

The 2nd Nature inspired Solutions for the Built Environment Eylül, North Cyprus

Effects of inherent anisotropy on soil steady states and its variability

Dr. Arya Assadi-Langroudi, Associate Professor
Dr. Soheil Ghadr, Research Associate



2nd National Civil Engineering Symposium
2. Ulusal İnşaat Mühendisliği Sempozyumu
14-15 Eylül 2022
14-15 September 2022

2nd Nature Inspired Solutions For The Built Environment Conference (NISE)
2. Uluslararası Yapılar İçin Doğadan İlham Alan Çözümler Konferansı
16 Eylül 2022
16 September 2022

International Workshop on Advances in Laboratory Testing of Liquefiable Soils
Sıvılaştan Zeminlerde Laboratuvar Uygulamaları Uluslararası Çalıştayı
17 Eylül 2022
17 September 2022

Acapulco Resort
Convention SPA Hotel

1. Effect of shape:

From undrained monotonic compression shear perspective,

From drained monotonic direct shear perspective.

2. Association of shape with anisotropy *in sands*

3. HCT, to determine,

Association of confinement with anisotropy *in sands*

Association of size with anisotropy *in sands*

Sand A

$$d_{50} = 0.2 \text{ mm}$$

$$R = 0.4$$

$$S = 0.6$$

Sand B

$$d_{50} = 0.2 \text{ mm}$$

$$R = 0.9$$

$$S = 0.8$$

Sand C

$$d_{50} = 0.9 \text{ mm}$$

$$R = 0.4$$

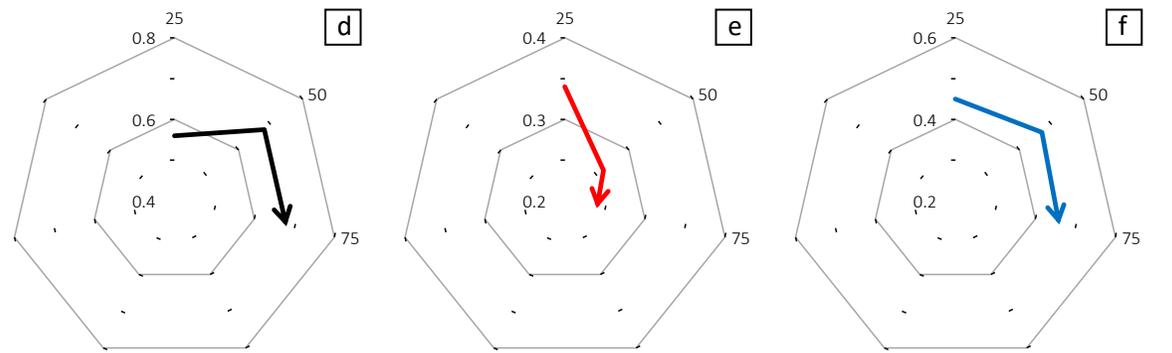
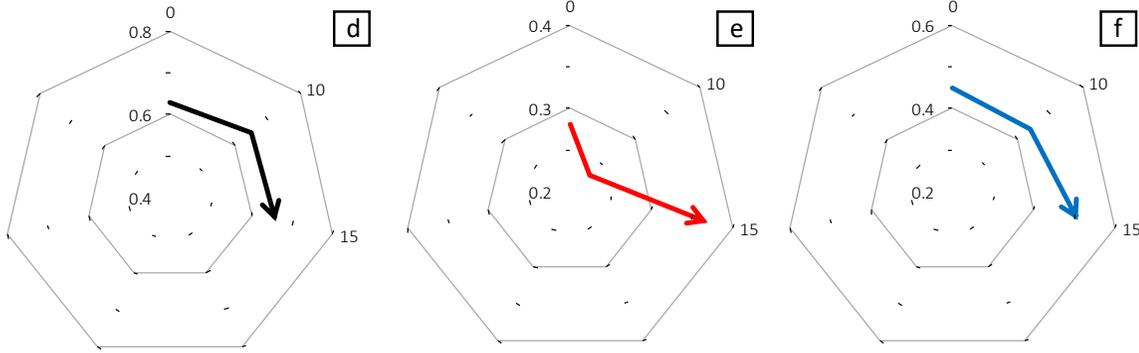
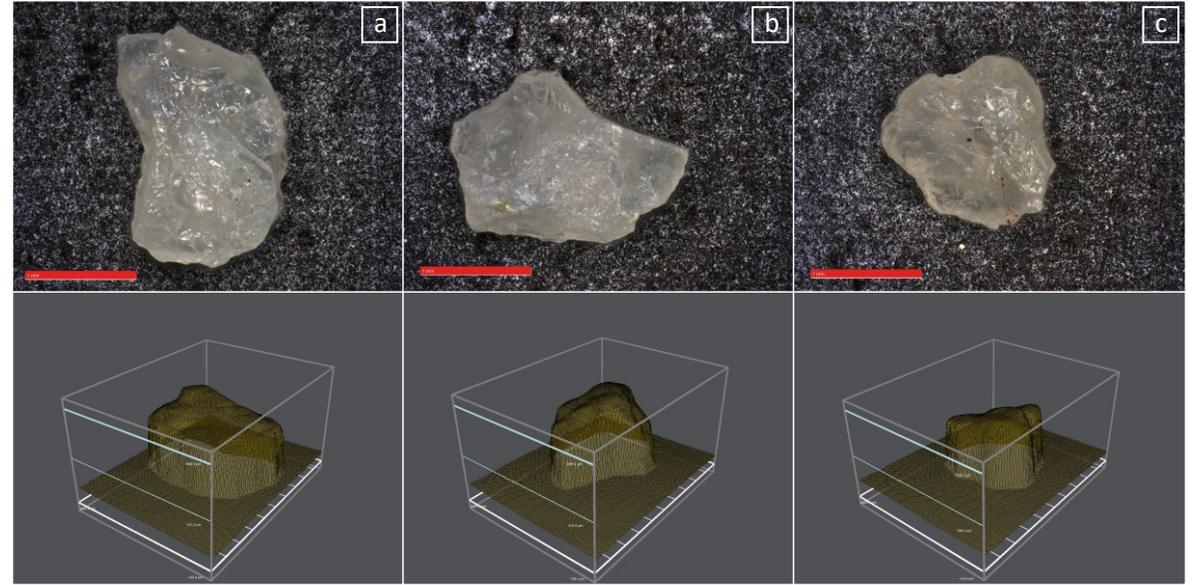
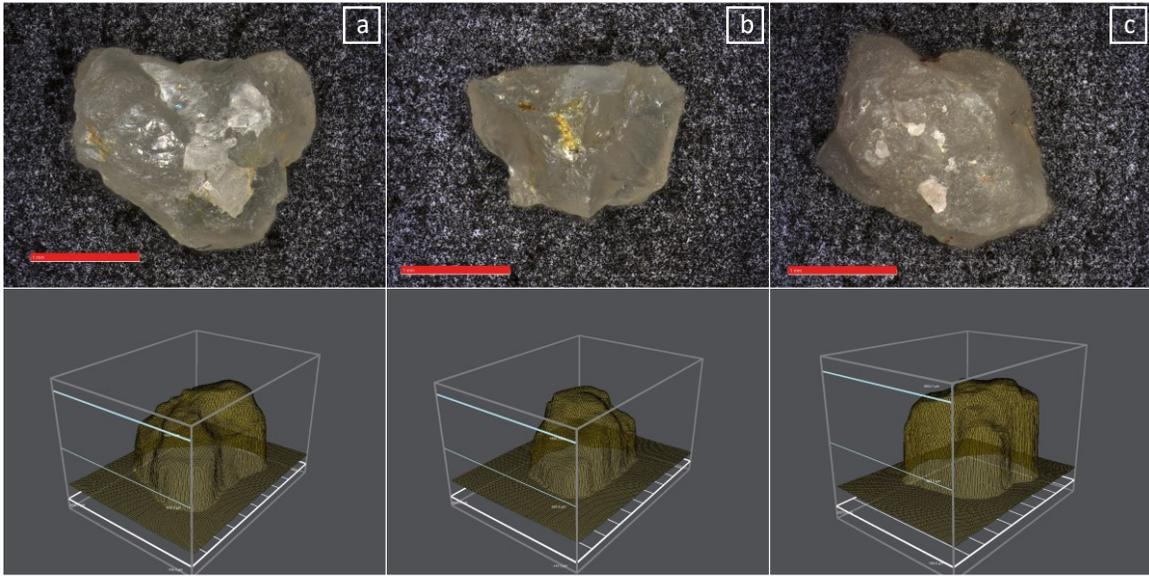
$$S = 0.7$$

