



Experiment study on landslide dams breach and its impact on morphological evolution

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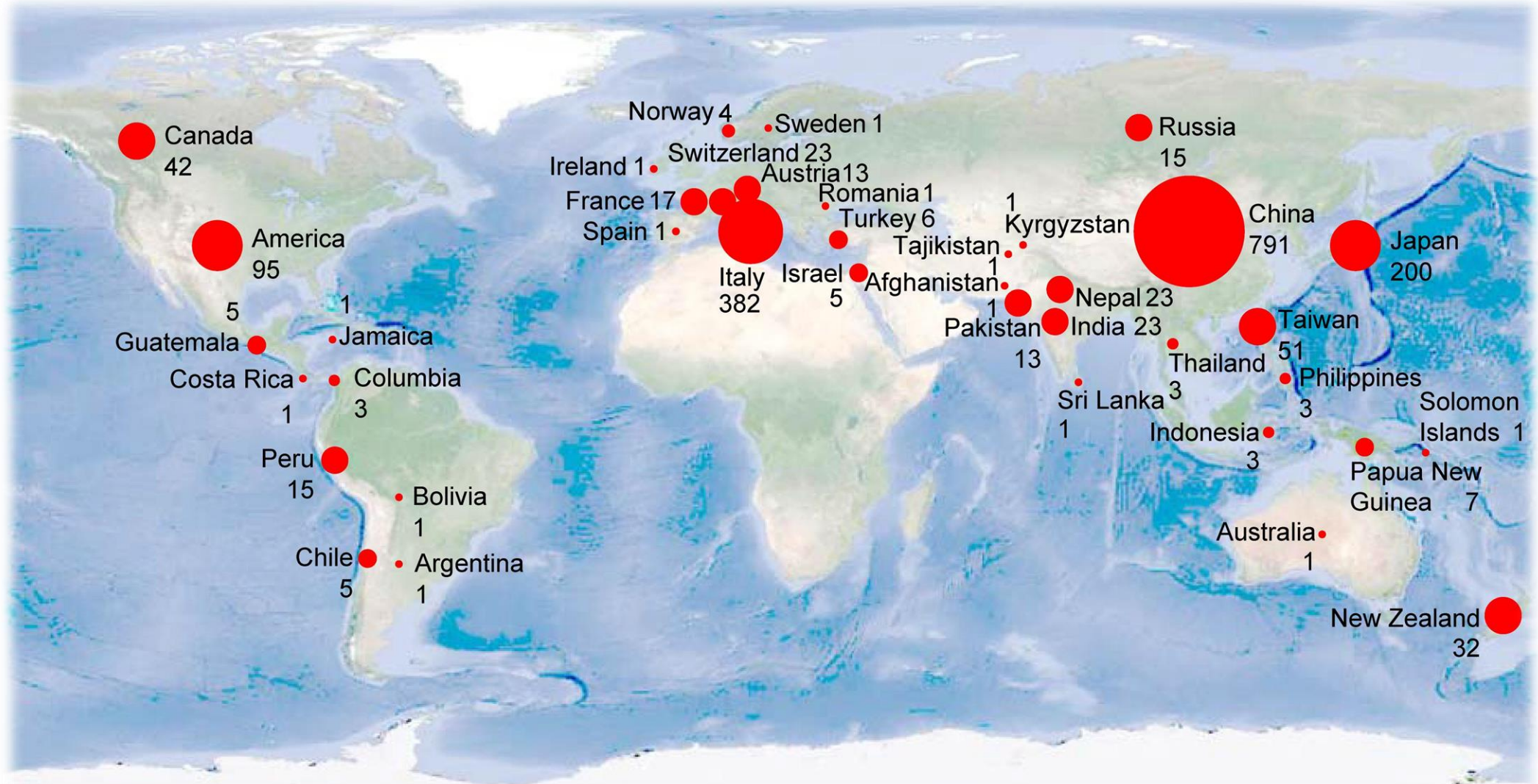
Sandra Soares-Frazão (UCLouvain)

● INTRODUCTION

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

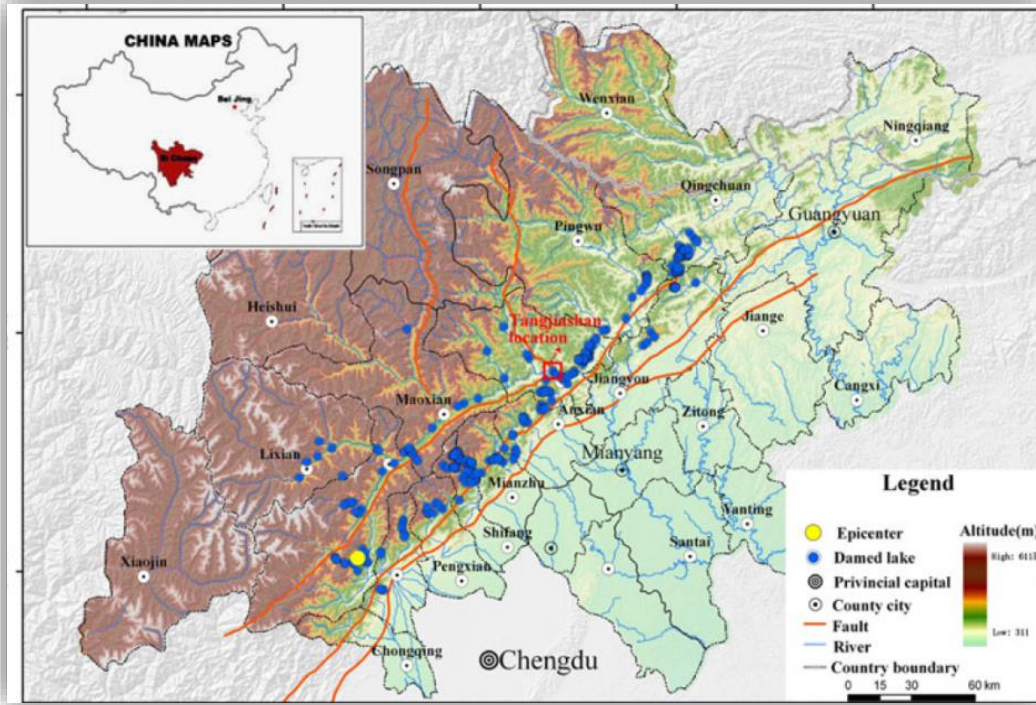


INTRODUCTION



Zheng *et al.* (2021)

INTRODUCTION



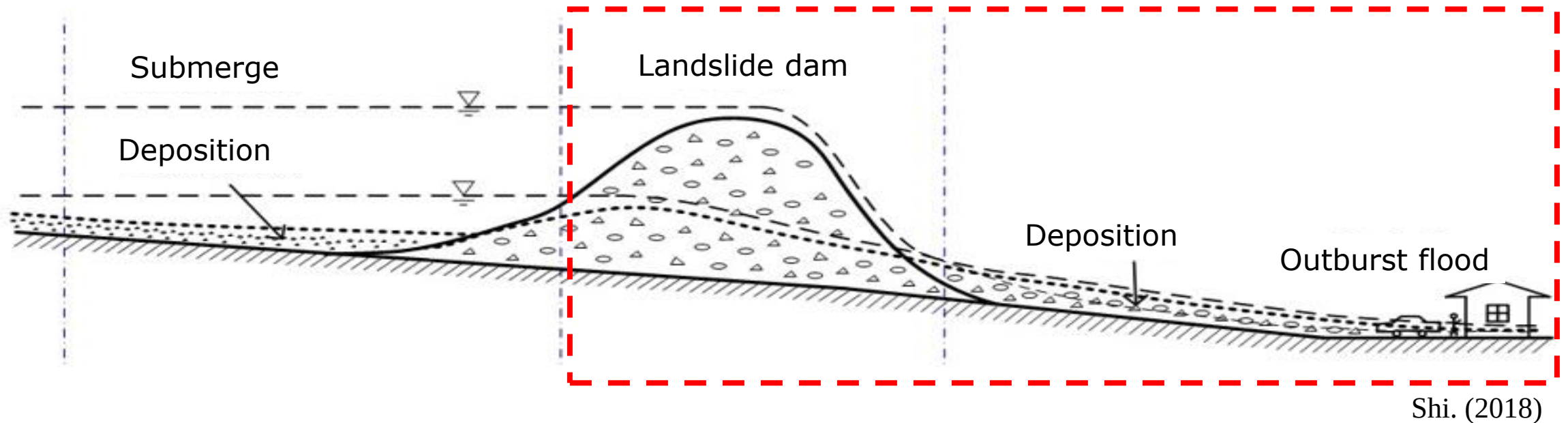
2008 “5.12” Wenchuan 8.0 earthquake:

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



● INTRODUCTION

- **The NSFC project:** Spatial-temporal evolutionary analysis and risk management of influence of whole life cycle on landslide dam (2018 – 2023).



