Exploring a Simplified Approach for Assessing the Flow of Collapsed Sediments

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1. Introduction

Approximately 70% of Japan's terrain is mountainous, and the country experiences frequent slope failures due to earthquakes and heavy rainfall. Hence, multiple surveys and studies have been undertaken, resulting in the accumulation of diverse findings. The Act on Sediment Disaster Countermeasures for Sediment Disaster-Prone Areas incorporates these findings, exemplified by designations like the Landslide Special Warning Zone (red zone) and Landslide Warning Zone (yellow zone). These measures contribute to the safety of local residents as illustrated in Figure 1. Meanwhile, reports have highlighted the fluidization of sediment flowing from collapsed slopes, primarily occurring in regions with volcanic soil originating from volcanic ash and pyroclastic flows. When sediment undergoes fluidization, it can extend beyond the anticipated sediment reach as illustrated in Figure 1. This can lead to severe and extensive damage, particularly in areas where countermeasures and preparedness measures are inadequately implemented. Sediment fluidization is primarily facilitated by the weathering and alteration of volcanic soil as noted by Chigira et al. (2012). Consequently, the urgent tasks from the perspective of disaster preparedness and damage mitigation involve identifying slopes with these geological risks and implementing effective countermeasures. The Sabo Department has compiled survey results on landslides in Japan and explored the feasibility of assessing the Approximate Mobility Index (AMI) as an indicator of sediment mobility, which uses an evaluation method based on soil properties.

2. Methods and Samples

The Approximate Mobility Index (AMI), introduced in the United States, is calculated by dividing the soil's saturated water content ratio (%) by its liquid limit (%) (Ellen and Fleming, 1987). Developed through research focusing on diverse sediment mobility processes in slope failure, this index has seen limited application in Japan with only a few cases documented, such as in the work of Yamamoto et al. (1999). In Japan, there are indicators like

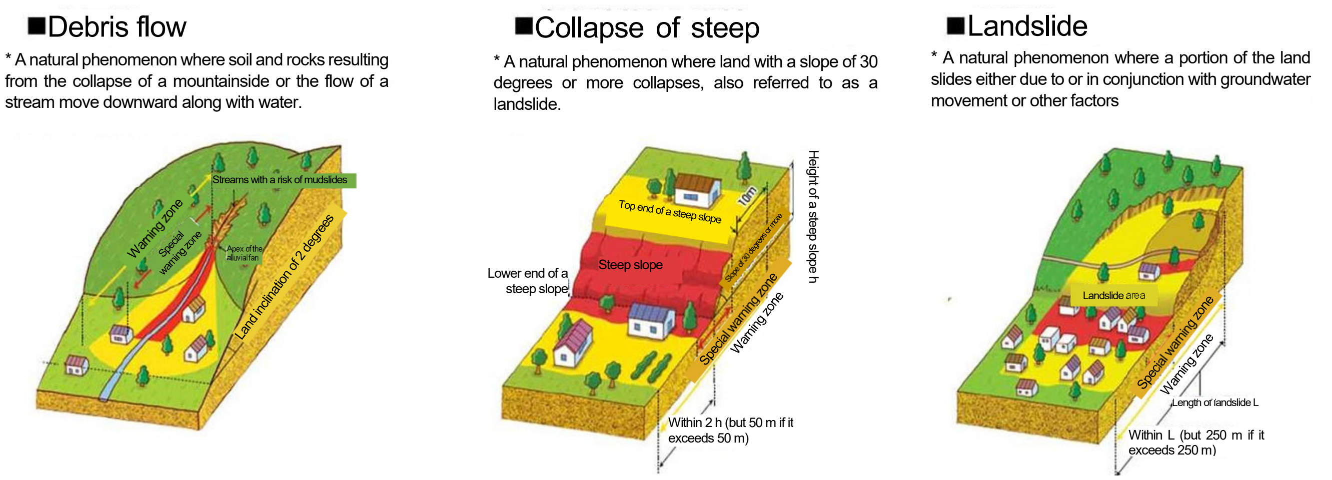

Figure 1. Range of Red Zone and Yellow Zone for mudslide, collapse of steep slopes, and landslides, based on the website of the Ministry of Land, Infrastructure, Transport and Tourism

the equivalent friction coefficient for assessing sediment mobility. However, these may not be suitable for evaluating potential geological risks because they necessitate an examination of such factors as slope height, sediment transport distance, and other factors. In contrast, the AMI is distinctive in that it does not signify the susceptibility of slope failure but rather the fluidity of the sediment when failure occurs. Furthermore, calculating the AMI does not necessitate any specialized machinery or processing; it can be derived from soil test values commonly conducted according to JIS standards. As mentioned earlier, the limited use of the AMI in Japan can be attributed to two primary reasons. First, in many slope disaster investigations, some soil tests are not conducted. Second, the geological complexity in Japan surpasses that of the United States, making interpretation challenging.

