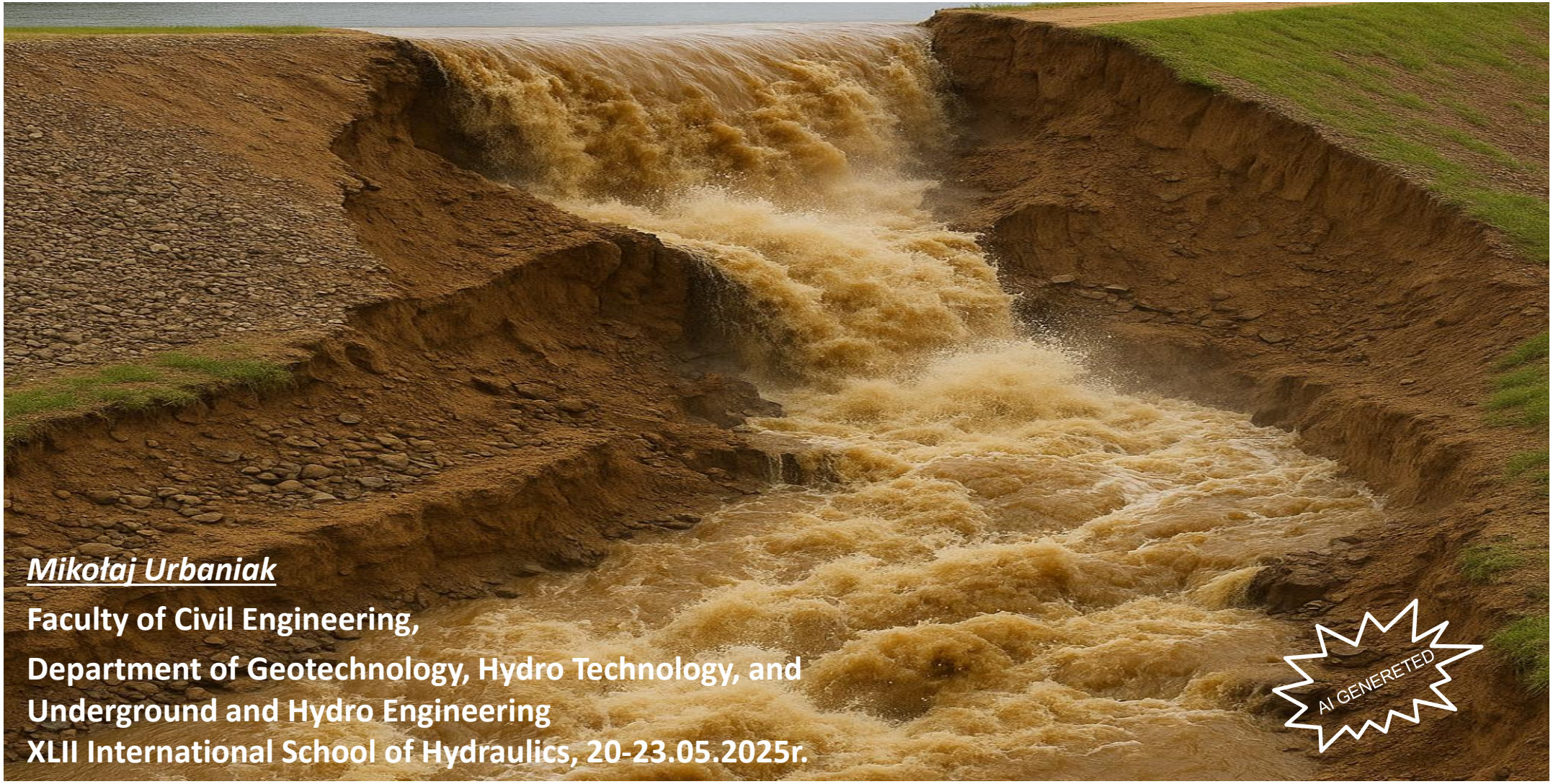
Wrocław University of Science and Technology

Numerical Simulation of Earth Dam Erosion due to Overtopping Using a One-Dimensional Model



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XLII International School of Hydraulics, 20-23.05.2025r.

