NJDOT Research Showcase
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Towards Use of Stabilized Sediments as a Sustainable Alternative to Traditional Infrastructure Materials: A Laboratory and Numerical Study

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Outline

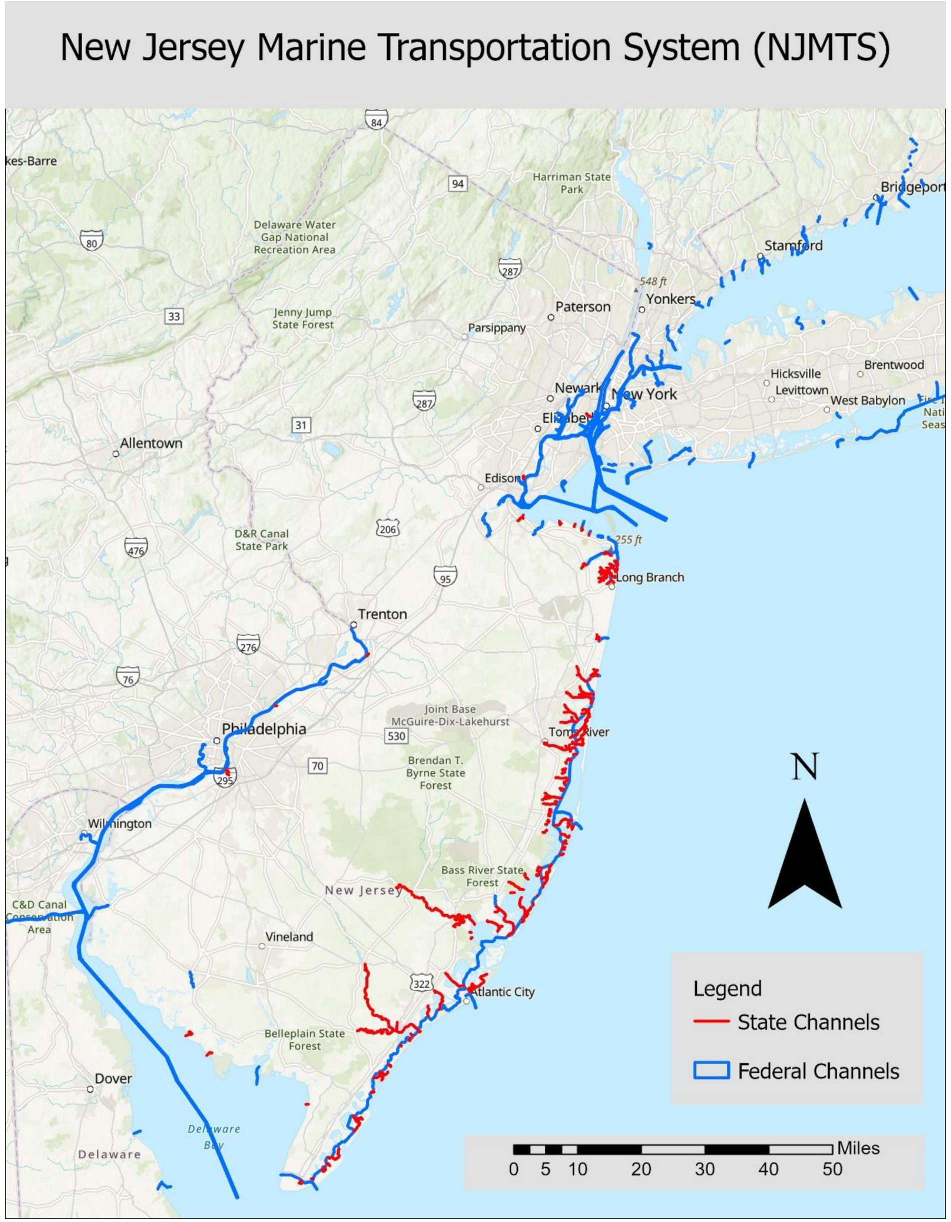
- *Background and Motivation*
- *Material Sampling*
- *Experimental Results*
- *Numerical modeling*
- *Conclusions*

New Jersey Marine Transportation System

- Contains over 300 nautical miles of engineered waterways

- United States Army Corps of Engineers operates and maintains the NJ Intracoastal Waterway
  - Over 117 miles of navigational channels

- NJDOT Office of Maritime Resources operates and maintains over 200 nautical miles of state navigation channels



Navigational channel maintenance

- *Regular maintenance dredging is required to maintain channel navigability*
  - *250,000 CY of sediments dredged annually from 2014 to 2018*

- *Sediment sources include:*
  - *Migration of flood tidal deltas (primarily sandy sediments)*
  - *Deposition of fine-grained sediments at transition areas between higher and lower currents*
  - *Mobilized sediments (sands/silts)*

- *Sandy sediments can be readily incorporated in earthwork or beach restoration projects*

