YMC 2023
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Flow-sediment-biota Interactions
In Fluvial system: recent research trends

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Experimental study on landslide dam breaching and the local morphological changes

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Introduction

- **Dams √, Landslides √, What is landslide dams ? Why should we study ?**

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Introduction

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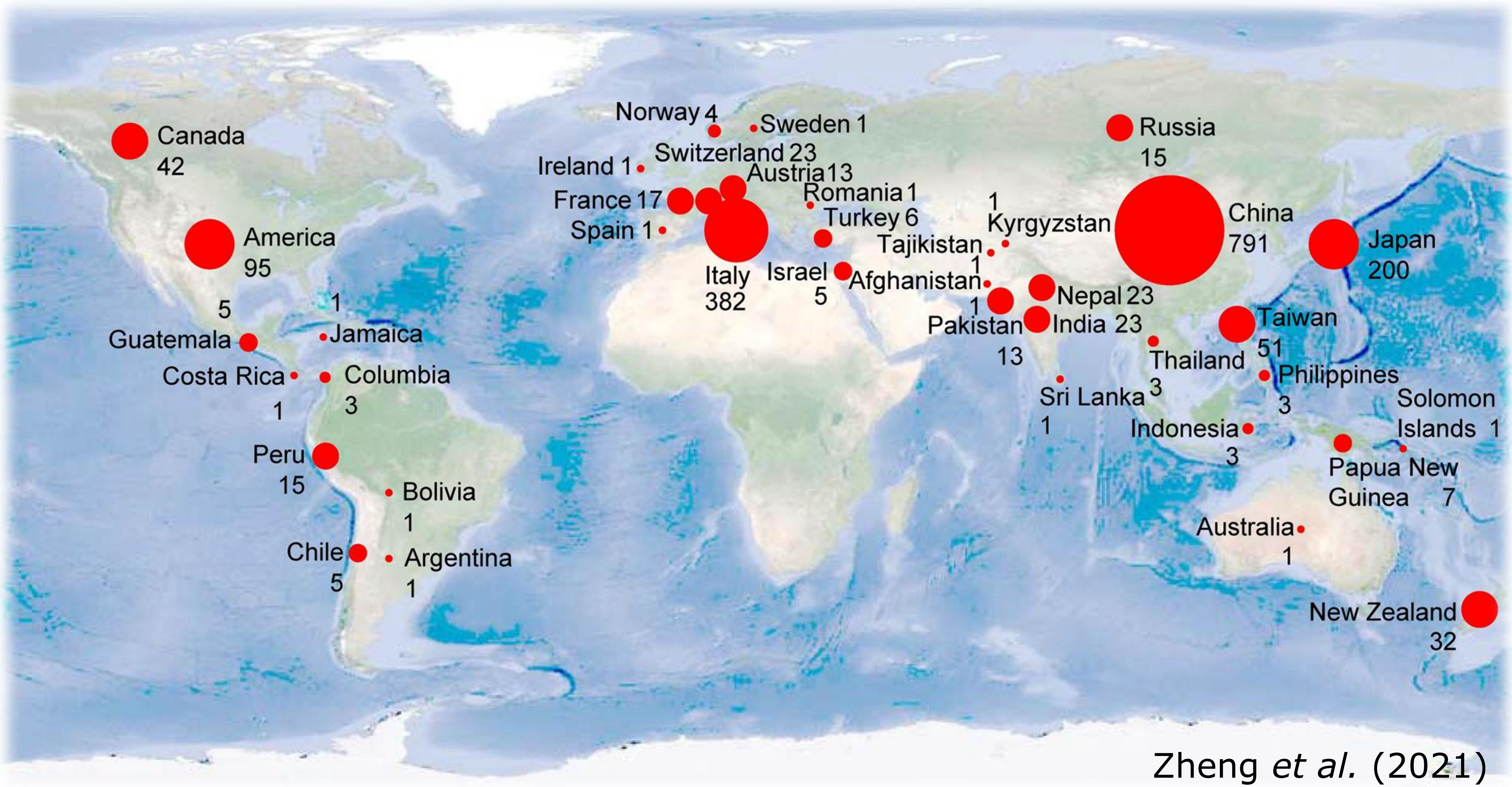

Zheng *et al.* (2021)

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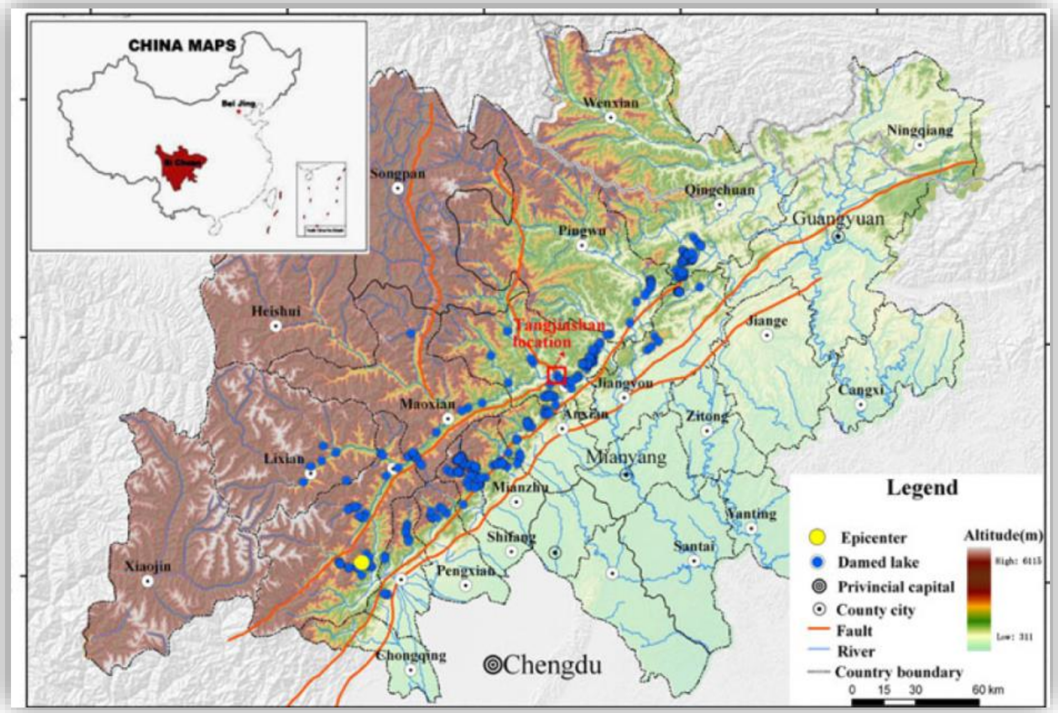
Introduction



2008 "5.12" Wenchuan 8.0 earthquake:

- More than 60000 landslides were triggered by the earthquake and 257 of them blocked river and formed landslide dams.

Introduction

- **Geometrical characteristics:** the slope and length of the dam;
- **Material characteristics:** wide graded materials;
- **Structure characteristics:** uneven distribution.

