Soil Testing Parameters and GTS NX Verification

杜志談

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GTS NX
Geo-Technical analysis System New eXperience

CONTENT

Why is the soil parameter input important?

表 2.2 簡化土層與建議工程性質參數表(摘自中聯公司，111 年 8 月)

地層說明 深度	分類	N 值	γ_t t/m³	總應力		有效應力		壓縮性質		不排水剪力強度Su t/㎡
				C t/㎡	ϕ 度	C' t/㎡	ϕ' 度	Cc	Cr	
一、回填覆土層 GL.-3.5±0.5m	SF	5～15 (10)	2.03	* 1	* 19	* 0	* 29	—	—	* 2.0
二、灰色粉土質黏土偶夾薄層細砂 GL.-11.3±0.8m	CL	3～12 (4)	1.83	* 1	* 19	* 0	* 29	—	—	0.27σ' (註3)
三、灰色粉土質細砂夾粉土質黏土偶夾砂質粉土 GL.-22.8±0.4m	SM；CL	5～38 (14)	1.93	—	—	0	31	—	—	—
四、灰色粉土質黏土夾黏土質粉土偶夾薄層砂質粉土 GL.-27.0±1.9m	CL、ML	5～11 (7)	1.81	1	20	0	30	0.210	0.021	0.27σ' (註3)
五、灰色粉土質細砂夾砂質粉土偶夾粉土質黏土 GL.-30.7±0.5m	SM；ML	10～33 (17)	1.93	—	—	0	32	—	—	—
六、灰色粉土質黏土偶夾砂質粉土及有機物 GL.-38.4±1.7m	CL	6～20 (10)	1.78	2	21	0	31	0.329	0.031	0.27σ' (註3)
七、黃棕、灰色粉土質黏土夾粉土質細砂偶夾砂質粉土 GL.-42.7±1.5m	CL；SM	11～44 (28)	1.95	* 2	* 23	* 0	* 32	* 0.249	* 0.024	0.27σ' (註3)
八、卵礫石夾棕灰色粉土質細砂 GL.-52.9m，孔底	GM	>50 (50)	* 2.20	—	—	* 1	* 38	—	—	—

In-situ soil investigation data

表 3.1 數值分析土層輸入參數表(HSsmall Model)

地層	底部深度 (m)	平均 SPT-N	γ_{sat} (kPa)	c' (kPa)	ϕ' (deg)	E_{50}^{ref} (kPa)	E_{oed}^{ref} (kPa)	E_{ur}^{ref} (kPa)	G_0^{ref} (kPa)	$\gamma_{0.7}$	土壤排水型態
SF	3.5	10	19.9	0.0	29	57850	57850	173550	72720	1.206×10^{-5}	drained
CL1	11.3	4	17.9	0.0	29	10873	7611	32618	45060	1.838×10^{-4}	undrained
SMCL	22.8	14	18.9	0.0	31	37690	37690	113069	47200	1.981×10^{-4}	drained
CLML	27	7	17.7	0.0	30	15943	11160	47829	36083	1.568×10^{-4}	undrained
SMML	30.7	17	18.9	0.0	32	36740	36740	110220	45940	2.547×10^{-4}	drained
CL2	38.4	10	17.4	0.0	31	11234	7863	33701	33480	1.866×10^{-4}	undrained
CLSM	42.7	28	19.1	0.0	32	14713	10299	44138	33480	1.757×10^{-4}	undrained
GM	50	50	21.6	10.0	38	97283	97283	291848	121700	3.229×10^{-4}	drained

GTS NX parameter input

Errors?

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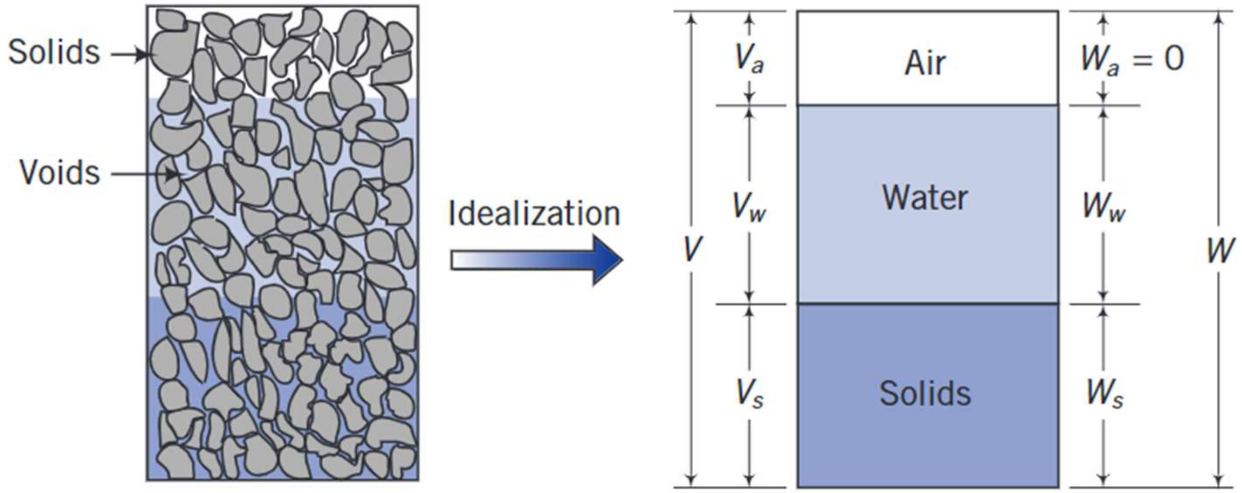
Part1. Soil Parameter Calculation

1.1 Physical Parameters



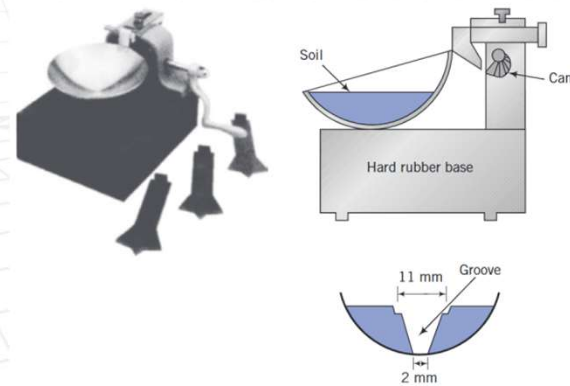
(a) Soil

(b) Idealized soil

Sand physical characteristics

(a) Grain sieve test

Clay physical characteristics

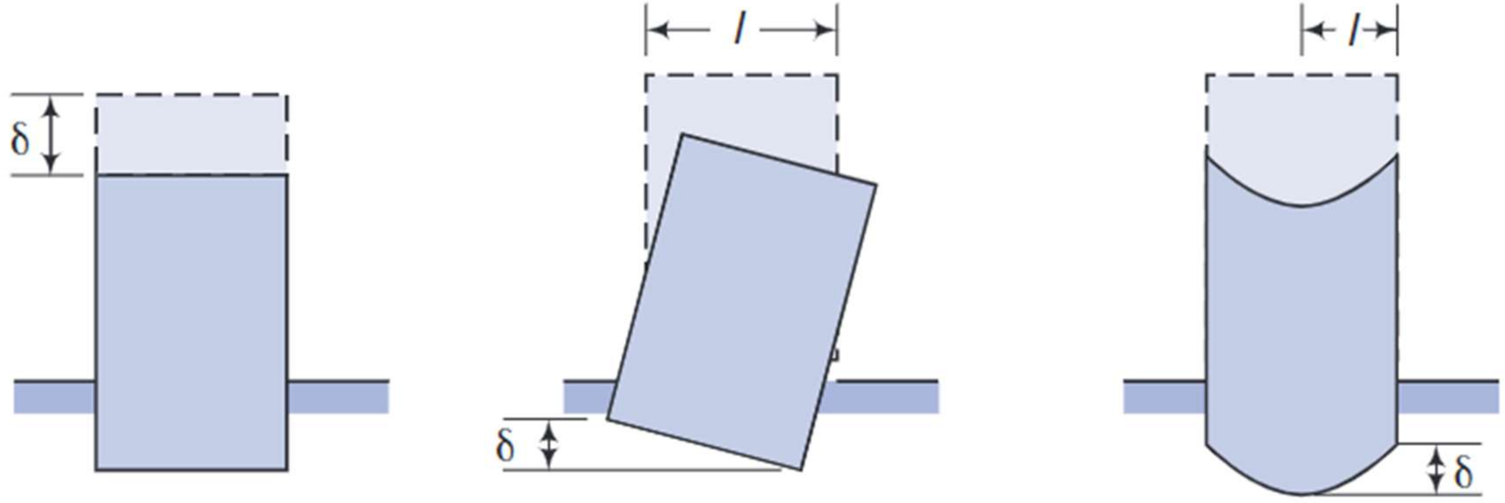


(b) Atterberg apparatus

Reference

Soil Mechanics Fundamentals – Muni Budhu (2015)

1.2 Mechanical Parameters



(a) Uniform settlement (b) Tilt or distortion (c) Nonuniform settlement

Testing for determining mechanical soil

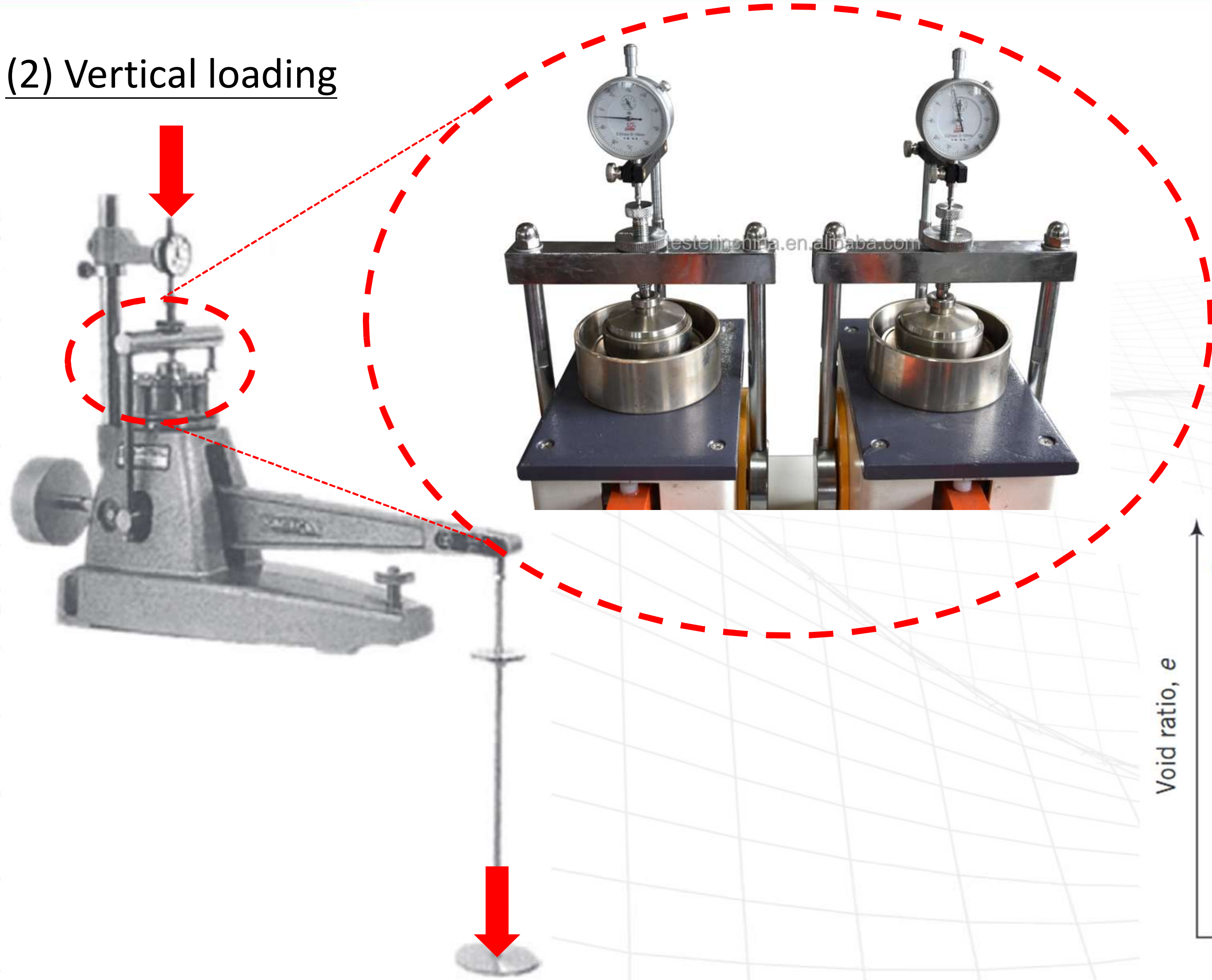
Oedometer test | Direct shear test | Triaxial test | Field tests

