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Elasto-plastic-μ(I) SPH model for landslide induced debris flow

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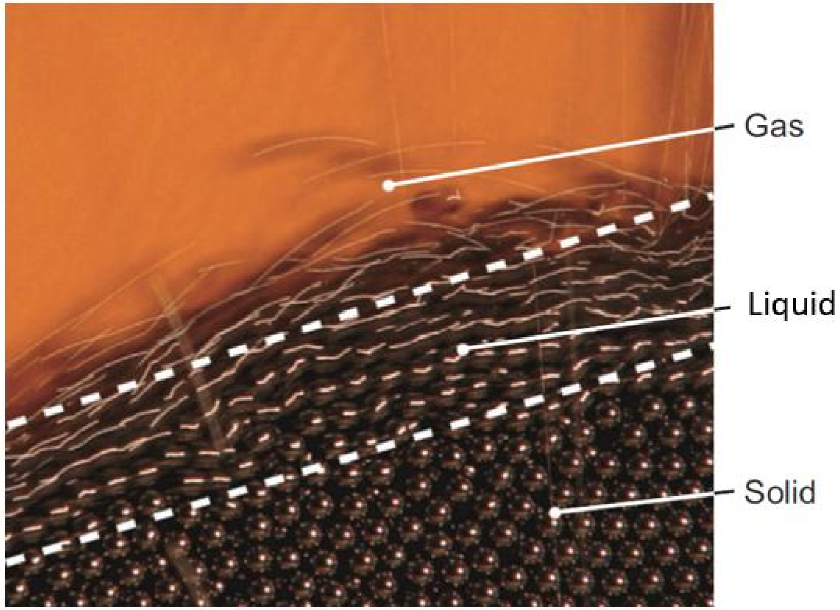
Outline