- **Temporal evolution:** formation stage, infilling stage, **breaching stage** and recovery stage;
- **Spatial evolution:** upstream (submerge and bank failure), dam site (breaching and seepage) and **downstream (dam break flood, morphology and risks)**.

● CHARACTERISTICS OF LANDSLIDE DAMS

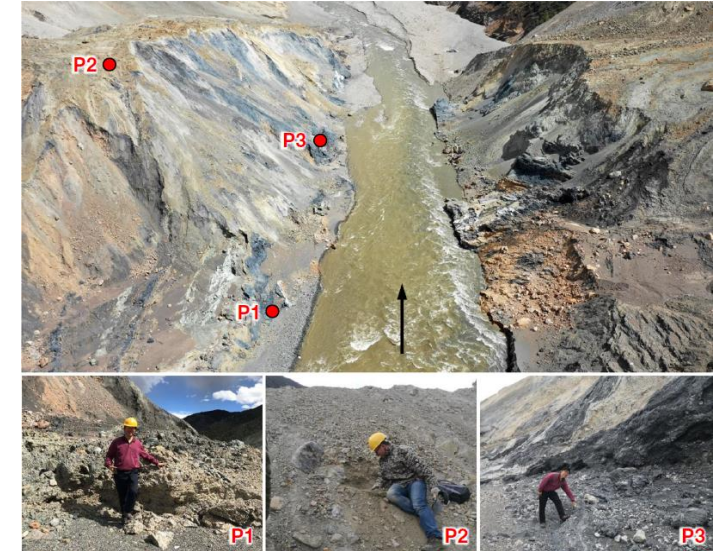
- **Geometrical characteristics:** the slope and length of the dam;
- **Material characteristics:** wide graded materials;
- **Structure characteristics:** uneven distribution.



