Evaluation of different erosion models for debris flow modeling

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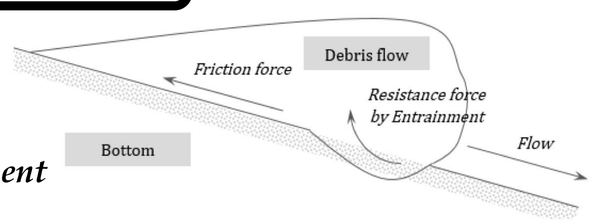
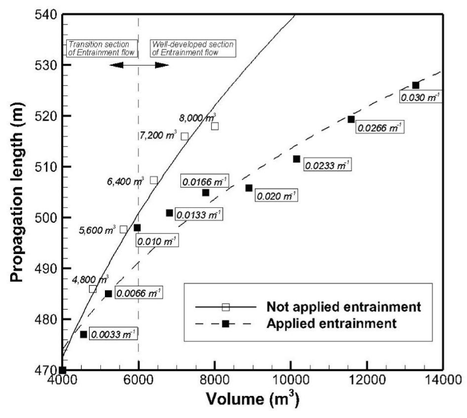
BACKGROUND



Concept of Resistance Generated by Entrainment



Comparison of propagation distance with debris volume and entrainment rate

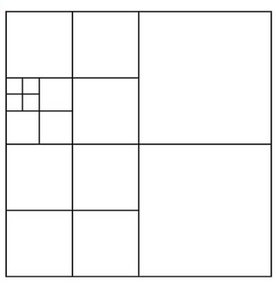
Entrainment Effect on Debris flow propagation (Seokil Jeong et al. 2018)

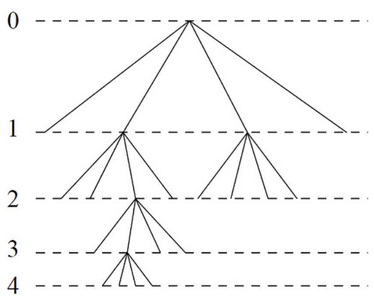
- A number of modeling approaches have been studied to explore the process and damage of debris flows.
- The entrainment process is an important factor determining the magnitude and intensity of debris flows.
- Sometimes, the entrained materials may accumulate 10–50 times their initial soil-water volume (Remaître et al., 2005).
- However, there are still a lot of uncertainties in the **erosion-entrainment process** although several entrainment(erosion) models have been proposed and used to simulate debris flow.
- The objective of this study is the evaluation of different entrainment(erosion) models for debris-flow modeling in **Deb2D**.

METHODOLOGY

Deb2D

- ✓ The Deb2D is two-dimensional debris flow simulation software based on **quadtree-grid**.
- ✓ It used a vertically integrated **shallow-water governing equation** and implemented a **finite-volume method(FVM)** for discretization.
- ✓ In the Deb2D**, Voellmy, Takahashi, Bingham, and Coulomb-vi models** can be selected as **rheological models**. In this study, **Voellmy** model was used.
- ✓ For the **erosion model**, **Sovilla, McDougall & Hungr and Frank** were applied and compared.
- ✓ The parameters were calibrated against the observed data(Aerial LiDAR DEM).
- ✓ The parameters were calibrated against the observed data in the Raemian apartment basin.
- ✓ The parameter of each erosion model calibrated in the Raemian was applied equally to the Sindong-A apartment basin, and the generality of the parameters and model was observed.





The application of rectangular grids using the adaptive mesh refinement technique (Quadtree)

Entrainment models

McDougall and Hungr (2005)

$$E = \frac{\ln\left(V_f / V_0\right)}{\bar{S}} h|\vec{u}|$$

$\bar{S}$: length of channel,
V_0 : initial volume of debris flow,
V_f : final volume of debris flow

Sovilla (2006)

$$E = \frac{\rho_i}{\rho} K_i |\vec{u}| = K|\vec{u}|$$

ρ_i : density of the each layer,
K_i : entrainment coefficient

Frank et al. (2015)

$$E = -\frac{dz}{dt} = \text{const. for } e \le e_m$$
$$e_m = \frac{dz}{d\tau}\left(\tau_c - \tau\right) = \frac{dz}{d\tau}\left(\tau_c - \rho g h S\right)$$

dz/dt : erosion rate
τ_c : critical shear stress,
$dz/d\tau$: potential erosion depth
ρ: density of debris flow

Rheological models

Voellmy
$$S_f = \left[\mu + \frac{|\vec{u}|^2}{\xi h}\right]$$

Bingham
$$S_f = \frac{1}{\sigma}\left[\frac{3}{2}\tau_C + \frac{3\mu|\vec{u}|}{h}\right]$$

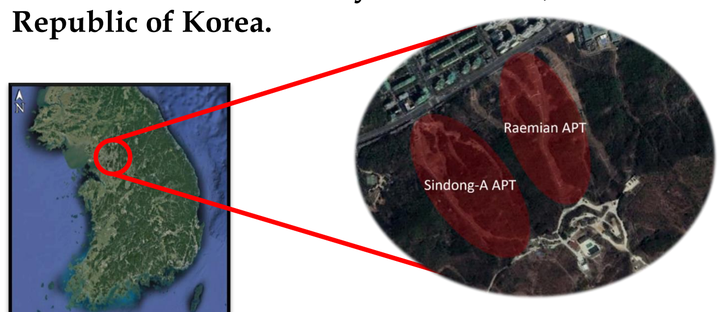
Coulomb-vi
$$S_f = \tan\varphi + \frac{1}{\sigma}\left[\frac{3}{2}\tau_C + \frac{3\mu|\vec{u}|}{h}\right]$$

