The 4th ASEAN Civil Engineering Conference

November 22-23, 2011 - Yogyakarta, Indonesia

Editors
Istiarto
Henricus Priyosulistyo
Budi Santoso Wignyosukarto
Sigit Priyanto

Organized by: AUN/SEED-Net
Supported by: JICA

PROCEEDINGS

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Organized by:
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Japan International Cooperation Agency (JICA)

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PREFACE

The Department of Civil and Environmental Engineering, Universitas Gadjah Mada, in collaboration with AUN/SEED-Net, is proudly organizing the 4th ASEAN Civil Engineering Conference (ACEC) and the 4th ASEAN Environmental Engineering Conference (AEEC) in Yogyakarta on 22-23 November 2011 under the auspices of JICA. The joint conference provides forum for engineers and researchers in the region to collect and disseminate current issues in technology and researches in the field of civil and environmental engineering. The joint conference is part of a continuing series of regional conferences. Previous conferences were held in Thailand (1st ACEC, 2009) and The Philippines (1st AEEC, 2009), Laos (2nd ACEC, 2010) and Indonesia (2nd AEEC, 2009), and The Philippines (3rd ACEC and AEEC, 2010).

More than eighty papers from twelve countries (Brunei Darussalam, Cambodia, Indonesia, Iran, Japan, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam) are presented in this joint conference. The papers are grouped in various topics, namely structural and material engineering, construction engineering and management, transportation engineering, geotechnical engineering, water resources engineering, disaster mitigation, green infrastructure, water quality and management, wastewater treatment, air quality management, climate change model, adaptation and mitigation, eco-hydraulics modeling. The papers are compiled in two volumes. This proceeding is the first volume containing paper topics related to civil engineering to be presented in ACEC, whereas the second volume groups paper topics related to environmental engineering to be presented in AEEC.

The organizing committee would like to extend its deepest gratitude to all participants who have contributed their papers and all parties involved throughout the conference without which this conference would not have been a success. The organizing committee wishes all participants a fruitful discussion during the conference and an enjoyable stay in Yogyakarta.

Yogyakarta, 22 November 2011

Dr. Istiarto
Chairperson of the Organizing Committee
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Soil Water Index Dynamics for the Identification of Initial Occurrence of Volcanic Deposit Instability

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Abstract: Several techniques have been introduced in order to monitor important parameters of disaster symptoms, and then utilizing them to develop necessary warning criteria. In case of Mt. Merapi disaster, where after the 2010 eruption the intensity of lahar flow occurrence increases significantly, such monitoring system is becoming very important. This is due to the fact that activity at the surrounding volcanic rivers is very intensive, in the form of both settlement at the surrounding rivers and the sediment mining activity in the rivers itself. Furthermore, in almost all cases of the development of early warning system, minimizing number of casualties or toll death has become main target. This paper presents the results of investigation on lahar flow warning criteria development through soil moisture monitoring activity at Gendol River of Mt. Merapi, before and after 2010 eruption confronted with some laboratory investigation. Correlation between the soil moisture dynamics and the initial occurrence of volcanic deposit instability are then presented. Analysis from relatively reliable data performs the goodness fit of the correlation between the aforesaid parameters.

Keywords: soil water index, warning criteria, deposit instability

1 INTRODUCTION

Soil water content is an important parameter on analyzing the soil movement. The ratio between water content or water volume and soil volume called as soil water index determines the driving and resisting force in such cross section area of soil. The composition of this driving and resisting force caused instability of soil layer. When in such cross-section of sediment block, the driving force greater than resisting force by increased water contents, the block will start moving immediately.

Soil water index is determined by physical characteristic of soil, topographical characteristic of surface, land covered, land used and characteristic of rainfall, but rainfall characteristic is the most important one. Some experts have already made researches to understand the relations between soil type, rainfall and soil water content and other factors, such as Farrar et.al., Dunkerley and Hunt et.al. Farrar et.al (1994) evaluated the influenced of soil type to the relation between vegetation formation, rainfall and soil moisture in semiarid Botswana. They concluded that each type of soil has difference response on generating soil moisture. Dunkerley (2001) calculated the infiltration rate and soil moisture in a grove mulga community. By this research, he concluded that infiltration rate and soil moisture is varied as a function of the mulga stem. Hunt et.al (2008) developed and evaluated the soil moisture index throughout Nebraska in the Automated Weather Data Network since 1999. They derived a Soil Moisture Index as a function of actual water content, field capacity and wilting point. It can be concluded that type of soil, land cover, vegetation formation and initial water content will influenced the soil water index.

