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Centrifuge modeling of contaminant transport in keyed sand-bentonite cutoff walls

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Advantages of Centrifuge Modeling Tests

- **Reproduce the stress state of the prototype**
  Can ensure the similarity of transport behavior of contaminants
- **Accelerate the transport of contaminants**
  Can simulate transport processes over timescales spanning decades to centuries



Fig. 1. Centrifuge Modeling Tests

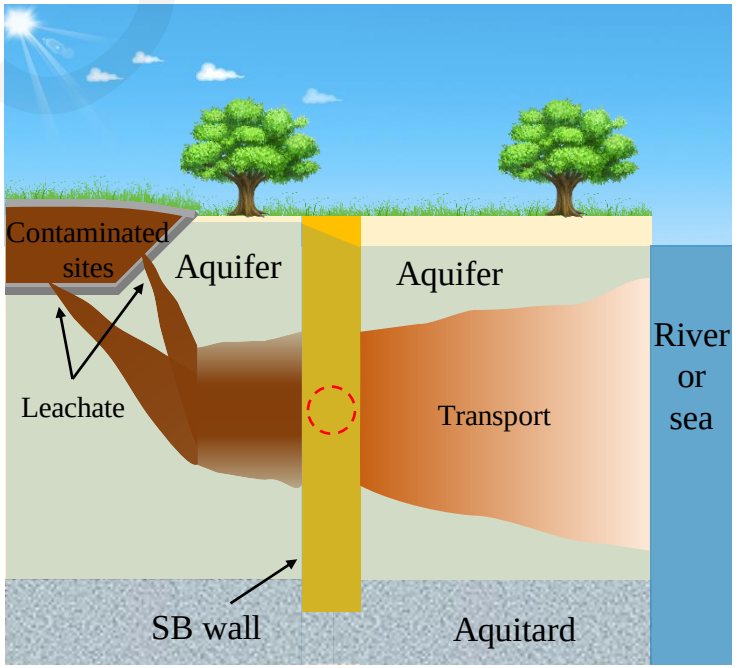

Fig. 2. Contaminant transport in SB walls

Centrifuge Modeling

- The centrifugal acceleration is 100g, and test simulats a 41 year transport process