1. The background
2. Experimental method and analysis
3. Numerical modeling
4. Numerical results
5. Future work

1. The background

Motion behavior of granular media



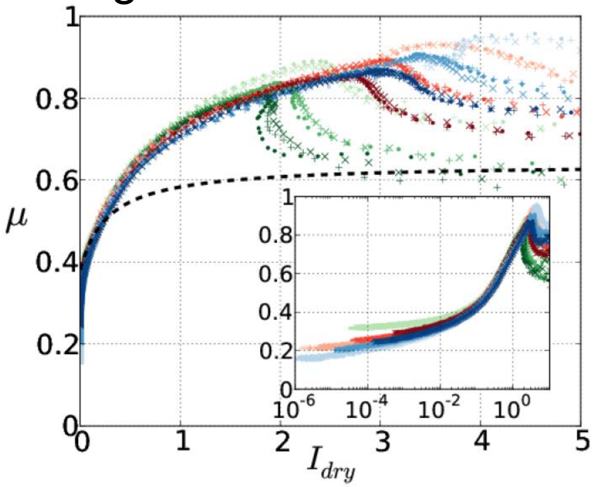
Forterre & Pouliquen 2008

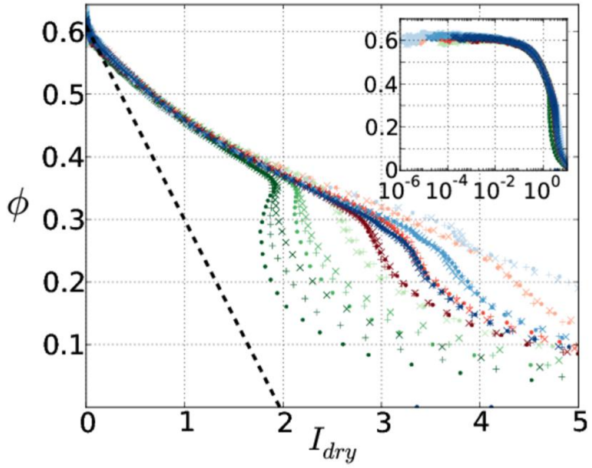
1. The background

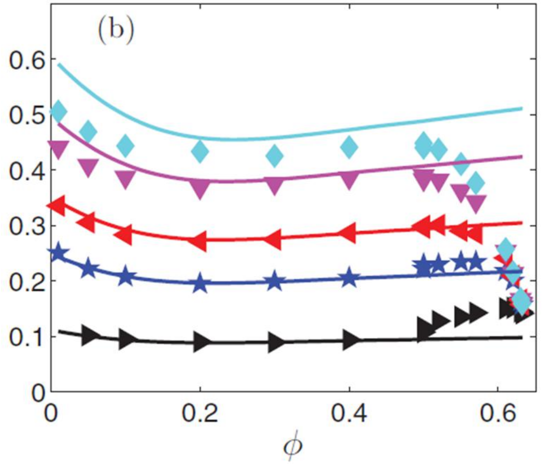
Granular solid → Soil mechanics

Granular liquid → $\mu(I)$ rheology $I = \frac{\gamma d}{\sqrt{P/\rho}}$

Granular gases → Kinetic theory







Range of $\mu(I)$ rheologic application

Range of kinetic theoretical application

2. Experimental design and method

Experiment condition

$\rho_s = 2200 kg/m^3; d \sim 10-30 mesh$

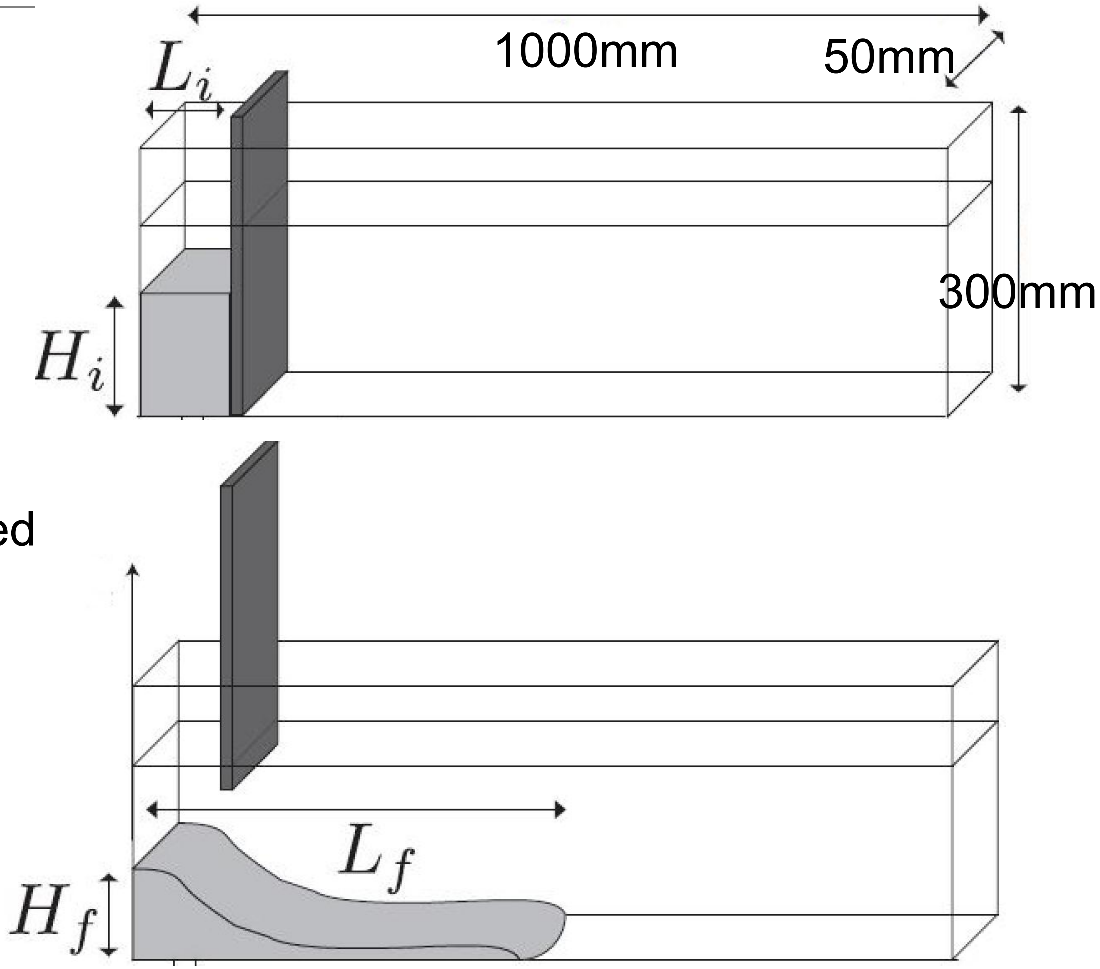
$W / \bar{d} \approx 90$

$W / \bar{d} \approx 90$ ➡ Sidewall effect ignored