Sand D

$$d_{50} = 1 - 2 \text{ mm}$$

$$R = 0.3$$

$$S = 0.6$$



Western Cape silica sand crushed to 7 grades,
1-2mm in diameter particles extracted,
PSD adjusted, and identical

Size constant
Sorting constant
Only variable: shape

Shape

Size constant

Sorting constant

Only variable: shape

$$e \sim 0.8$$

$$\omega = \omega_{hyg}$$

$$\sigma'_N = 200 \text{ kPa}$$

Some variation

As sand becomes rounder,
stress at both peak and
residual state slightly
decreases.

Shape

Distinct transition from NFHS to PFSS

Stress paths converging in 'B' i.e., the rounder sand

Diminished shape-induced disparity of data

hence, association of anisotropy with shape

A

$$d_{50} \sim 0.2 \text{ mm}$$

$$R = 0.45$$

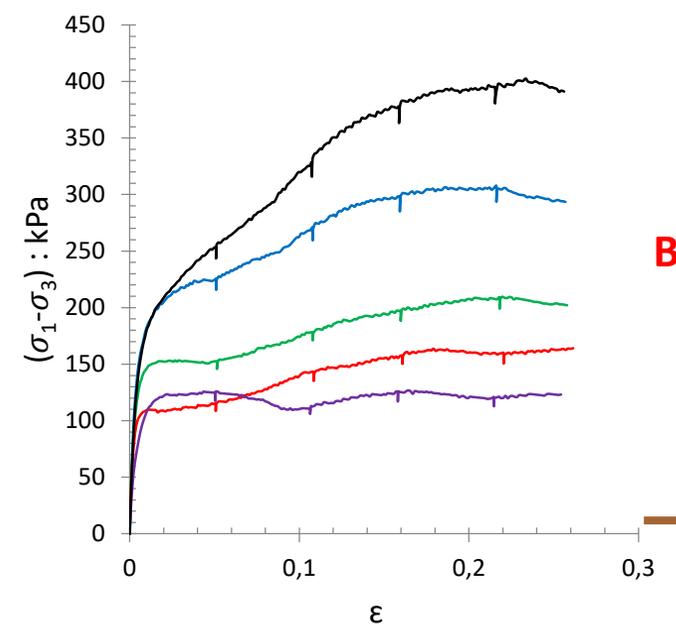
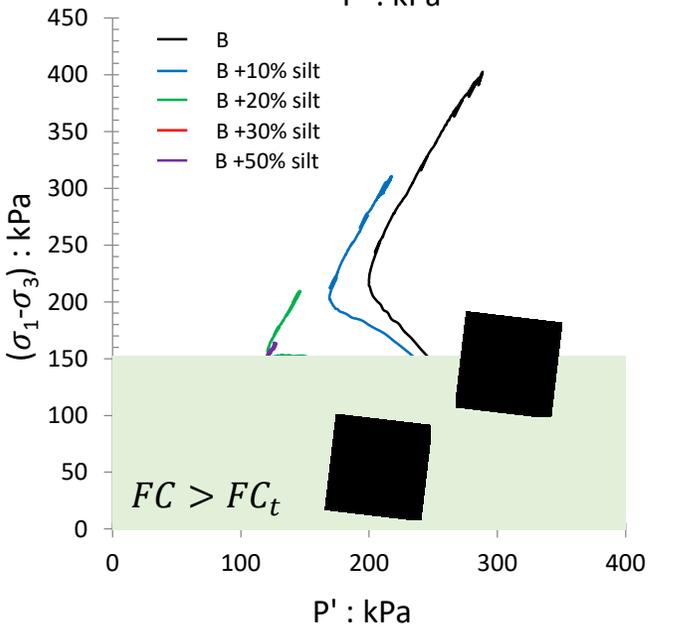
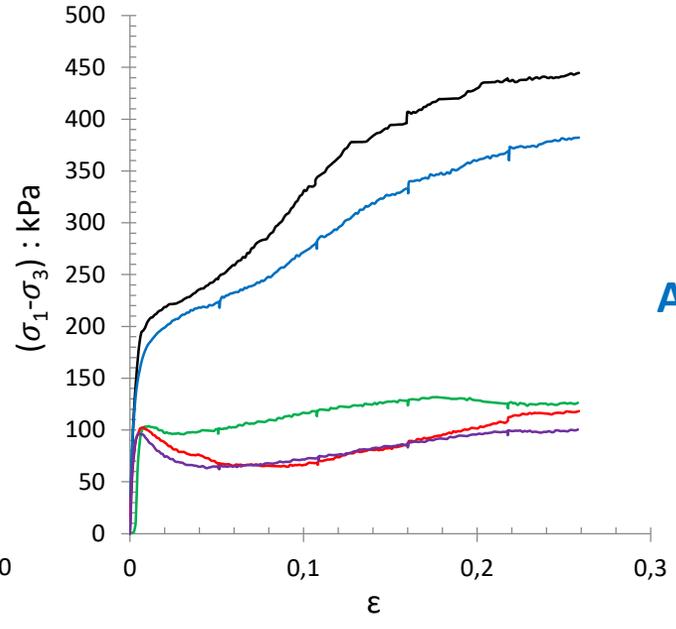
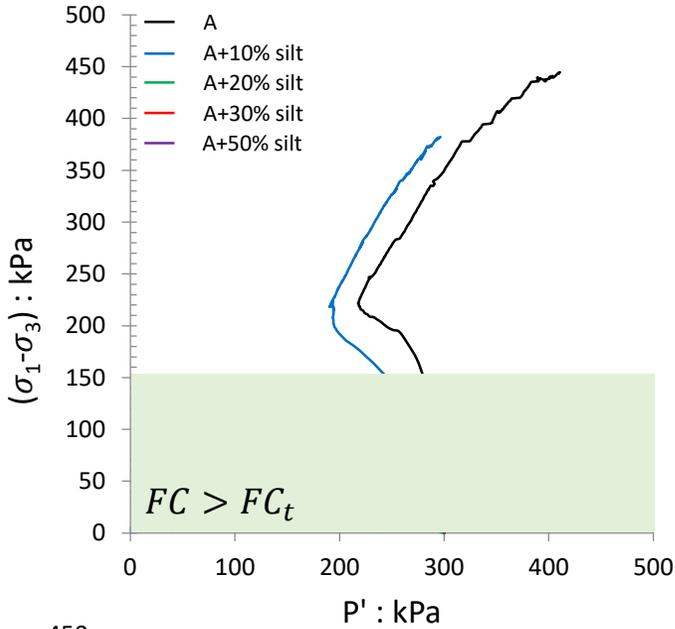
$$S = 0.7$$