The research of initial movement of deposited sediment in torrential area is categorized as high risk activity (Ishikawa and Yamada, 2001), therefore the installation and placement of each instrument should fulfilled security with respect to technical aspect and collecting data process. Therefore, the soil moisture sensor before the eruption, for example, was mounted at outer bank of the river on consideration of it. However, it should be more effort on interpreting data since the soil characteristic at outer bank and at river bed is quite different. This condition will of course have consequences on accuracy and process of analysis.

In case of creating and predicting critical line of volcanic deposit instability occurrence (initial movement of lahar flow) as part of early warning system, the soil index is known as one parameter to be used decoupling with rainfall intensity. Japanese experts create a guide lines or instruction to determine critical instruction of rainfall data setting for early warning and evacuation against debris flow disaster. This Guidance was formerly proposed by Ishikawa.
and Yamada (2001) that was built based on the debris flow occurrence data in Japan for more than twenty years. This guidance, then adopted by Ministry of Land, Infrastructure and Transport Japan (MLIT, 2004) as guidance for construction technology transfer on developing warning and evacuation system against sediment disasters in developing countries. This guidance introduces different parameter-pair on creating critical line of the occurrence of debris flow. The parameter pair is hourly intensity and working rainfall (Methods A), effective intensity and effective rainfall (Methods B) and intensity and soil index (Variance Method), as x and y axis respectively. The variance method, which the hourly intensity and Soil Index act as coordinate system, is applied on creating critical line of volcanic deposit instability for this paper.

Since the soil properties at the outer bank and river bed are quite different, the investigation of initial movement of sediment refers to a laboratory investigation doing by Fathani and Legono (2011). This is important stage of research in order to strengthen the understanding of deposit failure mechanism in non coverage soil. The main material for the laboratory investigation is taken from Merapi area. This on going model is conducting in Hydraulics Laboratory, Department of Civil & Environment Engineering, Universitas Gadjah Mada. The channel is 10.00 meter long, 1.50 meter width and 0.50 meter high with head tank at upper part of the channel. It is also equipped with Thompson type discharge measurement devices. The dam model was built is 40 cm height and 30 cm width of crest-weir with constant downstream slope inclination. The upstream slope inclination varies from 1:1 to 1:5. Beside three pieces of elevation gauge that are installed out of dam's body; some devices are mounted in the body of the dam, namely six pieces of soil moisture sensors, one piece of piezometric head and one piece of deformation detector. In order to understand the effect of upstream water to soil moisture, varied upstream water level from 10 cm up to 30 cm is simulated.

The rise of upstream water discharge and soil moisture will be recorded on data logger. Based on this data, the than the effect of the rising soil moisture to the initial occurrence of deposit instability will be analysis.

Fathani and Legono (2011) have already investigated the effect of upstream water level to the stability of earth dam. They evaluated the stability by simulating the rising rate of water level, slope inclination and material composing the dam body. It found that seepage discharge will increase as the upstream water level rises. It was explained that the hydraulic gradient is generated by the difference head of upstream and downstream water level so if the seepage discharge increase, then the seepage pressure and hydraulic gradient will also increase as well.

This seepage discharge occurring in every variation of slope inclination performed a linear relation. Refers to this condition it can be said that the seepage in such a dam is not affected by the upstream slope inclination and is linear to upstream water level. It was also concluded that in any model, the permeability coefficient will decline as water level in upstream of model rises. It misses the discussion in related with any soil index and instability of the dam. Therefore this running model investigated the relation of soil water content of dam body that is affected by variation of upstream water level.

2 FIELD INVESTIGATION

Two systems of instruments have already built refers to the time frame of eruptions (Figure 1 and Figure 2).

