Cross-shore Variations in Sediment Strength at a Sandy Beach

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Beach trafficability

- Landing missions
- Evacuation
- Access
- Recreational

http://www.abc.net.au/radionational/programs/offtrack/the-queensland-**beach-that-eats-cars**/6819550

Motivation:

Understanding variability in sediment strength across and along beaches regarding trafficability

Beach trafficability

Traction failure

~ friction angle φ

Bearing failure

bearing capacity $p = \rho g b N'_{\rho}$

with soil density ρ

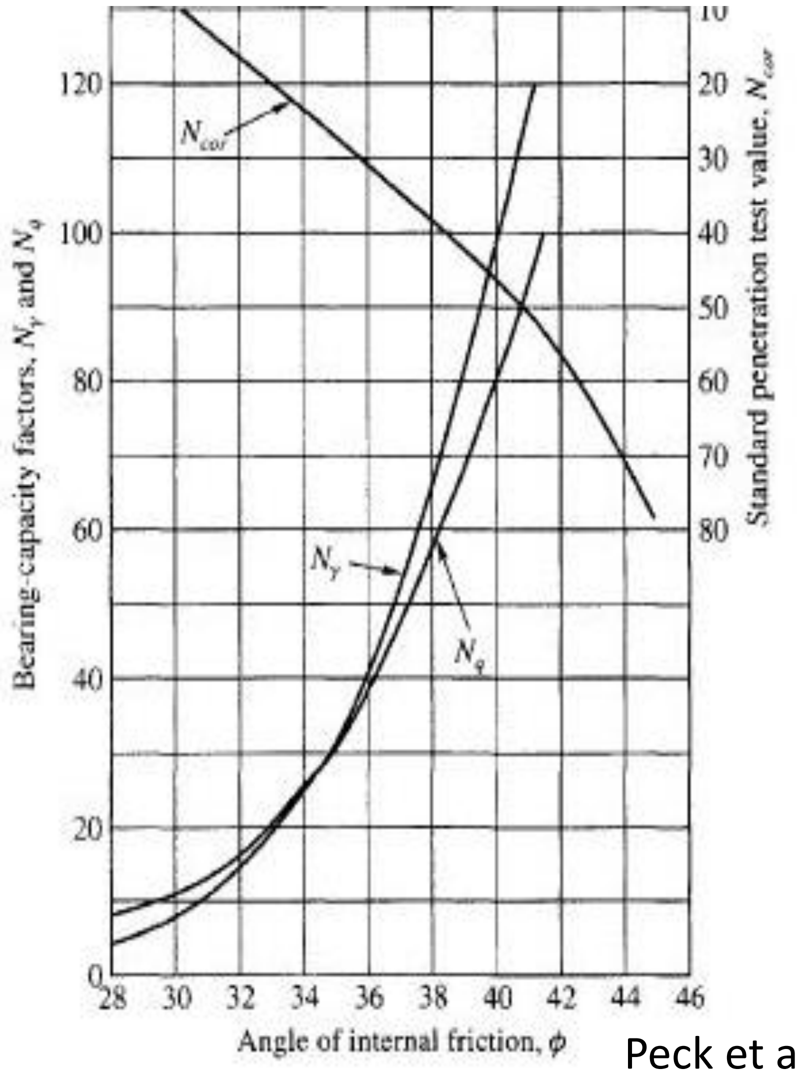
gravitational acceleration g

loading width b

bearing capacity factor N'_{ρ}

Motivation:
Understanding variability in sediment strength across and along beaches regarding trafficability

- Cone factors depend on friction angles, making friction angles a key parameter
- Friction angles also govern shear strength of cohesionless soils
- Friction angles depend on
  - Grain size distributions
  - Particle shapes
  - Mineralogy/ particle density
  - Soil bulk density
  - Moisture content
- Friction angles impact local geomorphology and soil surface roughness



Peck et al. (1974)

Understanding variability in sediment strength across and along beaches regarding trafficability

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Moisture content in granular soils can create an ***apparent cohesion*** c'.
Shear strength: $\tau_f = c' + \sigma' \tan \varphi'$

Moisture content or the state of saturation is affecting effective normal stress σ' by changing the unit weight.

