Characterisation of the reworked residual norite in the Rustenburg Region of South Africa

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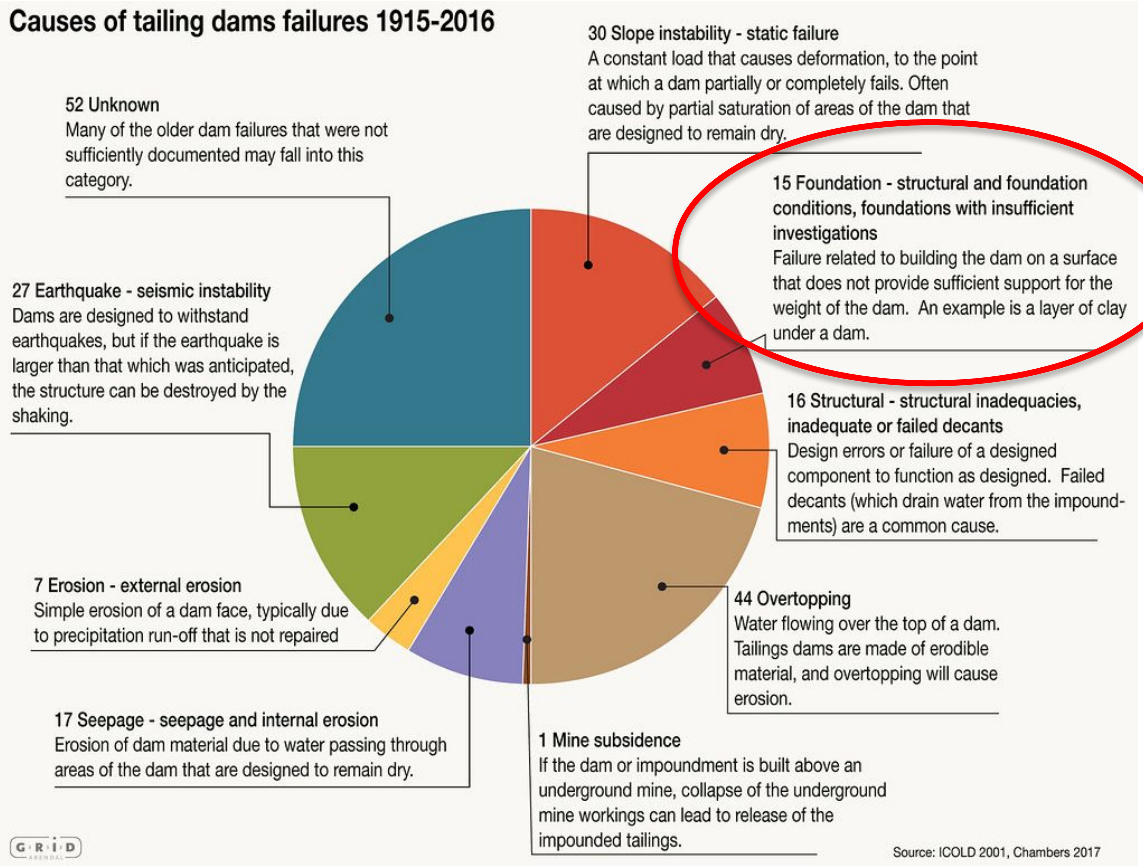
Why this matters – GISTM & TSF stability