Discussion

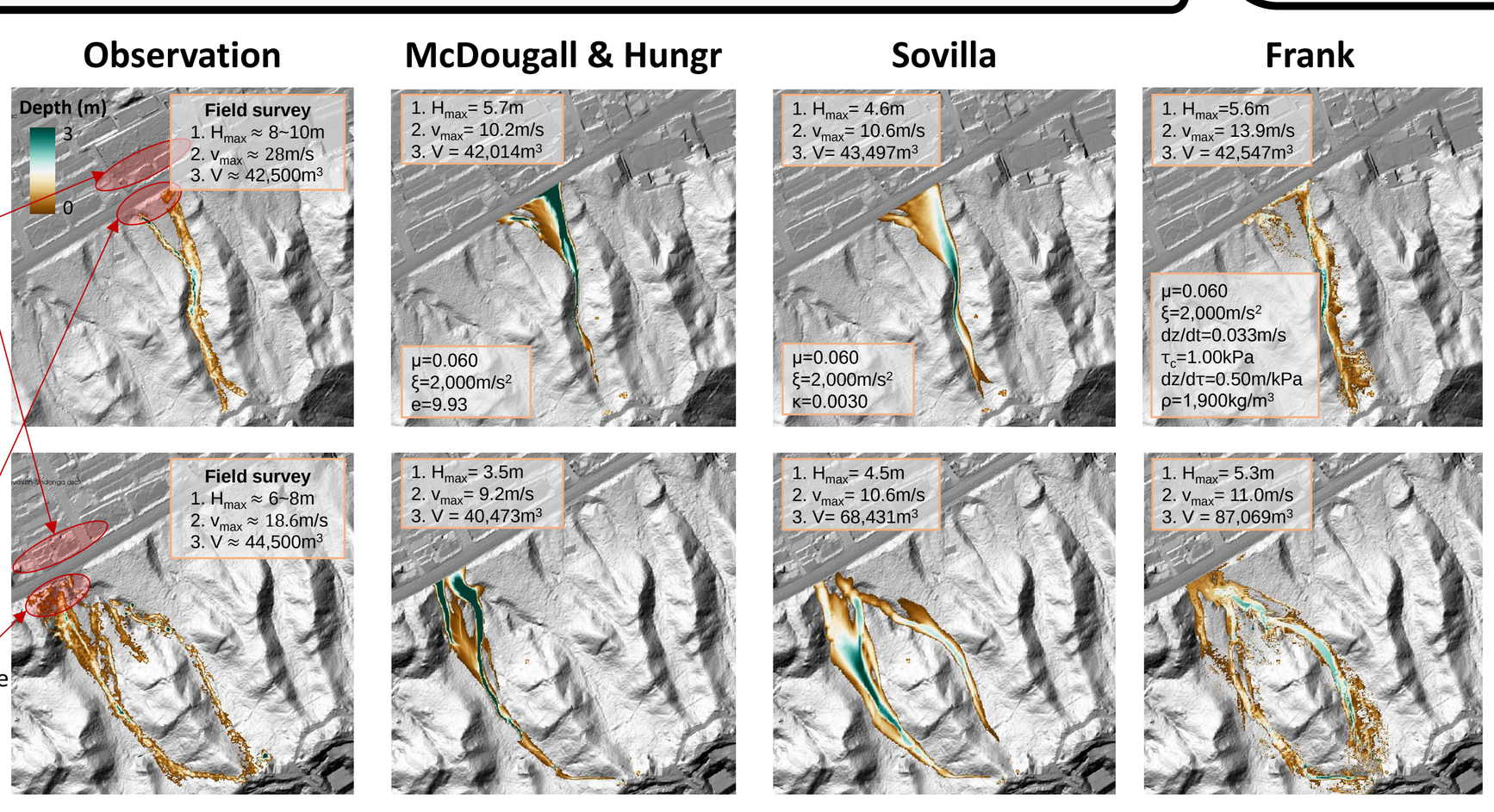
- The total debris-flow volume, maximum velocity, and inundated depth resulted from several erosion models were compared to the field survey data.
- The shape of the erosion depth that **Frank** model was most similar to the observation.
- However, the Frank model showed the worst accuracy in volume of entrainment
- The **Sovilla** model with one parameter showed the most stable results.
- Particularly, the flow velocity of the debris analyzed through the Deb2D model was found to be very low compared to the overall entrainment(erosion) model.
- Also, the observed flow velocity in the field are 28m/s and 18m/s, which is very large compared to the past debris flow events in the world.
- This was confirmed to be very large due to the continuous rainfall caused by the torrential rainfall in Mt. Umyeon in 2011, and it was difficult to implement it in the model.

STUDY EVENT

In July 2011, a landslide occurred due to torrential rain in Mt. Umyeon in Seoul, Republic of Korea.



In the series of landslides that occurred, we studied the watersheds of Raemian and Sindong-A .



Conclusion

- We analyzed the results by applying various erosion models to one rheological model using the Deb2D model.
- In future studies, **various erosion models will be applied to various rheological models**, and quantitative combinations as well as qualitative comparisons will be made to determine the best **combination and parameters** for the study area.
- Also, in the above process, we want to understand the features, advantages, and disadvantages of each model.