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Forensic assessment on near surface landslide using electrical resistivity imaging (ERI) at Kenyir Lake area in Terengganu, Malaysia

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Abstract

Electrical resistivity method which was championed by geophysicist has increasingly popular in civil engineering application due to its efficiency in term of cost, time and data coverage. This study performed with particular reference to electrical resistivity imaging (ERI) in evaluating the slope failure at Kenyir Lake, Malaysia. During the data acquisition, two lines of ERI was performed using ABEM Terrameter LS set of equipment based on Schlumberger array. Moreover, electrical resistivity anomaly was managed to detect the presence of geological structure with particular reference to fault and rock discontinuities which associated to low resistivity anomaly. The heterogeneous of the subsurface material presented using integrated analysis of ERI and borehole data enabled forensic assessment of the landslide. The combination of heavy rainfall and existing geological structure (weakness zone) was believed to be a major factor which triggered this failed slope. This result was applicable to assist the geotechnical engineer in design concept recommendation of the slope remediation with fast, less cost and wide data coverage. Finally, ERI results with borehole verification was applicable to be adopted in landslide forensic assessment based on slope geomaterials stiffness variations generated after the slope movement.

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Keywords: Electrical resistivity method; electrical resistivity imaging; forensic assessment; landslide; resistivity anomaly; geological structure

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1. Introduction

Forensic assessment in engineering is the investigation of materials, products, structures or breakdown components which may cause injury or property damage. Engineering forensic investigation used to identify causes of failure for rehabilitation or mitigation purposes or to assist a court in determining the facts of an incident. The process of engineering forensic assessment involve with investigation and data collection related to the materials, products, structures or components that failed such as inspections, collecting evidence, testing and measurements, developing models, obtaining prototype model and conducting experiments. Specifically in geotechnical forensic engineering, it involves analysis of a project, site conditions, or construction from a geotechnical point of view which can be performed during the design phase (e.g. checking calculations and engineering assumptions) or during or after the construction of the project (e.g. providing quality assurance or address issues that arise during or after construction) for rehabilitation purposes. Common related issues involving geotechnical forensic evaluation were ground settlement, slope instability, foundation failure, excavation failure, collapsible soil, soil corrosion, etc. Forensic geotechnical engineering is growing increasing important in most of the countries where the foundation failures may lead to litigation and even criminal action [1].

Conventionally, site investigation data used in ground instability assessment was based on borehole exploration method [2-4]. However, several limitations have been experienced related to conventional method due to its high cost, time consuming and limited data coverage. Furthermore, conventional method was based on the drilling data which represent only single point information (1-D) at the actual drilling location thus enables some degree of uncertainties due to the boring interpolation which consider critical in a complex geological area [5-7]. Lots number of drilling point was required in order to obtain higher accuracy of the subsurface results thus increasing cost and time of the project. Moreover, conventional method was based on drilling process which able to increased site damageability due to its destructive approach in field exploration. Therefore, the solutions to these challenges will require multidisciplinary research across the social and physical sciences and engineering [8]. Hence, geophysical method offers the chance to overcome some of the problems inherent in more conventional ground investigation techniques [9]. Geophysical techniques contributes several advantages such as it can be performed fast and low cost and has the ability to cover greater areas more thoroughly [10-13] and [6].

As reported by [14], Cummings and Clark have found that geophysical instruments used in landslides evaluation were heavily based on seismic refraction and electrical resistivity methods thru basis of interpretation of obvious different physical properties of the sliding materials compared to the underlying undisturbed sediments or bedrock. However, seismic refraction method experienced several limitations due to its physics fundamental constraint such as hidden and thin layer, inadequate sources, noisy and involve lots of data reduction thus promoting to increase the results ambiguity. Nowadays, electrical resistivity imaging (ERI) has greatly being improved in term of survey coverage, field measurement, processing techniques thus applicable to resolve complex geological structure compared to the previous sounding technique [15]. From the past, electrical resistivity survey has widely used as a tool for investigating the condition of the slope especially in landslide studies during the pre and post construction stages [16-21]. According to [22], landslides areas has widely being investigated using ERT technique with the aim to reconstruct the slope and body geometry, to locate the possible sliding surface, to identify vulnerability surfaces, to estimate the slide material thickness and to detect areas with high water content. According to [21-24] and [25], geophysical method such as the electrical resistivity can be practically adopted to determine the internal distribution of materials within a slope, identifying sliding surface geometry, water effect on slope, landslide material physical properties and mass movement. Furthermore, electrical resistivity data was able to show a two layer system in which the low resistivity landslide mass cross-cuts the resistivity layering in the higher resistivity sediments [26]. However, the standard performance of individual geophysical method always depends on fundamental physical limitation (e.g. penetration, resolution, and signal to-noise ratio) [21] and [27] Moreover, geophysical methods are unable to stand alone in order to provide solutions to any particular problems [28] and [29]. Hence, strong verification from direct test (field test, experimental test, etc.) was important to support the electrical resistivity anomaly interpretation. A number of researchers have shown that the integration of geophysical survey and geotechnical data can provide a meaningful data and interpretation for subsurface profile characterization [30-32] and [20]