Laboratory Facilities for Measuring the Stress-strain-strength Behaviour of Soils – the State of the Art

土力学室内试验设备与测试研究发展现状

by

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1. Geotechnical Laboratories

- Soil Mechanics Laboratory
  - JH Yin
- Rock Mechanics Laboratory
  - Robina Wong and KT Chau
- Geology Laboratory
  - Robina Wong, KT Chau, HY Lin

2. Rock and Geology Labs

- Rock Mechanics Laboratory
  (a) Large Size Rock Direct Shear Box
  (b) Acoustic Emission Apparatus
  (c) More …

- Geology Laboratory
  Geology info/models and samples
  Best collection of Hong Kong rocks
  Small-scale physical models

3. Soil Mechanics Laboratory

(a) GDS 2Hz Dynamic Triaxial Apparatus: stress-path control and bender elements (added by PolyU) for shear wave velocity measurement

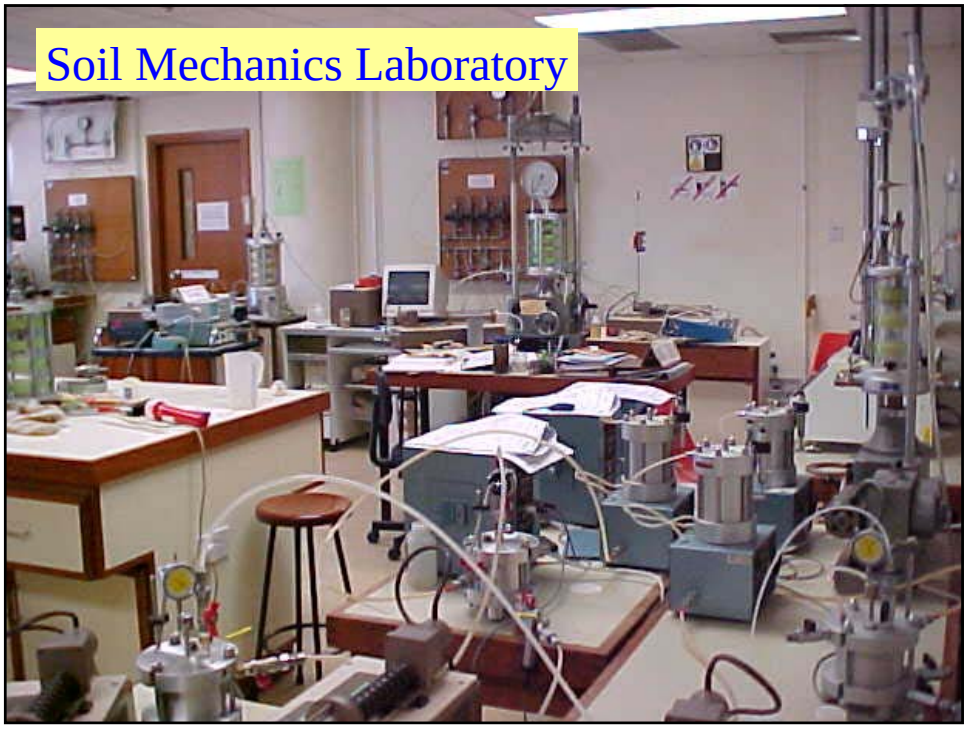
(b) A large-size direct shear box with PolyU modification:
304mm wide x 304mm (or 450mm) long x 204mm high

(c) A new double cell triaxial system: continuous measurement of total volume changes of unsaturated soils in triaxial testing

(d) A Hollow Cylinder Apparatus: control of 4 independent parameters, simulation of pure shearing, the principal stress rotation, …

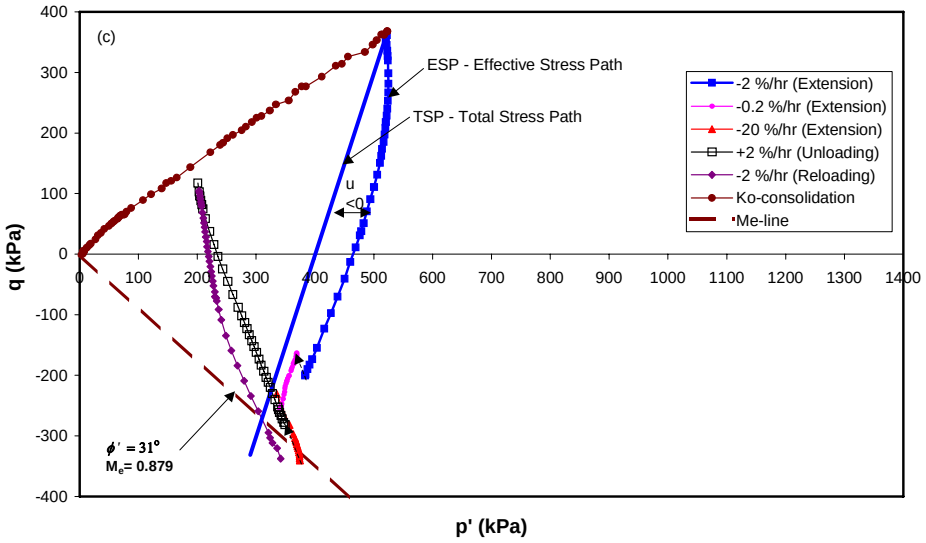
(e) A Truly Triaxial System with PolyU's new sliding loading plates: control of 3 principal stresses, study of middle principal influence …

(f) An innovative soil nail pullout box: for studying the interface shear strength between nail and soils under various controlled conditions



GDS 2Hz Dynamic Triaxial Apparatus – stress-path control and bender elements for shear wave velocity measurement

(b) Failure of specimen C400 after K_o-consolidated compression testing and (c) failure of specimen E400 after K_o-consolidated extension testing



Effective stress paths for test E400 – K_o-consolidation, step-changed axial extension and unloading/reloading