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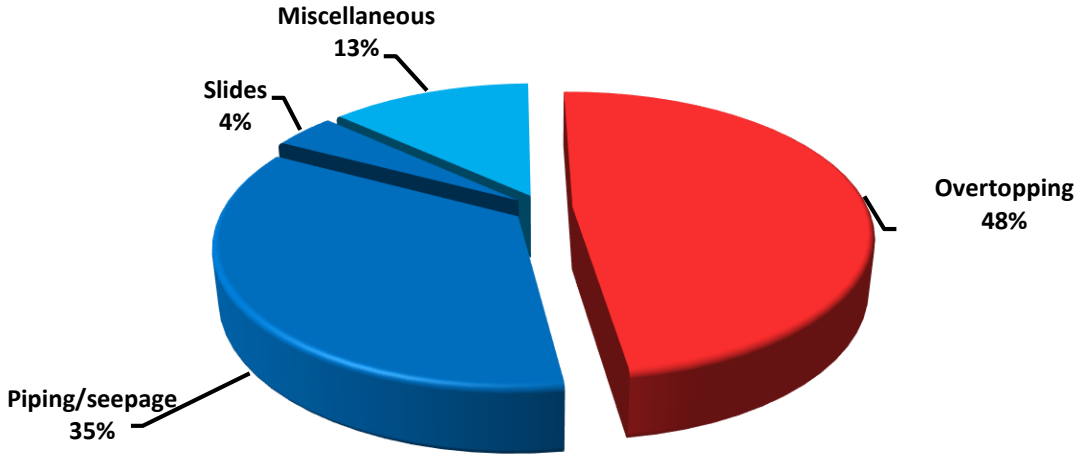
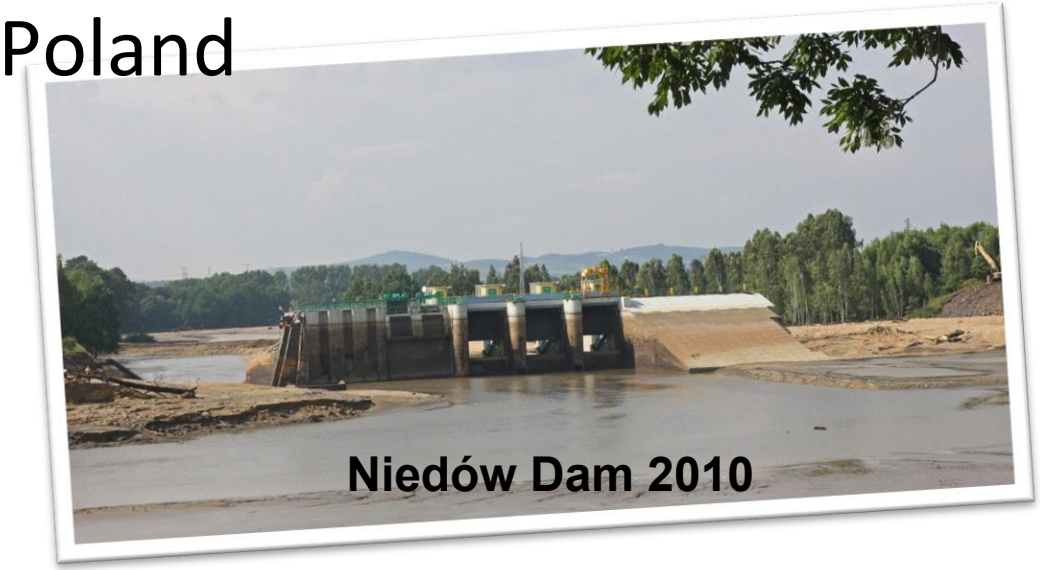
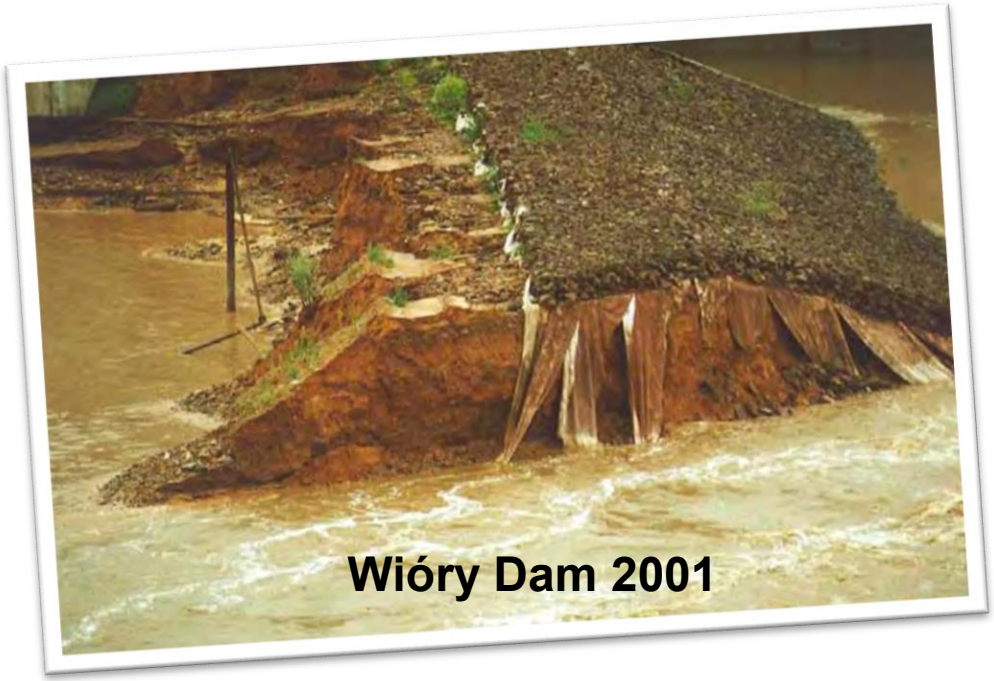
HR EXCELLENCE IN RESEARCH