B

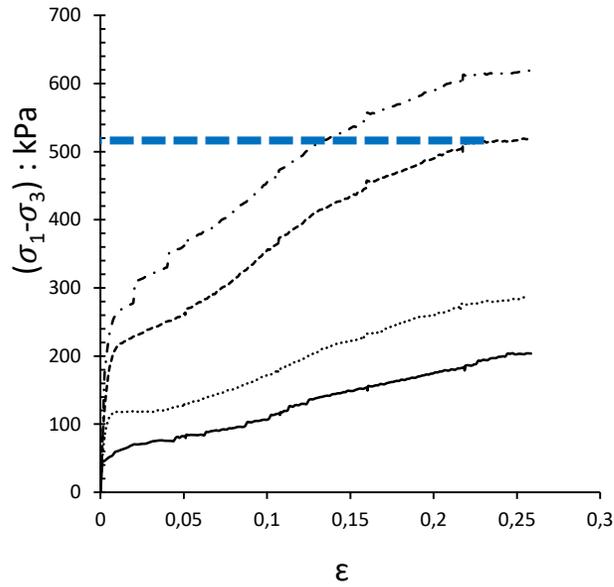
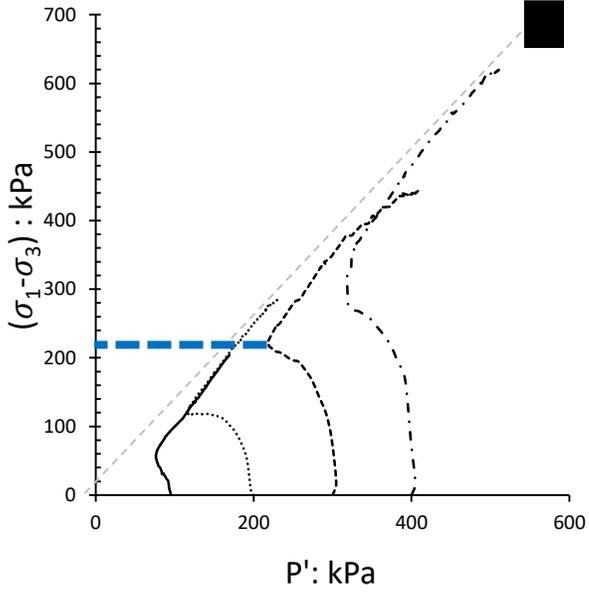
$$d_{50} \sim 0.2 \text{ mm}$$

$$R = 0.93$$

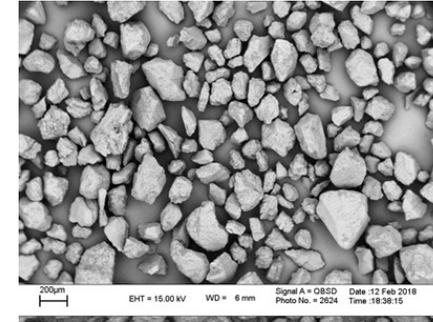
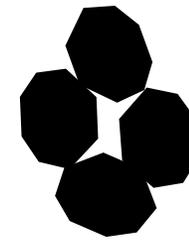
$$S = 0.85$$



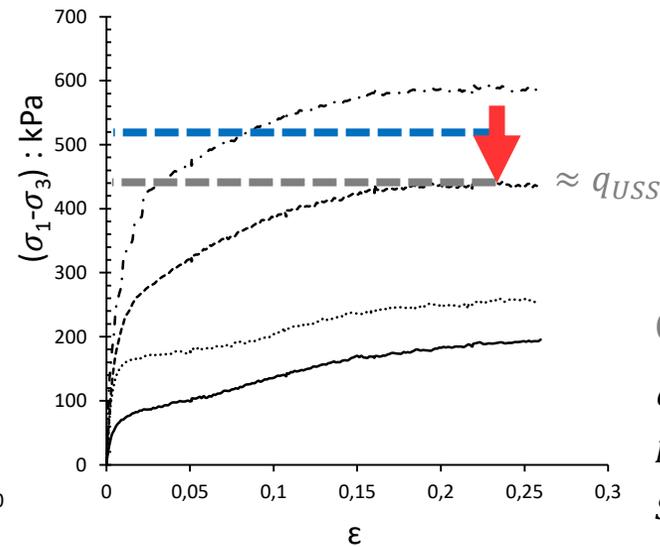
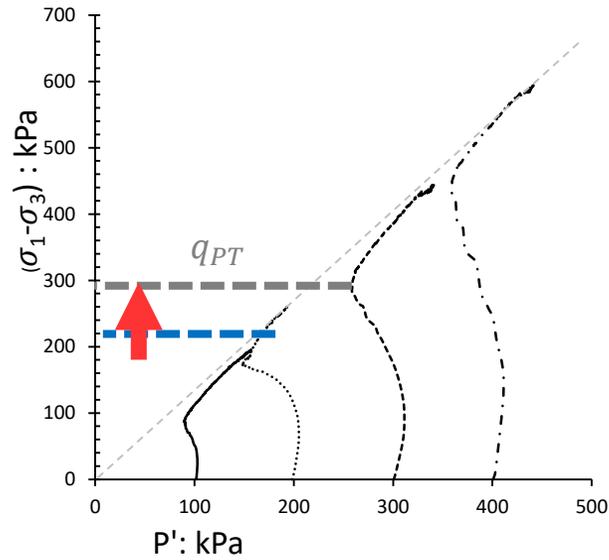
Size