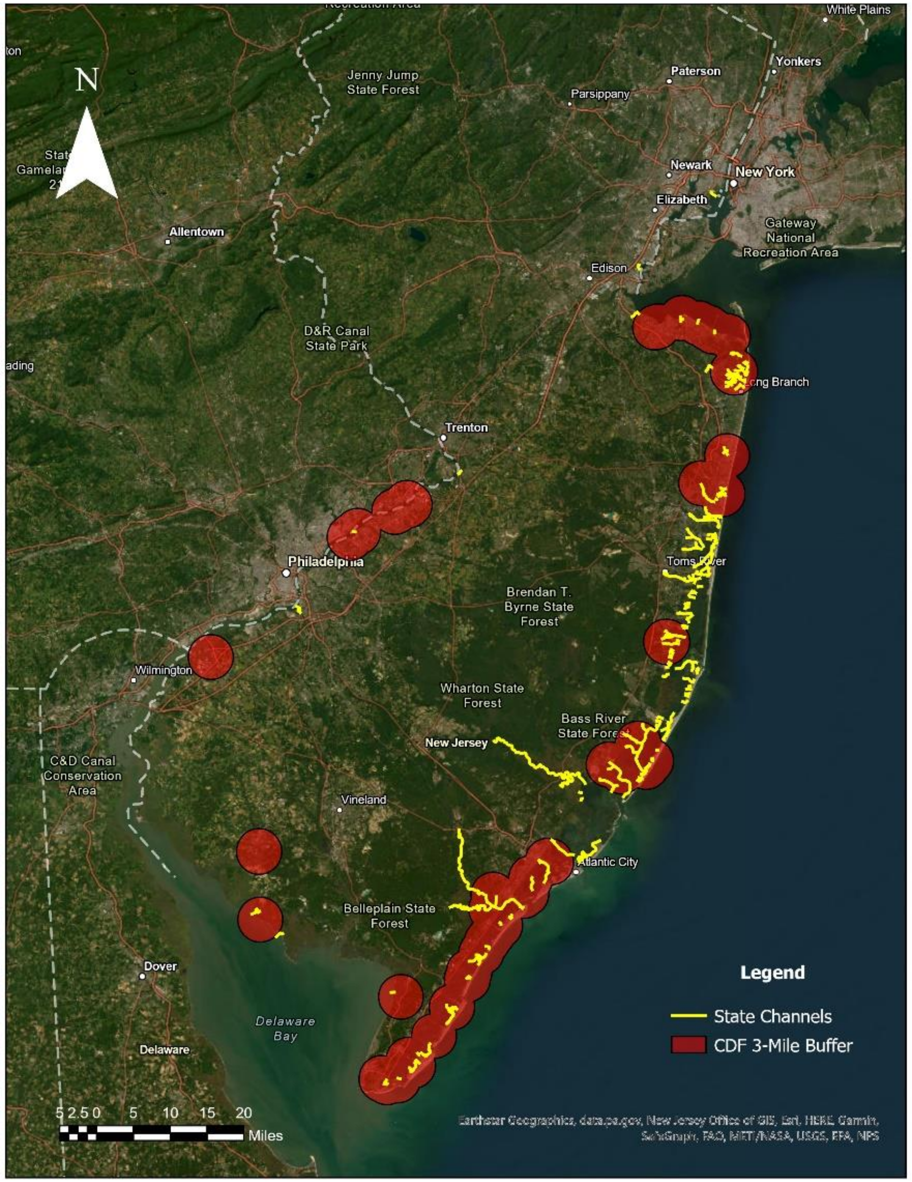
- *Fine-grained sediments are generally considered unworkable as a raw material due to their:*
  - *High moisture contents*
  - *Low strengths*
  - *Poor workability*

Storage of fine-grained sediments

- *Off-shore placement of sediments is highly regulated especially if fine-grained or impacted*

- *Sediments often placed in confined disposal facilities*
  - *Essentially landfills designed for storage of fine-grained sediments (impacted or non-impacted)*
  - *Current capacity is estimated to be approximately 2.9 million CY at current berm heights as of 2022*
  - *Capacity could be increased to ~5.5 million CY with berm raises*

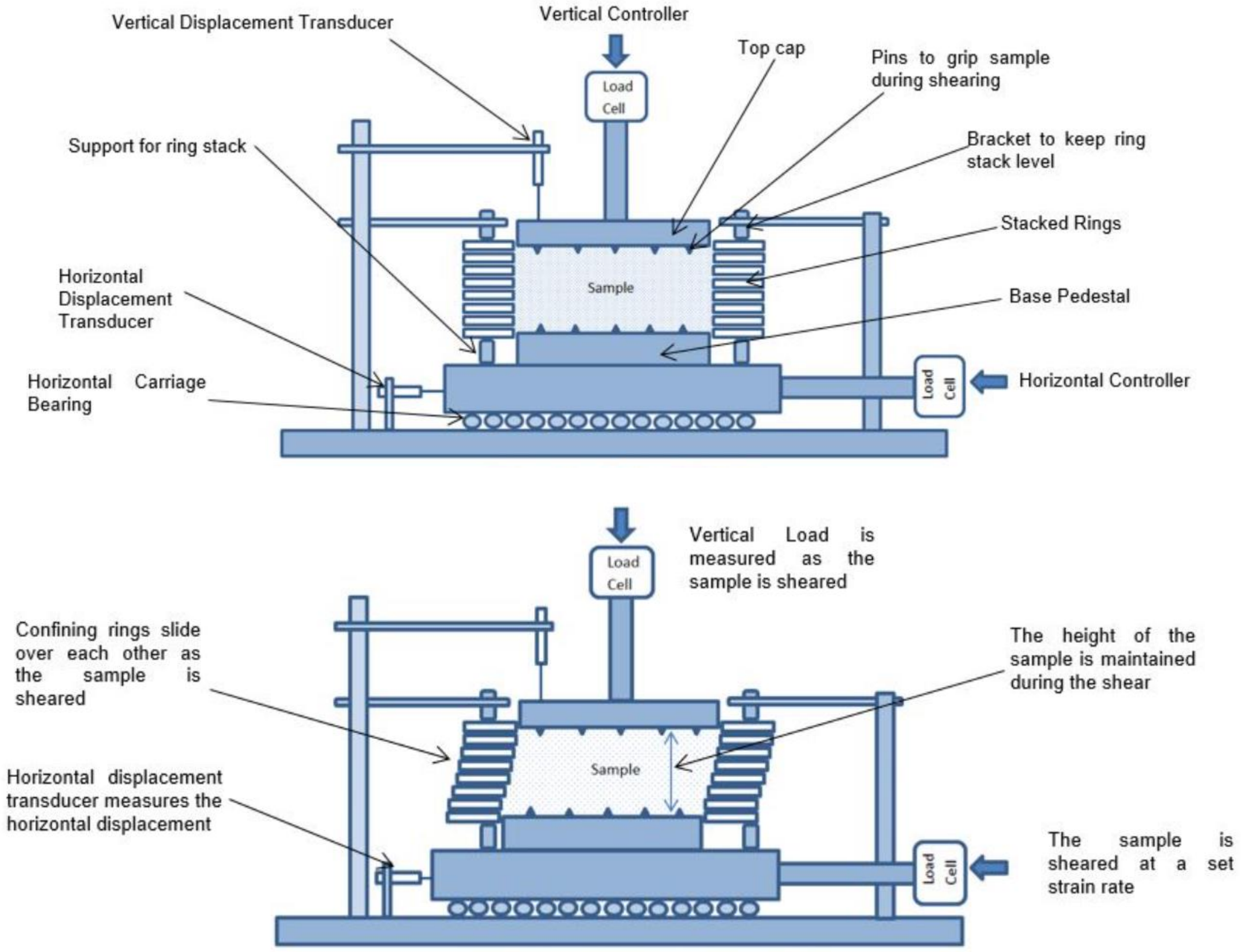
- *CDFs provide a potential abundant source of earthen material for use in infrastructure projects as an alternative to raw materials*



