

ESTIMATION OF DEBRIS FLOW SEDIMENTATION VOLUME
THROUGH NUMERICAL MODELLING

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DEDICATION

This project report is dedicated to my mother, Saadiah binti Abd. Rashid, who continually provides her moral support, spiritual, emotional and gave me strength when my spirit dwindled and almost gave up. I also dedicated this project to my late father, Jamri bin Ajar, who has been a source of inspiration

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ABSTRACT

Implementation of potential debris flow hazard in Malaysia has been conducted by Jabatan Kerja Raya in 2011. However, evaluation of this hazard level cannot deny the consequent to the nearest facilities. Thus, run-out analysis based on numerical modelling is the easiest and competent way to evaluate the risk level. There are more than 10 cases reported regarding debris flow occurrence from 1995 until 2015 in Malaysia. All these cases have caused severe damage to facilities and have involved a huge number of fatalities. Hence, an effective strategy is required on reducing the impact from these damages especially debris flow catastrophe. One of the structural measures for debris flow is a Sabo dam. This study presents a study on debris flow sedimentation volume with and without Sabo dam by numerical simulation using Kanako 2D software. Kanako 2D software is widely used in Japan and it is equipped with graphical user interface. A crossed verification upon numerical modelling and actual field data collection, and mitigation situation model that include Sabo dam has been conducted. Results show that Kanako 2D software has a precise output where the sedimentation volume is slightly higher in the range of 5 to 15 % compared to actual field data. It also proved that Sabo dam can reduce the impact of debris flow as it can bear the sedimentation volume about 91%.

ABSTRAK

Pembangunan tahap bahaya bagi potensi aliran puing di Malaysia telah dijalankan oleh Jabatan Kerja Raya pada tahun 2011. Walau bagaimanapun, penilaian terhadap tahap bahaya ini tidak dapat meniadakan pentingnya risiko atau impak aliran puing terhadap fasiliti berhampiran. Oleh itu, adanya keperluan untuk menilai risiko dengan penggunaan aplikasi numerik yang dapat memodelkan dan memberi keputusan dengan kadar segera dan lebih kompeten. Lebih dari 10 kes aliran puing telah direkodkan di Malaysia sejak tahun 1995 hingga 2015. Kesemua kes ini memberi kesan yang besar terhadap ekonomi dan ada antaranya melibatkan kadar kematian yang tinggi. Maka, satu strategi yang berkesan bagi mengurangkan impak aliran puing amat diperlukan. Salah satu strategi mengurangkan impak aliran puing adalah pembinaan empangan Sabo. Kajian ini telah memodelkan aliran puing menggunakan aplikasi Kanako 2D. Model dibina dalam dua keadaan iaitu keadaan sebenar (tanpa empangan Sabo) dan dalam keadaan terkawal (berserta empangan Sabo) bagi mendapatkan jumlah isipadu sedimen yang terhasil akibat aliran puing. Aplikasi Kanako 2D dilengkapi dengan grafik yang mudah difahami dan ianya telah digunakan secara meluas di Jepun. Verifikasi aplikasi ini dibuat dengan membandingkan isipadu sedimen yang dihasilkan dari model numerik dengan data sebenar ditapak. Bagi model keadaan terkawal iainya bertujuan melihat keberkesanan empangan Sabo dalam mengurangkan isipadu sedimen. Keputusan menunjukkan perbezaan jumlah isipadu antara model numerik dan isipadu sebenar di tapak adalah 5 hingga 15 %. Manakala verifikasi kedua telah membuktikan bahawa dengan wujudkan empangan Sabo, isipadu sedimen dapat dikurangkan sehingga 91 %.

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LIST OF ABBREVIATIONS

- Kanako 2D - Debris flow simulation software
- JICA - Japan International Cooperation Agency
- MLIT - Ministry of Land, Infrastructure, Transport and
Tourism
- JKR - Jabatan Kerja Raya, Malaysia
- NSMP - National Slope Master Plan (Malaysia)
- Sabo - Sand protection or Sustainable Actions Basin
Oriented
- LIDAR - Airborne Laser Scanning
- DTM - Digital Terrain Model
- DEM - Digital Elevation Model
- GIS - Geographic Information Systems

LIST OF SYMBOLS

τ	-	shear stress
c	-	soil or gravel cohesion
δ	-	normal stress
u	-	pore water pressure
ϕ	-	internal friction angle
h	-	thickness of accumulated layer
C_d	-	concentration of material ($0.3 \leq C_d \leq 0.54$)
C^*	-	concentration of moveable bed (approx. 0.6),
σ	-	mass density of bed material (kg/m ³),
ρ	-	mass density of fluid phase (kg/m ³),
φ	-	internal friction angle (degrees),
θ	-	channel bed gradient (degrees).
C_o	-	Cohesive component
μ	-	coefficient of viscosity
dv/dz	-	velocity gradient
$f(c)$	-	function of sediment concentration
τ_y	-	yield shear stress which not depend on velocity gradient
d	-	grain size in diameter
l	-	mixing length
v	-	velocity
Q_{sp}	-	debris flow peak discharge (m ³ /s),
ΣQ	-	total discharge of debris flow (m ³),