The overarching goal:

Provide recommendations and maps of soil behavior of coastal environments from satellite based remote sensing.

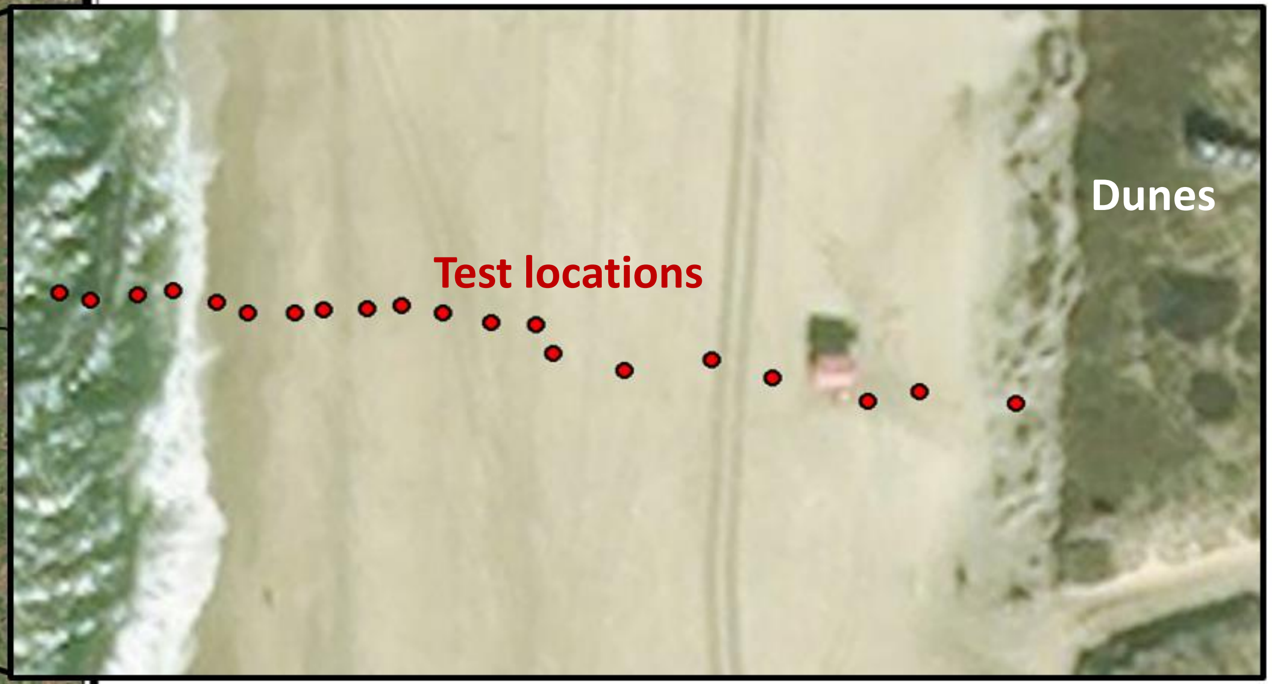
But first:

A detailed understanding of soil behavior with regards to the energetic nature of coastal environments is needed.

Towards these overarching goals, the goal of this study is:

Characterization of the cross-shore variability of sediment strength across a sandy, erosive beach at the west coast of the island of Sylt, Germany.

Regional context:
Sylt



Regional context:
Sylt

Some facts from Sylt:

- Barrier island in the eastern North Sea off the northwestern coast of Germany
- Fringed by a **38 km-long sandy beach** at the west coast
- The morphology of the western nearshore zone is dominated by a longshore bar and trough, and ridge-runnel systems.
- **Microtidal** regime with semidiurnal tides.
- A flat **beach slope of 1-2°**.
- Sediment transport is predominantly alongshore towards the south and **offshore-directed**.
- The **beach is subject to erosion**, and a number of countermeasures have been applied since the early 1900s, including beach nourishments, dune vegetation, and construction of groynes.
- **Beach nourishments** have been carried out since 1972, and since 1983 almost annually with a total volume of 42,700,000 m^3 by 2015 (LKN-SH 2016).