Reference

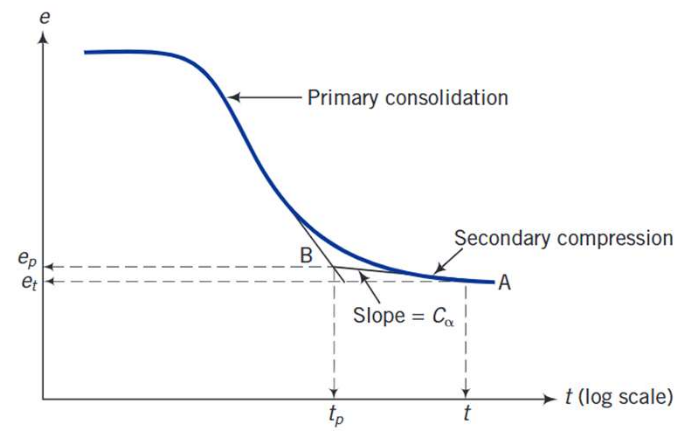
Soil Mechanics Fundamentals – Muni Budhu (2015)

A. Oedometer Test

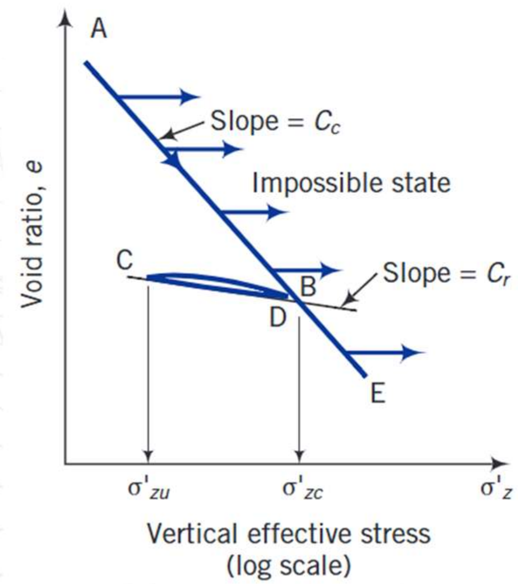
(2) Vertical loading



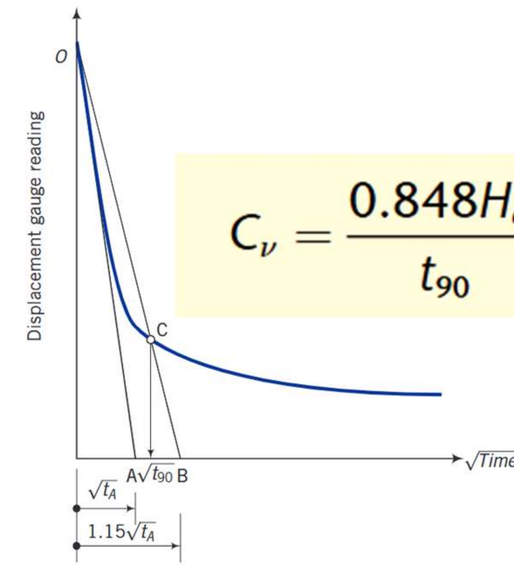
(1) Placing the load



Consolidation phases with time



C_c & C_s determination



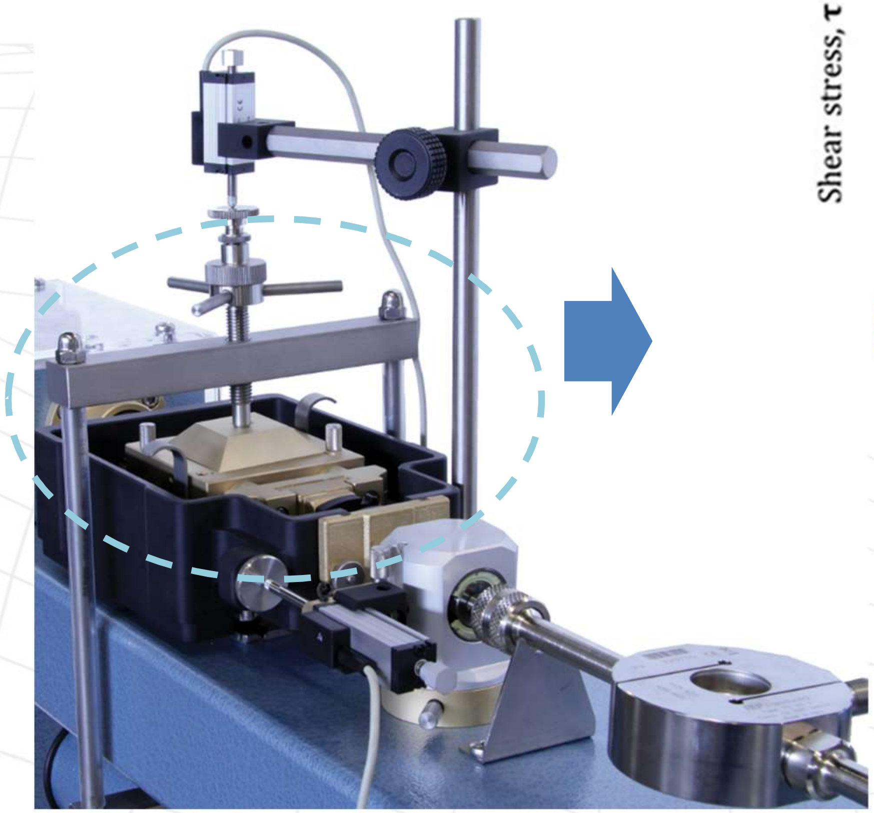
$$C_v = \frac{0.848 H_{dr}^2}{t_{90}}$$

C_v determination

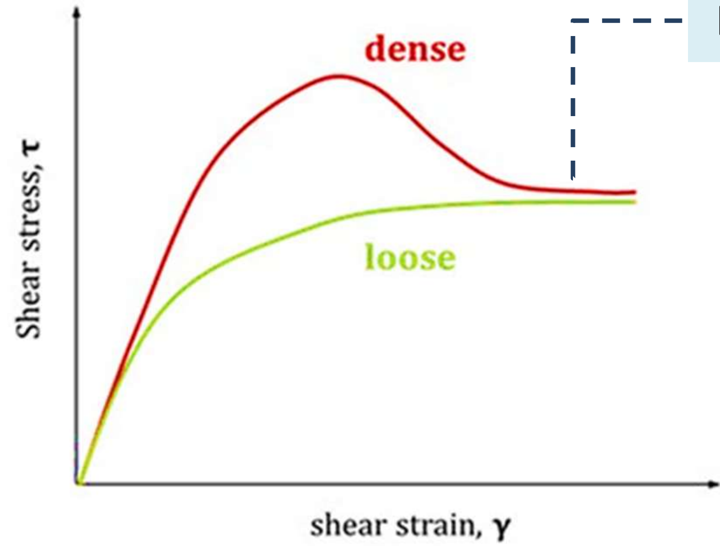
Reference

Soil Mechanics Fundamentals – Muni Budhu (2015)

