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2013

The Second International Conference on Engineering and Technology Development

2nd ICETD 2013

27, 28, 29 August 2013, Bandar Lampung, Indonesia

PROCEEDINGS

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2nd ICETD 2013

The Second International Conference On Engineering And Technology Development

28 -30 January 2013
Bandar Lampung University (UBL)
Lampung, Indonesia

PROCEEDINGS

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PREFACE

The Activities of the International Conference is in line and very appropriate with the vision and mission of Bandar Lampung University (UBL) to promote training and education as well as research in these areas.

On behalf of the Second International Conference on Engineering and Technology Development (2nd ICETD 2013) organizing committee, we are very pleased with the very good response especially from the keynote speaker and from the participans. It is noteworthy to point out that about 80 technical papers were received for this conference.

The participants of the conference come from many well known universities, among others : University Kebangsaan Malaysia – Malaysia, APTIKOM – Indonesia, Institut Teknologi sepuluh November – Indonesia, Surya Institute – Indonesia, International Islamic University – Malaysia, STMIK Mitra Lampung – lampung, Bandung Institut of Technology – Bandung, Lecture of The Malahayati University, B2TP – BPPT Researcher – lampung, Starch Technology Center – Lampung, Universitas Islam Indonesia – Indonesia, Politeknik Negeri Malang – Malang,University of Kitakyushu – Japan, Gadjah Mada University – Indonesia, Universitas Malahayati – Lampung, Lampung University – lampung, Starch Technology Center – Lampung, Universitas Riau – Riau, Hasanuddin University – Indonesia, Diponegoro University – Indonesia, King Abdulaziz University – Saudi Arabia, Parahyangan Catholic University – Indonesia , National Taiwan University– Taiwan, Surakarta Christian University – Indonesia, Sugijapranata Catholic University – Indonesia, Semarang University – Indonesia, University of Brawijaya – Indonesia, PPKIA Tarakanita Rahmawati – Indonesia, Kyushu University, Fukuoka – Japan, Science and Technology Beijing – China, Institut Teknologi Sepuluh Nopember – Surabaya, Researcher of Starch Technology Center, Universitas Muhammadiyah Metro – Metro, National University of Malaysia – Malaysia.

I would like to express my deepest gratitude to the International Advisory Board members, sponsor and also to all keynote speakers and all participants. I am also gratefull to all organizing committee and all of the reviewers who contribute to the high standard of the conference. Also I would like to express my deepest gratitude to the Rector of Bandar Lampung University (UBL) who give us endless support to these activities, so that the conference can be administrated on time

Bandar Lampung, 29 August 2013-08-26

Mustofa Usman, Ph.D
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Viscosity and Liquidity Index Relation for Elucidating Mudflow Behavior

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Abstract: *The mechanism of mudflow, which is a type of mass movement, is different from that of landslide. A landslide has a discrete failure surface, whereas a mudflow has flow characteristics. Hence, the conventional approach of explaining the characteristics of landslide is not applicable in mudflow. The adaptation of rheological models, such as the Bingham and Herschel–Bulkley models, is required to explain the characteristics of mudflow. Qualitative classifications of mudflow based on water content are also available. The mass movement of mudflow is initiated when the water content of the mudflow is equal to or higher than its liquid limit. Thus, the mass movement of mudflow occurs when the mud is in a viscous liquid state. However, up to now, a detailed explanation on how mudflow is initiated by using a rheological approach is nonexistent. In this study, a flow box test is developed to determine the rheological parameters of mud, including yield stress and viscosity. This test is established to overcome the lack of conventional viscometers, which can only measure the rheological properties of mud in a viscous liquid state. The flow box test utilized the Bingham model and a couple of trap door mechanisms. Results are then interpreted using a method similar to the Herschel–Bulkley model. The flow box test provides reliable results for both plastic and viscous liquid states. Results show that the mudflow characteristics can be explained based on the changes in viscosity. Sudden changes in viscosity occur when the mud reaches its liquid limit, implying that mudflow is possibly triggered when the soil water content of the mud is equal to its liquid limit. The results of this study provide a detailed explanation of mudflow initiation.*

Keywords: ·Flow box test · mudflow · viscosity · viscous liquid state

1. INTRODUCTION

Mudflow can be initiated by landslides triggered by rainfall. Many researchers suggest that mudflow occurs because of changes in water content. Hungr et al. [5] denoted that water content is equal to or higher than the liquid limit (LL), and the flow velocity is higher than 5 cm/s.

Slano Blato in Slovenia was an example of a landslide. During this landslide, Petkovsek et al. [13] placed several instruments (i.e., tensiometer) to measure suction changes. They determined that suction was about 6 kPa with a cohesion of about 2 kPa. The sudden change in water content, which reduces shear strength, is the main reason behind the initiation of the landslide. The flow velocity of Slano Blato ranged from 0.07 cm/s to 0.12 cm/s; thus, Slano Blato is classified as a landslide using the velocity criterion.

