

Impact of Calcium Carbonate Shell Hash on Geomechanical Properties of Sand

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Background

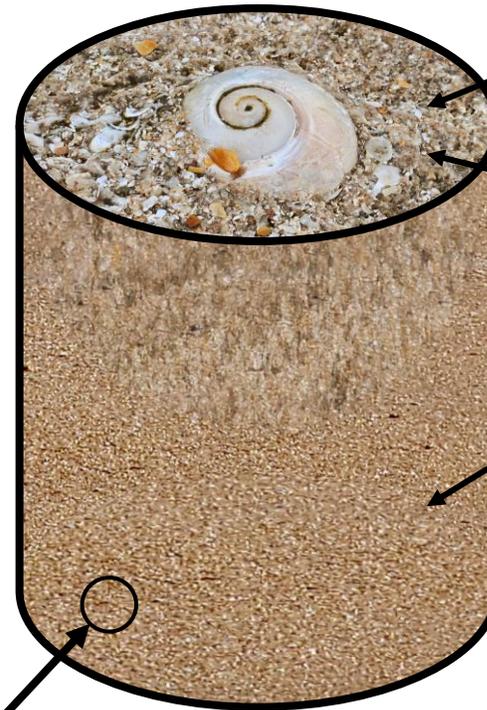
How does natural shell content impact the erodibility of beaches?

- Intertidal rock outcroppings (hardbottom)
- Shell hash presence
- Variance on spatial and temporal scales
- Collection of samples and in-situ measurements
- Index and strength testing



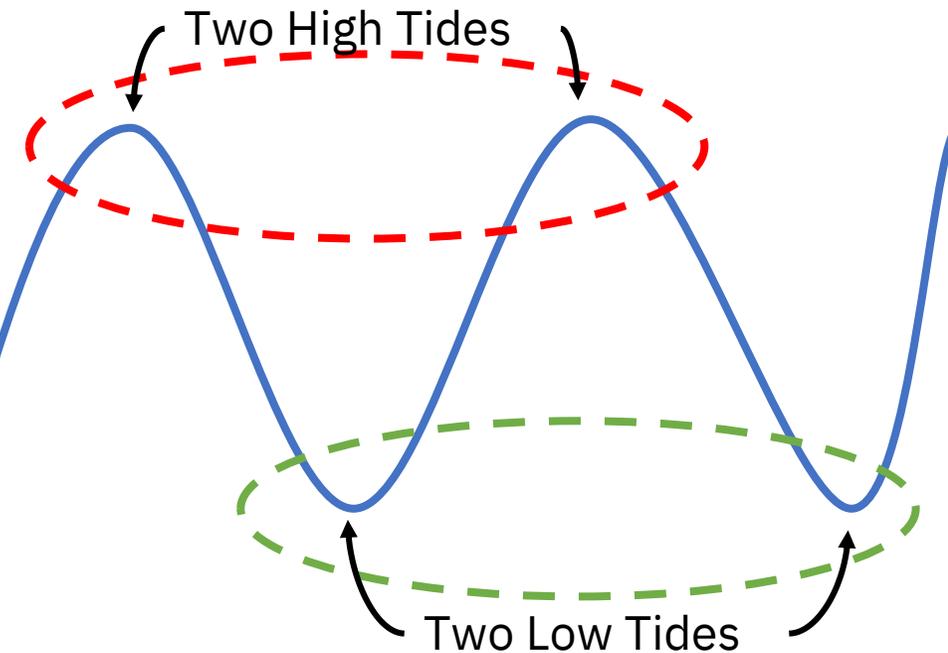
Location

- Quartz sand beach
- Presence of Calcium Carbonate shell hash
 - Fragmented shell material
- Semi-diurnal tide cycle
 - 1.1 m mean tidal range
- ~30 m wide intertidal zone
 - Slope of $\sim 5.2^\circ$



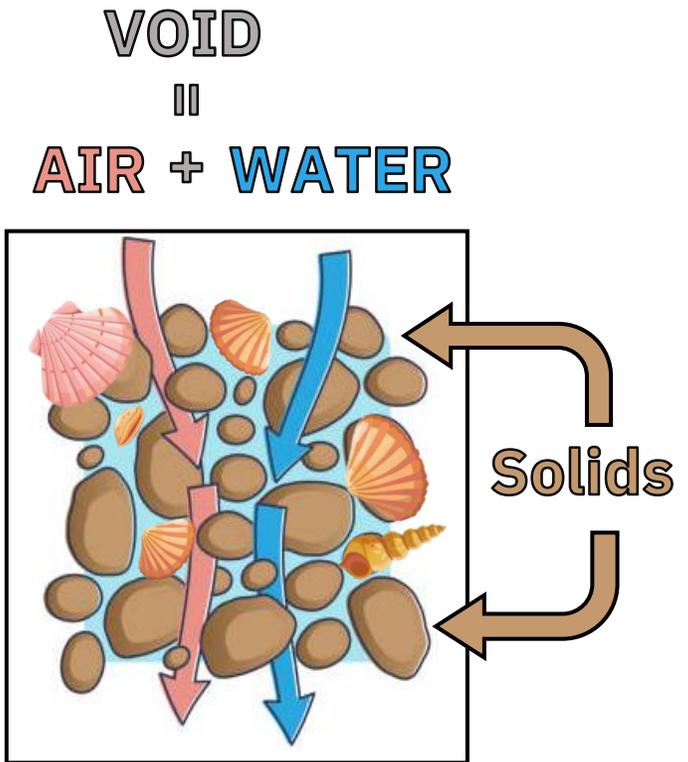
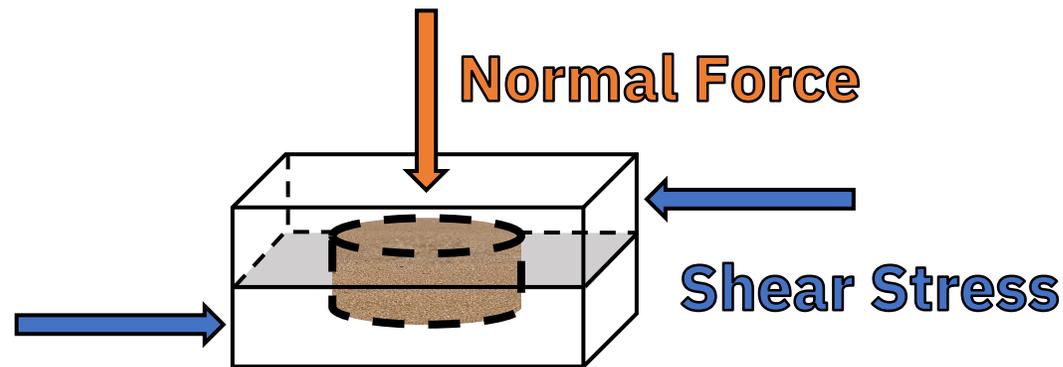
Calcium Carbonate shell hash