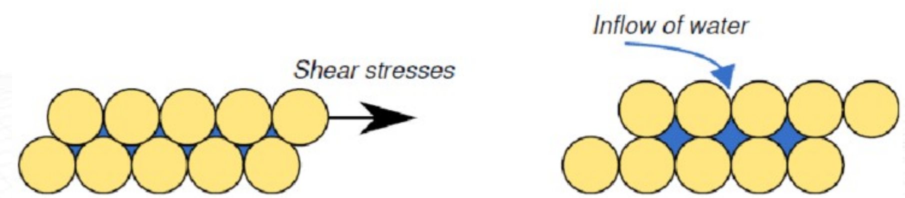
B. Direct Shear Test

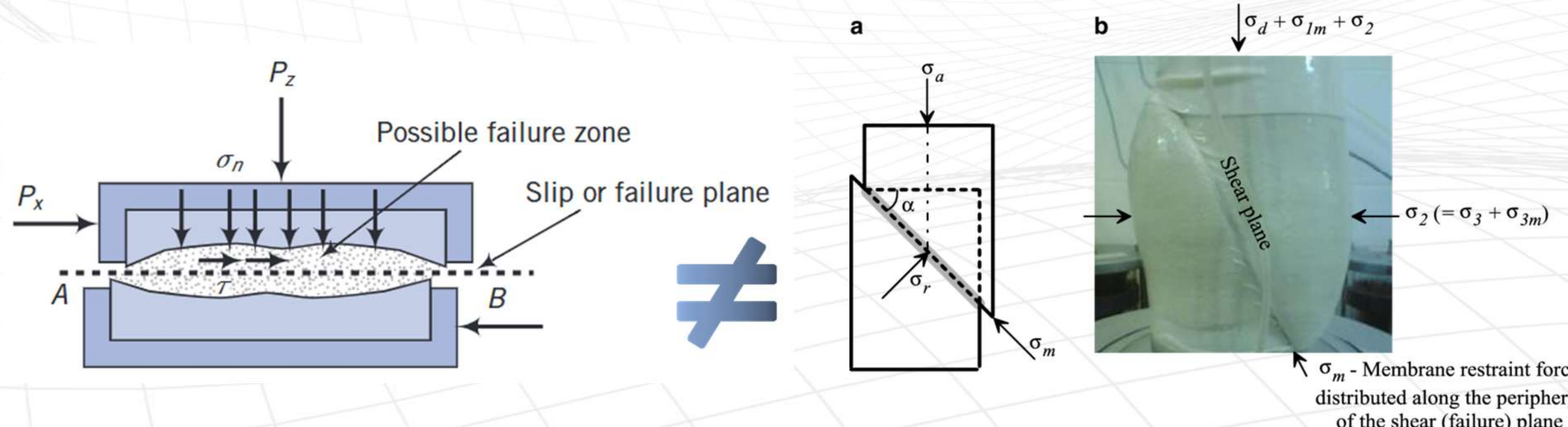


Direct shear apparatus



Dilatancy definition



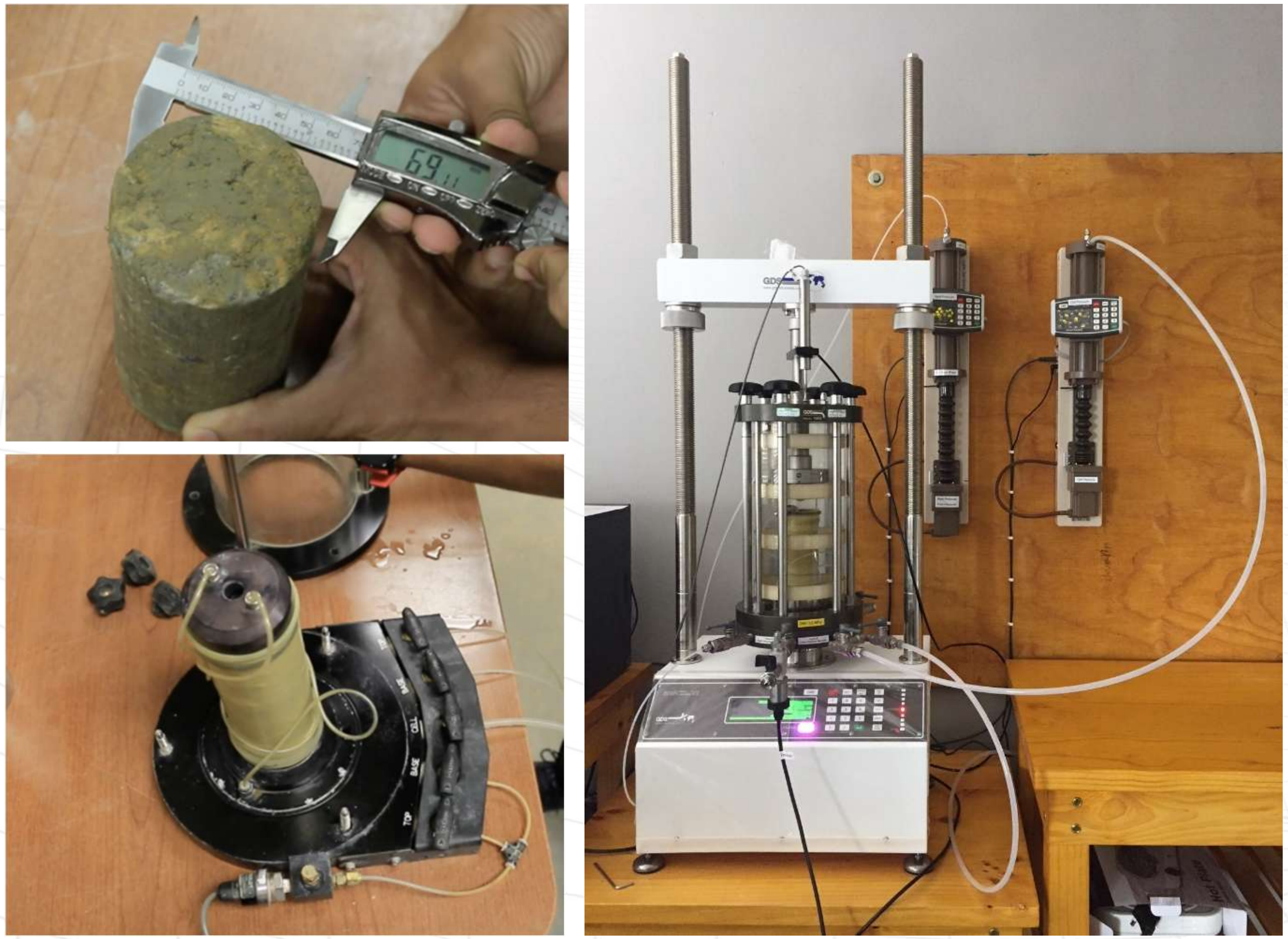


Difference in failure plane

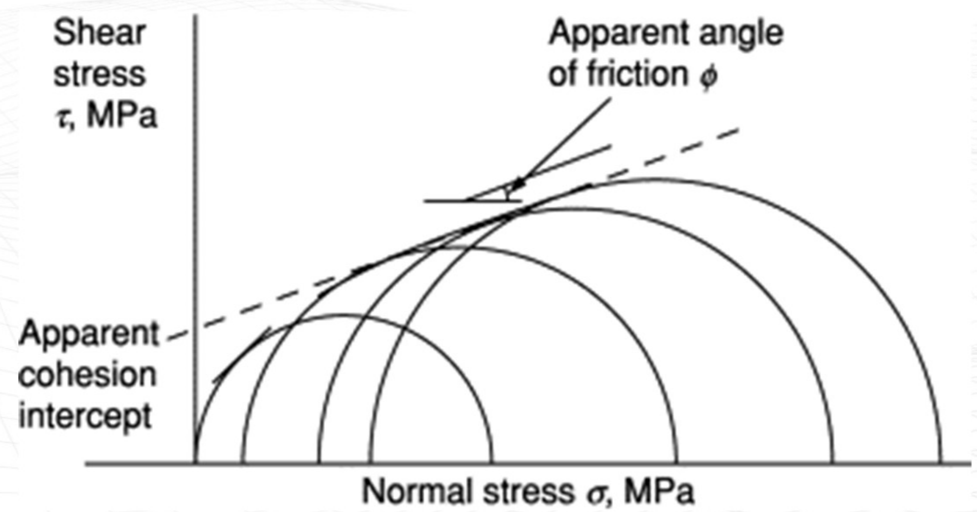
Reference

(PDF) A review on the effect of rubber membrane in triaxial tests

C. Triaxial Test



(a) Triaxial test apparatus



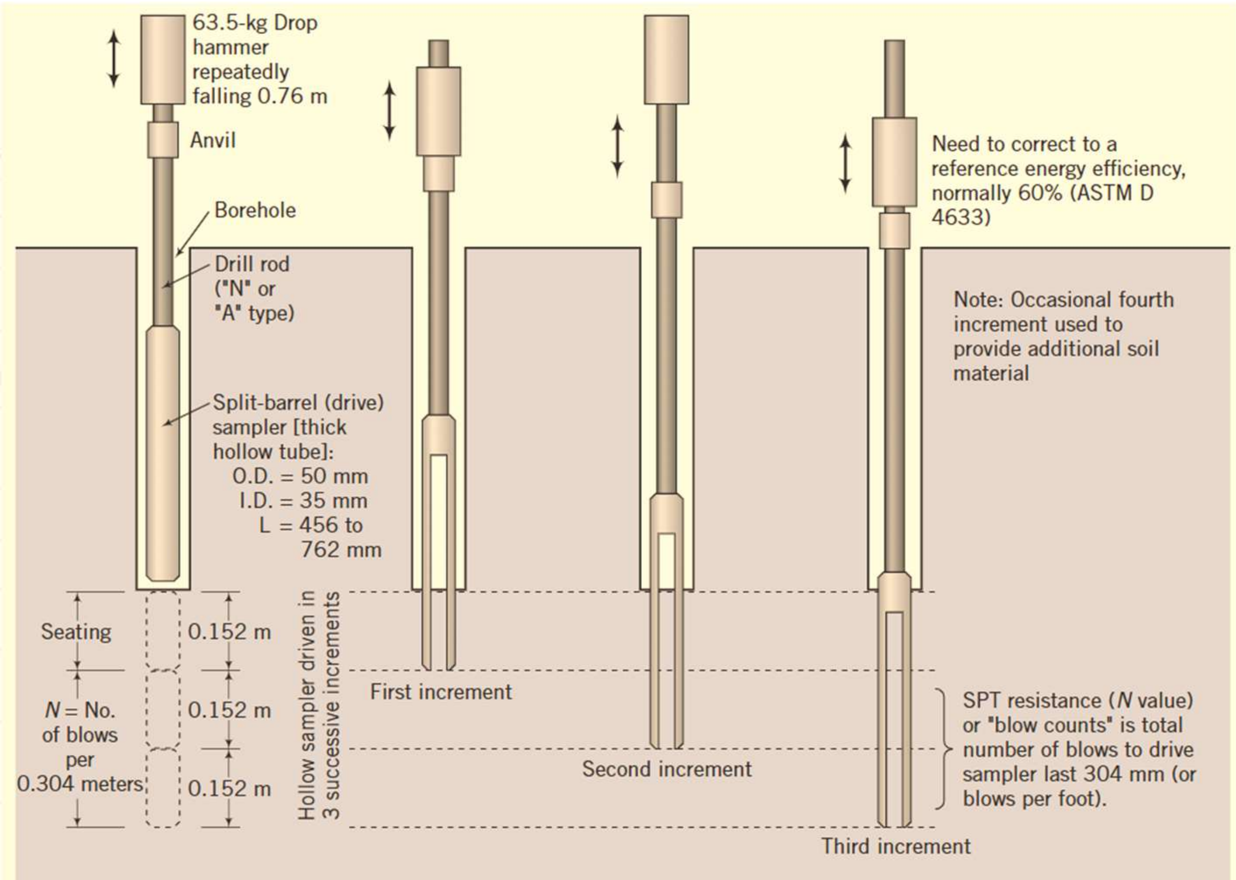
$$\tau = \sigma \tan(\phi) + c$$

(b) Results

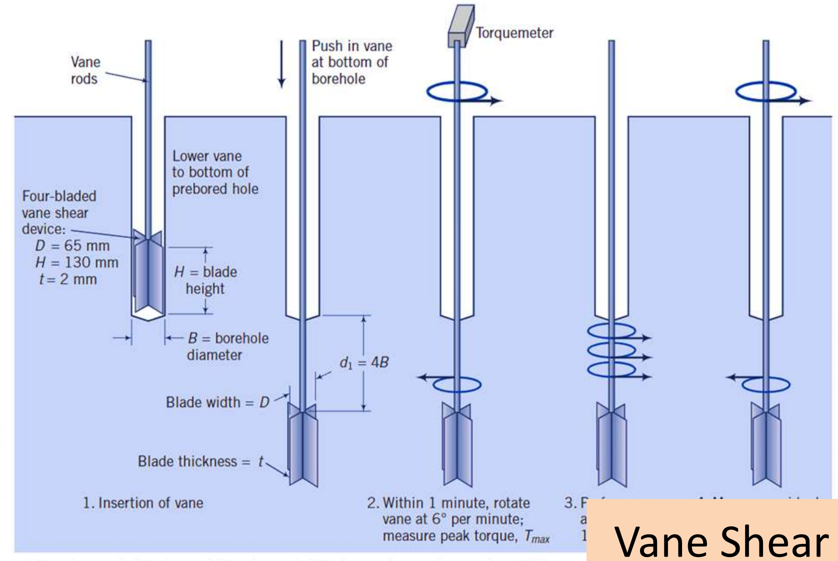
Reference

Soil Mechanics Fundamentals – Muni Budhu (2015)

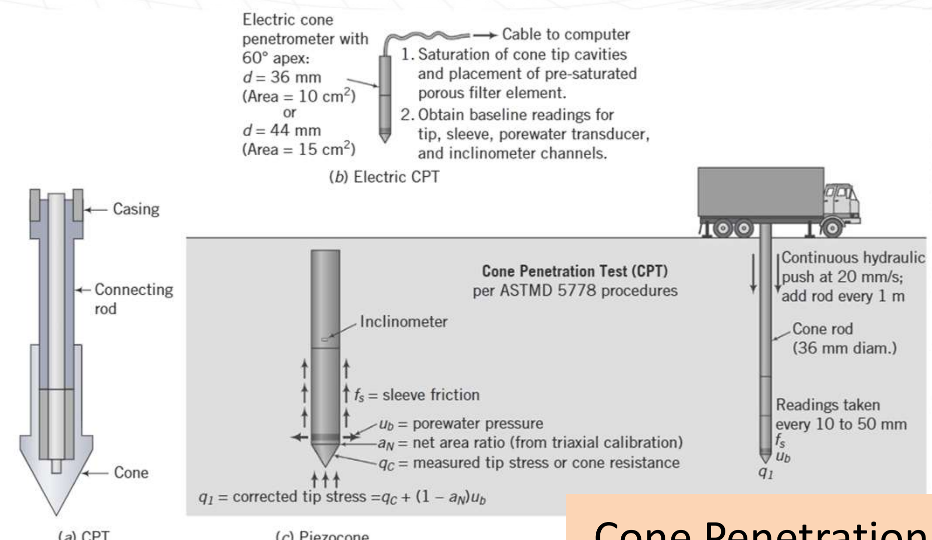
D. Field Tests



Standard Penetration Test (SPT)



Vane Shear Test (VST)



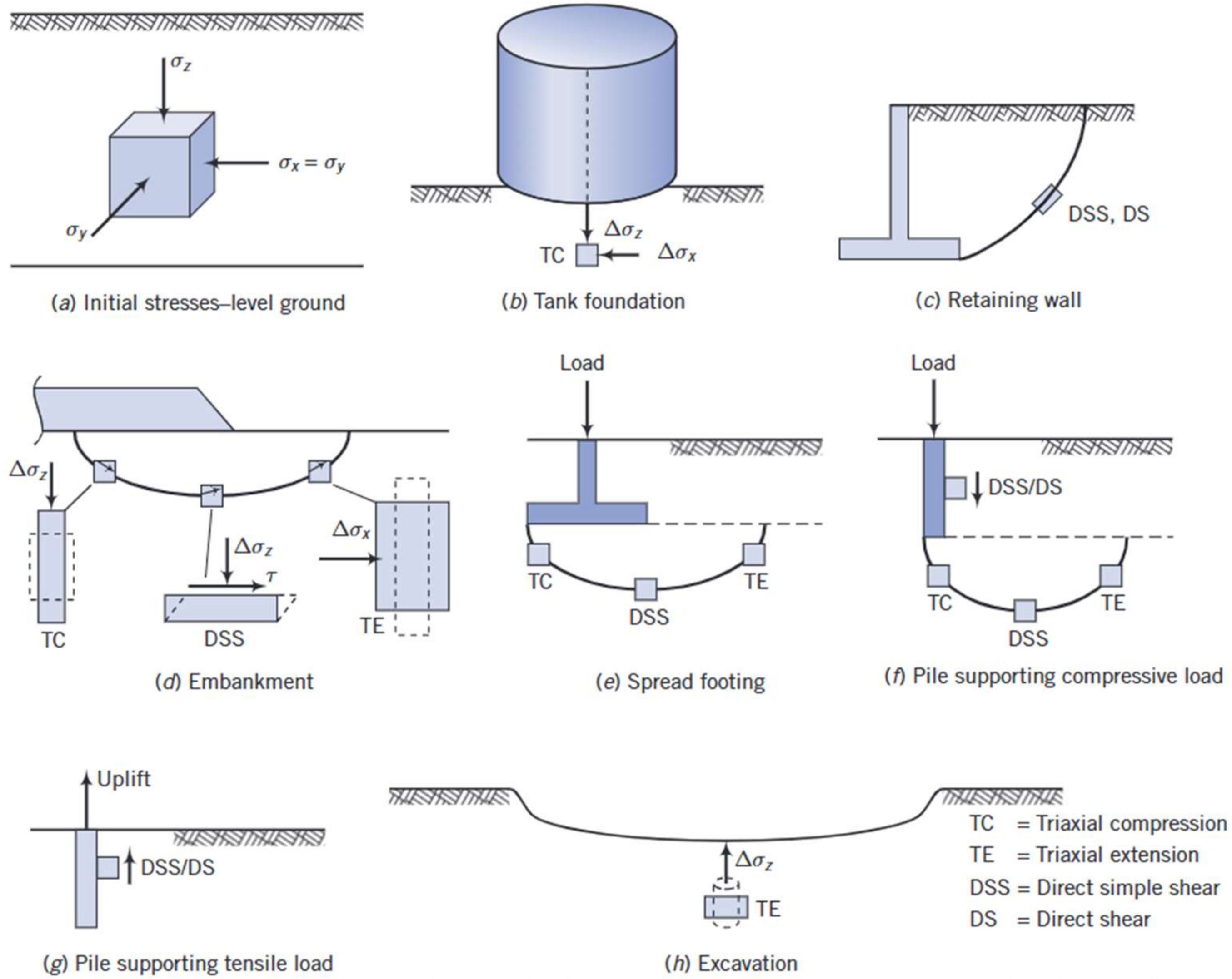
Cone Penetration Test (CPT)