Landslide dam geometry

Material composition

Material distribution

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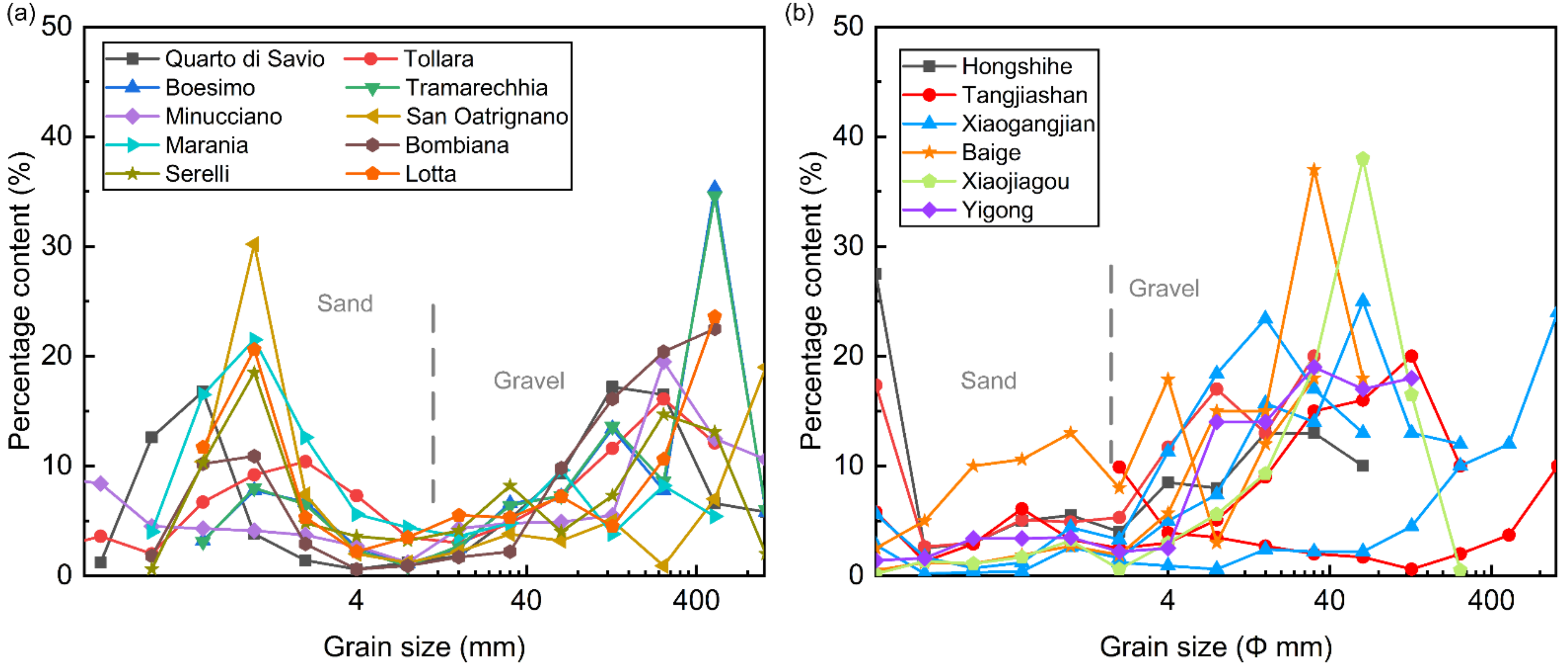
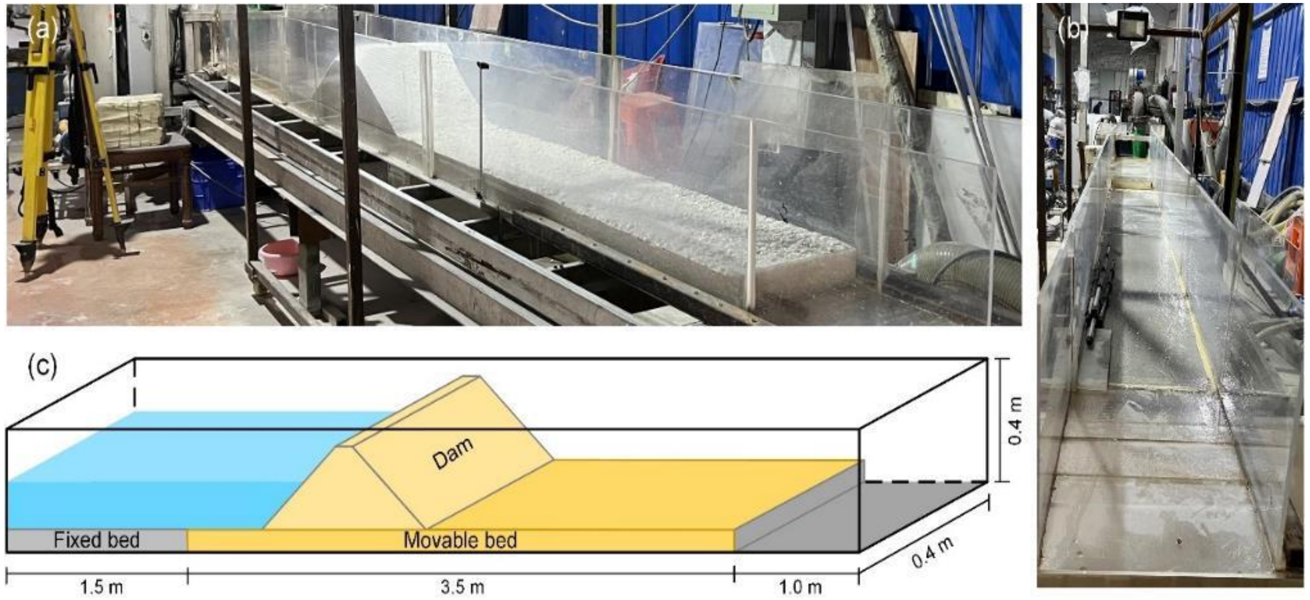
➢ **Material characteristics:** wide range of particle size and bi-modal or multi-modal characteristic of landslide dam material.

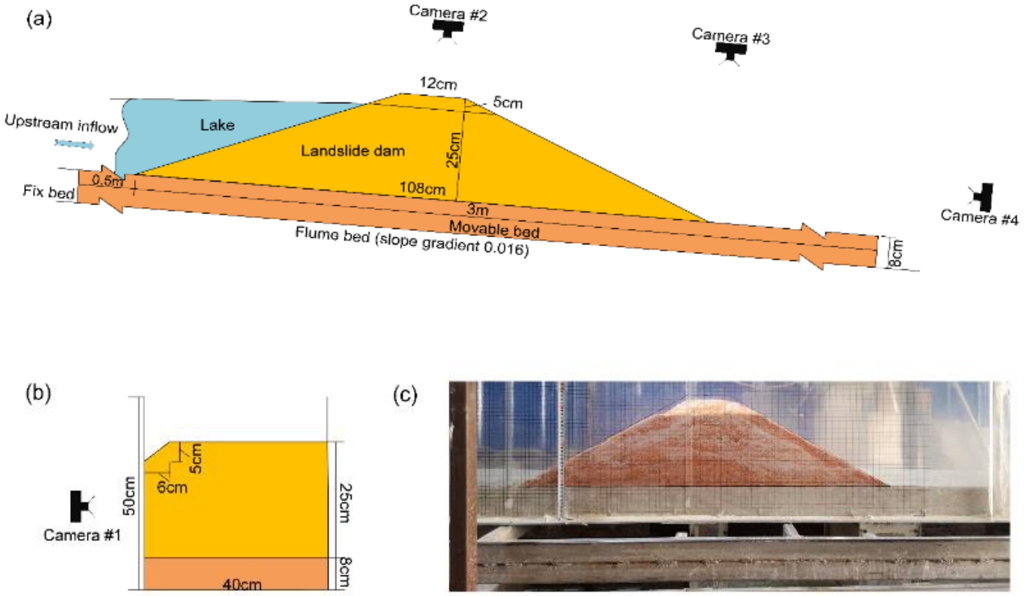


Landslide dams in Italy (Casagli et al., 2003) Landslide dams in China (Shen et al., 2003)

