A Laboratory Investigation into the Behaviour of Sand at Low Stresses

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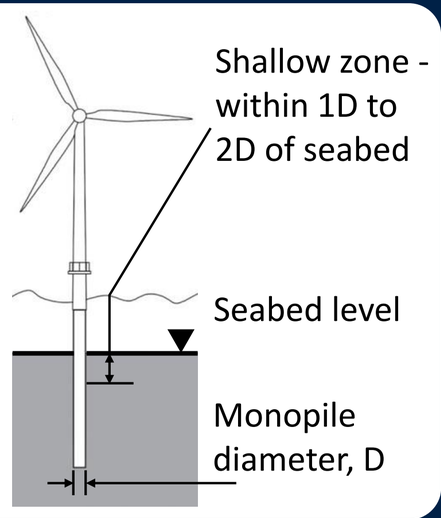
Introduction:

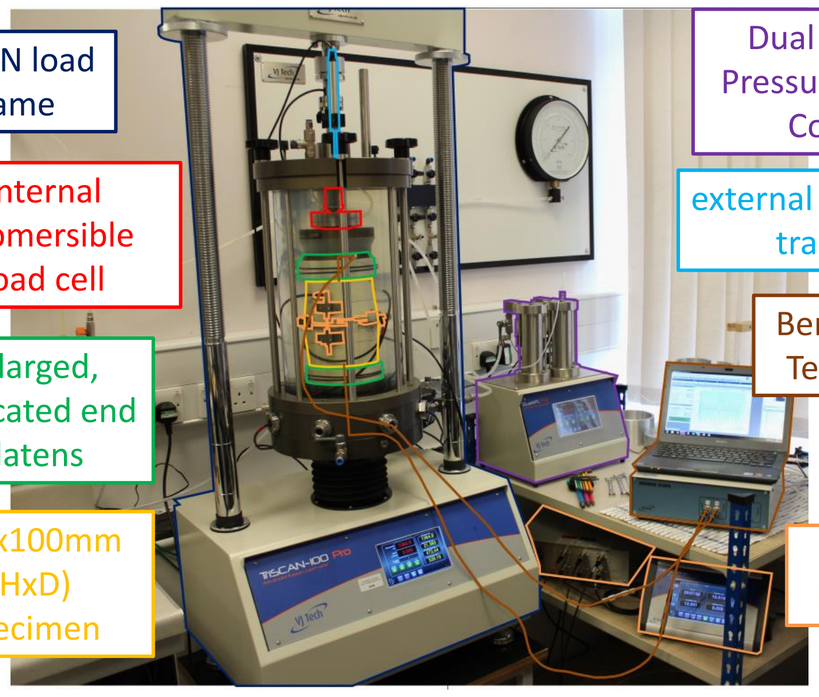
- Current design methods use constitutive models to predict the long-term behaviour of geotechnical structures.
- Reliable predictions depend on the selection of an appropriate constitutive model, and subsequent calibration against laboratory tests undertaken at stresses representative of the design situation.
- The performance of many geotechnical structures, e.g. offshore wind turbine monopile foundations, is significantly influenced by the strength and stiffness properties of the near-surface soils.
- Some evidence suggests that shallow soils, which are subject to relatively low confining stresses (i.e. p' ≤ 100kPa), may exhibit higher than anticipated shear strength properties, which could be taken advantage of in design.
- However, published high-quality experimental tests undertaken on sands at such low stresses are very limited and have yielded inconsistent results.



Research Aims:

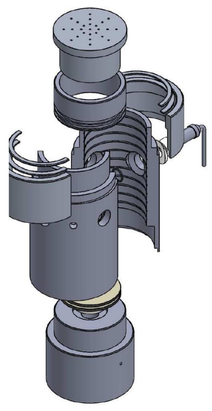
- Investigate the behaviour of sand at very low stress levels (6 ≤ p' ≤ 50kPa), and clarify the conflicting results seen in the literature.
- Compile a database of advanced, high-quality, triaxial tests to enable development of advanced constitutive models.
- Review, calibrate and validate constitutive models considered capable of capturing long-term cyclic behaviour.