4. Large-size Direct Shear Box Tests on Interfaces and Findings

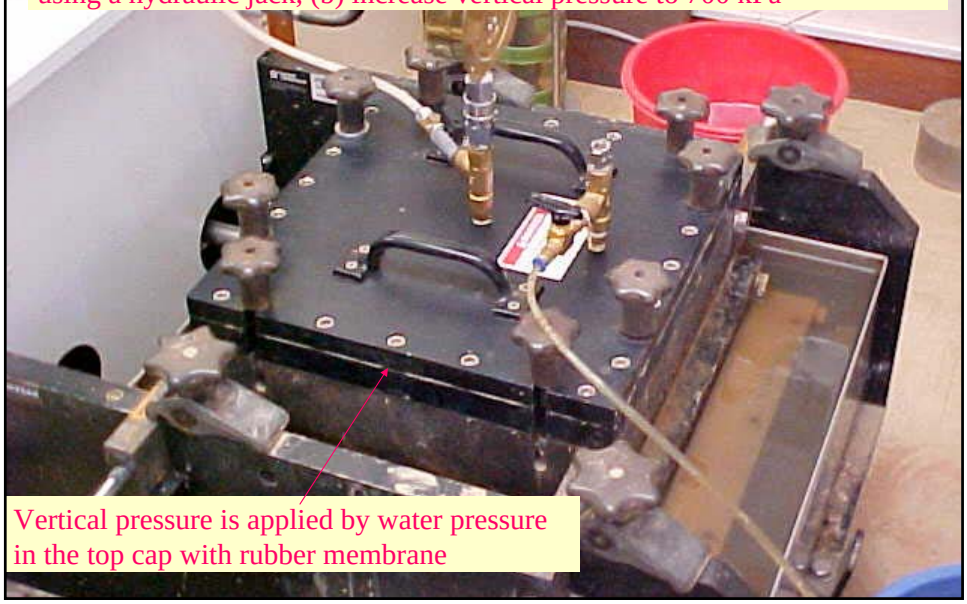
(a) Between metallic strips and fill

(b) Between geo-synthetics and fill

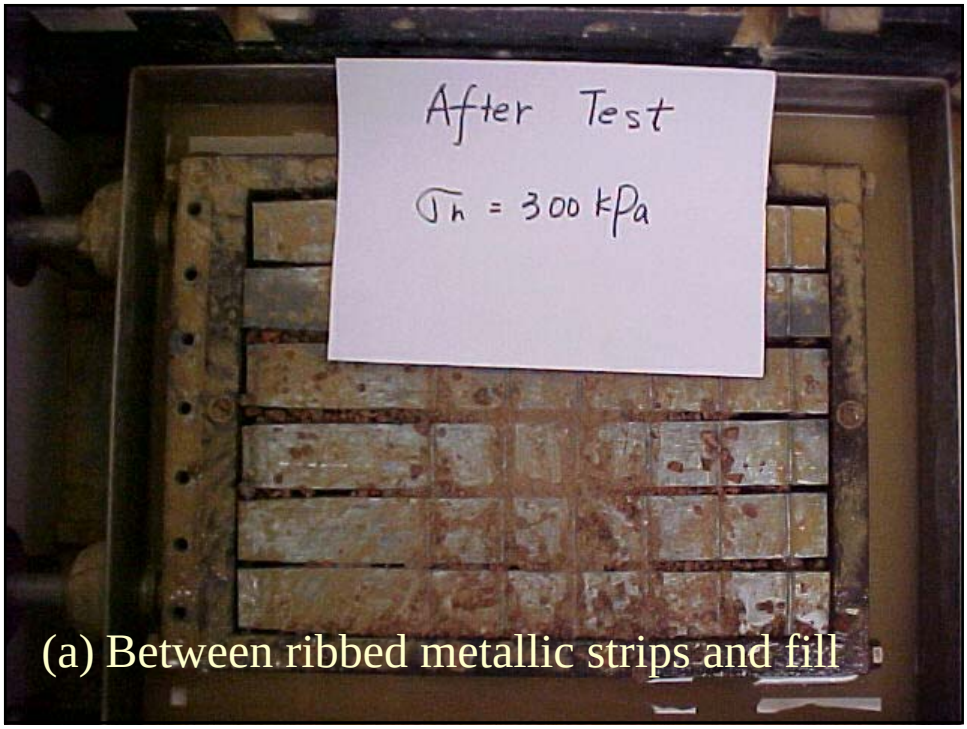
(c) Between pre-cast cement grout and soil

(d) Between cement grout and soil

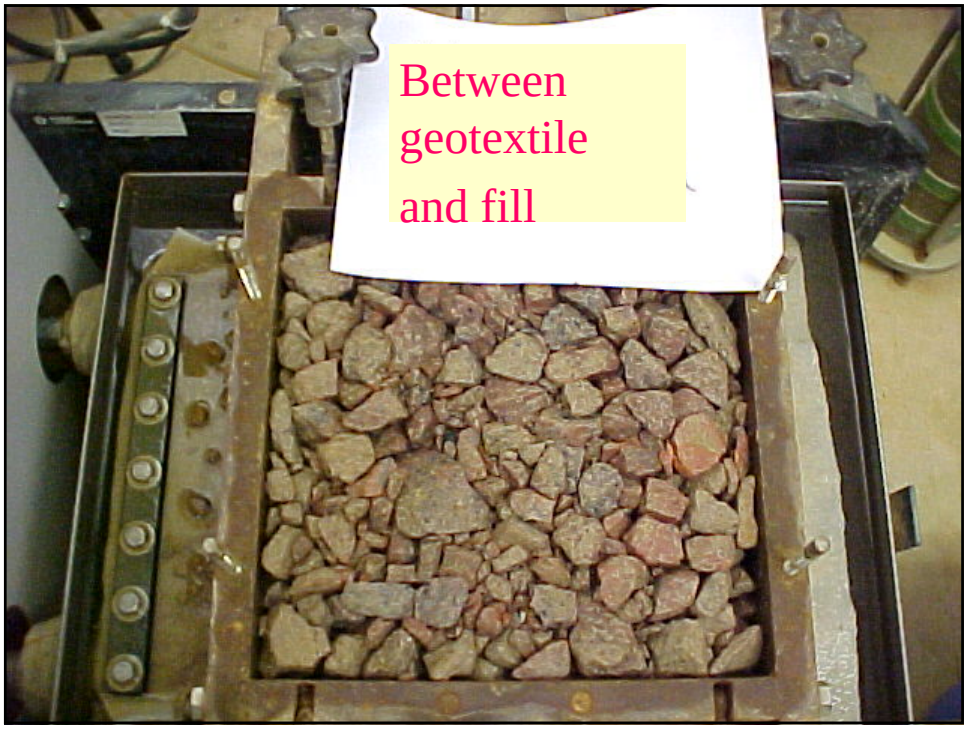
Large-size direct shear box： 304mm wide x 304mm (or 450mm) long x 204mm high - (a) increase horizontal load capacity using a hydraulic jack, (b) increase vertical pressure to 700 kPa

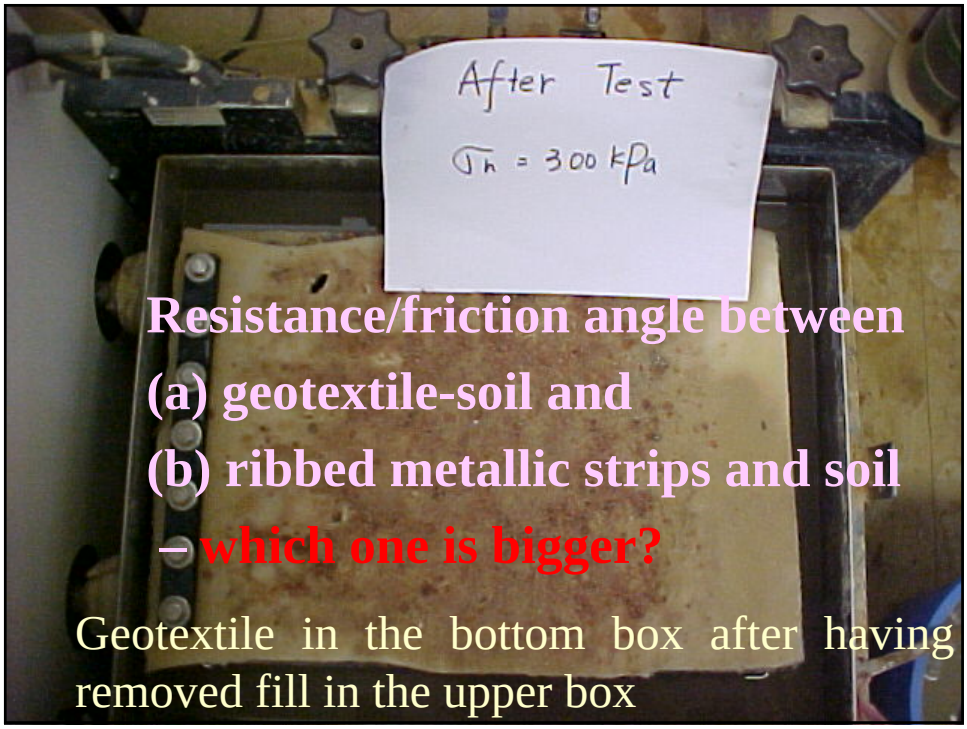


Vertical pressure is applied by water pressure in the top cap with rubber membrane