Experiments

➢ Experimental equipment and setup



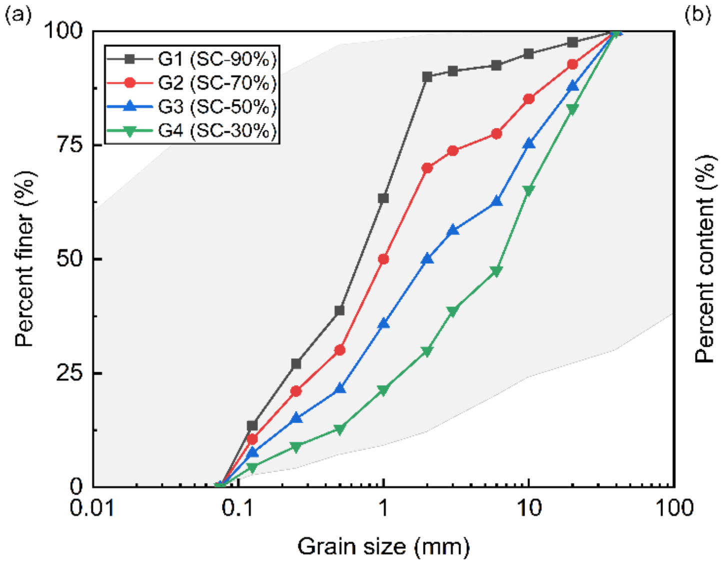


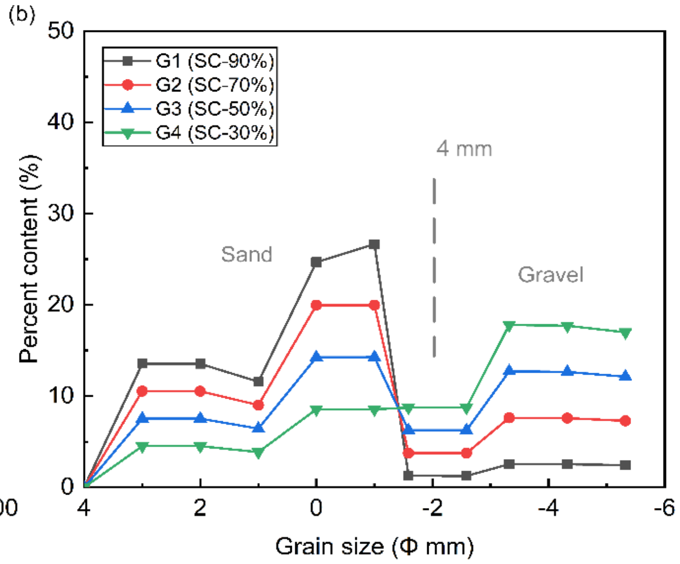
Dam geometry (cm)			Diversion channel (cm)		Movable bed		Inflow rate (m^3s^{-1})
Top width	Bottom width	Height	Width	height	Depth (cm)	Slope	
12	108	25	6	5	8	0.016	1×10^{-3}

Dam geometry and inflow rate are determined based on four dimensionless proposed in previous literature (Peng and Zhang (2012), Li et al. (2021)).

Experiments

➢ Material composition

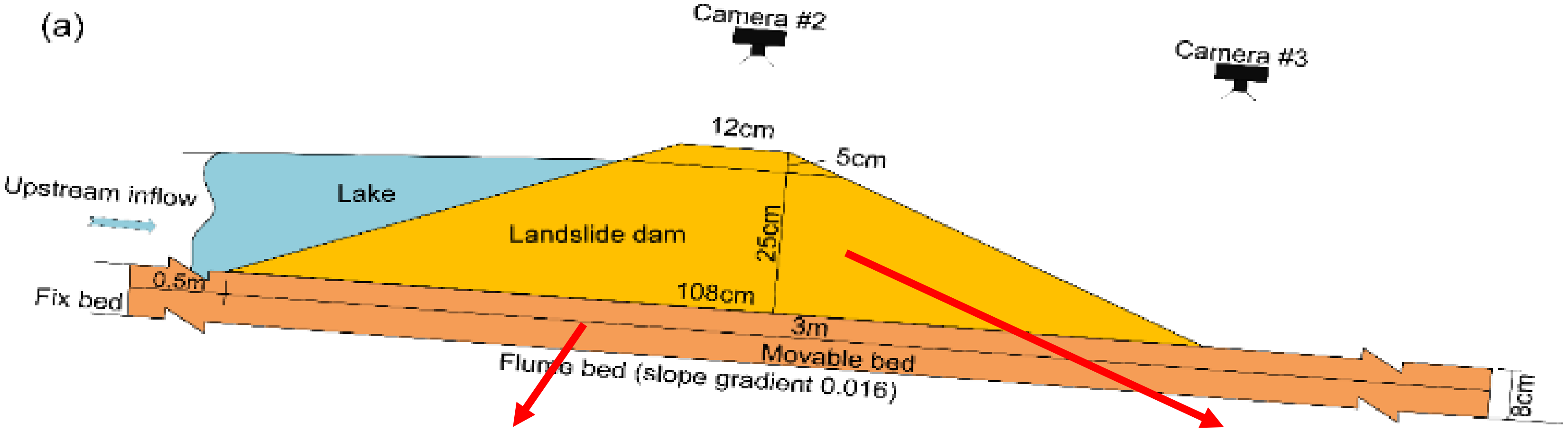




Material	d_{50}	S_c	G_c	C_c	C_u	ρ_{dmax}	φ	e
G1	0.730	90%	10%	0.939	8.321	1980	31.6	0.785
G2	0.999	70%	30%	1.356	12.287	2070	33.1	0.707
G3	2.000	50%	50%	0.801	28.916	2210	36.6	0.599
G4	6.562	30%	70%	1.451	28.144	2400	37.8	0.472

Experiments

➢ Experimental scenarios



Test	Movable bed material	Dam material		
		Material	d_{50}	S_c
T1	G1	G1	0.730	90%
T5	G4			
T2	G2	G2	0.999	70%
T6	G4			
T3	G3	G3	2.000	50%
T7	G4			
T4	G4	G4	6.562	30%
T8	G4			

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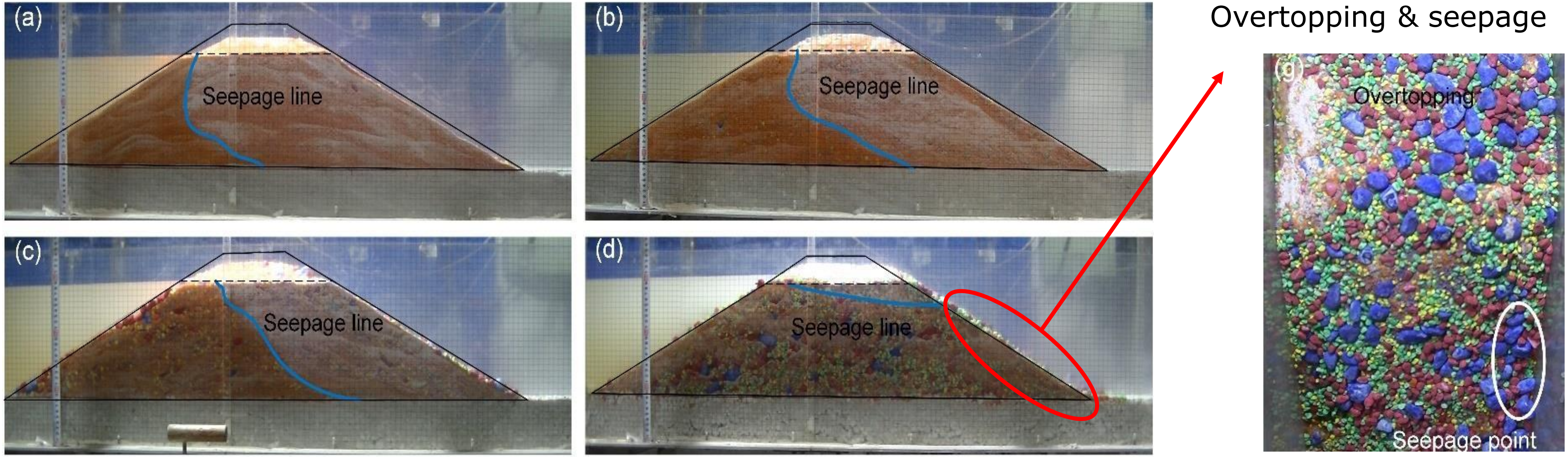
Results

➢ Dam failure mode



- Infiltration is enhanced before dam breach with the decrease of sand content of the dam;
- Overtopping failure mode is observed in all experimental dams;
- Seepage point is observed in T4, while it is relatively small and can be ignored.