Reference

Soil Mechanics Fundamentals – Muni Budhu (2015)

Practical consideration:

- Compression
- Extension
- Shearing



Fig, Practical cases and laboratory tests relation

Reference

Soil Mechanics Fundamentals – Muni Budhu (2015)

Part2. GTS NX Soil Constitutive Model

2.1 Various Constitutive Model
2.2 Non-linear Parameters
2.3 Soil Test Wizard

2.1 Various Constitutive Model

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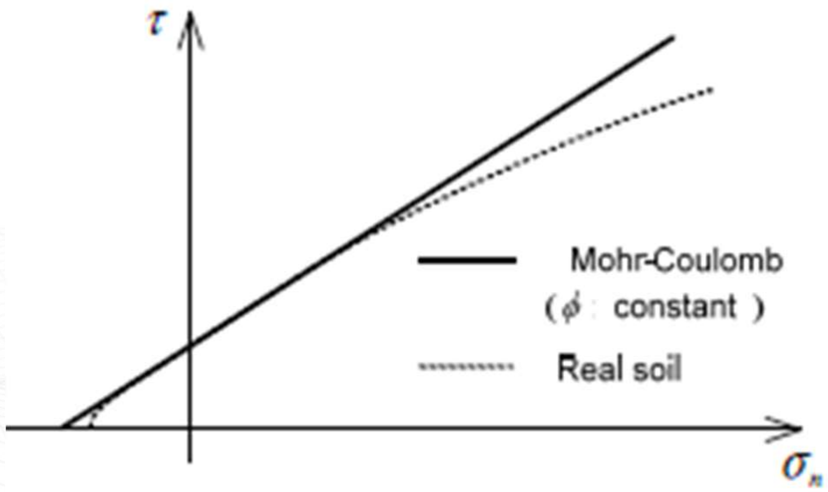
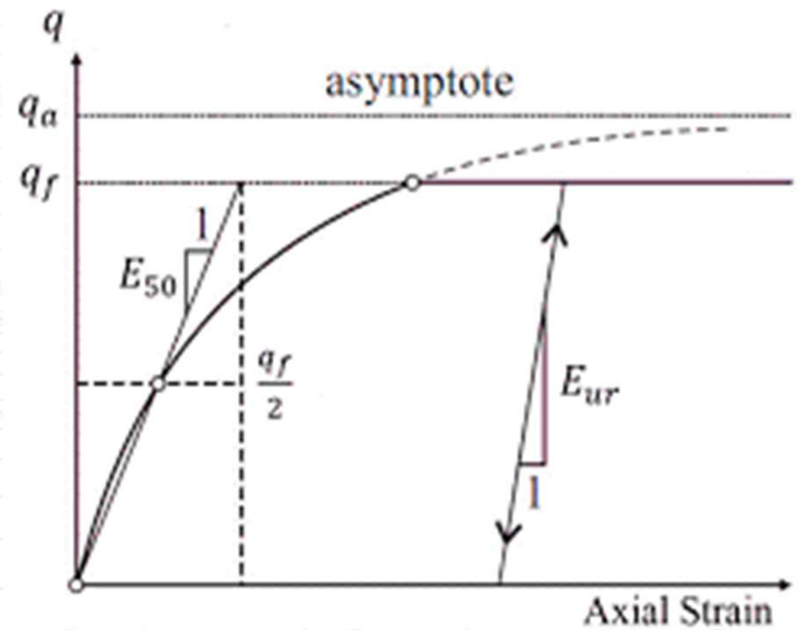
General	Mohr-Coulomb Hardening Soil (small strain stiffness)
Sand	Modified UBCSAND PM4Sand
Clay	Soft soil (Creep) Modified Cam Clay Sekiguchi-Ohta(Inviscid) Sekiguchi-Ohta(Viscid) Generalized SCLAY1S
Rock	(Generalized) Hoek Brown Jointed Rock Mass CWFS

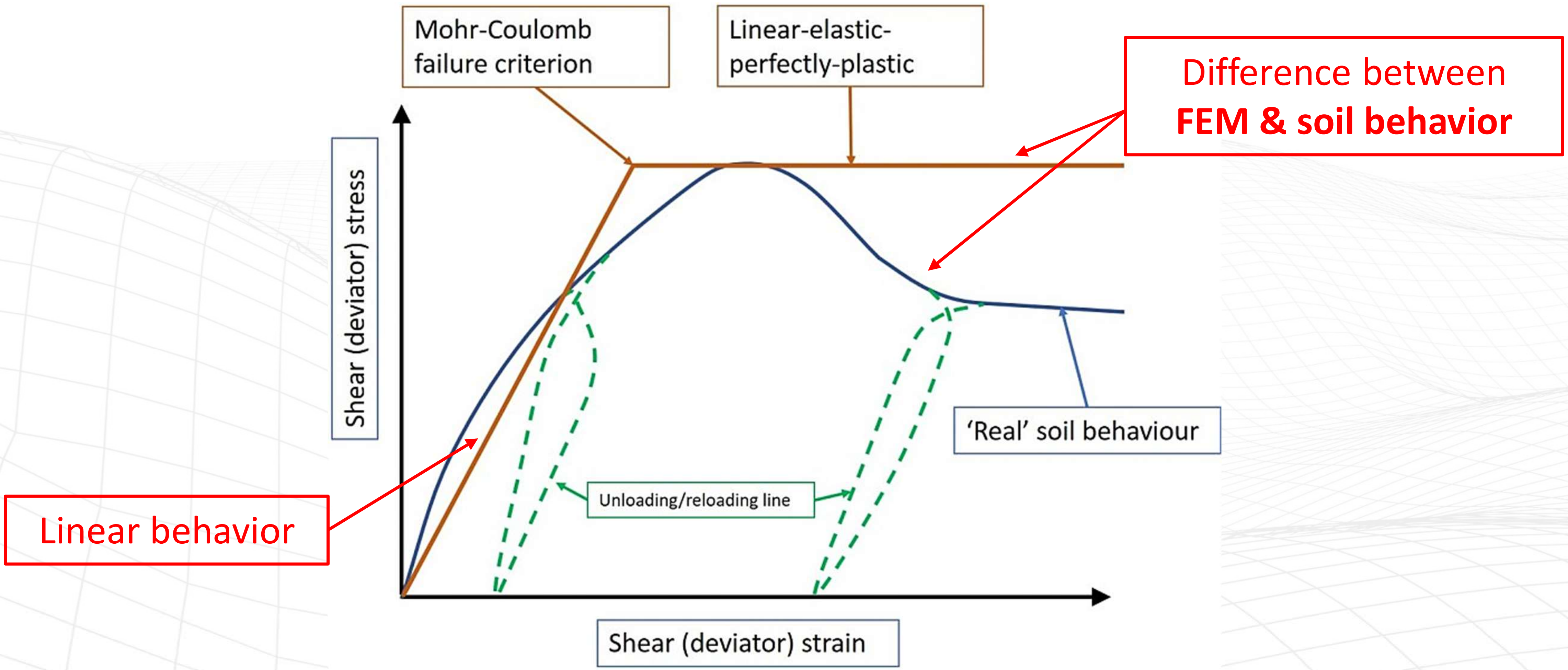


Mohr-Coulomb



Hardening Soil Model

2.1 Various Constitutive Model



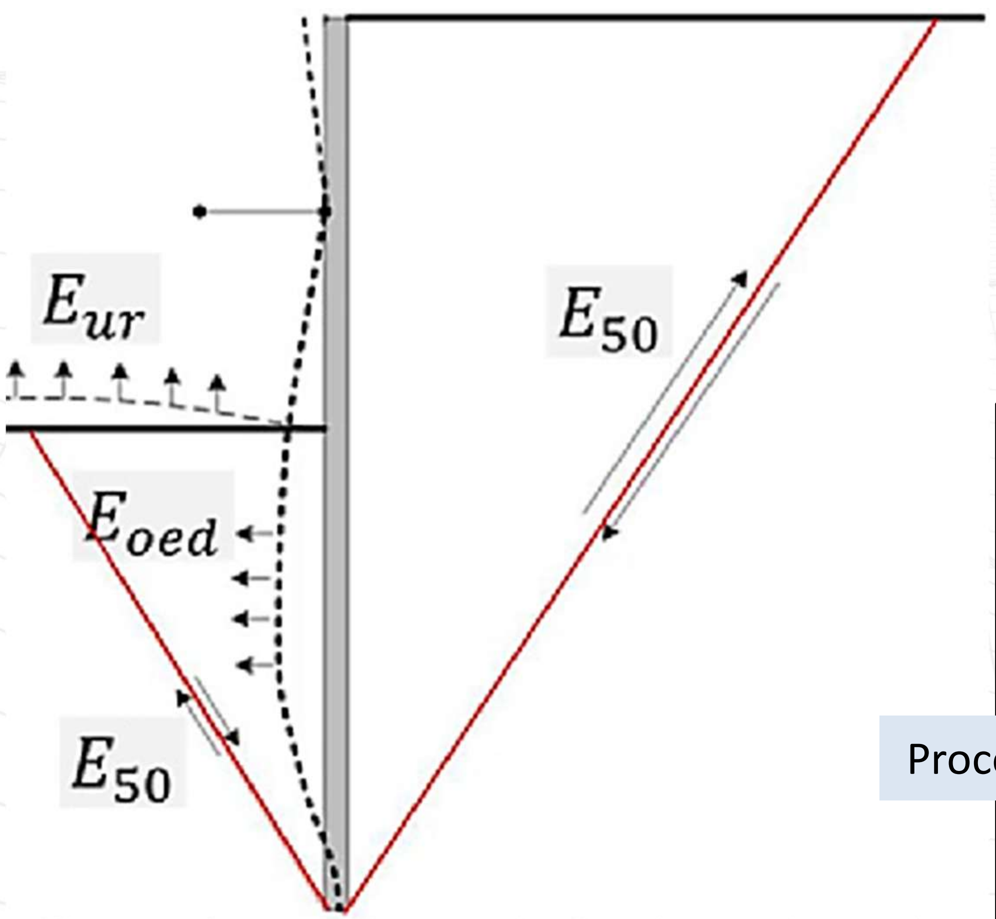
Fig, Schematic of soil behavior and FEM simulation

Reference

[Determination of Model Parameters for the Hardening Soil Model]

2.2 Non-linear Parameters

Soil stiffness



Input

$$E_{50} = E_{50}^{ref}\left(\frac{\sigma'_3 + c'\cdot\cot\varphi'}{P_{ref} + c'\cdot\cot\varphi'}\right)^m$$

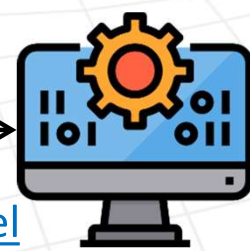
$$E_{oed} = E_{oed}^{ref}\left(\frac{\sigma'_1 + c'\cdot\cot\varphi'}{P_{ref} + c'\cdot\cot\varphi'}\right)^m$$

$$E_{ur} = E_{ur}^{ref}\left(\frac{\sigma'_3 + c'\cdot\cot\varphi'}{P_{ref} + c'\cdot\cot\varphi'}\right)^m$$

