Effects of Negative Ageing on Deformation and Strength Response of Geomaterials

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Abstract

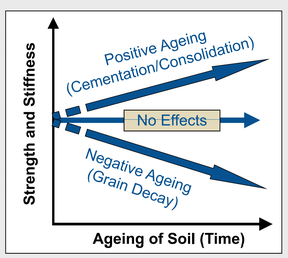
This paper presents unique data from torsional shear tests on crushed soft rocks. Material being sensitive to disintegrate by water-action allowed to simulate the long-term stress-strain and volume change response under saturated conditions whereas dry tests on similar soil represent initial intact response of the material. Negative ageing is manipulated by an enormous decrease in shear strength parameters, changes in grain size curve and increase in volumetric compression. It is concluded that for long-term hazard evaluation of various geotechnical structures, the effects of loss of strength due to decay of grains with time under saturated conditions should be incorporated in conventional analysis and design models.

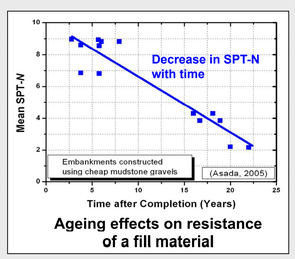
1. Introduction

Problem Statement

Stress-strain and volume change characteristics of conventional granular materials are generally assumed to be time-independent because;

- Soil grains are durable under working confining stresses
- Time-effects are generally positive for durable soils
- No effects of saturated or dry conditions on σ – ε response





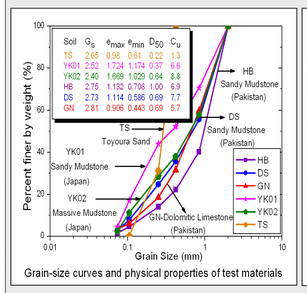
Ageing effects on resistance of a fill material

Objectives of the Study

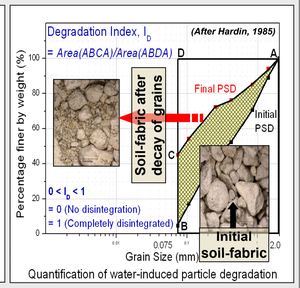
Effects of saturated and dry conditions on strength and deformation response of non-conventional soils have been investigated for the following main reasons;

- Most of the soil models do not incorporate such phenomena
- Extensive infrastructure developments in hilly areas
- Increasing demand of long-term risk assessment in geotechnical design

2. Methodology

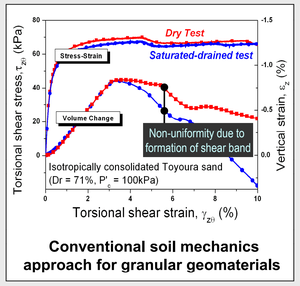


Grain-size curves and physical properties of test materials

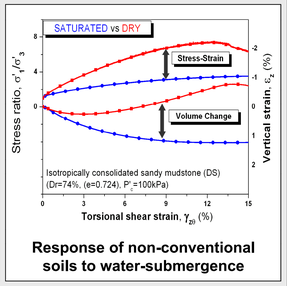


Quantification of water-induced particle degradation

Residual soils of various soft rock deposits in Japan and Pakistan were reconstituted in the laboratory to grain-size of 2.0-0.075mm. Use of crushed soft rocks was intended to accelerate the degradation process upon saturation.



Conventional soil mechanics approach for granular geomaterials



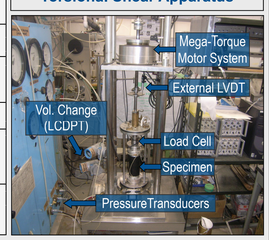
Response of non-conventional soils to water-submergence

Consolidated drained (CD) torsional shear tests on hollow cylindrical specimens (H=20, D_o=10 and D_i=6cm) keeping exactly analogous conditions were performed under fully saturated and dry conditions.