Overtopping failures – lessons from Poland







Stronie Śląskie Dam 2024

Overtopping threatens all types of earth dams

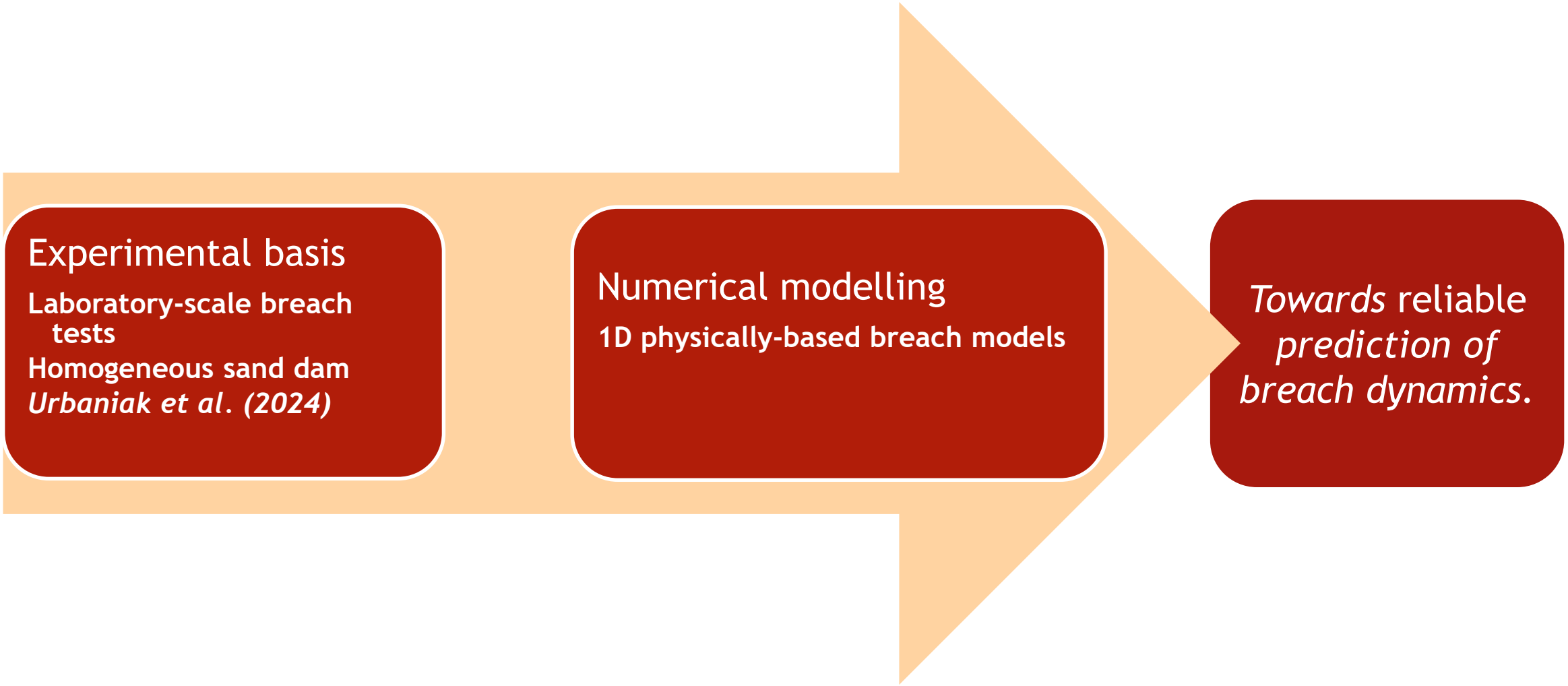
Construction-stage dam (cofferdam) – *Wióry (2001)*
→ temporary structure, failed during flood before commissioning