$t_{lift}/t_{total} \approx 0.05\,s/1\,s = 1/20$ ➡ Lift plate effect ignored

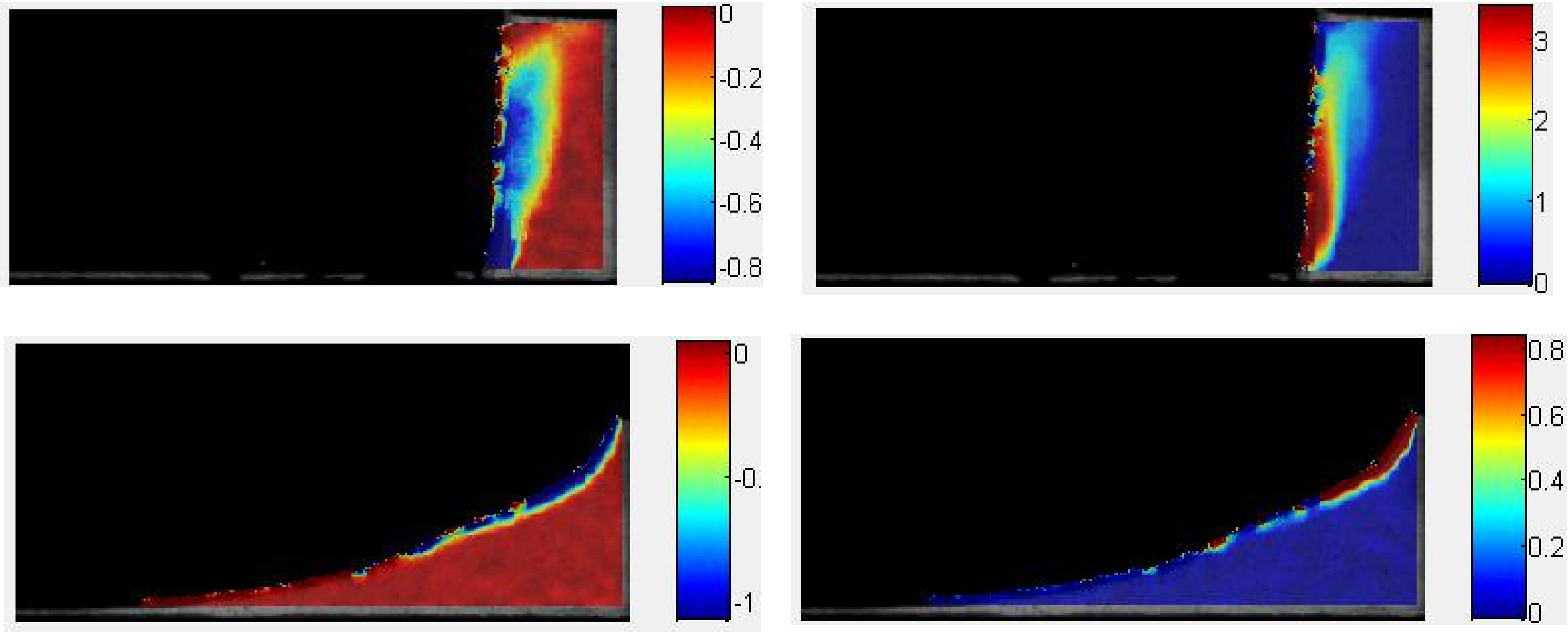
Add 5% dyed sand ➡ PIV ,DIC

Photographic recording rate: 8000 fps



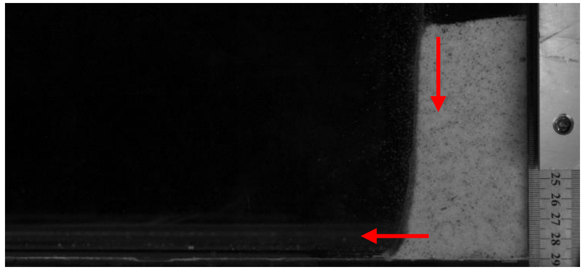
2. Experimental result and analysis

Result of DIC

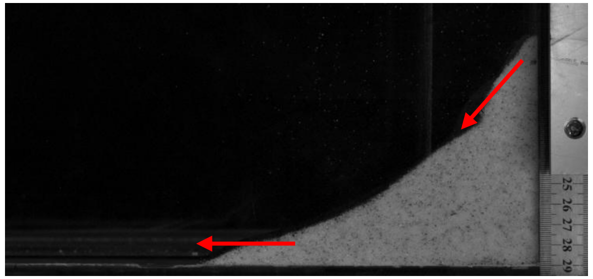


2. Experimental result and analysis

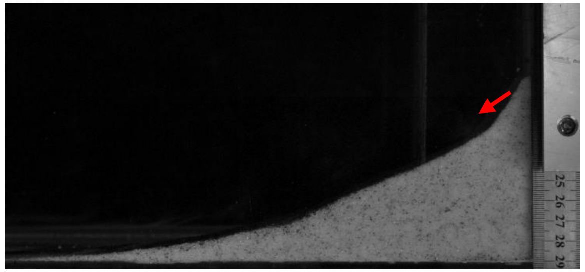
Basic phenomenon： H/W=2.4



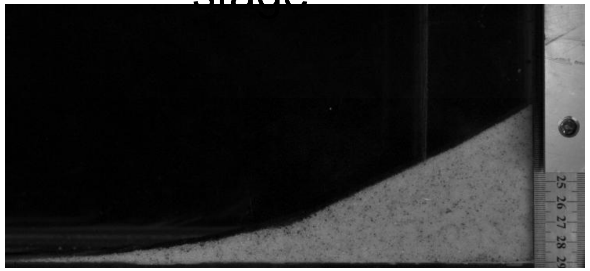
First stage



Second stage



Third stage



Final deposit

3. Numerical modeling

Governing equations：

$$\frac{D\rho_i}{Dt} = \sum_{j=1}^{N} m_j (v_i^{\alpha} - v_j^{\alpha}) \frac{\partial W_{ij}}{\partial x_i^{\alpha}}$$

$$\frac{Dv_i^{\alpha}}{Dt} = \sum_{j=1}^{N} m_j \left(\frac{\sigma_i^{\alpha\beta} + \sigma_j^{\alpha\beta}}{\rho_i \rho_j} - \Pi_{ij} \delta^{\alpha\beta} + F_{ij}^{n} R_{ij}^{\alpha\beta} \right) \frac{\partial W_{ij}}{\partial x_i^{\beta}} + g^{\alpha}$$

Constitutive relation

Granular solid

$$\frac{D\sigma_{epi}^{\alpha\beta}}{Dt} = \sigma_i^{\alpha\gamma} \dot{\omega}^{\beta\gamma} + \sigma_i^{\gamma\beta} \dot{\omega}_i^{\alpha\gamma} + 2G\dot{e}_i^{\alpha\beta} + K\varepsilon_i^{\gamma\gamma} \delta_i^{\alpha\beta} - \dot{\lambda}_i \left[3\alpha_{\psi} K \delta^{\alpha\beta} + \frac{G}{\sqrt{J_2}} s_i^{\alpha\beta} \right]$$

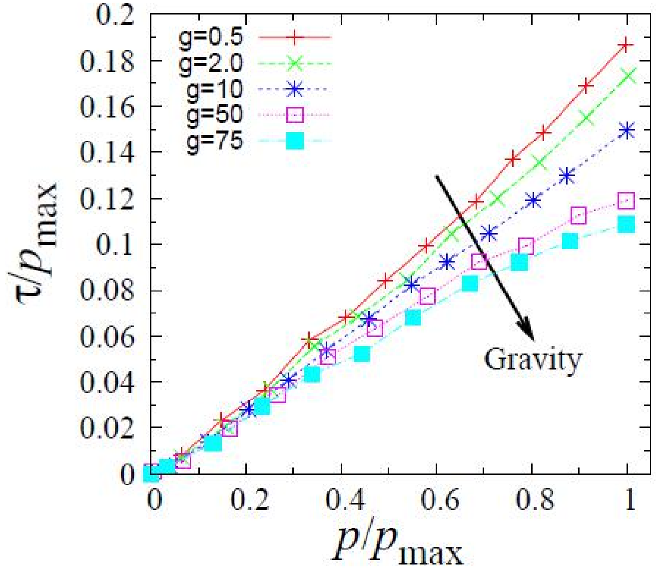
$$\dot{\lambda}_i = \begin{cases} \dfrac{3\alpha_{\phi} K \dot{\varepsilon}_i^{\gamma\gamma} + (G/\sqrt{J_2}) s_i^{\alpha\beta} \dot{\varepsilon}_i^{\alpha\beta}}{9\alpha_{\phi}\alpha_{\psi} K + G} & f(I_1, J_2) = 0 \\ 0 & f(I_1, J_2) < 0 \end{cases}$$