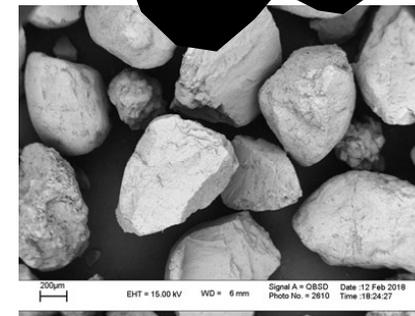
$e_c = 0.771 - 0.806$
 $P' = 100 - 400 \text{ kPa}$



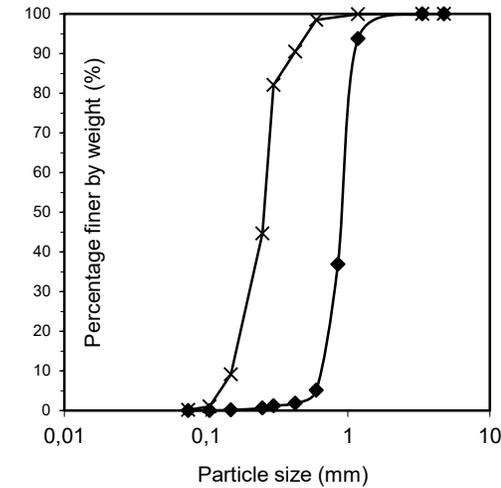
A
 $d_{50} \sim 0.2 \text{ mm}$
 $R = 0.42$
 $S = 0.60$



C
 $d_{50} \sim 0.9 \text{ mm}$
 $R = 0.45$
 $S = 0.69$



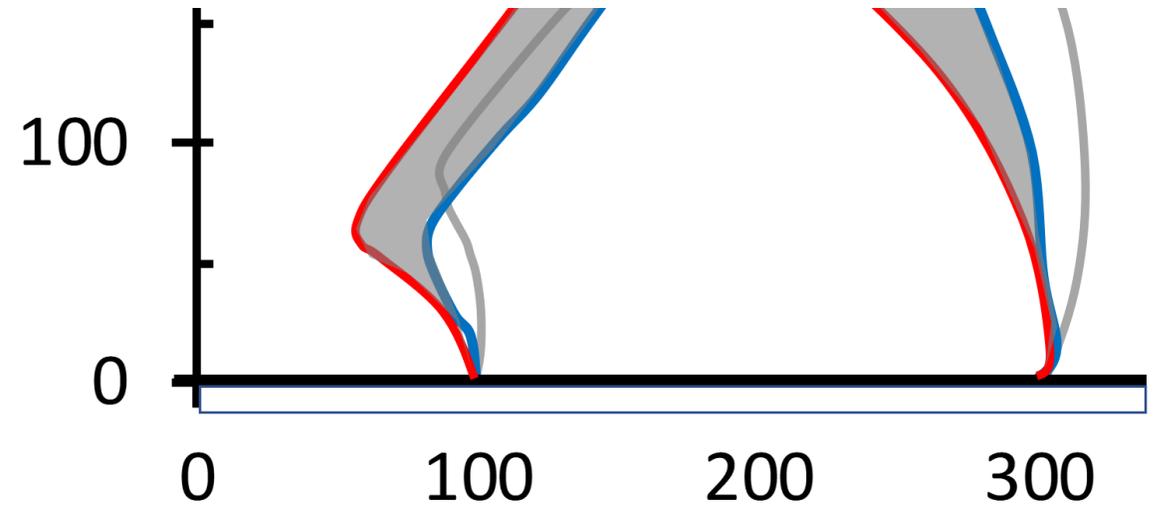
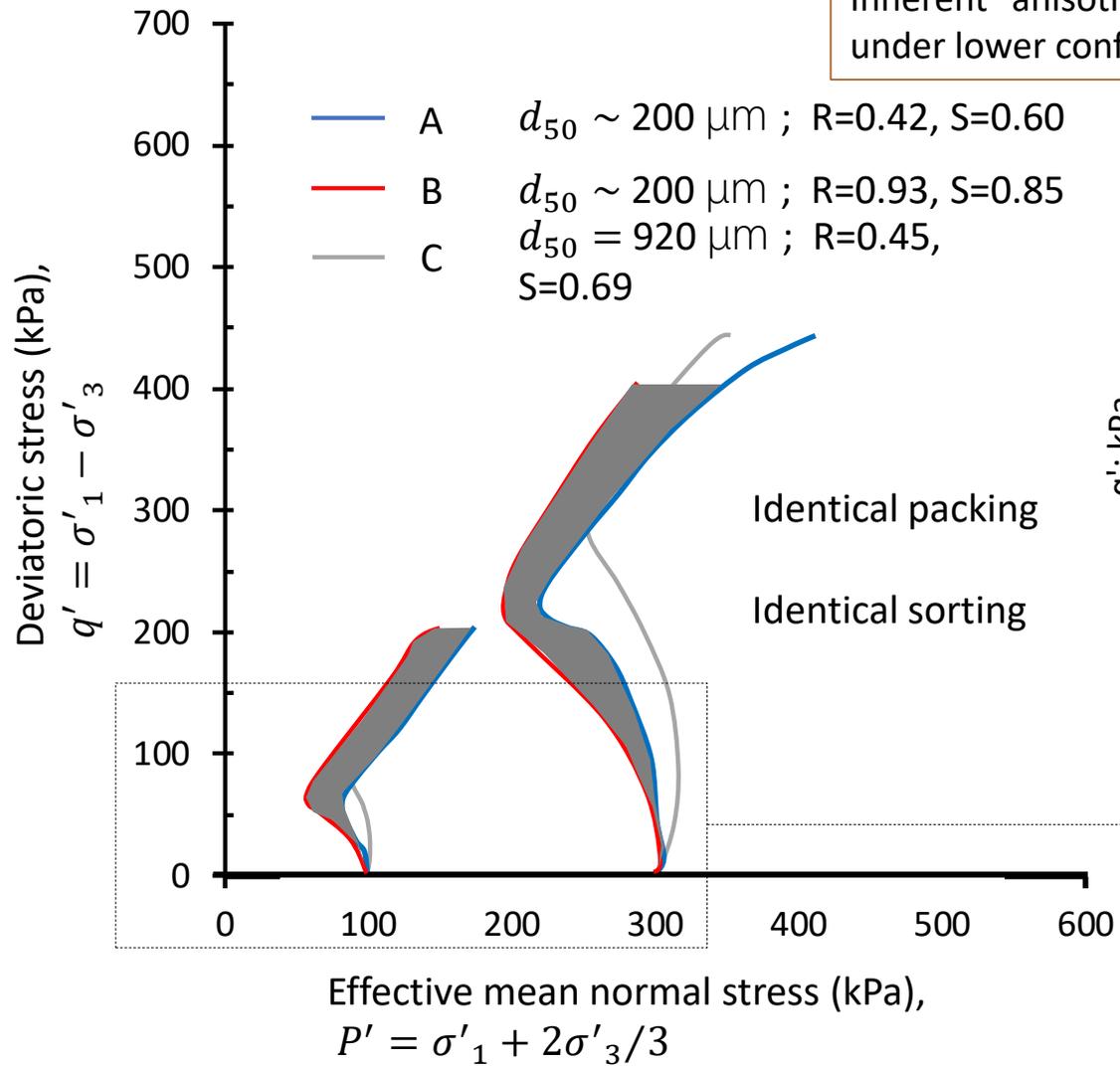
Same shape
 0-4% FC
 Well-sorted
 $e_c \sim 0.8$
 CU
 Only variable: size