![Figure 1. Location of each instrument before eruption.](image-url)
The second one is built to replace the first, since it was totally destroyed due to Merapi eruption 2010. Both have similar concept and type of instruments to be installed: rainfall gauge, soil moisture sensor and garden-watch automatic camera; but the placement of each is rather different. Detail of type and amount of each instrument had been discussed by Wardoyo et. al. (2011), while both locations can be seen in Figure 2 and Figure 3. The main goals of these instruments installation are remained the same, namely to support early warning system in Merapi.

A tipping bucket rainfall gauge is used to measure rainfall intensity for short duration. It was set ten minutes for the first system and three minutes for the second one. A Time Domain Reflectometry (TDR) type sensor was used as soil moisture measurement devices and it is replaced by Cencera type sensor for the second term. The same type of automatic camera namely Brino garden-watch automatic cameras are used in both frame time.

Figure 2. Location of each instrument after eruption.

A non scale position of each type of devices near Kaliadem dam is presented in Figure 3. Three cameras were installed in this cross section, namely one for river bed sediment movement and two others for outer bank sediment movement. The position of these instruments installed in Jambu is presented in Figure 4.

Figure 3. Position of rainfall gauge, camera and soil moisture sensor in Gendol cross-section.

Figure 4. Position of rainfall gauge and soil moisture sensor at Jambu.

The position of rainfall gauge was chosen to fulfill the hydrological prerequisites. It should cover and represents upper part of Gendol catchments area and should be installed in open space. For the first term, the position of soil moisture measurement and camera as monitoring instrument of volcanic deposit instability at Gendol river bed is rather far away each other that leads to carefully calibration and verification stage due to lack of soil properties uniformity. It is not a big problem for the second stage, since the soil covered in study area is almost similar namely cooled pyroclastic material.
DATA COLLECTION AND ANALYSIS

For this analysis, the rainfall data is sufficient enough. These consist of ten (10) minutes observed interval data from 14\textsuperscript{th} of January up to 24\textsuperscript{th} September 2010 and three minutes interval data on certain dates as shown in Table 1, whilst Table 2 shows the data of soil data respectively. Table 3 shows the condition of flow in Gendol River. It was recorded by garden watch automatic camera that was installed in the side of inner river bank.

Table 1: Rainfall data

<table>
<thead>
<tr>
<th>Time range</th>
<th>Type of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 January- 24 September</td>
<td>10 minutes interval</td>
</tr>
<tr>
<td>07 – 11 February 2011</td>
<td>3 minutes interval</td>
</tr>
<tr>
<td>26 February – 01 March</td>
<td>3 minutes interval</td>
</tr>
<tr>
<td>11 March – 18 March</td>
<td>3 minutes interval</td>
</tr>
<tr>
<td>23 March – 04 April</td>
<td>3 minutes interval</td>
</tr>
</tbody>
</table>

Table 2: Soil Moisture data

<table>
<thead>
<tr>
<th>Time range</th>
<th>Type of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 January- 24 September ‘10</td>
<td>10 minutes interval</td>
</tr>
<tr>
<td>07 – 11 February 2011</td>
<td>3 minutes interval</td>
</tr>
<tr>
<td>26 February – 01 March</td>
<td>3 minutes interval</td>
</tr>
<tr>
<td>11 March – 18 March</td>
<td>3 minutes interval</td>
</tr>
<tr>
<td>23 March – 04 April</td>
<td>3 minutes interval</td>
</tr>
</tbody>
</table>

Table 3: Automatic Camera data

<table>
<thead>
<tr>
<th>Time</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 14, at noon</td>
<td>Rainfall and caused morphological changes</td>
</tr>
<tr>
<td>Jan 16, 14:50 pm</td>
<td>Start raining</td>
</tr>
<tr>
<td>15:00 pm</td>
<td>Surface flow detected</td>
</tr>
<tr>
<td>15:25 pm</td>
<td>Sediment movement occurred</td>
</tr>
<tr>
<td>16:50 pm</td>
<td>No more surface flow</td>
</tr>
<tr>
<td>Jan 17, 17:15 pm</td>
<td>Start raining</td>
</tr>
<tr>
<td>18:05 pm</td>
<td>Surface flow detected</td>
</tr>
<tr>
<td>Jan 18, 05:25 am</td>
<td>Change of morphological conditions</td>
</tr>
<tr>
<td>Jan 20, 11:20 am</td>
<td>Start raining</td>
</tr>
<tr>
<td>12:00 am</td>
<td>Surface flow detected</td>
</tr>
<tr>
<td>12:25 pm</td>
<td>No more surface flow</td>
</tr>
<tr>
<td>13:35 pm</td>
<td>New surface flow detected</td>
</tr>
<tr>
<td>14:15 pm</td>
<td>Sediment movement occurred</td>
</tr>
<tr>
<td>Jan 21, 16:30-17:45</td>
<td>Surface flow detected</td>
</tr>
<tr>
<td>Jan 24, 13:55-14:30</td>
<td>Surface flow detected</td>
</tr>
<tr>
<td>Jan 26, 13:30-15:00</td>
<td>Surface flow detected</td>
</tr>
</tbody>
</table>

