Perspectives of Codes and Standardization for Geotechnical Engineering

VSSMGE - JGS
joint workshop on geotechnical design and practice

23 September 2015
at National University of Civil Engineering, Hanoi, Vietnam

25 September 2015
at Ho Chi Minh City University of Technology, Vietnam

Port and Airport Research Institute

Yoichi Watabe

Major Japanese Foundation Codes

- Specifications for Highway Bridges
  IV: Substructures

- Technical Standards for Port and Harbor Facilities

- Railway Structure Design Standard:
  Foundations and Retaining Structures

- Recommendations on
  Limit State Design of Buildings

The three civil structural codes for Highway Bridges, Port and Harbor Facilities, and Railway Structure are grounded on the laws

→ Mandatory Standards

Legal hierarchy structures:

the Law

→ the ministerial ordinance

→ the ministerial notification

Commentaries are very important in these codes

→ The actual design procedures are given in these commentaries

although one of possible methods and not mandatory, these methods are mostly used in the actual design

http://www1.gifu-u.ac.jp/~infdesig/list/honjo02/Original_060a.pdf

Recommendations on Limit State Design of Buildings
→ Supplemental document: not mandatory standard

Legal hierarchy structures
Building Standard Law
→ the ministerial ordinance
→ the ministerial notifications
(mandatory as the minimum requirements)

with recommendations given by supplemental documents (not mandatory)

http://www1.gifu-u.ac.jp/~infdesig/list/honjo02/Original_060a.pdf

Memorandum
between
the Ministry of Land, Infrastructure, Transport and Tourism of Japan
and
the Ministry of Transport of the Socialist Republic of Viet Nam
on
cooperation in development of the national technical standards for port and harbour facilities of the Socialist Republic of Viet Nam

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FOR THE MINISTRY OF LAND, INFRASTRUCTURE, TRANSPORT AND TOURISM OF JAPAN

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Mr. Yaichi Nakahara
Parliamentary Vice-Minister

March 2014

FOR THE MINISTRY OF TRANSPORT OF THE SOCIALIST REPUBLIC OF VIET NAM

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Mr. Nguyen Ngoc Dong
Deputy Minister

Technical Standards and Commentaries for Port and Harbour Facilities in Japan

Japanese version **English translation** **Vietnamese version**

Collaboration

by courtesy of NILIM MLIT

High Level Seminar on Soft Infrastructure for Development of Safe and Efficient Transport Network, March 2014

Technical Workshop between ITST (Institute of Transport Science and Technology, Vietnam) and NILIM (National Institute for Land and Infrastructure Management, Japan), January 2014

OCDI 2009 version
You can download freely all the documents through
http://www.ocdi.or.jp/en/technical-st-en.html
Introducing reliability-based performance-based design
Ideal, but difficult to understand.

OCDI 2002 version
Easy understandable for engineers
Clear concept (e.g. factor of safety)

ITST (Vietnam) is writing a Vietnamese original technical code based on both 2002 and 2009 versions in collaboration with MLIT.

Part II Design Conditions (in OCDI 2002 version)

Chapter 11 Subsoil

11.1 Method of Determining Geotechnical Conditions
- 11.1.2 Selection of Soil Investigation Methods
- 11.1.3 Standard Penetration Test

11.2 Physical Properties of Soils
- 11.2.1 Unit Weight of Soil
- 11.2.2 Classification of Soils
- 11.2.3 Coefficient of Permeability of Soil

11.3 Mechanical Properties of Soils
- 11.3.1 Elastic Constants
- 11.3.2 Consolidation Properties
- 11.3.3 Shear Properties

11.4 Angle of Internal Friction by *N*-value

11.5 Application of Soundings Other Than SPT

11.6 Dynamic Properties of Soils
- 11.6.1 Dynamic Modulus of Deformation
- 11.6.2 Dynamic Strength Properties

Part II Design Conditions (in OCDI 2002 version)

Chapter 13 Liquefaction

13.2 Prediction of Liquefaction

13.3 Countermeasures against Liquefaction

Chapter 14 Earth Pressure and Water Pressure

14.2 Earth Pressure under Ordinary Conditions

- 14.2.1 Earth Pressure of Sandy Soil under Ordinary Conditions
- 14.2.2 Earth Pressure of Cohesive Soil under Ordinary Conditions

14.3 Earth Pressure during Earthquake

- 14.3.1 Earth Pressure of Sandy Soil during Earthquake
- 14.3.2 Earth Pressure of Cohesive Soil during Earthquake
- 14.3.3 Apparent Seismic Coefficient

14.4 Water Pressure

- 14.4.1 Residual Water Pressure
- 14.4.2 Dynamic Water Pressure during Earthquake

Part V Foundations (in OCDI 2002 version)

Chapter 2 Bearing Capacity of Shallow Foundations

2.2 Bearing Capacity of Foundation on Sandy Ground
2.3 Bearing Capacity of Foundation on Clayey Ground
2.4 Bearing Capacity of Multilayered Ground
2.5 Bearing Capacity for Eccentric and Inclined Loads

Chapter 3 Bearing Capacity of Deep Foundations

3.2 Vertical Bearing Capacity
3.3 Lateral Bearing Capacity

Chapter 4 Bearing Capacity of Pile Foundations

4.1 Allowable Axial Bearing Capacity of Piles
(Single Pile, Loading Test, Formulas, Joints, Slenderness Ratio, Pile Group, Negative Skin Friction, Settlement)
4.2 Allowable Pulling Resistance of Piles
4.3 Allowable Lateral Bearing Capacity of Piles
4.4 Pile Design in General
4.5 Detailed Design

