Comparison between Static and Dynamic Behavior measured in Triaxial and Oedometric test systems

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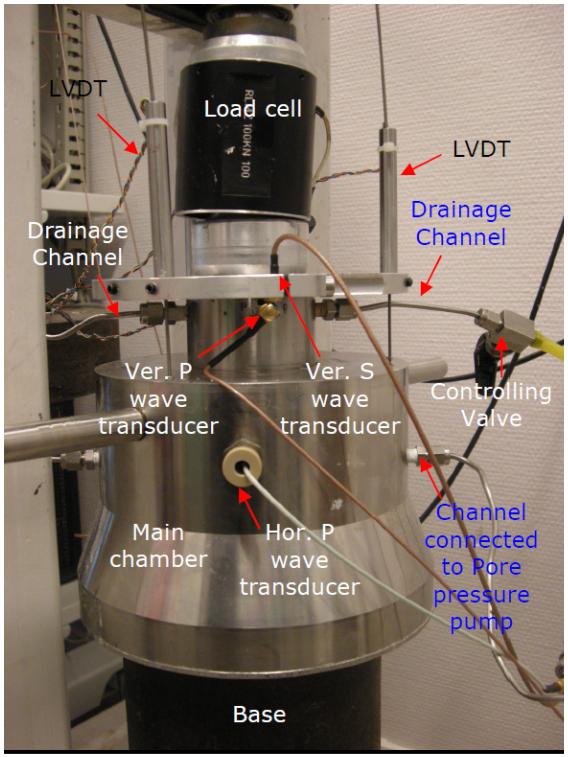
Motivation and Objective

- Uniaxial compaction (K_0) tests with uncemented sand and clay in an oedometer and a triaxial set-up show different results:
  - Larger static modulus in triaxial set-up, in particular for clay
  - Higher wave velocities in triaxial set-up, but similar stress sensitivities
- Why?
  - Stress paths were not REALLY the same in the two set-ups?
  - Samples were not the same?
  - We did something stupid..

Oedometeric Set-up



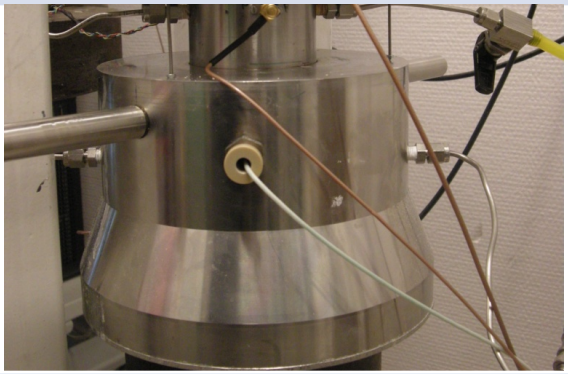
- Uniaxial strain set-up
- Vertical P- & S- + Horizontal P-wave transducers.
- Dimension of the sample:
  - Diameter: 70mm
  - Height: 22-25mm

Triaxial Set-up

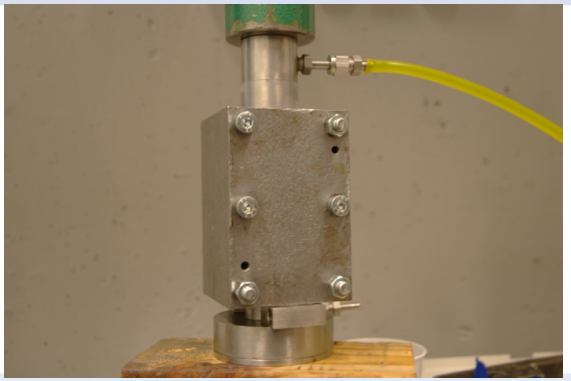
- Biaxial stress set-up
  - Confining pressure monitored
- Vertical & horizontal P- & S-wave transducers
- Dimension of the sample:
  - Diameter: 38mm
  - Height: 60-65mm

Sample Preparation & Boundary conditions

Oedometer	Triaxial
Clay: Little amount of dry Kaolinite (< 5 µm) powder mixed with 3.5 % NaCl brine and stirred until visible homogeneous mixture. Procedure repeated until dry powder converted to slurry which was evacuated to remove trapped air	
Clay: Sample was directly poured into the sample holder	Clay: Sample was poured into Pre-compaction cell.
Sand: Medium Ottawa sand w 3.5 % NaCl directly poured into the sample holder	



Pre-compacted under about 2.7 MPa

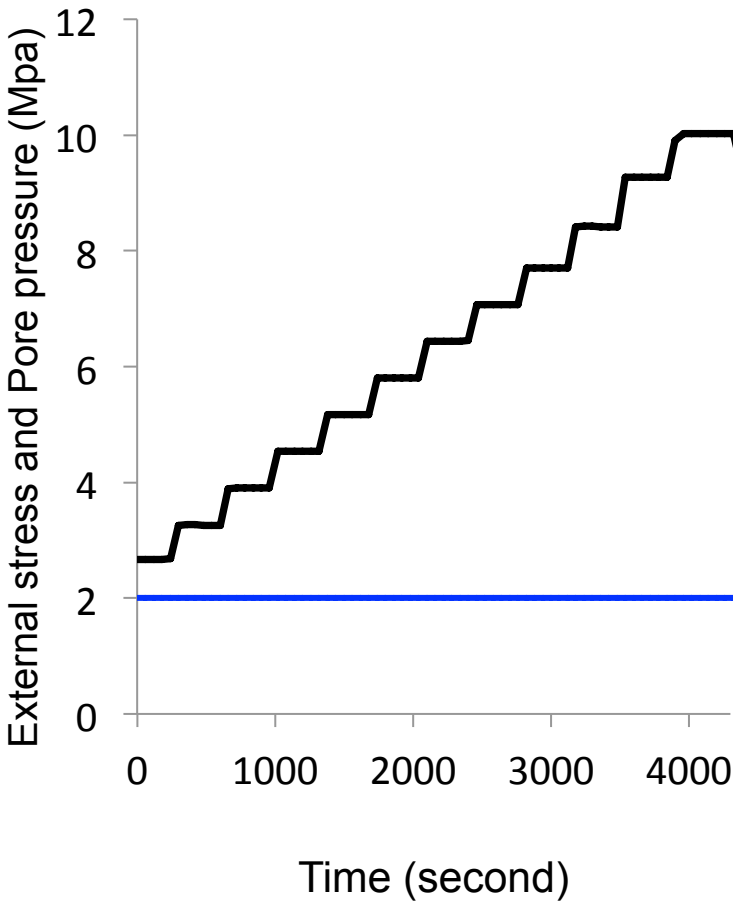


Pre-compacted under about 3.0 MPa

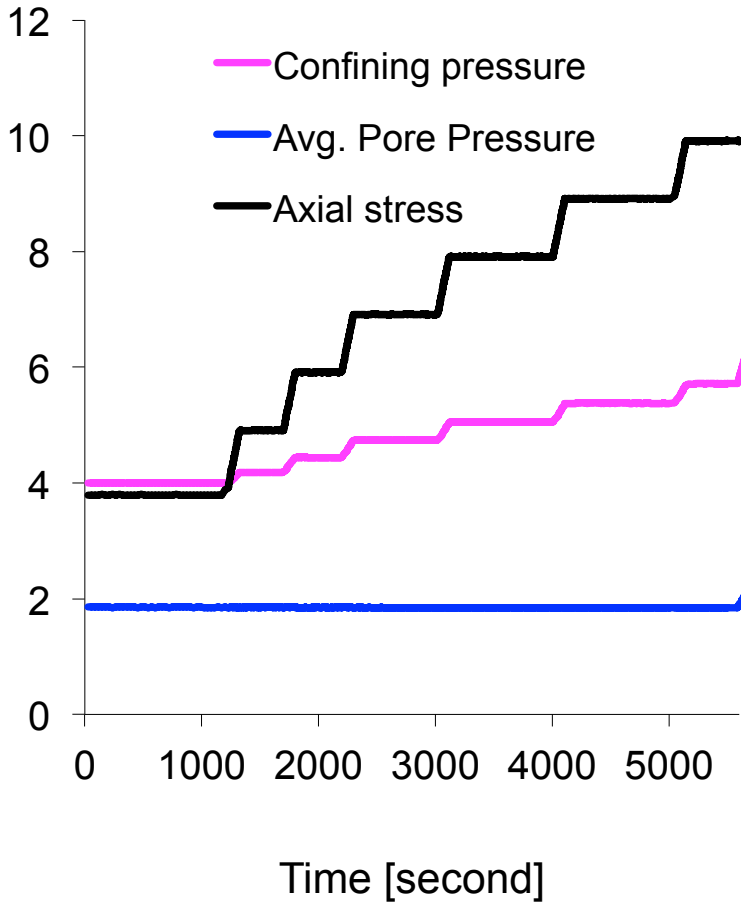
Oedometer	Triaxial
Samples in direct contact with steel wall	Samples in contact with rubber/teflon sleeve
K_0 mode maintained by thick steel wall	K_0 mode maintained by confining pressure increment to keep zero horizontal strain

