluruh dunia. Ini disebabkan penyusupan air hujan telah menyebabkan air bawah tanah meningkat dan berkurangan menyebabkan turun naik paras air bawah tanah. Di mana gempa bumi telah merosot kekuatan ricih tanah disebabkan oleh beban dinamik. Selain itu, Ranau dan Kota Belud, Sabah telah dipilih dalam kajian ini kerana kehadiran kedua-dua faktor penyumbang dan terletak dalam formasi geologi yang sama. GeoStudio digunakan untuk melakukan analisis kestabilan cerun dengan menggunakan ciri Cerun/W dan Seep/W menggunakan input parameter tanah yang diperoleh daripada kerja-kerja penyiasatan tanah dan ujian makmal. Juga, analisis statistik telah dijalankan untuk membangunkan graf Intensity Duration Frequency (IDF) menggunakan data sedia ada untuk pengiraan intensiti hujan. Objektif kajian ini adalah untuk mengenal pasti kesan hujan dan gempa bumi terhadap faktor keselamatan cerun di RNU1, KB1 & KB2. Berdasarkan graf IDF yang dibangunkan menggunakan data yang diperoleh telah menunjukkan bahawa Ranau dan Kota Belud mengalami hujan lebat setiap tahun dengan intensiti hujan maksimum adalah antara 175.2 mm/jam hingga 220.3 mm/jam. Bagi gempa bumi, Ranau mencatatkan aktiviti seismik tertinggi dengan 1,093 kejadian antara tahun 2000 hingga 2020. Manakala Kota Belud merekodkan kejadian seismik yang tidak ketara bagi tempoh tingkap yang sama. Daripada kestabilan cerun tanpa gempa bumi, dan faktor keselamatan yang dicatatkan di Kota Belud adalah antara 2.333 hingga 3.375 manakala Ranau mencatatkan faktor keselamatan antara 2.431 hingga 2.572. Bagi kestabilan cerun dengan gempa bumi, empat nilai gempa bumi diperkenalkan ialah 0.03g, 0.06g, 0.09g dan 0.12g. Kehadiran gempa bumi telah menurunkan faktor keselamatan bagi Kota Belud kira-kira antara -16.8% hingga -9.6%. manakala bagi Ranau faktor keselamatan menurun kira-kira dalam -9.3% kepada -7.7%. Analisis kestabilan cerun telah menunjukkan bahawa terdapat turun naik tekanan liang semasa penyusupan hujan ke dalam tanah. Kesimpulannya, kombinasi hujan dan gempa bumi mengakibatkan tanah runtuh yang masing-masing memberi kesan kepada tekanan liang dan kekuatan geseran.

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IDF	-	Intensity Duration Frequency
LEM	-	Limit Equilibrium Method
FEM	-	Finite Element Method
FOS	-	Factor of Safety
SWCC	-	Soil Water Characteristic Curve

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CHAPTER 1

INTRODUCTION

1.1 Background

Developing country like Malaysia is having a few mega infrastructure projects such as Mass Rapid Transit (MRT), East Coast Rail Link, Pan Borneo Highway and few others. For such development, geotechnical engineering is one of the critical areas that should be investigated in detail to avoid failure and asset damaged. Slope failure or landslide is one of the major issues related to geotechnical engineering especially when it is involving construction of facilities across hilly area and challenging terrain location.

Malaysia have undergone rapid development since 1980s and since then, the availability of strategic and suitable low-lying areas for the development have become very limited as mentioned by Rahman and Mapjabil (2017). As the result, construction of building and facilities on hilly terrain has increased, particularly in areas adjacent to densely populated cities thereby exposing the urban communities to an increased risk of landslide occurrence as mentioned by Rahman and Mapjabil (2017).

Malaysia is not a precipitous country, but slope failures and landslides are happened frequently throughout the country. Data collected from 1993 until 2011, it shows that around 23 major landslides were reported in Malaysia and causing a total loss of more than 100 lives. In addition, from 1973 until 2007, it was estimated around US dollar 1$ billion economic losses due to the landslide. It has indicated an alarming result of death and economic lost due to landslide in Malaysia for the past 20 years. It was recorded there were 21,000 landslide prone areas throughout Malaysia. 16,000 of the locations are located at Peninsular Malaysia while about 3,000 locations located in

Sabah and the remaining 2,000 locations are located at Sarawak.

