UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF RISK ASSESSMENT AND EXPERT SYSTEMS FOR CUT SLOPES

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By

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Slope Assessment System (SAS) was developed to evaluate the risk of the cut slopes that will be used for slope monitoring, management and maintenance. The system was developed through consultations with field experts and field studies. The purposes of the consultations were to identify risk parameters. The risk rating was determined through field studies and then assigned to every parameters. Based on the field results, the risk hazard value (G-Rating) was proposed. The discontinuity data were analysed using stereographical method for Potential Instability (PI) Statement. By combining the PI Statement and G-Rating, the Slope Evaluation Statement (SES) was developed. The SES was divided into four categories: No Risk, Low Risk, Medium Risk and High Risk. To complete the evaluation process for SAS, suggestions were made for each category. The SAS was then transferred into a computer system which is the D-Slope. The D-Slope is an expert system (ES) application to evaluate the cut slope conditions. The field data was stored in a database which can be updated and referred to through the ES. The possible roles for D-Slope are as an assessor and a peer system for cut slopes assessment.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah.

PEMBANGUNAN SISTEM PENILAIAN RISIKO DAN SISTEM PAKAR UNTUK CERUN POTONGAN

Oleh

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Sistem Penilaian Cerun (SAS) telah dibina untuk menilai risiko cerun-cerun potongan yang akan digunakan bagi pengawalan, pengurusan dan penjagaan cerun. Sistem ini dibina melalui temubual dengan pakar-pakar dan kajian di lapangan. Tujuan temubual dengan pakar-pakar adalah untuk menentukan parameter-parameter yang berisiko ke atas ketidakstabilan cerun. Kadar risiko setiap parameter ditentukan melalui kajian di lapangan. Berdasarkan keputusan kajian, nilai risiko (G-Rating) dicadangkan. Data diskontinuiti dianalisa menggunakan kaedah stereografikal bagi menentukan Potensi Ketidakstabilan (PI). Melalui kombinasi PI dan nilai G-Rating, Catatan Penilaian Cerun (SES) dibentuk. SES dibahagikan kepada empat kategori: Tiada Risiko, Risiko Rendah, Risiko Pertengahan dan Risiko Tinggi. Untuk melengkapkan proses penilaian pada SAS, cadangan baikpulih cerun telah dibuat pada setiap kategori. SAS seterusnya dipindahkan kepada sistem komputer yang diberi nama D-Slope. D-Slope adalah aplikasi sistem pakar (ES) bagi menilai cerun potongan. Data kajian lapangan akan disimpan di dalam pangkalan data yang kemudiannya boleh dikemaskini dan dirujuk melalui ES. Tugas yang mungkin dijalankan oleh D-Slope adalah sebagai penasihat dan saling membantu pihak penilaian cerun dalan menilai cerun potongan.

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LIST OF ABBREVIATIONS

AR	Area Ratio
°C	Degree of Celsius
CH	Chainage
ES	Expert System
F	Faults
FoS	Factor of safety
GA	Geological Affected Area
G-Rating	Geological Rating
H, h	Height
HR	High Risk
IA	Investigated Area
J	Joints
km	kilometers
L, l	Length
LR	Low Risk
m	metres
mm	millimeters
MoF	Mode of Failure
MR	Medium Risk
NR	No Risk
PI	Potential Instability
R_i	Individual rating
R_{max}	Maximum Rating
RSD	Rock Slope Database
SAS	Slope Assessment System
SEA	Slope Evaluation Analysis
SES	Slope Evaluation Statement
α	Slope angle
ϕ	Angle of internal friction

CHAPTER I

INTRODUCTION

Background

Malaysia has a total land area of about 330,000 square kilometers. The length of road network totals almost 80 328 km, of which 15% traverses mountainous terrain that features steep to very steep slopes (Ab. Jalal, 2000). In most mountainous areas the topography is very steep and slope failures are often caused by the construction of roads. The warm and wet climatic conditions of Malaysia affect the weathering of the rocks to a great depth. Therefore, it is very important to construct roads on stable slopes and it should be noted that high-structure roads constructed on steep terrain often end up with failures of cut slope. Minimum attention has been given to the assessment of cut slopes when planning roads are done in mountainous areas. In fact, techniques of planning roads in mountainous areas have yet been generalized and at present, success of such work depended on individual knowledge and experiences of experts.

Slope failures often occur because the slopes are steeper compared to the equilibrium grade. Prolong intense rainfall and treacherous instable geological settings such as presence of permeable and unstable relict joints, dykes and unfavourable bedding planes are identified as major factors causing slope instability. In fact, in slope design process, it is difficult to include the geological structures in stability analysis. This is because most of the slope stability analysis will only require the strength parameters of the materials and the slope dimensions.

Slope failure occurrences are rather common in Malaysia and are associated with the development of hilly terrain and construction of roads and highways. The rapid economic development in Malaysia over the last decades has resulted in the construction of many new roads and highways. Previously constructed roads tend to follow the ground contours as far as possible to minimise the difficulties and costs of construction. The newer roads have been built to a much higher standard of alignment and this meant that cut slopes have become higher and it has been necessary to excavate in a wide range of geological profiles.