Landslide dam geometry



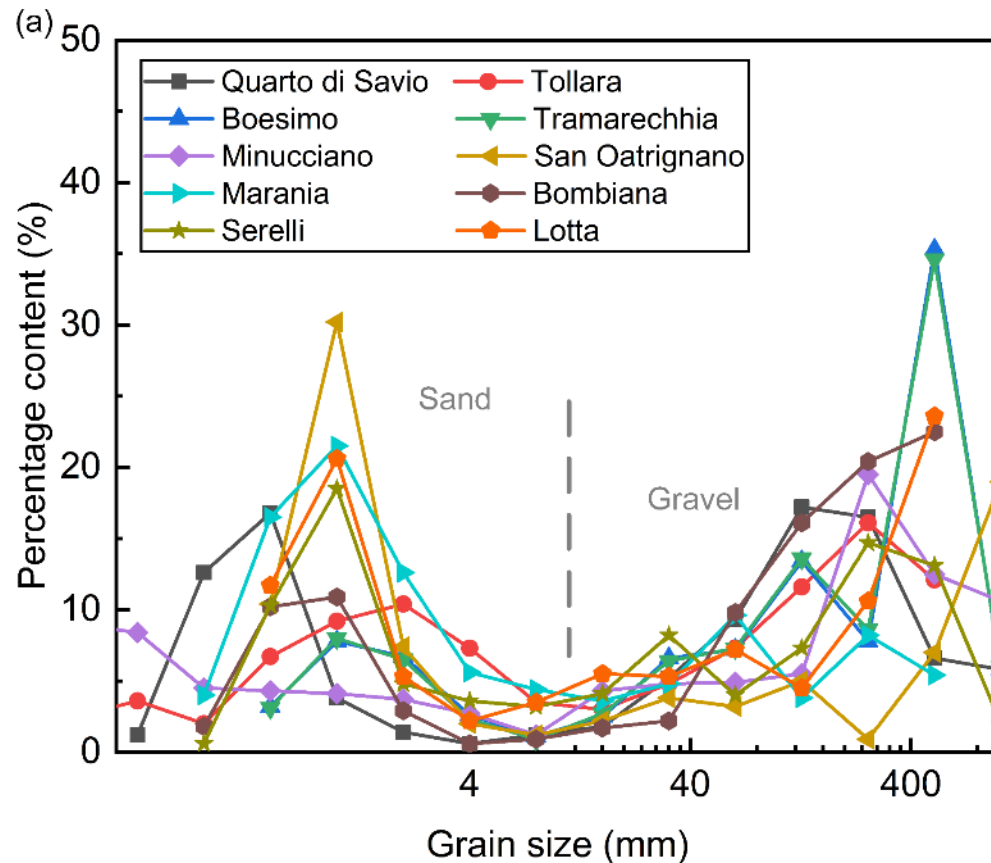
Material composition



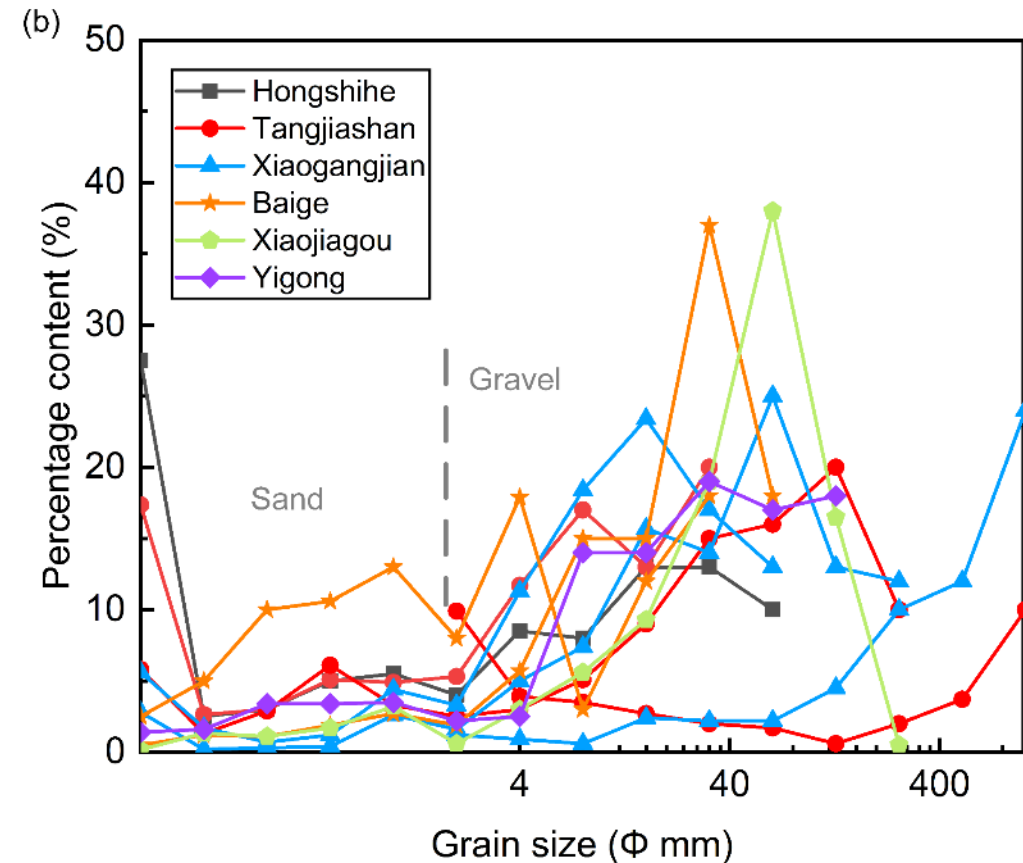
Material distribution

CHARACTERISTICS OF LANDSLIDE DAMS

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



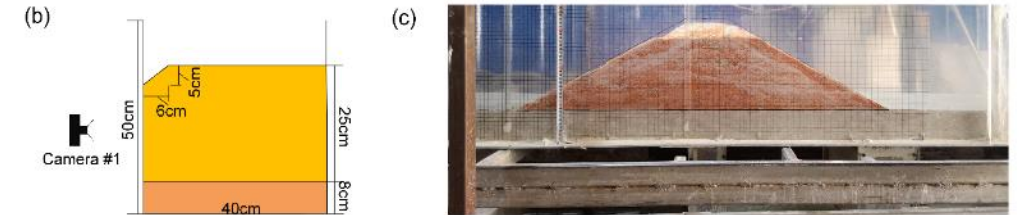
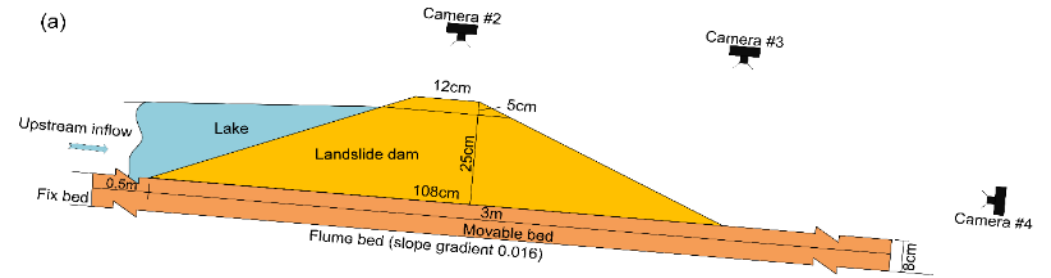
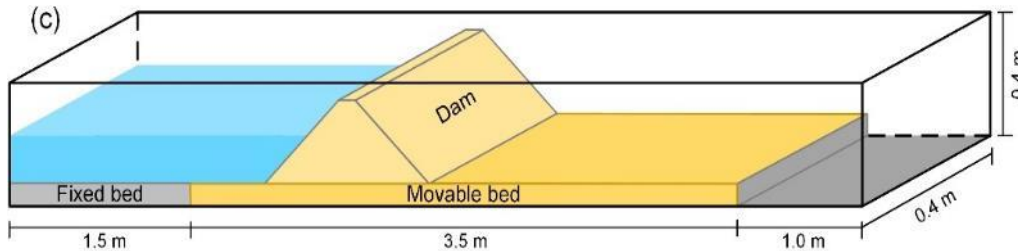
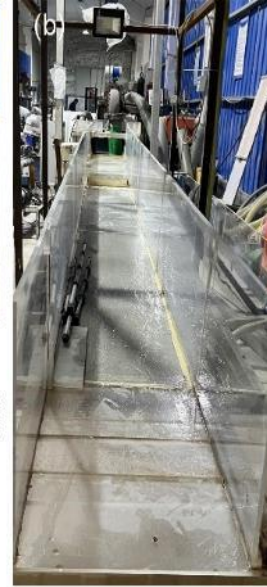
Landslide dams in Italy (Casagli et al., 2003)



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

● EXPERIMENTAL STUDY

➤ Experimental equipment and setup

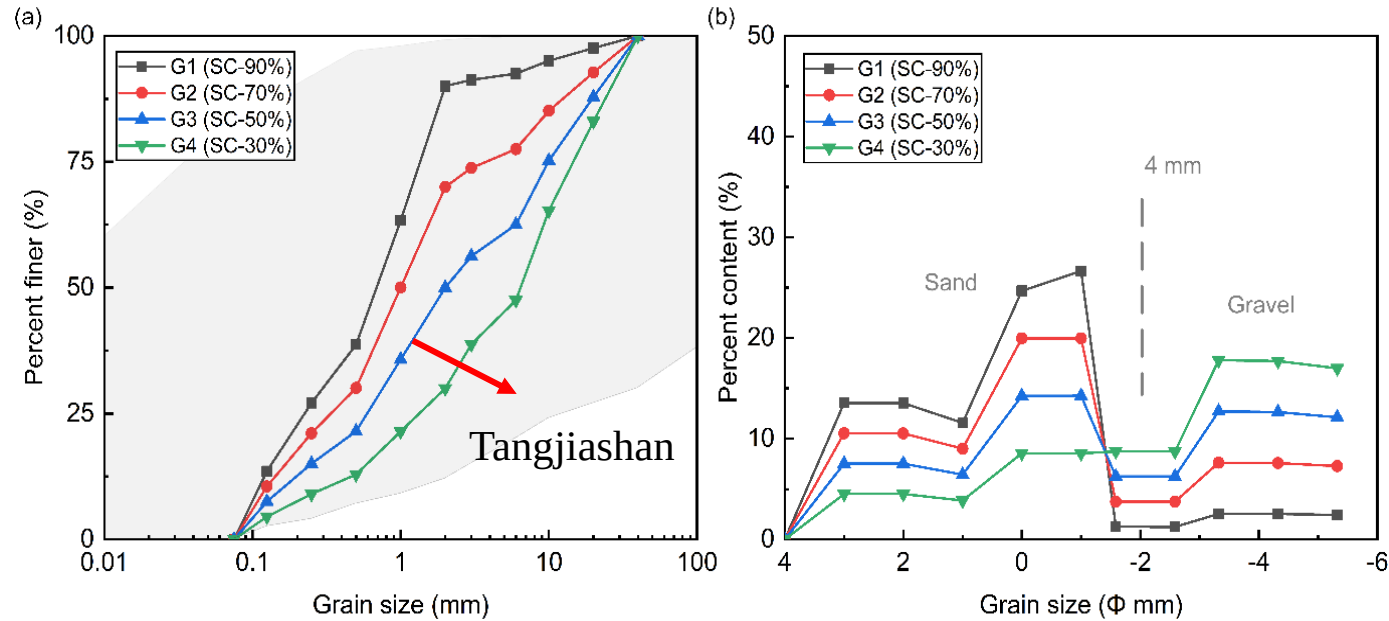


- Dam geometry and inflow rate are determined based on four dimensionless proposed in previous literature (Peng and Zhang (2012), Li et al. (2021)).

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}

EXPERIMENTAL STUDY

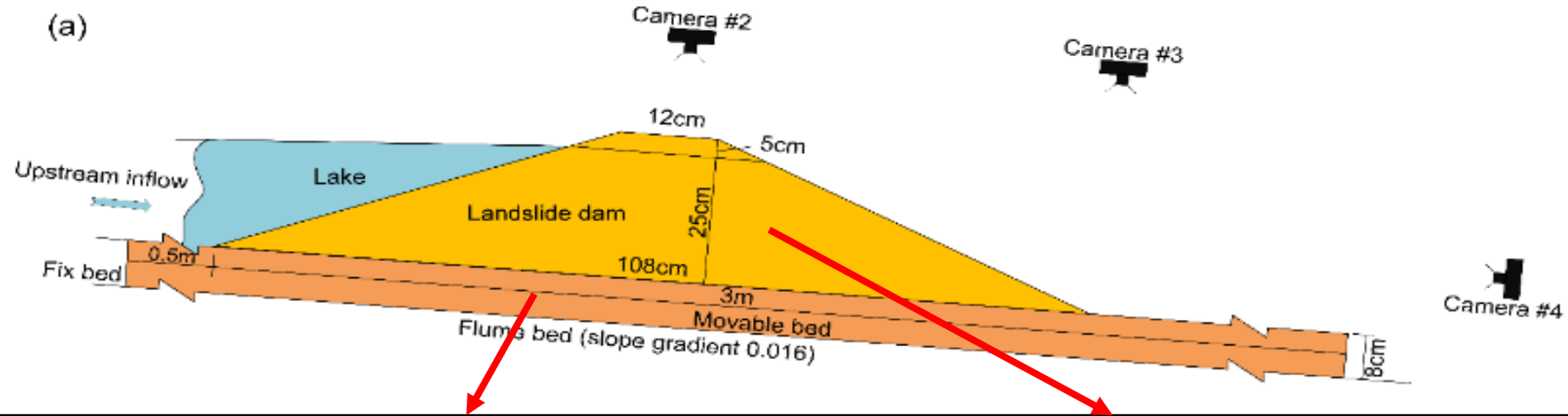
➤ Material composition



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

EXPERIMENTAL STUDY

➤ Experimental scenarios

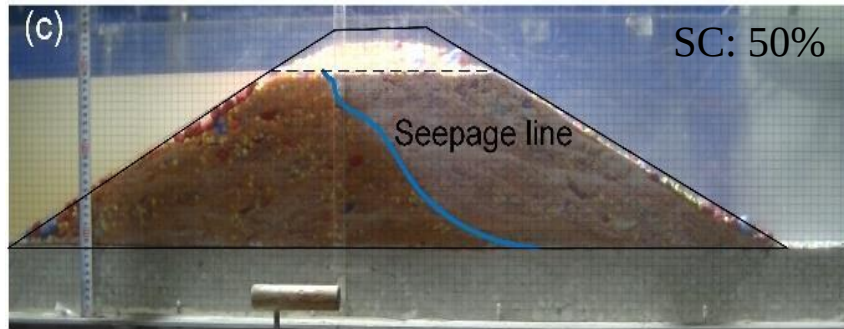


Test	Movable bed material	Dam material		
		Material	d_{50}	S_c
T1	G1	G1	0.730	90%
T5	G4	G1	0.730	90%
T2	G2	G2	0.999	70%
T6	G4	G2	0.999	70%
T3	G3	G3	2.000	50%
T7	G4	G3	2.000	50%
T4	G4	G4	6.562	30%
T8	G4	G4	6.562	30%