Permanent impounding dam – *Niedów (2010)*
→ active reservoir, full-scale breach during extreme rainfall

Dry reservoir dam – *Stronie Śląskie (2024)*
→ designed for flood detention only, still failed under extreme inflow

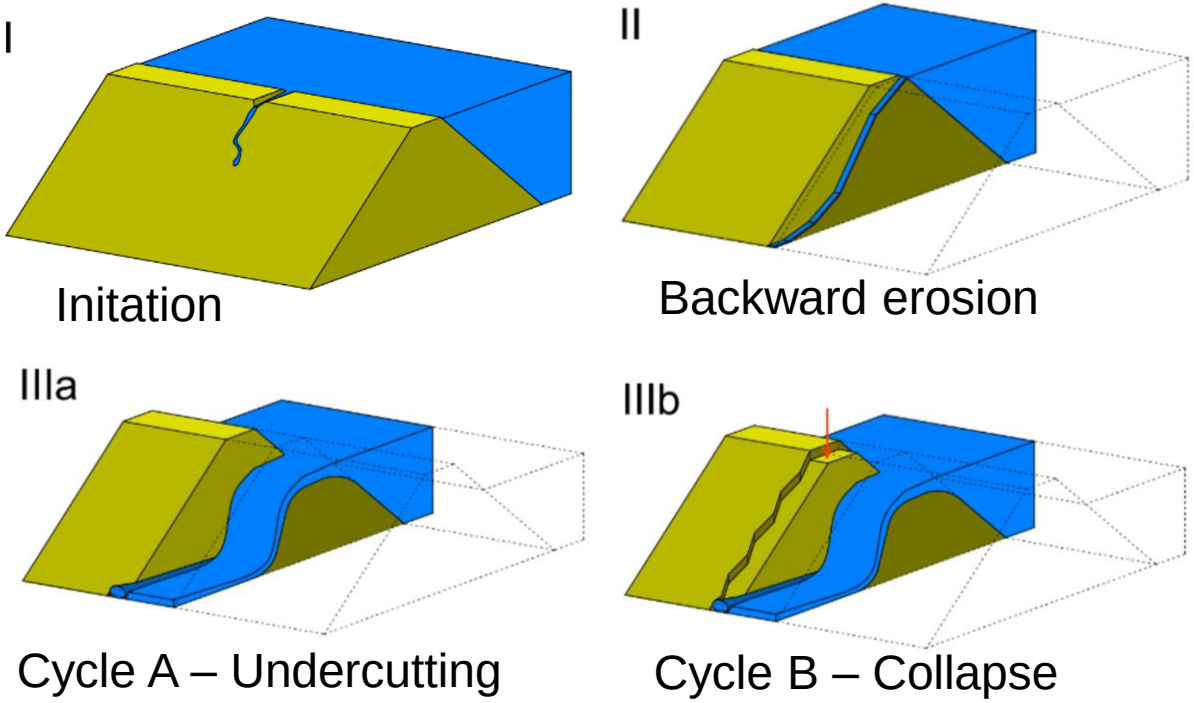
Key takeaway: *All types of earth dams are vulnerable to overtopping — regardless of their purpose or design flood assumptions.*