Methods:

Free fall penetrometer

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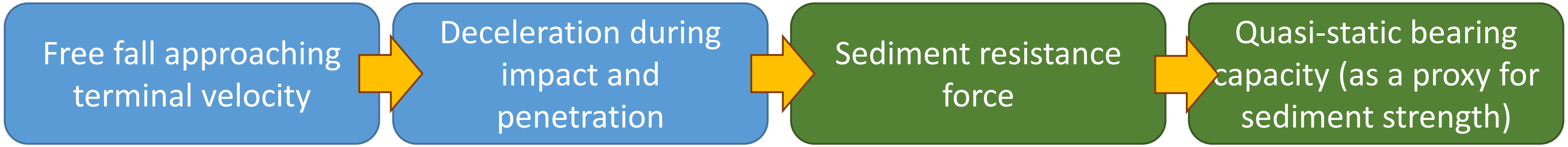
Free fall penetrometer

- Portable free fall penetrometer *BlueDrop*
- Acceleration from <0.1 *g* to 200 *g* (with *g* being gravitational acceleration)
- Ambient pressure measured behind cone (u_2 position)
- Sampling rate 2 kHz (i.e., vertical resolution < 0.5 cm)



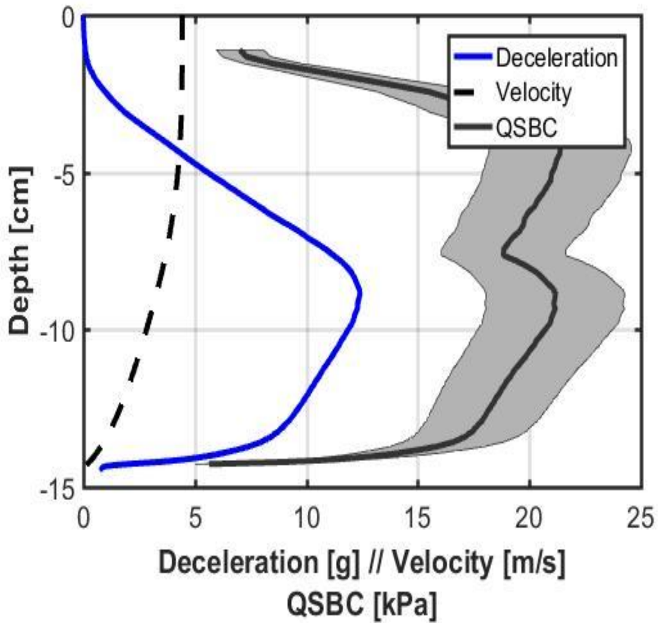
Methods:
Sediment sampling

- Grab sampling of surface samples
- Coring of samples down to 40 cm sediment depth

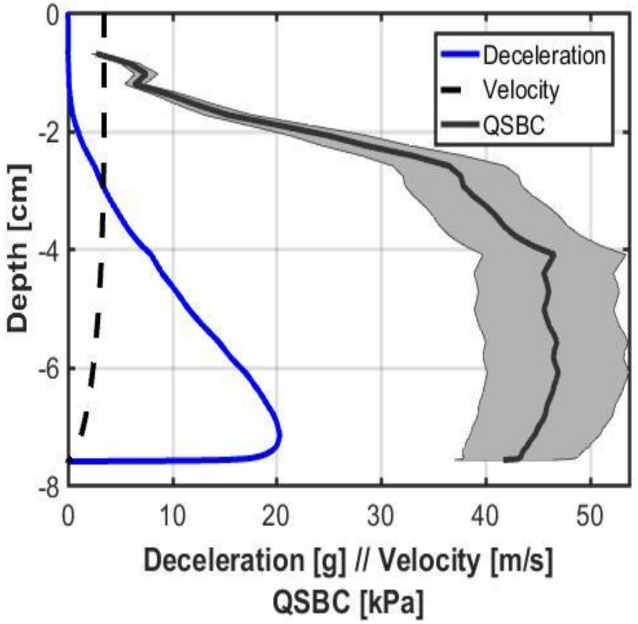
- Grain size distributions (sieving)
- Friction angles (direct shear tests)