Experimental methods

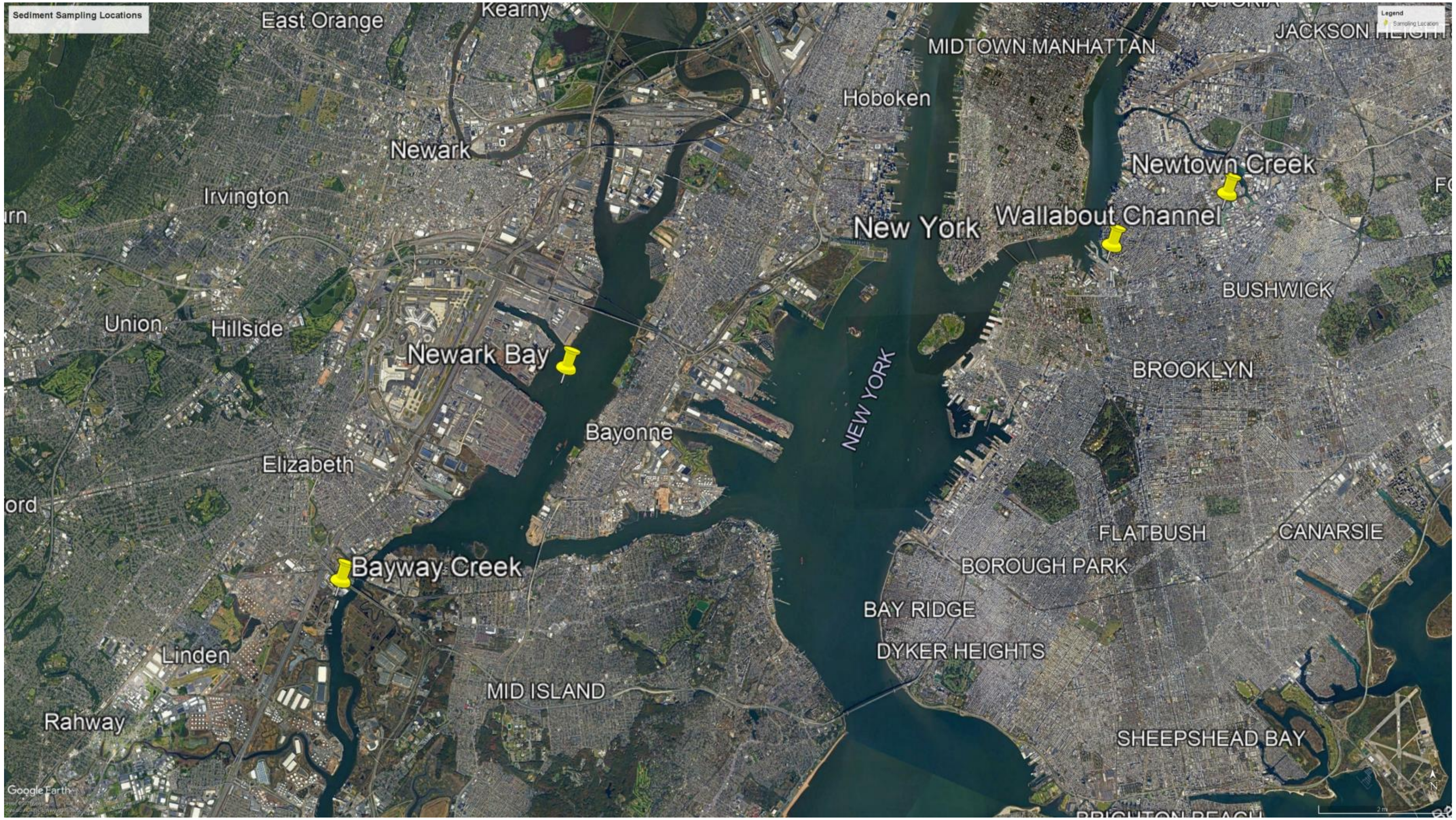
- *Goal:*
  - *To evaluate the engineering performance of stabilized sediments under more field-realistic loading conditions*