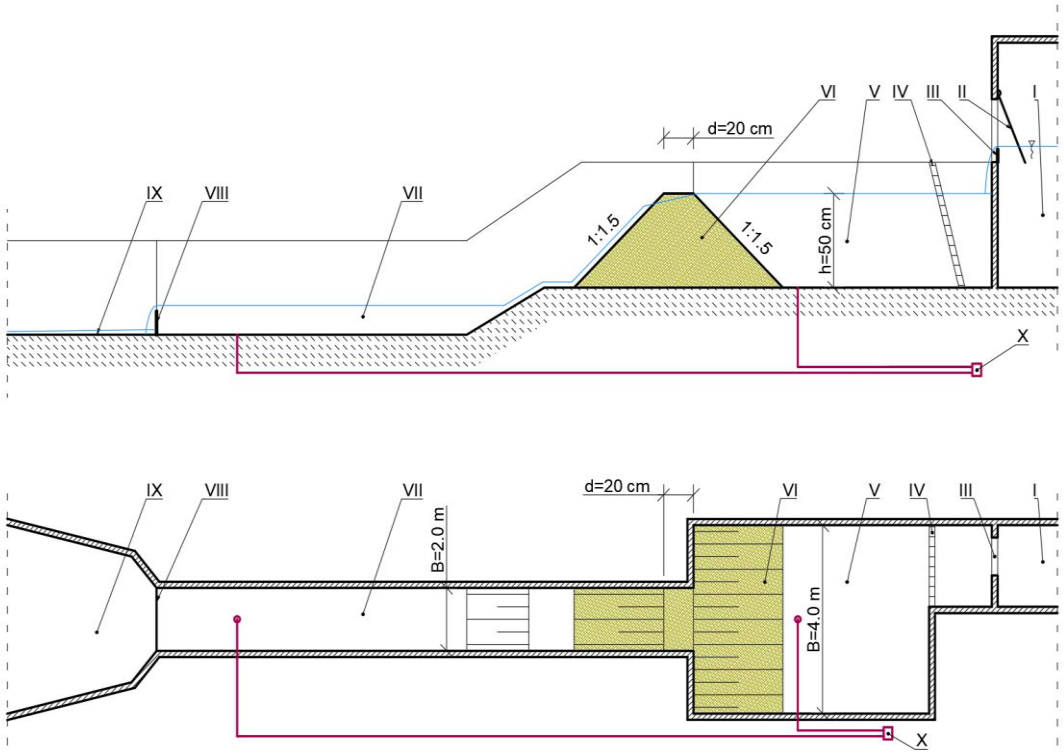
Combining laboratory data and numerical prediction



Experimental setup – physical breach test facility

- Embankment height: 50 cm
- Crest length: 200 cm
- Crest width: 20 cm
- Tank capacity: 14,4 m^3
- Initiating channel depth: 2.4 cm





Experimental setup
I – balancing tank, II – check valve (overflow window closing), III – overflow window with Thomson's weir, IV – energy dissipation device, V – upper tank V_{max}=14,4m^3, VI – analysed embankment, VII – downstream channel B=2.0 m, VIII – two Thomson's weirs, IX – free discharge channel B>>2.0m, X – hydrostatic pressure sensors.

