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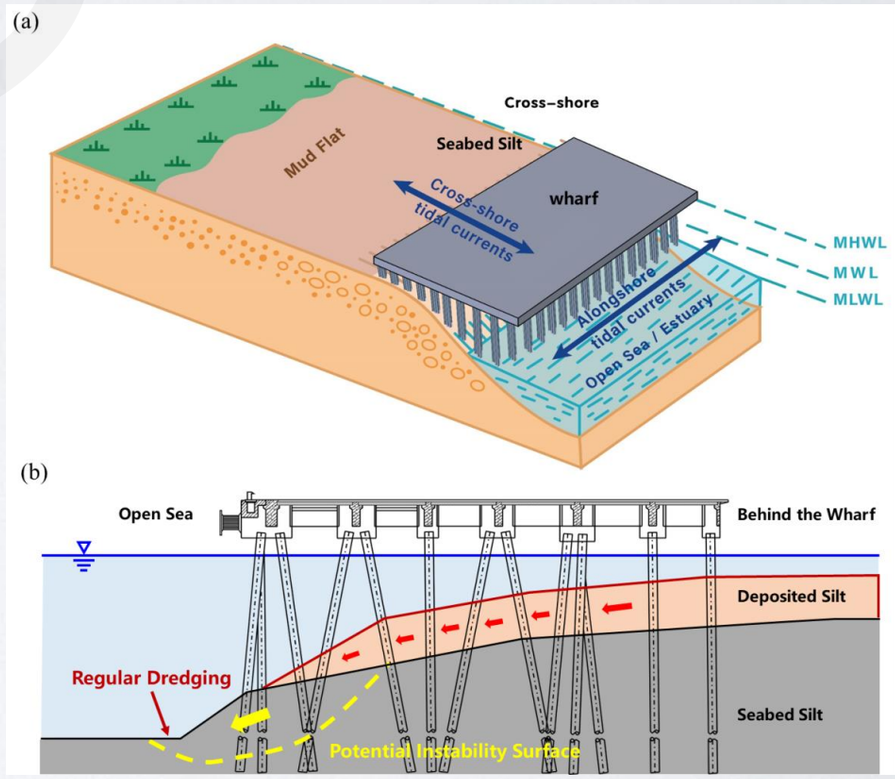
Sediment transport characteristics and siltation reduction method of high-pile wharves: a physical model and field observation study

Haojun Yang, Yangyang Gao, Lizhong Wang

Field–model
multi-scale evidence

24.6%
maximum siltation reduction

Groyne
eco-friendly mitigation



Key words:
High-pile wharves, Field observation, Sediment transport, Large-scale physical model experiment, Groynes

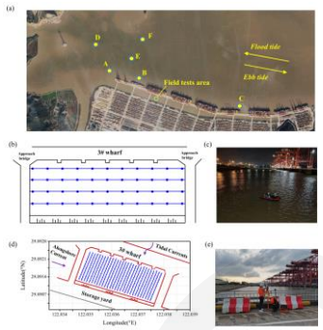
Innovation: field-validated, multi-scale diagnosis of wharf siltation

Research gap

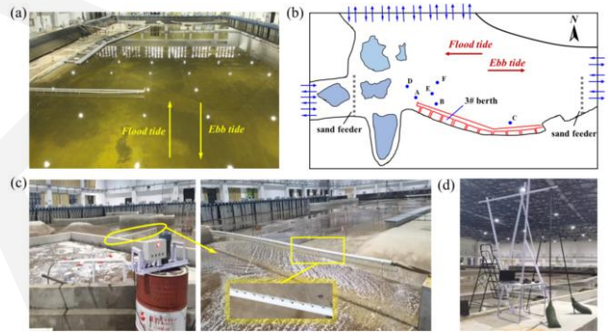
- Sediment-reduction mechanisms of groynes are well known on open coasts, but not verified behind semi-enclosed high-pile wharves.
- Existing evidence is often limited to small flumes or short-term simulations.
- Tide–topography–pile interactions accumulate over multiple tidal cycles.