- *Methods:*
  - *Monotonic, constant volume, direct simple shear loading*
    - *Vertical confining pressures of 25, 100, and 400 kPa*
  - *Sediments stabilized with 4% Portland cement by wet weight*
  - *Samples cured in closed coolers (constant humidity conditions) for 3, 7, and 14 days*



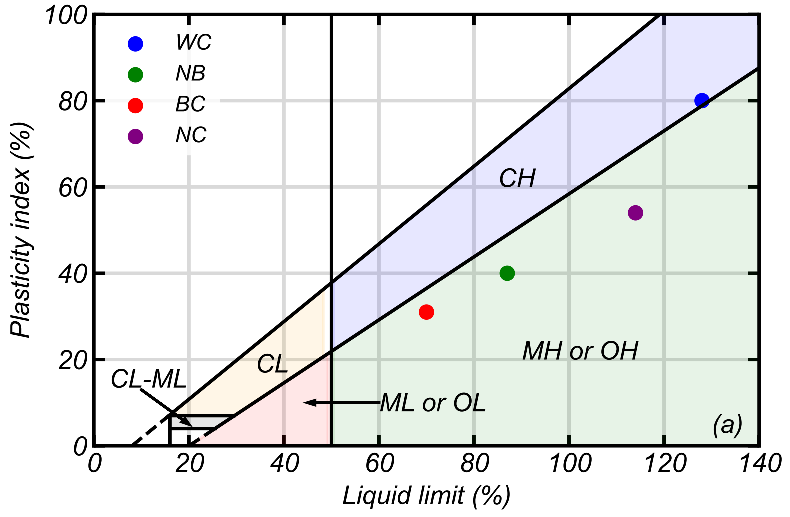
Figures via VJ Tech

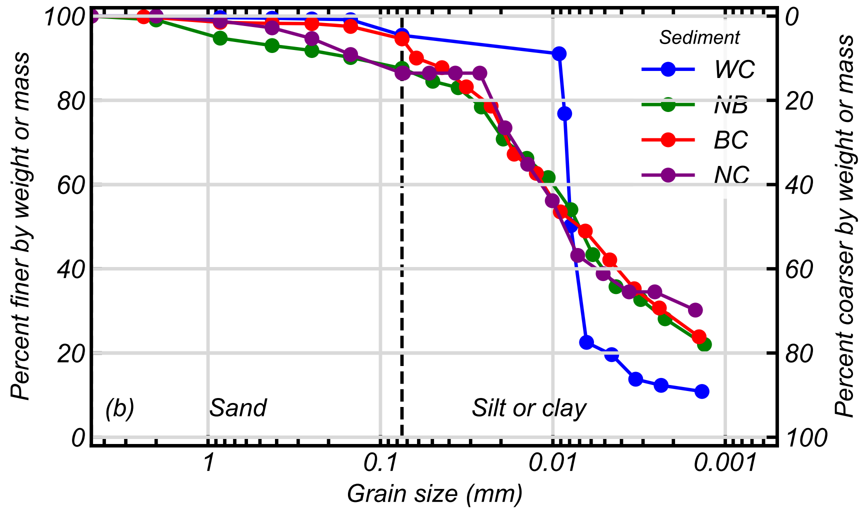
Sampled sediments



Sediment properties

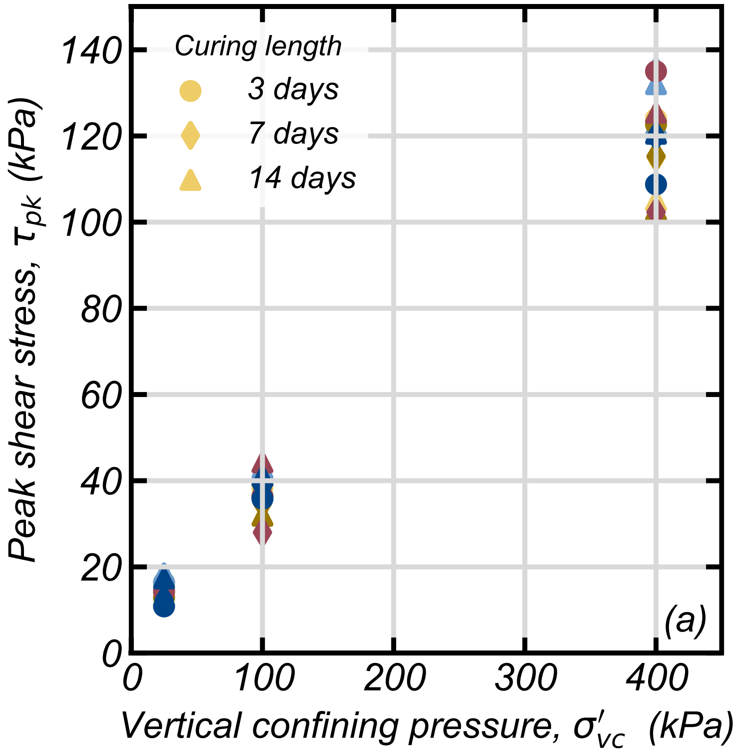
Physical index	ASTM Standard	NB	NC	WC	BC
Water content (%)	D2216	139	245	272	116
Specific gravity	D854	2.57	2.27	2.62	2.4
Liquid Limit (LL) (%)	D4318	87	114	128	70
Plastic Limit (PL) (%)	D4318	40	60	48	38
Plastic Index (PI) (%)	D4318	47	54	80	31
Clay fraction (%)	D7928	43.4	38.9	10.8	49.0
Silt fraction (%)	D6913/7928	44.2	47.6	84.6	45.7
Sand fraction (%)	D6913	12.4	13.5	4.6	5.4
Organic content (%)	D2974	7.6	25.3	12.6	12.4
USCS	D2478	OH	OH	OH	OH
tPAH (mg/kg-ds)	--	20.2	308	13.9	377