One-dimensional breach modeling – two perspectives

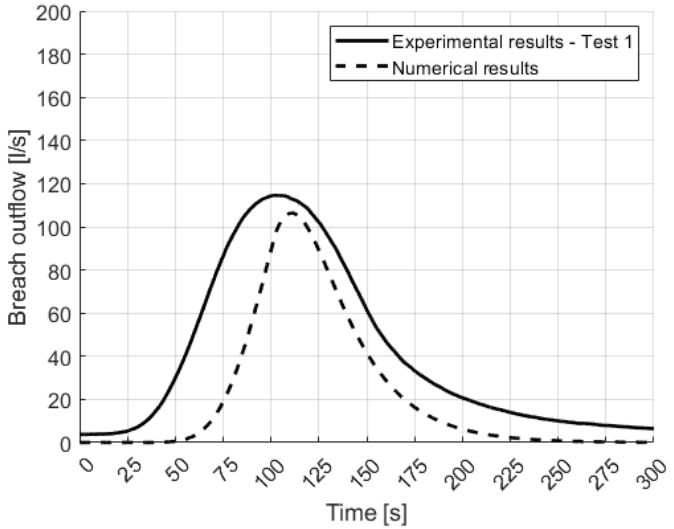
❑ Model 1

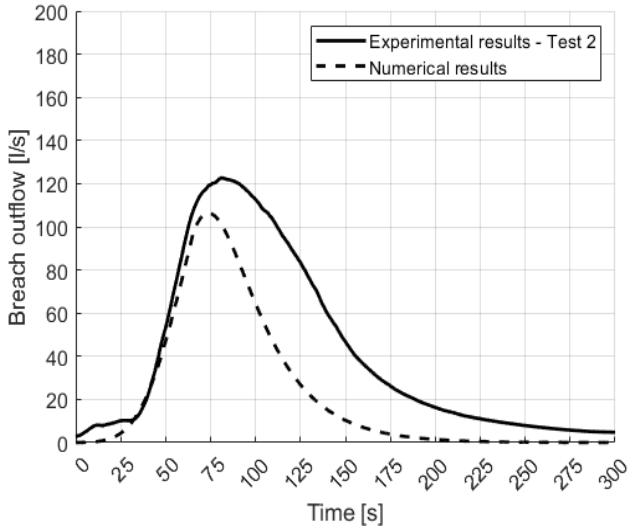
- Breach cross-section evolves from triangular to trapezoidal shape.
- Flow is calculated using a broad-crested weir equation assuming critical flow conditions,
- Breach growth based on global sediment mass balance,
- Sediment discharge calculated using the Meyer-Peter and Müller formula
- Critical shear stress is neglected – erosion starts immediately once flow begins,
- Material properties indirectly considered through calibration,
- ⚠ No breach slope stability check included.

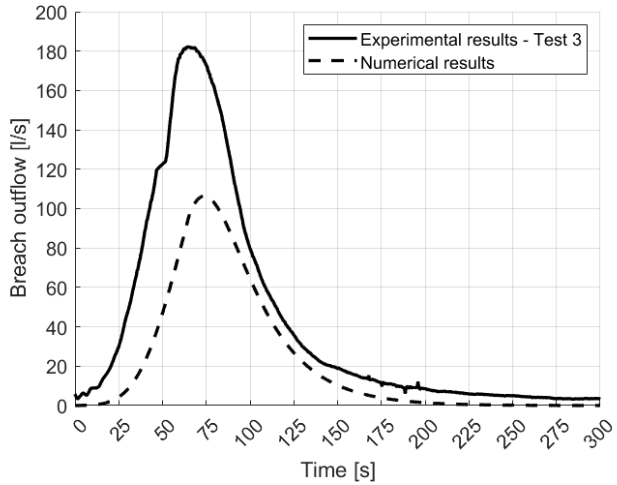
❑ Model 2

- Breach cross-section is assumed trapezoidal throughout the simulation,
- Flow is calculated using a broad-crested weir equation,
- Breach growth based on local surface erosion rate,
- Erosion rate defined by the difference between applied and critical shear stress,
- Material properties directly included via erodibility coefficient and critical shear stress,
- Shear stress distribution considered along the breach surface,
- ⚠ No slope breach stability check included.