(a) Between ribbed metallic strips and fill





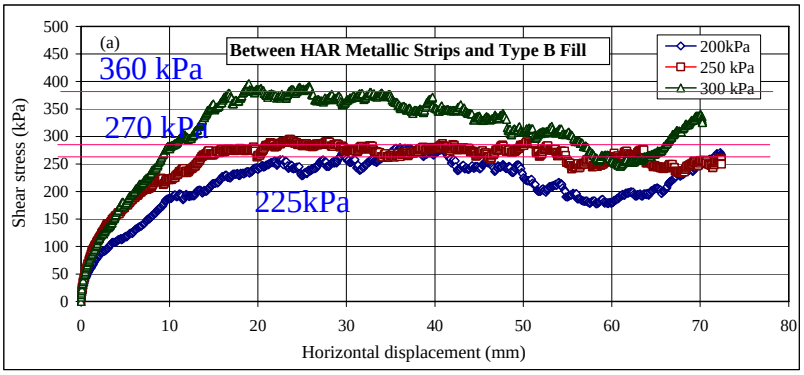
Resistance/friction angle between

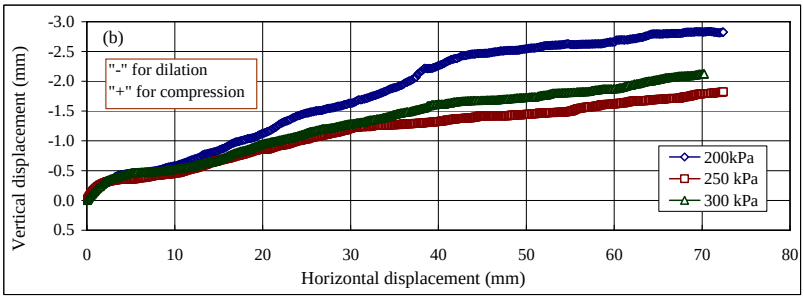
(a) geotextile-soil and

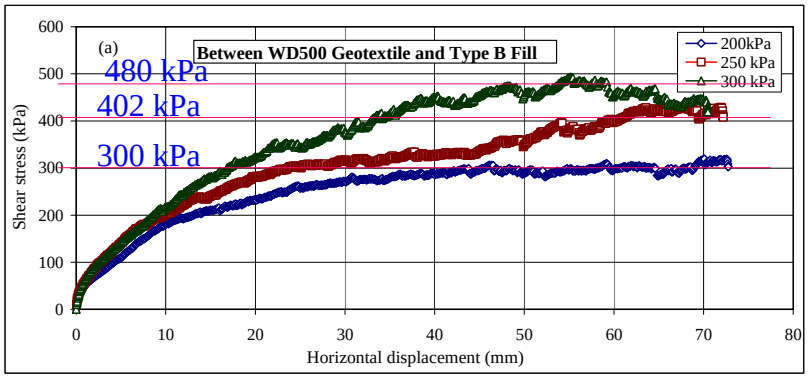
(b) ribbed metallic strips and soil

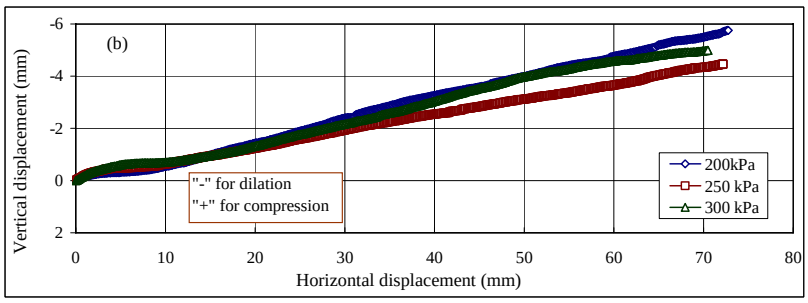
– which one is bigger?

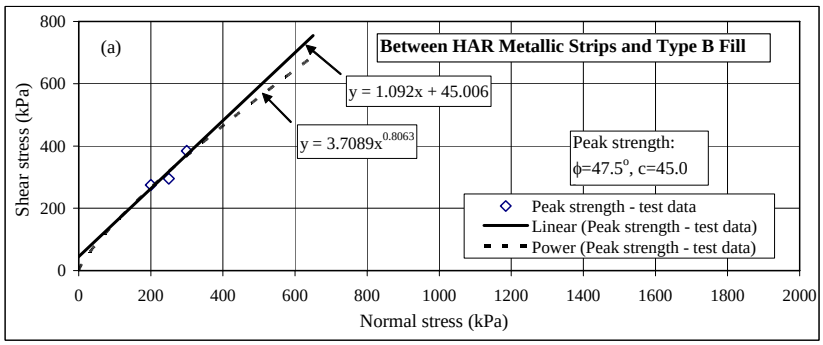
Geotextile in the bottom box after having removed fill in the upper box

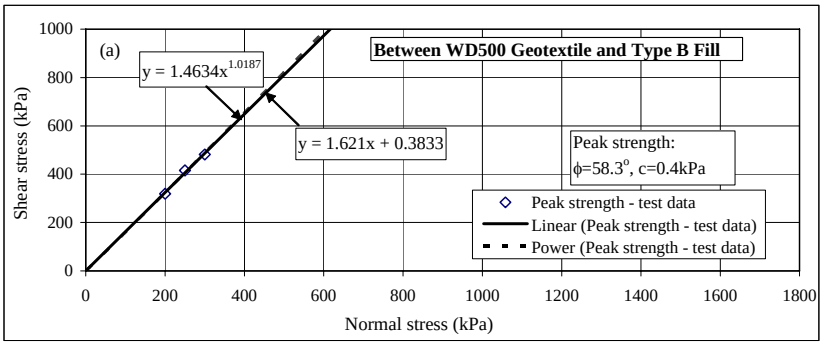

(a)
Between HAR Metallic Strips and Type B Fill
360 kPa
270 kPa
225kPa
200kPa
250 kPa
300 kPa
Shear stress (kPa)
Horizontal displacement (mm)


(b)
"-" for dilation
"+" for compression
200kPa
250 kPa
300 kPa
Vertical displacement (mm)
Horizontal displacement (mm)


(a)
Between WD500 Geotextile and Type B Fill
480 kPa
402 kPa
300 kPa
200kPa
250 kPa
300 kPa
Shear stress (kPa)
Horizontal displacement (mm)


(b)
"-" for dilation
"+" for compression
200kPa
250 kPa
300 kPa
Vertical displacement (mm)
Horizontal displacement (mm)





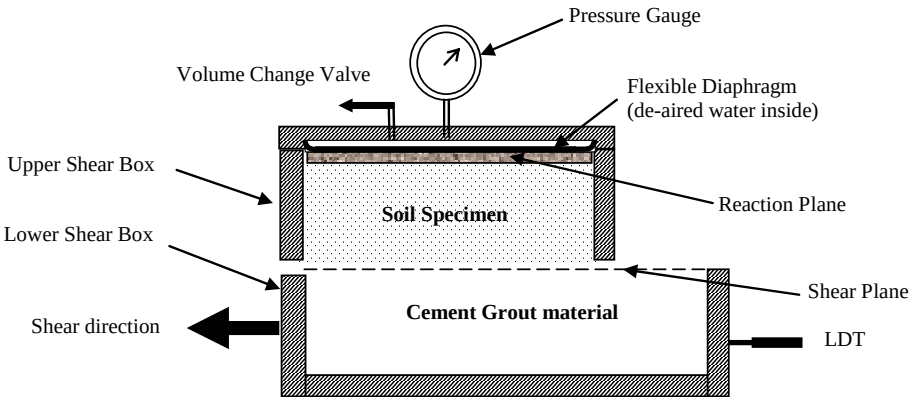
Comparison and Why:

(a) Between ribbed metallic strips and fill – smaller friction angle due to sliding on the metallic strips

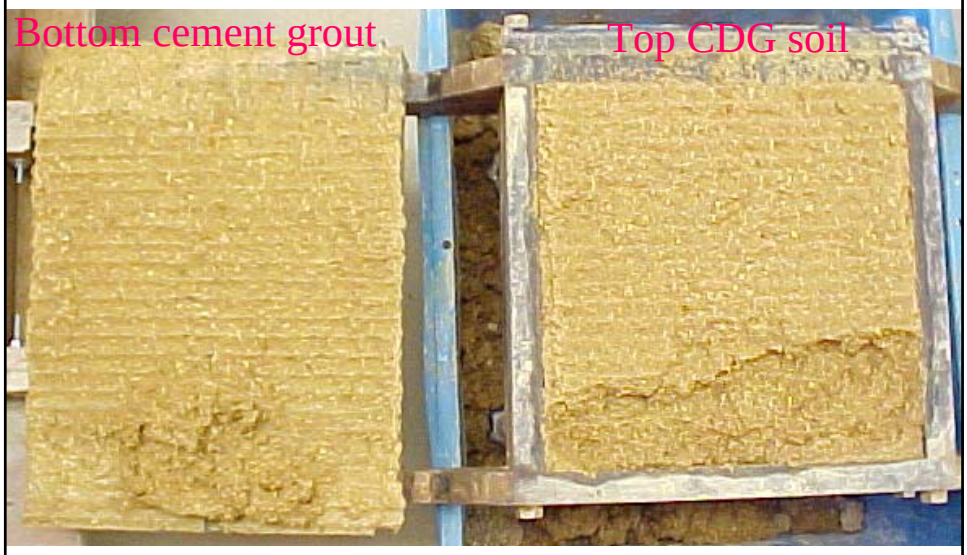
(b) Between geo-textile and fill – higher frictional angle – interlocking of particles which penetrate through the geo-textile

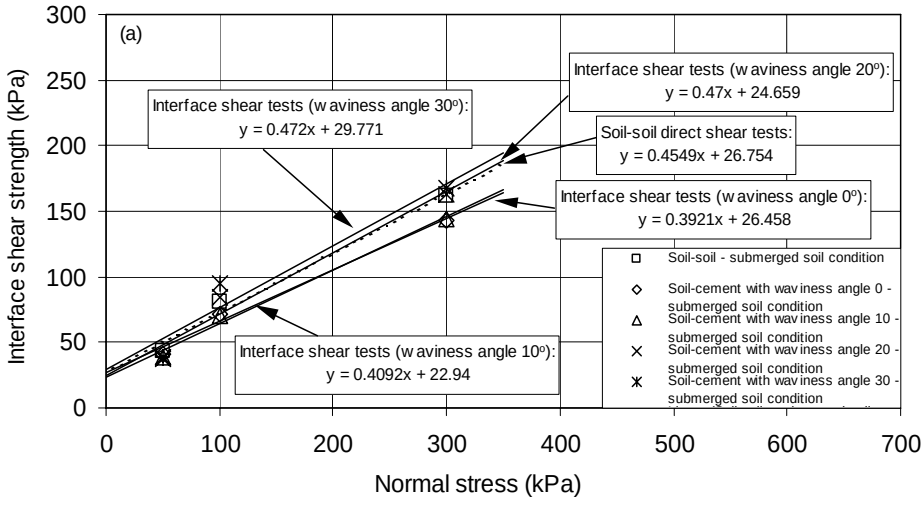
(c) Test results give you the fact !