In one frame

Inherent anisotropy, caused by shape, in one frame!

Inherent anisotropy, appears to have more substantial implications under lower confinement levels.



Inherent anisotropy
HCTA

$b = 0.5, 1.0$
 $P' = 200 \text{ kPa}$

$\alpha = 60^\circ$

$\alpha = 30^\circ$

$\alpha = 15^\circ$

$b = 0.5, 1.0$
 $P' = 400 \text{ kPa}$

$\alpha = 60^\circ$

$\alpha = 30^\circ$

$\alpha = 15^\circ$



$d_{50} \sim 0.2 \text{ mm}$

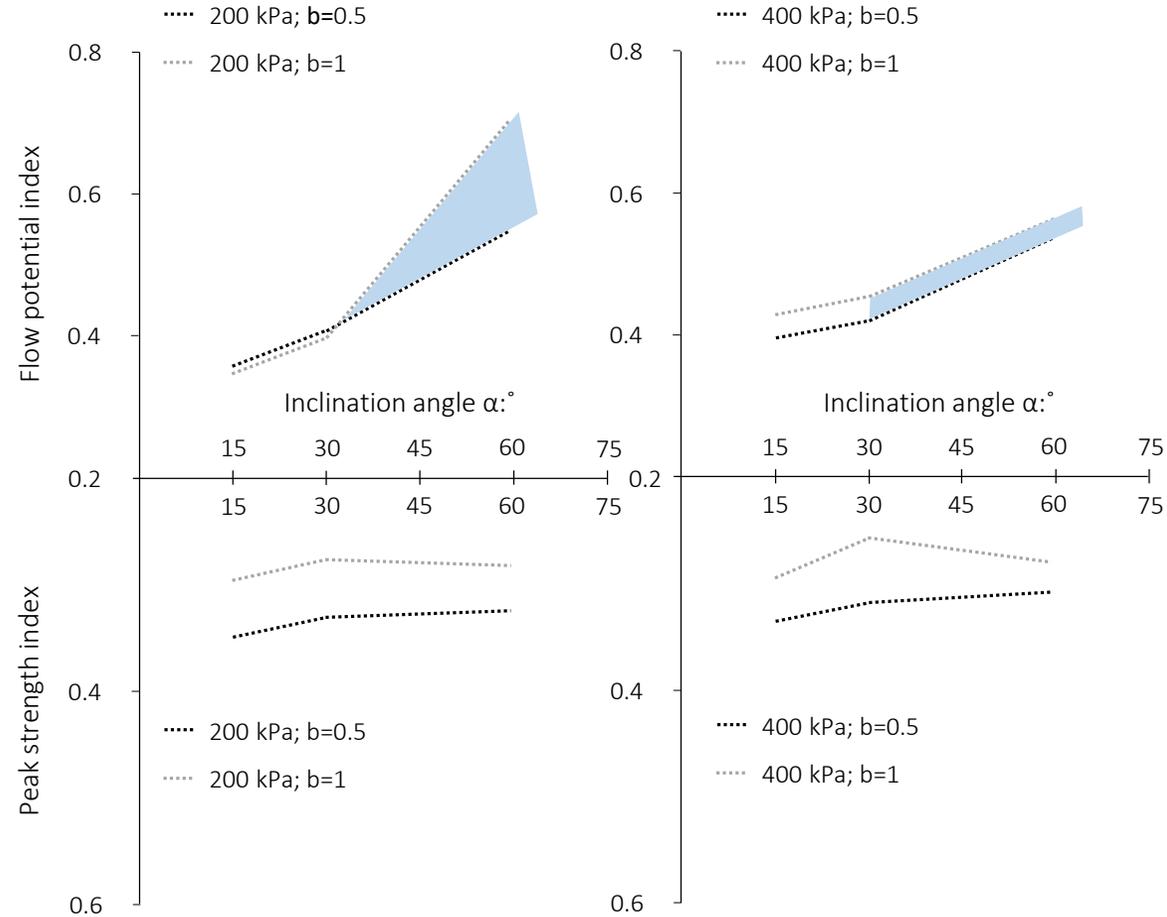
$R = 0.45$

$S = 0.7$

- For Sand A (a medium, angular sand), HS changes to SS as loading environment changes from Compression, and Compression+Torsion, to Torsion.