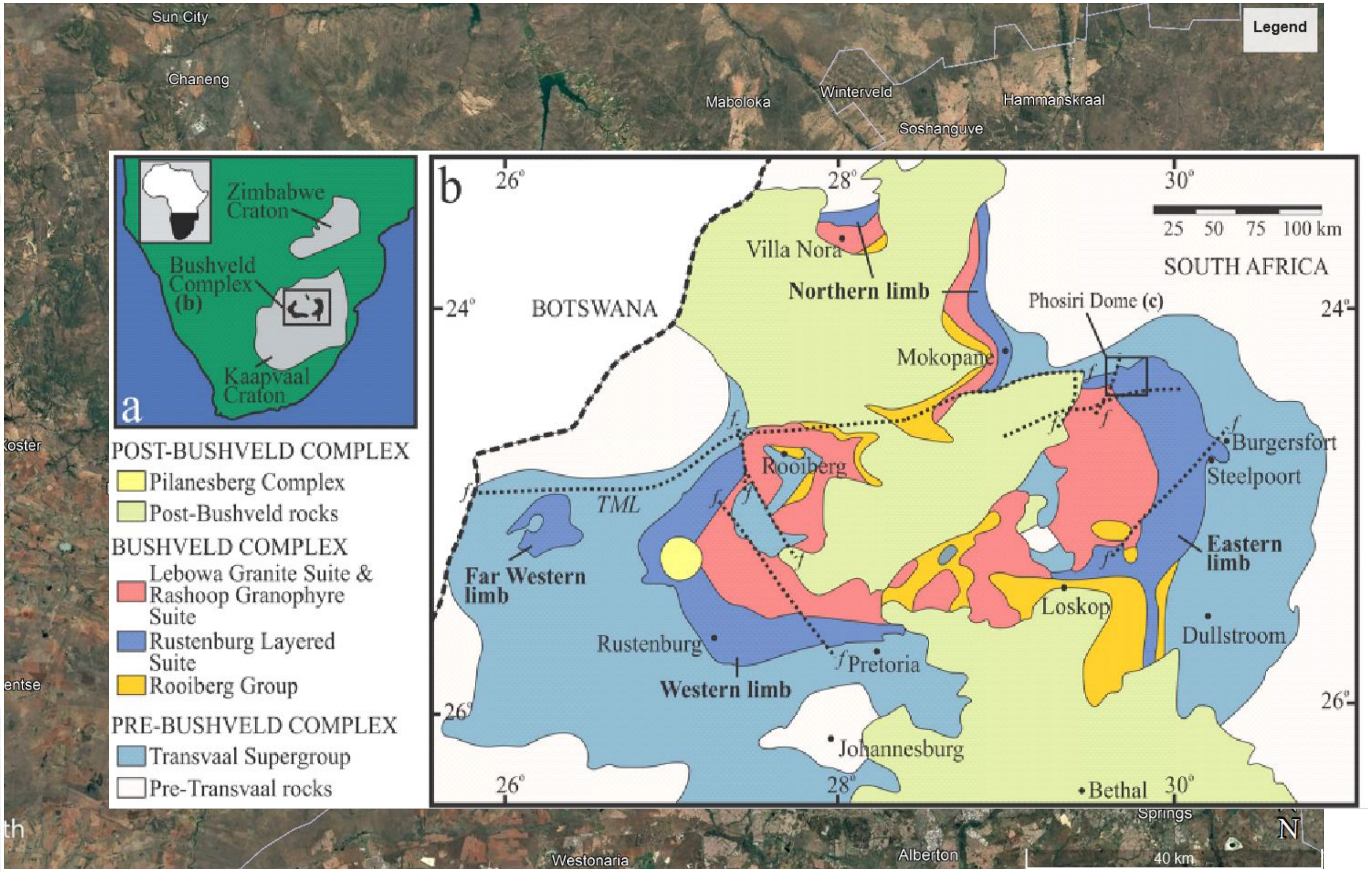
Requirement 5.4	Address all potential failure modes of the structure, its foundation, abutments, reservoir (*tailings* deposit and pond), reservoir rim and appurtenant structures to minimise risk to *ALARP*. Risk assessments must be used to inform the design.
Credible Failure Modes / Scenarios	Refers to technically feasible failure mechanisms given the materials present in the structure and its foundation, the properties of these materials, the configuration of the structure, drainage conditions and surface water control at the facility, throughout its lifecycle. Credible failure modes can and do typically vary during the lifecycle of the facility as the conditions vary. A facility

- Notorious for low shear strength, high compressibility and heave.
- Testing challenges (Grading and strength determination)
- Drained and undrained conditions need to be considered.