3. Experimental Setup & Testing Plan

Testing Plan (Monotonic Torsional Shear Tests)	
Specimen	Dry deposition method
Effective Stress	Constant during shearing (50-75-100kPa)
Strain rate	0.018%/min (Max. 15%)
Test Conditions	Saturated-drained & Dry Tests Ko=1.0 & 0.5
Relative Density	Dr ≥ 75% (Simulation of practical design)

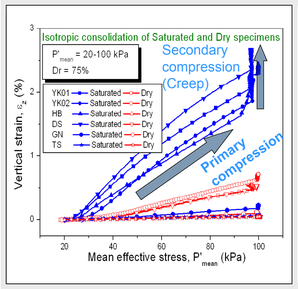
Mega-Torque Hollow Cylindrical Torsional Shear Apparatus

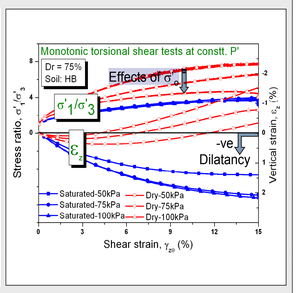


Advantages of Torsional Shear Tests

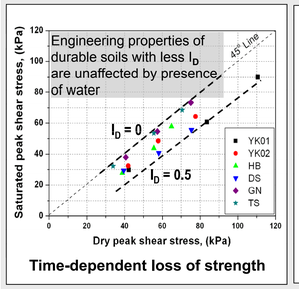
- Benefit of shearing to large strains
- Many stress paths can be generated
- Advantages over triaxial & plain strain compression

4. Test Results

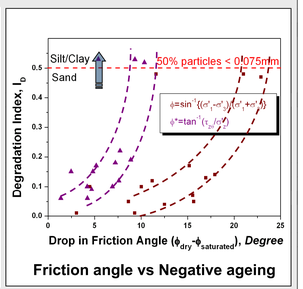




Large volume-compression (during consolidation and shearing stages) and no effects of confining stress level (during shearing) for soils undergoing negative ageing (decay of grains upon water submergence) can be observed.



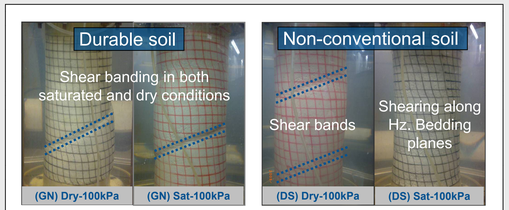
Time-dependent loss of strength



Friction angle vs Negative ageing

Peak strengths under saturated & dry conditions are considerably different for non-conventional soils.

Difference b/w ϕ and ϕ* decreases with deterioration of grains because shearing plane remains horizontal in saturated tests (No shear banding)



No effects of saturation — Different failure modes

Effect of decay of grains on failure mode of specimens

Under anisotropic stress state (Ko=0.5), shear banding is observed both in dry and saturated conditions with its thickness in saturated tests being less than dry cases because of disintegration of soil grains

5. Conclusions

Degradation of soil grains with time (water being the most severe and frequent causitive agent) can be attributed to "Negative Ageing of Soil" and based on this hypothesis, the following conclusions are drawn from this study:

- Strength & deformation response of dry tests is similar to conventional soils whereas the soil behavior all together changes with decay of grains: Crucial for risk-assessment.
- Secondary compression observed in test results can be one of the reasons of progressive slope failures, continued foundation settlements, etc.
- Large effects of different failure modes on strength parameters have been observed (ϕ_{Dry} vs $\phi_{Saturated}$).
- I_D can be a useful and quick index for field judgment of strength degradation.

Future Studies

Cyclic torsional shear tests to study the dynamic response of dry and saturated degradable geomaterials

6. References

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- Ghiabi, H. & Selvadurai, A. P. S. (2009). "Time-dependent mechanical behavior of a granular medium used in laboratory investigations". International Journal of Geomechanics. 9(1):1-8.
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