Stress Path during tests

Oedometer

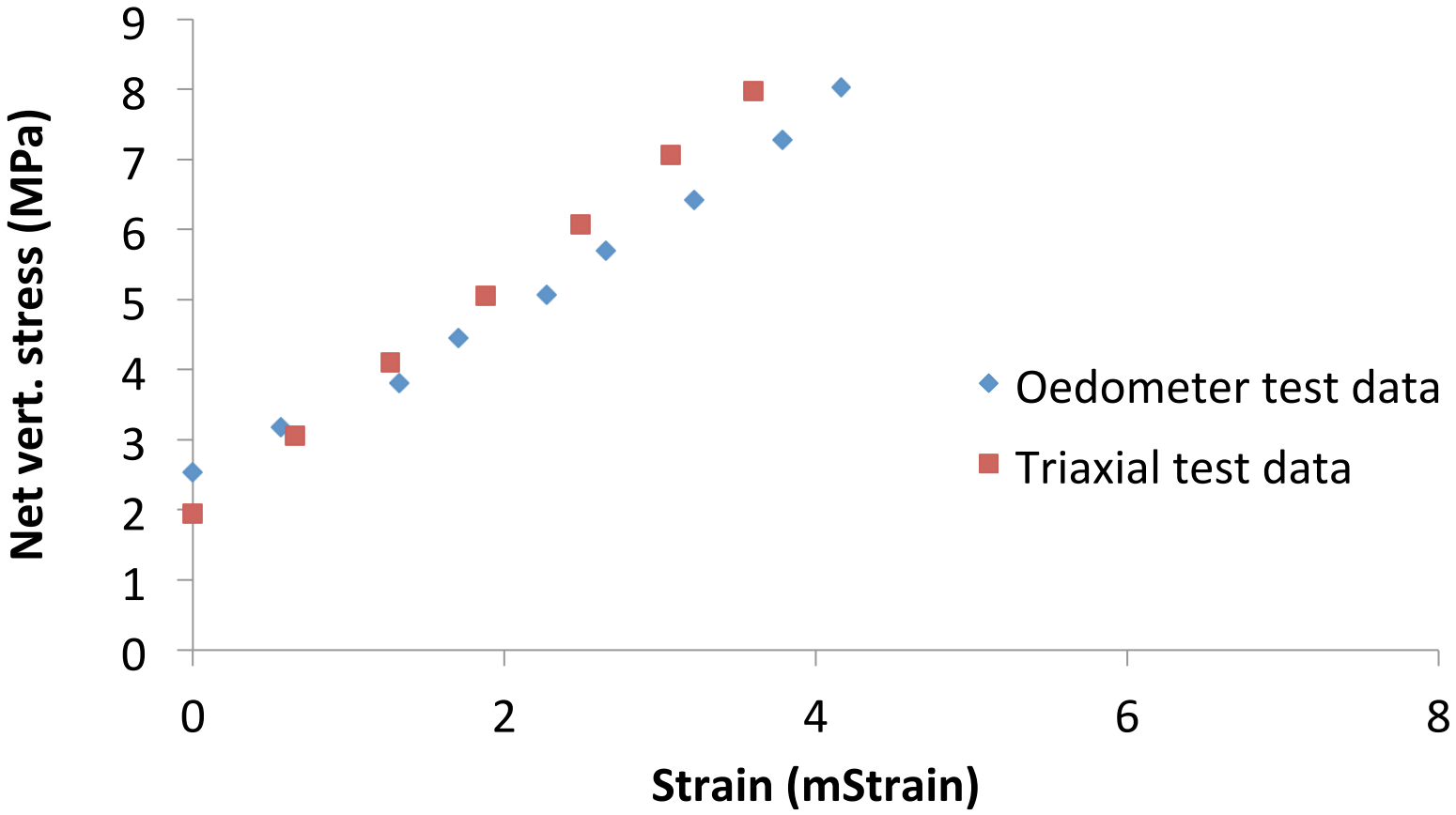


Triaxial



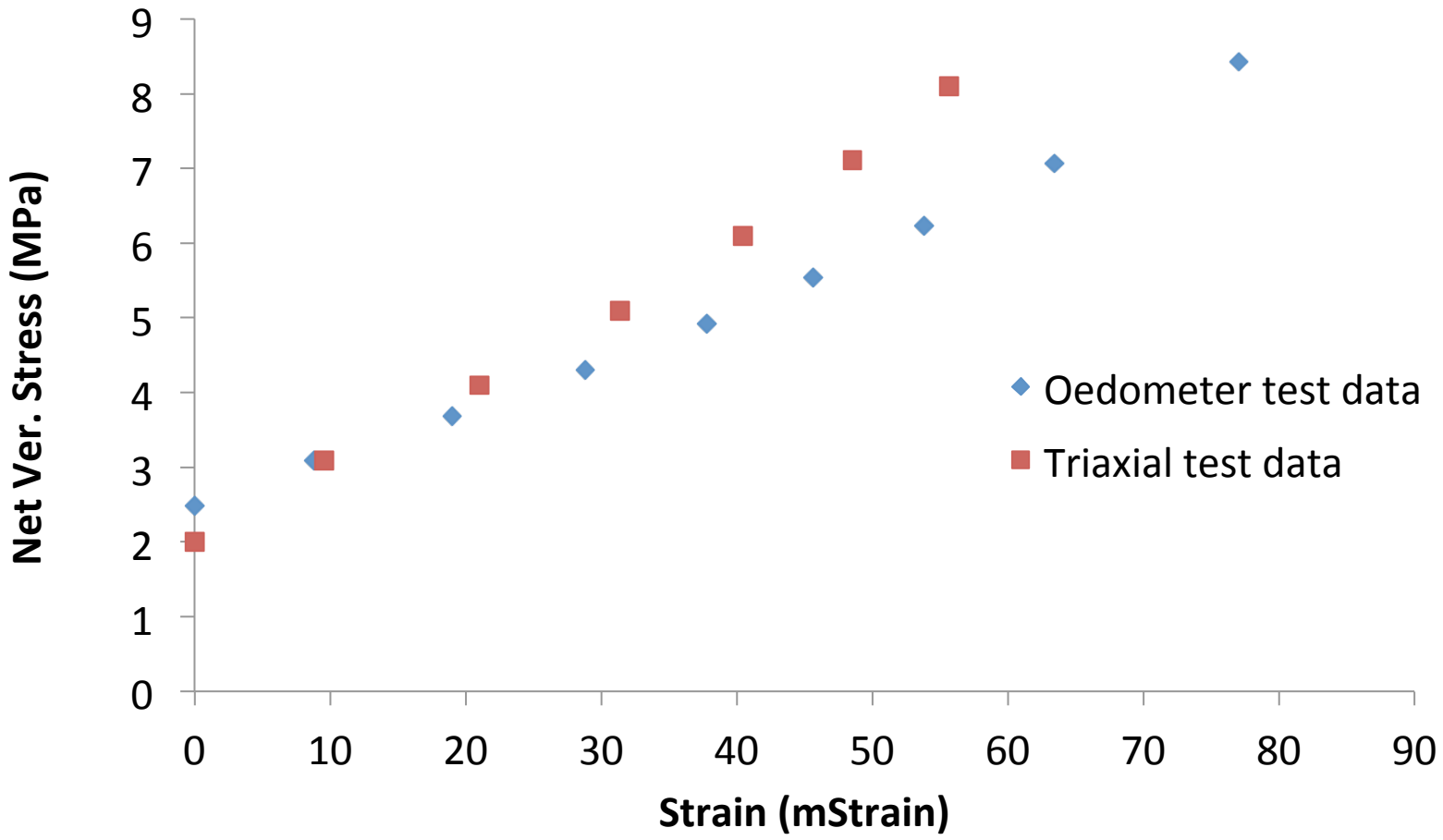
Example from sand test

Static Behavior: Sand



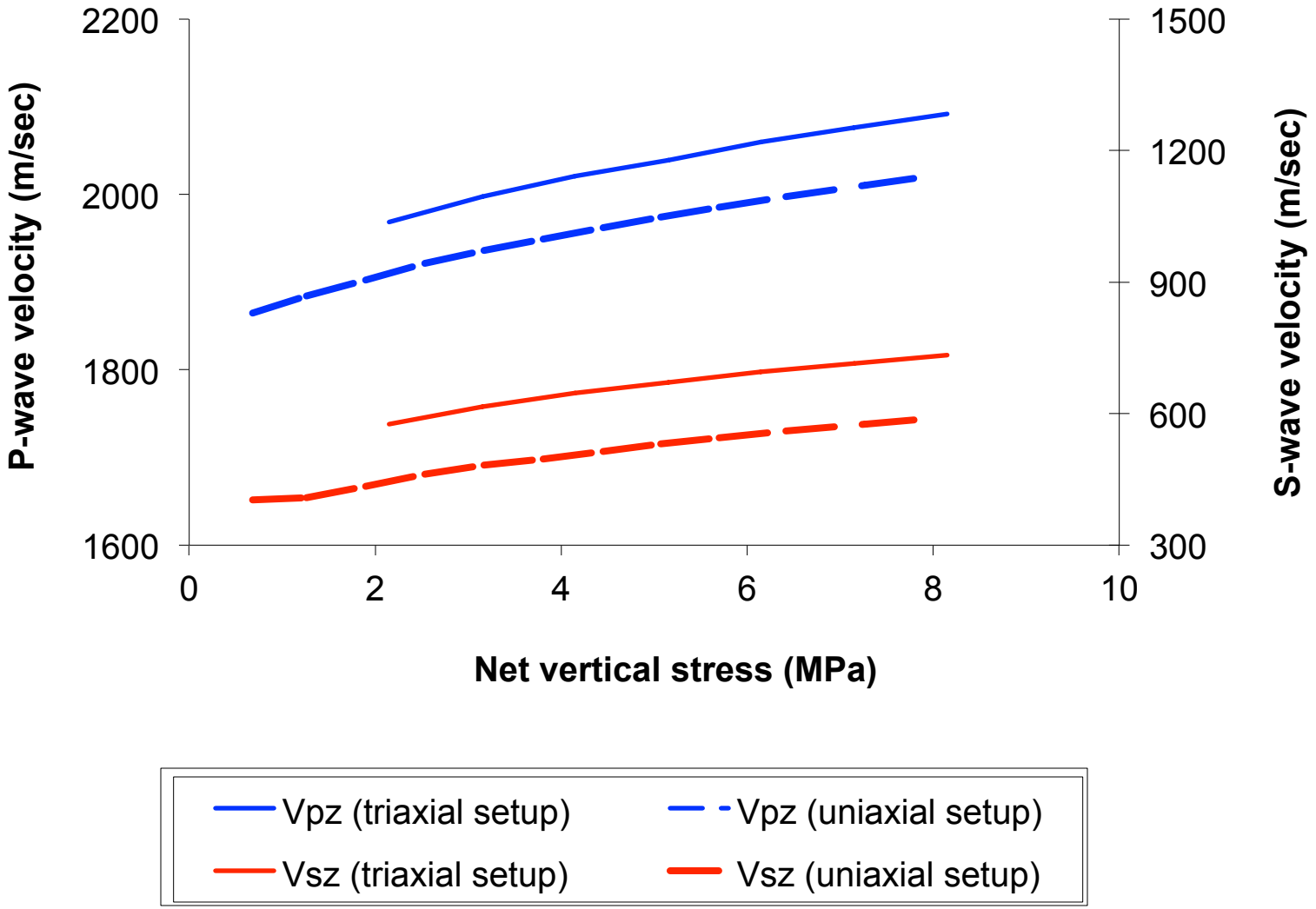
Sand is softer in oedometer than in the triaxial set-up at all stresses