Rahman and Mapjabil (2017) also mentioned that slope failure shall be carefully studied starting from the root cause up to the mitigation proposal for a long-term solution. It is found that most landslides emerge on manmade slopes, and this is in essence the upshot of uncertainties related to human factors like insufficiency in design, failing in construction or lack of maintenance. However, slope failure or landslide will not happen without external forces disturbing the stability of the slope. This external force can be considered as triggering factor. Based on study by Kazmi et. al. (2016), the common triggering factors are rainfall, earthquakes, volcanic activities, change in groundwater, disturbances and change of slope profile by construction activities or combination of the factors.

In addition, Kazmi et. al. (2016) mentioned that triggering factor in Malaysia contributed around 58% from rainfall and followed by loading changes which contributes around 35% and most failures recorded are happen during rainy the season. This has indicated that water is the main cause landslide prone to happen in Malaysia. Prior to the selection of the mitigation measures of slope failure, the slope stability analysis needs to be done to determine the condition of the slope before or during it is fail. The basic principle of slope failure is when the acting force which are forces that causing the slope mass to move exceed the resisting force which are the forces that resist or keep the slope mass intact. This can be calculated through slope stability analysis to determine the factor of safety.

Slope stability analysis is required to determine the Factor of Safety (FOS) of slope. Furthermore, rainwater infiltration shall be taken into consideration during slope stability analysis. This study is conducted to identify the Factor of Safety of Slope within Ranau and Kota Belud under Rainfall Intensity with impact from earthquake event. The location for this study has been specified to be at East of Malaysia which are Ranau and Kota Belud, Sabah due to the repeated landslide occurrence recorded within these areas that suspected to be the consequence of heavy rainfall and unexpected earthquake occurrence. Figure 1.1 shows the location of the Ranau and Kota Belud.

Rainfall intensity is obtained from rainfall data extracted via rainfall station and further developed into rainfall intensity with different Average Recurrence Interval (ARI). Fluctuations of groundwater level is recorded for each different limits together with the respective Factor of Safety in the analysis using GeoStudio software Slope/W and Seep/W feature. Whereby, the earthquake impact is analyze using the Slope/W by incorporating the earthquake value.

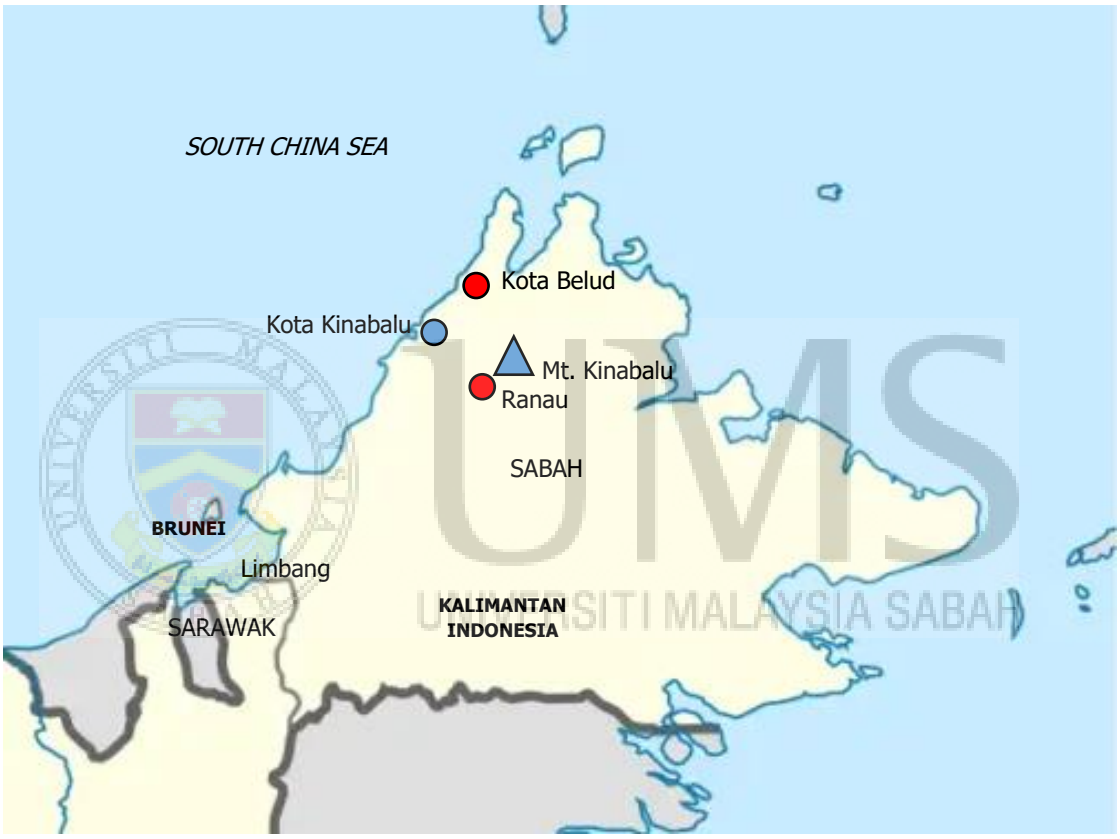
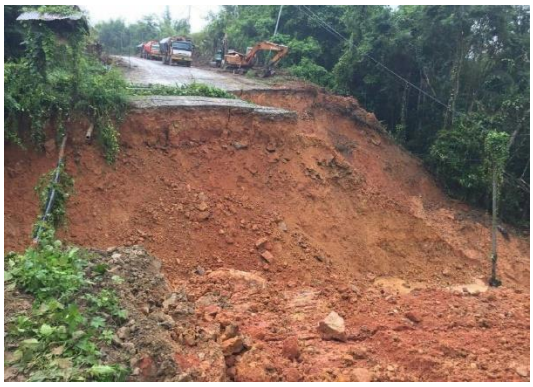