Results:
Penetrometer

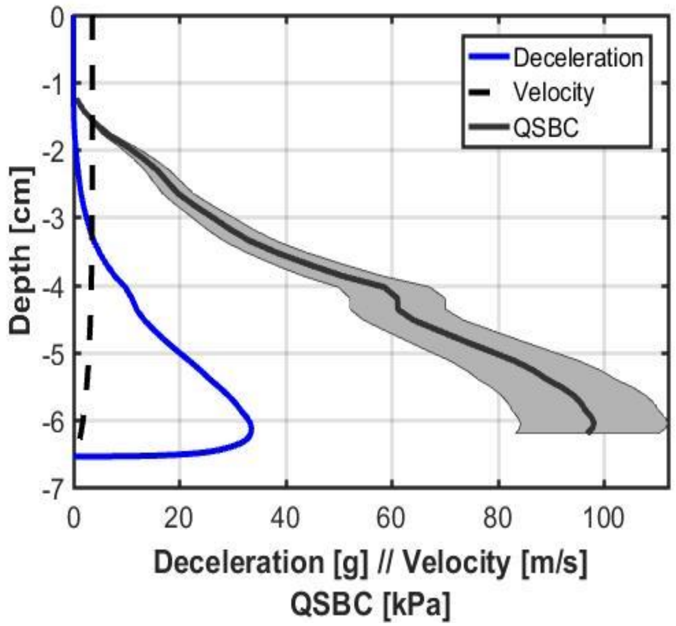
Location #1 (dune toe)