This study adds

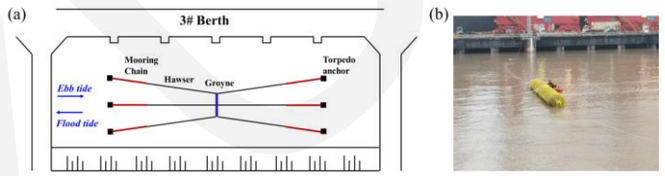
- Field observations across 2020–2023, including eight intratidal cycles.
- Large-scale distorted physical model with LSPIV visualization.
- Prototype groyne deployment and one-year field verification.



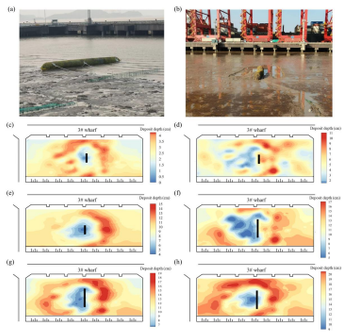
Field observation



Large-scale model



Groyne deployment



Field verification

Core mechanism: a balance between flow reduction and turbulence enhancement

Competing controls on sediment fate

Pile sheltering

↓ velocity
↓ transport capacity

Sloping bed

↑ shear
↑ resuspension

Net bed change behind wharf

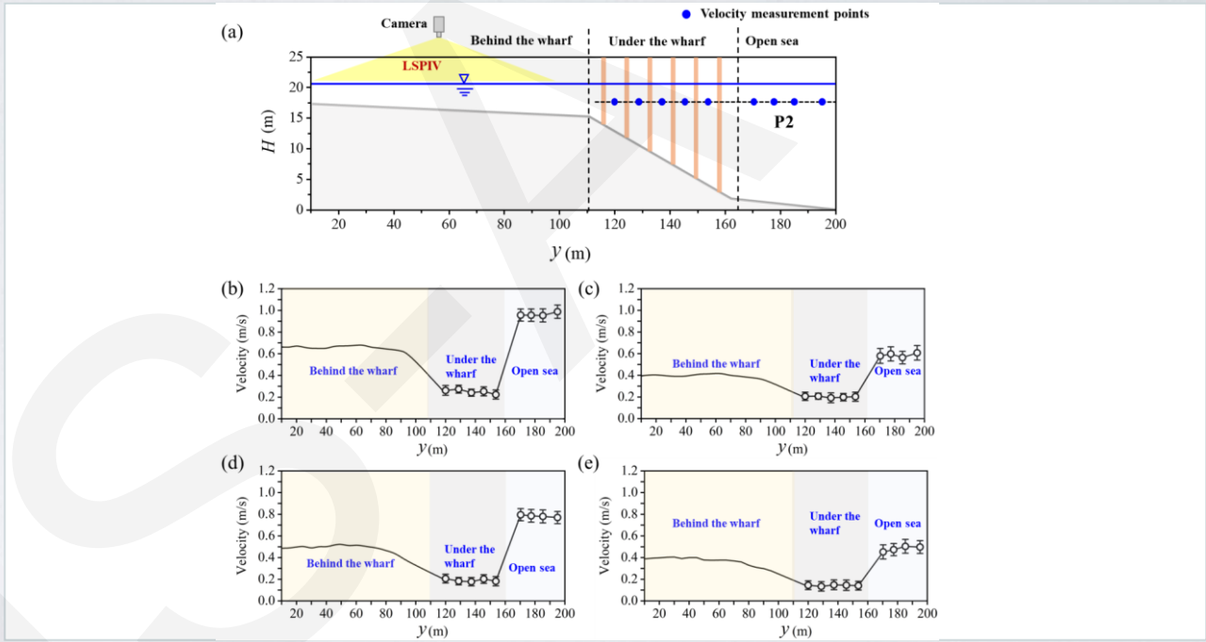
Topographic recirculation

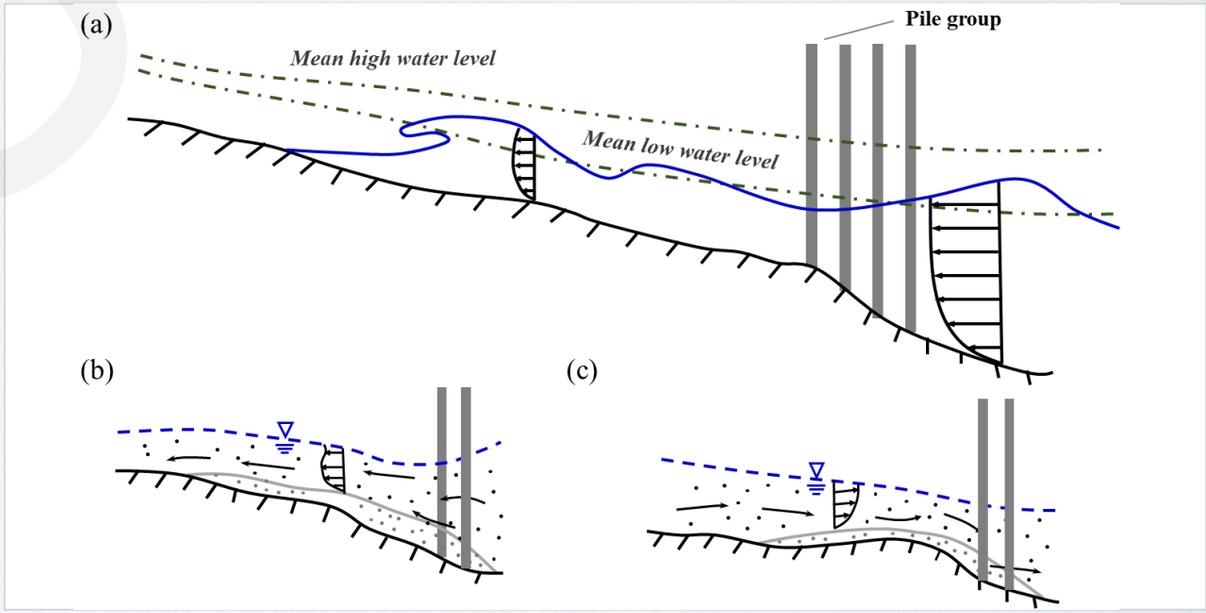
reverse flow +
secondary currents

Tidal transitions

ESWS: sharp gradients
& high bed stress

Deposition is promoted by pile-induced velocity reduction, while turbulence and bed-slope effects enhance sediment entrainment and redistribution.