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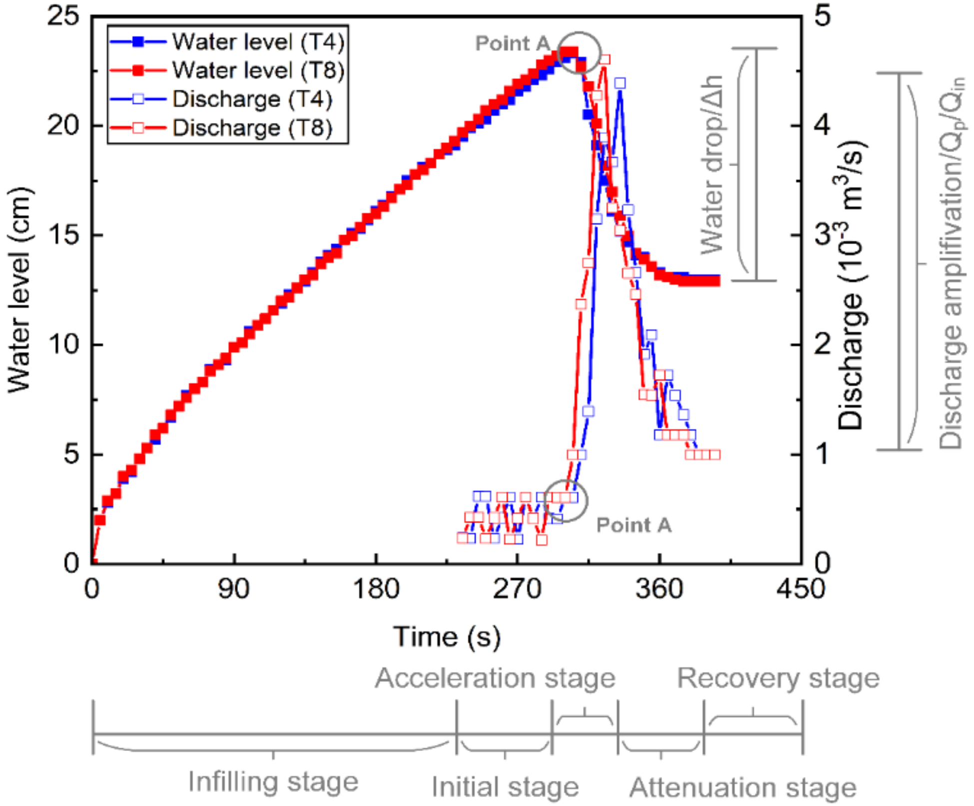
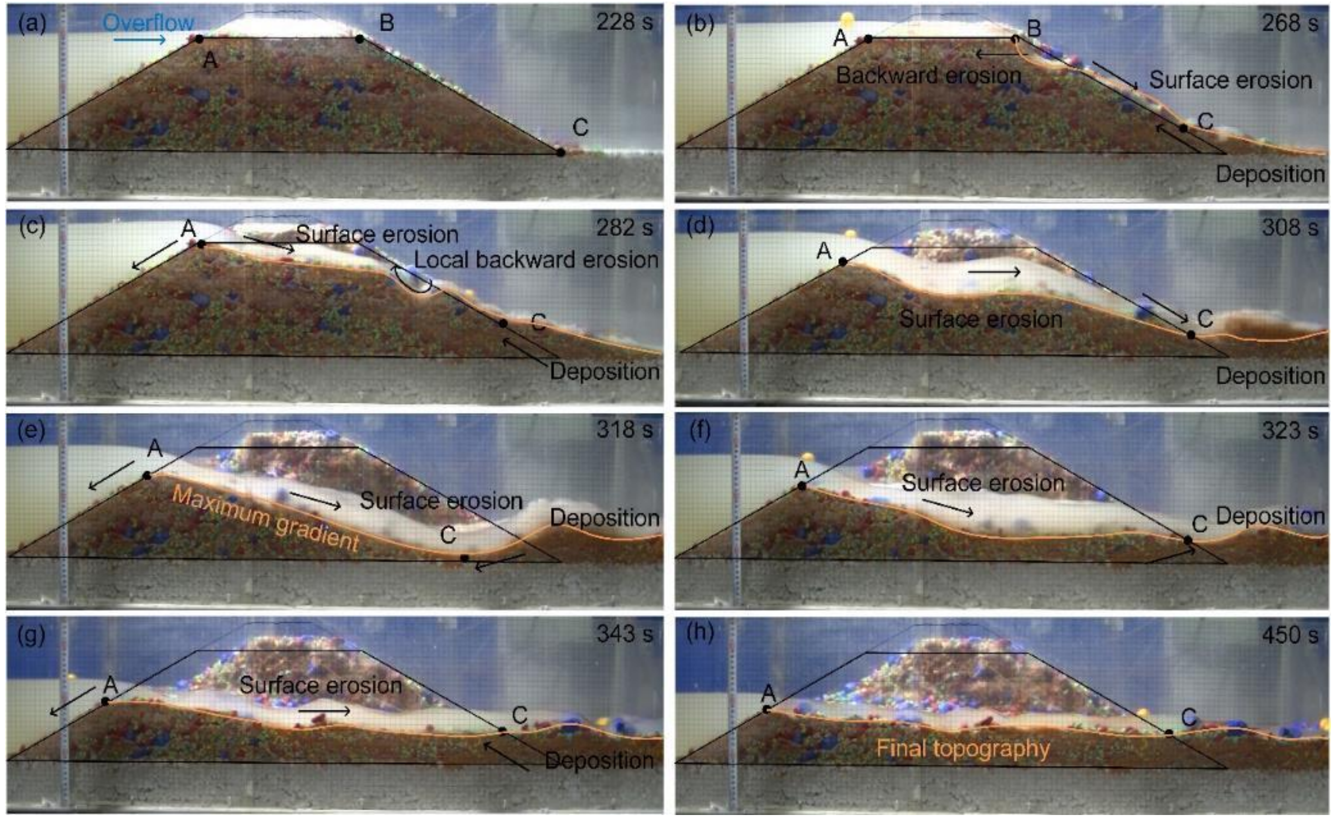
Results

➢ General description of overtopping failure





Dam breaching: initiation, acceleration, attenuation and recovery stages.

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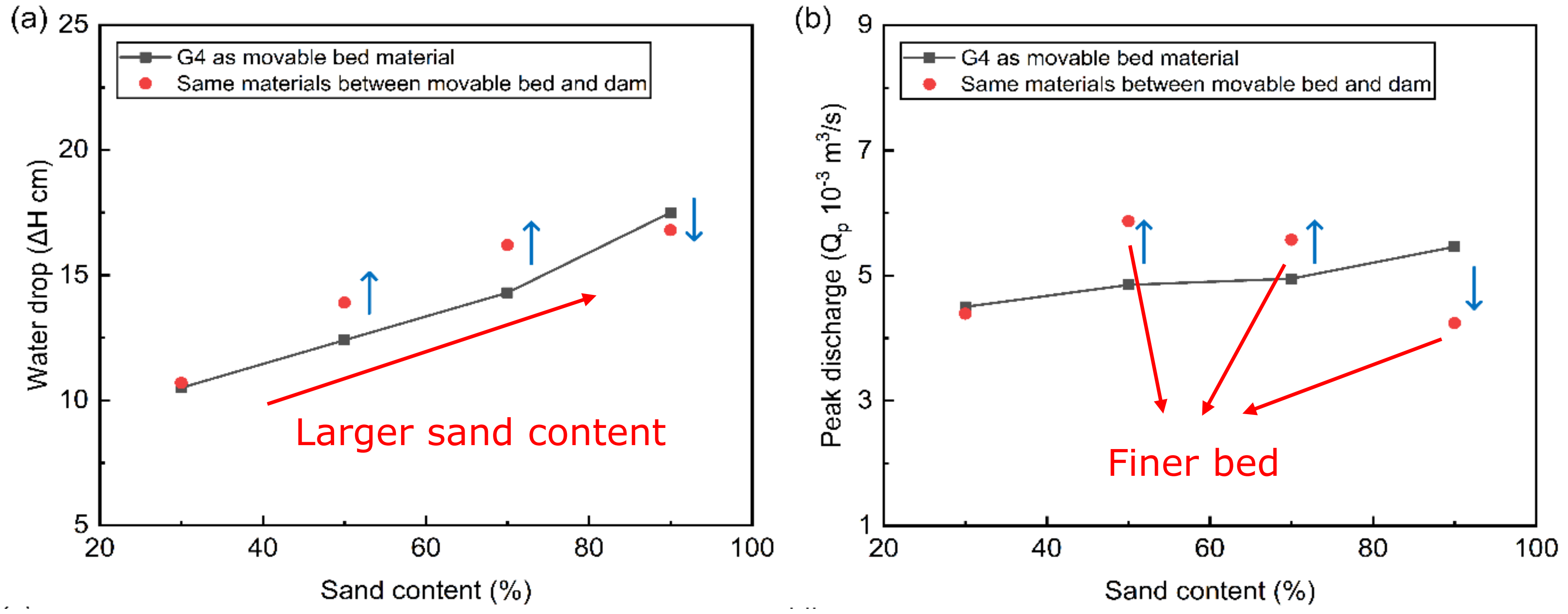
Results