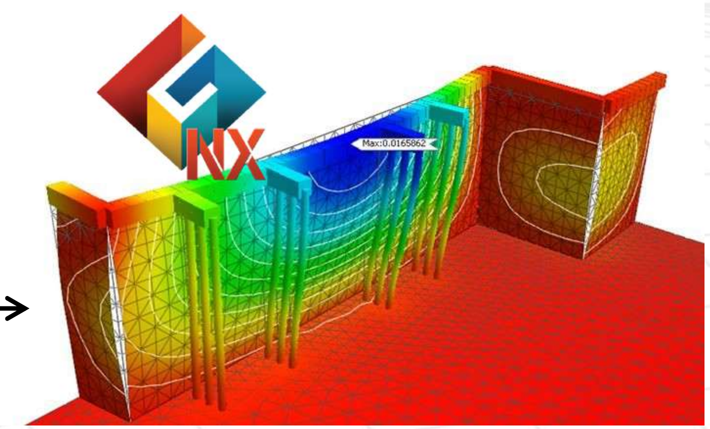
Where

- E_{50}(ref) - Shear deformation
- E_{oed}(ref) - Compression
- E_{ur}(ref) - Loading/unloading

Process



Output

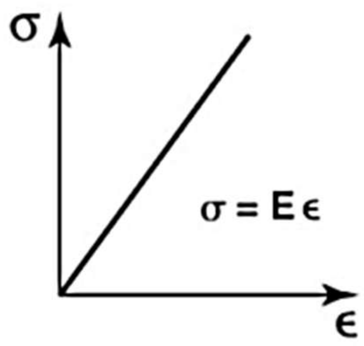


Reference

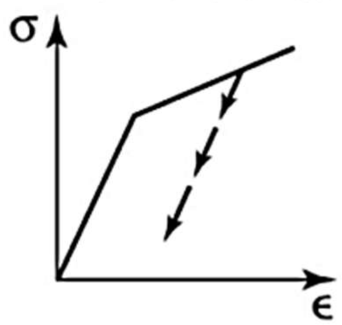
Determination of Model Parameters for the Hardening Soil Model

Different range of strains

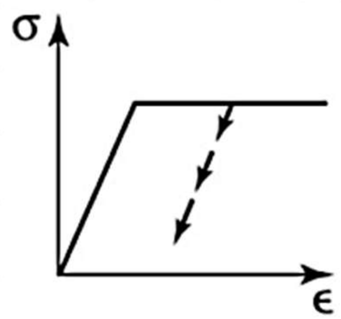
Linear Elastic

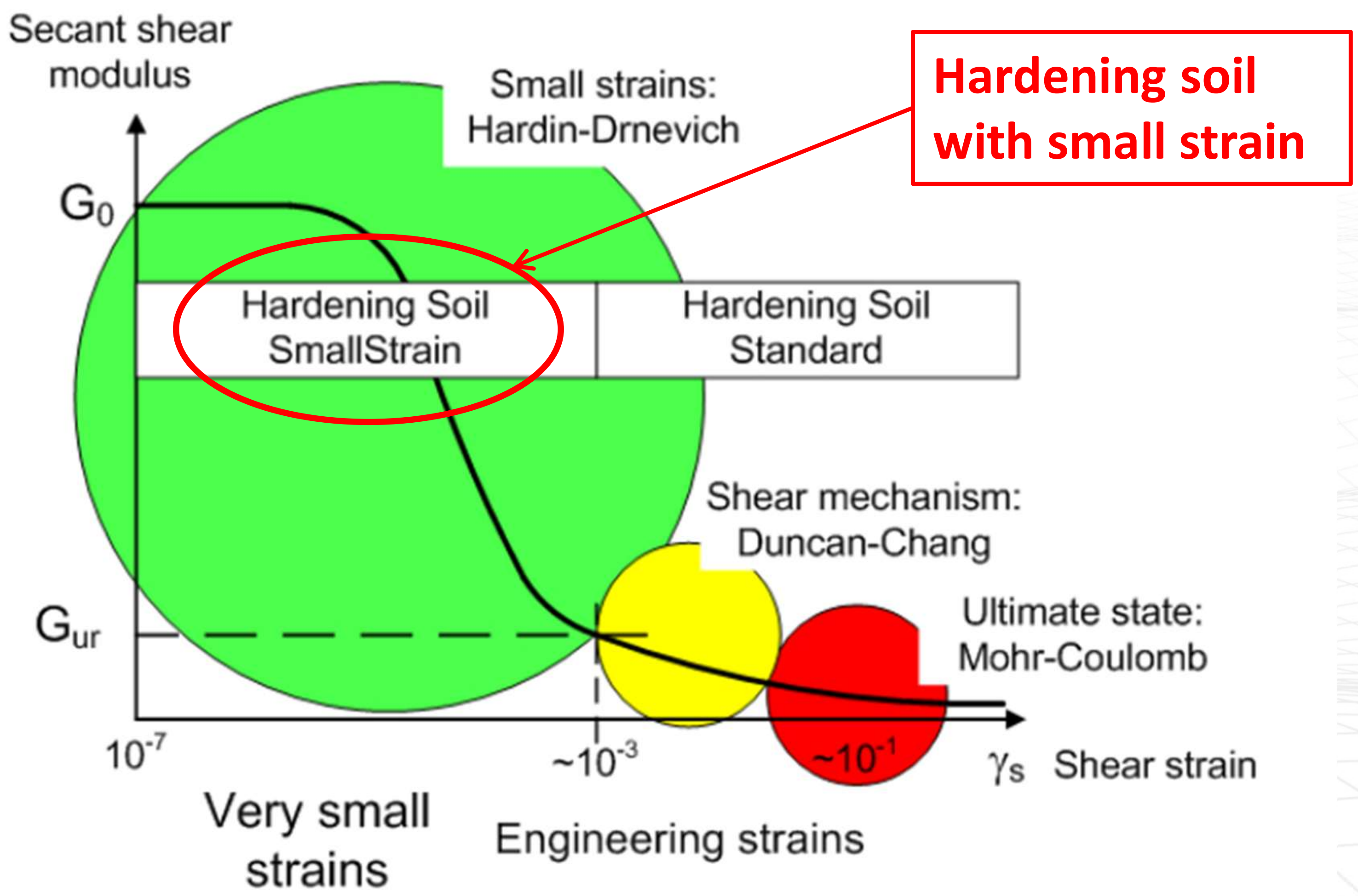


Elastic-Perfectly Plastic



Linear Hardening





Fig, Schematic of shear strain in difference of ranges

2.4 Soil Test Wizard

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Triaxial test

表 3.1 數值分析土層輸入參數表(HSsmall Model)

地層	底部深度 (m)	平均 SPT-N	γ_{sat} (kPa)	c' (kPa)	φ' (deg)	E_{50}^{ref} (kPa)	E_{oed}^{ref} (kPa)	E_{ur}^{ref} (kPa)	G_0^{ref} (kPa)	$\gamma_{0.7}$	土壤排水型態
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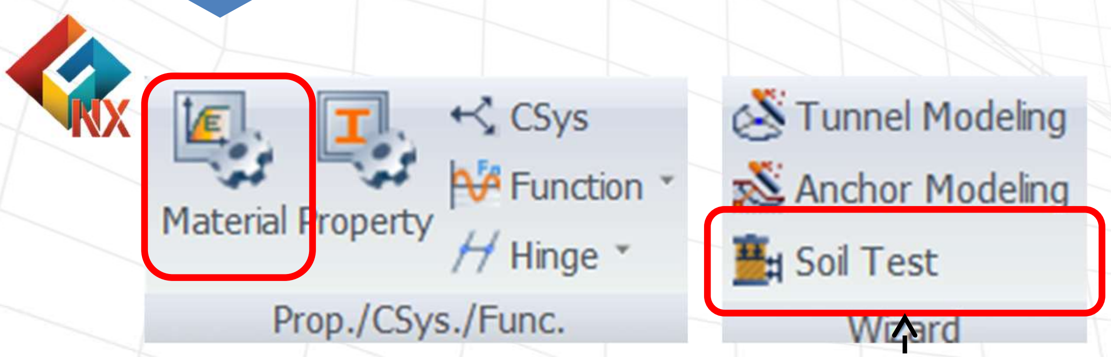
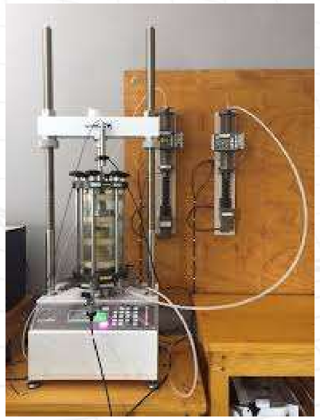
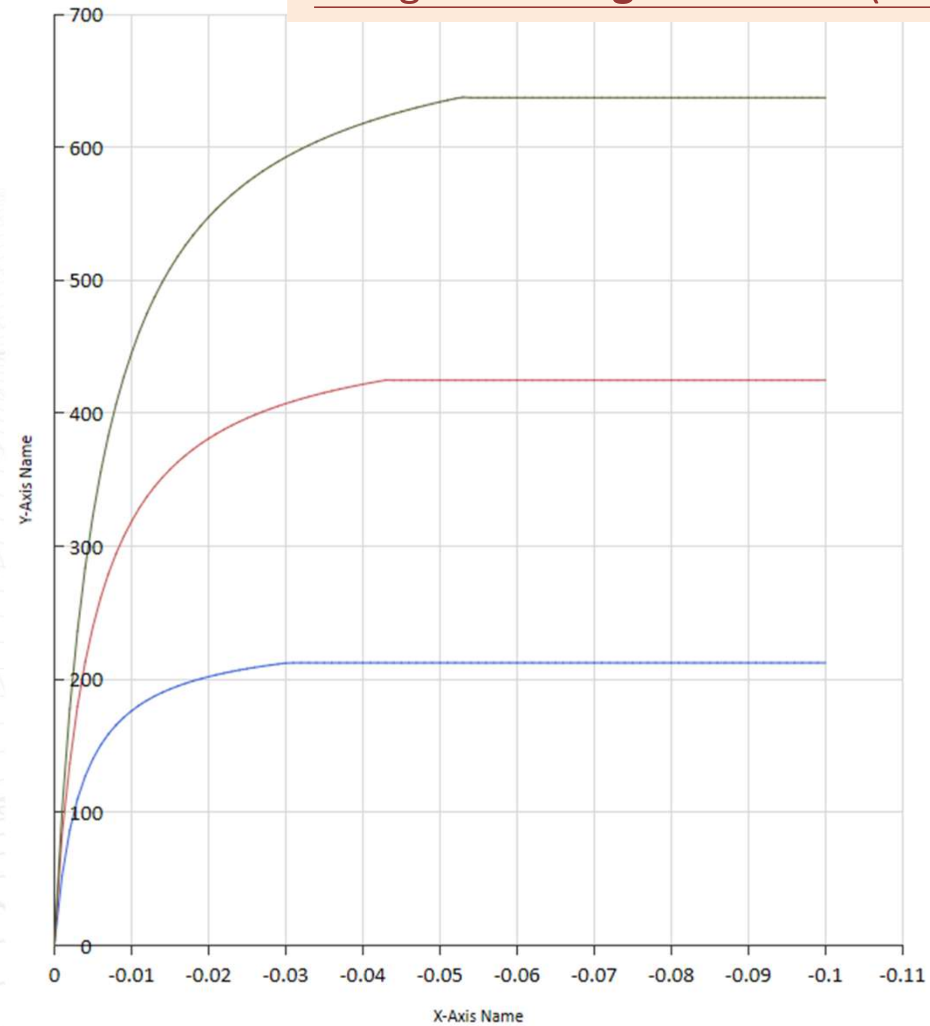
GM	50	50	21.6	10.0	38	97283	97283	291848	121700	3.229×10^{-4}	drained



Input in-situ soil data



Using **Hardening Soil Model** (HSS)!