Part V Foundations (in OCDI 2002 version)

Chapter 5 Settlement of Foundations

5.1 Stress in Soil Mass
5.2 Immediate Settlement
5.3 Consolidation Settlement
5.4 Lateral Displacement
5.5 Differential Settlements

Chapter 6 Stability of Slopes

6.2 Stability Analysis
  6.2.1 Stability Analysis Using Circular Slip Surface Method
  6.2.2 Stability Analysis Assuming Slip Surfaces Other Than Circular Arc Slip Surface

Part V Foundations

Chapter 7 Soil Improvement Methods

7.2 Replacement Method
7.3 Vertical Drain Method
7.4 Deep Mixing Method
7.5 Lightweight Treated Soil Method
7.6 Replacement Method with Granulated Blast Furnace Slag
7.7 Premixing Method
7.8 Active Earth Pressure of Solidified Geotechnical Materials
7.9 Sand Compaction Pile Method (for Sandy Subsoil)
7.10 Sand Compaction Pile Method (for Cohesive Subsoil)

Soil parameters

JIS or JGS is required

Table T- 11.1.2 Soil Investigation Methods and Soil Parameters.

Purpose	Investigation method	Soil parameters	
Verification of conditions of stratification	Boring Sounding Geophysical exploration	Depth of bearing layer Thickness of soft layer Stratification	
Bearing capacity Slope stability Earth pressure	Undisturbed sampling Sounding Field test	Unconfined compressive strength Shear strength Angle of shear resistance Relative density	q_u τ_f ϕ D_r
Consolidation characteristics	Undisturbed sampling	Coefficient of consolidation Coefficient of volume compressibility	c_v m_v
Permeability	Undisturbed sampling Field test	Coefficient of permeability	k
Compaction characteristics	Disturbed sampling is allowed Field test	Maximum dry density Optimum moisture content CBR	$\gamma_{d\max}$ w_{opt}
Classification	Undisturbed sampling (Disturbed sampling is allowed except for γ_t)	Unit weight Moisture content Soil particle density Gradation Consistency	γ_t w ρ_s w_L, w_P

Shear properties

For cohesive soil (the sand content is less than 50%)

$$\tau = c_u$$

where

- τ : shear strength (kN/m^2)
- c_u : undrained shear strength (kN/m^2)

For sandy soil (the sand content is higher than 80%)

$$\tau = (\sigma - u)\tan\phi_d$$

where

- τ : shear strength (kN/m^2)
- σ : normal stress to shear plane (kN/m^2)
- u : steady water pressure at the site (kN/m^2)
- ϕ_d : angle of shear resistance for drained conditions (º)

Shear strength

- In-situ test

  Standard Penetration Test =SPT (N-value)

  Cone Penetration Test = CPTU (q_t, u_d, f_d)