$$AMI = \frac{W_{sat}(Saturated\ water\ content)}{W_L(Liquid\ limit,\ \%)} \cdots Equation\ (1)$$

The formula for calculating the AMI is presented in Equation (1). However, as previously discussed, certain soil tests are omitted in the slope failure case studies we gathered. In these instances, the AMI was computed either by substituting the standard values provided by the

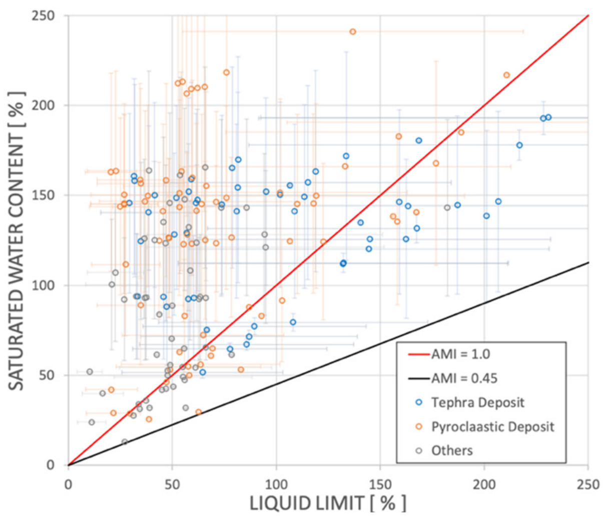

Figure 2. AMI distribution based on differences in geological differences

The red line indicates AMI = 1.0 and black line AMI = 0.45.

Japanese Geotechnical Society or by estimating the substituted values through the conversion equations proposed by Matsuo et al. (1970) and Kek et al. (2021). This study involved computing the AMI for 173 samples from 21 cases of sediment disasters, accompanied by reported sediment flow incidents across Japan. These incidents include factors such as the cause of landslides (induced by earthquakes or rainfall) and geological characteristics (volcanic or non-volcanic etc.).

Table 1. Sediment flow characteristics based on AMI value range

AMI < 0.45	Sediment is not fluidized.
0.45 < AMI < 1.0	Sediment is not fluidized, but is fluidized by excessive moisture supply
1.0 < AMI	Sediment is fluidized.

3. Results

As illustrated in **Figure 2**, the AMI values are designed to exhibit varying flow characteristics in three regions defined by the red and black lines. The AMIs acting as boundary values are set at a black line = 0.45 and a red line = 1.0, with the flow characteristics of each region detailed in **Table 1**.

Overall, approximately 80% of the samples exhibited a value of 1.0 or higher, while the remaining fell within the range of 0.45 to 1.0. This suggests that the AMI closely aligns with the actual cases, showing minimal deviation. In addition, the estimated range depicted by the error bar in **Figure 2** does not go below 0.45. This suggests that even the estimates derived from converted values do not exert a substantial influence on the results. Moreover, the AMI values for samples from volcanic geology (represented by blue and orange circles) ranged from 0.9 to 3.0, indicating a trend towards higher flowability compared to non-volcanic geology.

Once more, considering the formula presented in Equation (1), the AMI reflects the water volume ratio with the numerator representing the maximum water retention of a natural slope and the denominator indicating the minimum water retention necessary to sustain flowability after a collapse. In other words, a higher AMI value implies a longer duration for the disturbance and drainage of collapsed sediment as well as an extended distance of sediment movement. This is consistent with both the organized results and the actual sediment dynamics.

4. Summary

Despite its origin in the United States, the AMI, when interpreted in light of its physical properties, has demonstrated potential applicability in evaluating the flow of collapsed sediment in Japan as well. This is noteworthy given the complex distribution of geology and the humid climate zone in the region. However, caution is necessary in handling errors when utilizing estimated values. We plan to incorporate topographical conditions and other factors into our future studies.