Many slope failures have been reported in Malaysia, for example the Highland Tower tragedy in 1993 which claimed 48 lives and the Bukit Antarabangsa landslide in 1999 crippled the livelihood of the people residing in that housing estate for a couple of days. Some of the slopes failed during construction and some only after many years of completion. Omar et al. (2001a) reported on continuous failure of cut slopes during construction of highway in mountainous areas. The complexity of geological structures is reported as one of the factors that contributed to the slope failures. It is not easy to predict when the slopes are going to fail. Once a slope fails, intensive manpower and finance are required for restoration.

Many studies on the prediction of slope failures have been carried out using statistical methods (Kobashi, 1973 and Othman, et al., 1992), which employed as many factors possible to enhance the accuracy of prediction. But there are some limitations on the statistical methods because factors influencing the occurrences of slope failure vary greatly depending on the characteristics of each region (Kobashi, 1973), and no means have been established to investigate conditions within slopes (Tsukamoto and Kobashi, 1991).

The large variations of residual materials from geological and weathering points of view are such that it is not generally possible to apply satisfactory slope design procedures, engineering judgement and precedent being relied upon for the determination of cut slope angles. As a result, failures in cut slopes are increasingly common, and they represent a continuing heavy maintenance commitment and a substantial economic nuisance (Tan, 1984).

In the past, research work by many researchers like Donald and Chen (1997), Cheng (1999), Sarma (1973), Janbu (1973), Spencer (1967), Chowdhury (1987), Passalacqua and Dalerci (1999), and Fredlund and Krahn (1977) was directed towards developing slope stability analysis. There are a few researchers were studied on slope assessment, for example Hudson (1992) discussed on rock engineering system; Matheson (1983) on rock stability assessment in preliminary site investigation discussed on graphical methods; Nathanail et al. (1992) discussed on stability hazard indicator system for slope failures in heterogenous strata; Hearn and Griffith (2001) discussed on landslide hazard mapping and risk assessment.

In Malaysia, the Public Works Department makes concerted effort to produce guidelines and better design strategy for geotechnical engineers and geomorphologists involved in slope stability analysis and design. The Malaysian Engineered Hillslope Management System (MEHMS) (JKR Malaysia, 1998) and JKR Slope Inspection Guidelines and Notes (JKR Malaysia, 2000) have been widely used by local contractors.

Most of the above studies have not addressed how to carry out the slope assessment in the proper manner and they also have not developed a system that enables engineers to consider for evaluating the conditions of the cut slopes. As such, a systematic method and tool are required in carrying out slope assessment in the proper manner for geological point of view. The study is focused to develop a slope assessment system based on selected geological parameters. The slope assessment system will then be transferred into a computer system as an Expert System (ES). This ES is a system developed as a support tool that will facilitate users.

In summary, the development of a Slope Assessment System using expert system techniques or artificial intelligence requires the involvement of slope experts, geological knowledge and user requirements. The implementation of this system for the conduct of slope assessment has resulted in the reduction of rehabilitation cost and improvement of evaluation technique. Furthermore when constructing roads in steep mountainous areas, this system will be helpful to determine slope conditions for maintenance purposes.

Research Aims and Objectives

The main aim of this research is to develop a slope assessment system based on geological parameters which will assist geotechnical engineers and geological engineers in slope evaluation. This slope assessment system will then be transferred into a computer programme to form an Expert System.

The main objectives were:

- to develop the risks hazard value (Geological Rating) based on the selected field parameters
- to study the Potential Instability (PI) of slopes using stereographic projection analysis (Schmidt net Methods)
- to integrate the Geological Rating and Potential Instability for Slope Evaluation Statement

Scope and Limitation

The study focuses on two aspects, which are development of Slope Assessment System (SAS) and it's expert system. Firstly, the development of slope assessment system is conducted through interviewing the experts followed by field study and then analyzing the field data for the determination of potential risk parameters. The risk rating could be determined and slope category would be developed to complete the slope evaluation process.

Secondly, the Slope Assessment System (SAS) is then transferred into computer programming for the development of Expert System (ES). The SAS is then translated into numerical form or specific rules for the ES and the database is created for the data input.

Expected Outcome of the Research

The expected outcome of the research is the development of Geological Rating (G-Rating) based on the selected parameters for risk assessment and the Potential Instability Statement (PI) of slopes using stereographical plot or Schmidt net methods. The potential instability analysis is carried out on the geological discontinuities. As such, a systematic slope category is developed. The integrations of these elements are used for the development of an Expert System for slope assessment which is called D-Slope. This ES could be a useful tool for field engineers to use in carrying slope assessment works.

CHAPTER II

LITERATURE REVIEW

Introduction

There are many slope failures being reported today in Malaysia. Most of these failures are triggered by prolonged intense rainfall. Rain water infiltrates into the slope and reduce the soil matric suction and the strength of the soil. Many researchers found out that rainfall infiltration is a single most important triggering factor for most landslides or slope failures (Affendi, 1996, and Fredlund and Rahardjo, 1993). Rain induced landslides and slope instability are really a costly recurring problem faced by many tropical countries like Malaysia.

In January 1996, a cut slope collapsed on the North-South Expressway (one of the major highway in Malaysia) at Gunung Tempurung. In this slope failure, one of the road users was killed. Table 2.1 shows a record of some major landslides in Malaysia (The Sun, 1996). From 1997 to 2001, many cut slope fails during construction of the highway at Pos Selim and the project was delayed because of the continuous failures of cut slopes due to the complexity of the geology of the areas (Omar et al. 2001a).