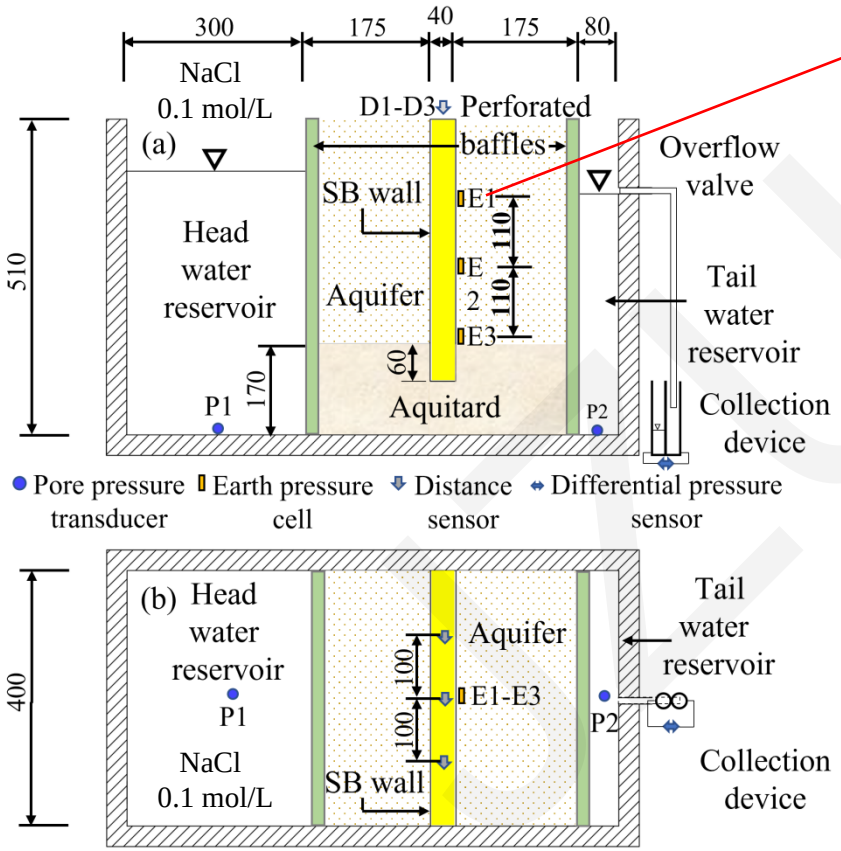

Fig. 3. Schematic diagram of the centrifuge model set-up (mm): (a) profile view; (b) plan view

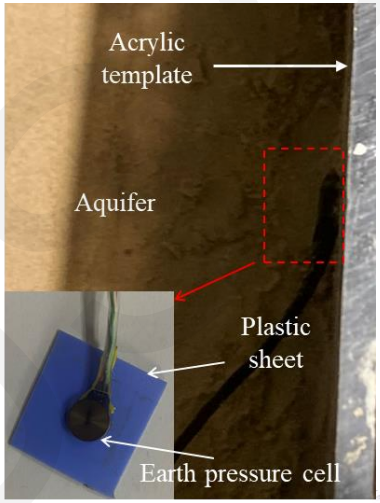

Fig. 4. Installation method of earth pressure cell

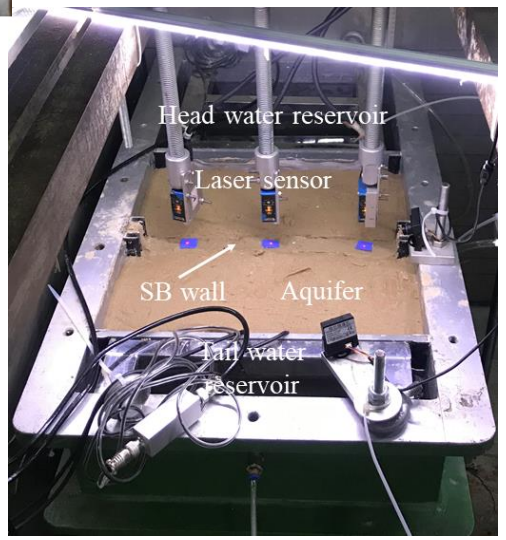

Fig. 5. Photo of centrifuge model

Numerical simulation

■ The model considering preferential interface migration is established

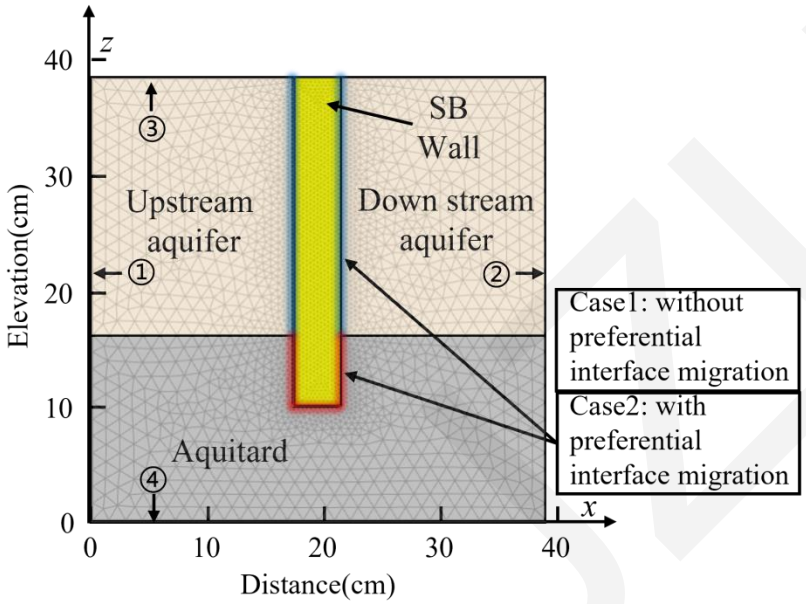

Fig. 6. 2D finite-element model of centrifuge test

Governing equation of contaminant transport:

$$\frac{\partial C_i}{\partial t} = D_{x,i}\frac{\partial^2 C_i}{\partial x^2} + D_{z,i}\frac{\partial^2 C_i}{\partial z^2} - v_{x,i}\frac{\partial C_i}{\partial x} - v_{z,i}\frac{\partial C_i}{\partial z}$$