- Laboratory test

  Undisturbed Sample ← Sampling Method

In Japan,

"sampling + laboratory tests" is for clayey soils

"SPT" is for sandy soils

Sampling

→ How to collect an undisturbed sample

- **Thin-walled tube sampler with fixed piston**

For soft clay

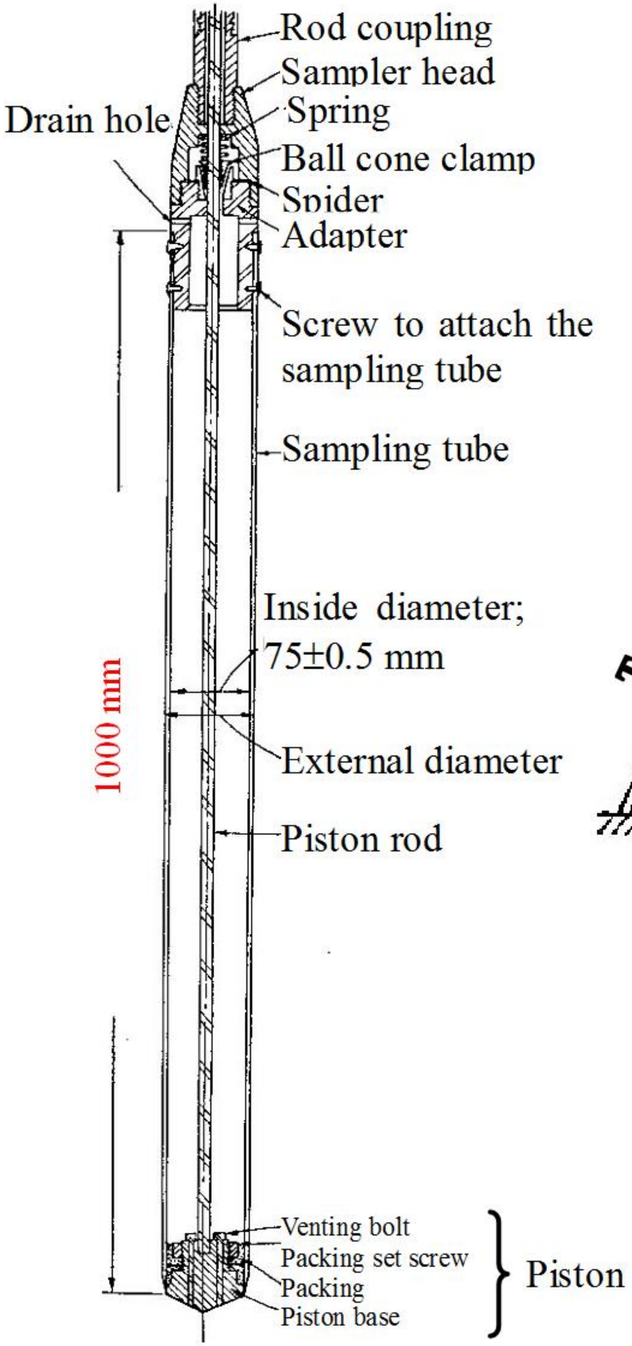
Very popular in Japan

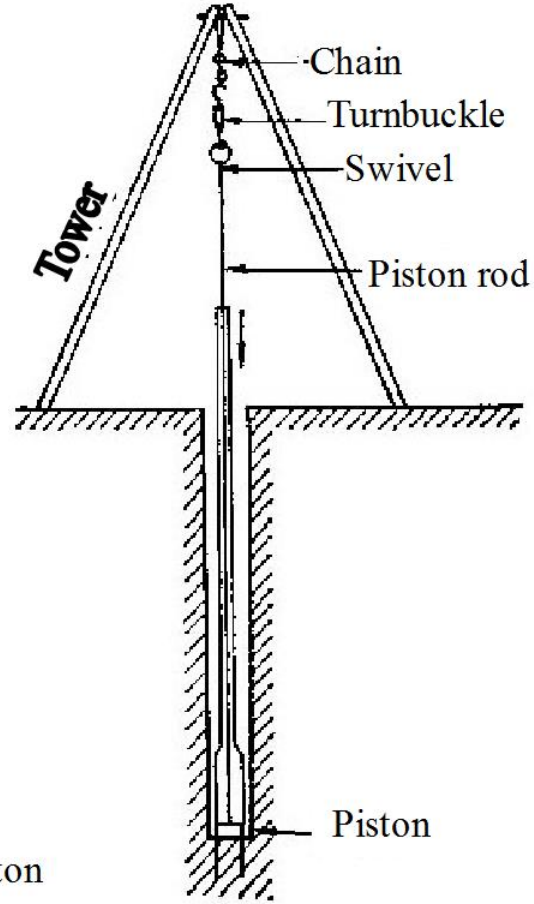
Role of piston is important

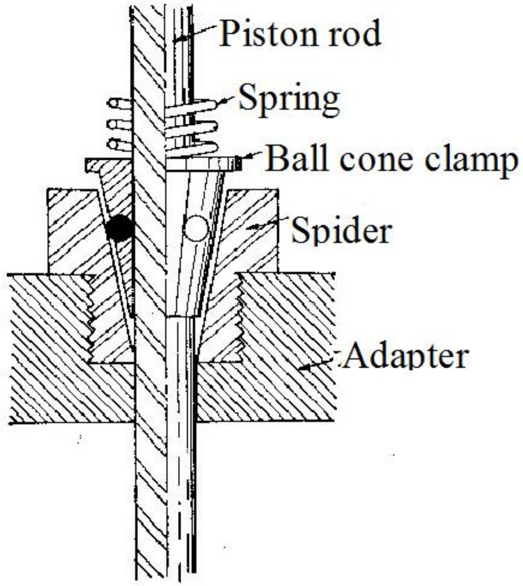
- **Denison sampler (Rotary double tube sampler)**