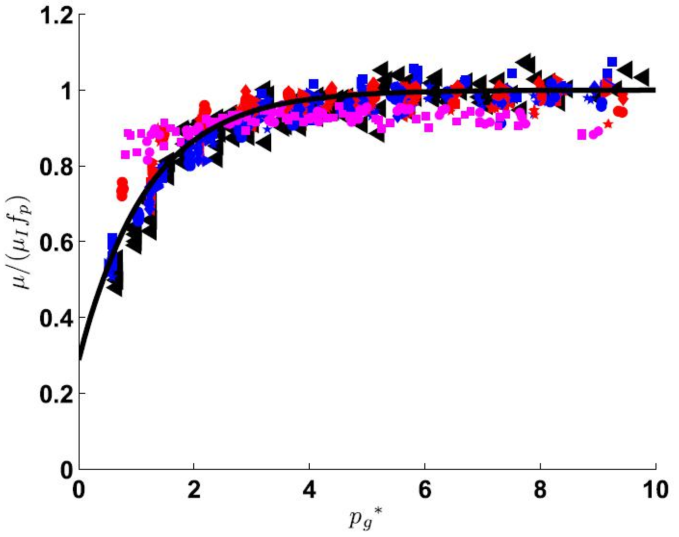
Granular liquid

$$\sigma_{vi}^{\alpha\beta} = \frac{(\mu_2 - \mu_1)(P)}{2\|\dot{\varepsilon}\| + I_0 \sqrt{P} / (d\sqrt{\rho_s})} \dot{\varepsilon}^{\alpha\beta}$$

3. Numerical modeling

Gravity mechanism：

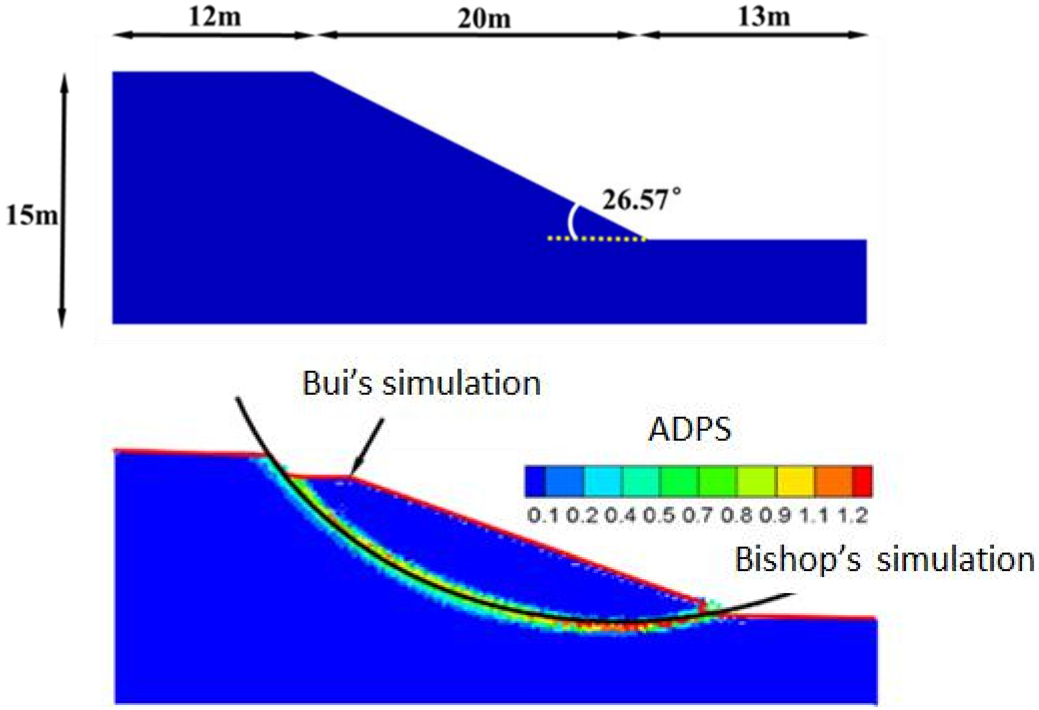




$$\sigma_{vi}^{\alpha\beta} = \frac{(\mu_2 - \mu_1)(P)}{2\|\dot{\varepsilon}\| + I_0\sqrt{P}/(d\sqrt{\rho_s})}\dot{\varepsilon}^{\alpha\beta} \Rightarrow \sigma_{vi}^{\alpha\beta} = \frac{(\mu_2 - \mu_1)(P + \kappa\rho_s g d)}{2\|\dot{\varepsilon}\| + I_0\sqrt{P + \kappa\rho_s g d}/(d\sqrt{\rho_s})}\dot{\varepsilon}^{\alpha\beta}$$