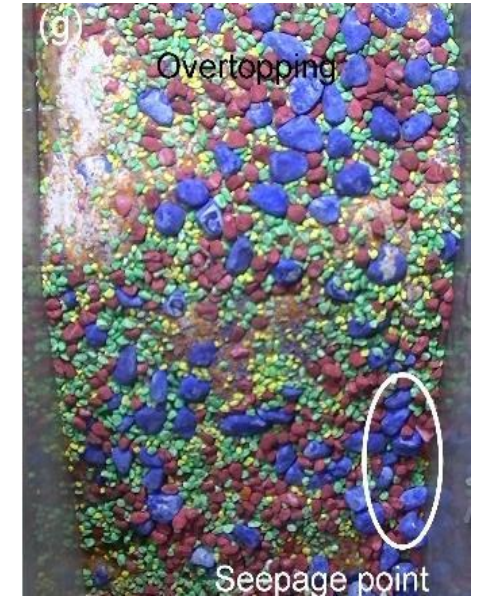
Same tests to check the repeatability

● EXPERIMENTAL STUDY

➤ Dam failure mode



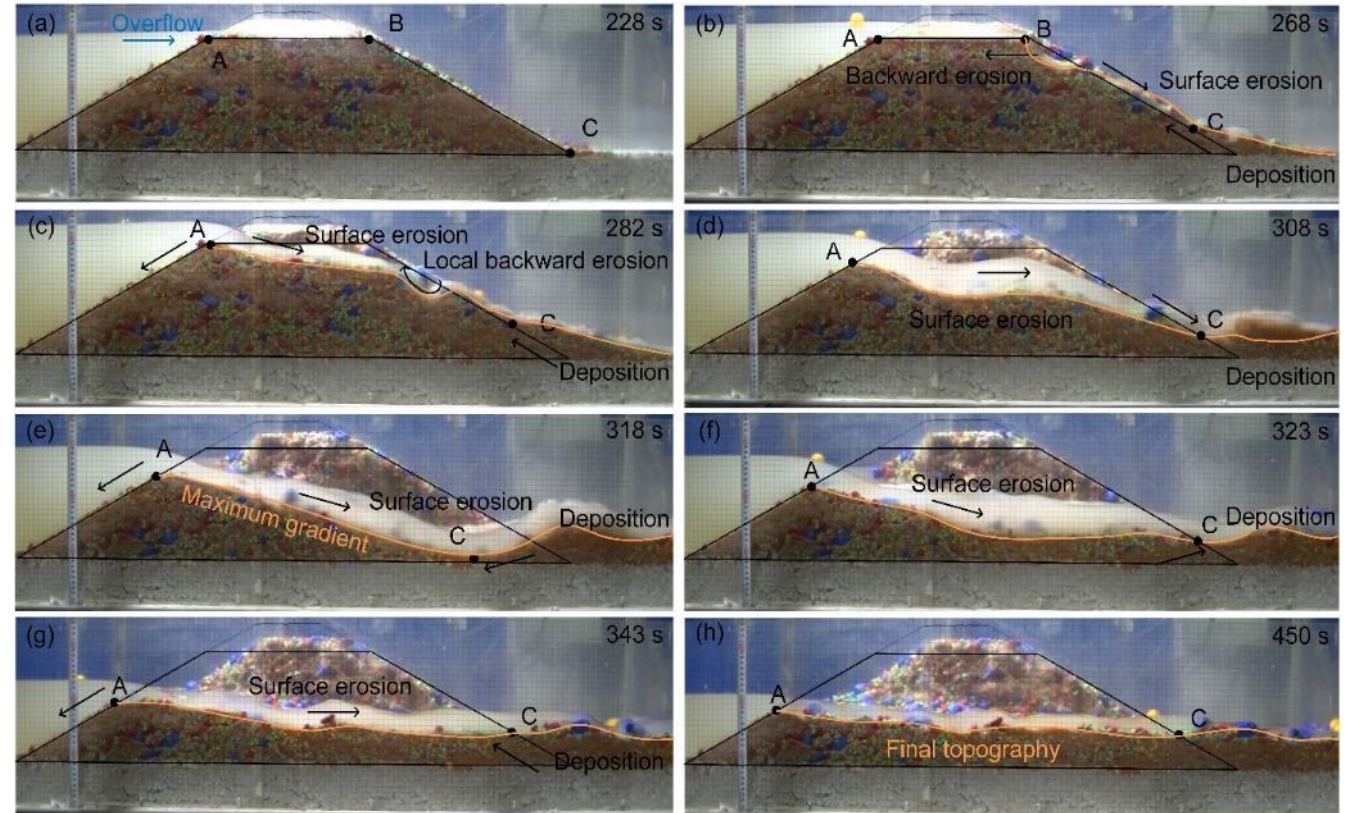
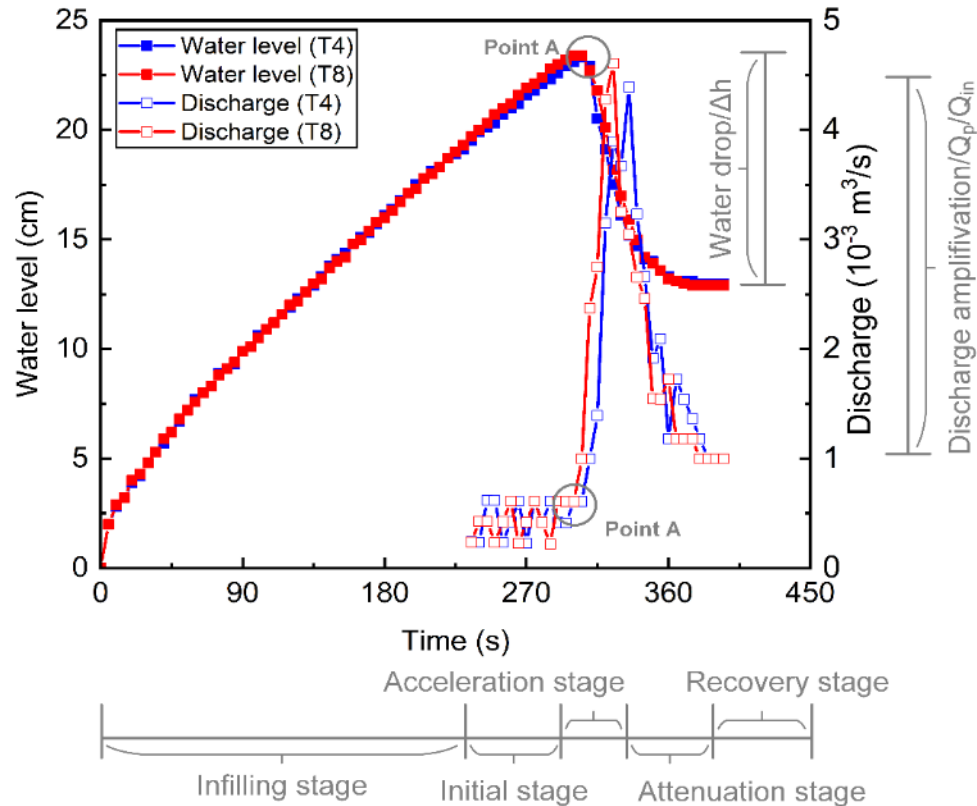
Overtopping & seepage



- 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.