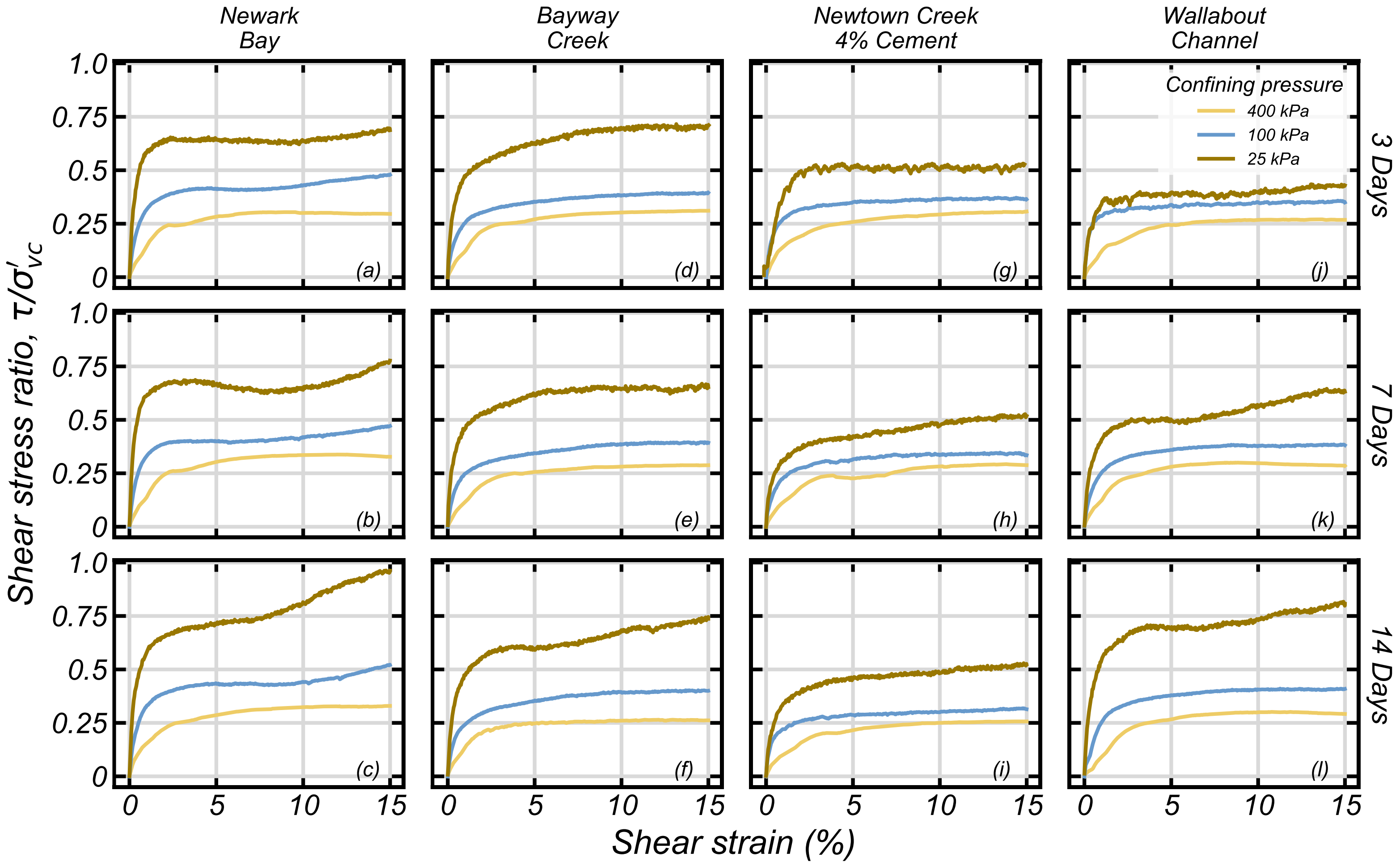
Peak strengths

- *Mobilized peak shear stress increases with vertical confining pressure*
  - *Consistent with expectations of a stress-dependent material*
- *Peak shear stress ratios decrease with an increasing confining pressure*
  - *Cementation plays a larger role in shear stress at lower confining pressures where the frictional resistance is lower*