Quartz sand



Methods

- Bulk density and unit weight are representative of soil compaction
- Grain size distribution moisture content, and unit weight are informative of soil porosity and drainage
- Direct shear testing for evaluation of shear strength of the soil under applied normal forces
- Shell hash content as a comparative metric



$$V_{Soil} = V_{Solids} + V_{Voids}$$

$$\gamma_{Dry} = \frac{W_{Solids}}{V_{Soil}}$$

$$w = \frac{W_{Water}}{W_{Solids}}$$

Methods: In-Situ Testing and Sampling

- Two cross-shore transects from dune toe to the swash zone (30 m)
- Survey points every 5 m along transect
- Points surveyed at low tide
- 10 cm core tubes
- In-Situ moisture content from handheld probe



Methods: Soil Index Testing

Weighed core tube samples to calculate wet density and unit weight

$$\gamma_{Total} = \frac{W_{Total}}{V_{Total}}$$

Dried representative sub-samples (x3) from each tube sample to calculate gravimetric moisture content

$$w = \frac{W_{Water}}{W_{Solids}}$$

Dried whole sample to conduct sieve analysis

Used ~5 mol HCL to dissolve calcium carbonate

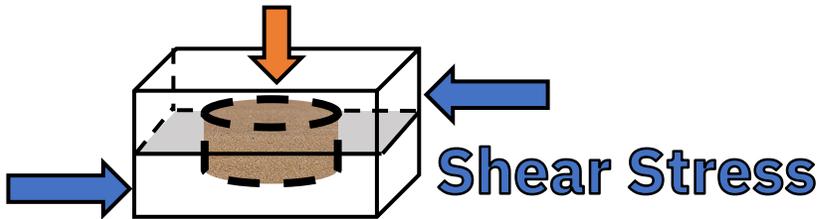


Methods: Soil Strength Testing

Dried samples from three locations along each transect and one pure sand sample

Points 2,4,6 along each transect