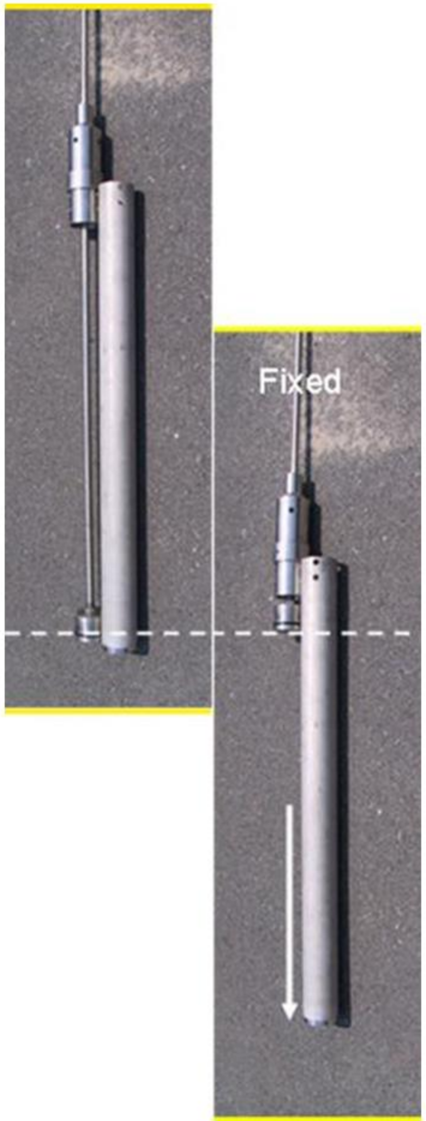
For stiff clay

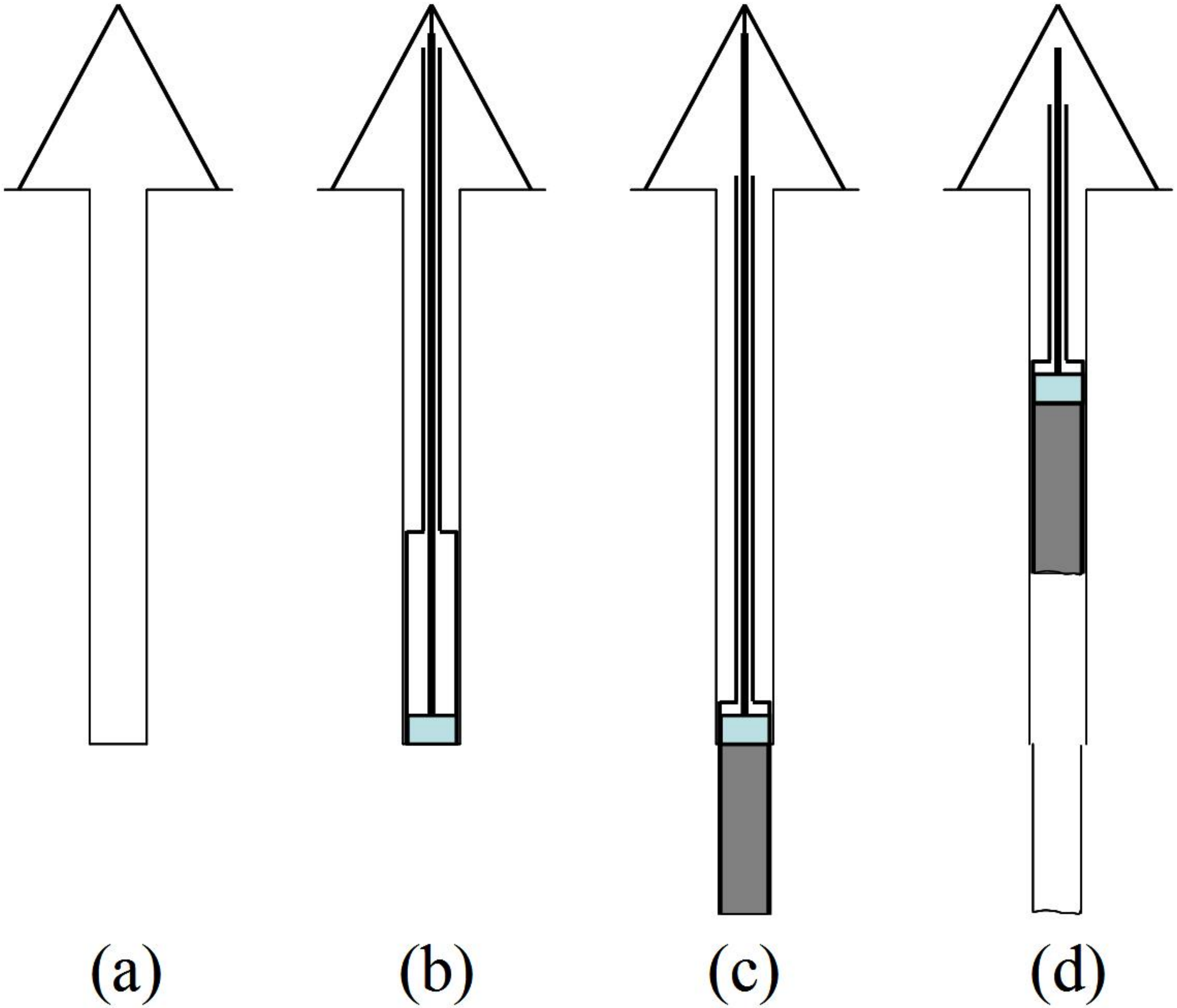
Thin-walled tube sampler with fixed piston











Sampling procedure using the Japanese thin-walled tube sampler with fixed piston

Thin walled tube sampler with fixed piston:

Left: hydraulic operation type

Right: extension rod type

hydraulic operation type

Disturbance in the sampling

- **Stress release → Inevitable**

- **Mechanical disturbance**
  (Strain, Deformation, Crack)
  → Depends on the Sampling method