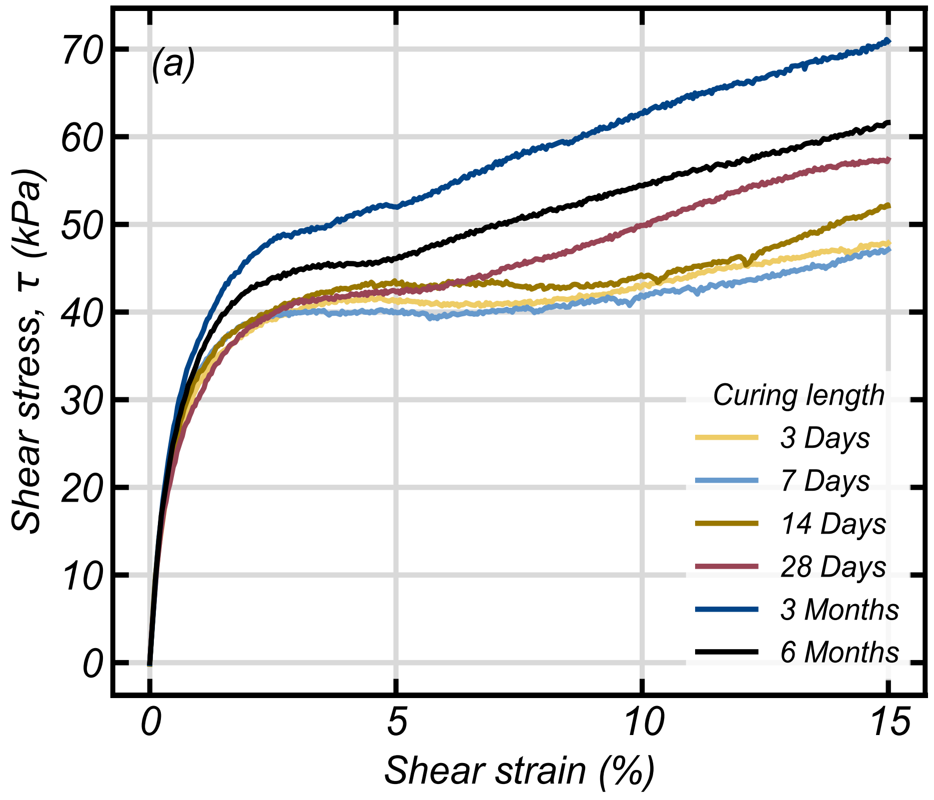
Stress-strain responses

- *Limited to no post-peak strength loss observed*
- *Peak shear stress mobilized between approximately 3 and 5% shear strain*
- *Strain-hardening observed with confining pressures of 25 kPa*



Impact of long-term curing

- *Long-term curing typically increases the mobilized peak shear stress*
- *Strain-hardening tends to begin at lower strain levels with additional curing time*
- *Initial stiffness appears to be relatively independent of the curing length*



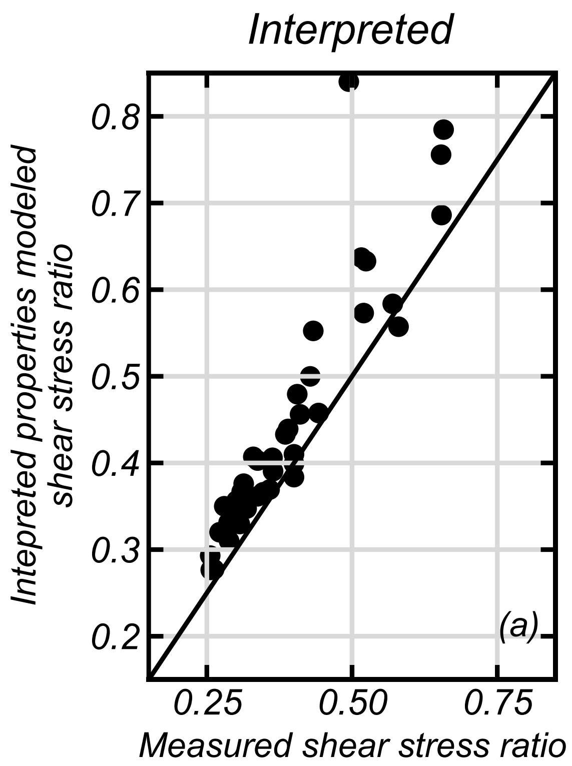
Numerical modeling

- *Goal: Evaluate the ability of different numerical approaches to capture the results of the laboratory testing program (peak strengths and stress-strain response)*

- *Methods:*
  - *Single element simulations with the finite difference program FLAC 8.1 (Itasca 2019)*
  - *Two different constitutive models*
    - *Mohr-Coulomb – one of the most commonly used “simple” models in practice*
    - *PM4Silt (Boulanger and Ziotopoulou 2022) – more complicated model developed for plastic soils under cyclic loading*