EXPERIMENTAL STUDY

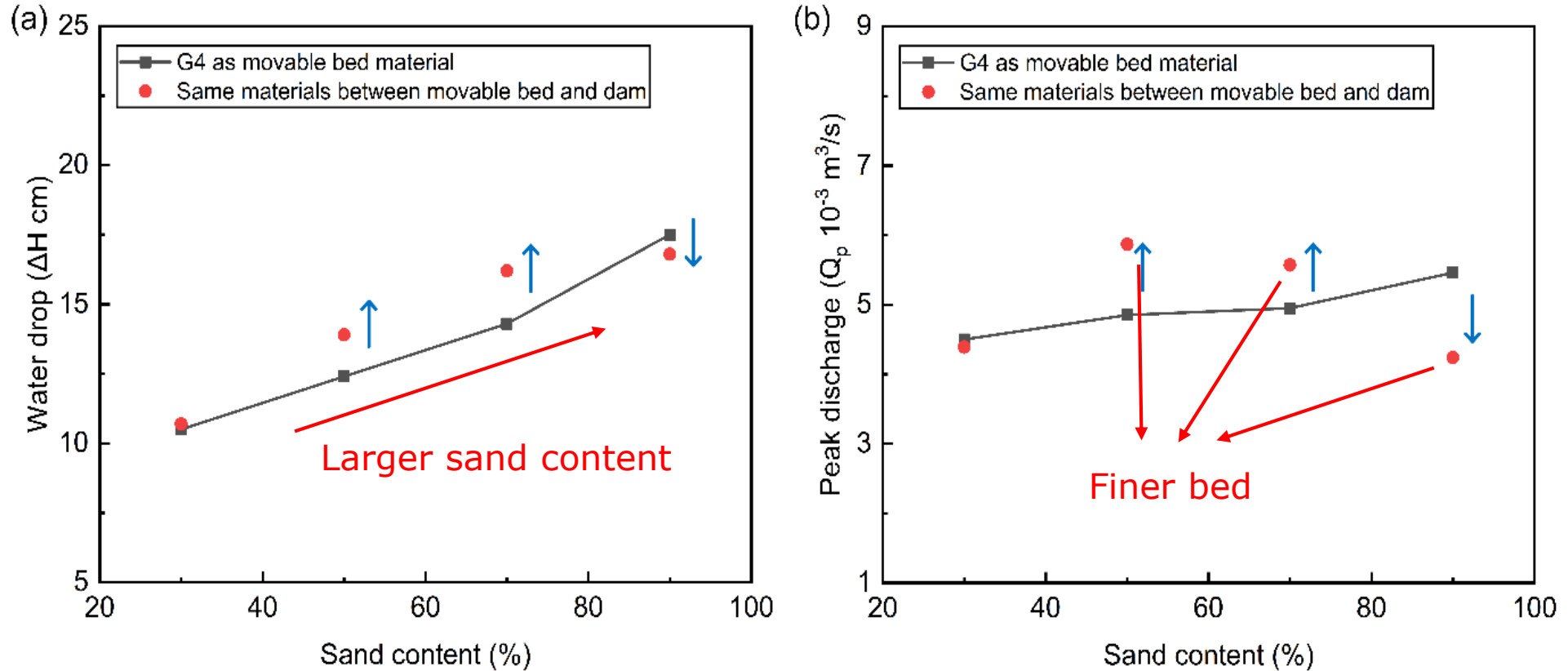
➤ General description of overtopping failure



- **Initial stage:** Erosion of dam crest, surface erosion and backward erosion can be observed;
- **Acceleration and attenuation stage:** Surface erosion, deposition and peak discharge;
- **Recovery stage:** Long-term evolution of morphology.

EXPERIMENTAL STUDY

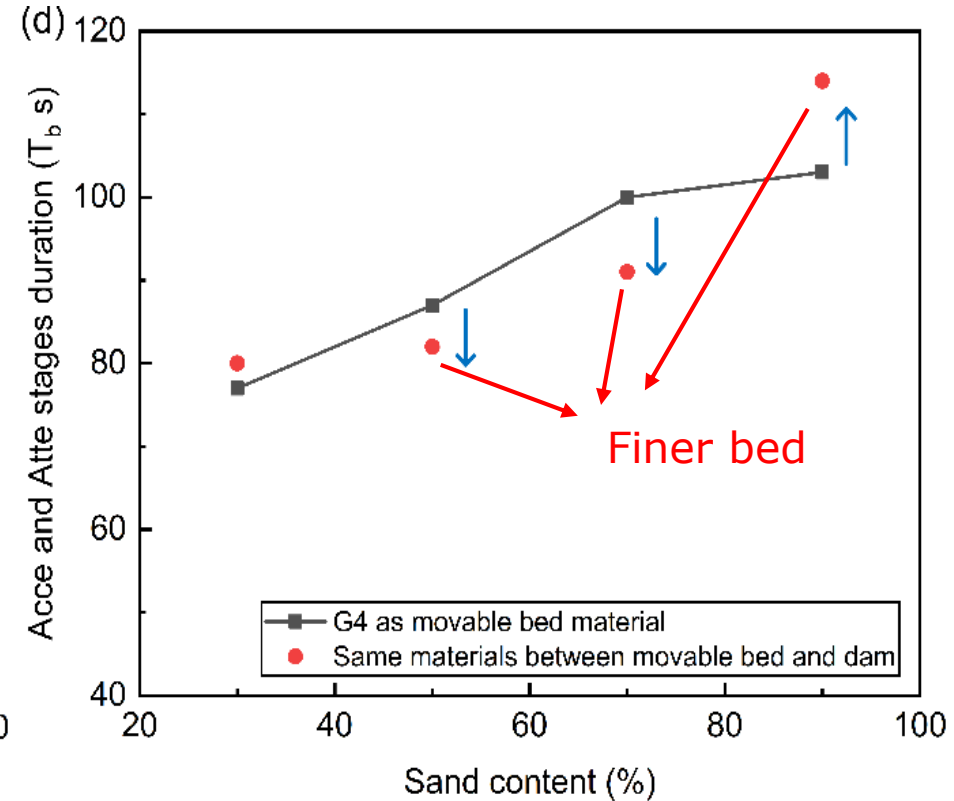
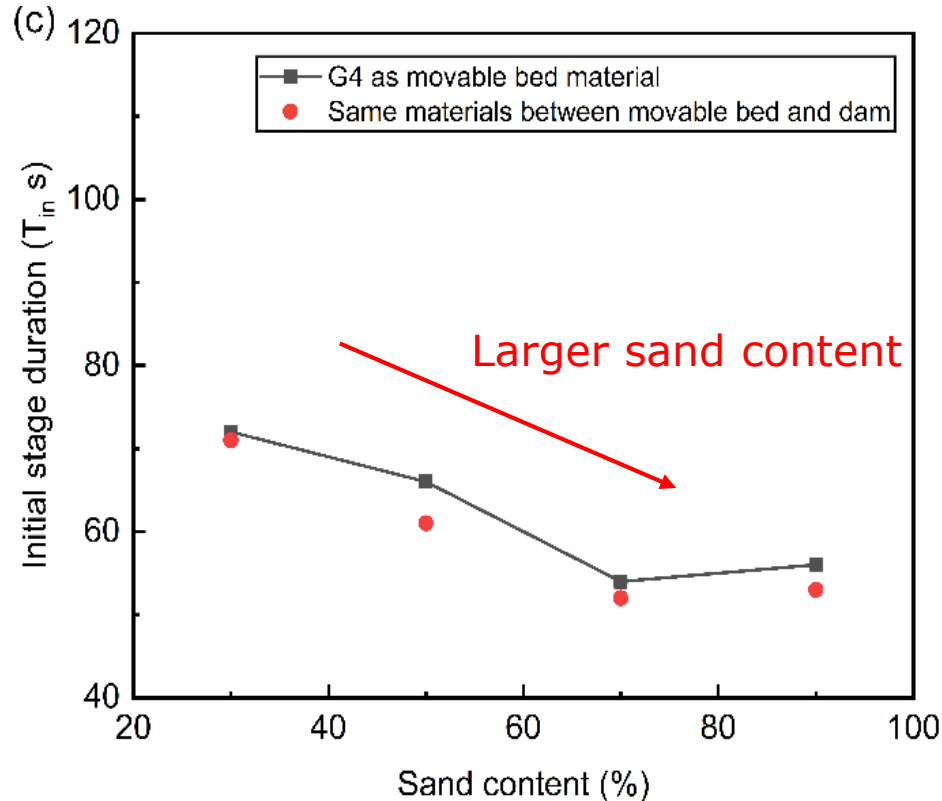
➤ Variation of water drop and peak discharge



- **Increase of SC in dam material:** Larger 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%.