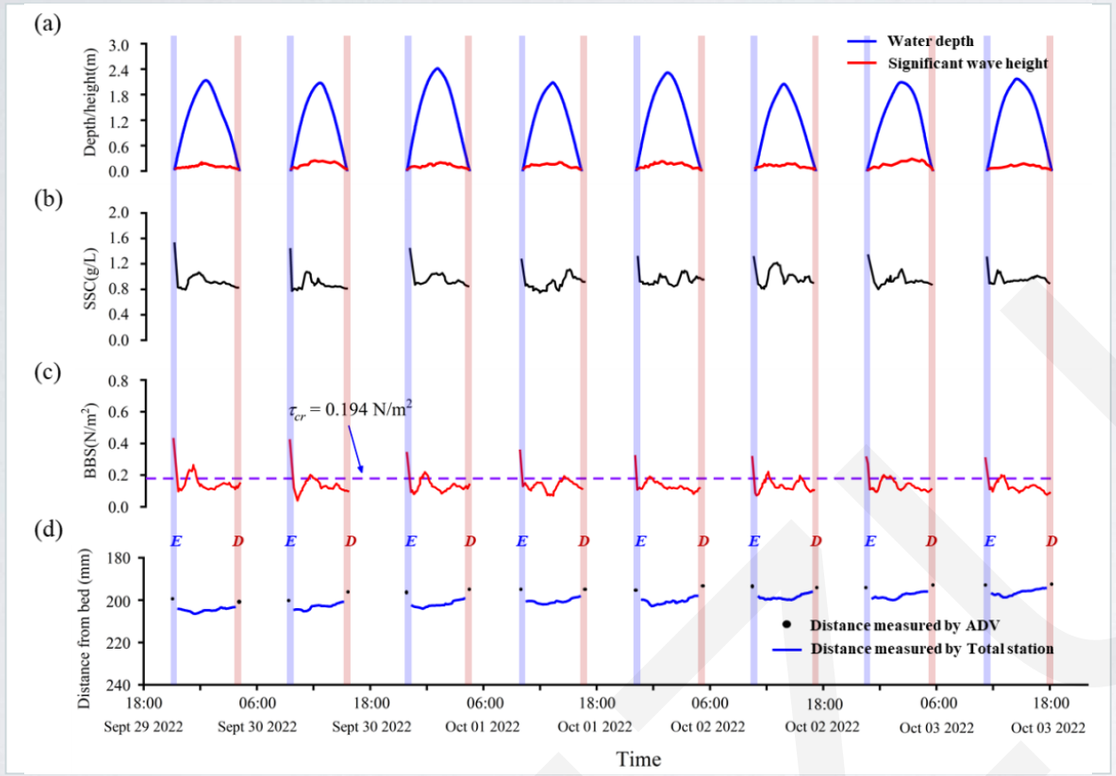
Key result: tidal stage controls sediment delivery and bed evolution