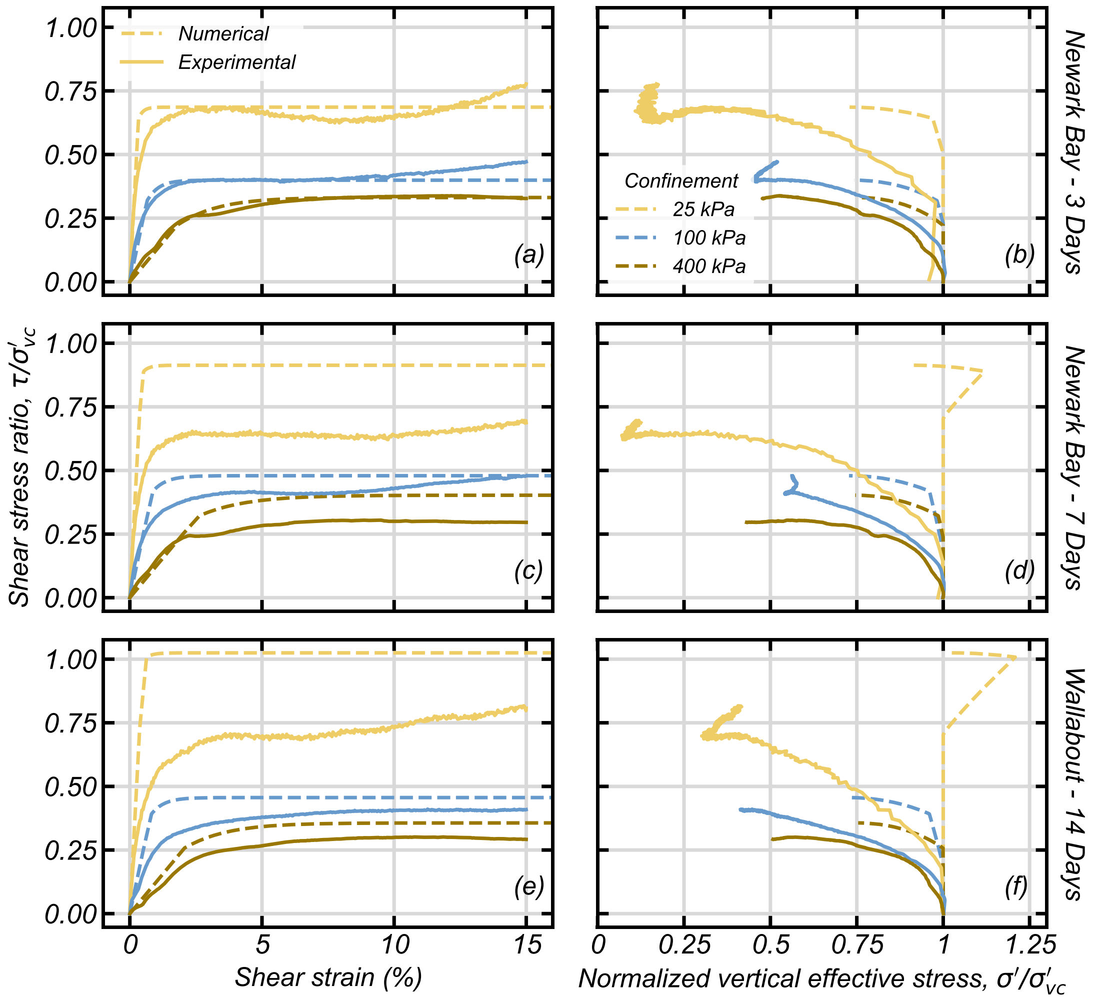
Mohr Coulomb strengths and properties

- *Two sets of Mohr Coulomb properties were used: (1) interpreted and (2) optimized*
- *Interpreted soil properties consistently overpredict the measured peak stress ratio*
- *Optimized soil properties generally reduced the friction angle and cohesion*
  - *Better captured the peak shear stress ratio*