Boundary conditions:

Number	Type	Contaminant transport	Seepage
①	Inflow boundary	$C = C_0$	$P = \rho_f N g(H_m - z + h_w)$
②	Outflow boundary	$\frac{\partial C}{\partial x} = 0$	$P = \rho_f N g(H_m - z)$
③	Upper boundary	$\frac{\partial C}{\partial z} = 0$	$\frac{\partial P}{\partial z} = \rho_f N g$
④	Lower boundary	$\frac{\partial C}{\partial z} = 0$	$\frac{\partial P}{\partial z} = \rho_f N g$

Test results

- The stress state of the SB wall in the Centrifuge model is similar to that of the prototype

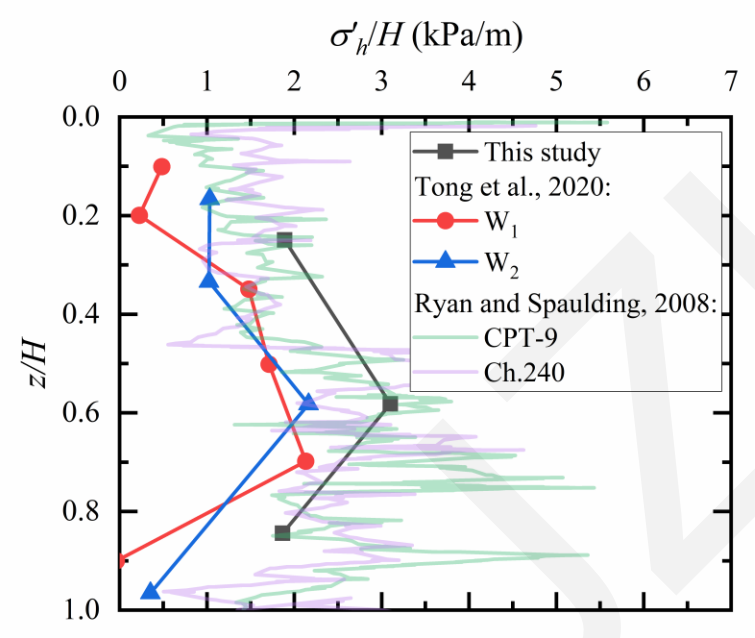

Fig. 7. Horizontal effective stress of SB wall

- The simulation results considering preferential interface migration are more consistent with the test results

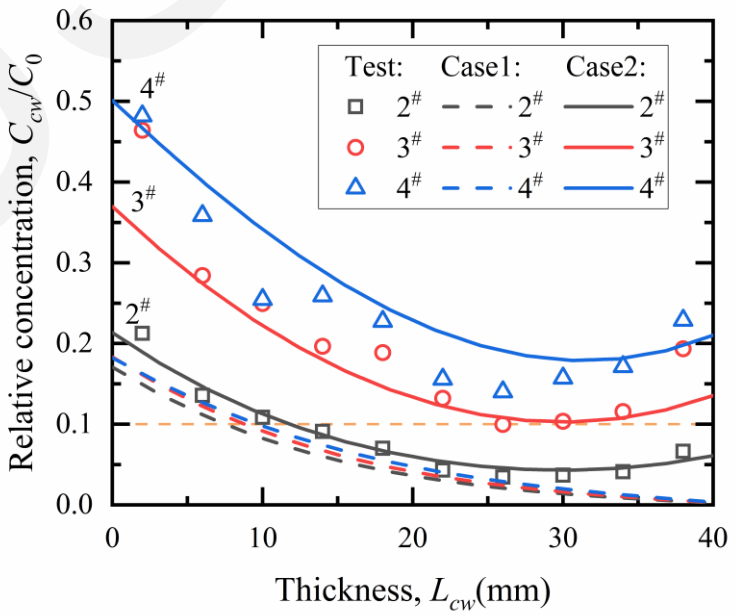

Fig. 8. Cl^- concentration distribution within SB wall

Preferential interface migration

- The existence of preferential interface migration greatly accelerated the transport of contaminants