Example of river bed pictures are presented at Figure 5, 6 and Figure 7 respectively.
After getting data of rainfall and soil moisture, then this record are confronted with the occurrence not only the rainfall or surface flow but also the occurrence of sediment movement caught by the camera. These three types of data are then analyzed to figure out the influence of characteristic of soil indexes to initial occurrence of deposit instability. The diagram of analysis methods is shown by Figure 8.

Figure 8. Diagram procedure of data analysis.

In order to make the analysis easier, the Duration of rainfall is grouped as Short Duration (SD), Medium Duration (MD) and Long Duration (LD), while the intensity is categorized in three group as well, namely Low Intensity (LI), Medium Intensity (MI) and High Intensity (HI). In the first step, four category of rainfall pattern are chosen to be analyzed: Rainfall with Long Duration – Low Intensity (LDLI), Medium Duration – Medium Intensity (MDMI), Medium Duration – High Intensity (MDHI) and rainfall with Long Duration – High Intensity (LDHI). It seems that each category has different effect to soil moisture rate. The 1st category represented by rainfall data on 21st of January 2011 along 230 minutes with no intensity highest than 24 mm/hour, while the 2nd represented by rainfall data of 18th January 2011. The 3rd was taken from rainfall data on 20th of January, while 4th represented by rainfall data on 30th of January along 140 minutes with 6 data highest than 24 mm/hour.

Further if the soil moisture data confronting with captured condition of river bed, it could be concluded that the generating of free surface flow or of initial sediment movement is strongly affected by soil moisture condition. By soil moisture at the outer bank > 0.350, free surface flow in the river can be detected. If the rainfall is still ongoing and the soil moisture rises, it will affect the initiation of soil movement. This process is suitable with Takahashi theory (1980, 1991).

Figure 9. Relation between rainfall intensity and soil index of each category of rainfall pattern.

Figure 10 figures out the time series of rainfall and its effect to the soil moisture. It shows that the both pattern are similar but by analyzing the soil moisture data, it was found that the rainfall intensity correlates to the soil moisture with time lag around 1 hour.
4. CONCLUSIONS

The sensitivity and level of accuracy of soil moisture sensor plays important role on withdrawing a good conclusions. In case of soil moisture sensor which was installed before eruption, the conclusion was easier to be done since the data was available continuously. By exploring difference pattern of rainfall, it can be concluded that, neither free surface flow nor initial movement of deposit sediment could be generated by any single high rainfall intensity. It needs quite long rainfall duration with sufficient intensity to trigger the initial movement.

The evaluation of the sensor respond to the rainfall should be calculated carefully with respect to the distance between rainfall gauge to the sensor, land coverage and topographical conditions. Although the sensor was only 20 meter away bellow the rainfall gauge but since the outer bank was covered by dense grass, the responds of rainfall to the sensor was found six time intervals later. That means, there are 1 hour lag between rainfall data and upper sensor. This can be concluded that the water pathway at subsurface plays an important role as well. Therefore, further research about lag time should be done intensively.

By analyzing each category of rainfall pattern, it can be concluded that not only the duration of rainfall but also the sequence of rainfall show similar pattern to water index. Both parameters affect the soil water index and these determine the instability of deposit.

By confronting the soil moisture data and river bed condition that was captured by camera, it can be concluded that the surface flow will appear when the soil moisture in outer bank greater than 0.35% and initial movement will happen when the soil moisture is above 36%.

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