V_{dqp}	-	sediment predicted to be run-off by a single wave debris flow (including voids) (m^3),
Q_p	-	discharge of clear water under rainfall (m^3/s),
K_q	-	coefficient,
P_{24}	-	rainfall intensity (mm/daily),
K_{fl}	-	peak run-off coefficient
K_{pl}	-	coefficient (120)
A	-	watershed area (km^2)

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Debris flow is a movement of mass or slurry comprising of loose soil, rock, and water to down slope. It is capable of moving trees, boulder and even structures because of the momentum generated under the influence of the gravity. In Malaysia, debris flow is referred as mud flow or in other word, landslide.

Debris flow usually occurs when unstable soil from hillside collapsed and blocked the valley area. Heavy rainfall will worsen the condition whereby when water level becomes too high causing overflow, weakening the already unstable debris eventually leading to flow down. Normally the flow stops at region 2° to 3° gradient (JICA, 2014).

The worst debris flow cases recorded in Malaysia were in 1996 at Pos Dipang, Perak and Keningau, Sabah. 38 fatalities with estimated damage cost about RM69 million for the former and 302 fatalities with estimated damage cost about RM459 millions for the latter.

In Japan, a comprehensive contingency plan and countermeasures are conducted after experiencing countless losses on debris flow-related incidents in the past. Early mitigation measures have been carried out such as early warning system and evacuation system, producing hazard map and designation of special team based on Sediment Disaster Prevention Act, raising awareness of residents and locals to ensure that they are well aware with the hazard map, and the expansion of Sabo dam especially at debris-flow prone areas (JICA, 2014).

Cawangan Kejuruteraan Cerun, Jabatan Kerja Raya (JKR) had started to study and understand the elements and factors of debris flow since 2008 with cooperation of Japan consultant. A report on triggering factors of debris flow in Malaysia was produced in 2010 (Jabatan Kerja Raya, 2011). A plan of producing hazard map for potential debris flow for all Federal Route in Malaysia is already in the arrangement and JKR is planning to launch the hazard mapping monitoring system in the near future.

Therefore, as initiative, JKR has done a pilot project in producing potential debris flow map for selected federal routes. This potential debris flow was digitized purely from Airborne Laser Scanning Data (LIDAR) integrated with Geographic Information System (GIS) which has no physical verification on site.

Physical verification of potential debris flow on site is difficult and effect on time consuming. It requires vast man-hour to verify all components of identified slopes and sometimes can be risky for high

slopes. As an alternative, verification using numerical modelling is put forward. This type of verification will give stronger prediction of the type of hazard and the mitigation measures should there be any incidents.

1.2 Problem Statement

Hazard assessment is an indication of potential damaging event or phenomena, while risk assessment is an indication the probability of harmful consequence or expected losses (Jabatan Kerja Raya, 2009). Therefore, it is important to potential debris flow generate risk map as one of the decision making tool in mitigation work. Assessment of risk debris flow is difficult without assistance from numerical modelling. As numerical modelling method can provide required measurement in an easy and faster way plus interactive visualization of debris flow, this method was adopted. It can visualize pattern of debris flow spreading at alluvial fan. However, there is a need to have crossed verification upon numerical modelling and actual field data collection in order to have a precise outcome which will result in constant authentication.

1.3 Objective

The aim of this study is to verify sedimentation volume of debris flow in Kanako 2D simulation with actual field data using. The objectives of this study are:

- i. To identify debris flow channel, alluvial fan and watershed area by using GIS software
- ii. To determine the percentage difference of sedimentation volume between actual field data and numerical modelling using debris flow simulation Kanako 2D software
- iii. To verify the effectiveness of Sabo dam in reducing sedimentation volume via Kanako 2D software

1.4 Significance of the Study

This study focus on verification of debris flow sedimentation volume between Kanako 2D simulation and actual site study. This verification will give assurance to legibility of hazard and risk map, which in turn will have implication on deciding the best method for mitigation work in future.

1.5 Scope of the Study

A case study located at Simpang Pulai, Cameron Highland is used to verify the sedimentation volume. The debris flow incident occurred in 12 April 2006 at KM 33, Jalan Simpang Pulai-Cameron Highland Highway. There were no casualties reported and the total estimated loss was around RM 354.65 million. The catastrophe led to gridlock to all vehicles and many activities in Cameron Highland were affected. Site investigation and geotechnical forensic work were carried out by Cawangan Kejuruteraan Cerun, Jabatan Kerja Raya to determine the cause of the incident.

In this study, numerical modelling is used to verify the sedimentation volume by using debris flow simulation Kanako 2D. This software has been widely used especially in Japan due to its proven result in showing the best solution in providing countermeasures of the failure. After verification process is complete, simulation was continues to ascertain the effectiveness of Sabo dam to reduce the sedimentation volume. For this study, three numbers of Sabo dam were applied with 15m height and adopted closed type of Sabo dam.

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