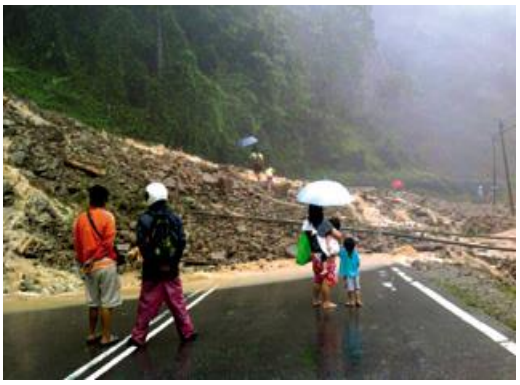
Figure 1.1 : Map of Sabah

Figure 1.2 shows the previously reported landslide events occurred at Sabah within year 2020 until 2022. Referring to Figure 1.2, all of the landslide events occurred are during or right after rainfall as per indicated in the picture with presence of wet road surface, debris flow and wet soils. Besides, the landslides also occurred on the road that was being used by public for daily activities. Therefore, the road linkage has been blocked due to the landslides and cause the public unable to cross and creating

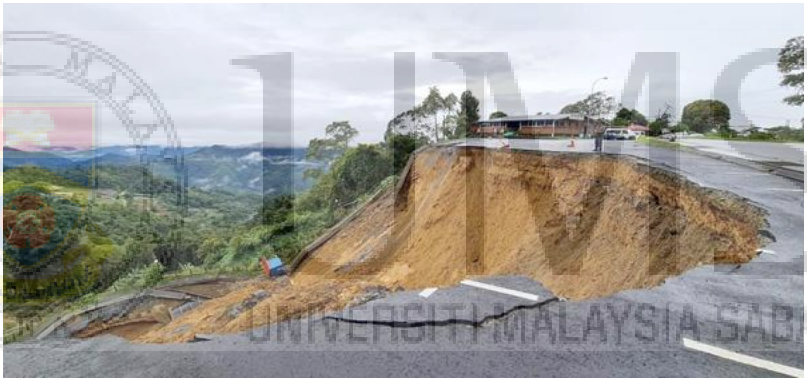
safety concerns towards the surrounding area.



a) Tambunan



b) Ranau



c) Kundasang

Figure 1.2 : Landslides Event at Sabah within year 2020 until 2022

1.2 Problem Statement

Sabah is currently having vast highway construction such as the Pan Borneo Highway that involved in combination of expansion of current road and exploration of new road. Due to the natural geomorphological condition of Sabah that consist of hilly terrains, the exploration of hilly area has started, and it is involving cut and fill activities to get