Location #12

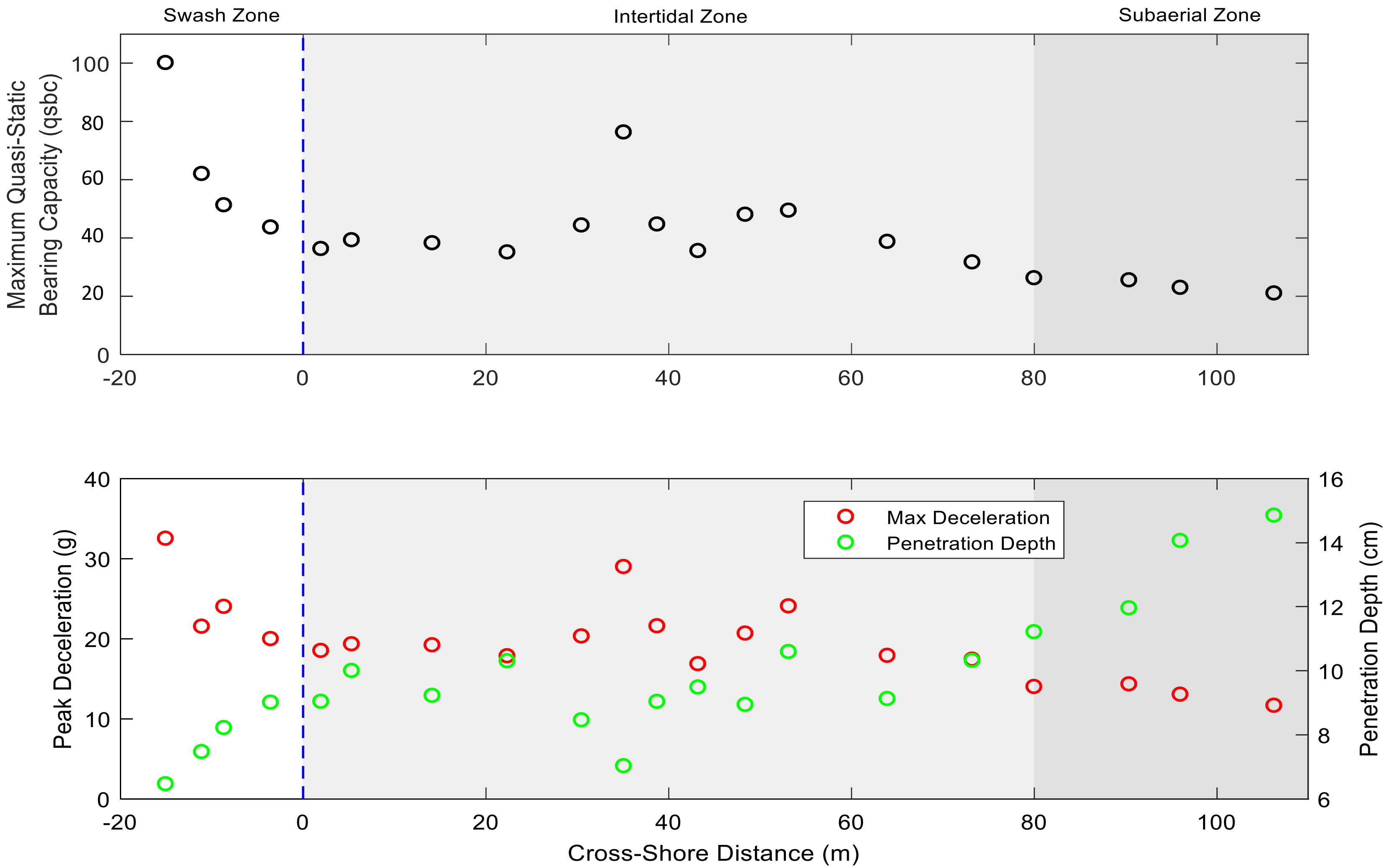


Location #20 (knee deep water)



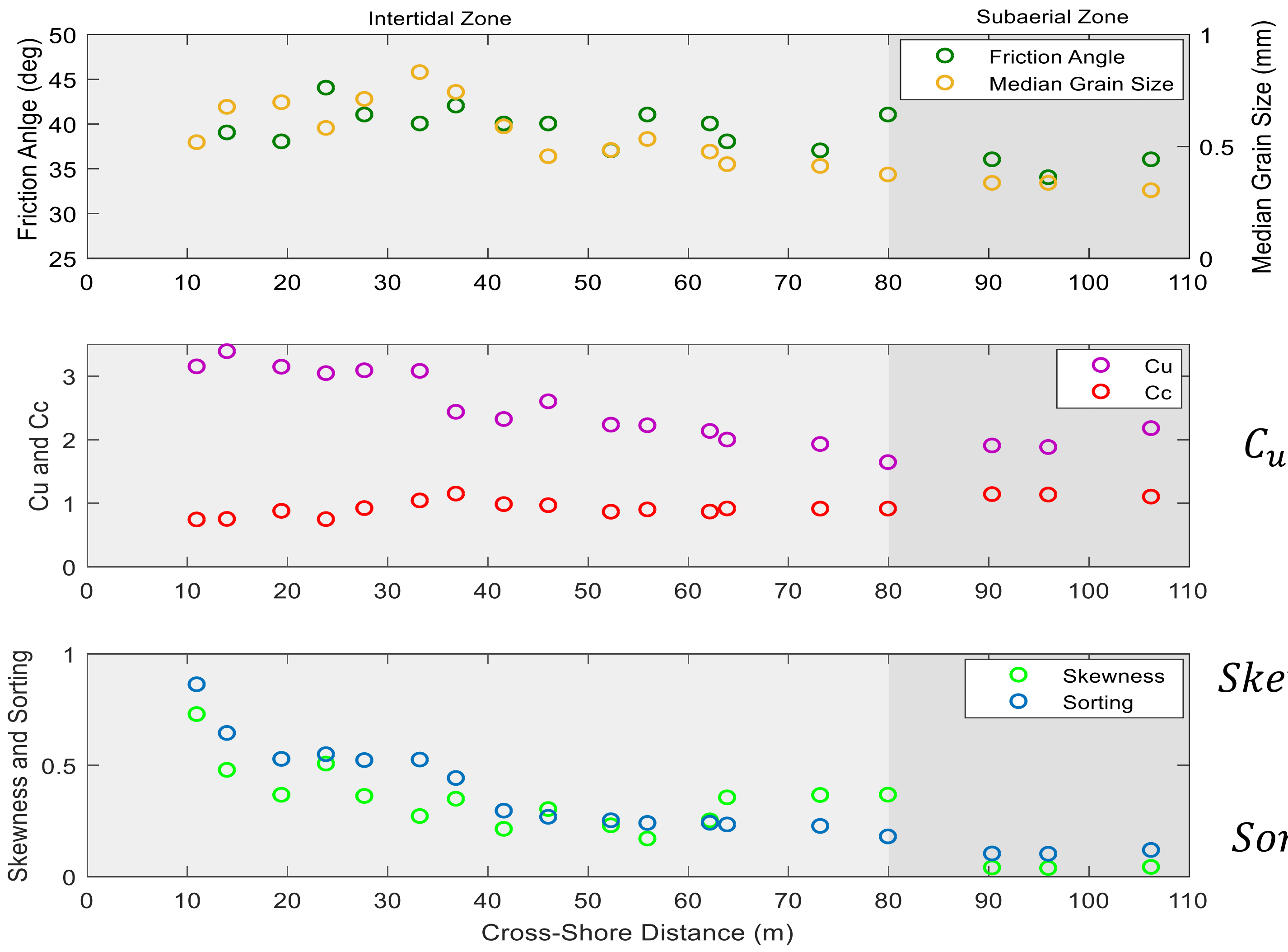
Results:

Penetrometer



Results:

Sediment samples

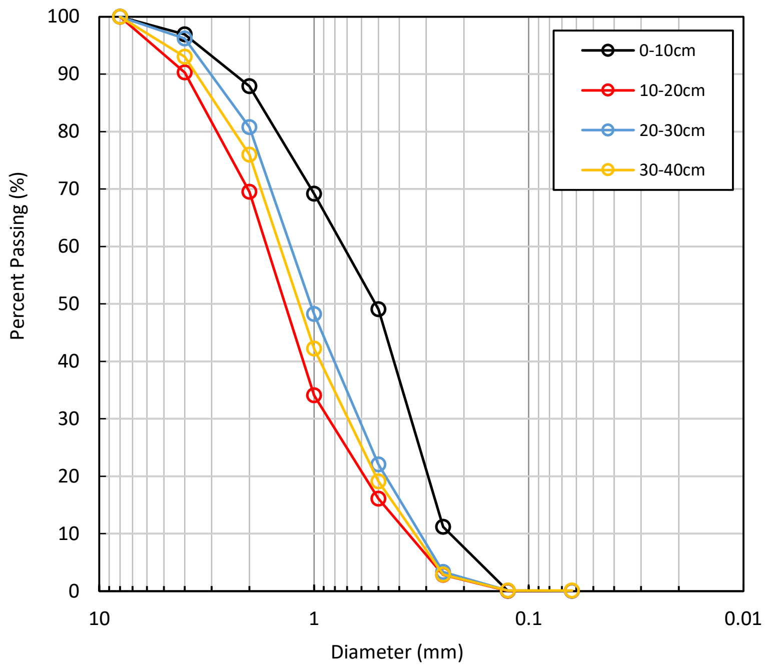


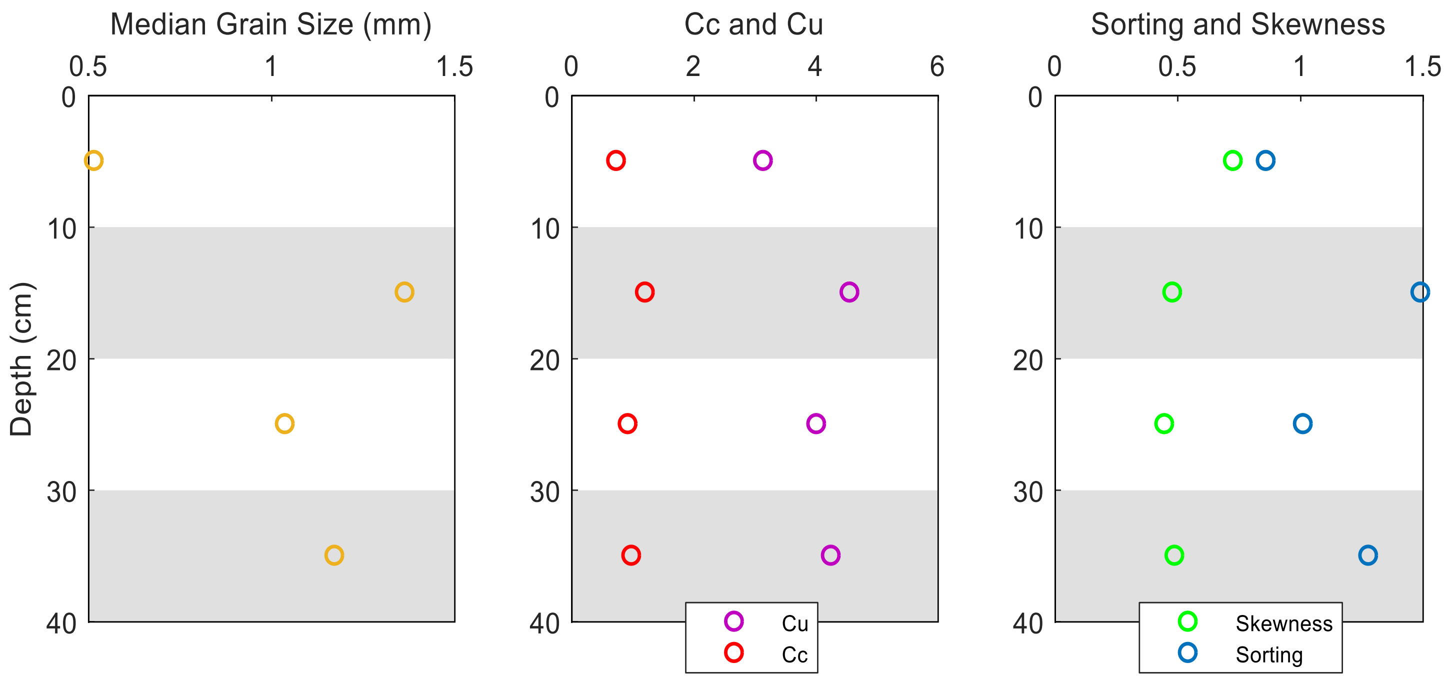
$$C_u = \frac{d_{60}}{d_{10}} \qquad C_c = \frac{(d_{30})^2}{d_{60} \times d_{10}}$$

$$Skewness = \frac{d_{16} + d_{84} - 2d_{50}}{2(d_{84} - d_{16})} + \frac{d_5 + d_{95} - 2d_{50}}{2(d_{95} - d_5)}$$

$$Sorting = \frac{d_{84} - d_{16}}{4} - \frac{d_{95} - d_5}{6.6}$$

Results:
Sediment samples





Concluding Remarks

- **Sediment gradation is spatially variable** in the intertidal and subaerial zones of the cross-shore beach profile. Spatial variability of gradation with depth was also observed in the intertidal zone.

- The **highest in situ sediment strengths were observed in the swash zone**, and an overall coarsening of sediments was observed in the offshore direction.

- Under consistent, controlled laboratory conditions, **sediments from different locations in the cross-shore profile exhibited a range of shear strengths**, suggesting the effects of physical characteristics like gradation and angularity.

- Overall trends in measured in situ shear strengths generally agree with laboratory data. However, differences were noted, and may be attributed to **in situ characteristics like void ratio, moisture content, and the soil fabric**.

- A dynamic free-fall penetrometer (**FFP) is an appropriate and efficient method** of obtaining in situ geotechnical sediment characteristics at a beach, being able to cover emerged and submerged areas.

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Next steps

- Computation and simulation of local beach morphology and sediment transport
- Investigate role of geomorphology and moisture content (groundwater & surface water)
- Development of spatial sediment strength maps
- Investigate relevance for erodbility and liquefaction
- Correlation to remotely sensed data (e.g., multispectral and SAR satellite imagery)

Thank you for your attention!

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