(c) Between cement grout and soil –
grouted/cast-in-place pile/nail and soil interface



(c) Between cement grout and soil –
grouted/cast-in-place pile/nail and soil interface





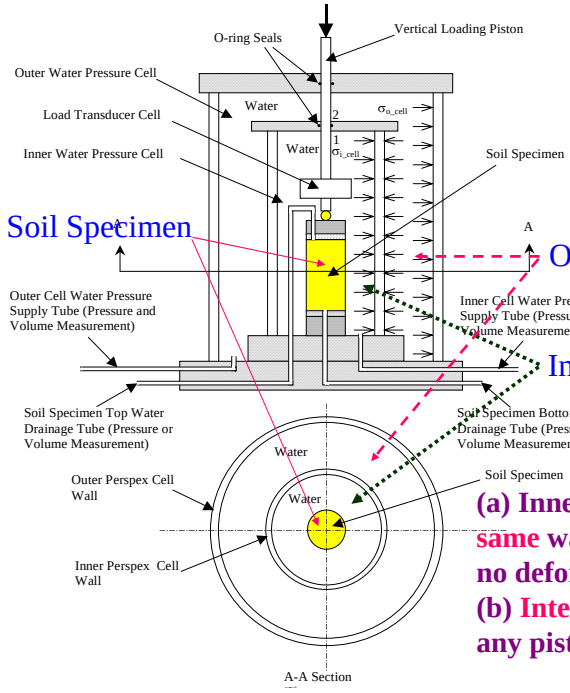
Comparison of shear strength parameters between the soil-soil direct shear tests and the soil-grout interface shear tests of different waviness angles in the submerged condition – peak shear strength and

5. A New Double Cell Triaxial System

(a) Continuous measurement of total volume changes of unsaturated soils in triaxial testing – PolyU's contribution

(b) Calibrations: How ? Results?

(c) Applications to test CDG soils



New double cell triaxial system for unsaturated soil testing

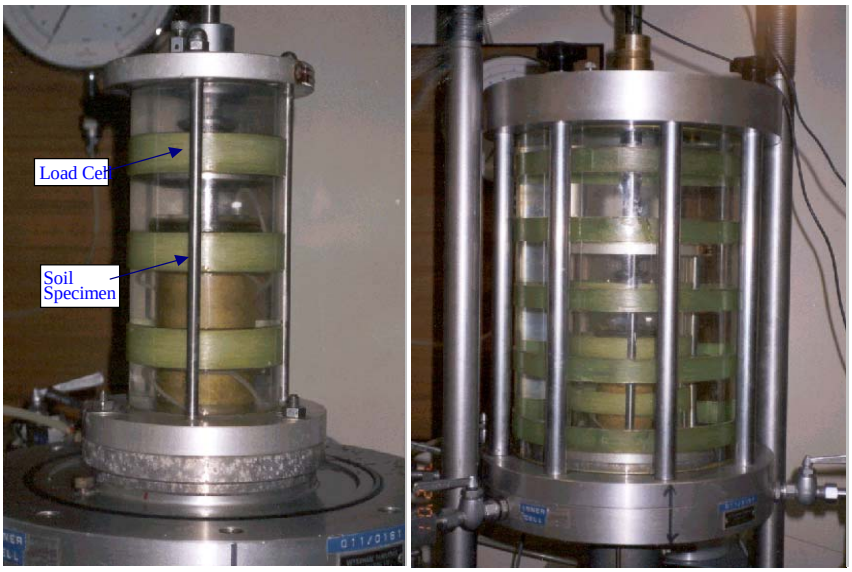
Outer Cell Water

Inner Cell Water

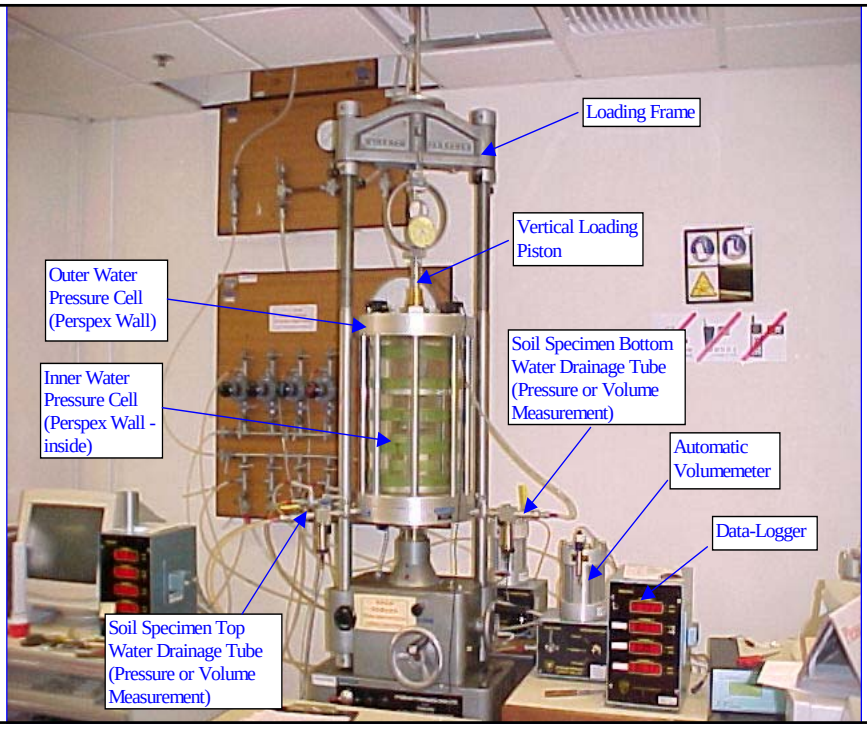
为什没要双室?

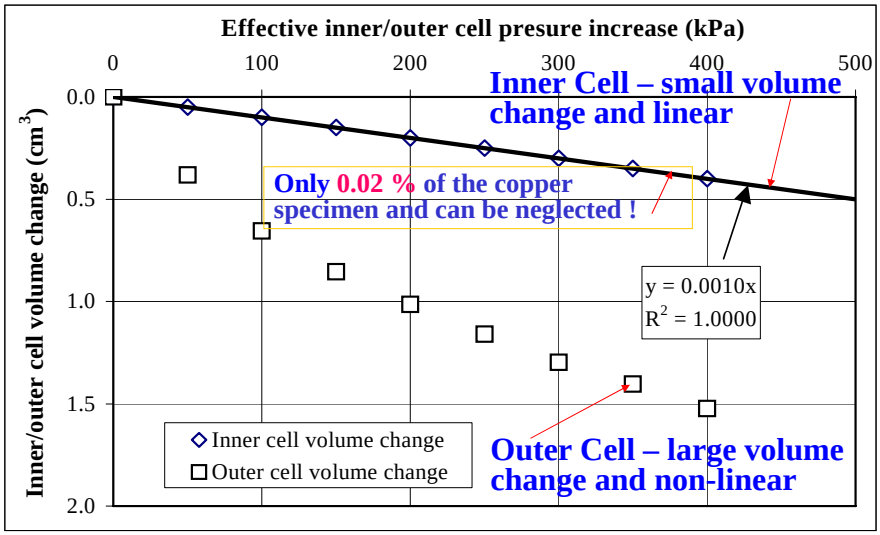
(a) Inner cell is fully balanced by the same water pressure – no leaking and no deformation of perspex cell wall

(b) Internal load cell is used to avoid any piston friction influence

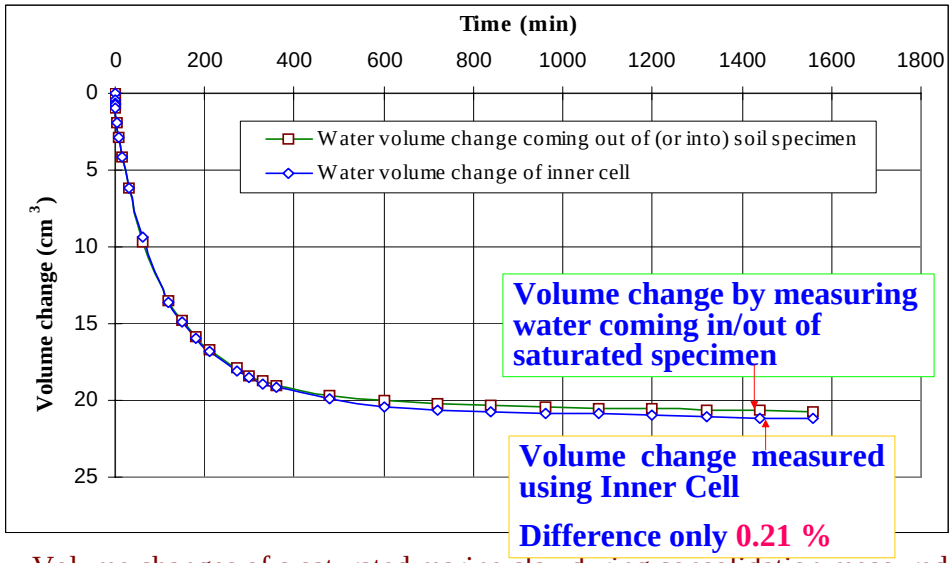


(a) Left photo - a close-up view of the inner cell (left) and (b) right photo - a close-up view of the outer cell (right)