Normal Force



Samples tested at unit weight of 16 kN/m^3



11.5 kN/m^3 (measured) was too loose

Sub-samples normalized to shell hash % matching sample

Sub-sample tested at 16 kPa

Multiple normal stresses to construct shear stress vs displacement curves

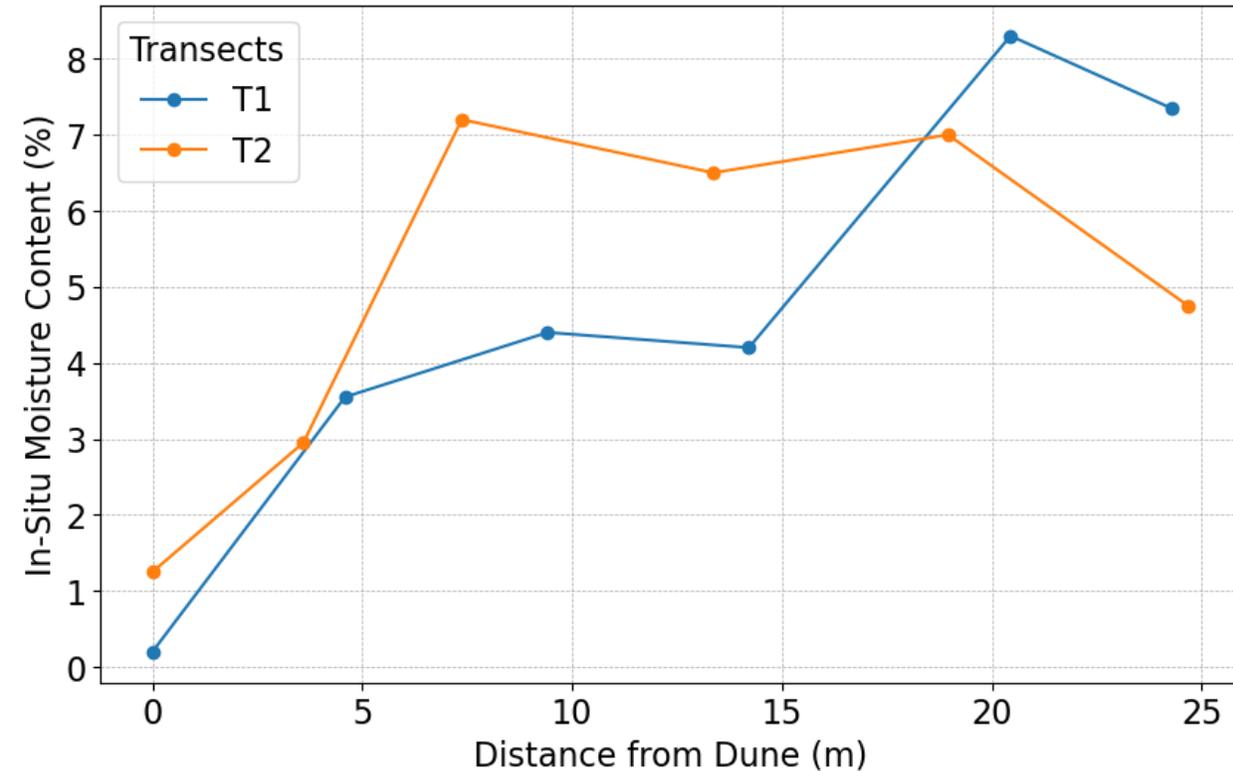
Sub-sample tested at 31 kPa

Low normal stresses to mimic beach face sediments

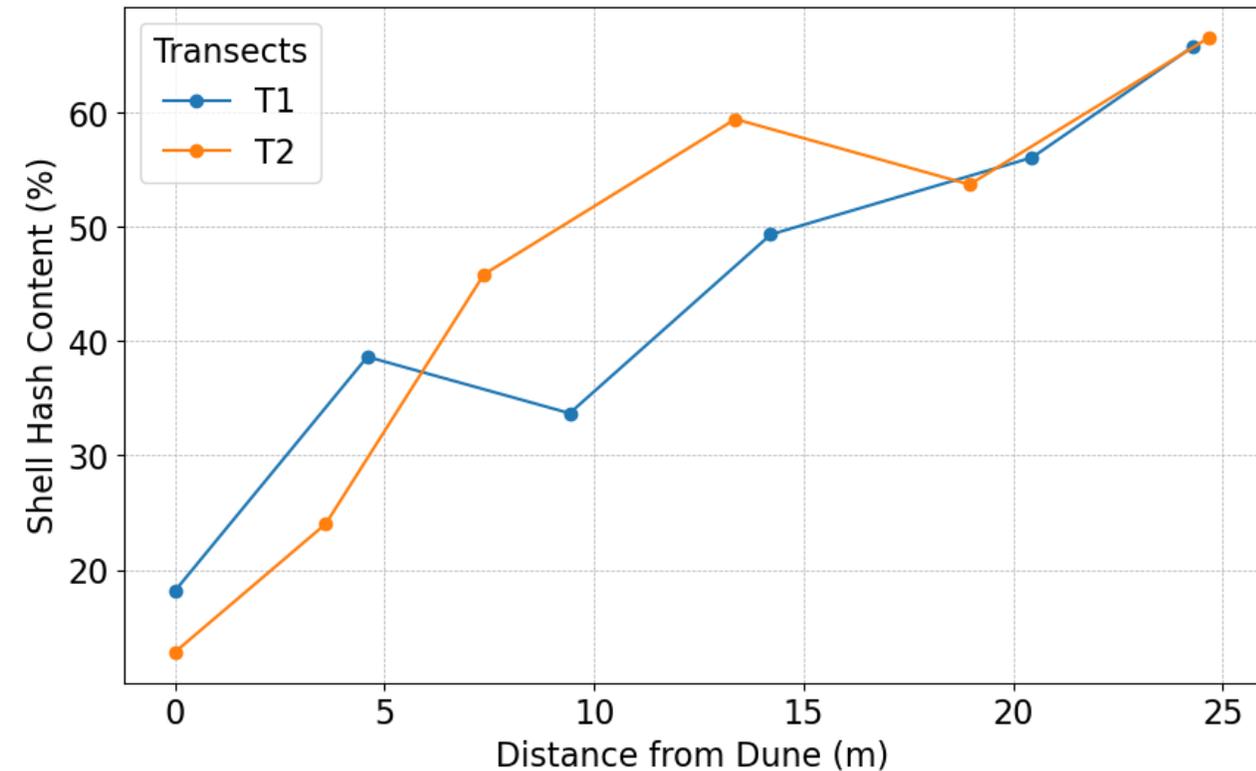
Sub-sample tested at 51 kPa

Results: In-Situ Measurements

In-Situ Moisture Content Across the Beach



Shell Hash Content Across the Beach

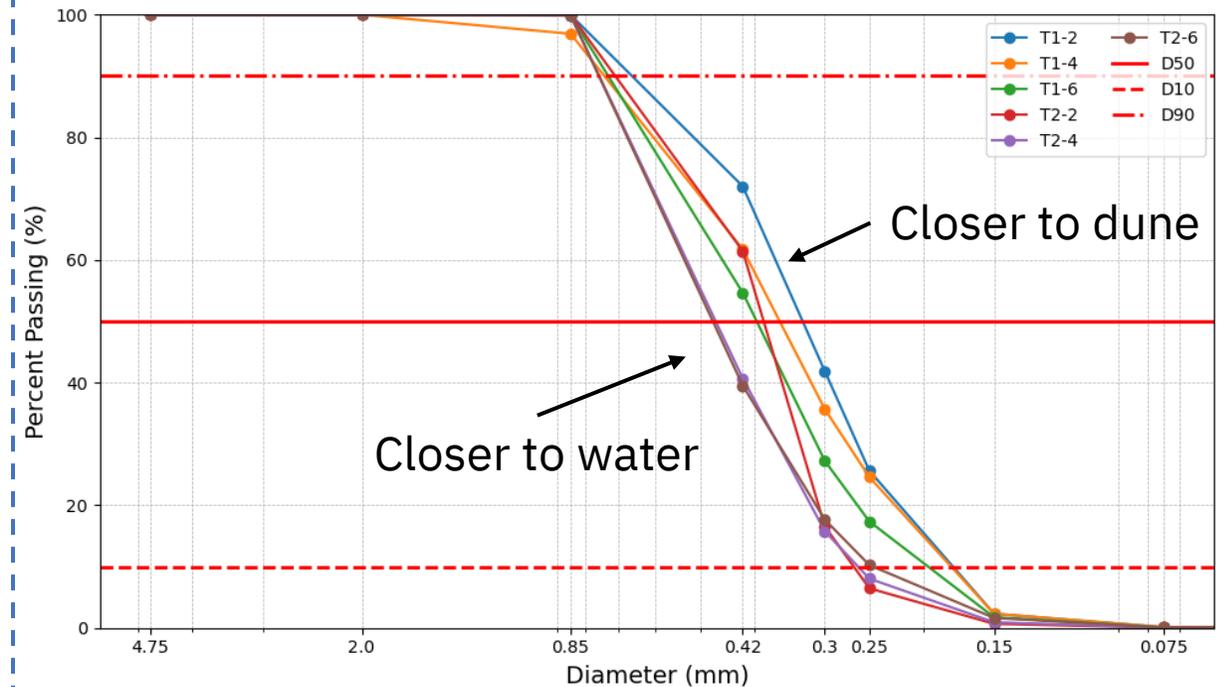
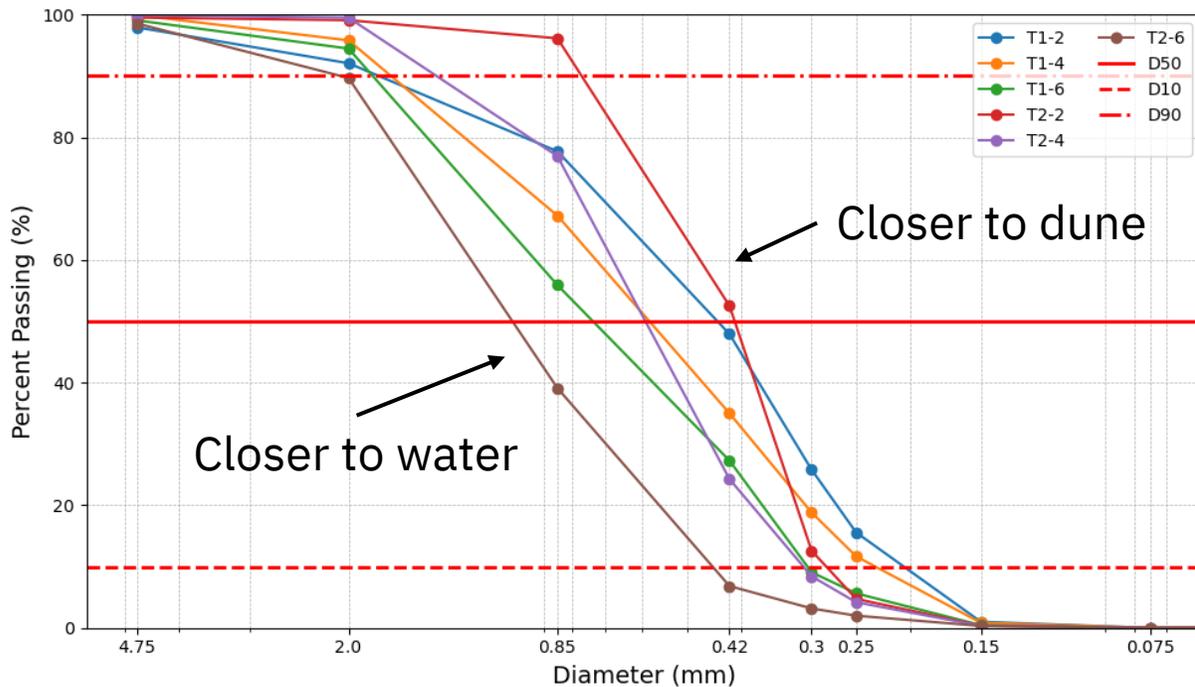