EXPERIMENTAL STUDY

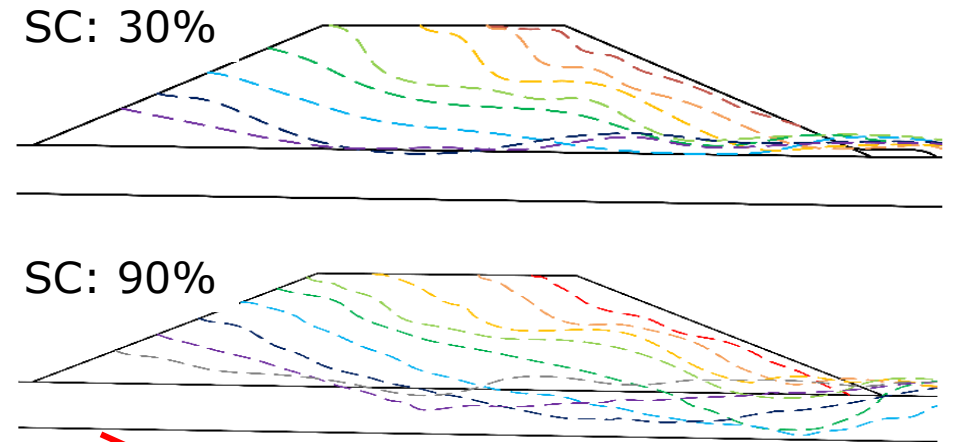
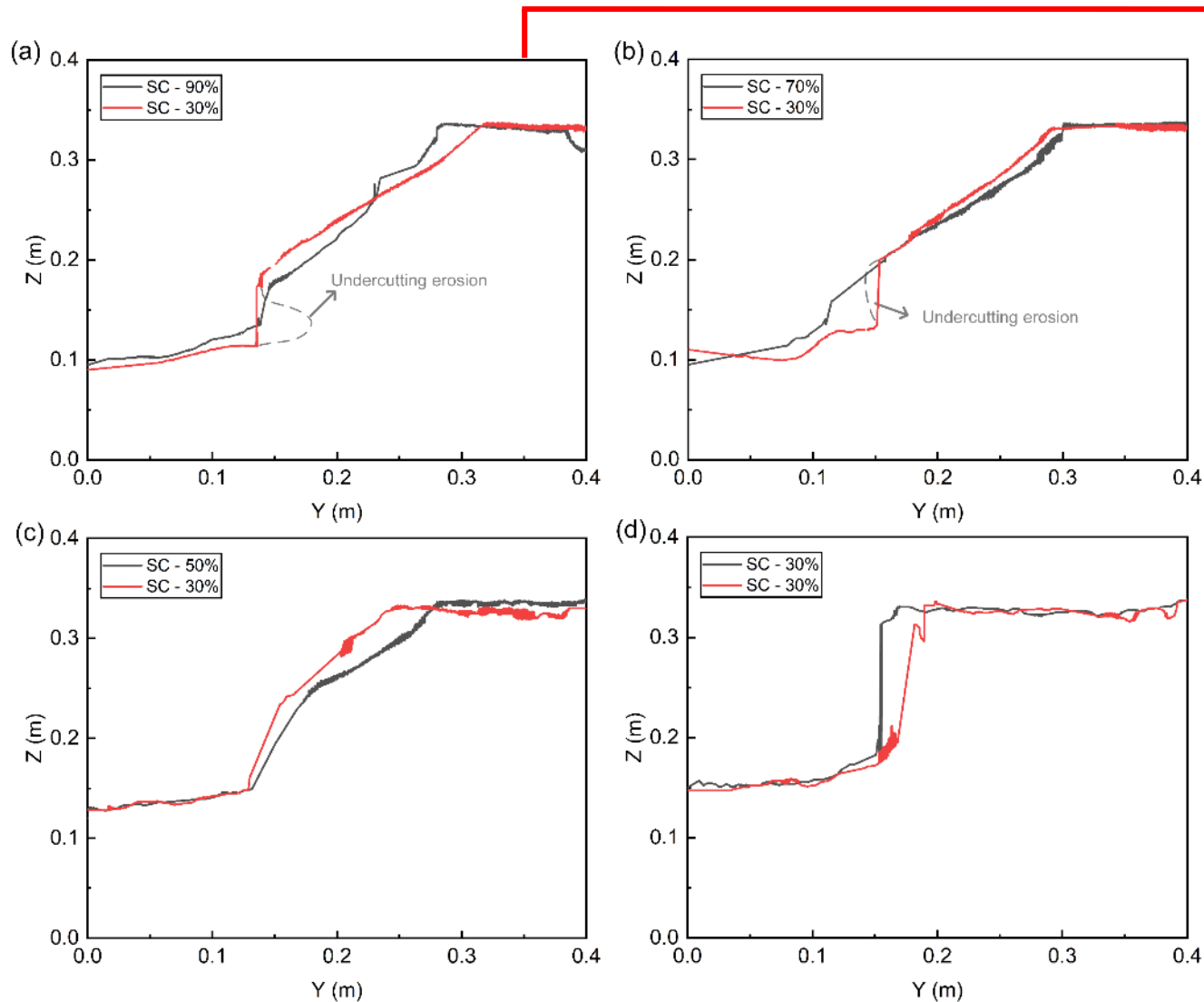
➤ Breach duration (initial stage, acceleration and attenuation stage)



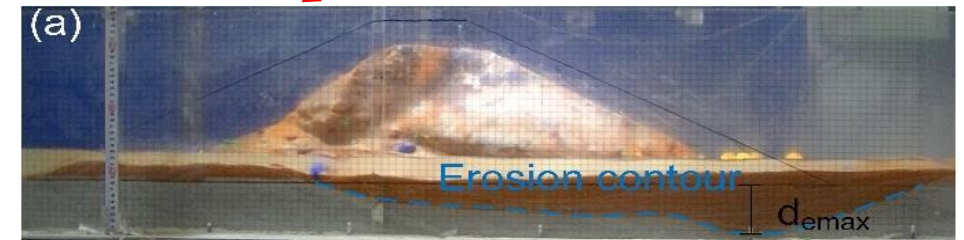
- **Increase of SC in dam material:** Longer in acceleration and attenuation stages but shorter in initial stage;
- **Influence of SC in movable bed material:** Depends on dam material composition.