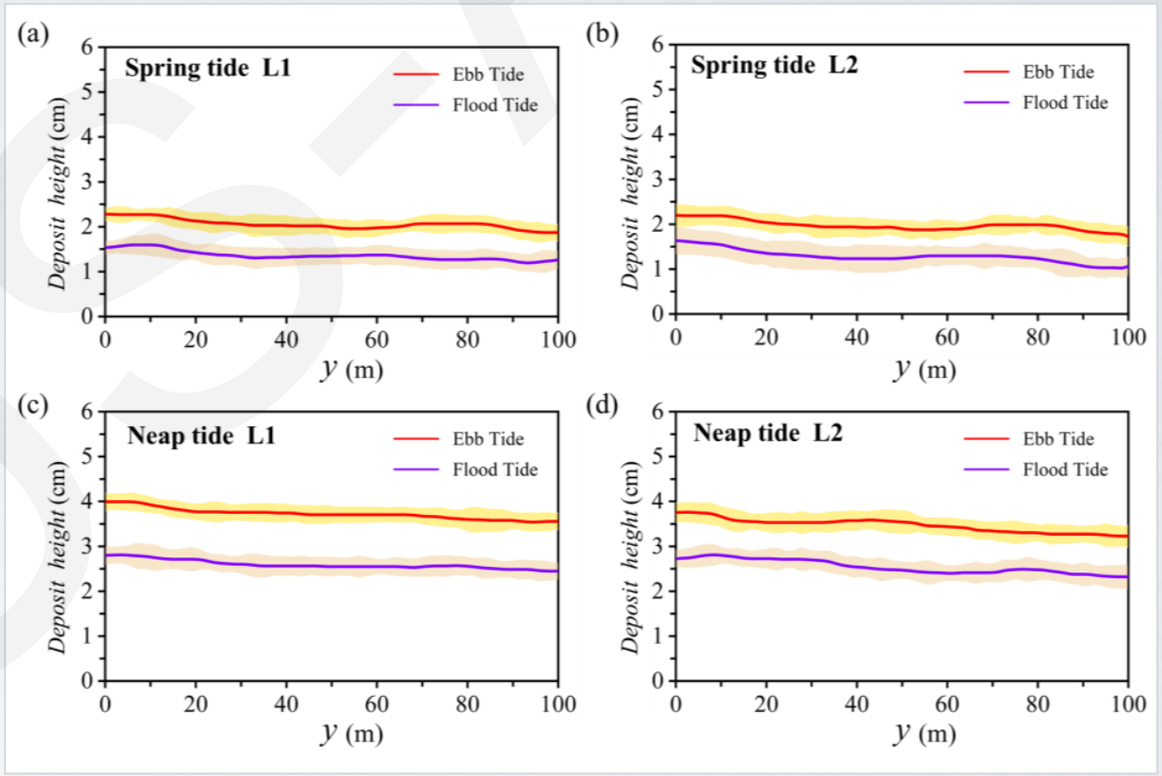
1.6×
flood velocity ≈ ebb velocity at wharf front