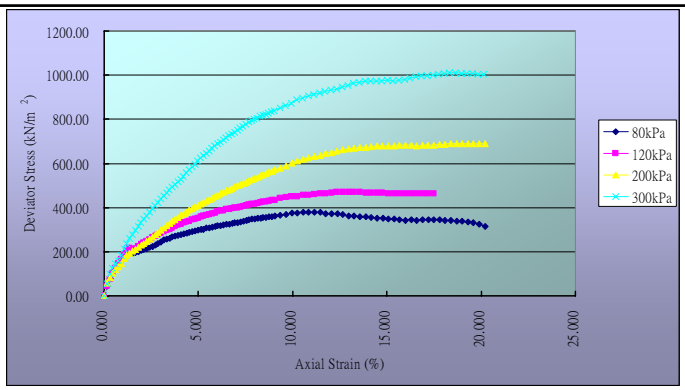


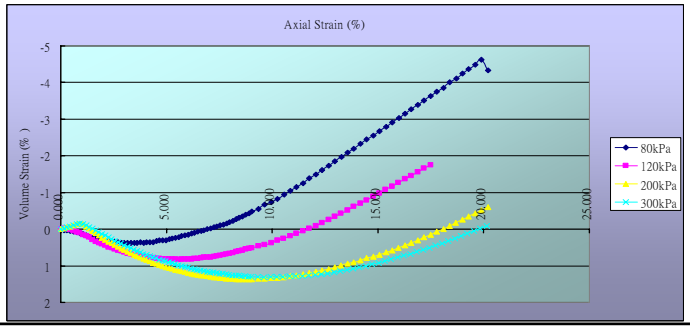


Volume changes of a **copper specimen** under isotropic compression measured by the changes of (a) water volume of the inner cell and (b) the water volume of the outer cell with back pressure equal to 100kPa and the specimen drainage valve closed (Yin 2002a,b)



Volume changes of a saturated marine clay during consolidation measured by the changes of (a) the water coming out of (or into) the clay specimen and (b) water volume of the inner cell (Yin 2002a,b)





Double Cell Triaxial compression tests on a CDG soil with initial degree of saturation of 35%

6. A Hollow Cylinder Apparatus (HCA) for Soil Testing

For measuring the behaviour of a hollow soil specimen (100mm height by 100mm external diameter by 50mm inner diameter) under conditions of

(a) pure shearing

(b) plane strain

(c) rotation of the principal stress

(d) influence of the middle principal stress

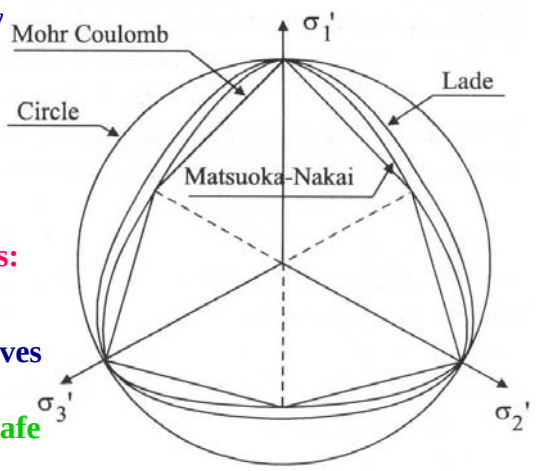
(e) …

Development of failure criteria and constitutive models

Extension to/study in a general stress space: advanced lab facilities are needed

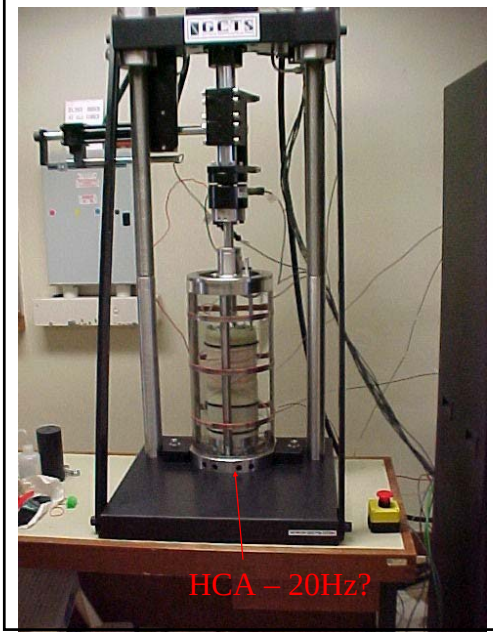
Useful to engineers:

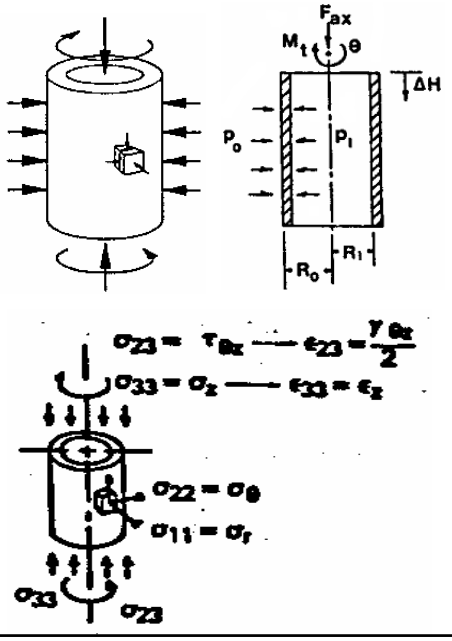
Mohr-Coulomb failure criterion gives more conservative strength – on the safe side !



Failure surfaces in π–plane

Hollow Cylinder Apparatus (HCA): control of **4** independent parameters





7. A Truly Triaxial System (TTS) for Soil Testing

For measuring the behaviour of a "brick" soil specimen (70mm by 70mm by 140mm) under conditions of

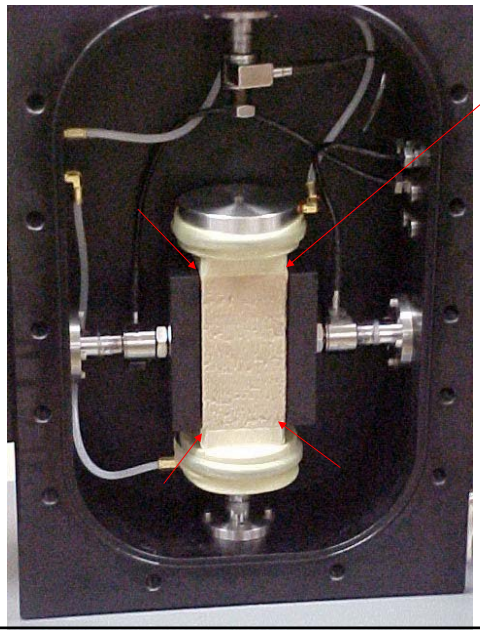
(a) plane strain,

(b) influence of the middle principal stress

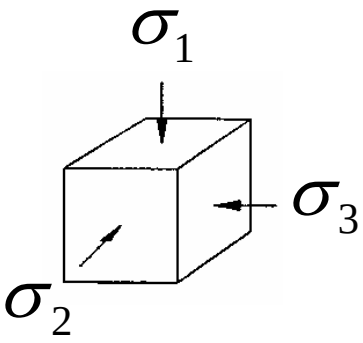
(c) …

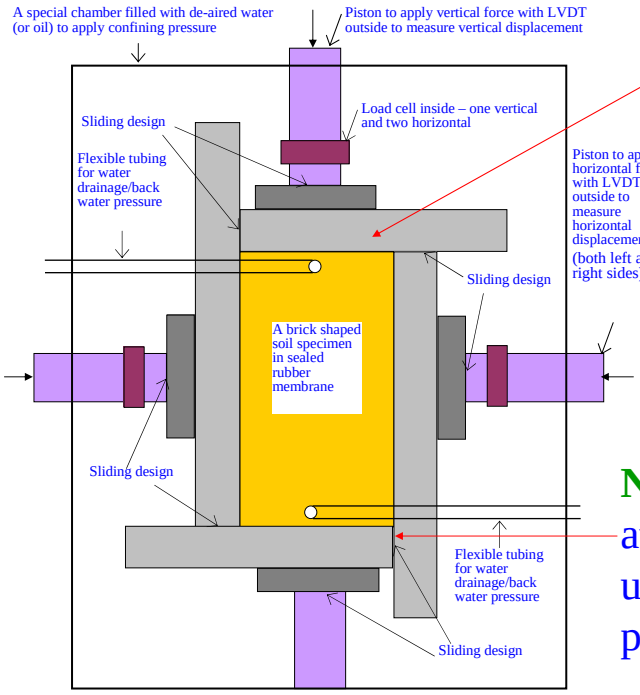
Development of **new sliding loading plates** and setup