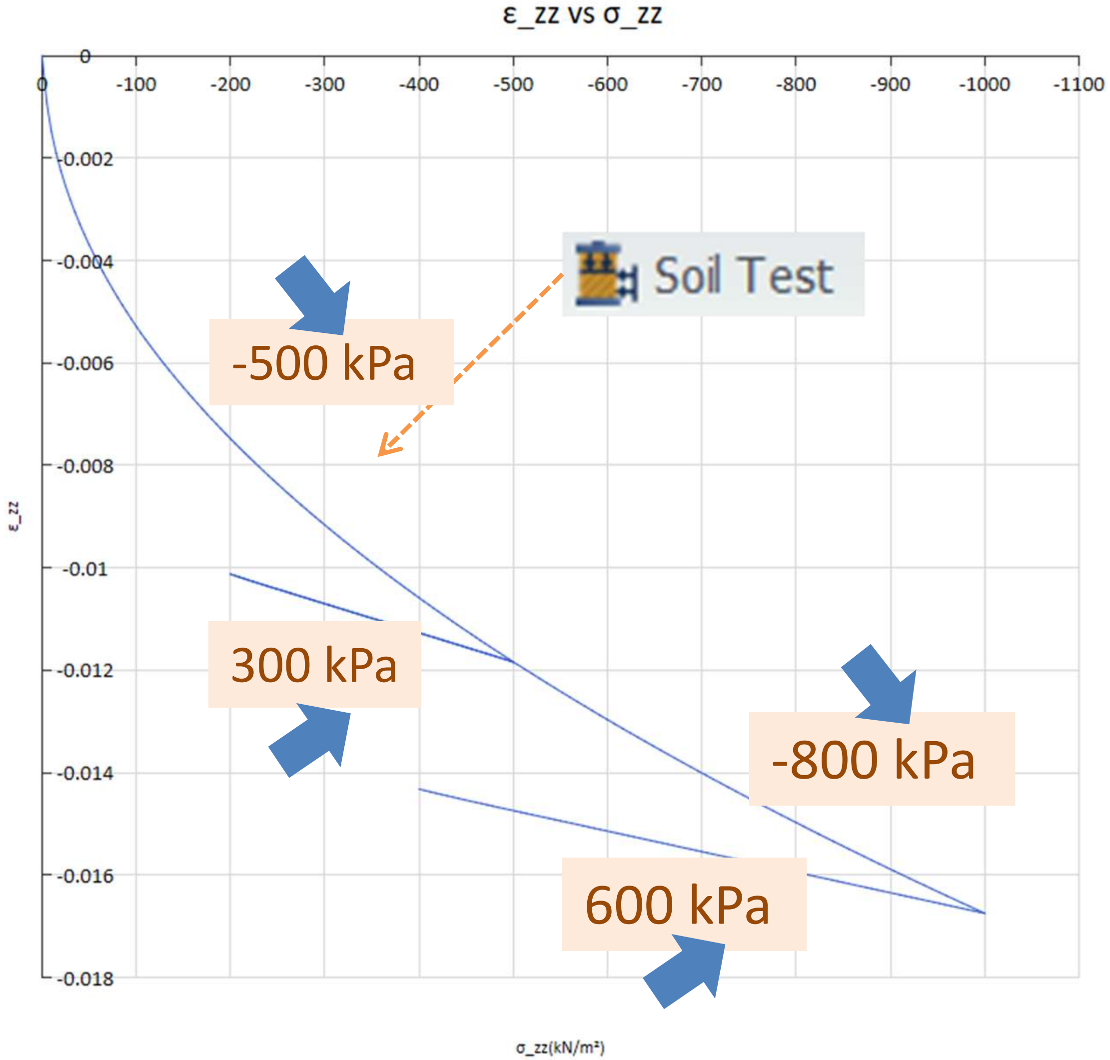
Fig, Representation of triaxial test data by 'Soil Test' in GTS NX

Oedometer test

Table, Stage of loading assignment

	Stage Name	Inc.	Time(day)	σzz (kN/m²)
1	Loading1	100	1.00	-500.000
2	Unloading1	100	1.00	300.000
3	Loading1	100	1.00	-800.000
4	Unloading1	100	1.00	600.000

Fig, Oedometer test



Fig, Schematic of 2 times loading/ unloading

Part3. GTS NX Verification

3.1 Unconfined Compressive Strength (UCS) Test
3.2 Oedometer Test
3.3 Direct Shear (DS) Test

3.1 UCS Test – Lab testing data

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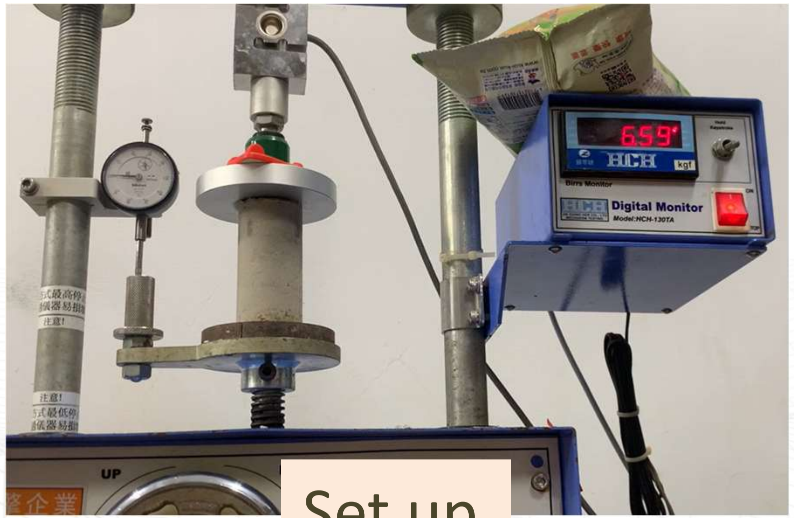
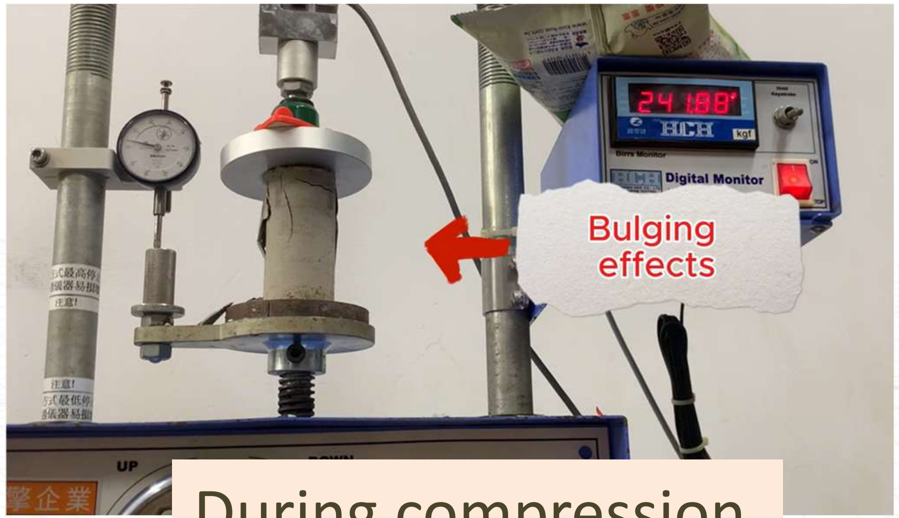
Specimen



Set up



During compression

RESULTS

3.1 UCS Test – GTS NX simulation

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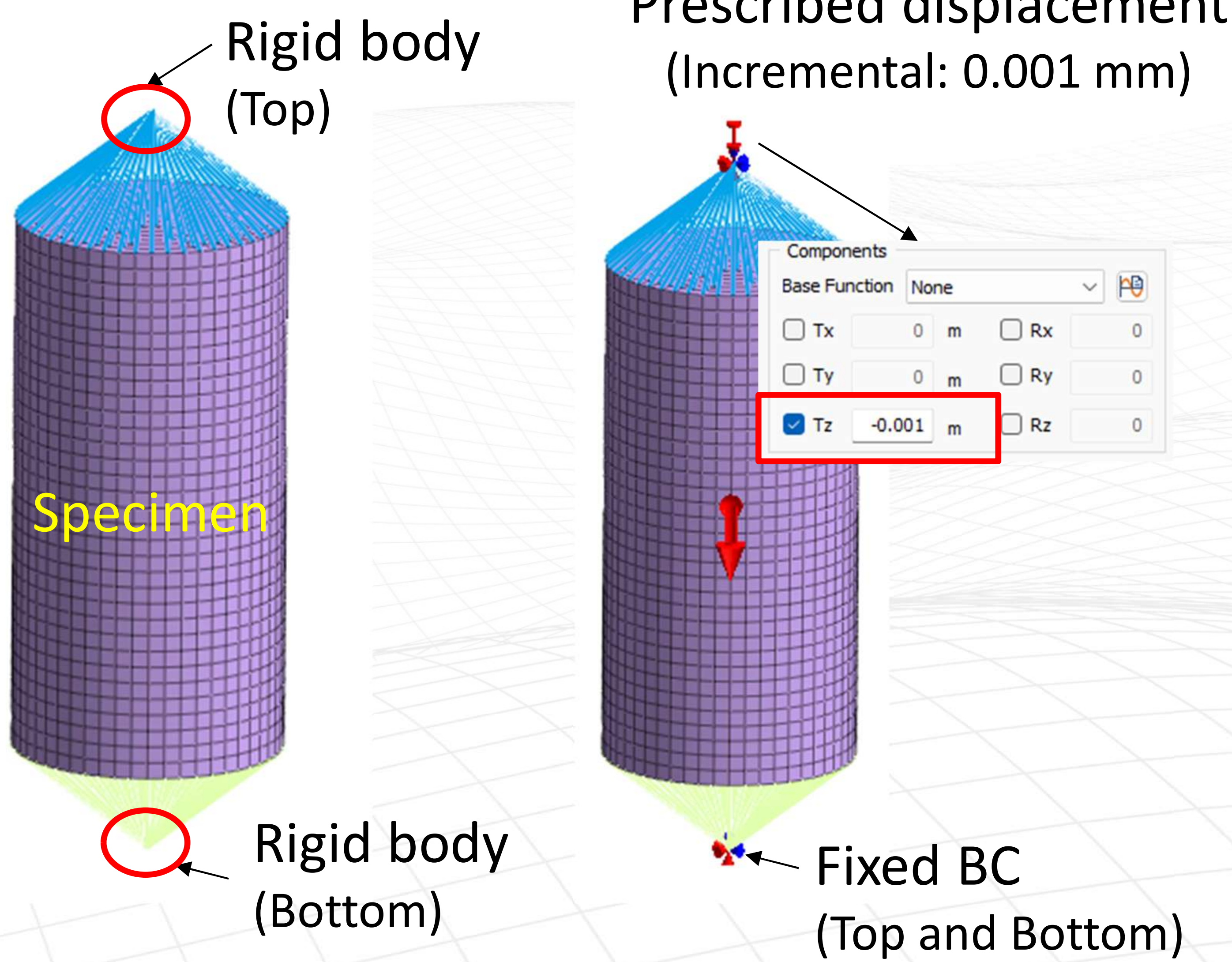
UCS Test with specimen dimension:

5 cm diameter x 10 cm height (H/D=2)

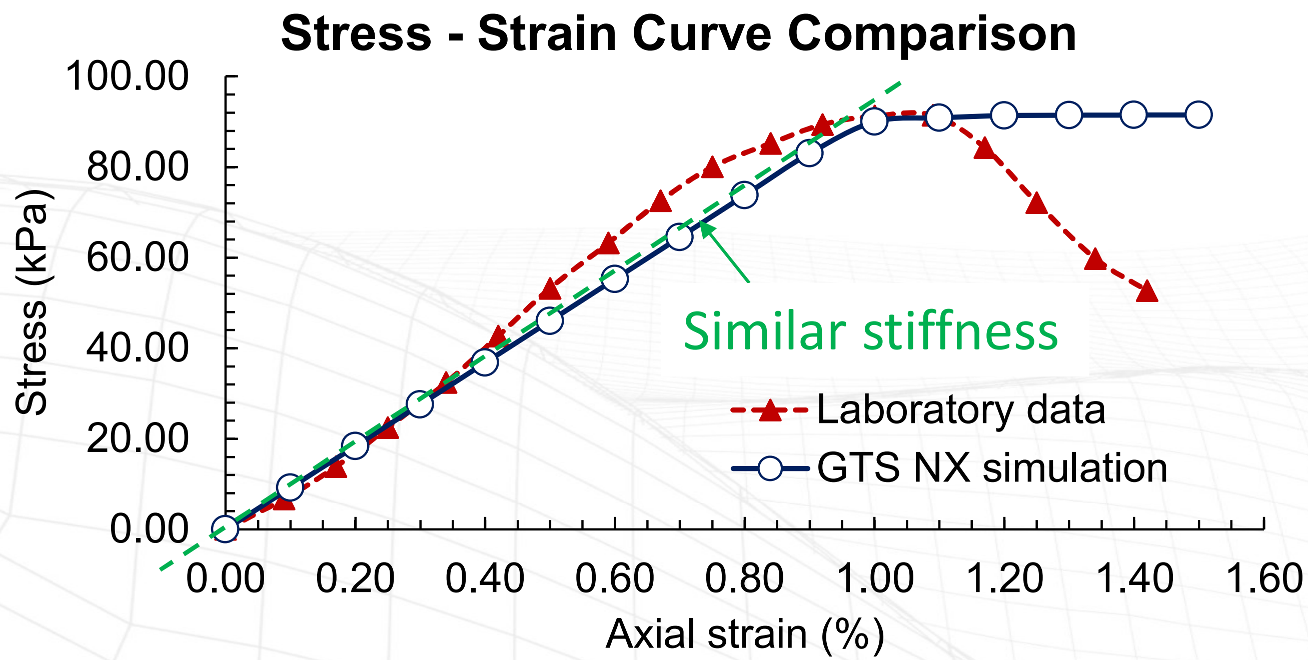
Table, Mohr-coulomb soil parameter input