Static Behavior: Kaolinite

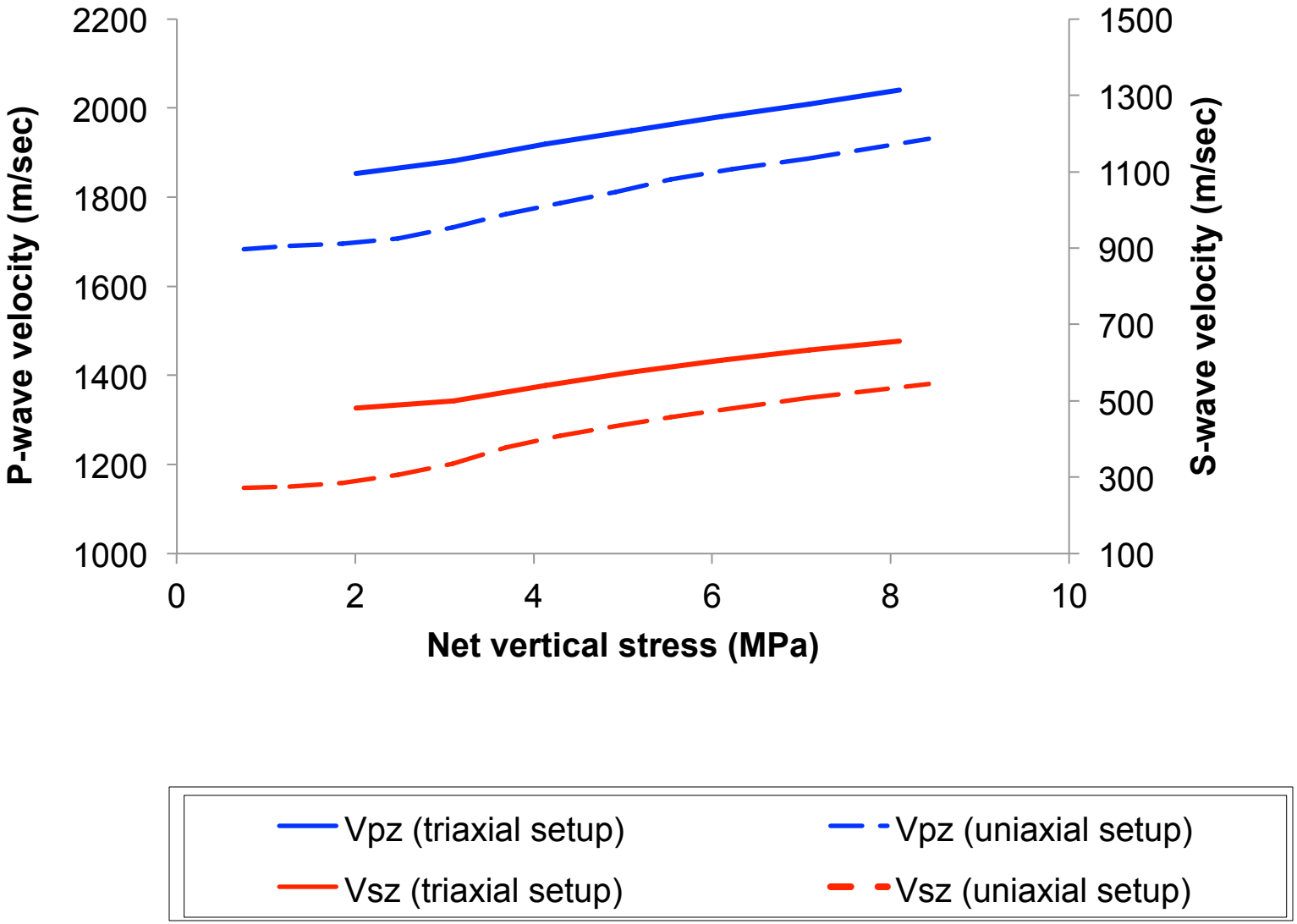


Compacted kaolinite is softer in oedometer than in the triaxial set-up at all stresses

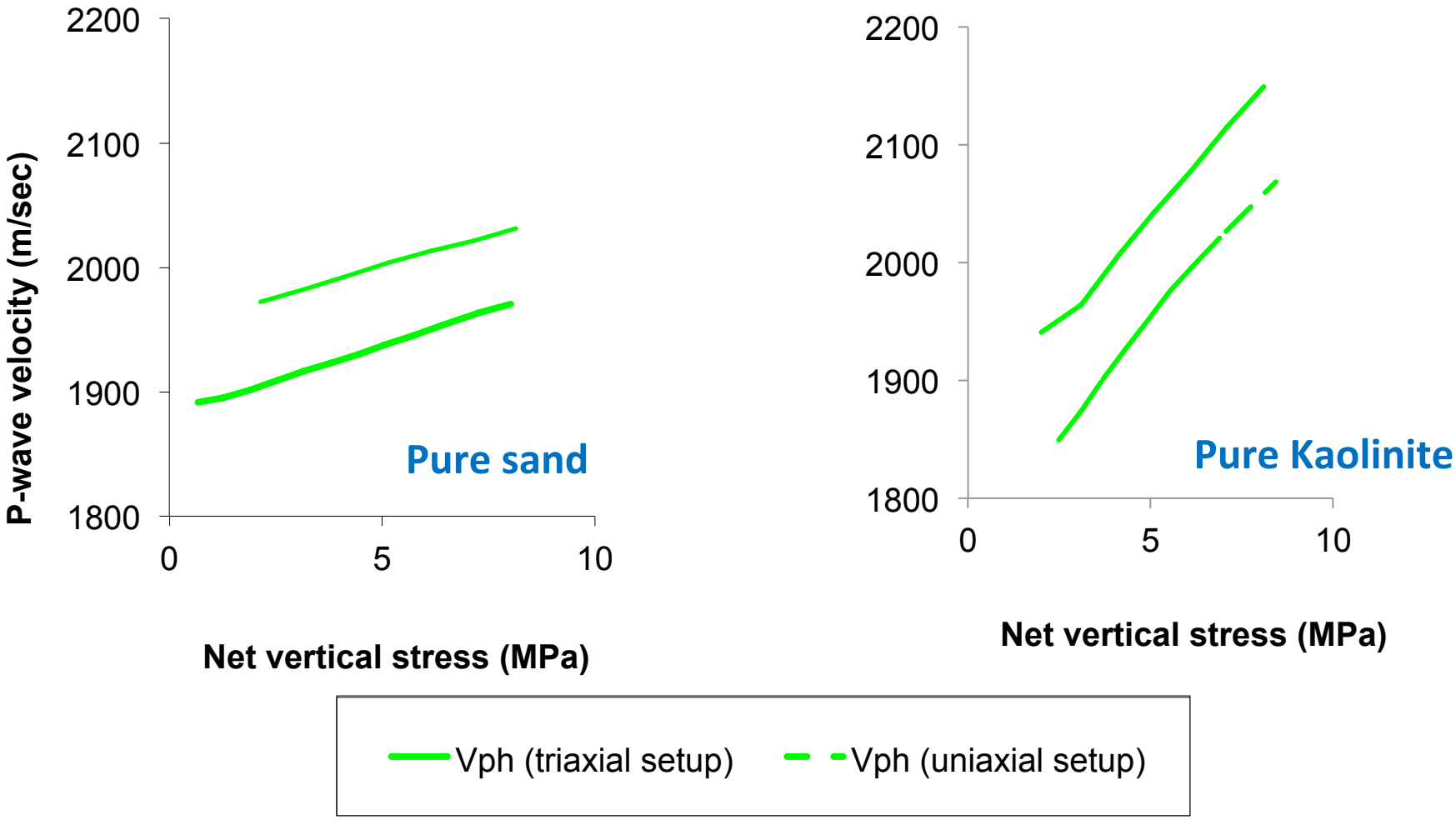
Dynamic Behavior: Pure Sand



Dynamic Behavior: Pure Kaolinite

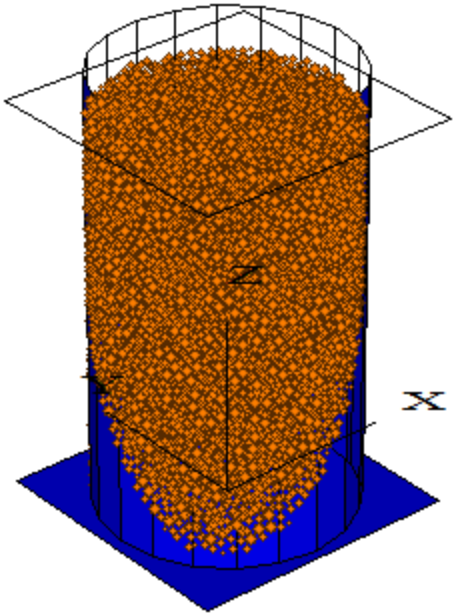


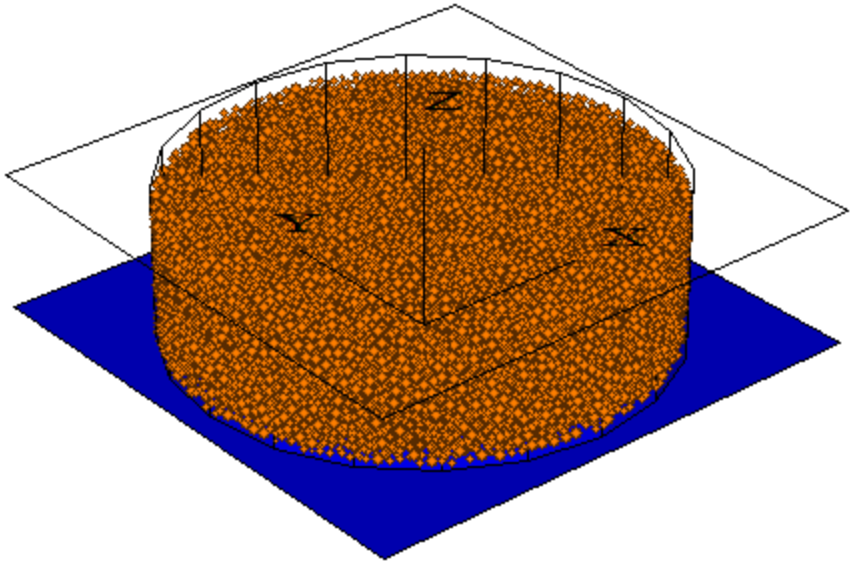
Dynamic Behavior: Horizontal P-Wave velocity



So: In all cases, wave velocities are higher in the triaxial set-up, but stress sensitivities are apparently the same

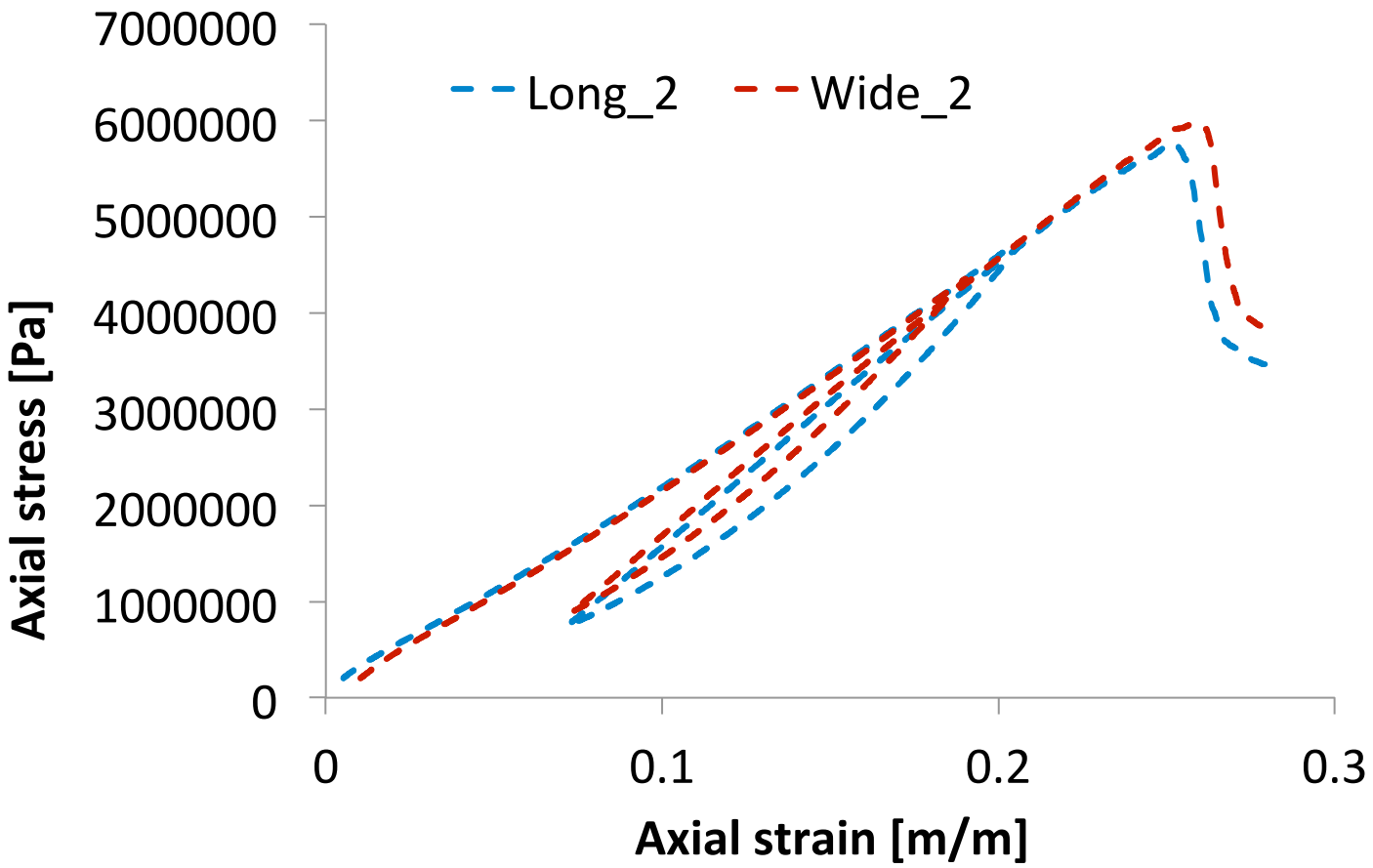
Are Stress Paths the same - Effects of Sample Geometry?