-Remolding type・・・Shallow and Soft clay

-Crack type・・・Deep and Stiff clay

Stress path during the sampling

A: Ideal sample

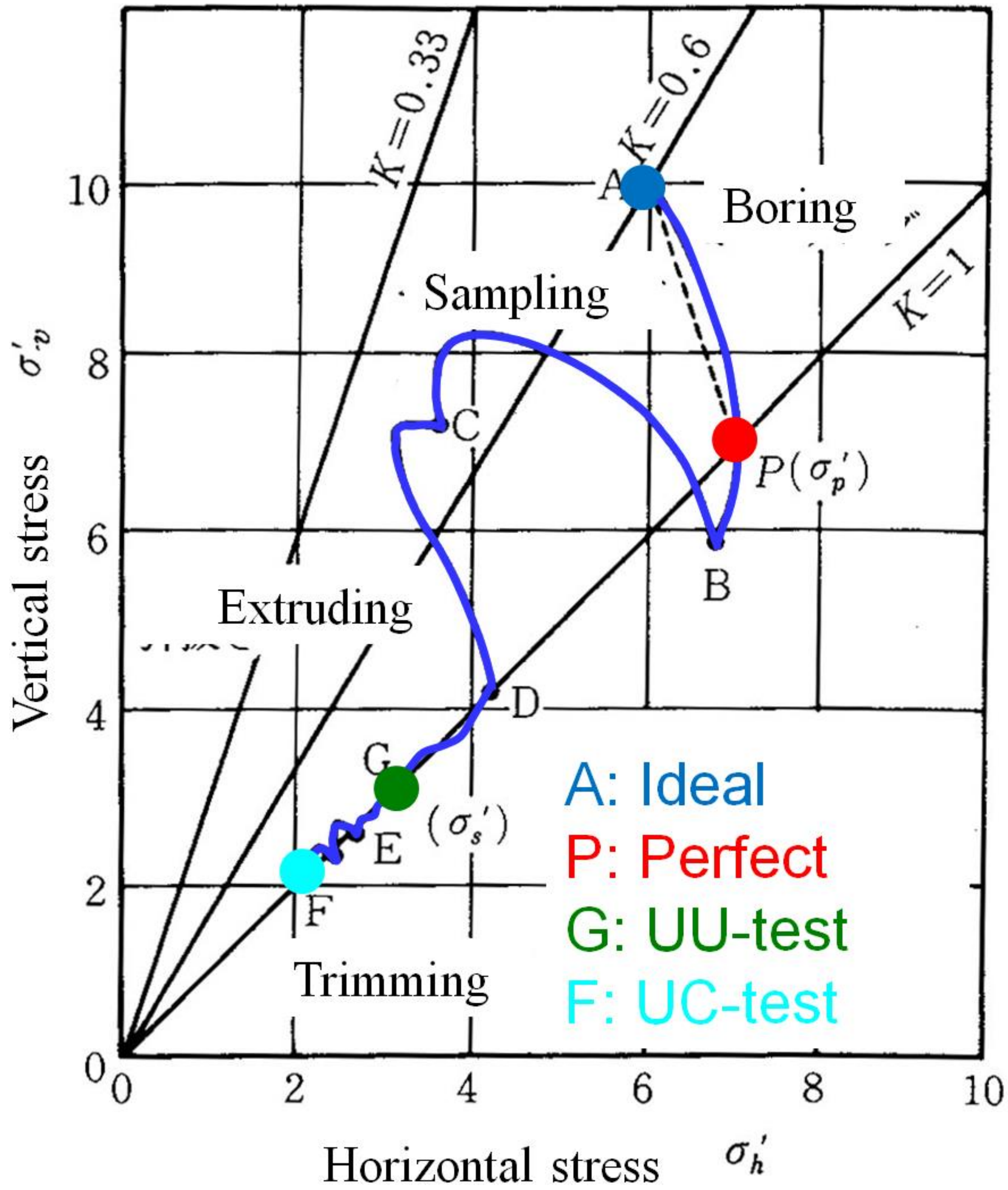
Impossible by stress release

B: Perfect sample

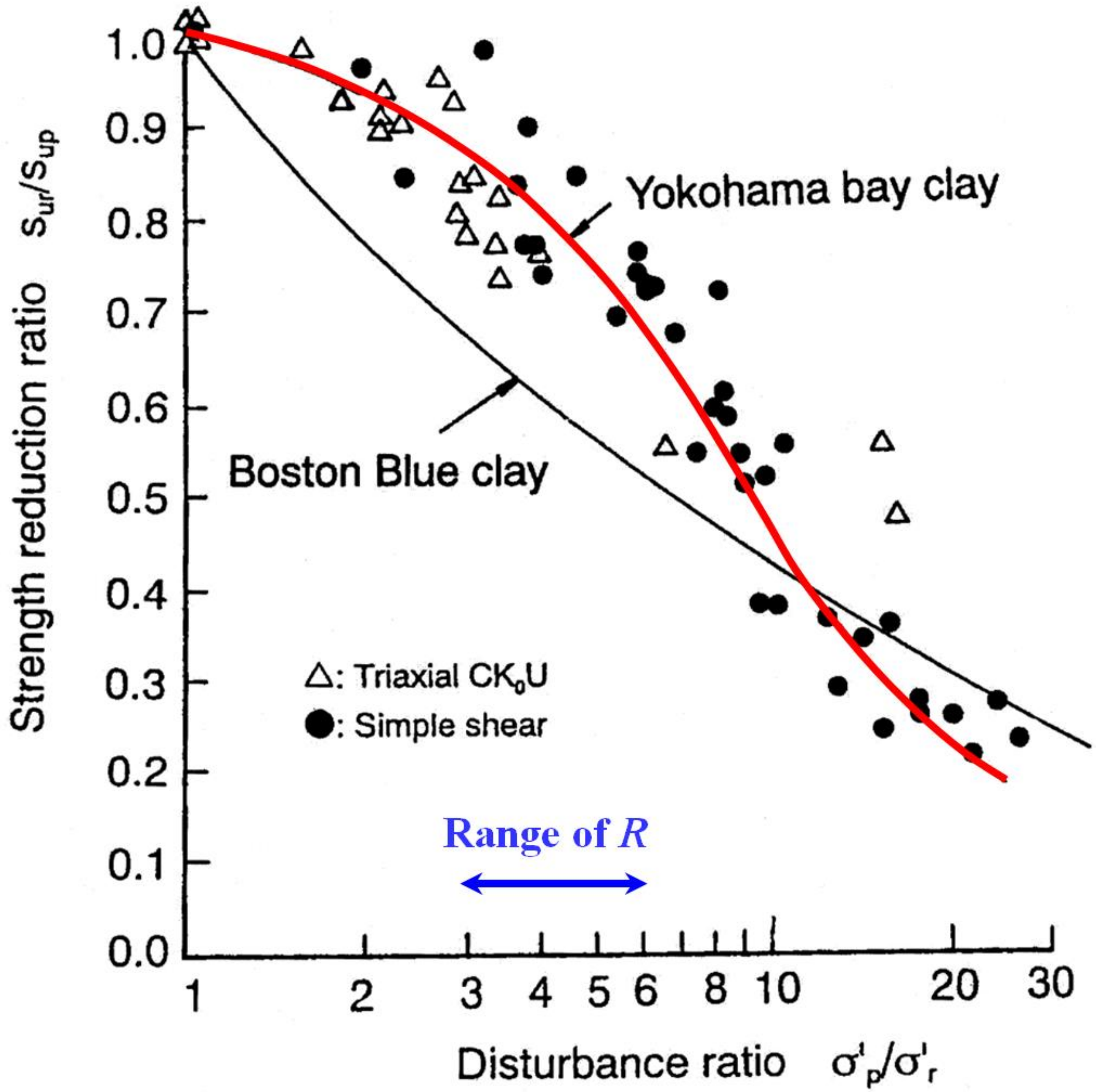
No mechanical disturbance with stress release