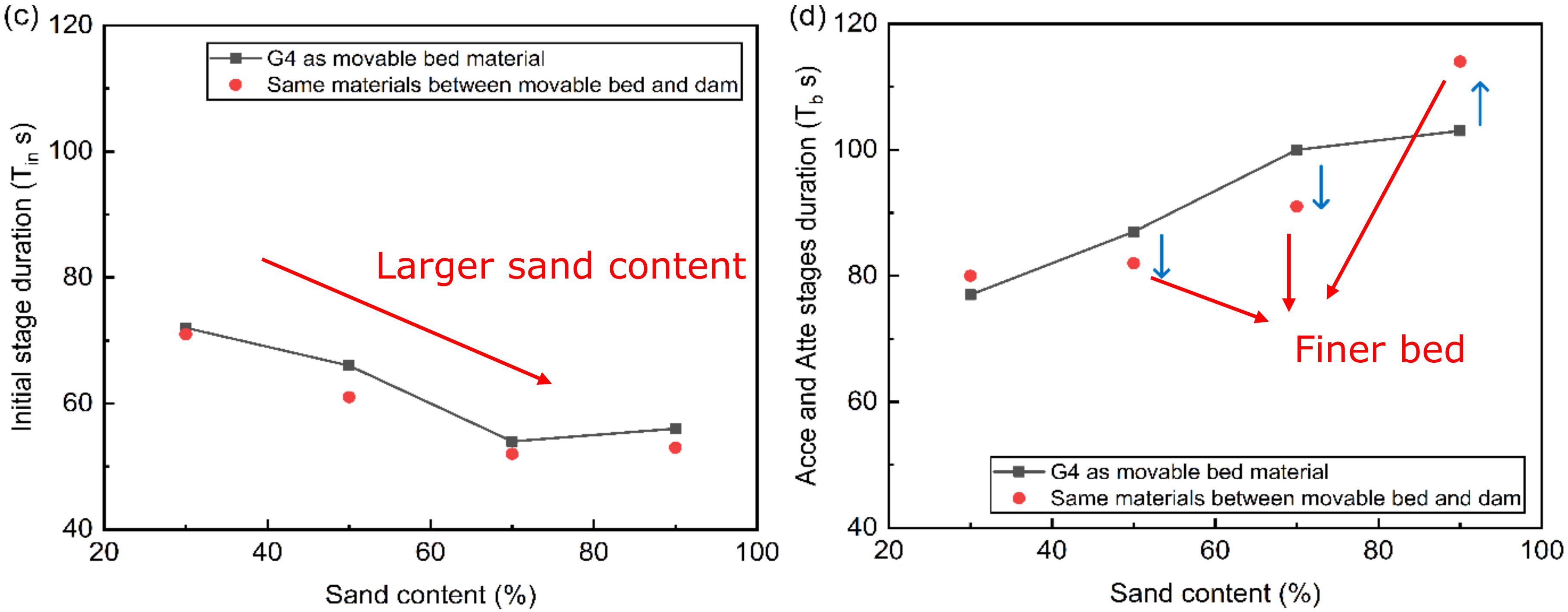
➢ Variation of water drop and peak discharge



- **Increase of SC in dam material:** Lager discharge and water drop are observed;
- **Influence of SC in movable bed material:** Different variations are observed with SC of dam material is smaller than 70% and SC of dam material is 90%.

Results

➢ **Breach duration (initial stage, acceleration and attenuation stage)**



- **Influence of SC in movable bed material:** Depends on dam material composition.
- **Increase of SC in dam material:** Longer in acceleration and attenuation stages but shorter in initial stage;

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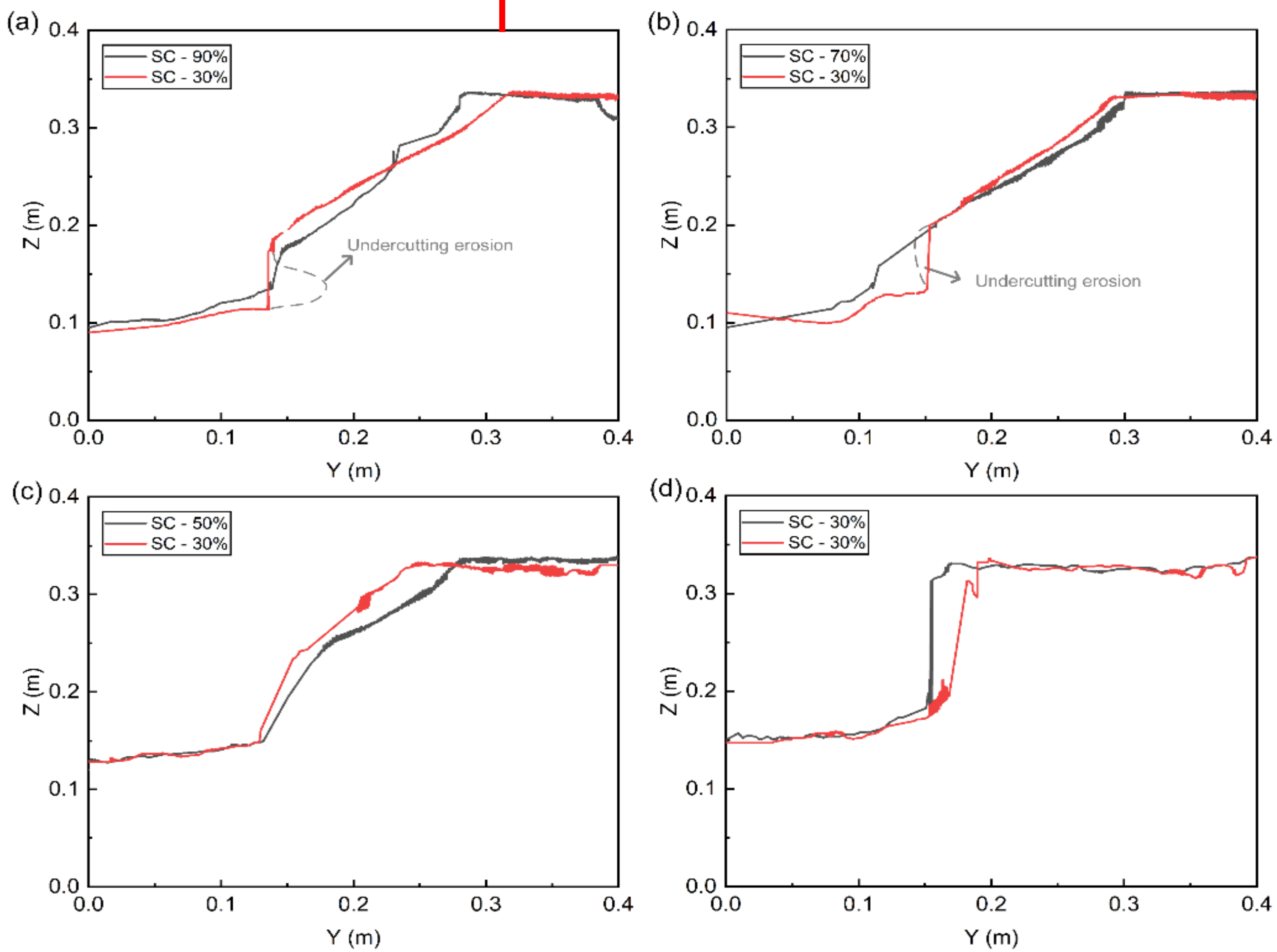
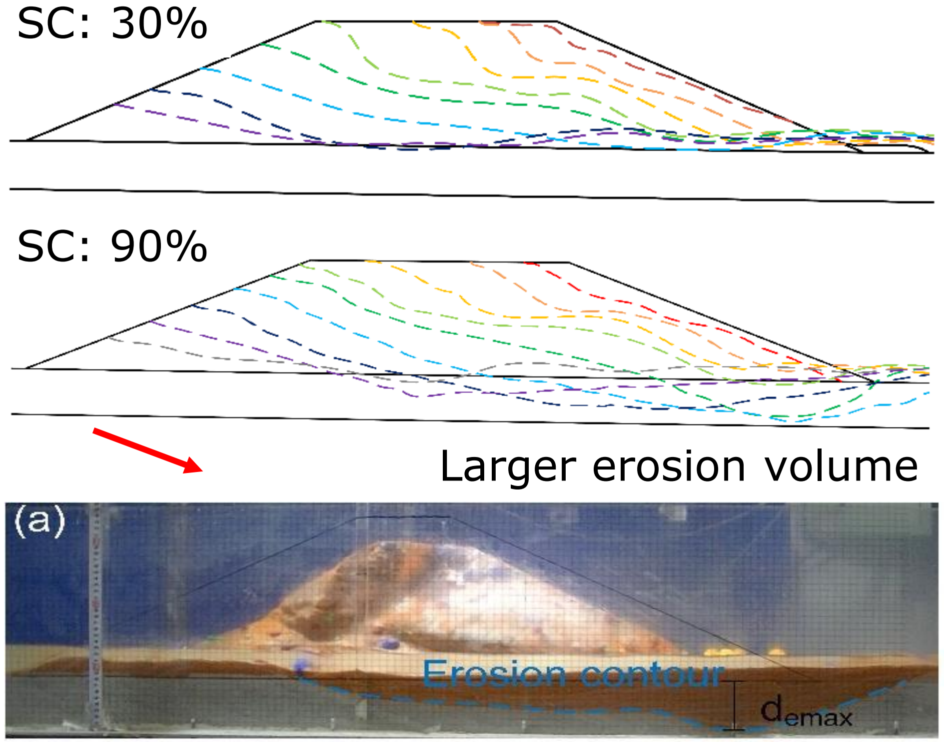
Results