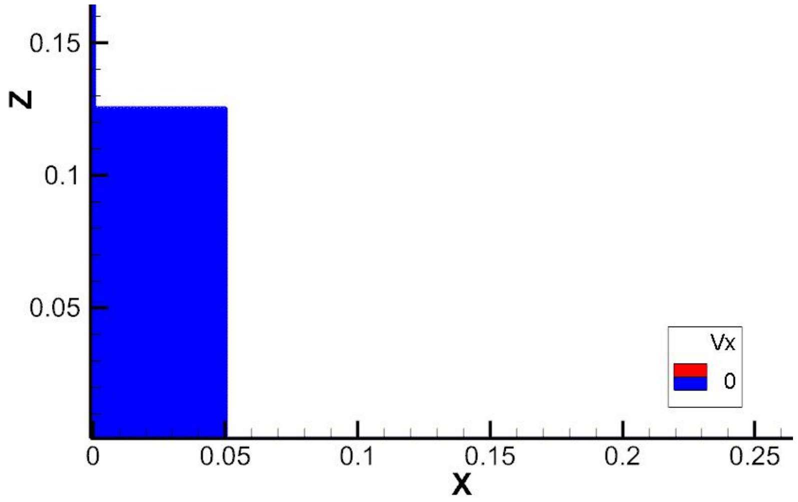
4. Numerical results

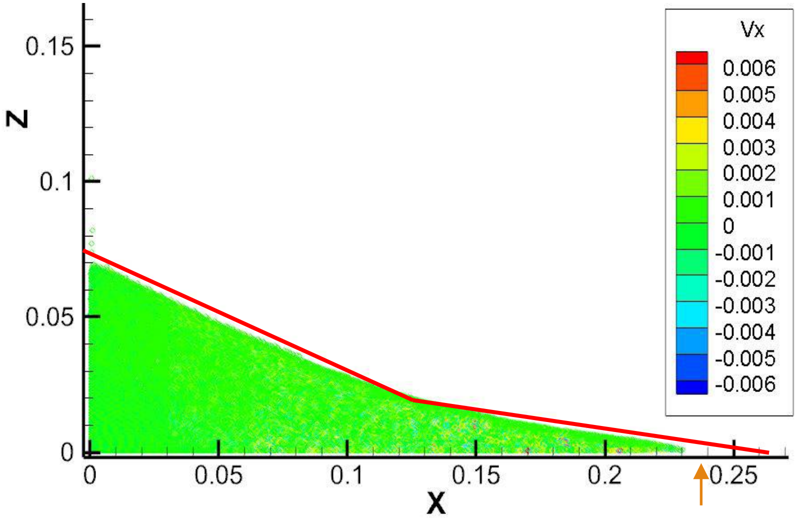
Elasto-plastic model verification：



4. Numerical results

Elasto-plastic viscous model result : final deposit



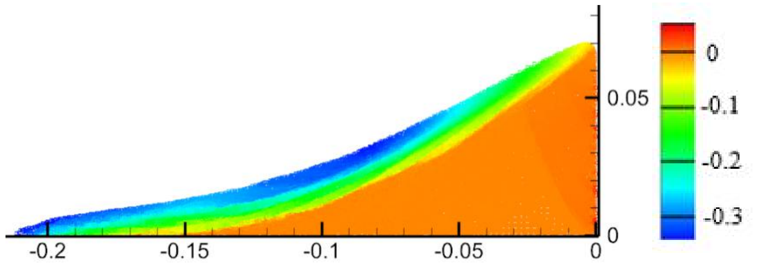


continuous medium hypothesi
s isn’t applicable？

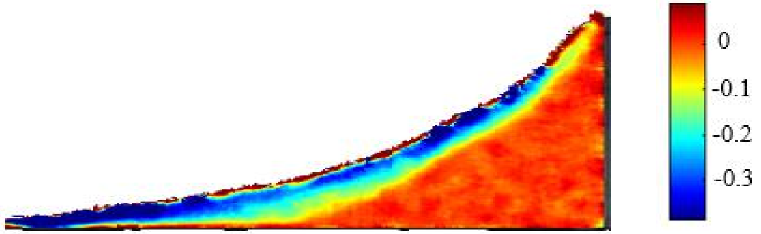