Mudflow exhibits instantaneous velocity at initiation. Measuring flow velocity can be dangerous when a landslide changes to mudflow. Considering its sudden occurrence, mudflow is a more dangerous type of mass movement compared with a landslide.

The Achacolla mudflow in Bolivia was the largest mudflow in the

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world, which traveled a distance of approximately 25 km as in Hunt [6]. In Indonesia, Karanganyar in Central Java in 2007 and Ciwidey in West Java in 2010 were examples of mudflow, in which the former traveled a distance of about 260 m and the latter a distance of about 3300 m. The Maokong mudflow in Taiwan traveled a distance of approximately 200 m.

No technical explanation exists on how and why mudflow is initiated (Hungr et al. [5]; Lee and Widjaja [14]). The only feasible qualitative method is using geological classifications. Hence, this paper aims to describe behavior of mudflow as one of mass movement type in a quantitative way using a rheological approach based on a relationship between viscosity and liquidity index.

2. MATERIALS AND METHODS

7.1 Classification of Mudflow

Several criteria that can be used to categorize mass movement as mudflow are as follows:

a. Soil type
Mudflow comprises more than 50% fine soil.

b. Viscous liquid state
Mudflow material is saturated and has water content equal to or higher than LL. Mudflow soil occurs in a viscous liquid state.

c. Ratio of width and length
This criterion is recommended by Liu and Mason [8]. Width refers to the average width of mudflow, and length refers to the transportation length from the source area to the end of deposition area. The width-to-length ratio should range from 0.05 to 0.3.

d. Solid concentration by volume
O'Brien and Julien [12] proposed utilizing solid concentration by volume (C_v) in determining mudflow. C_v is defined as

$$C_v = \frac{V_s}{V_w + V_s} \qquad (1)$$

$$C_v = \frac{1}{1 + w.G_s} \qquad (2)$$

where V_w is the volume of the water part, V_s is the volume of the solid part, w is water content, and G_s is the specific gravity. C_v ranges from 0.45 to 0.55 in mudflow. C_v is higher than 0.55 in landslides.

e. Flow velocity
Hungr et al. [5] identified the flow velocity of mudflow as higher than 5 cm/s. However, obtaining C_v and flow velocity (v) is difficult. Back analysis is recommended in categorizing mudflow. Mudflow can be triggered by changes in water content, for example, infiltration of water into soil due to heavy rainfall. However, weather prediction is difficult, and mudflow prediction is more difficult because mudflow is a function of weather. Back analysis can be used after mudflow by numerical analysis such as Flo2d software. The results obtained are compared with that of mudflow simulation.

7.2 Landslide Versus Mudflow

The first criterion of mass movement classification is flow velocity. The flow velocity of the landslide is less than 5 cm/s. The water content of landslide is lesser than LL or is in plastic state as in Abbot [1]. By contrast, mudflow material exists in a viscous liquid st ate (Fig. 1).

Landslide has a discrete failure surface, whereas mudflow is a type of flow with fine material without a clear failure surface. Mudflow moves around gullies and can hit anything in instantaneous way, thus making this flow dangerous.

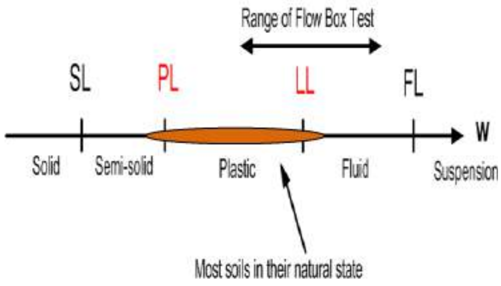

Fig. 1 Atterberg limits as boundary of material condition

(after Germaine and Germaine [4]).

7.3 Rheology

In geotechnical engineering, a landslide can be presented by a safety factor. The soil mass is assumed to be a solid material using a limit equilibrium method, such as Ordinary Method of Slices and Bishop in Bishop [2]. The soil strength model used for the plastic state is the Mohr–Coulomb model.

Mudflow is in a viscous liquid state. Rheology, which can be used to define flows, is the science dealing with flow characteristics of a material. Mudflow is categorized as non-Newtonian flow. The shear strength of mudflow is called yield stress (□$_y$). When shear stress (□) is lower than □$_y$, the material is not in flow mode (Fig. 2). However, when shear stress is higher than □$_y$, the material is in flow mode. Flow is governed by another parameter called viscosity (□).

The Bingham model can be applied to simplify mudflow behavior. This model uses a straight line in shear stress and a shear strain rate ($\dot{\gamma}$) plane. The intersection in the shear stress line is □$_y$, and the positive gradient of the line is □. The Bingham model can be be presented as

$$\tau = \tau_y + \eta\dot{\gamma} \qquad (3)$$

Alaboratory conventional viscometer is used to obtain the rheology parameters, yield stress and viscosity. However, this test can be applied only in viscous liquid state as in Dinger [3].