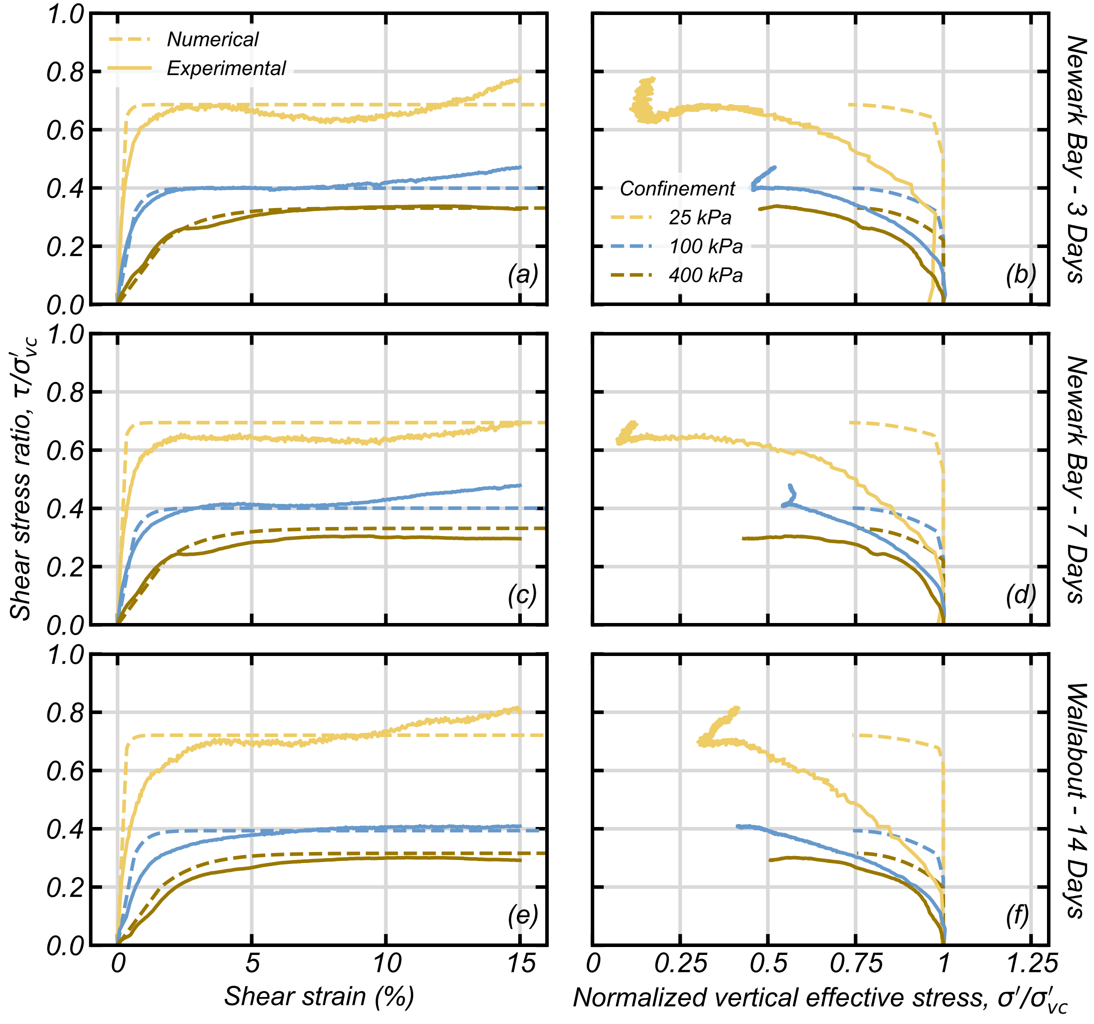


Peak shear stress ratios

Mohr Coulomb – stress strain response



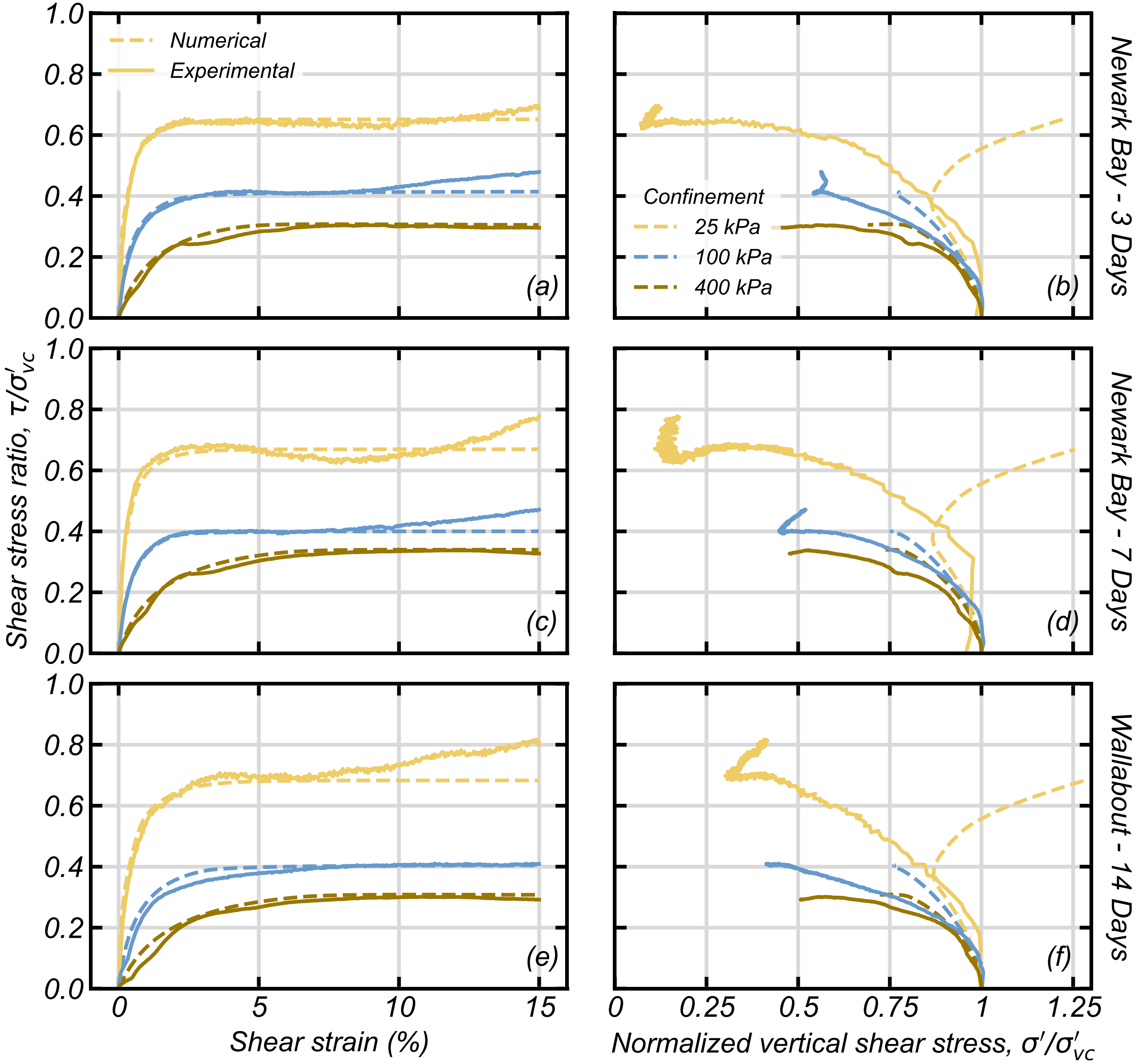
Interpreted



Optimized

PM4Silt

- ➢ *PM4Silt is better able to capture the stiffness degradation across all confining pressures*
- ➢ *PM4Silt is unable to capture the stress path of the low confining pressure tests*
    - *Unable to directly account for the cementation*
    - *Assumes the material is dense and dilative to mobilize the high strength ratios*
    - *Constitutive models developed for cemented soils likely could address this gap*



Conclusions

- *Constant volume direct simple shear tests were performed on four New York Harbor sediments*

- *Tests showed that generally the stabilized sediments behaved similarly to other plastic soils*
    - *Mobilized shear strengths increased with confining pressure (mobilized strength ratios decrease as confining pressure increases)*
    - *Limited to no post-peak strength loss was observed*
    - *At low confining pressures the sediments underwent strain-hardening*

- *Numerical approaches were shown to reasonably capture the experimental test results*
    - *Mohr-Coulomb could capture the mobilized peak strengths but was unable to capture the stiffness degradation and stress path*
    - *PM4Silt was able to better capture the stiffness degradation and stress path but was unable to capture the stress-path at low confining pressures*

- *Overall, the results indicate that sediments have the potential to be used in more structural beneficial uses and could be a readily available alternative to environmentally intensive raw soils*

Acknowledgements

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Center for Advanced Infrastructure and Transportation

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Impact of cement content