➢ Final breach geometry





Similar final breach geometry but breaching process varies

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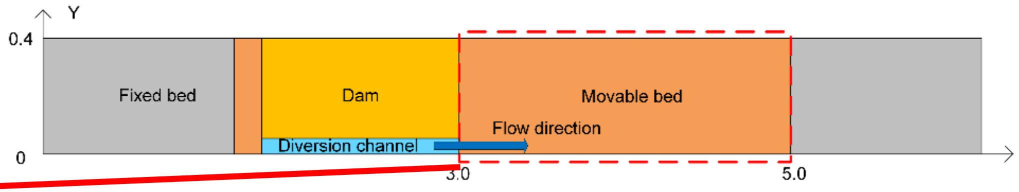
Results

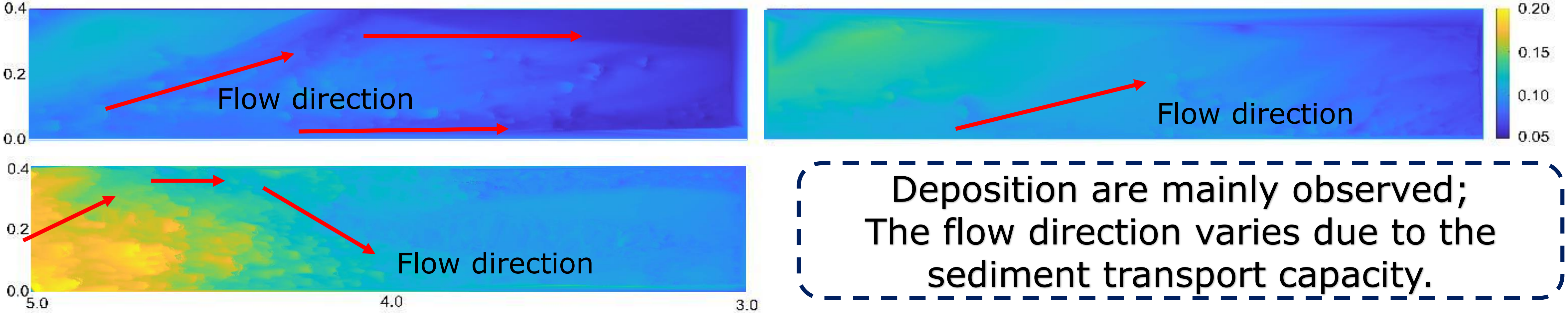
➢ Final topography of the movable bed



50% of SC for dam and bed materials

Coarser dam material

Coarser of bed material (Sand content from 90% to 30%)



Deposition are mainly observed;
The flow direction varies due to the sediment transport capacity.

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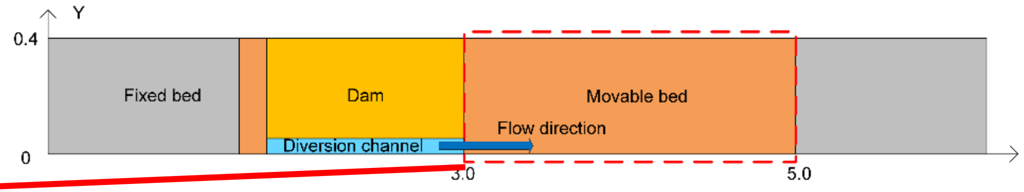
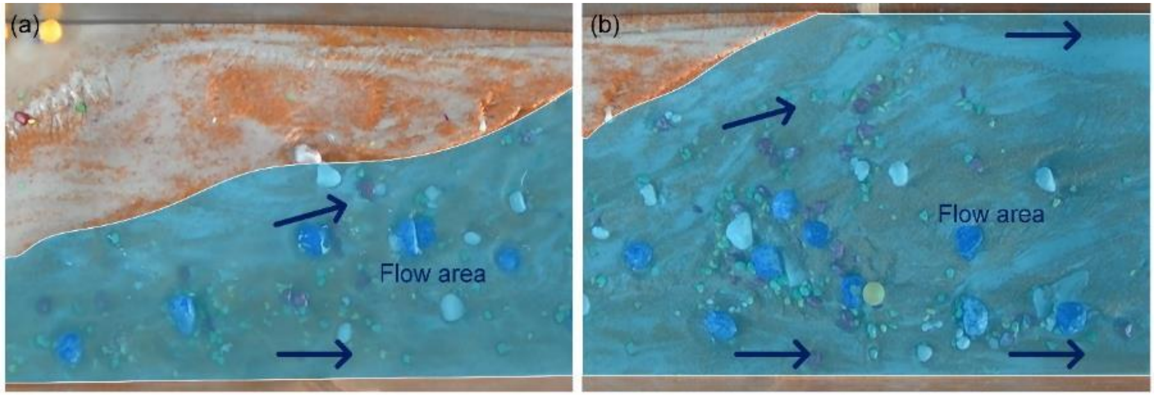
Results

➢ Final topography of the movable bed

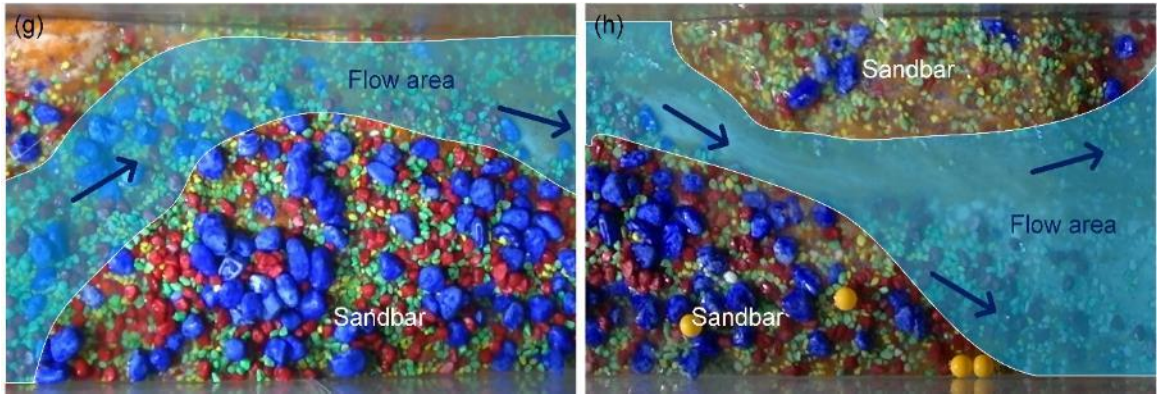


50% of SC for dam and bed materials

90% of SC for dam and bed materials



30% of SC for dam and bed materials



- Meandering channel due to the sediment transport and the formation of sandbars.