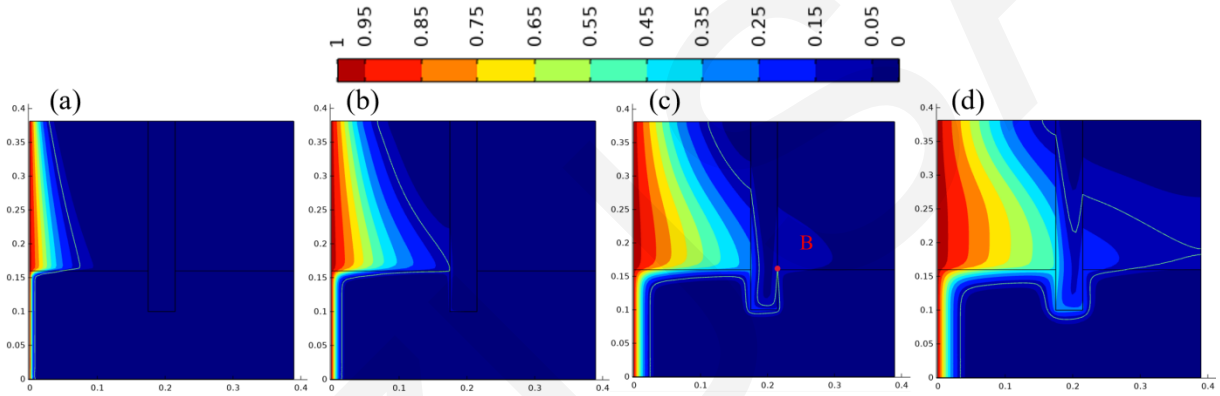

Fig. 9. Numerical simulation of contaminant plume variation

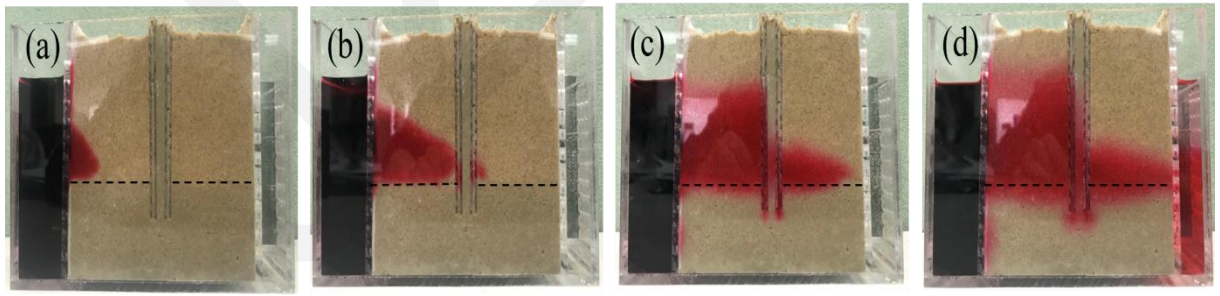

Fig. 10. Test result of contaminant plume variation

Conclusions

- The horizontal effective stress of the SB wall in the centrifuge modeling showed an initial increase and then a decrease with depth, which is consistent with some field measurements.
- In the vertical SB barrier system, preferential interface migration occurred betwen the interface of the SB wall and aquitard, which greatly accelerated the migration speed of contaminants.
- An internal boundary called a “fracture” was used in the numerical model to simulate the interface preference migration. The simulation results agreed with those from the centrifuge test, affirming the viability of this simulation approach.