4. Numerical results

Elasto-plastic viscous model result : velocity profile

velocity of X direction

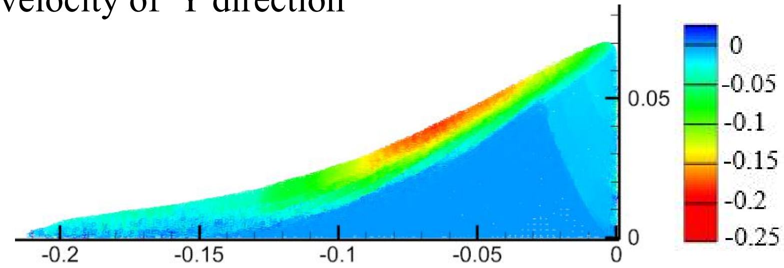


Numerical result



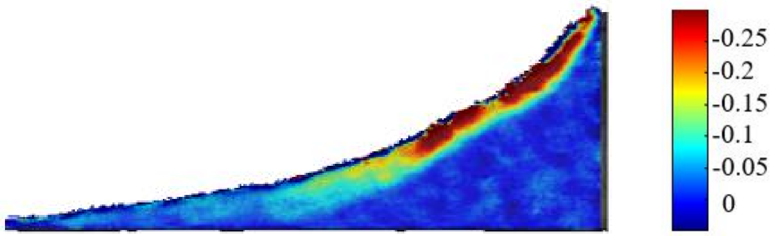
Experimental result

velocity of Y direction



Numerical result

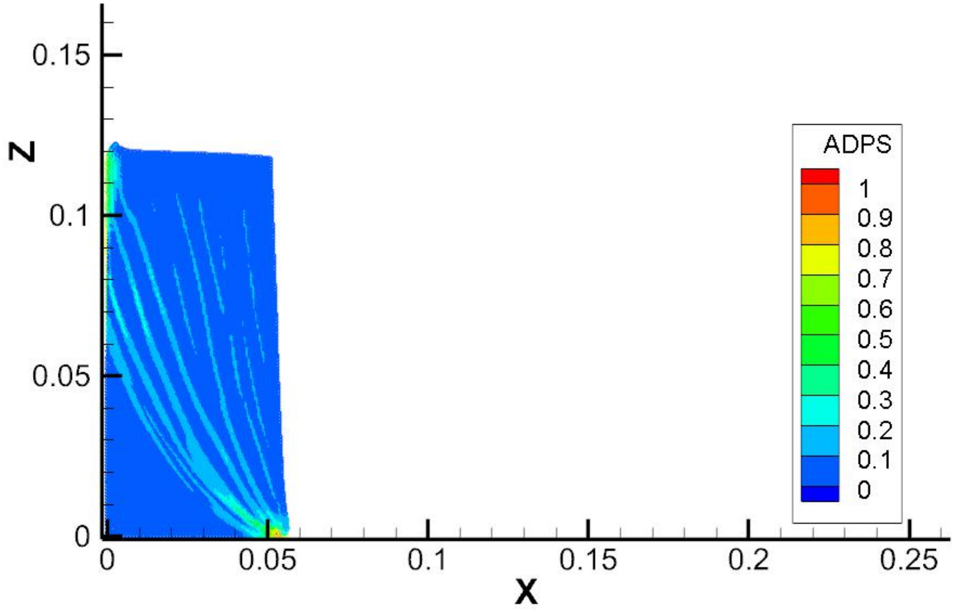
t=0.3s