Inherent anisotropy HCTA testing programme

For angular Sand A, the impacting of anisotropy is probably more pronounced under lower confinement levels



$$P' = 200 \text{ kPa}$$

$$b = 0.5, 1.0$$

$$\alpha = 60^\circ$$

$$\alpha = 30^\circ$$

$$\alpha = 15^\circ$$

$$P' = 400 \text{ kPa}$$

$$b = 0.5, 1.0$$

$$\alpha = 60^\circ$$

$$\alpha = 30^\circ$$

$$\alpha = 15^\circ$$

B

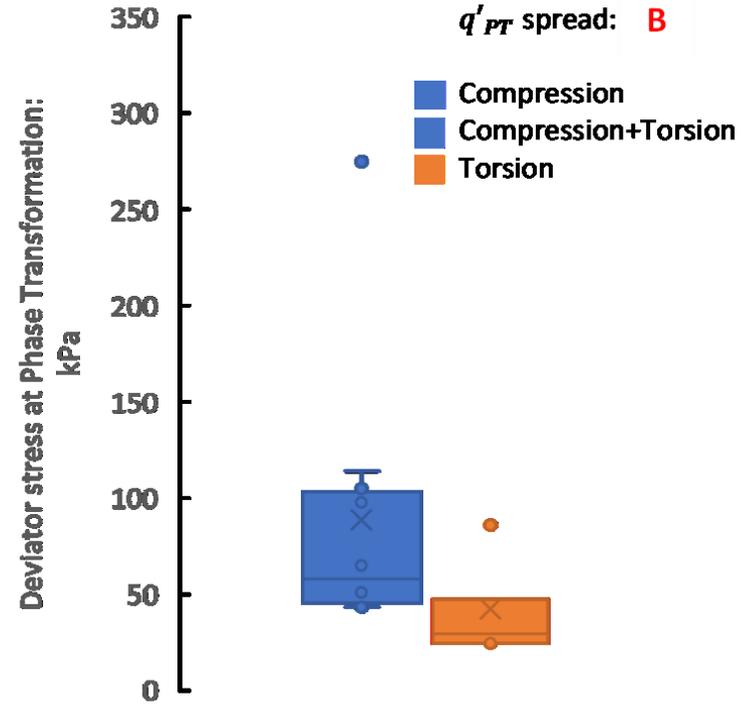
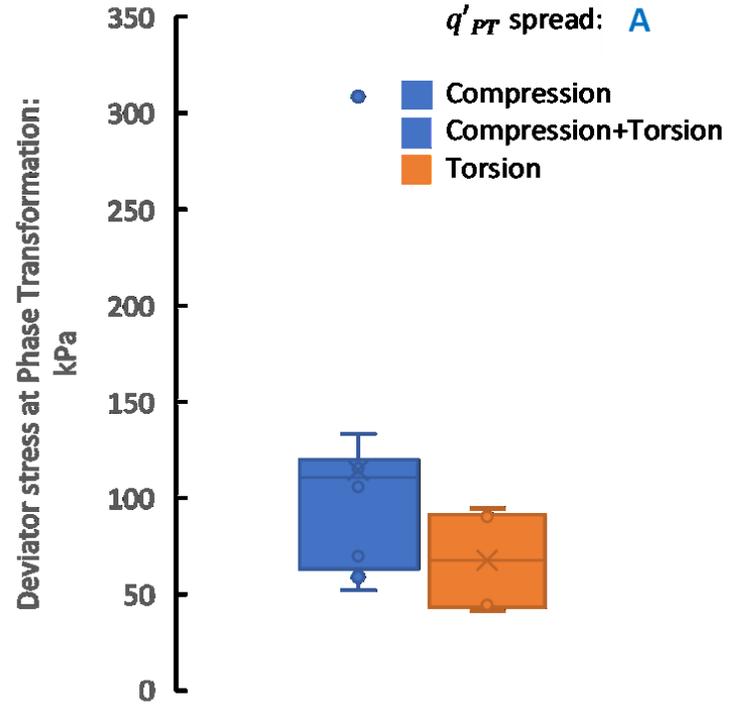
$$d_{50} \sim 0.2 \text{ mm}$$

$$R = 0.93$$

$$S = 0.85$$

- As of Sand A, in rounded Sand B, HS changes to SS as loading environment changes from Compression, and Compression+Torsion, to Torsion.