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Numerical simulation

- One single grain diameter

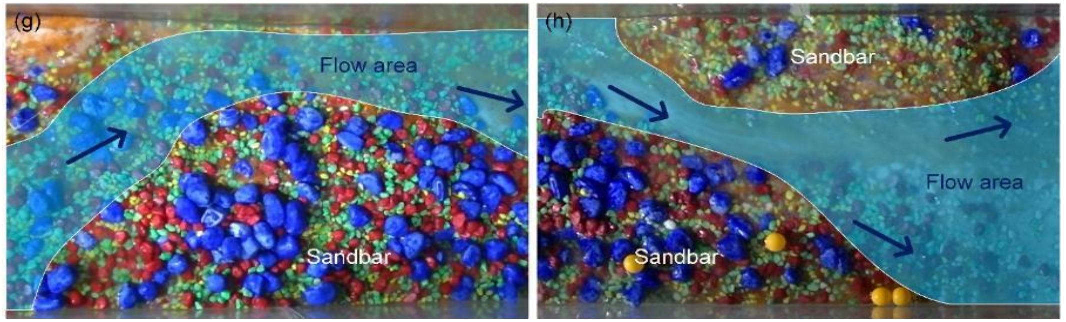
$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}=0$$

$$\frac{\partial (hu)}{\partial t}+\frac{\partial (hu^2+\frac{1}{2}gh^2)}{\partial x}+\frac{\partial (huv)}{\partial y}=gh(S_{0,x}-S_{f,x})$$

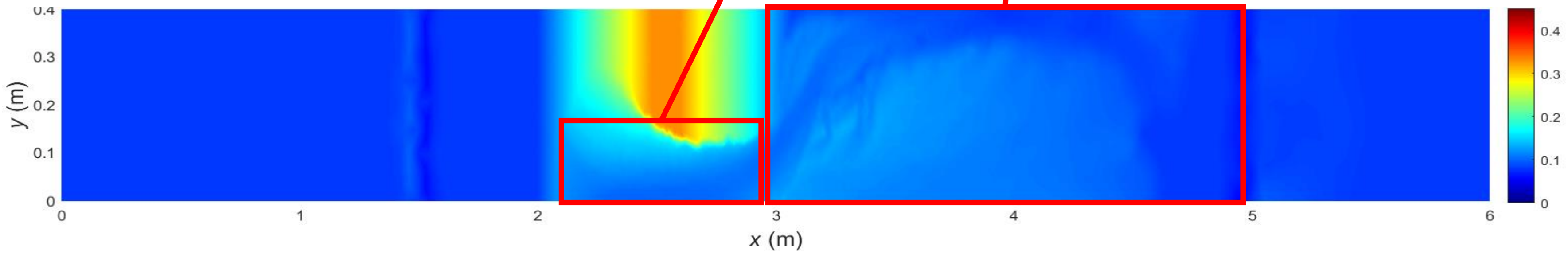
$$\frac{\partial (hv)}{\partial t}+\frac{\partial (huv)}{\partial x}+\frac{\partial (hv^2+\frac{1}{2}gh^2)}{\partial y}=gh(S_{0,y}-S_{f,y})$$

$$\frac{\partial z_b}{\partial t}+\frac{\partial (\varepsilon q_{s,x})}{\partial x}+\frac{\partial (\varepsilon q_{s,y})}{\partial y}=0$$

- The overestimation of the erosion depth;
- The model can not be used to simulate the change of grain size distribution on the movable bed.



Grain size distribution



Bed elevation

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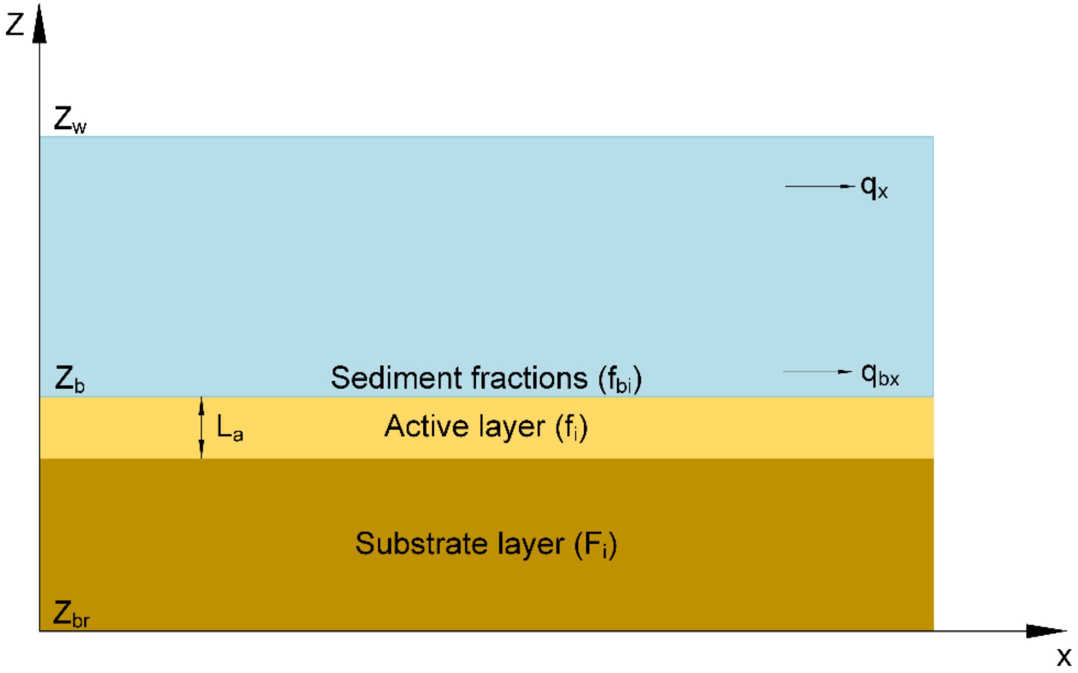
Numerical simulation

➢ Hirano’s active layer model



$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}=0$$

$$\frac{\partial (hu)}{\partial t}+\frac{\partial \left(hu^2+\frac{1}{2}gh^2\right)}{\partial x}+\frac{\partial (huv)}{\partial y}=gh\left(S_{0,x}-S_{f,x}\right)$$

$$\frac{\partial (hv)}{\partial t}+\frac{\partial (huv)}{\partial x}+\frac{\partial \left(hv^2+\frac{1}{2}gh^2\right)}{\partial y}=gh\left(S_{0,y}-S_{f,y}\right)$$

$$\frac{\partial z_b}{\partial t}+\frac{\partial (\varepsilon q_{s,x})}{\partial x}+\frac{\partial (\varepsilon q_{s,y})}{\partial y}=0$$

$$\boxed{\frac{\partial (f_i L_a)}{\partial t}=-\left(\frac{\partial\left(\varepsilon f_i q_{si,x}\right)}{\partial x}+\frac{\partial\left(\varepsilon f_i q_{si,y}\right)}{\partial y}\right)-f_{es}\frac{\partial (z_b-L_a)}{\partial t},\qquad i=1,2,\ldots,N}$$

$$\boxed{q_{s,y}=\sum_{i=0}^{N} f_i q_{si,y}\quad q_{s,x}=\sum_{i=0}^{N} f_i q_{si,x}}$$

Multi fractions and hiding-exposure effect

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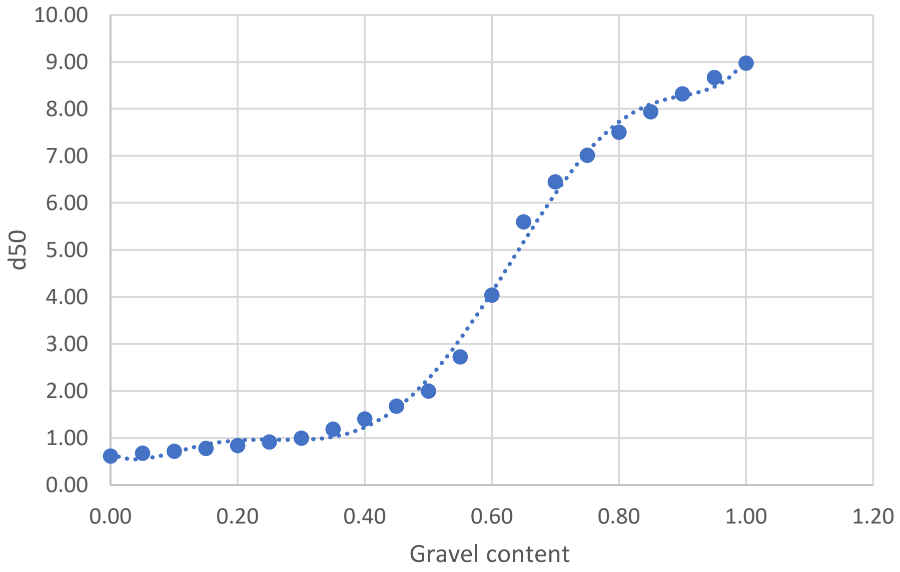
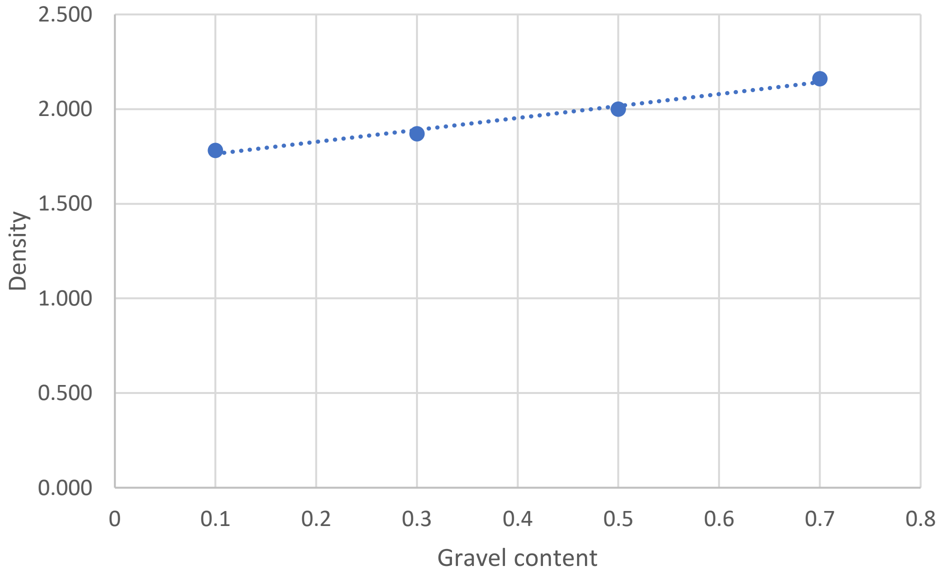
➢ Hiding-exposure effect