PFC^{3D} was used to simulate the two geometries, varying the number of particles, the particle size distributions, the confining wall stiffness, and the friction between the samples and the walls

Sample Geometrical Effect?



The simulations do not indicate any difference in stiffness resulting from sample geometry

	Height (mm)	Width (mm)	# balls	Min_rad (mm)	Max_rad (mm)	Wall stiff	Wall fric.	Ball fric.
Long_1	60	38	28416	0.5	0.9	1.00E+07	0	0.5
Wide_1	20	70	32142	0.5	0.9	1.00E+07	0	0.5

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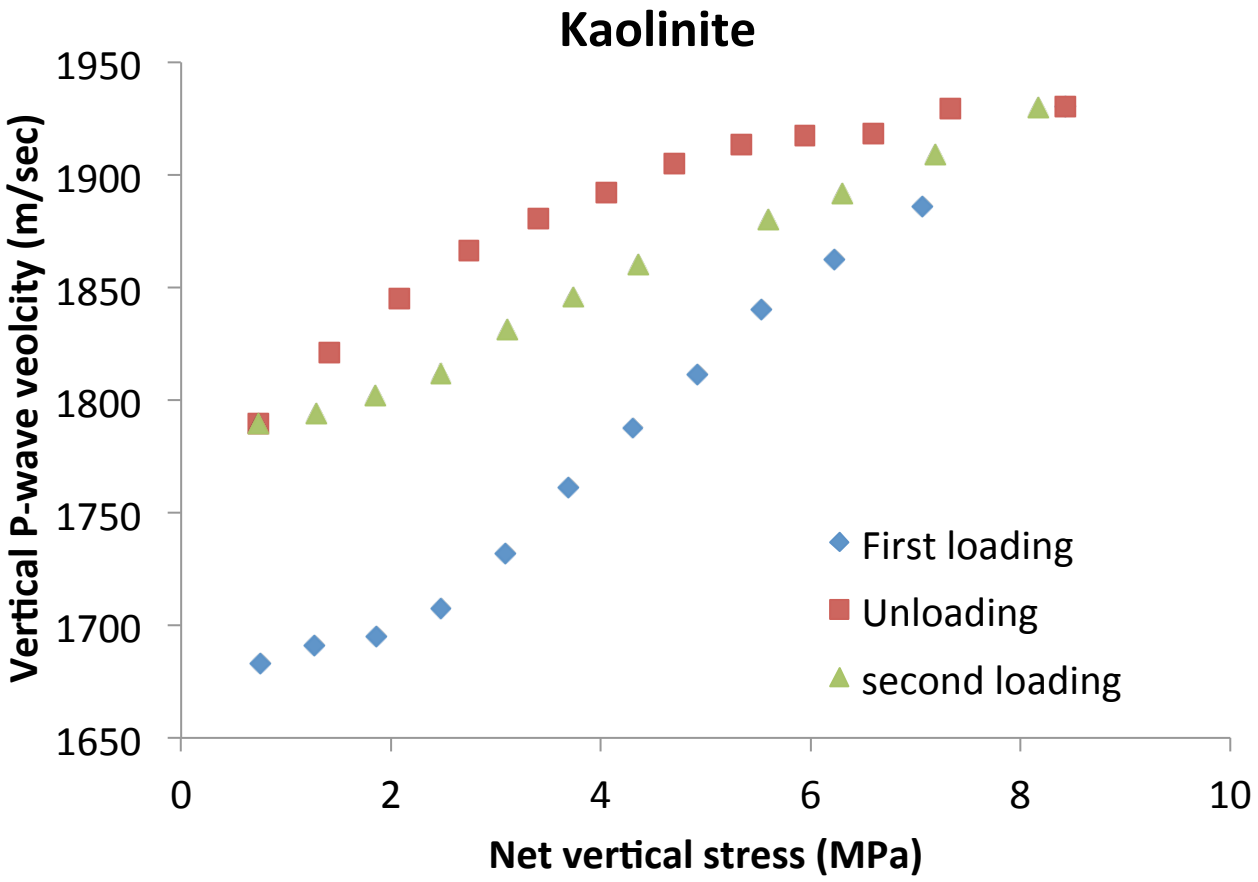
Kaolinite

A Closer Look at Stress History Influence

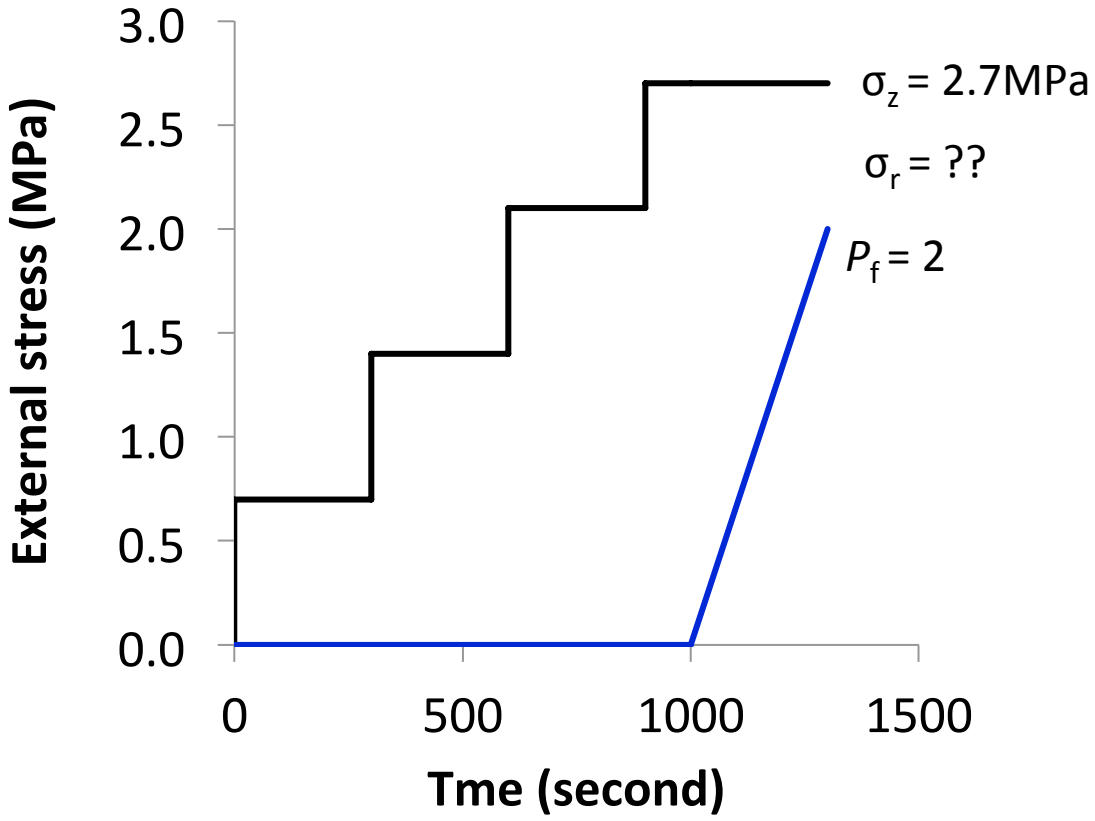


Unloading – Reloading does not causes apparent change in P-wave velocity

Stress Path (Prior to test start): Oedometer

Are the Samples equal?