Truly Triaxial System (TTS): control of **3** independent parameters



Problems:
Interference at the corners
(a) non-uniform stresses
(b) small compression





New sliding loading plates and setup

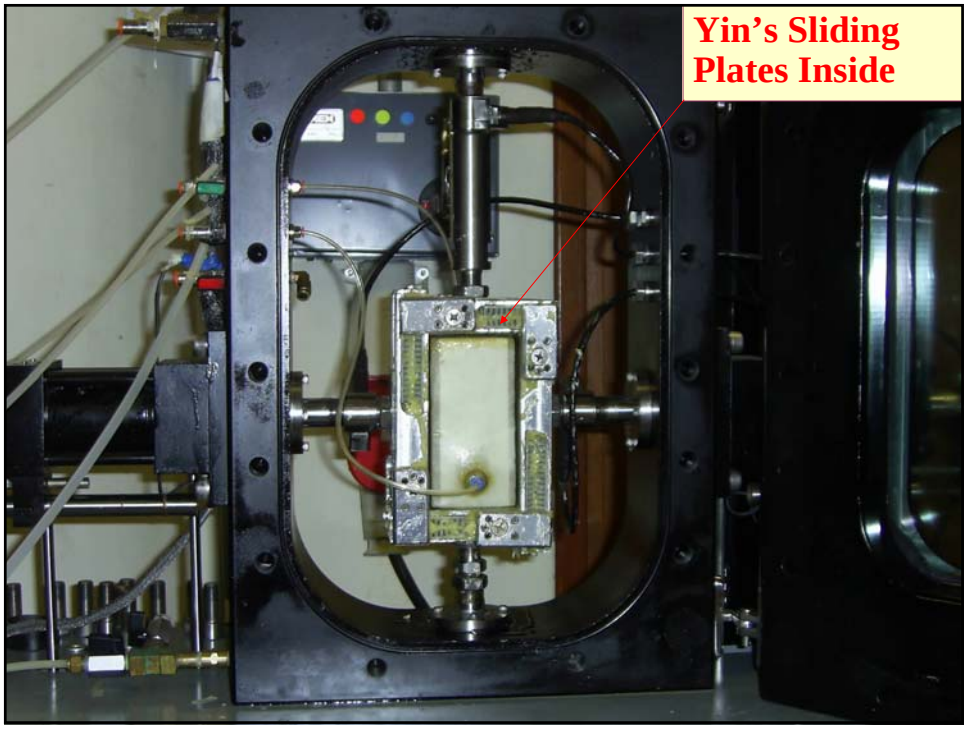
创新的设计

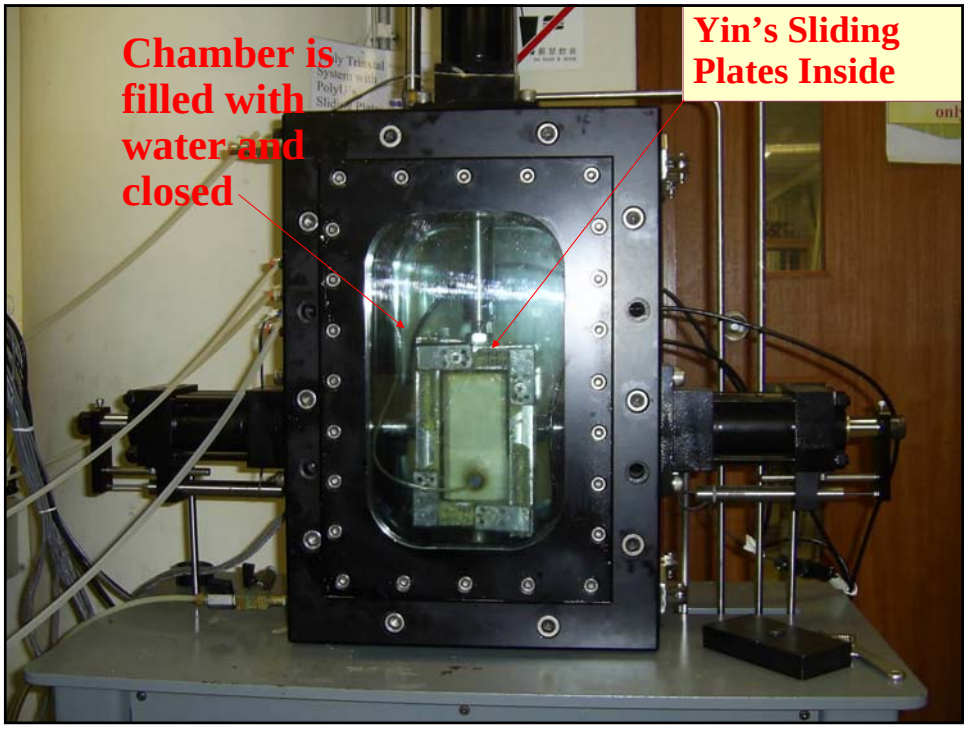
No Interference at the corners using sliding plates

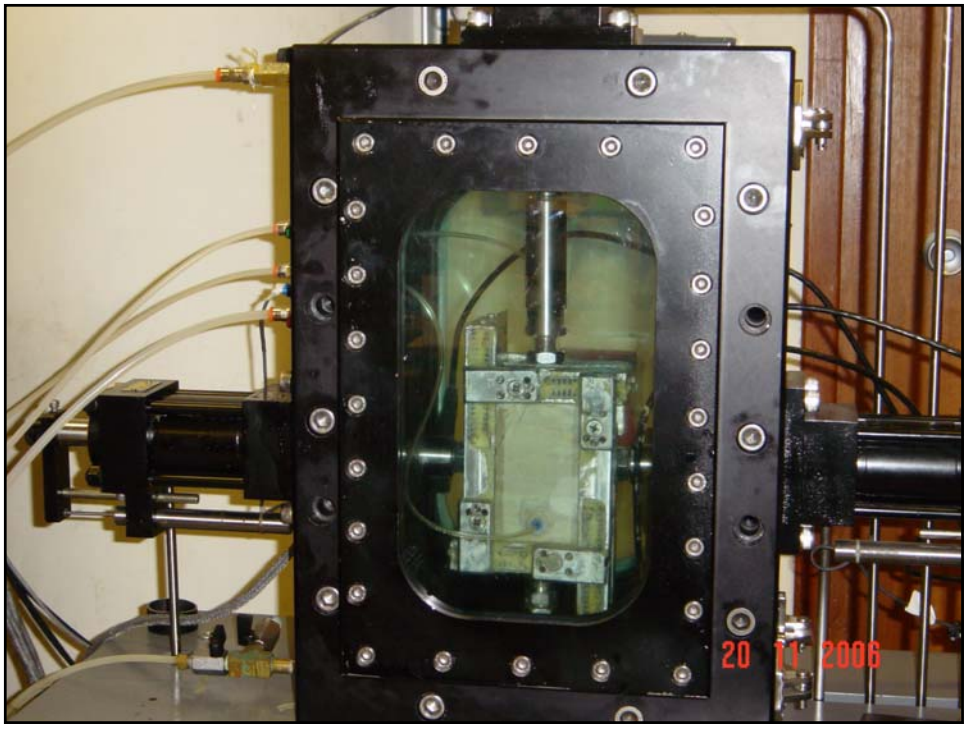
The best in the World?