Tailings Dam Failures



Regional Geology



Reworked Residual Norite

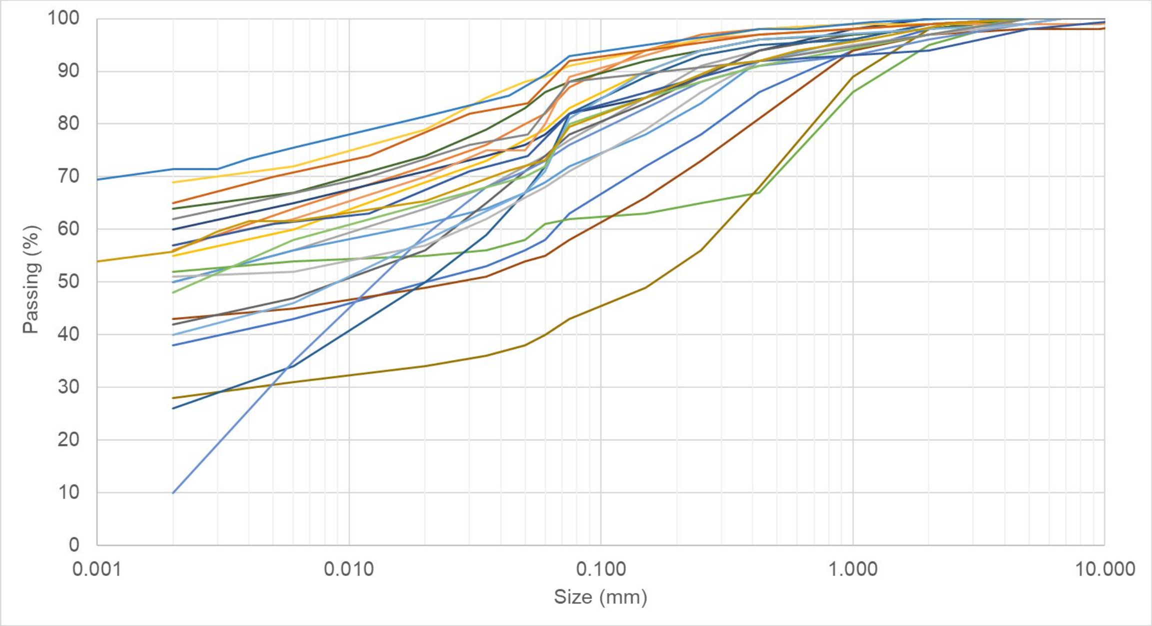
Due to the high swell and shrinkage potential, remulching is common which results in the presence of slickensides. These planes are not aligned and non-continuous which is characteristic of residual soils

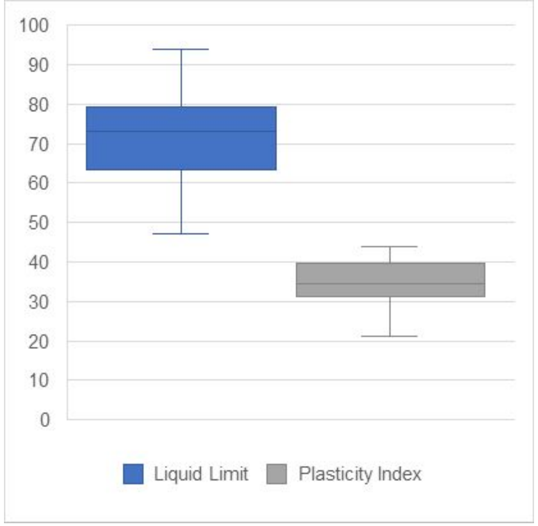
Testing Database

- Different laboratories (South Africa and overseas)
- Mostly undisturbed samples (block samples)
- Foundation Indicator - 26 samples
- Oedometer - 3 specimens
- Triaxial permeability - 2 specimens
- Consolidated Undrained Triaxial - 71 specimens
- Direct Simple Shear - 3 specimens
- Ring shear - 3 specimens