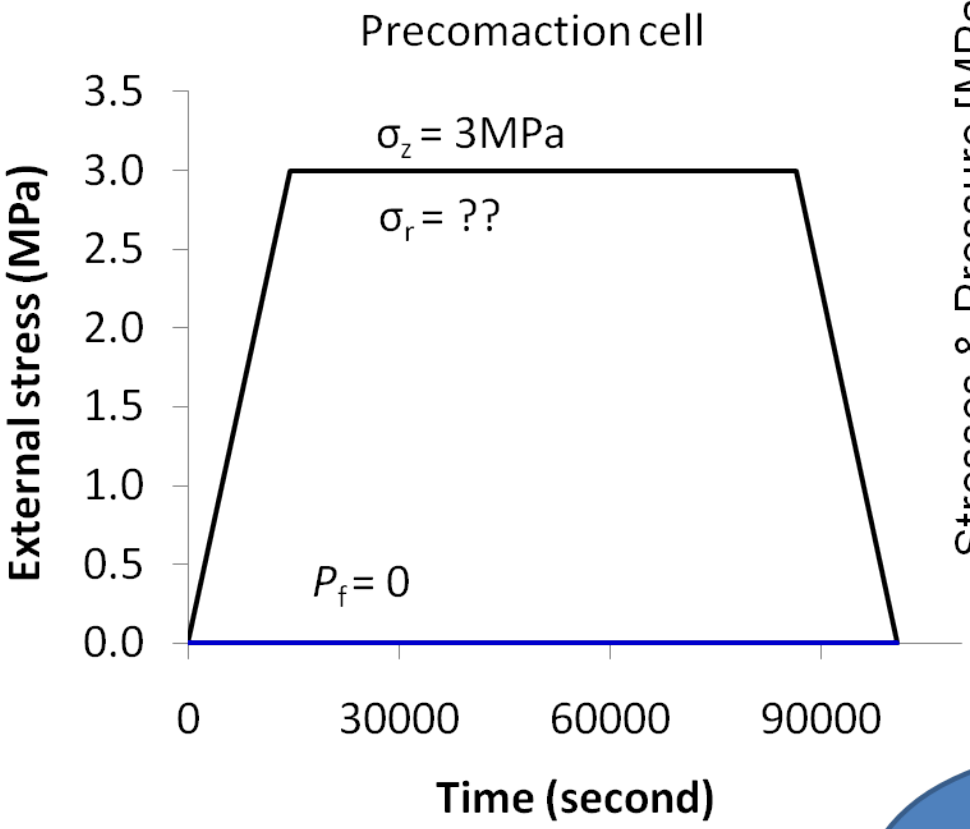
Only for Clay

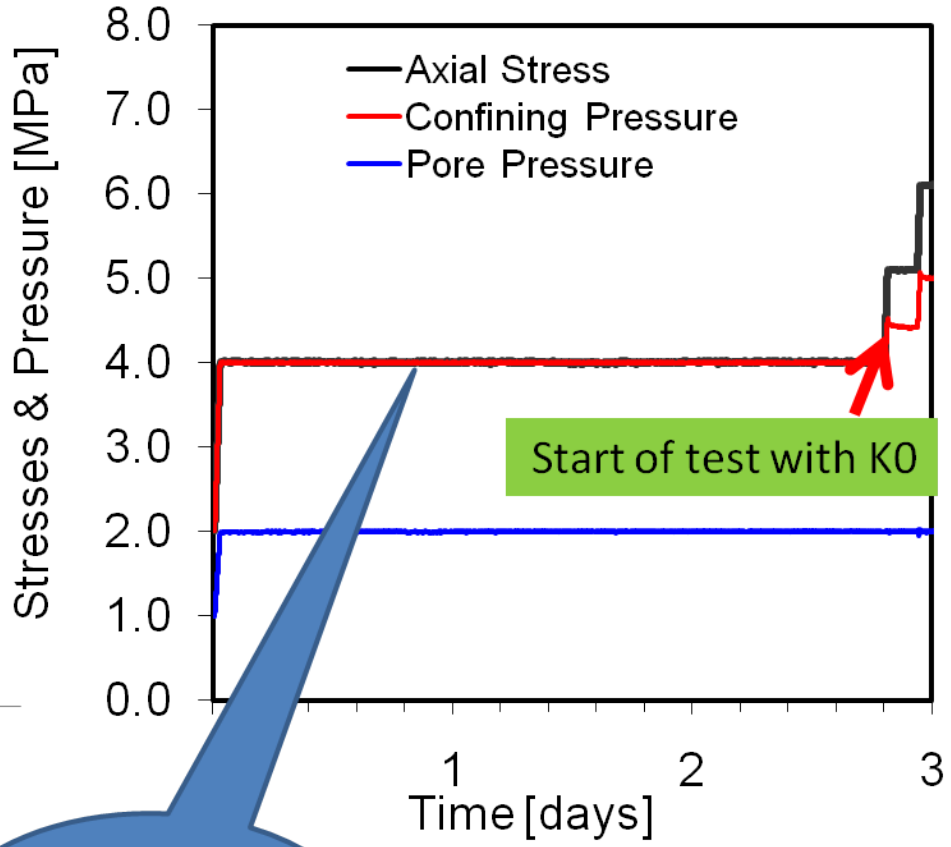


Note: Effective unloading when pore pressure was ramped up to the test level @ 2 MPa

Stress Path (Prior to test start): Triaxial

Are the Samples equal?

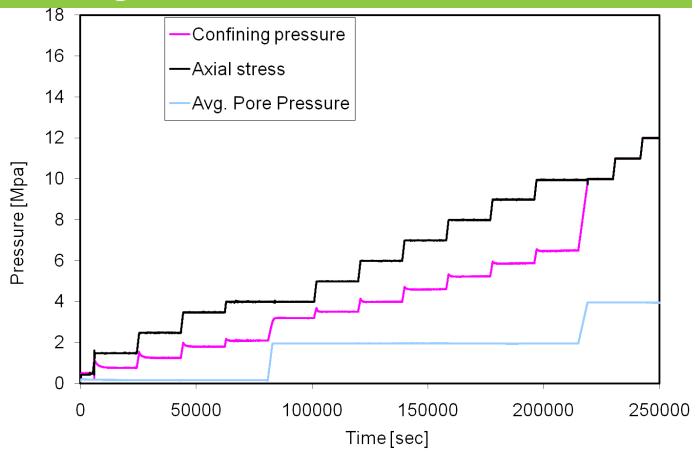


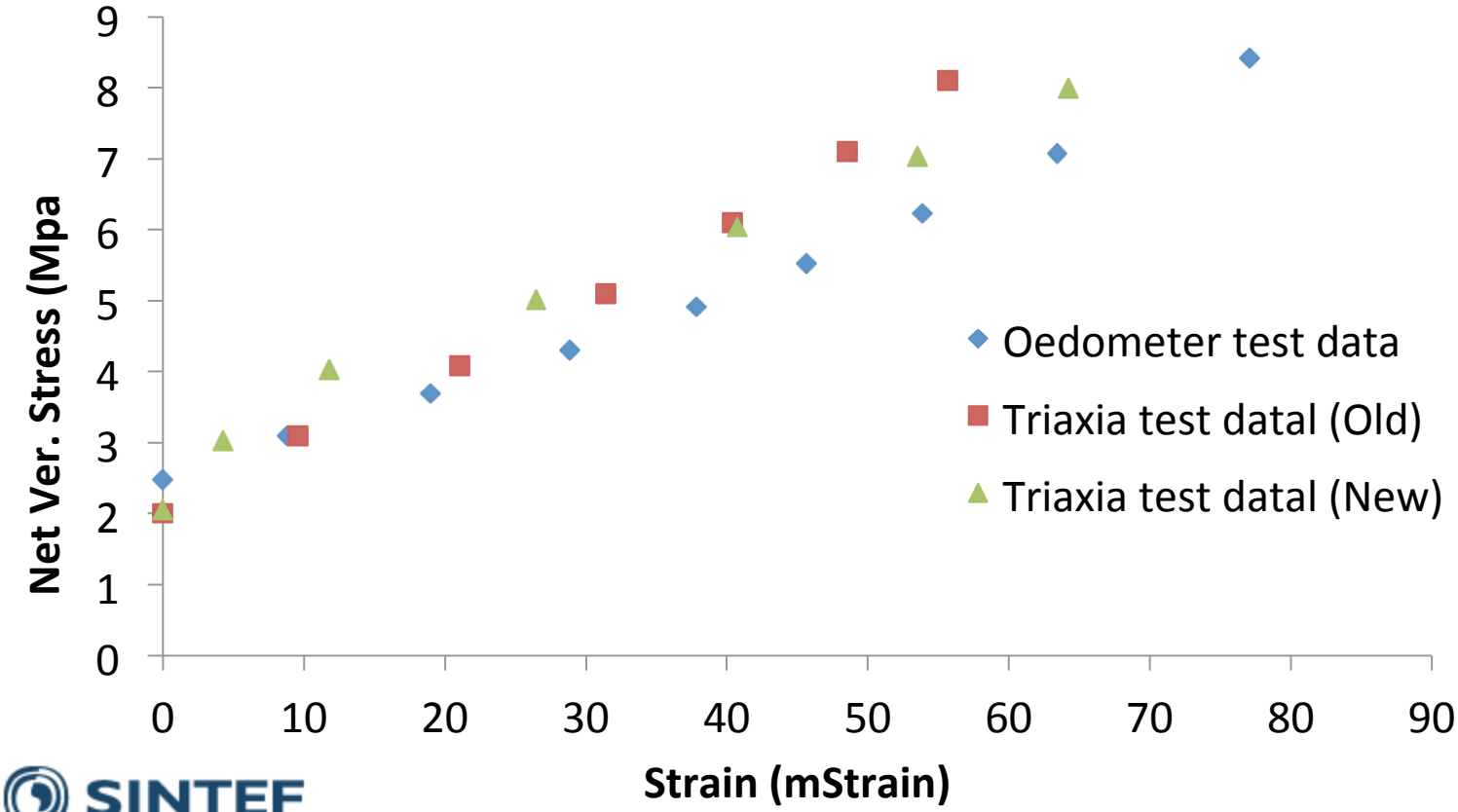


Hydrostatic loading prior start test

New Kaolinite test in Triaxial set-up: K_0 from the start

Static behavior got closer to that measured in the oedometer test, because of less reduced porosity during pre-conditioning of the sample





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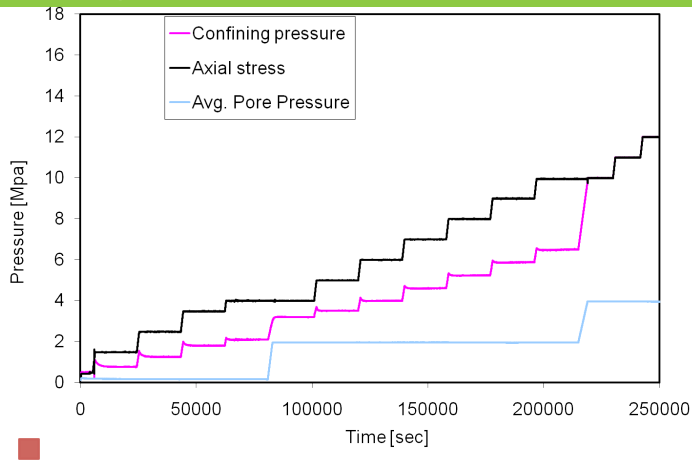
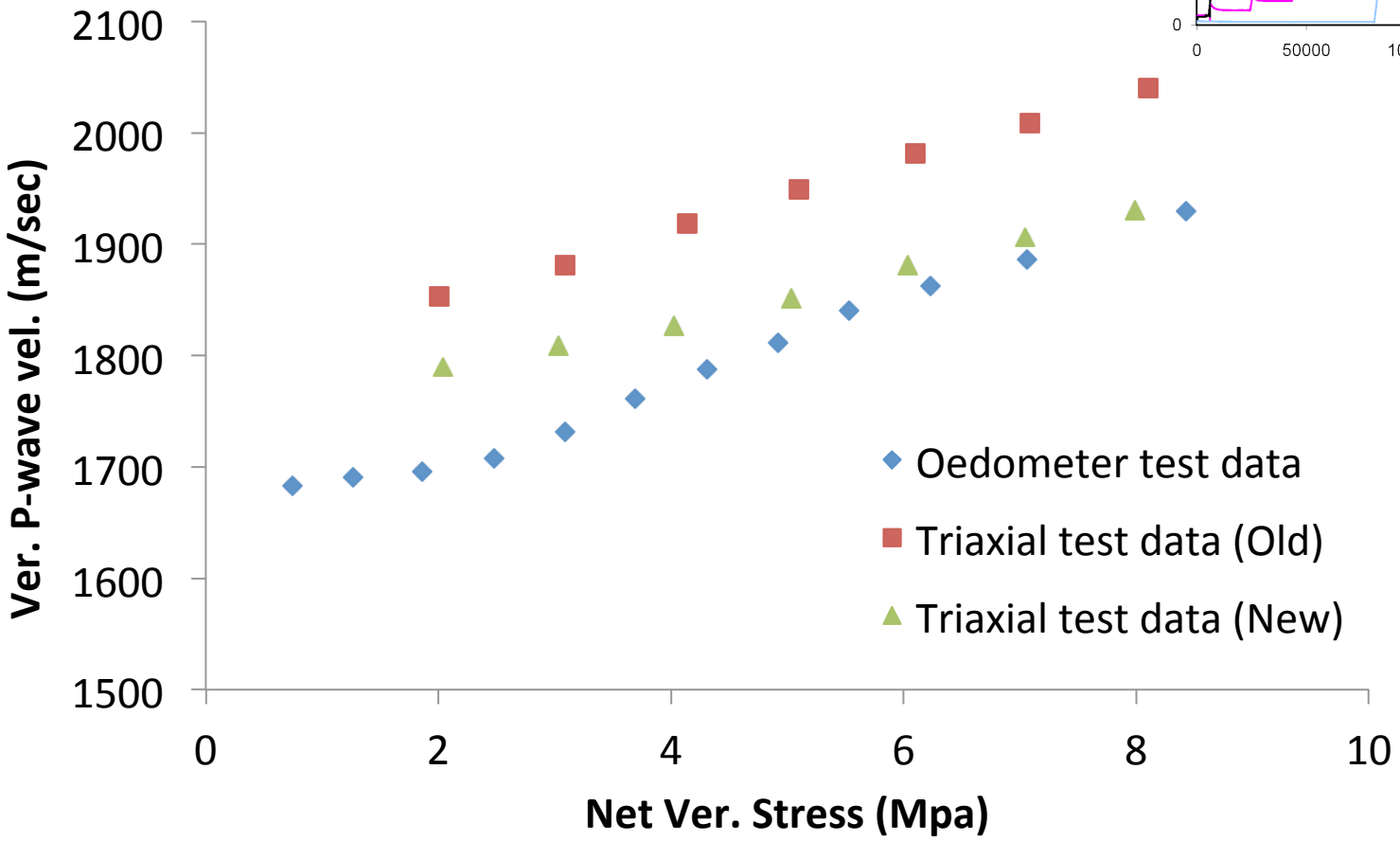
New Kaolinite test in Triaxial set-up: K_0 from the start