EXPERIMENTAL STUDY

➤ Final breach geometry



Larger erosion volume

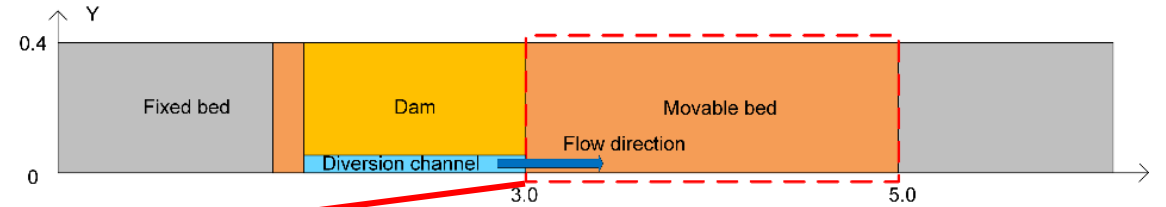


Similar final breach geometry
but breaching process varies

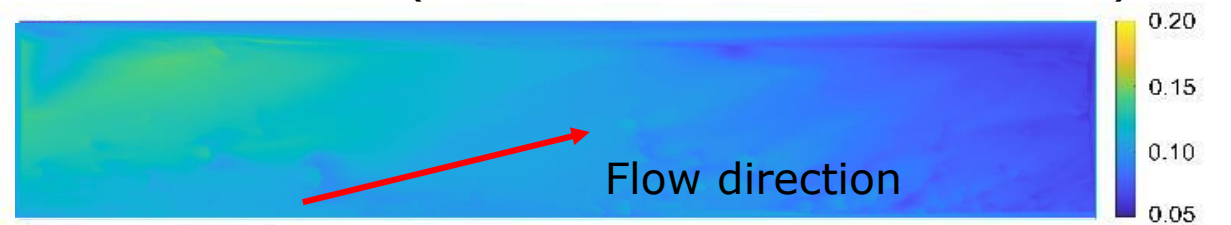
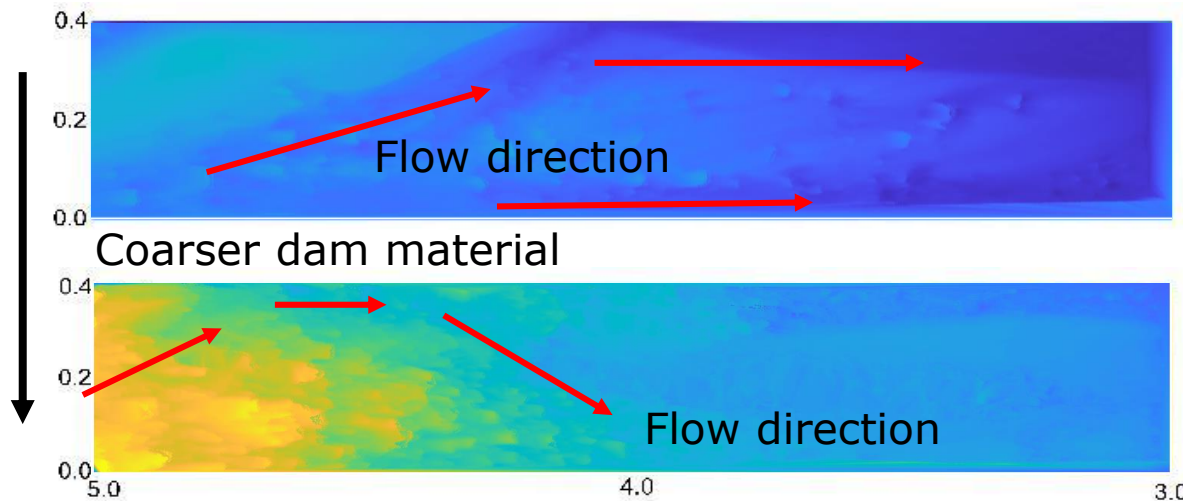
● EXPERIMENTAL STUDY

➤ Final topography of the movable bed

50% of SC for dam and bed materials



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



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

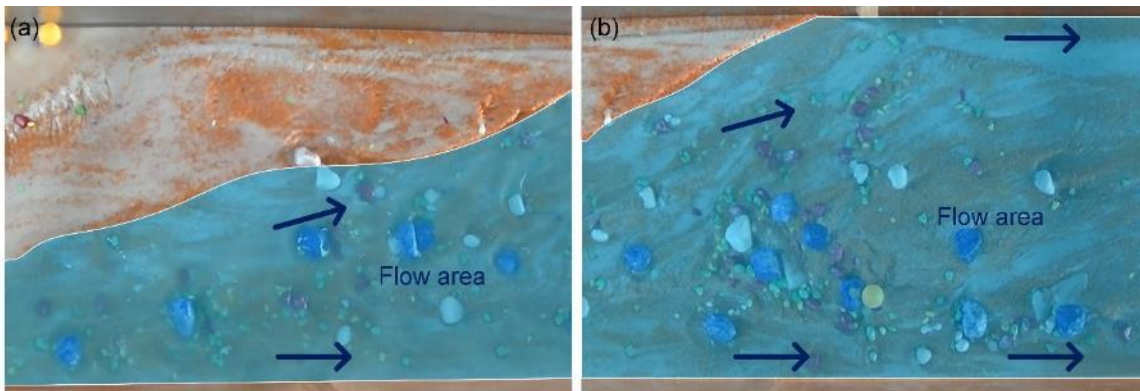
● EXPERIMENTAL STUDY

➤ Sediment distribution

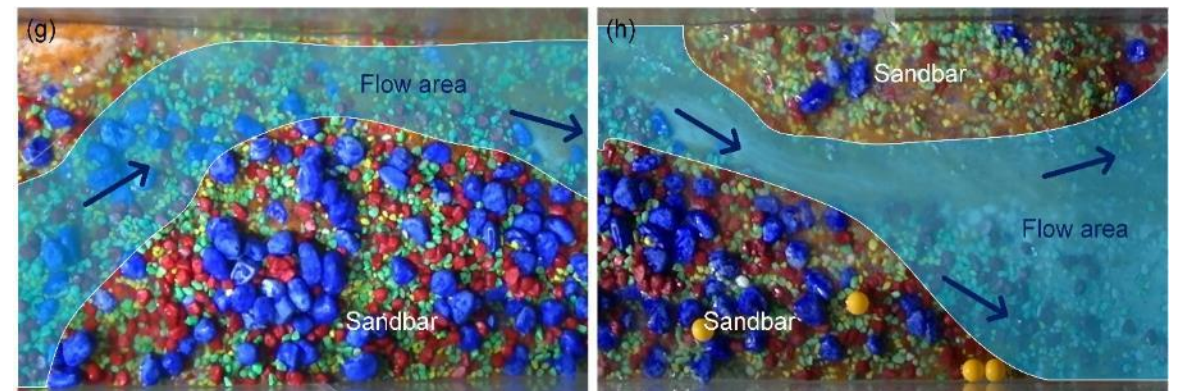
50% of SC for dam and bed materials



90% of SC for dam and bed materials



30% of SC for dam and bed materials

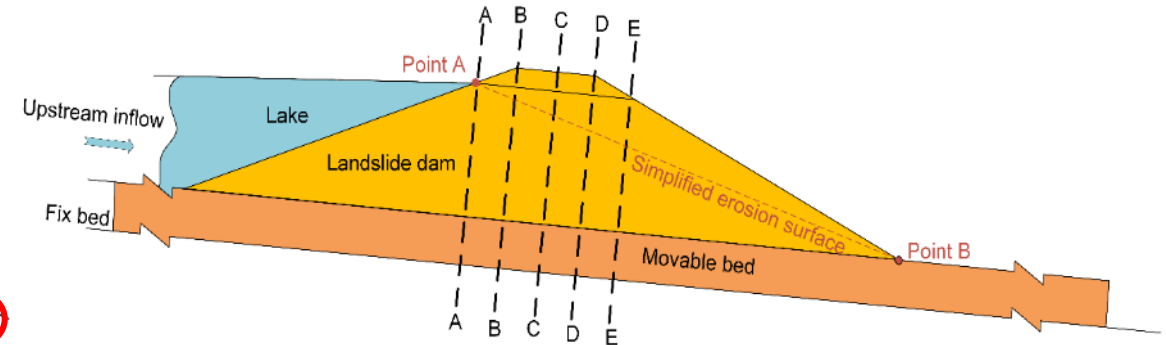
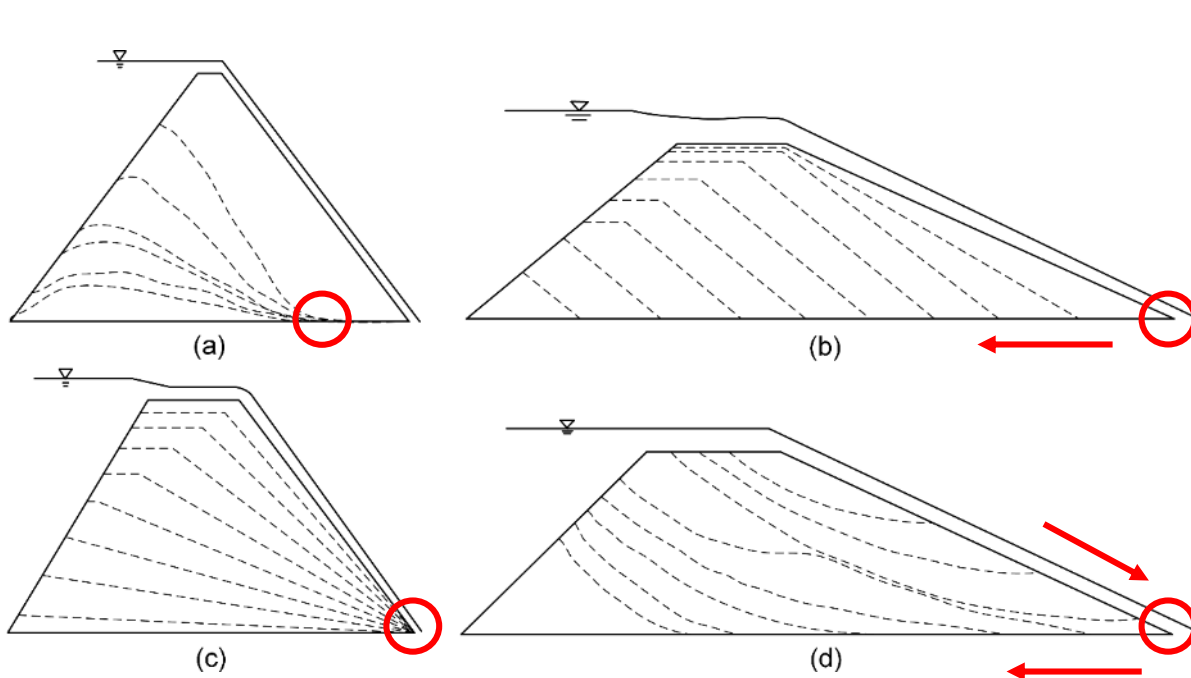


- Meandering channel due to the sediment transport and the formation of sandbars.