Results: Grain Size Distribution

Pre Shell dissolving



Post Shell dissolving



T1 Mean D50 = 0.56 mm



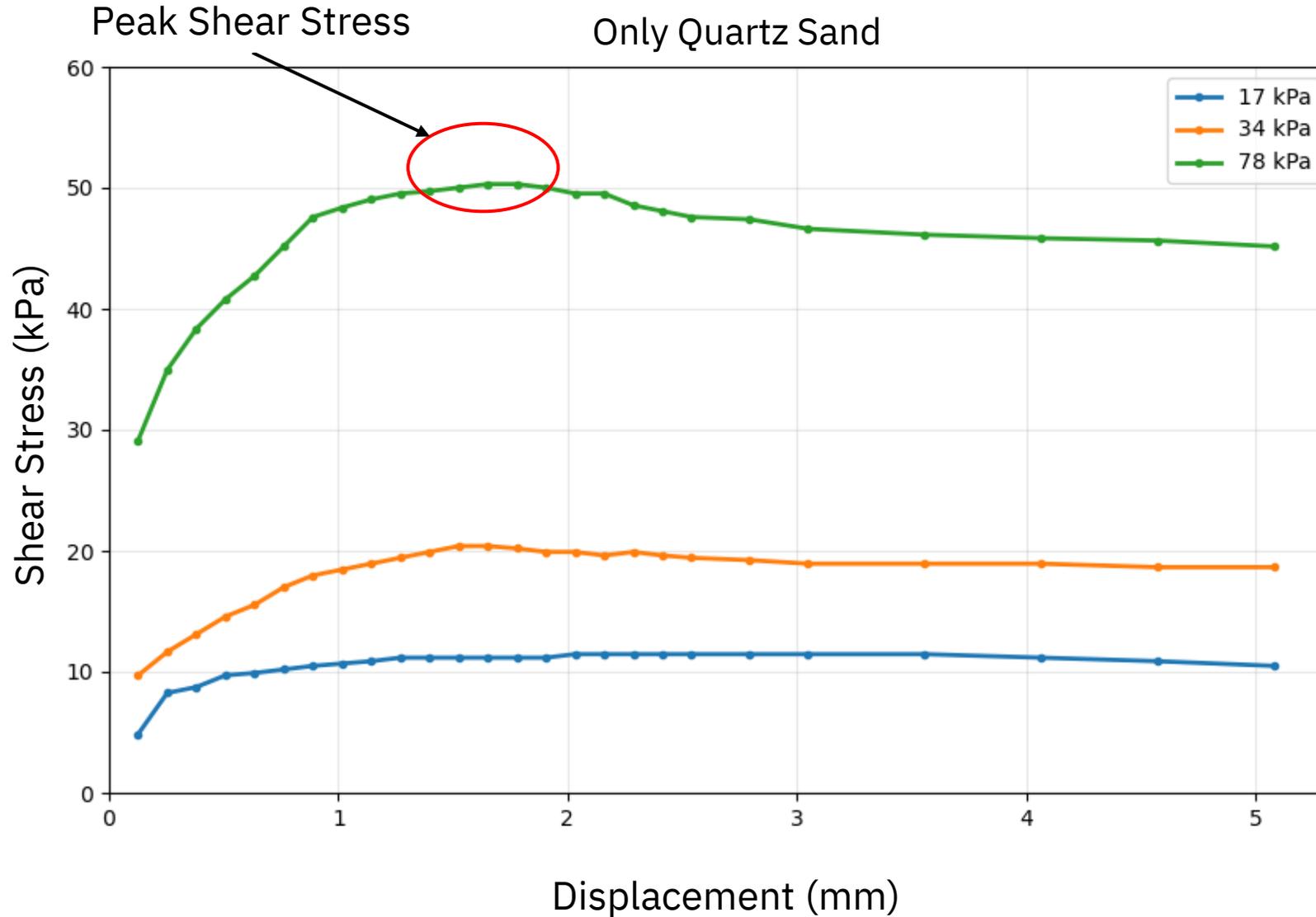
T1 Mean D50 = 0.33 mm

T2 Mean D50 = 0.83 mm