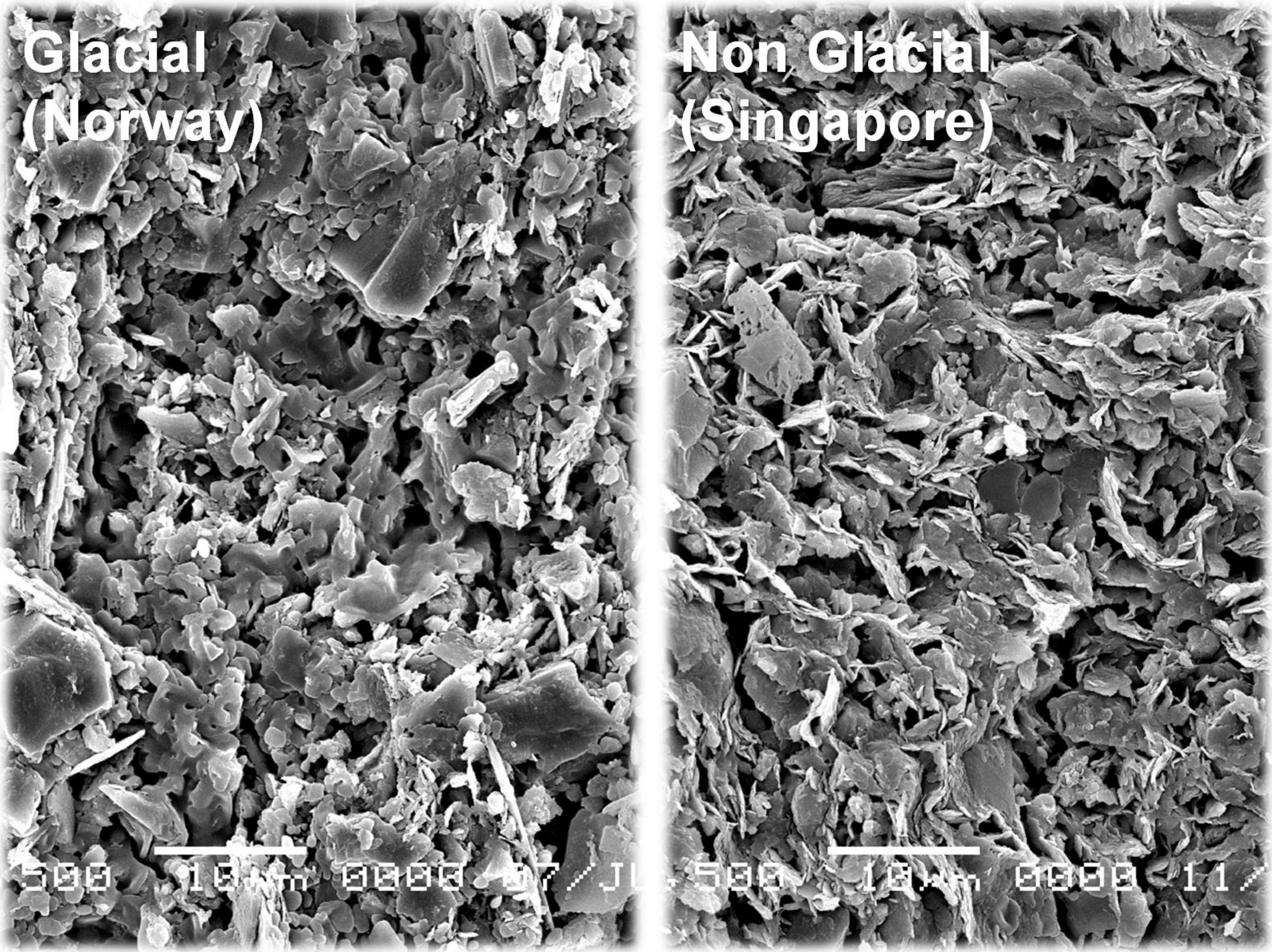
Disturbance Ratio

$R = \sigma'_p / \sigma'_s \rightarrow 3—6$

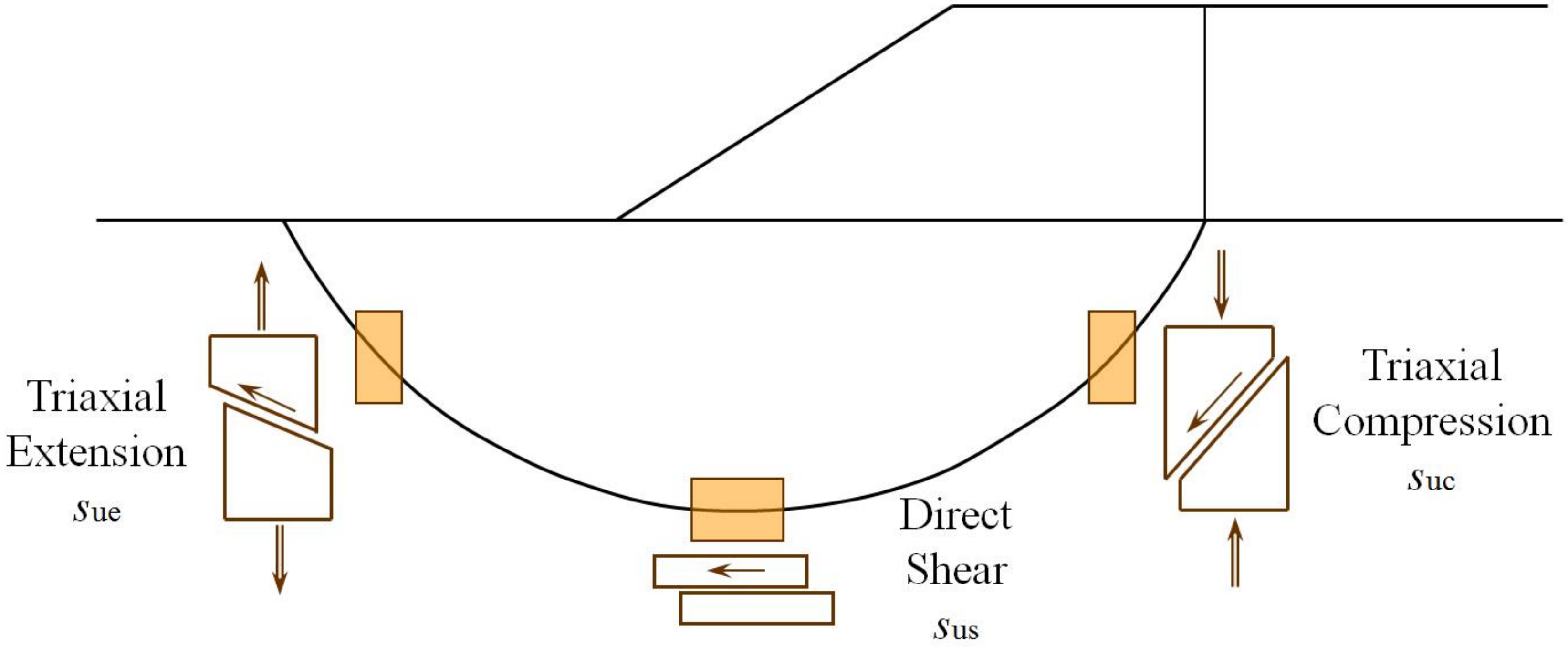


Disturbance ratio and Strength reduction




Glacial
(Norway)
Non Glacial
(Singapore)