世界上最佳？

由你评价！




Chamber is filled with water and closed
Yin's Sliding Plates Inside


20 11 2006

电子控制仪器、油压系统、软件、
静与动态(20Hz) 试验等

塑料泡沫材料 –软土填料，挡土墙填料等

塑料泡沫材料 –应力-应变-强度如何？


PLEASE
DON'T DISTURB!
2006 12 8

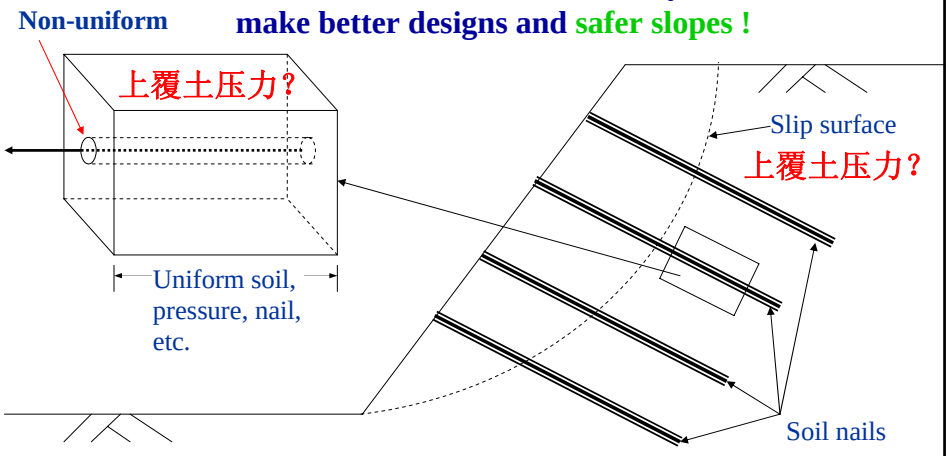

2006 12 8

8. An Innovative Soil Nail Pullout Box with Instrumentation

- For studying the interface shear strength of soil nail and soil under various controlled conditions
- Saturated or unsaturated soils, stress release, grouting pressure, *etc*.
  (simulating real construction process)

New soil nail pullout box testing – simulating a segment of a soil nail in a slope

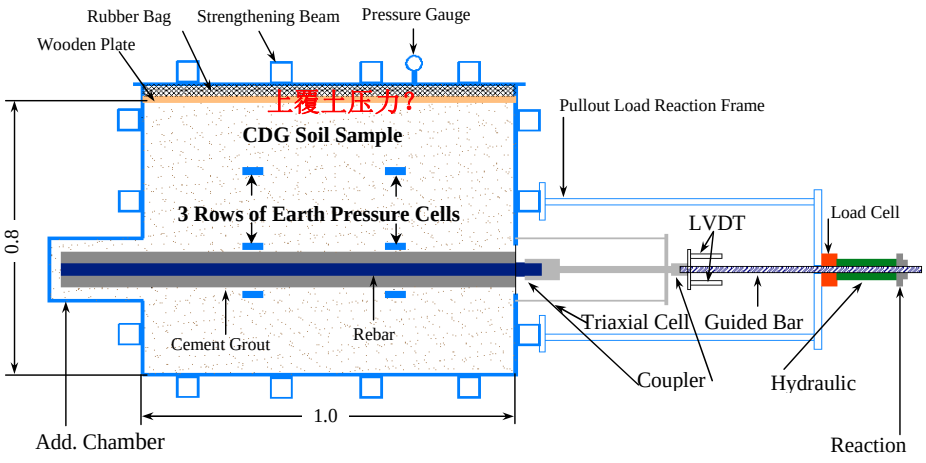
Useful to engineers:
Know the influences of a few key factors and make better designs and safer slopes !



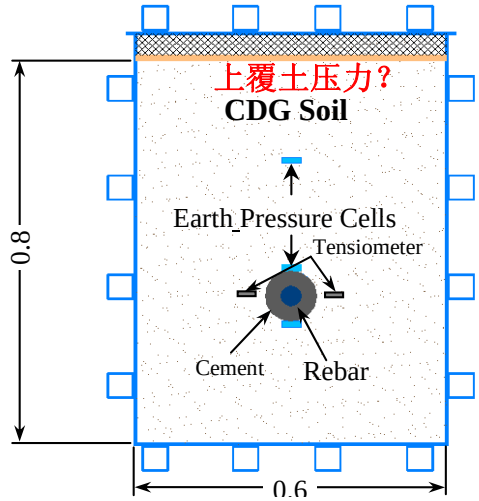
Soil nail pullout test studies on:

(a) Overburden pressure? 上覆土压力?
(b) Water saturation/suction/water table rising?
(c) Cement slurry grouting pressure?
(d) Drill hole roughness/dilation?
(e) Different soil types?
(f) Different nail materials (fibre/carbon-glass)?
(g) Block soil samples *vs* compacted samples?
(h) Comparison of lab pullout test results with field pullout test results?
…

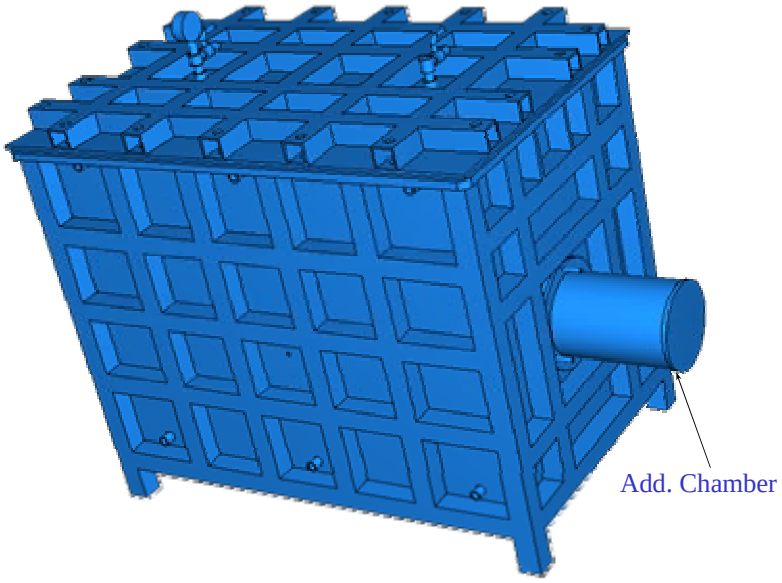
Studies in (a), (b) and (c) have been done.



(i) Six earth pressure cells for measuring total earth pressures
(ii) Four strain gauges on the re-bar for measuring nail axial strains
(iii) Pressure gauges and volume change meter in the top cover cap for water pressure control and vertical soil movement
(iv) Two LVDTs and one load cell for measuring pullout displacement and load.



(v) Four miniature tensiometers for measuring suctions and small pressure transducers for measuring positive pore water pressures



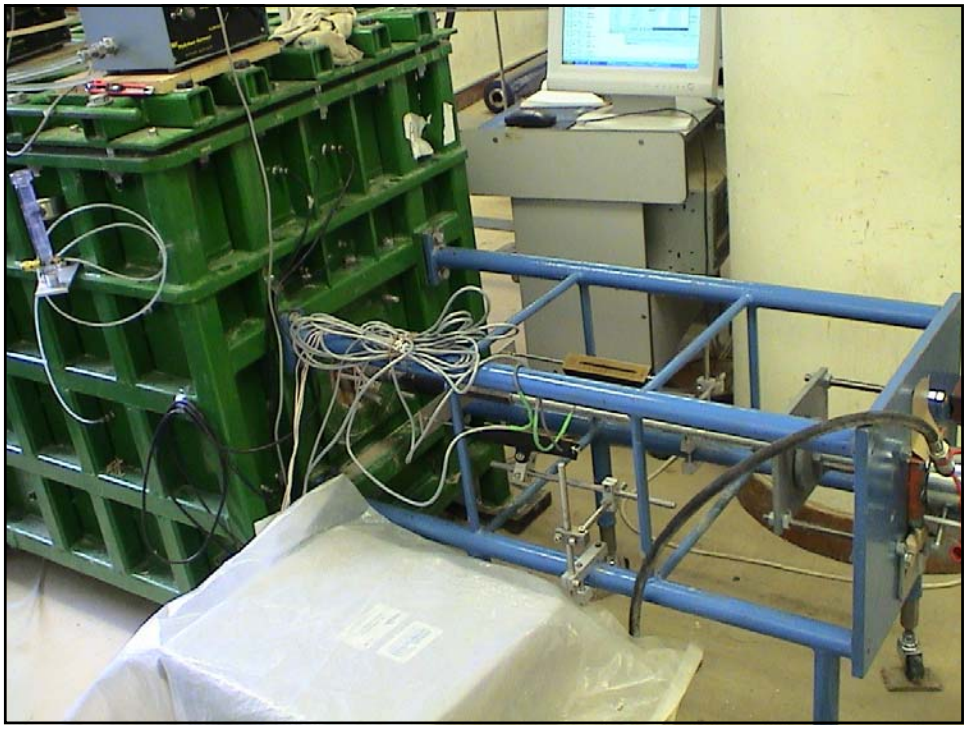
An additional chamber is attached to the end of the soil nail.