MPM: $q_{si} = 8\sqrt{g(s-1)d_{50}^3}(\theta_i - \theta_{ci})^{3/2}$

$$\theta_{ci} = \begin{cases} \theta_c\left[\dfrac{log19}{\log\left(\dfrac{19d_{50,i}}{d_{50}}\right)}\right]^2 & \dfrac{d_{50,i}}{d_{50}} \geq 0.4 \\ \theta_c\dfrac{d_{50}}{d_{50,i}} & \dfrac{d_{50,i}}{d_{50}} < 0.4 \end{cases}$$

Ashida and Michiue (1971)





Variation of median diameter, manning coefficient, density

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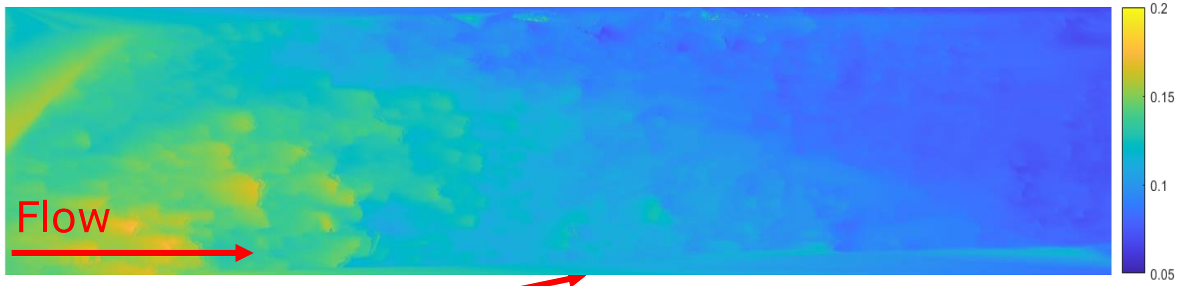
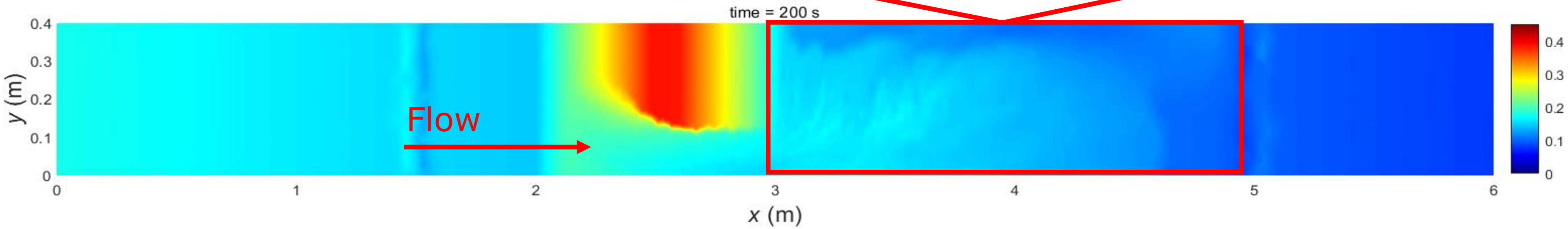
Numerical simulation

➢ Dam breaching and morphological change

Numerical result



Experimental result



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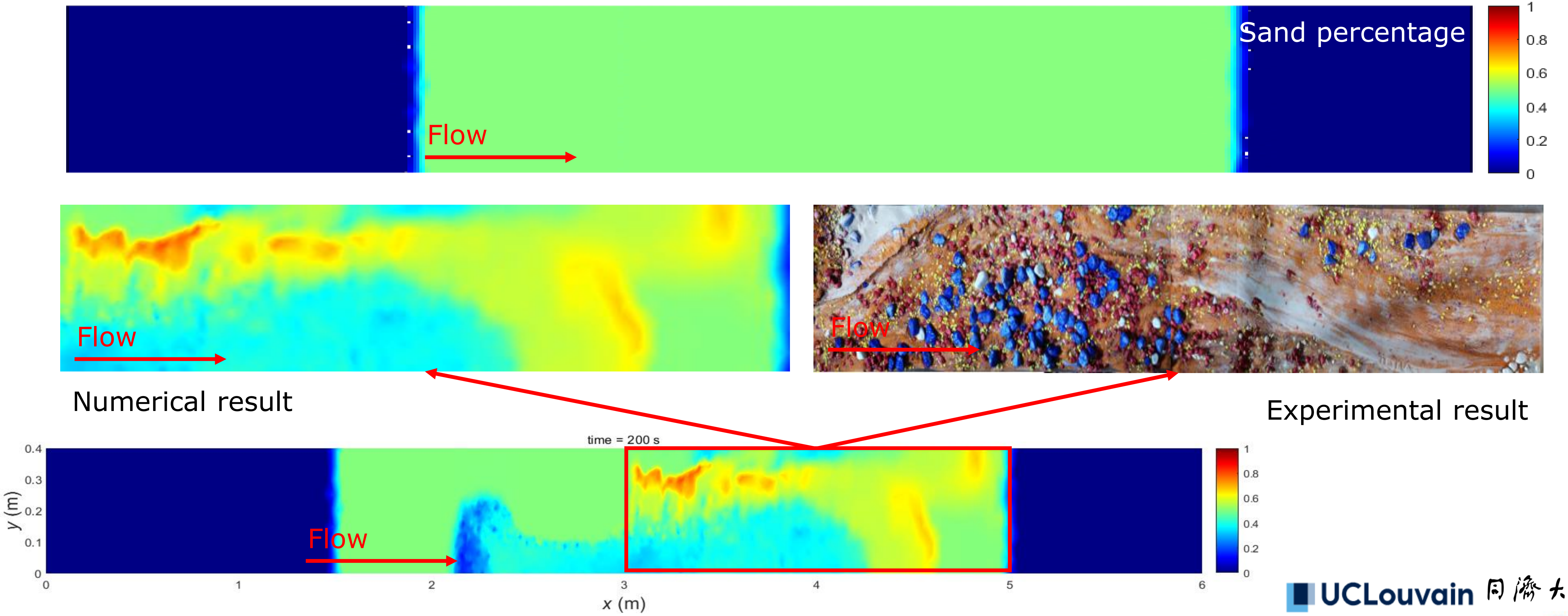
Numerical simulation

- **Sand content distribution**



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➢ Improvement of the model

- The sediment transport rate decreases with the increase of the median diameter, thus a smaller erosion depth can be observed;
- A better result of bed level can be obtained;
- The distribution of sediment with different diameter can be simulated.

➢ Problems and what's next?

$$\frac{\partial(f_i L_a)}{\partial t} = -\left(\frac{\partial\left(\varepsilon f_i q_{si,x}\right)}{\partial x} + \frac{\partial\left(\varepsilon f_i q_{si,y}\right)}{\partial y}\right) - \boxed{f_{es}}\frac{\partial(z_b - L_a)}{\partial t}, \qquad i = 1, 2, \dots, N$$

$$f_{esi} = \begin{cases} F_i & \textit{if erosion} \\ a f_i + (1-a) f_{bi} & \textit{if deposition} \end{cases}$$

→ The sorting effect during the deposition process

Thanks for your attention!

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