Herschel–Bulkley (or pseudoplastic) model is another type of rheology model. The Herschel–Bulkley model derives the rheology parameters using a graphical procedure of matching curves.

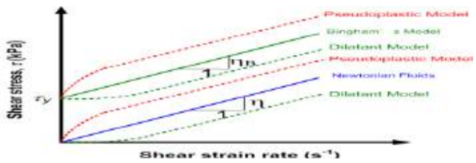

Fig. 2 Comparison among Newtonian, dilatant, Herschel-Bulkley, and Bingham models (modified from Lorenzini and Mazza [11])

7.4 Flow Box Test

Soil can change from plastic to viscous liquid state because of increased water content. Hence, the Flow Box Test (FBT) is proposed as a new laboratory test which couples Terzaghi's trap door and the Bingham model (Fig. 3). A detailed explanation of FBT such as governing equation was provided by Widjaja and Lee [14]. FBT utilizes displacement-time data using linear variable differential transformer (LVDT) and transforms the data into a relationship between viscosity and the liquidity index (LI). LI is defined as

$$LI = \frac{w - PL}{LL - PL}$$

(4)

LL can be treated as a limit for determining mudflow based on water content. However, the conventional viscometer cannot be applied for soil around its LL. Moreover, a conceptual, qualitative geological classification of mudflow is applied when LL is used as the indicator of mudflow limit. No quantitative explanation is available to elucidate mudflow behavior.

FBT can determine the viscosity for both plastic and viscous liquid states (Fig. 1). Real mudflow cases were used to validate the FBT results (Maokong in

Taiwan and Karanganyar and Ciwidey in Indonesia).

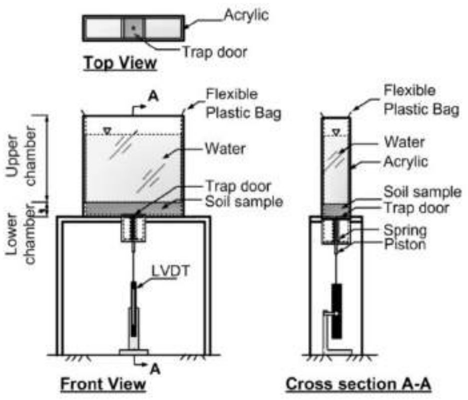

Fig. 3 Setup of flow box test (after Widjaja and Lee, 2013 [14])

3. RESULT AND DISCUSSION

Kaolin soil (circle number 8) was used as a pilot project; the Maokong mudflow case (circle number 11) was also utilized, and the Karanganyar and Ciwidey mudflow were applied to validate FBT results.

Compared with the results of other studies, the FBT results are reliable (Fig. 4). The lower value of mudflow was 0.0076 Pa•s by using a conventional viscometer as in Locat and Demers [10], which is lower than the FBT results for viscous liquid state. For comparison, water has viscosity of 0.001 Pa•s at room temperature.

The general mudflow behavior can be described as in Widjaja and Lee [14]. When soil changes from the solid state to the plastic state, the soil starts to move slowly due to high viscosity. When the water content increases progressively, the soil may enter the viscous liquid state gradually, leading to faster movement. At this point, mudflow may occur. The results confirm that viscosity is affected by increased water content as in Kooistra et al. [7]. Thus, LL (or LI = 1) is the lower limit for mudflow.

FBT uncovered the reason behind the in viscous liquid state of mudflow. The results thus prove that LL can be considered as the lower limit of mudflow.

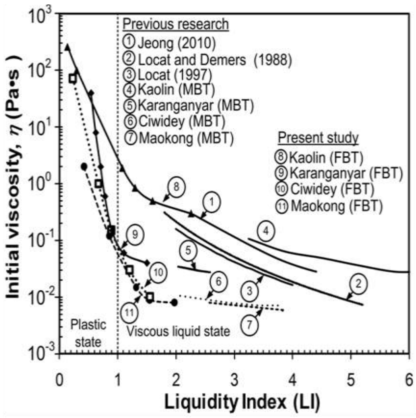

Fig. 4 Viscosity for Maokong, Karanganyar, and Ciwidey using FBT

4. CONCLUSIONS

In this paper, mudflow boundary is elucidated from the FBT results. FBT is reliable in determining the relationship between viscosity and LI for both plastic and viscous liquid states. Laboratory viscometers cannot provide data around LL. The general characteristics of this relationship have been described based on changes in water content. Increased water content results in decreased viscosity. Based on the rheological approach, mudflow may occur when water content reaches its LL. The results prove that using theology approach, LL can be considered as the lower limit of mudflows. Thus, FBT is successful in quantitatively describing the boundary of mudflow initiation.

5. ACKNOWLEDGEMENT

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