上覆土压力？

应力释放了

土钉上的应力为零

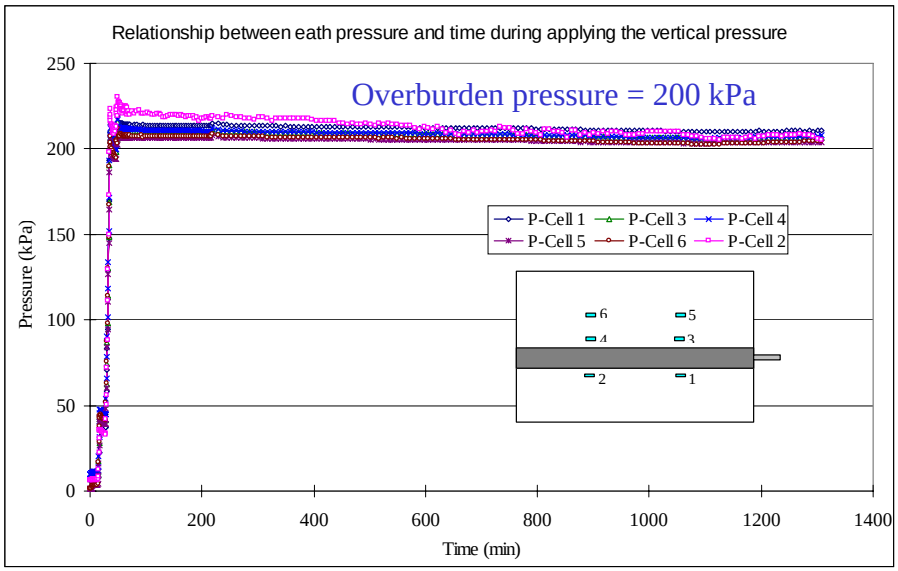
Stress is released (to zero).
What is the normal stress on nail?



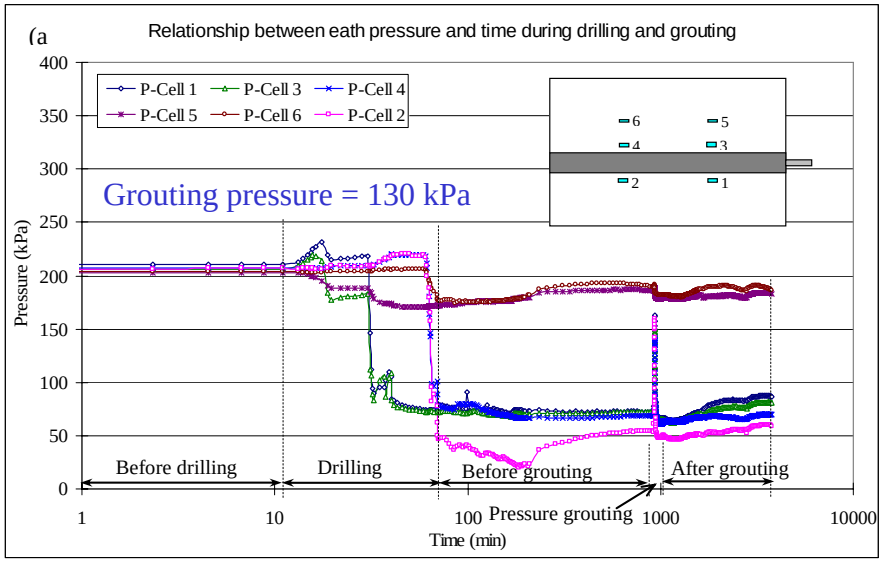
Example data from a pressure grouted soil nail pullout test :

Vertical Pressure (VP) = 200 kPa
Degree of saturation S_r = 50%
Cement grouting pressure = 130 kPa

Step 1: Establishment of field overburden pressure

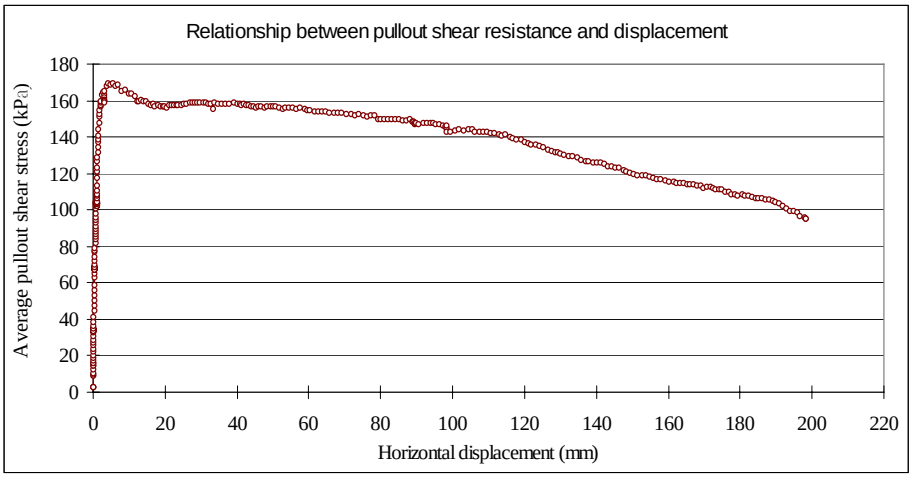


Step 2: Drilling and nail installation with cement slurry pressure grouting



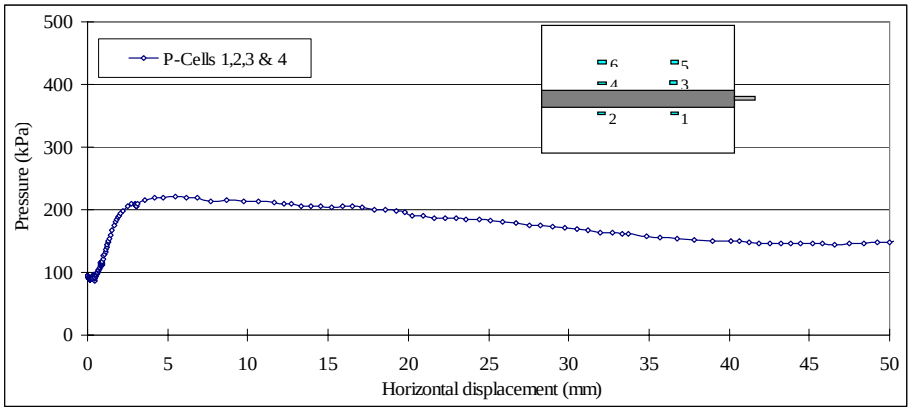
Step 3: Soil nail pull-out with full monitoring

(i) Average pullout shear stress (or load) *vs* horizontal displacement



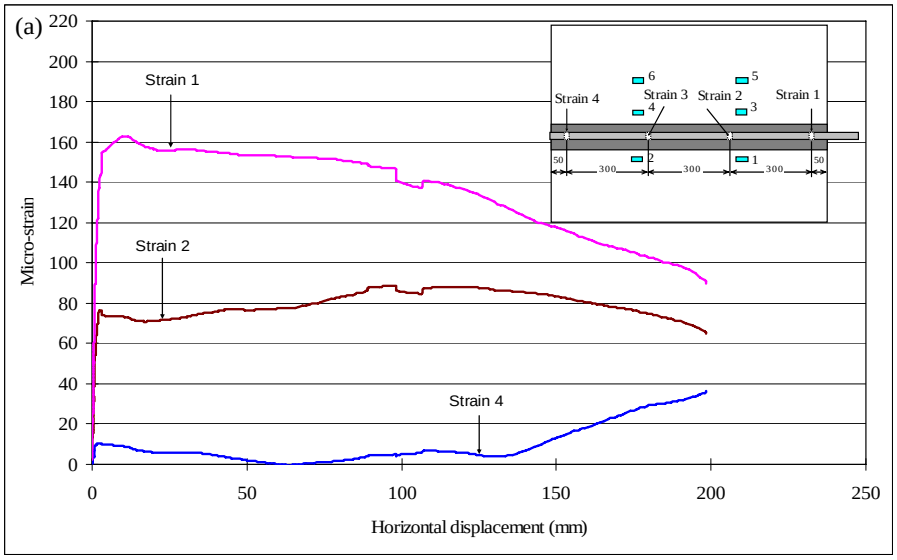
Step 3: Soil nail pull-out with full monitoring

(ii) Average earth pressure on the nail surface *vs* horizontal displacement



Step 3: Soil nail pull-out with full monitoring

(iii) Strains on re-bar *vs* horizontal displacement



Key References:

Yin, J-H. (2003). A double cell triaxial system for continuous measurement of volume changes of an unsaturated or saturated soil specimen in triaxial testing. Geotechnical Testing Journal (ASTM), Vol.26, No.3, pp353-358.

Hung Bo, Chen, Y.M., Yin, J-H. and Wu, S.M. (2002). Liquefaction evaluation by means of shear wave velocity method based on cyclic triaxial tests. Journal of Hydraulic Engineering (Shuili Xuebao – in Chinese), Vol.10, page 21-26.

Chu, L.M. and Yin, J.H. (2005). Comparison of Interface Shear Strength of Soil Nails Measured by both Direct Shear Box Tests and Pull-out Tests. J of Geotechnical and Geo-environmental Engineering, ASCE, Vol.131, Issue No.9 , pp.1097-1107.

Yin, J-H and CM Cheng (2006). Comparison of Strain-rate Dependent Stress-Strain Behaviour from K_o-consolidated Compression and Extension Tests on Natural Hong Kong. Marine Deposits. Marine Georesources and Geotechnology (in press).

Yin, J-H and LJ Su (2006). An Innovative Laboratory Box for Testing Nail Pull-out Resistance in Soil. ASTM Geotechnical Testing Journal (in press).