1.4×
front velocity ≈ rear velocity

ESWS
extremely shallow-water stage drives bed change

Ebb/neap
dominant deposition phases

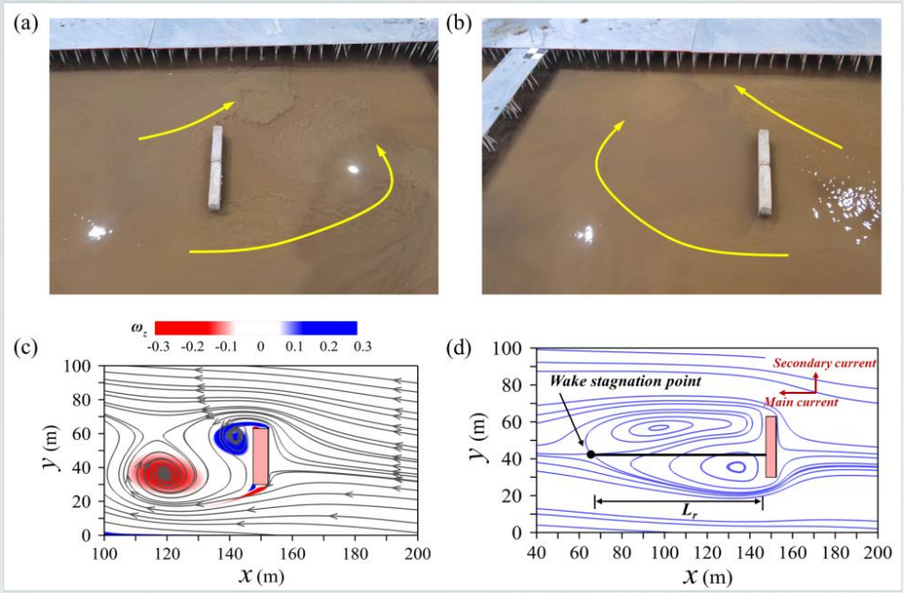


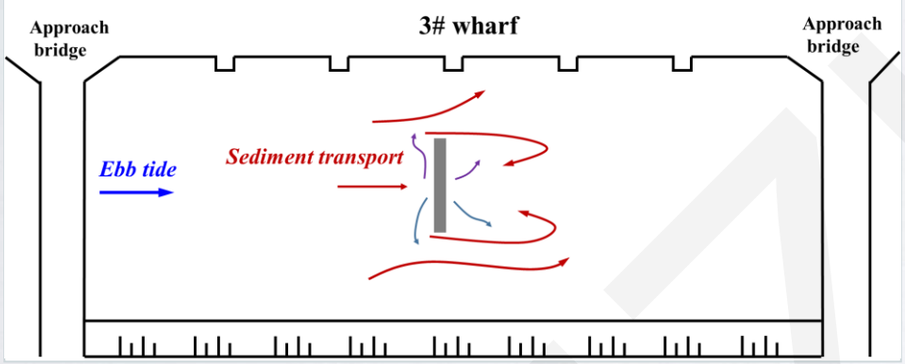


Interpretation

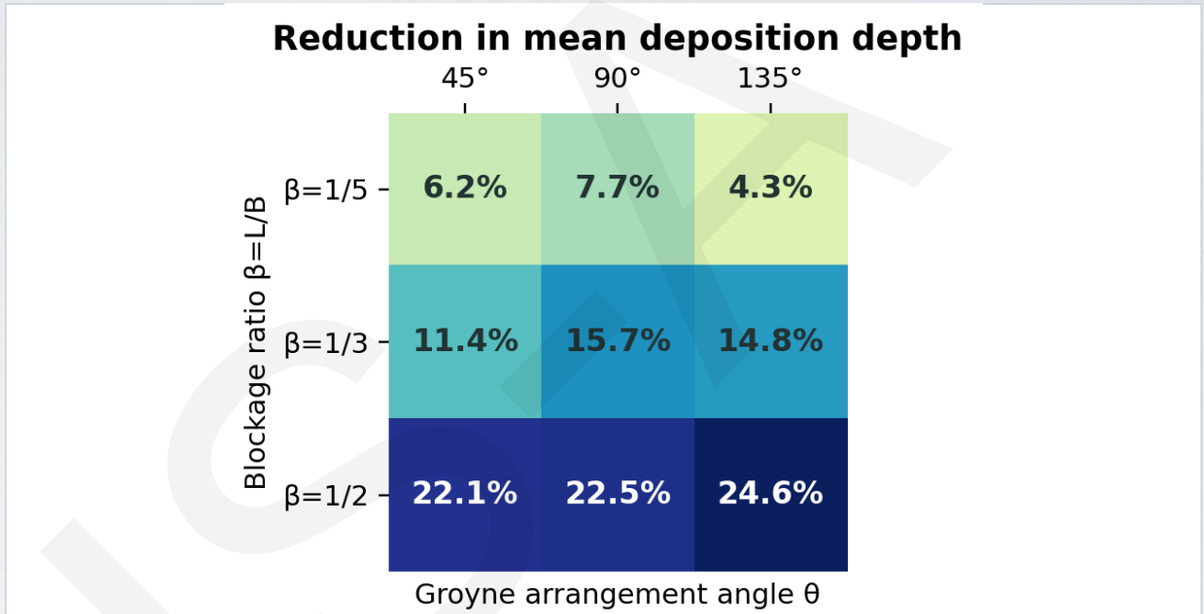
- Initial flood/ebb stages: cross-shore sediment delivery dominates.
- After submergence: alongshore current and secondary flow redistribute sediment.
- Shallow-water transitions create steep velocity gradients and high bed shear stress.