Vertical P-wave velocity got closer to that measured in the oedometer test





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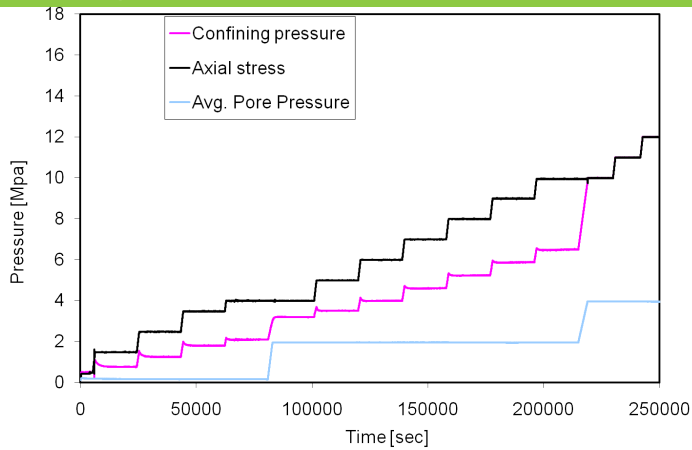
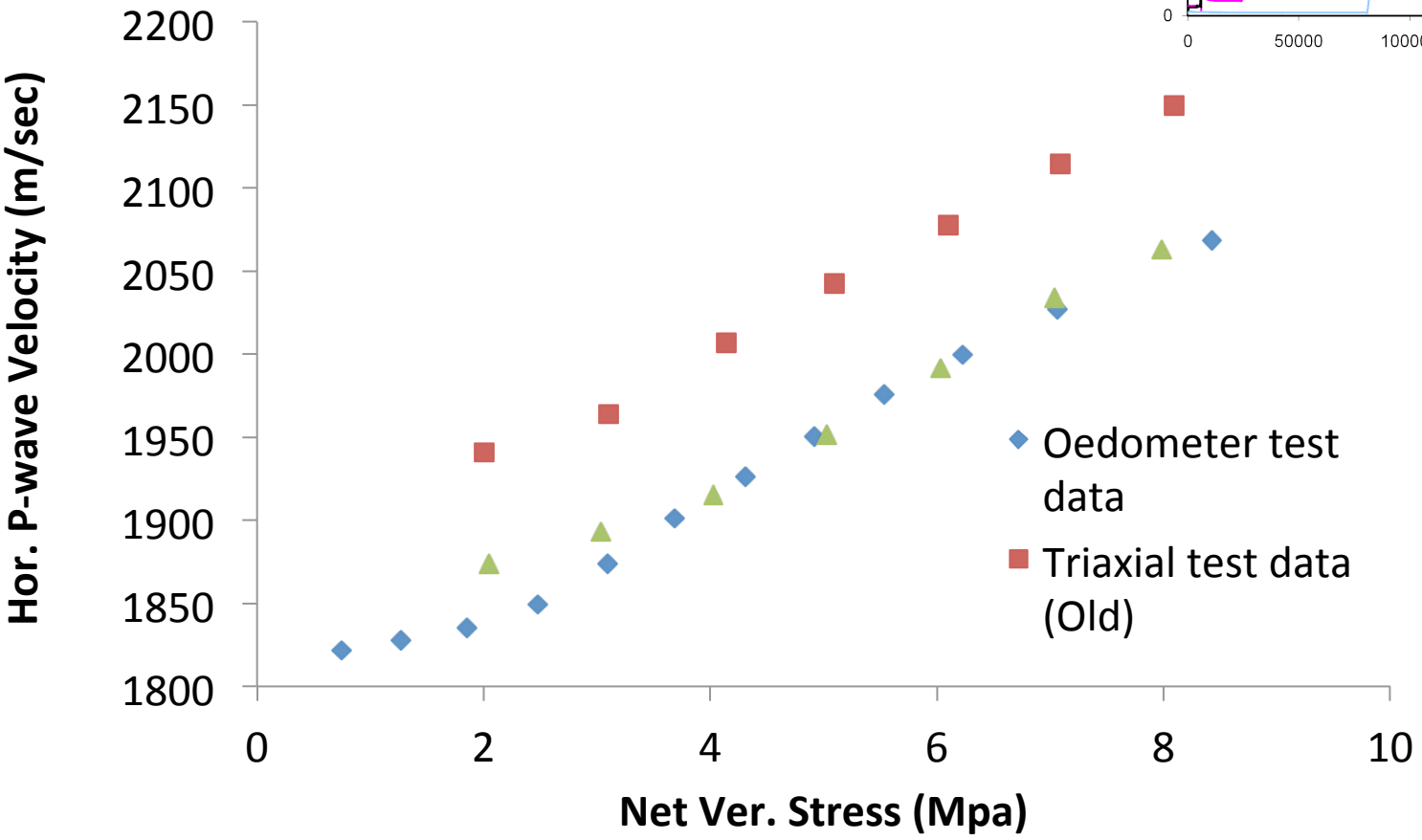
New Kaolinite test in Triaxial set-up: K_0 from the start

Horizontal P-wave velocity got closer to that measured in the oedometer test





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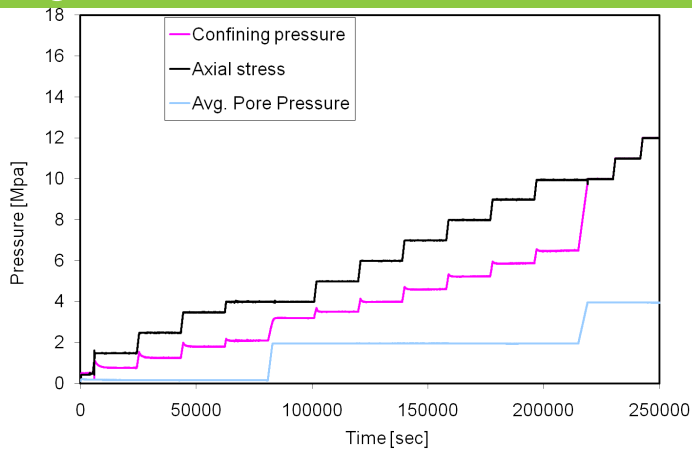
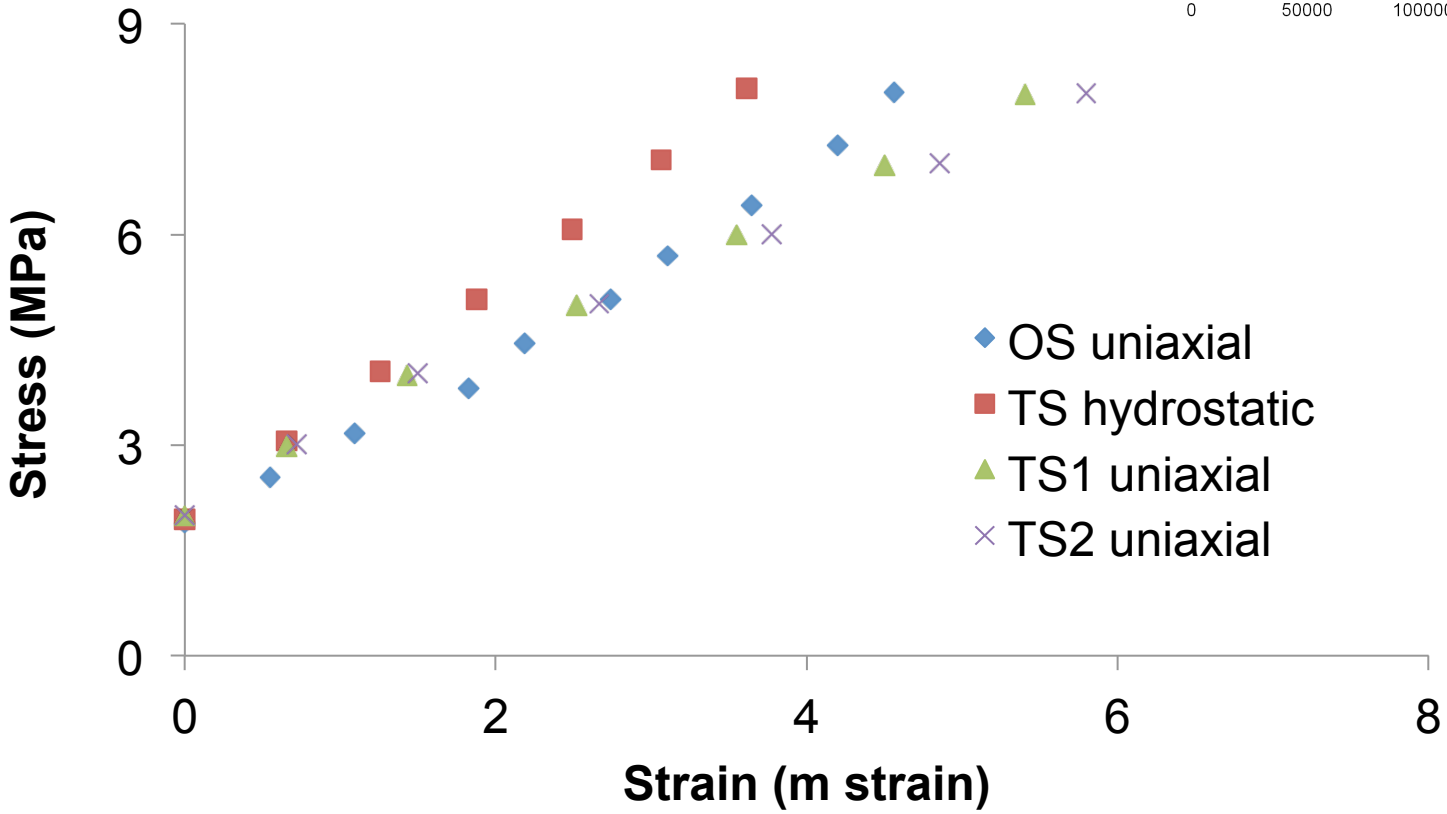
Sand