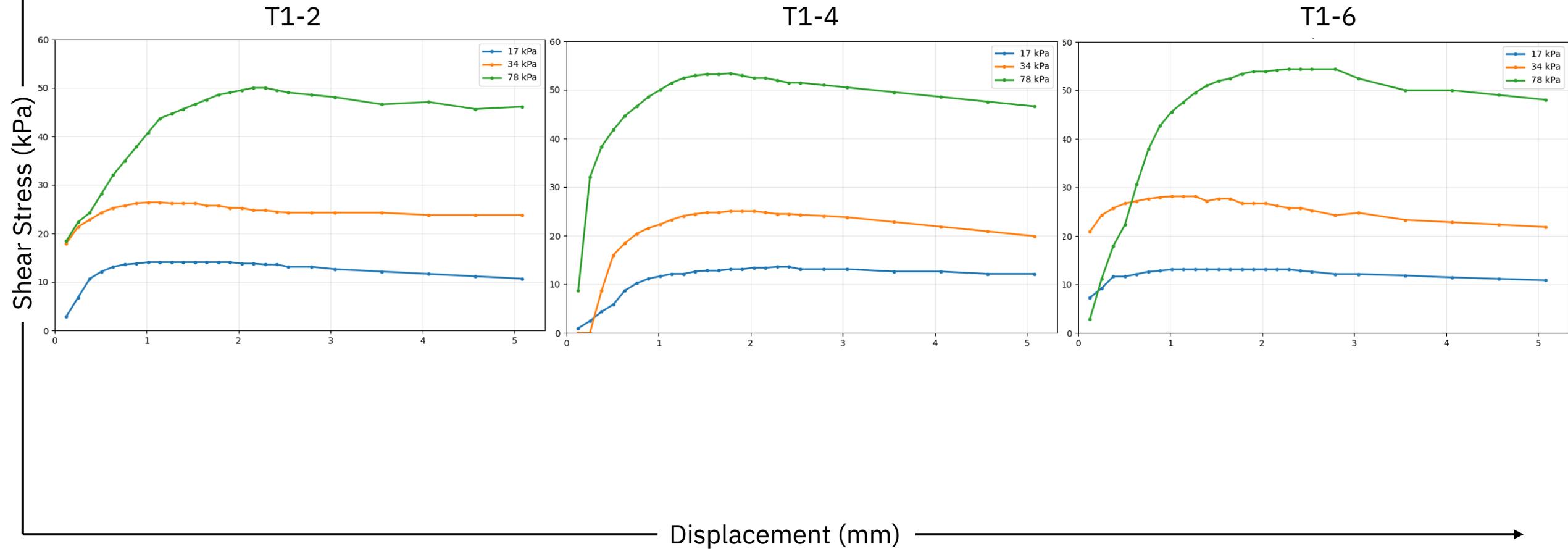


T2 Mean D50 = 0.37 mm

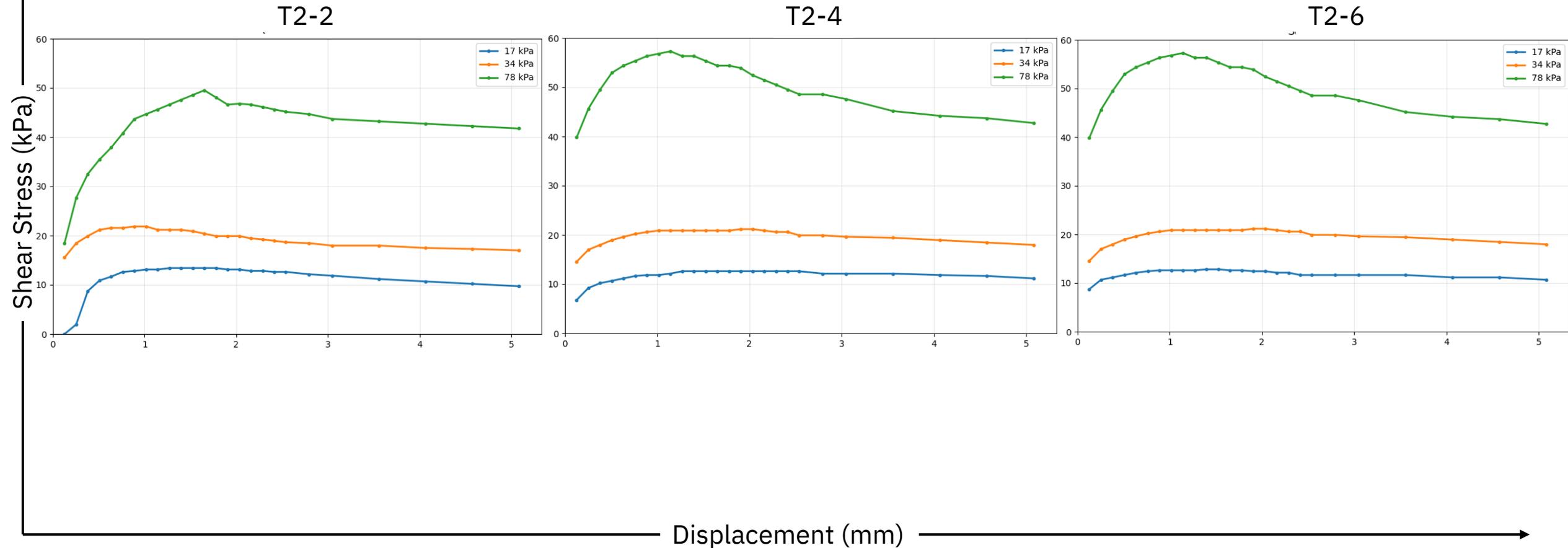
Results: Direct Shear Testing



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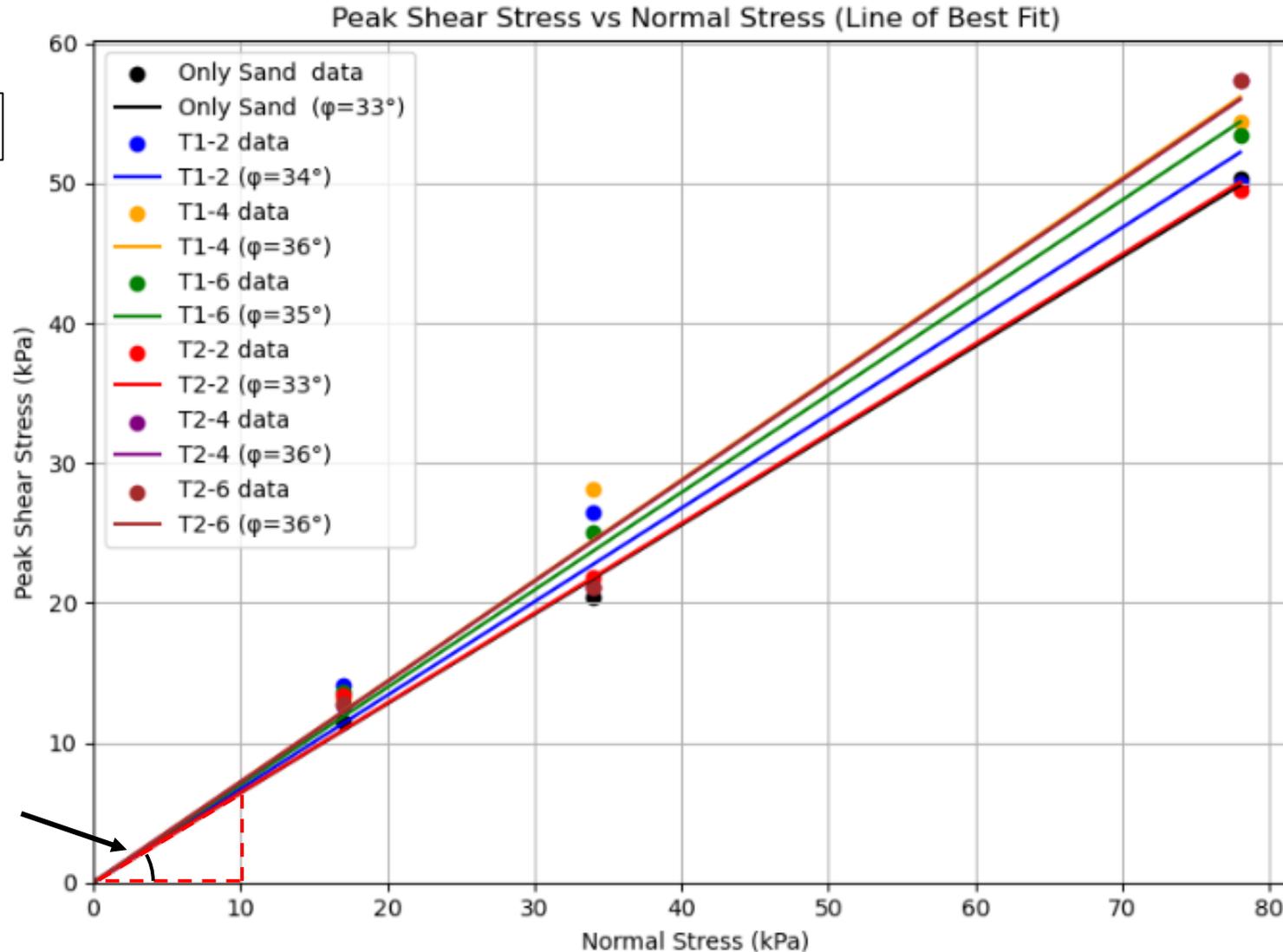