EXPERIMENTAL STUDY

➤ Dam breach pattern

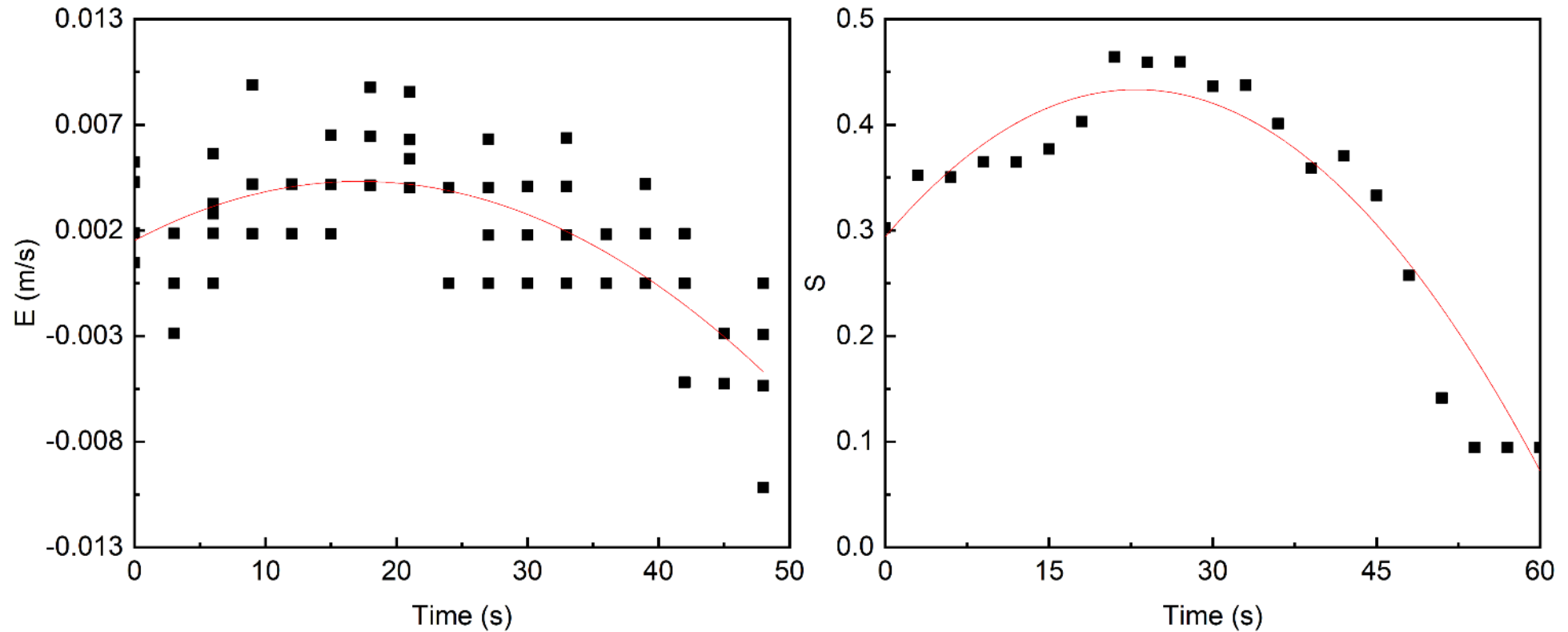
Model	Resources	Erosion rate	Erosion surface gradient
(a)	Coleman et al. (2002)	Decreases during dam breaching	Decreases during dam breaching
(b)	Chang and Zhang (2012)	Remains constant	Remains constant
(c)	Zhong et al. (2018)	Remains constant	Decreases during dam breaching
(d)	Zhou et al. (2019)	Remains constant after erosion of A	Increases during dam breaching



- Erosion rate: $E = dh/dt$;
- Erosion surface gradient: $S = \Delta z_{AB}/\Delta x_{AB}$;
- Pivot point: point B.

● EXPERIMENTAL STUDY

➤ Erosion rate and erosion surface gradient



Take T1 as an example (90% of SC for dam and bed materials)

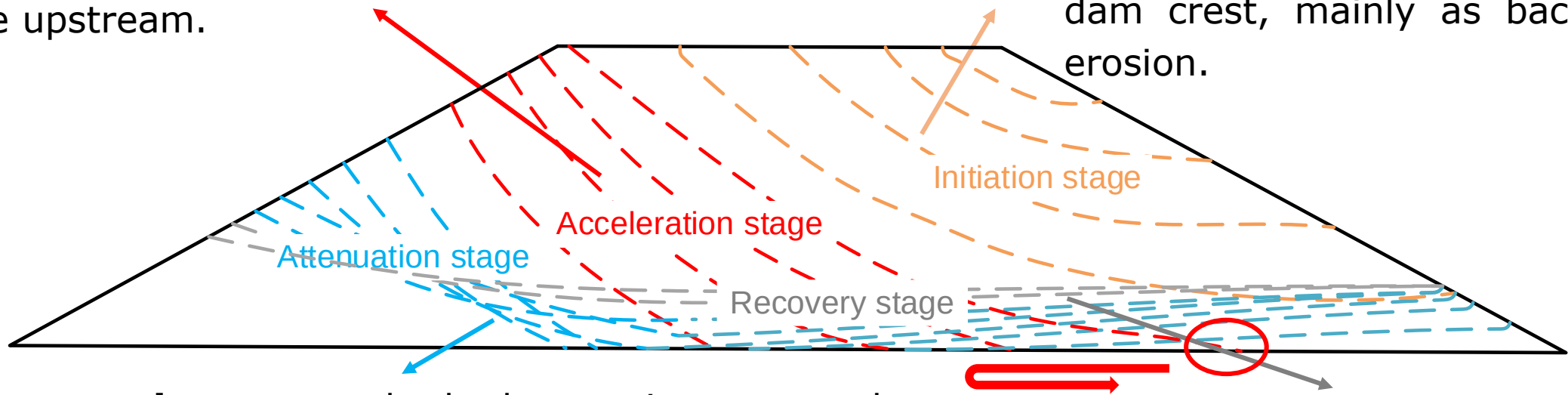
- **Erosion rate:** First increases and then decreases;
- **Erosion surface gradient:** The same variation with erosion rate is observed.

● EXPERIMENTAL STUDY

➤ New dam breach pattern

- **Acceleration stage:** both the erosion rate and erosion surface gradient increase. Point B moves to the upstream.

- **Initial stage:** erosion of the dam crest, mainly as backward erosion.



- **Attenuation stage:** both the erosion rate and erosion surface gradient decrease. Point B moves to the downstream, and deposition increases gradually.

- **Recovery stage:** long-term evolution of local topography.

- **Pivot point:** the boundary of erosion and deposition during dam breaching.

● LIMITATIONS AND WHAT'S NEXT

➤ Limitations

- The geometry of the dam: the **trapezoidal** shaped that considered in our experiment is not **consistent** with real landslide dams;
- The similarity of the experiments: only four dimensionless parameters are considered in our experiments.
- The structure of landslide dams is ignored in our experiments.

➤ What's next?

- Numerical model establishment and simulation of real events.



Numerical simulation of the experiments



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