New Sand test in Triaxial set-up: K_0 from the start

Static behavior got closer to that measured in the oedometer test (to some extent), but deviated at higher stress level





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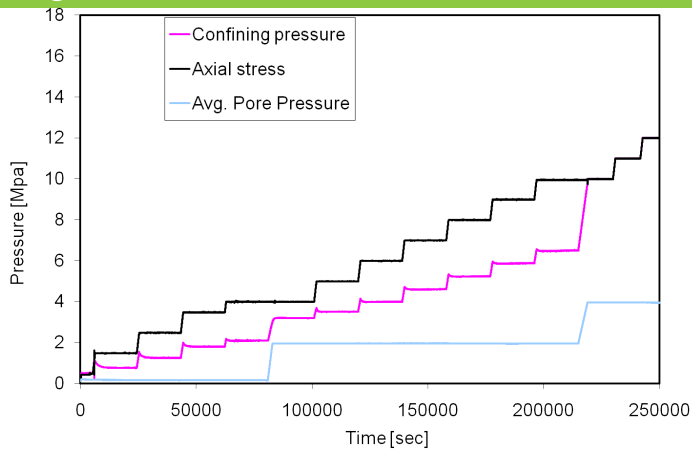
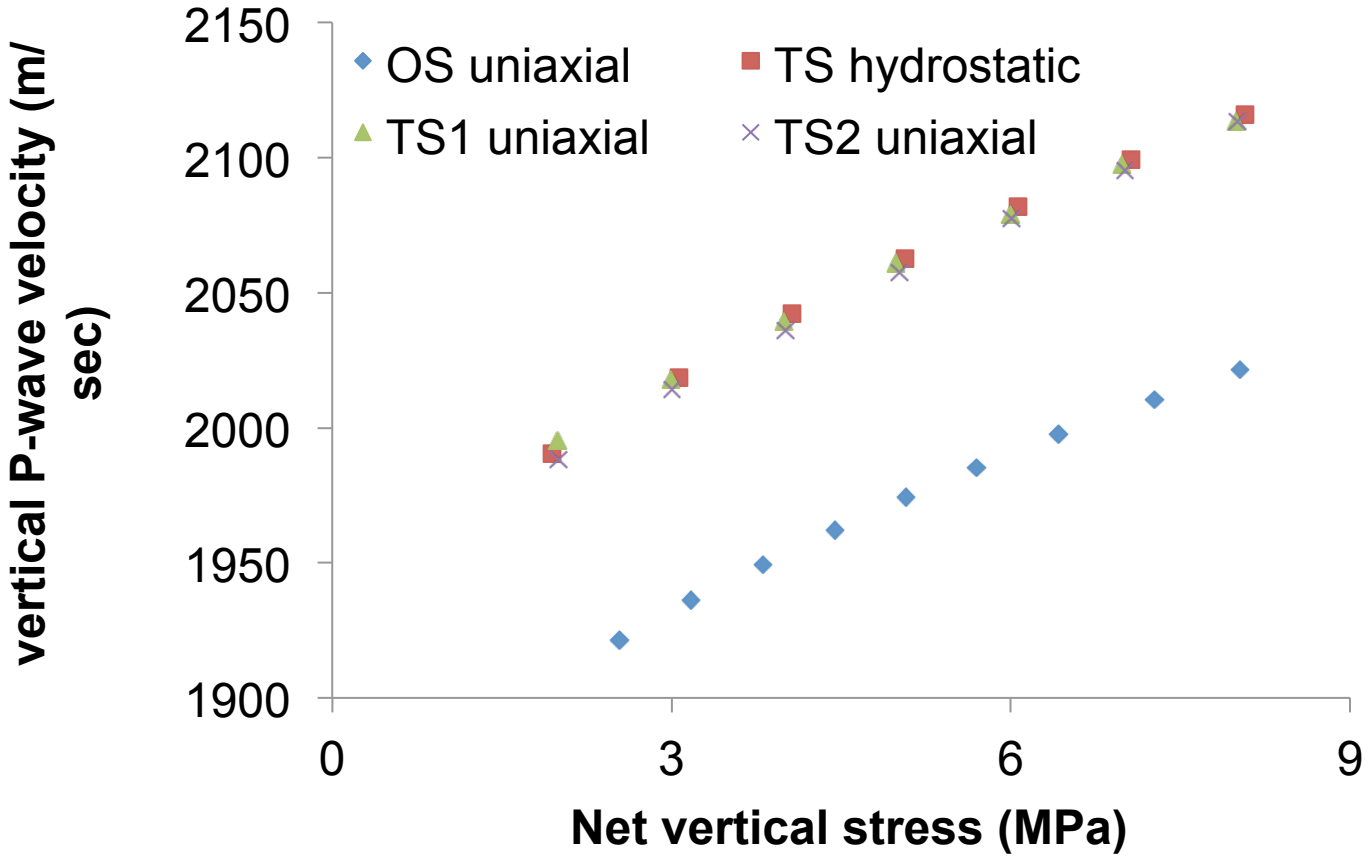
New Sand test in Triaxial set-up: K_0 from the start

P-wave velocity show a perfect match to each other tested in triaxial system and Oedometric velocity still too low





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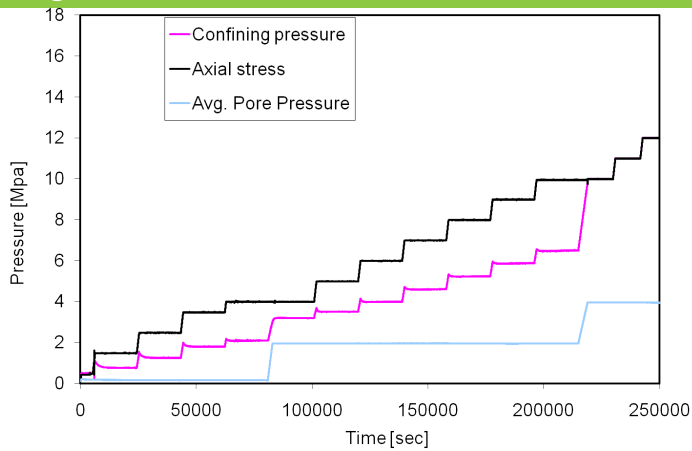