Model 1 – breach outflow performance

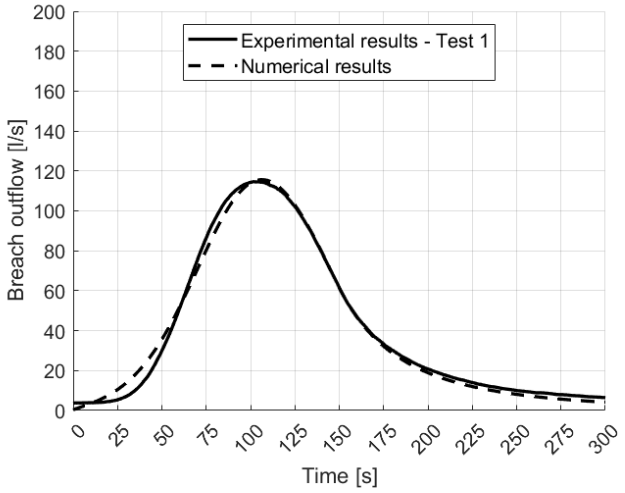


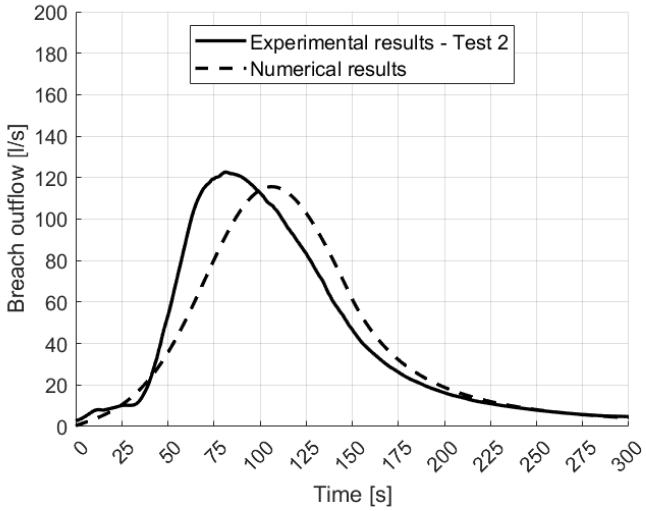


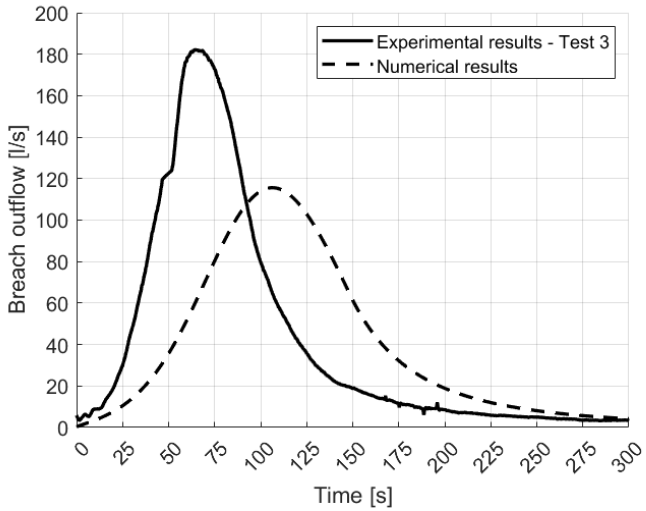


	$k_0 = 1,8\ [m^5 s^{-1} N^{-\frac{3}{2}}]$; $\beta = 30[°]$								
	Test 1			**Test 2**			**Test 3**		
	Exp	Num	Error	Exp	Num	Error	Exp	Num	Error
$Q_p\ [ls^{-1}]$	114,65	106,39	−7,20%	122,67	106,39	−13,27%	182,17	106,39	−41,60%
$T_p\ [s]$	102	111	+8,80%	86	74	−13,95%	64	74	+15,62%
$R^2\ [-]$	0,88			0,36			0,21		

Model 2 – breach outflow performance







	$k_d = 2070,90\left[\mathrm{mm^3N^{-1}s^{-1}}\right]$; $\beta = 2$ [°]								
	Test 1			**Test 2**			**Test 3**		
	Exp	Num	Error	Exp	Num	Error	Exp	Num	Error
$Q_p\ [ls^{-1}]$	114,65	115,62	+0,85%	122,67	115,62	−5,75%	182,17	115,62	−36,53%
$T_p\ [s]$	102	107	+4,90%	86	107	+24,42%	64	107	+67,19%
$R^2\ [-]$	0,97			0,87			0,42		

Key findings

- Experimental investigations have shown that dam breaching due to overtopping is a **highly complex** and **multi-phase process**, involving both vertical and lateral erosion mechanisms.
- The presented results focused on **preliminary numerical analysis** for homogeneous earthfill dams, providing insights into the model's capabilities and limitations.
- ▨ While the model does not fully predict peak discharge and time to peak, it **captures the general hydrograph shape**, which can be used as a practical tool for safety assessment in dam engineering.
- ⚠ Important limitation is the **lack of slope stability checks** for the breach sidewalls, which **should be incorporated in future work**, as slope failure significantly contributes to breach widening and overall dam collapse dynamics.
- ? A major challenge identified was the difficulty in sourcing reliable **erodibility parameters** for soil materials and the complexity of accurately estimating **the critical shear stress**, both of which emphasize the need for **further experimental and field validation studies**.

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Thank you for your attention!

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