Results: Direct Shear Testing

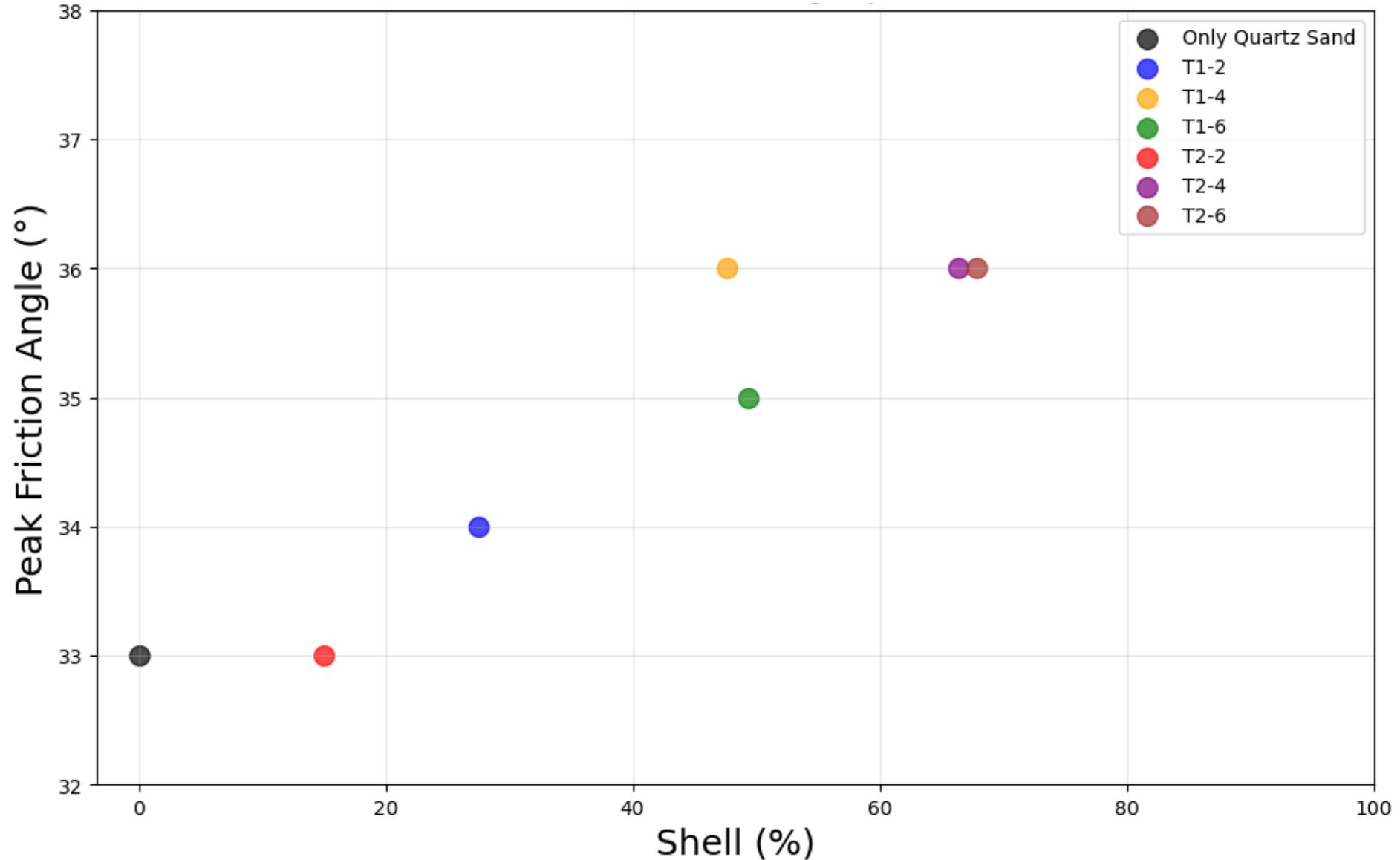
$$\tau = c + \sigma \tan \phi$$

Mohr-Coulomb failure criterion

Φ Calculated as angle of line of best fit

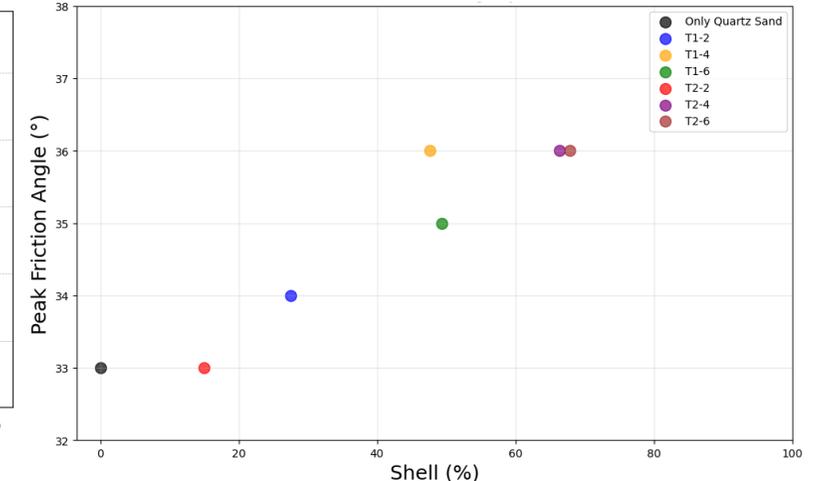
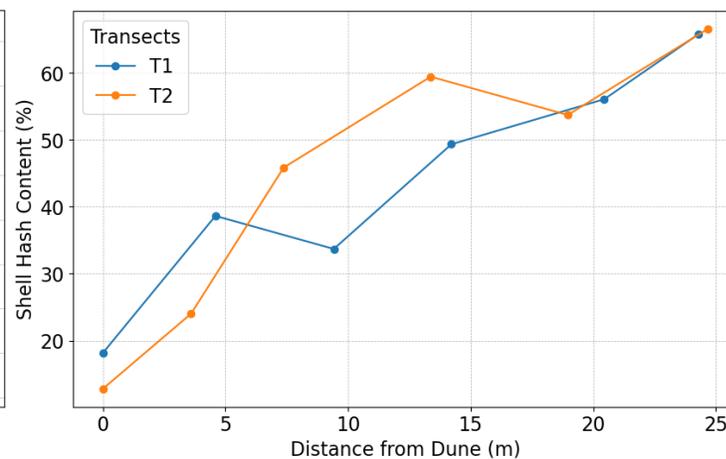
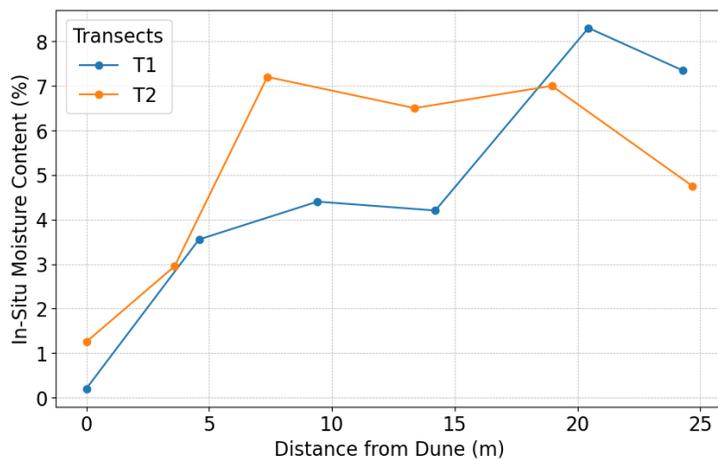


Results: Peak Friction angle vs Shell Content



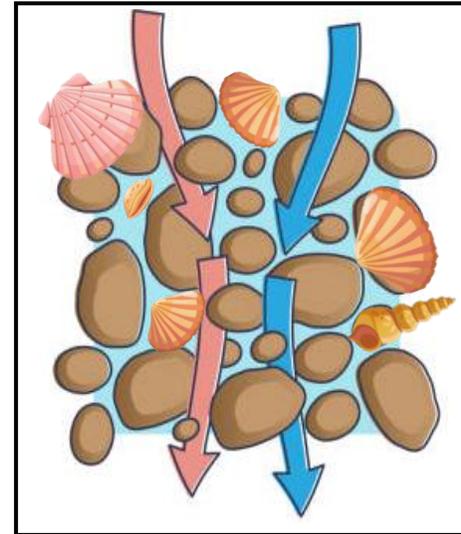
Conclusions

- D50 for both transects decreased after shell hash was dissolved
 - Large shell pieces increase the grain size distribution of sand samples
- Moisture content regulated by shell hash content
 - Increased shell hash promotes accumulation
- Positive correlation between shell hash content and friction angle
 - Increased friction angle suggests increased resistance to erosion



Conclusions

- Further investigation:
 - Grain size verse grain shape
 - Compare samples with and without shell hash of the similar grain size distribution
 - Confirm that correlation between shell content and peak friction angle is not primarily impacted by shell hash having larger grain size
 - Shell hash impact on porosity



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Thank you to everyone who attended today's presentation!

Upcoming Publications

Adusei, S., Stark, N., Evans, N., Muller, J., Martin, A. (In Press).
Assessing the Spatial Variability in Geotechnical Sediment Properties
on a Sandy Hardbottom Intertidal Beach. Geo-Congress 2026. Salt
Lake City, Utah.