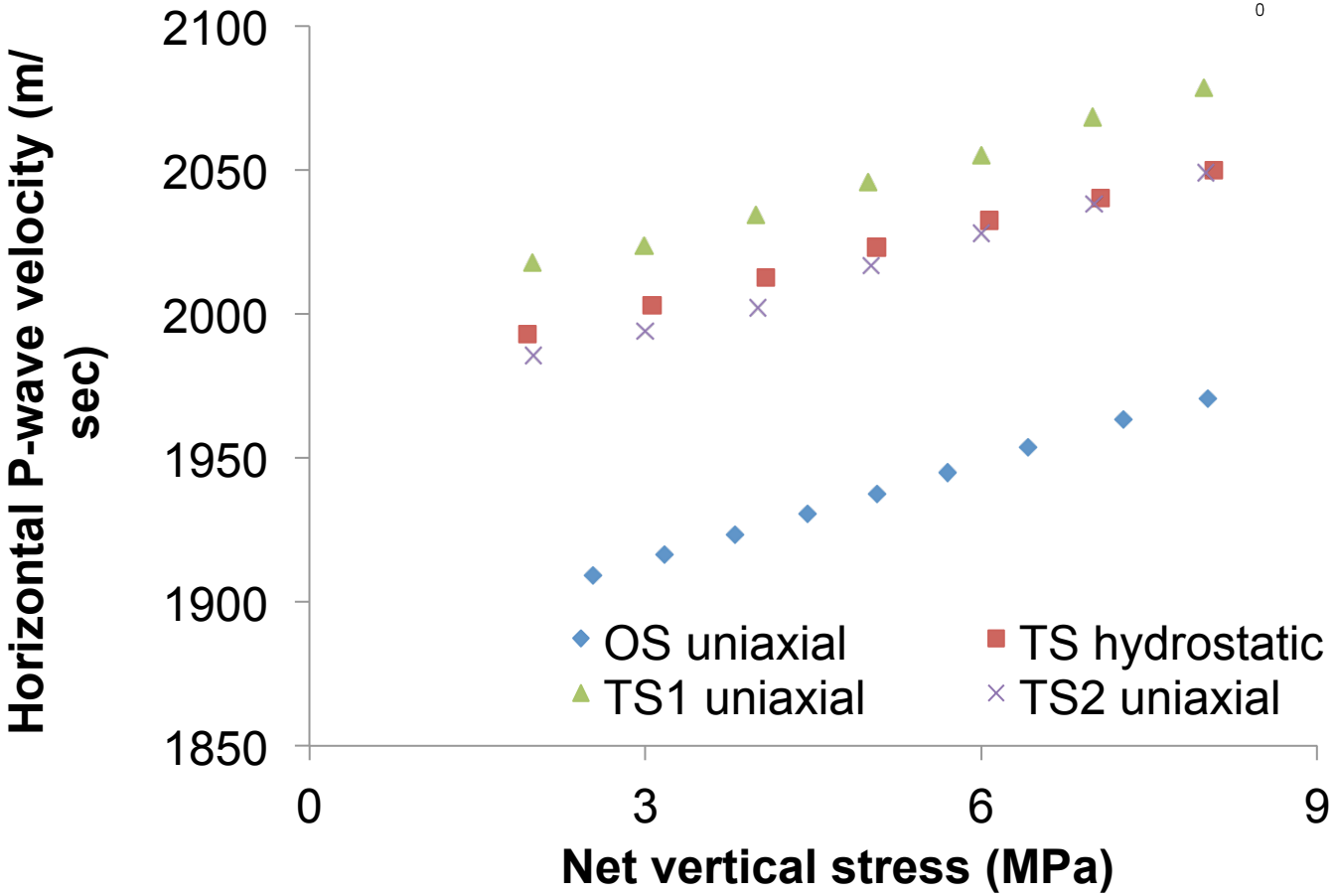

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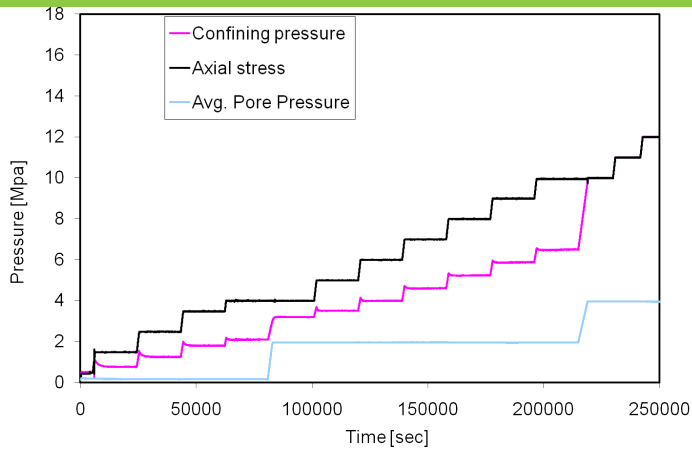
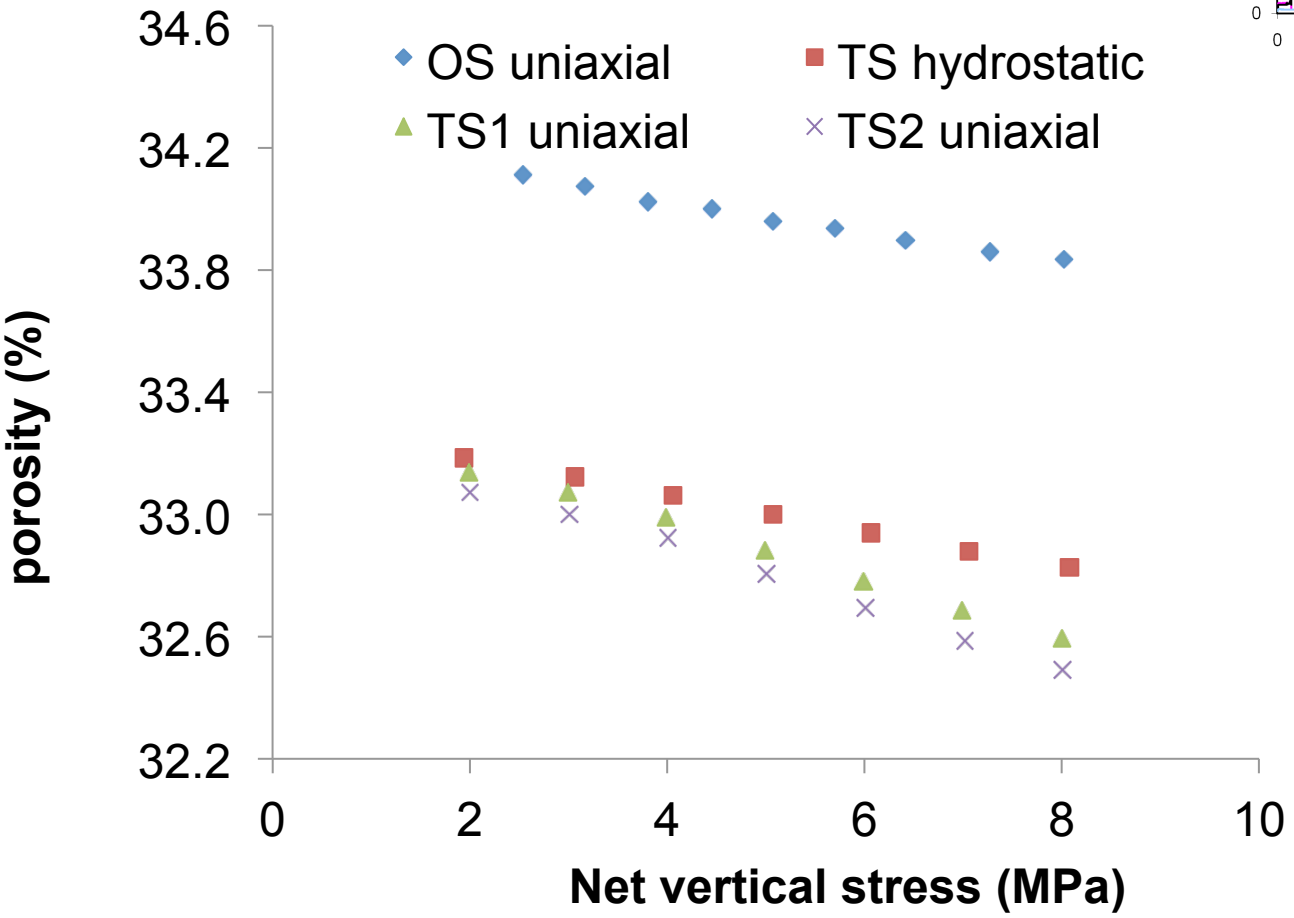
New Sand test in Triaxial set-up: K_0 from the start

Higher porosity for Oedometric test explain the lower P-wave velocities





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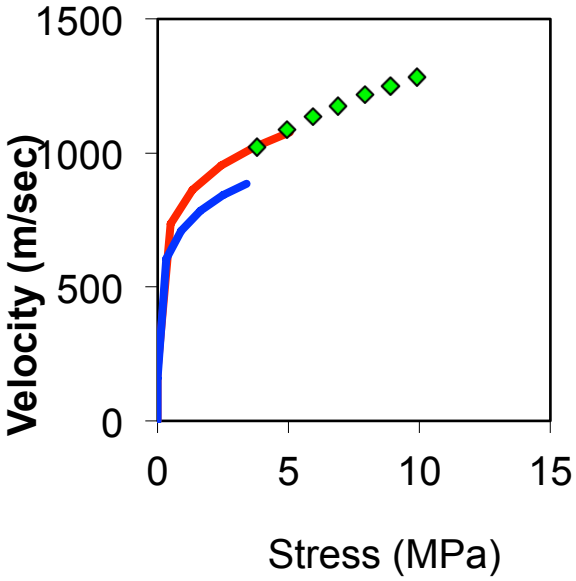
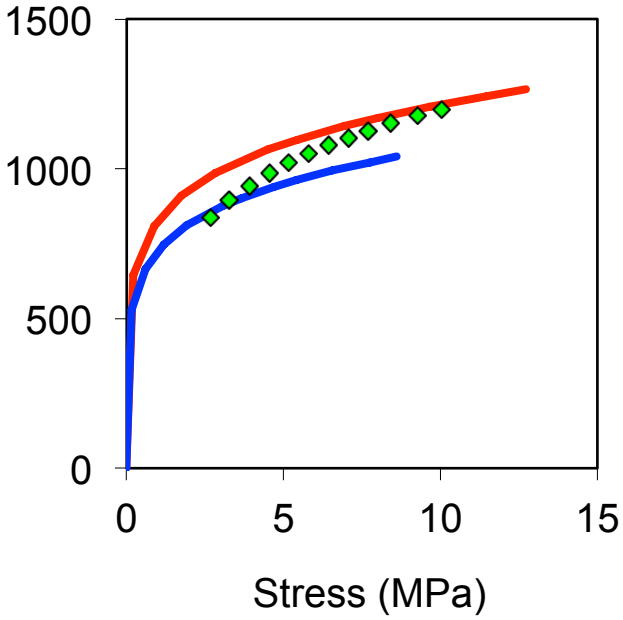
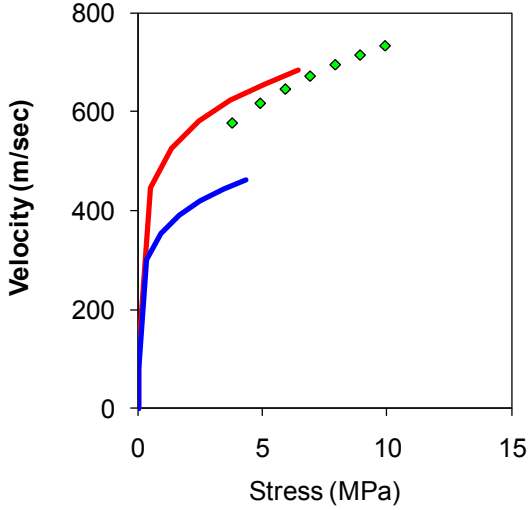
Theoretical Consideration



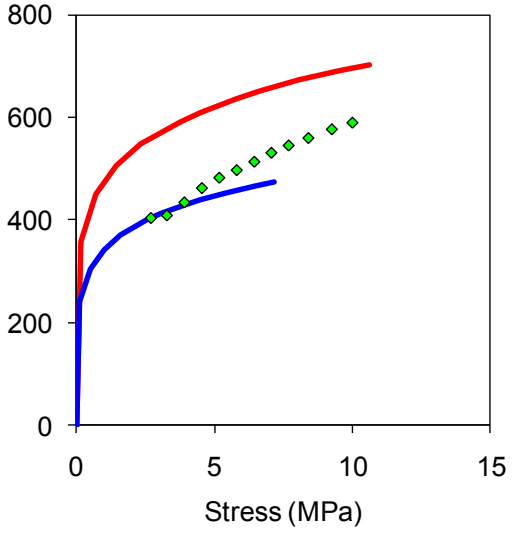
Vertical P-waves

- Velocities are computed for dry velocities by removing the fluid contribution according to Biot-Gassmann
- Walton Grain Contact Model rough and smooth limits are shown (coord. # = 6)
- The enhanced confinement during the pre-conditioning in the triaxial set-up has moved the sand in direction of the rough contact limit





S-waves



Triaxial test system

Uniaxial test system

Conclusions

- ✓ Difference in geometry of the sample does not have influence on wave velocity
- ✓ Precompaction was different in the triaxial and oedometric set-up
  - Complete unloading before testing in triaxial set-up, incomplete effective unloading (with clay) in oedometer
  - Tests in triaxial set-up started from hydrostatic stress causing higher mean stress than in the oedometer
- ✓ Clay specimens were primarily affected by reduced porosity in the triaxial set-up, leading to stiffer static behavior and increased velocities
- ✓ Sand specimens were primarily affected by the increased pre-stress in the triaxial set-up, alteraing the grain contact stiffness and reducing contact slip

Conclusions

- ✓ The sand experiments demonstrate that the static and dynamic response did not depend on the stress path prior to the uniaxial strain test
- ✓ The wave velocities do however depend strongly on the initial degree of compaction of the sand, i.e. on its porosity

Acknowledgement

- ROSE program @ NTNU funded by Norwegian Research Council and sponsoring companies

Thank You

Dynamic Behavior

Prior to exploring the difference in static and dynamic behavior, an obvious question can be raised:

1. Can these differences be explained by the measurement uncertainty?

Answer: Perhaps the horizontal P-velocity can be explained, but not the vertical P- and S- wave velocities

Wave Velocity type @ 8MPa	Vertical P-wave velocity (m/sec)		Horizontal P-wave velocity (m/sec)		Vertical S-wave velocity (m/sec)	
Test system	Oedometric	Triaxial	Oedometric	Triaxial	Oedometric	Triaxial
Pure sand	2021	2092	1971	2032	590	733
Pure Kaolinite	1930	2041	2069	2150	543	656
Uncertainity	±50 m/sec		±85 m/sec		±30 m/sec	