Stress Path Triaxial Apparatus:



Sample Preparation:

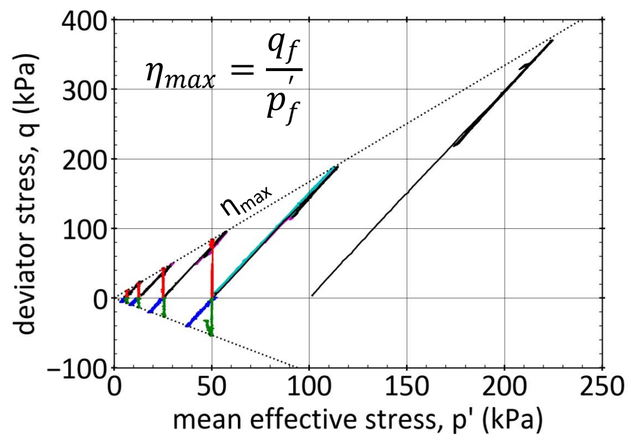
- 'Undisturbed' sand samples are expensive and difficult to obtain from the field.
- Test specimens are reconstituted to target densities using:
  - Modified wet pluviation technique;
  - Moist tamping (Undercompaction) technique.
- Test Material: Leighton Buzzard Sand (Fraction B).
  - 200mm(H) x 100mm(D) specimens tests.

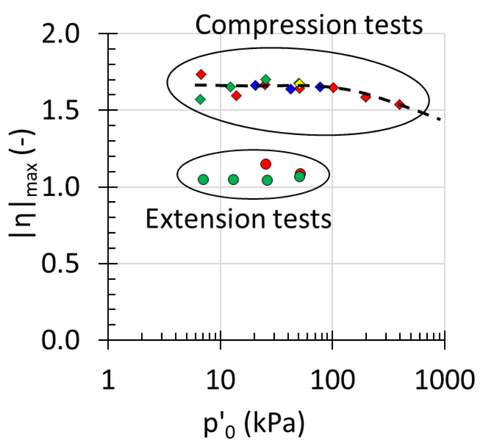


Test Results:

Low Stress Triaxial Tests:

- 25 isotropically & anisotropically consolidated, drained triaxial compression (TXC) and extension (TXE) tests undertaken.
- Stress path and initial mean effective stress appear to have negligible influence on peak shear stress ratio, η_{max}, for $p'_0 < 100$kPa:
  - η_{max} = 1.68 in TXC; η_{max} = -1.08 in TXE

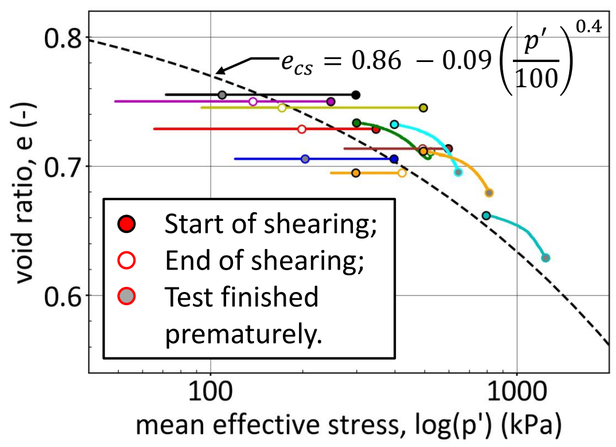




Critical State Line Tests:

- Many constitutive models require accurate determination the critical state line (CSL).
- 11 isotropically consolidated, drained and undrained triaxial compression tests undertaken on 'loose' samples.
- Tracking of void ratio changes throughout all test stages (including any flushing and saturation stages) imperative for accurate determination.
- CSL may be approximated by a power function of the form (Li and Wang, 1998):

$$e_{cs} = e_{cs,ref} - \lambda \left(\frac{p'}{p'_{ref}} \right)^{\xi}$$



Conclusions:

- Higher peak shear strengths are mobilised at low effective confining stresses, but are found to stabilise once p' ≤ 100kPa.
- Challenging, 'very low stress' (i.e. p' ≤ 10kPa) triaxial tests may therefore not be necessary; tests performed at p' = 50kPa appear to adequately capture 'low stress' behaviour.
- Local strain instrumentation may be used to reliably estimate void ratio changes during flushing and saturation, as conventional volume change instrumentation may be unsuitable during these stages.

Acknowledgements:

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References:

Li, X. & Wang, Y. (1998). Linear Representation of Steady-State Line for Sand. *J. Geotech.& Geoenviron. Engng.* 124(12), 1215-1217

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