Groyne regulation: turning local turbulence into siltation reduction





Engineering implication: reduce repeated dredging demand



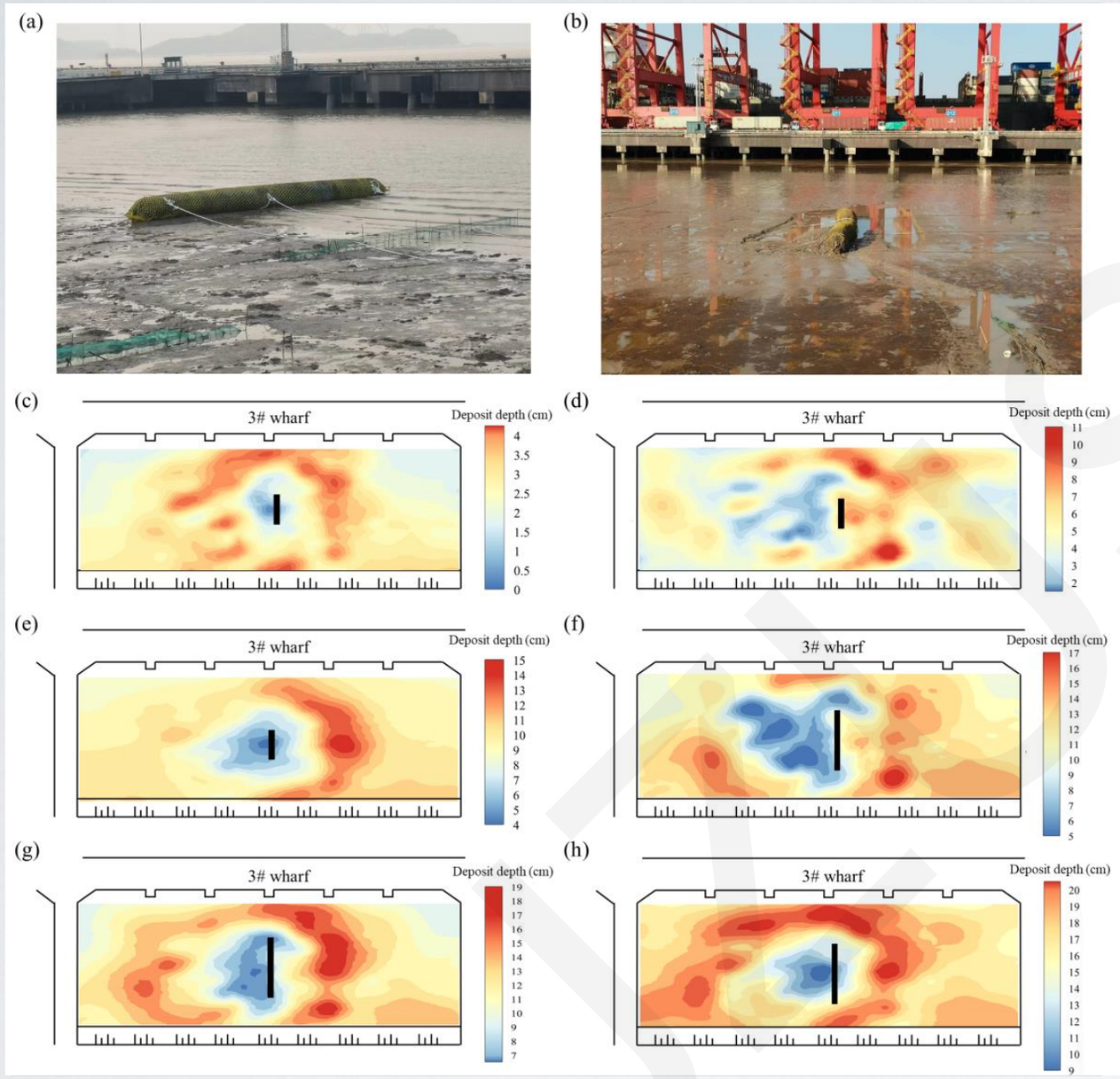
24.6%
maximum reduction at β=1/2, θ=135°

θ=90°
highest TKE / strongest eddy activity

≈2L
recirculation zone length at θ=90°

- The groyne enhances lateral flow, bottom shear, and sediment resuspension.
- Reduction efficiency increases mainly with blockage ratio β; layout angle is secondary.
- A practical strategy emerges: increase hydrodynamic connectivity instead of relying on repeated dredging.

Field validation and take-home messages



1 Mechanism

Complex topography forms recirculation and reverse flows; pile groups reduce velocity and favor deposition.

2 Time scale

Early tidal stages are controlled by cross-shore transport; later stages by alongshore and secondary flows.

3 Mitigation

Groynes enhance TKE, lateral flow and local scouring, providing field-supported sediment reduction.

Main contribution

A field-calibrated and experimentally optimized framework for understanding and reducing siltation behind high-pile wharves.

Publicity focus: field-supported, low-impact engineering control for port siltation.