- *The study should not be considered for design purposes due to the inherent variability of the material and site-specific investigation, according to SAICE Investigation Code of Practice, shall be followed*

Index & Classification



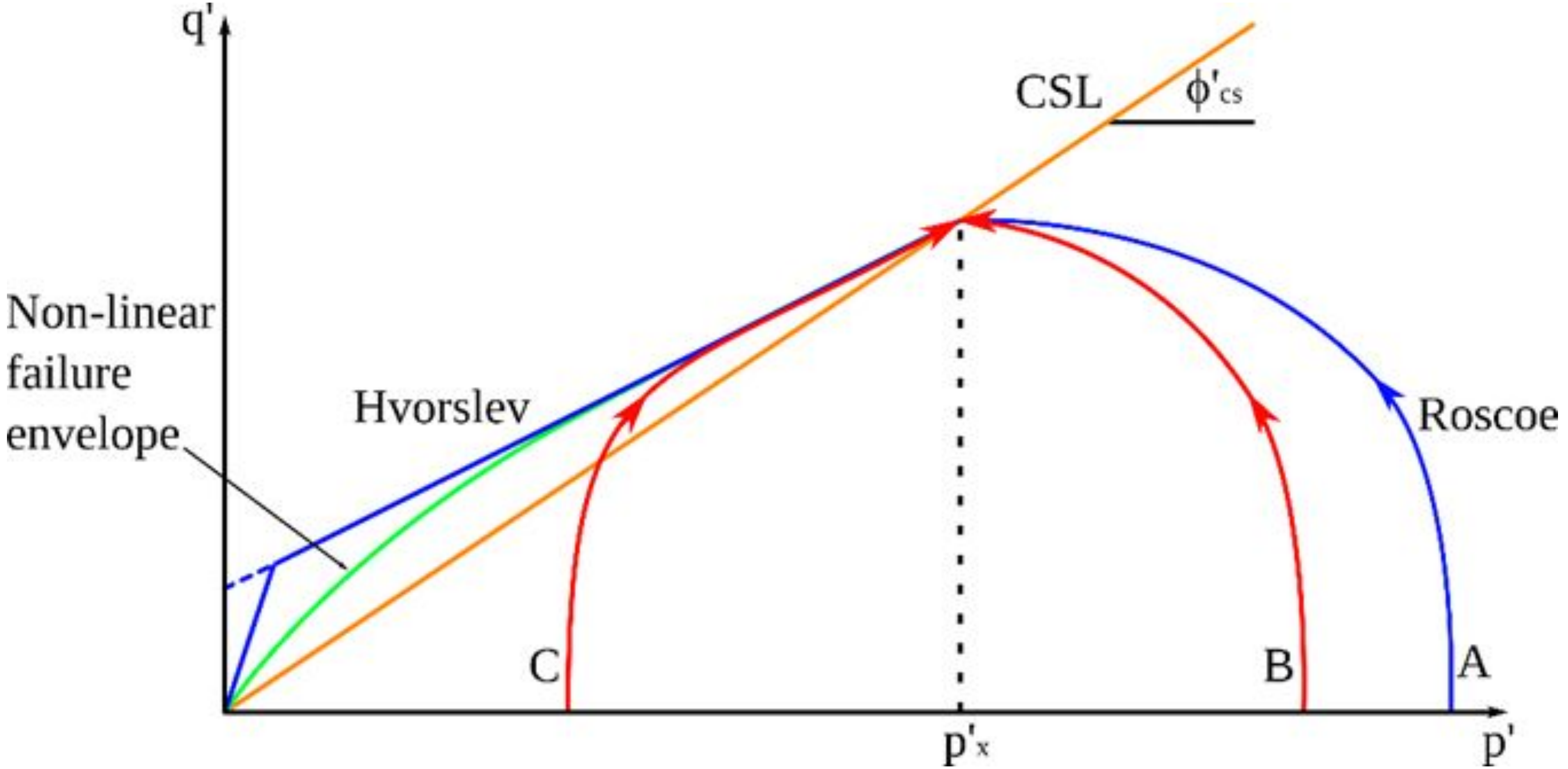


- Clay with high plasticity (CH)
- Permeability at 1×10^{-8} m/s

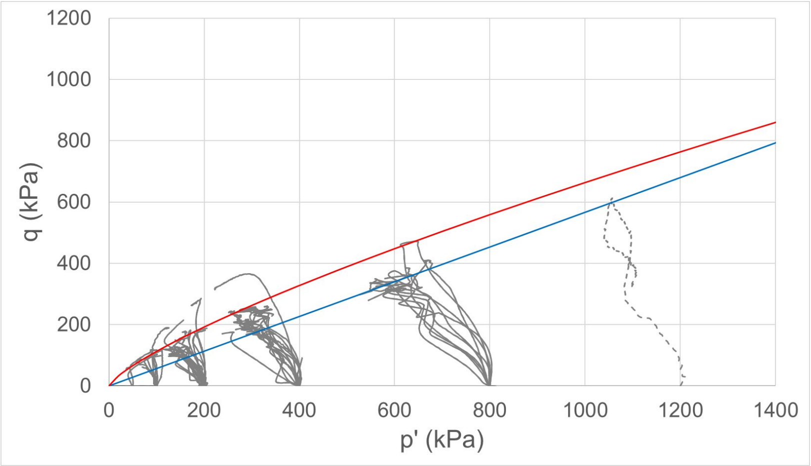
Stiffness Behaviour

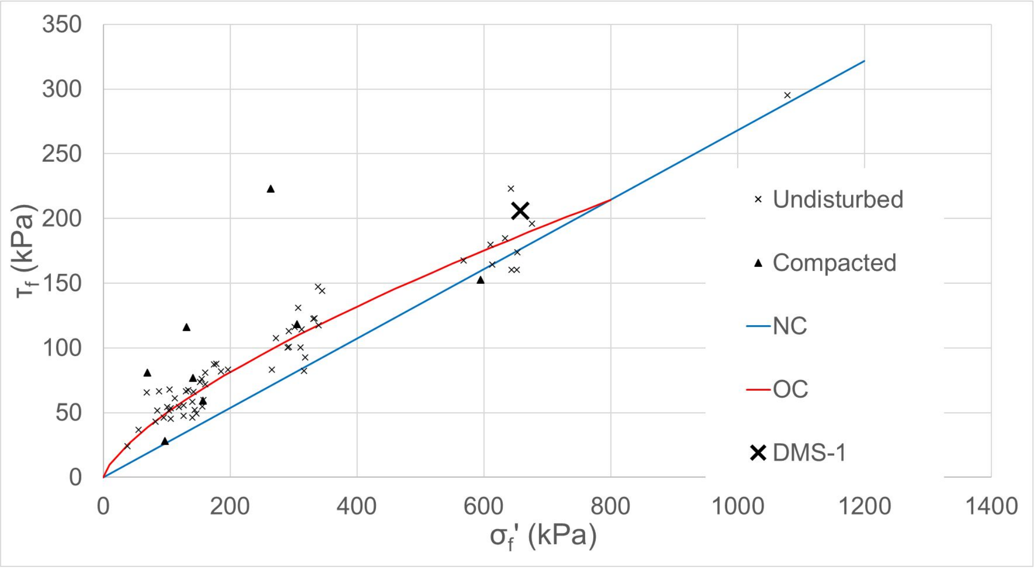
Void ratio			Coefficient of Volume Compressibility m_v (1/MPa) / Coefficient of Consolidation (c_v) (m^2/year)					
Initial	Post Swell	@ 1600kPa	25-50	50-100	100-200	200-400	400-800	800-1600
			(kPa)					
0.58	0.98	0.55	0.50	0.47	0.36	0.25	0.14	0.07
			5.65	0.76	0.70	0.10	0.04	0.02
0.57	1.02	0.63	0.42	0.43	0.32	0.21	0.12	0.06
			0.18	3.19	0.75	0.14	0.08	0.04
0.81	1.15	0.70	0.52	0.45	0.35	0.23	0.13	0.07
			0.23	1.73	1.12	0.30	0.06	0.03