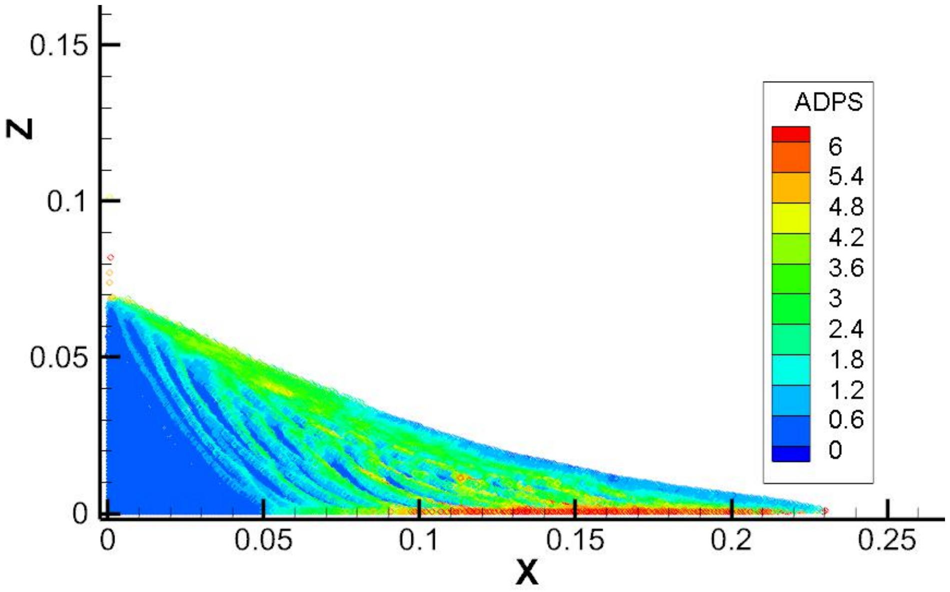


Experimental result

4. Numerical results

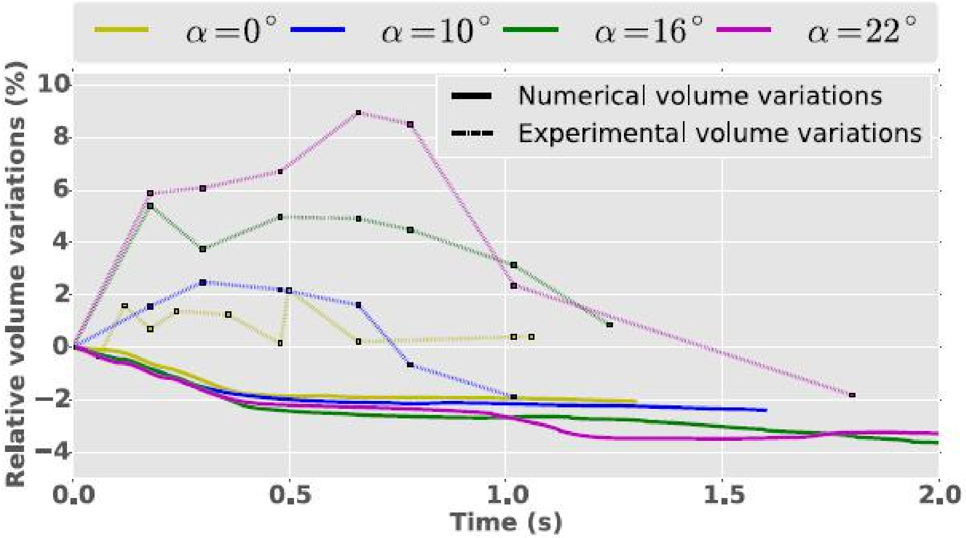
Elasto-plastic viscous model result : ADPS





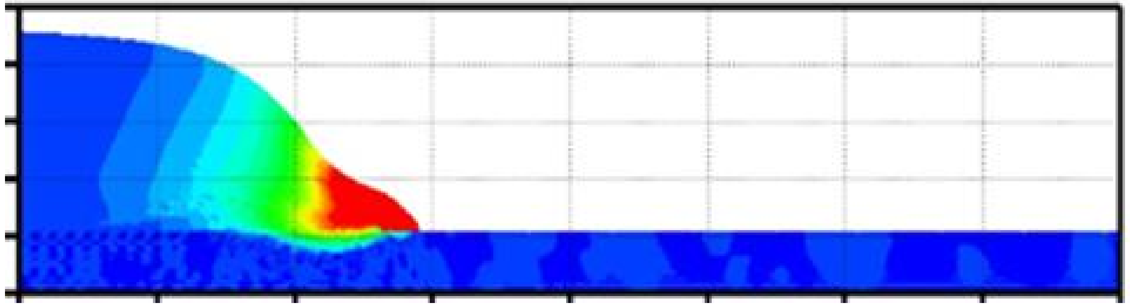
5. Future work

A: Extend to compressible system



Martin et al. 2017

B: Extend to solid-liquid coupled



Q & A

THANKS !