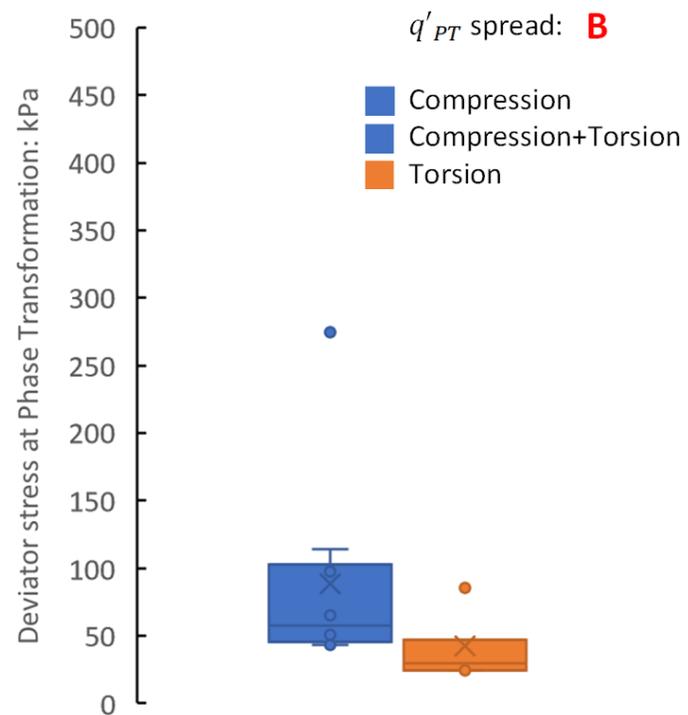
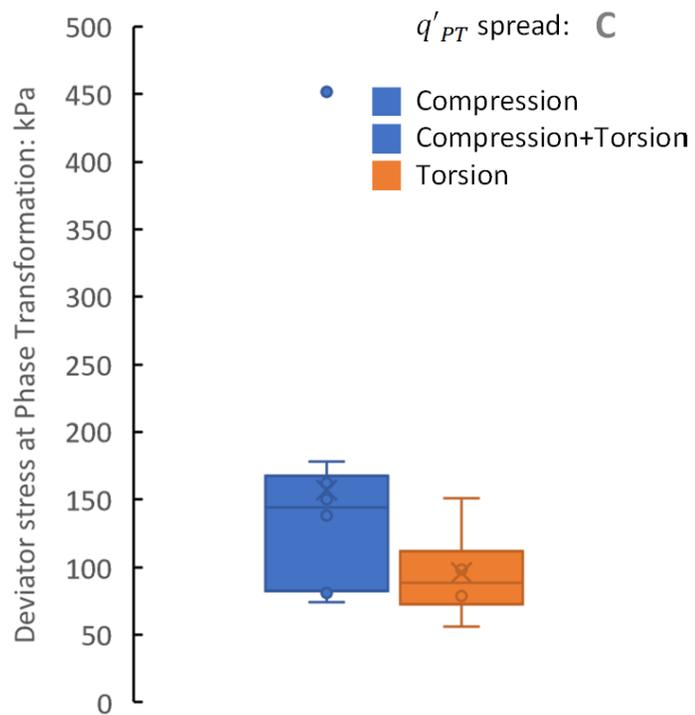
Shape & anisotropy affirmation of association



For Sands A & B (similar size, different shape): The stress at phase transformation shows greater disparity in less spherical, less rounder sands.

Size & anisotropy

Data disparity



For Sands B & C (similar shape, different size): The stress at phase transformation shows greater disparity in coarser sized sands.

Cautious conclusions

Affirmation of what already is known

- A granular matter is defined by Size, Shape and Sorting of its constituting particles.
 - Roundness of sand particles (loose, and under undrained conditions) yield lower stress at USS
 - Roundness of sand particles (loose, and under drained conditions) yield lower stress at peak and residual strains
 - Roundness of sand particles (loose, mixed with silt $>FC_t$) improves the stress at QSS.
-
- Irrespective of inherent anisotropy, pure torsion appears to yield flow and stress softening.
 - Inherent anisotropy becomes evident in angular sands.
 - But diminishes as silt content is increased beyond the fines content threshold,
 - Inherent anisotropy is probably a greater problem for coarser granular matters.
 - Inherent anisotropy, possibly has more substantial implications under lower confinement levels.

The 2nd Nature inspired Solutions for the Built Environment Eylül, North Cyprus

Effects of inherent anisotropy on soil steady states and its variability

Thank you!



2nd National Civil Engineering Symposium
2. Ulusal İnşaat Mühendisliği Sempozyumu
14-15 Eylül 2022
14-15 September 2022

2nd Nature Inspired Solutions For The Built Environment Conference (NISE)
2. Uluslararası Yapılar İçin Doğadan İlham Alan Çözümler Konferansı
16 Eylül 2022
16 September 2022

International Workshop on Advances in Laboratory Testing of Liquefiable Soils
Sıvılaştan Zeminlerde Laboratuvar Uygulamaları Uluslararası Çalıştayı
17 Eylül 2022
17 September 2022

Acapulco Resort
Convention SPA Hotel