Critical-State Framework for Clays

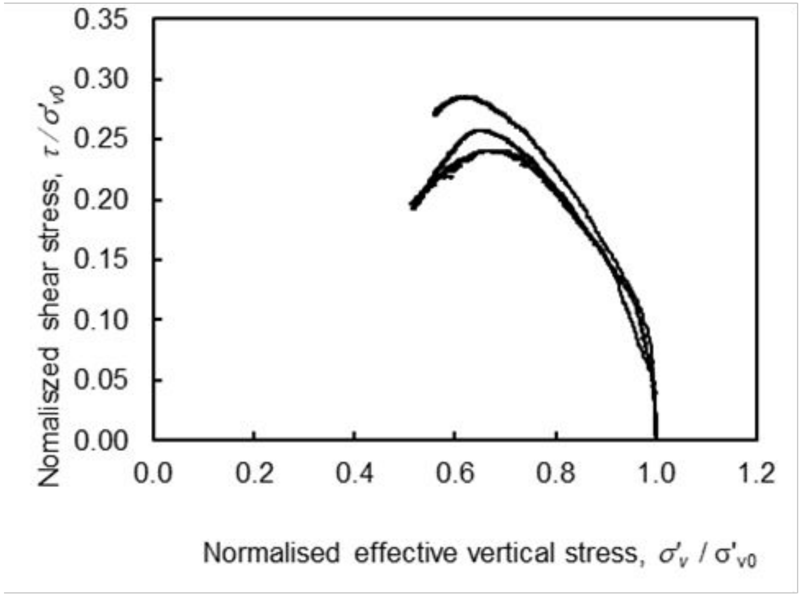


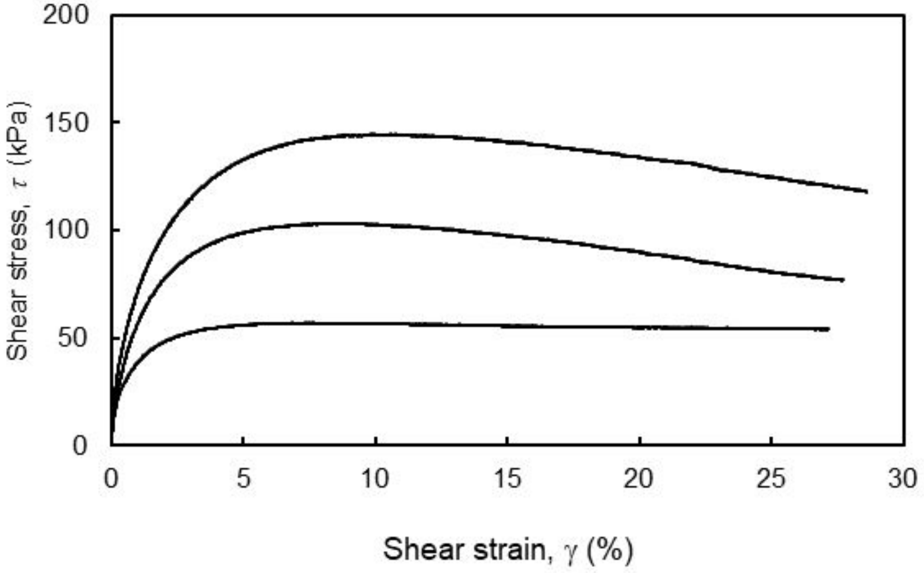
Consolidated Undrained Triaxial Results



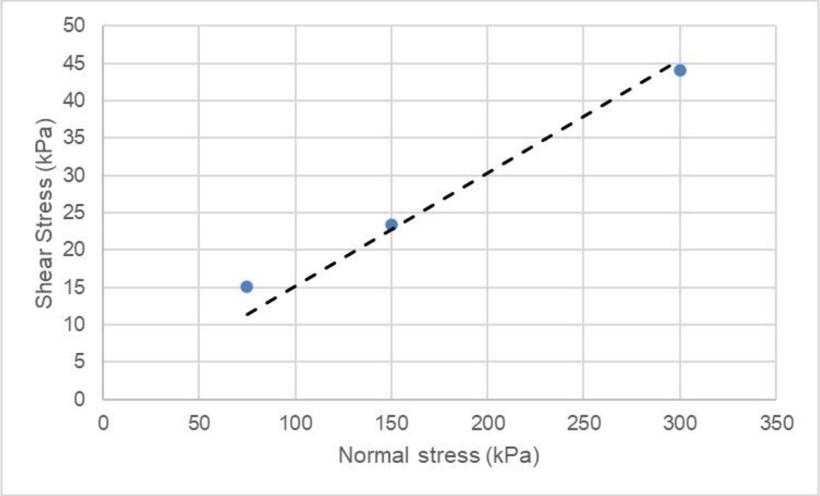


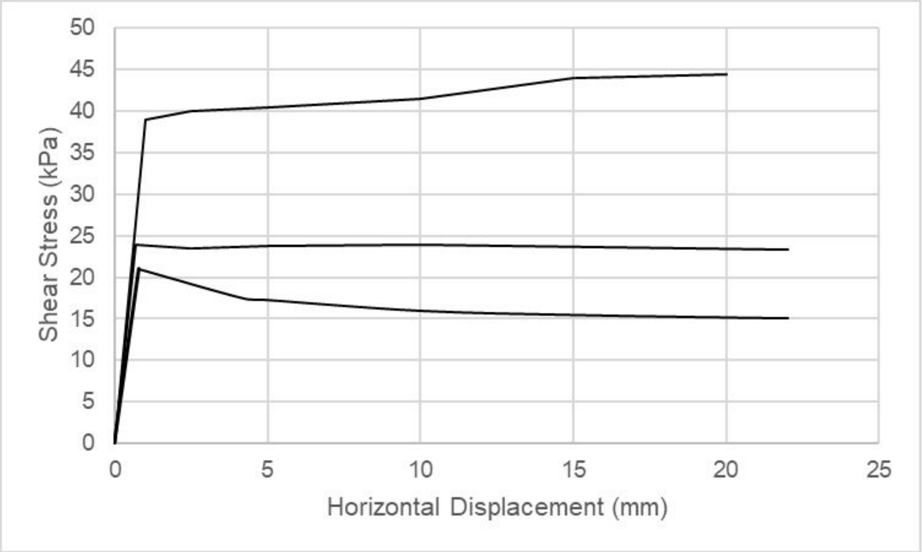
Direct Simple Shear Results





Residual Strength – Bromhead Ring Shear





Conclusions & Practical Implications

- GISTM requirement
- Large dataset – site-specific assessment required
- High clay content, high PI, low permeability
- Overconsolidated clay → nonlinear failure envelope at lower stresses
- Yield stress ≈ 800 kPa → nonlinear behaviour below ~800 kPa, linear above
- Mesri & Abdel-Ghaffar (1993) envelope applied to capture this nonlinearity
- Extensive multi-laboratory testing confirms trends across wide effective stress range
- Residual φ’ = 8.5 but slickensides are not aligned

Acknowledgements

- G. Wiid
- R. Cooper

QUESTIONS