Chapter V

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Mudflows can have severe impacts on societies. Research on the behavior of mudflows is just as important as research on the explanations about their governing parameters. This research proposed a new design "flow box" in order to obtain the relationship between initial viscosity and liquidity index. Governing equations of this flow box test (FBT) were derived by coupling the trap door principle with the Bingham model. Together with the Moving Ball Test (MBT) designed earlier, this flow box test can provide the initial viscosity of soils related to their liquidity index in both plastic and viscous liquid states. Hence, the viscosity becomes a key parameter for the FBT.

From the relationship between initial viscosity and liquidity index, general characteristics of behavior of mudflow can be described. The increase of clay content leads to an increase in initial viscosity, which points to the importance of mineral composition of soils in their susceptibility to mudflows. If the water content increases slowly, the soil will gradually change to the plastic state and start to move slowly like earthflow with a high viscosity. If the water content increases quickly, the soil may enter the viscous liquid state faster and thus move faster. This would be the point at which mudflow would be transported.

In this research, the author has shown how the flow box test makes it possible to measure viscosity in both plastic and viscous liquid states and contribute to the study of the factors leading to the behavior of mudflows with viscosity as a key parameter.

Mudflow has an initial tendency to move when the water content (w) is equal to the liquid limit (LL). This deduction is based on a three-scenario numerical simulation of the Maokong mudflow using different viscosities. The input rheology parameters were determined from laboratory tests by moving ball test (MBT) and flow box test (FBT). The results support current mudflow classifications that operate on key criteria of the solid concentration by volume (C_v). The other factor that is field evidence for the deposition area is confirmed to be relatively the same. The conducted simulations demonstrated how mudflow behaves as a flow material with a relatively constant thickness during its transportation, and then stops in a deposition area.

The current study also shows that the viscosity (η) derived from the flow box test (FBT) is important for explaining the general characteristics of mudflow movement. Using the FBT, the viscosities for both the plastic and viscous liquid states can be determined and can be directly inputted into numerical simulations. The η controls the flow velocity while the solid concentration by volume (C_v) affects the thickness of flow and deposition. For water content (w) equal to or larger than the LL, the numerical results confirmed that the mass movement is mudflow, based on the key criteria of solid concentration by volume (C_v) and water content (w). Therefore, the combination of laboratory tests, specifically the moving ball test and the flow box test, is necessary to determine the rheology parameters for numerical simulation. A "phase concept" is then proposed in this research as well.

The change in water content and loading were the main triggering factors in initiating the mudflow. Furthermore, rheology parameters emphasize that the engineering behavior of fine-grained soil is governed by its mineral and structural

composition and water content. The appropriate model for mudflow which has higher concentration of fine grained, one can choose Bingham's and Herschel Bulkley's model as a non-null yield stress.

The decreasing of yield stress (τ_y) is followed by increasing of transportation length (L') for both plastic and viscous liquid states. But, the result shows more significant in plastic state. The influence of viscosity (η) and Manning's coefficient (n) for viscous liquid state (i.e., mudflow) is more significant rather than for plastic state (i.e., landslide) for obtaining maximum velocity. Increasing of both values causes the reducing of maximum velocity. Increasing of concentration by volume (C_v) or reducing of specific gravity (G_s) is followed by increasing of flow depth. C_v or G_s is significantly influences flow depth at plastic state. Resistivity parameter for laminar flow (K) significantly influences affected area especially for plastic state.

The key parameter in the present simulation using FLO2D is η. Changes in the soil states (i.e., from plastic state to viscous liquid state) govern mudflow behavior, including flow velocity. Therefore, the results of the present case study elucidate the process of mudflow from its transportation to its deposition.

The rheological parameters derived from FBT are reliable to simulate the behavior of mudflow. The interesting finding here is that for the plastic phase, the gradient of curve is higher than that for the viscous liquid phase. The results are in a good agreement with the findings of other scholars. Hence, FBT should be considered especially to obtain initial viscosity.

Study case of Karanganyar and Ciwidey mudflows using FLO2D emphasizes the result of Maokong mudflow. The simulation divided into three scenarios based on the

different water content. Scenario 1 for plastic state is shown that for all scenarios that the soil movement can be classified as landslide. Both Scenario 2 (for water content equal to LL) and Scenario 3 (water content is higher than LL) show that soil movement can be categorized as mudflow based on its velocity and water content. Therefore, the deposition area is close to the actual deposition area. From the calculated velocity and its water content, this mass movement has the characteristics of mudflow.

5.2 RECOMMENDATIONS

For the future research, collecting the data of mudflow especially in Asian region (e.g., Taiwan, Japan, China, Philippines and Indonesia) is possible to do to provide more confidence results using Flow Box Test (FBT). Prospective development by applying advanced method (e.g., development of viscosity function) could be promising too. The continuing research to combine this research with the initiation of landslide triggered by rainfall is also a potential good research to do.

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