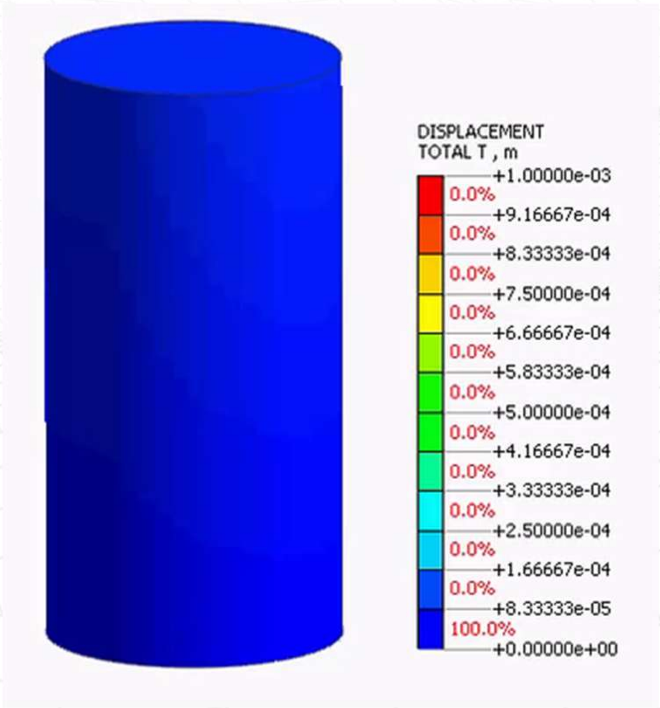
Soil Parameter	Value
Mohr-coulomb model	Drain
Young's modulus (kPa)	18,000
Poisson ratio	0.3
Unit weight (unsat) (kN/m^3)	20
Unit weight (sat) (kN/m^3)	20
Cohesion (kPa)	25
Friction angle (degree)	33



Reference GTS NX file name: UCS Test_final

3.1 UCS Test – Comparison





There are three key highlights:

- Similar peak of stress
- Similar stiffness evolution
- Reality soil & constitutive model is represented

3.2 Oedometer test – Lab testing data

Procedure:

- Increased loading phase: 12 ▶ 25 ▶ 50 ▶ 100
- Decreased loading phase: 100 ▶ 50 ▶ 25 ▶ 12
- Remain 24 hours for each phase

RESULTS

3.2 Oedometer test – GTS NX simulation

GTS NX
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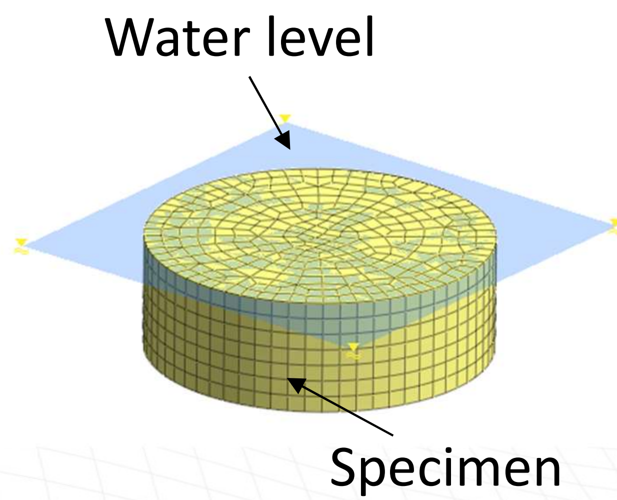
Oedometer Test with specimen dimension:

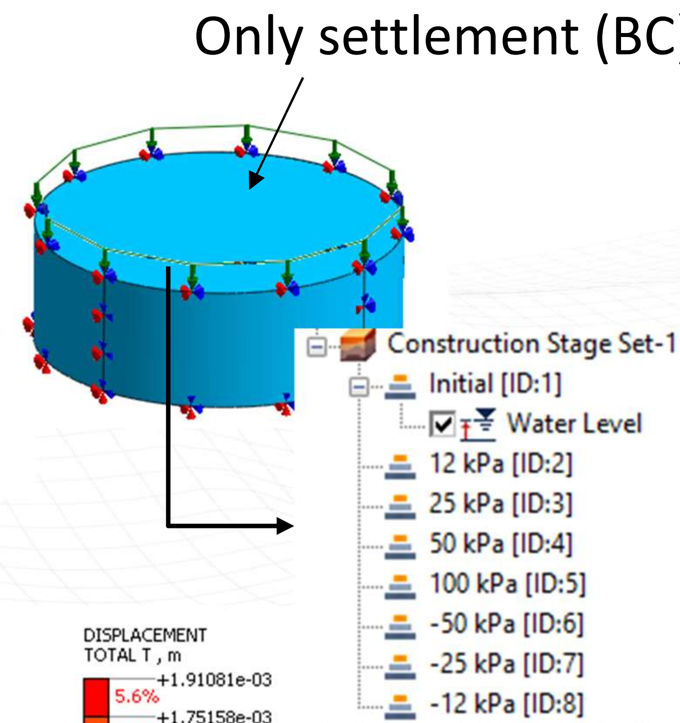
6 cm diameter x 2 cm height (D/H=3)

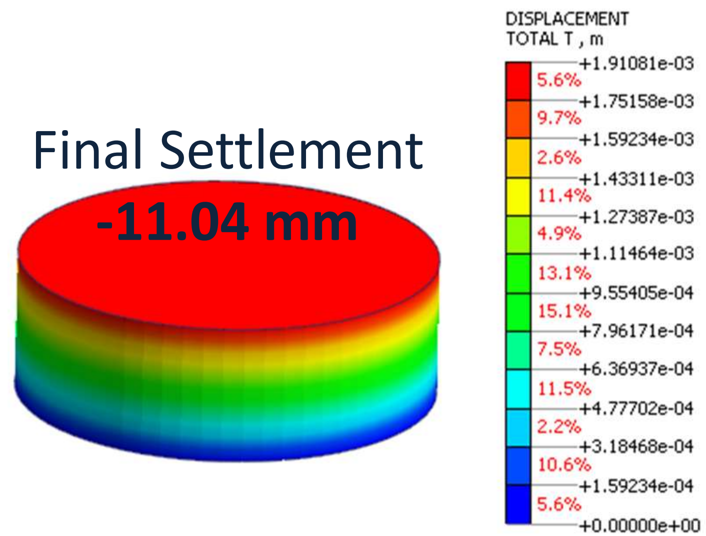
Table, Hardening Soil model parameter input

Soil Parameter	Value
Parameters	Value
Unit weight (dry/sat), g [kN/m^3]	17/18
Cohesion, c [kN/m^2]	25
Power of stress level dependency, m	0.3
E50 (ref), [kPa]	700
Eoed (ref), [kPa]	700
Eur (ref), [kPa]	2100
Friction angle, f [º]	25
Hydraulic conductivity, k (m/s)	$1.167.10^{-8}$
Poisson ratio, n [-]	0.3

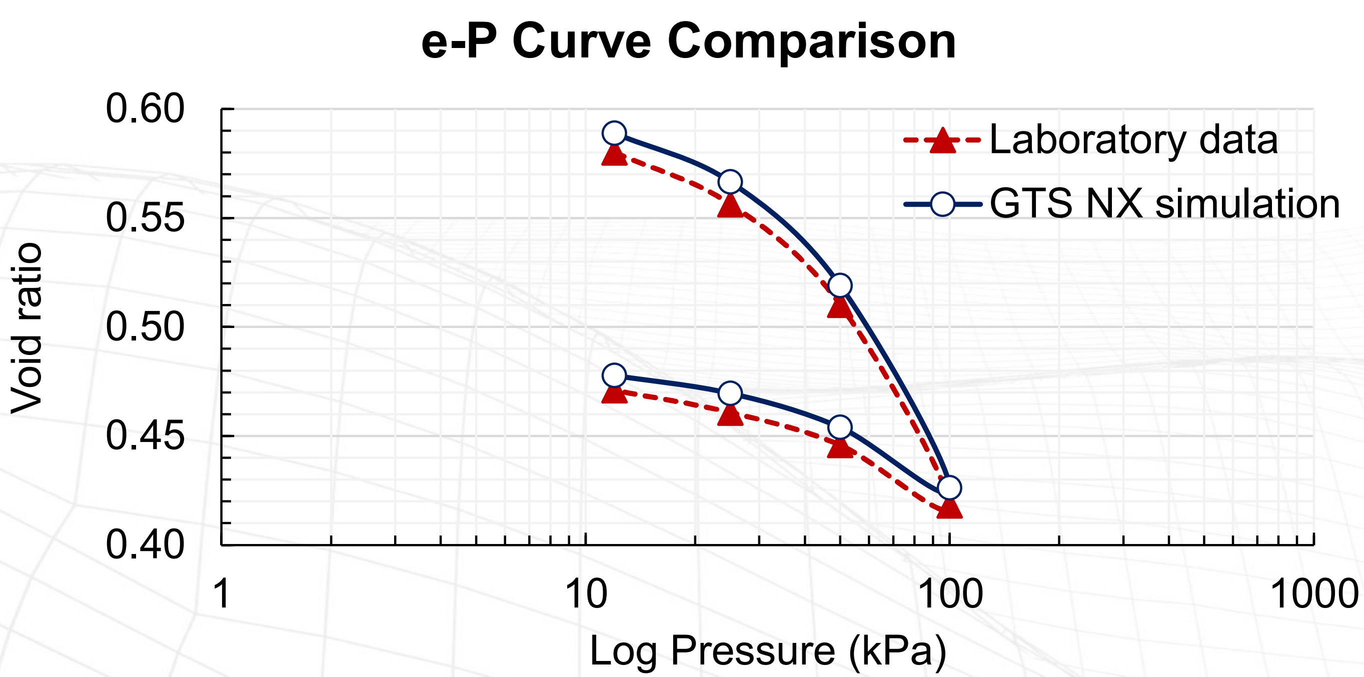
Reference GTS NX file name: Oedometer Test_final



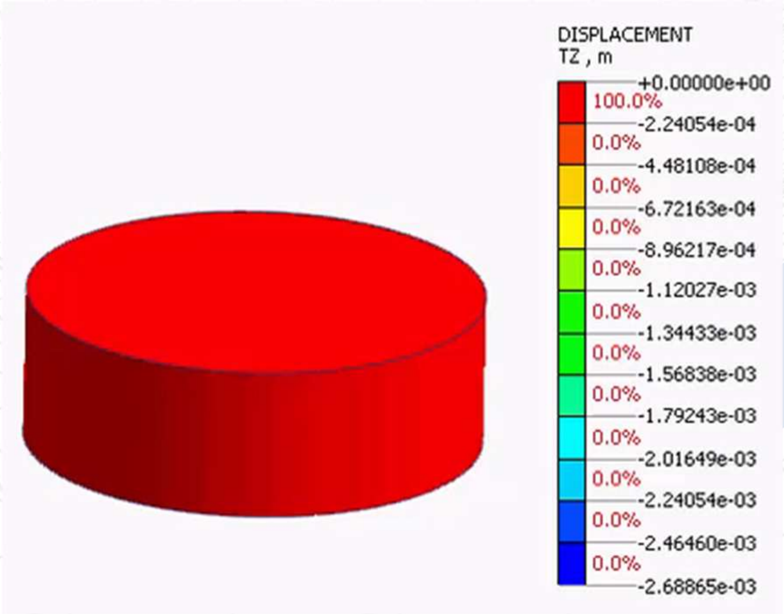




3.2 Oedometer test – Comparison



Laboratory:
-11.15 mm



Simulation:
-11.04 mm

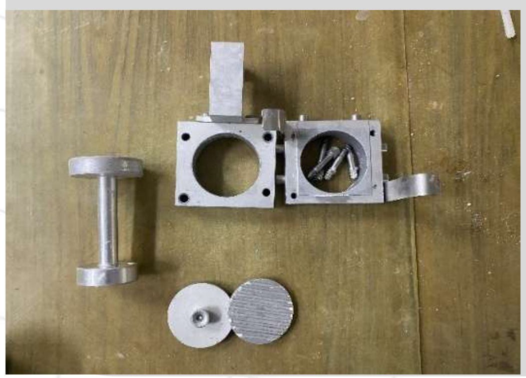
There are two key highlights:

- Similar e-log P curve is represented
- Variation in loading/unloading phase is captured by Hardening Soil Constitutive Model

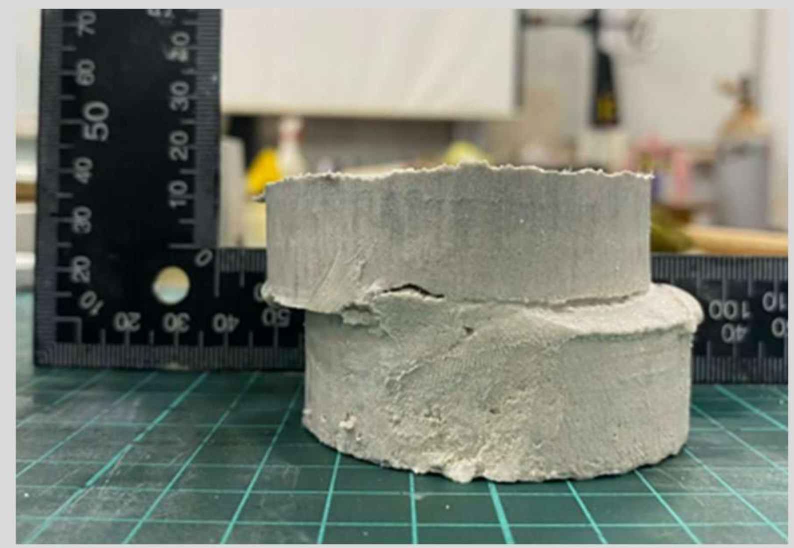
3.3 Direct shear test – Lab testing data

Procedure:

- Normal force: 20 kPa
- Shear force and horizontal displacement are recorded



RESULTS



3.3 Direct shear test – GTS NX simulation

GTS NX
Geo-Technical analysis System New eXperience

Oedometer Test with specimen dimension:

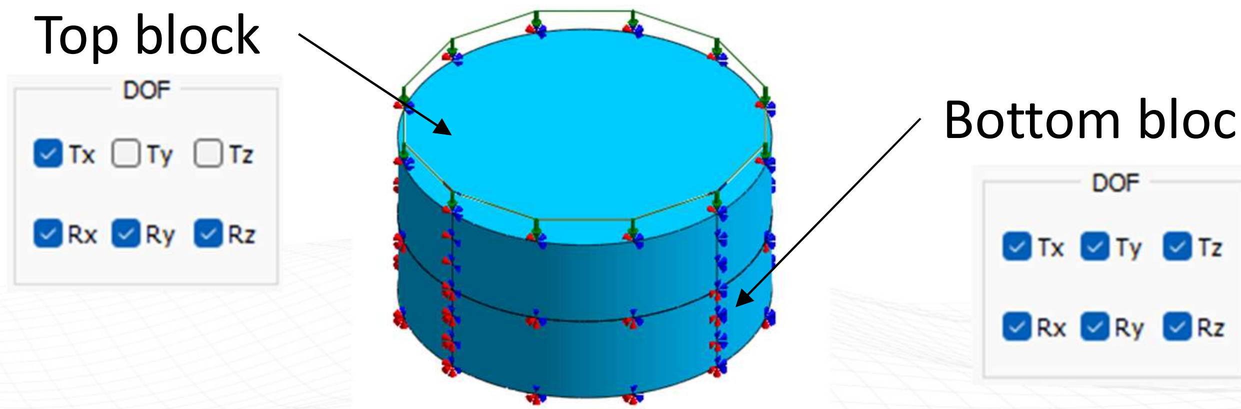
6 cm diameter x 2 cm height (D/H=3)

Table, Mohr-coulomb soil parameter input

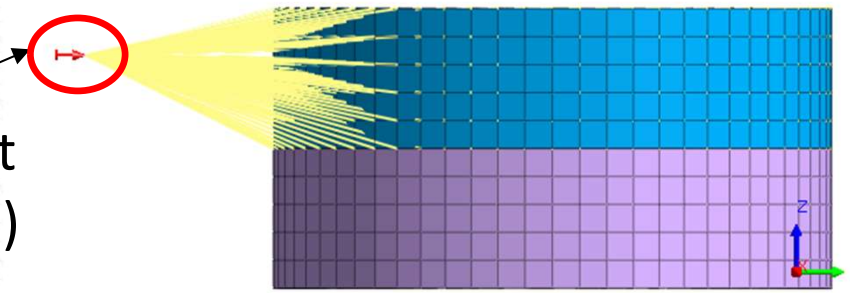
Soil Parameter	Value
Mohr-coulomb model	Drain
Young's modulus (kPa)	5,000
Poisson ratio	0.35
Unit weight (dry) (kN/m^3)	18
Unit weight (sat) (kN/m^3)	19
Cohesion (kPa)	5
Friction angle (degree)	10

Top block

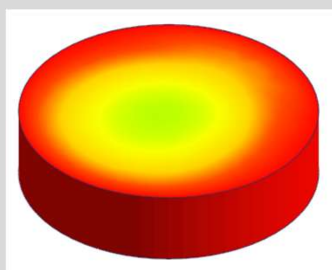
Bottom block

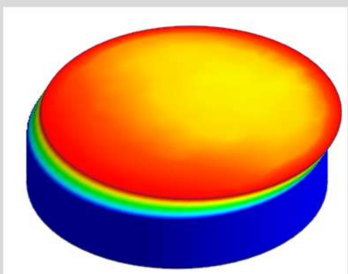


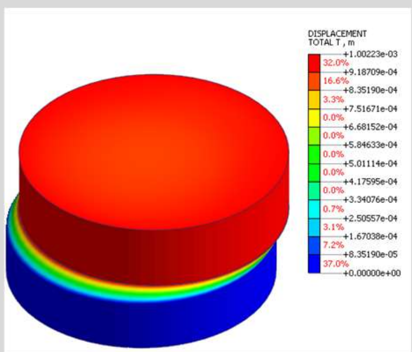
Prescribed displacement
(Incremental: 0.001 mm)



Displacement observation


Top block

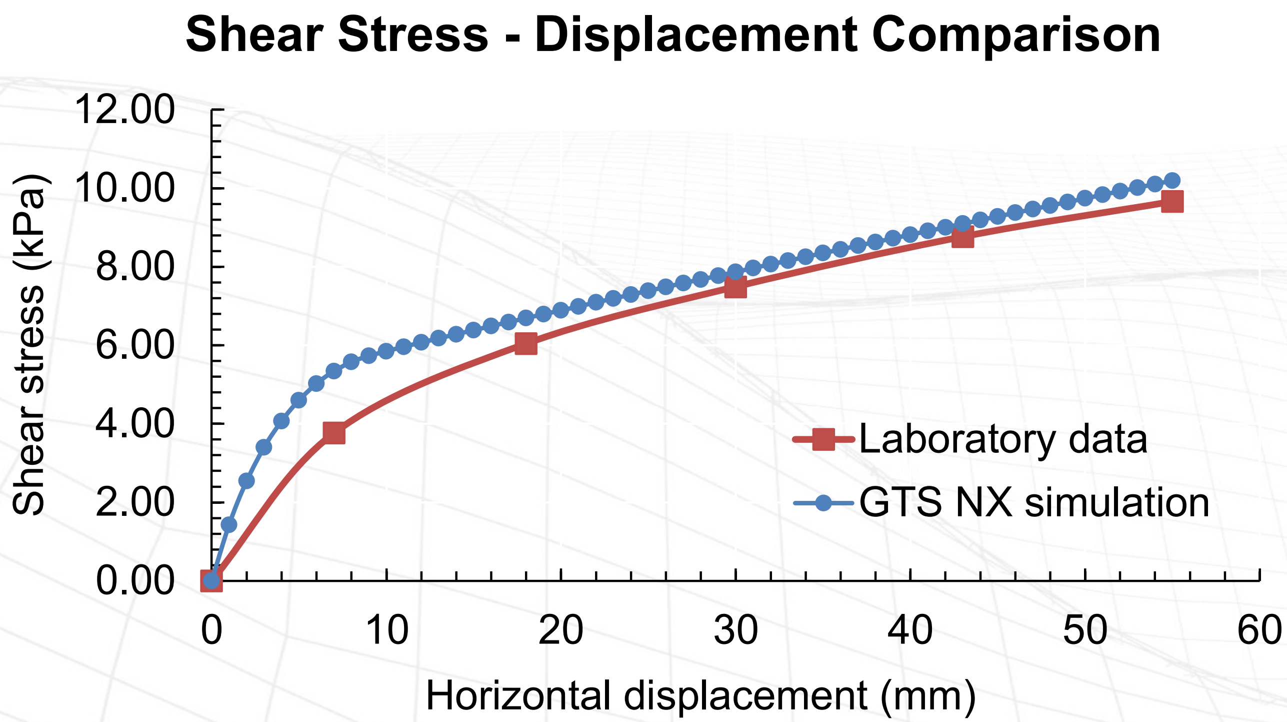

Bottom block

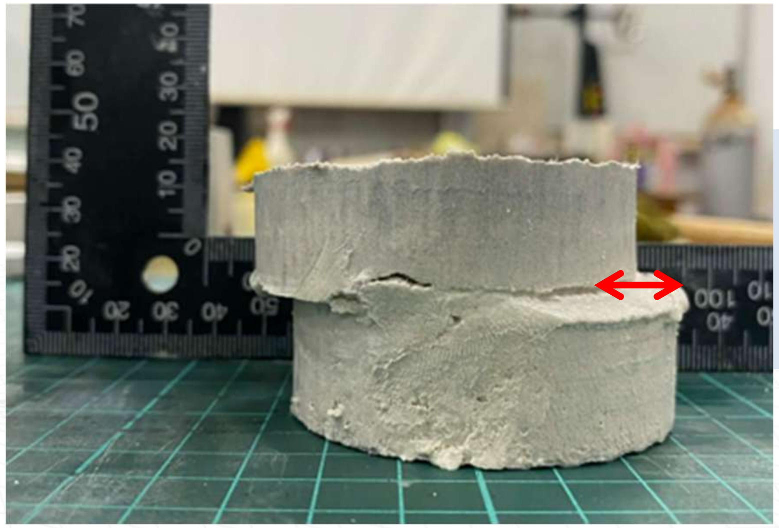

Full block

Reference GTS NX file name: DS Test_final

3.3 Direct shear test – Comparison

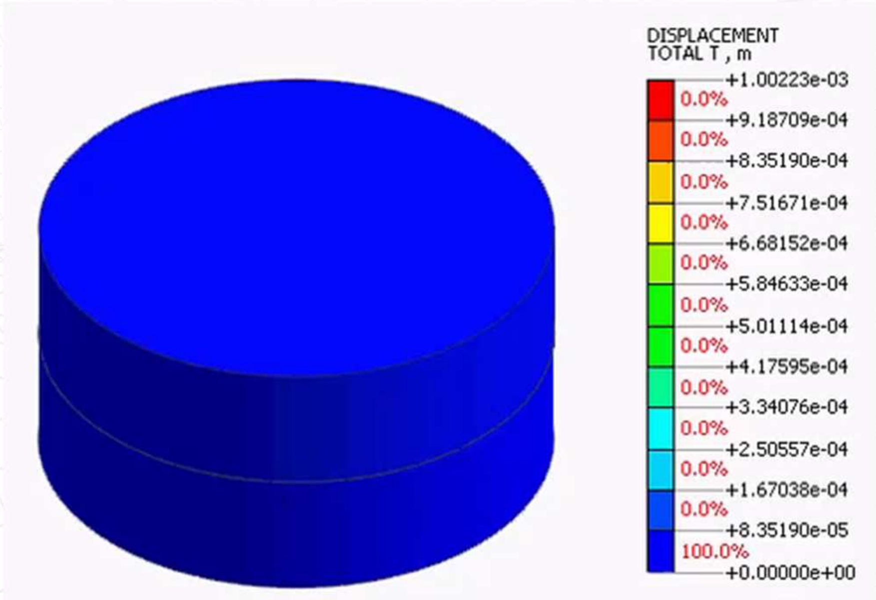
GTS NX
Geo-Technical analysis System New eXperience





Laboratory:
Disp.: 20 mm
Shear stress: 6 kPa

Similar result



The evolution of the shear stress is captured,
with the behavior is agree with the laboratory testing data.

THANK YOU FOR YOUR ATTENTION

support@midasuser.com.tw