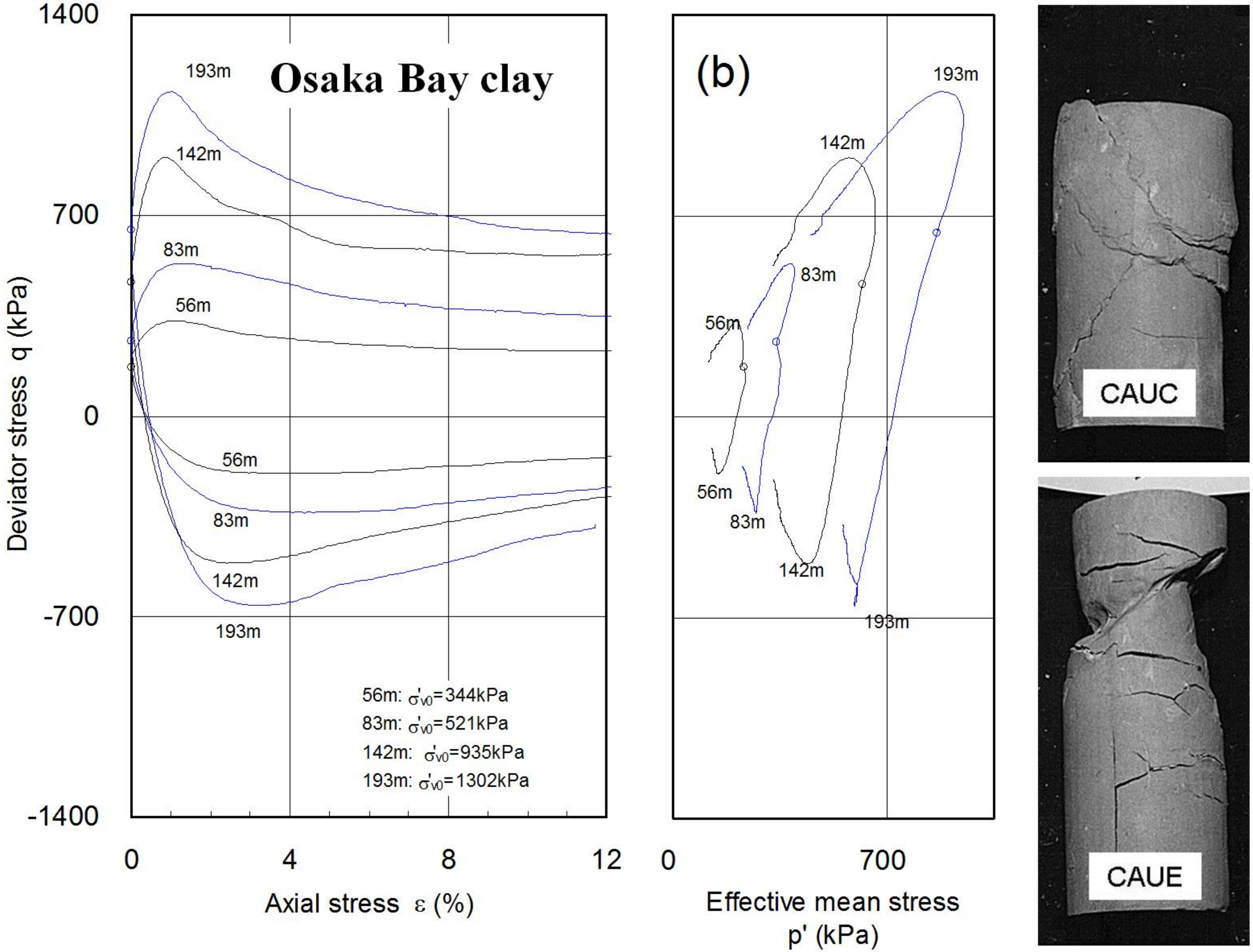
Strength anisotropy



$$s_u = (s_{uc} + 2s_{us} + s_{ue}) / 4$$

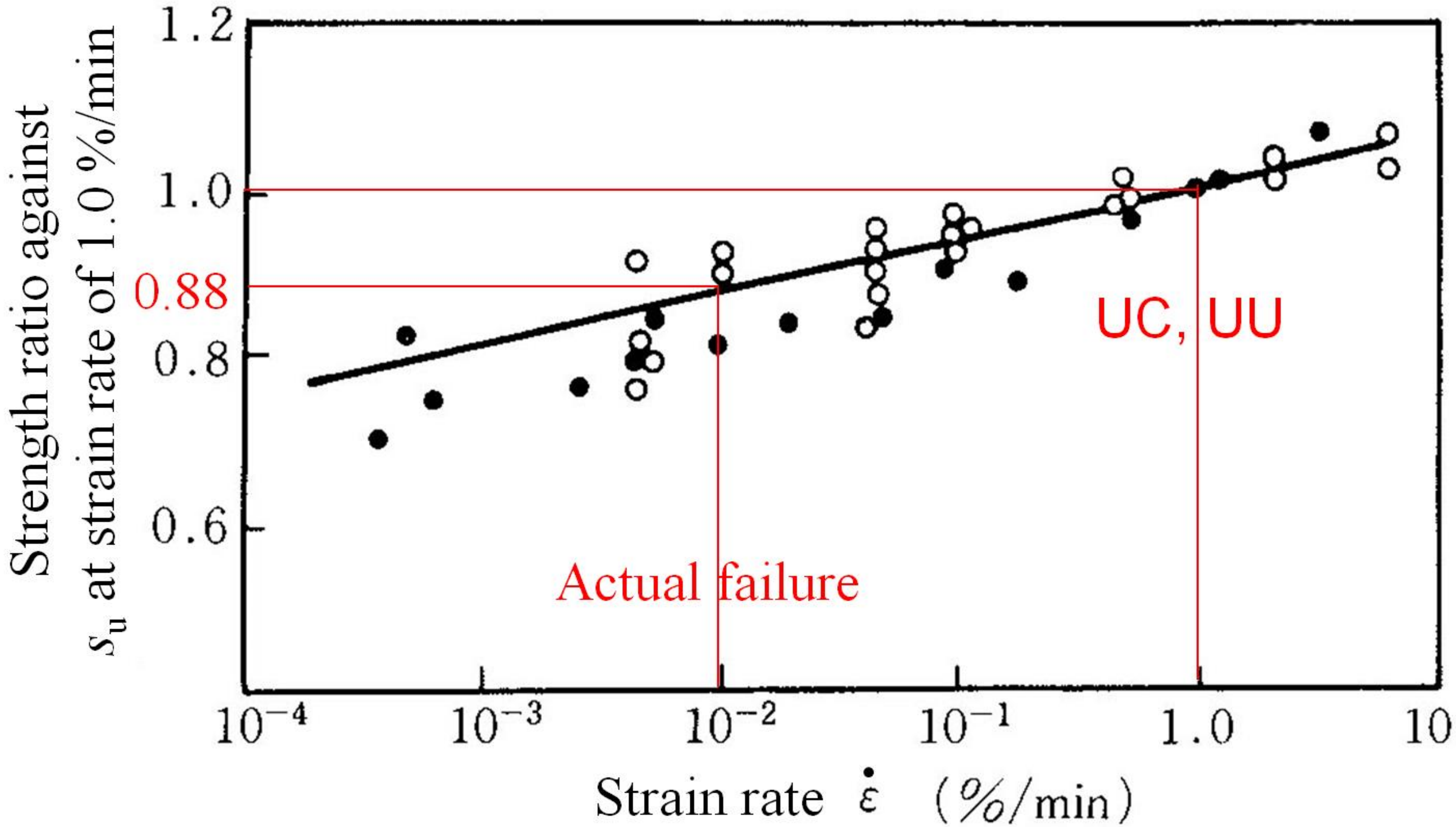
$$s_u = (s_{uc} + s_{ue}) / 2 \quad \text{or} \quad s_u = s_{us}$$

Strength anisotropy $s_{ue}/s_{uc} \fallingdotseq 0.7$



Osaka Bay clay
(b)
Deviator stress q (kPa)
1400
700
0
-700
-1400
193m
142m
83m
56m
56m: σ'v0=344kPa
83m: σ'v0=521kPa
142m: σ'v0=935kPa
193m: σ'v0=1302kPa
0
4
8
12
Axial stress ε (%)
0
700
Effective mean stress
p' (kPa)
CAUC
CAUE

Strain rate effect



Shear strength for design

$s_u^* = (q_u/2) \times c_1 \times c_2 \times c_3$

c_1: correction factor for sample disturbance

c_2: correction factor for strength anisotropy

c_3: correction factor for strain rate

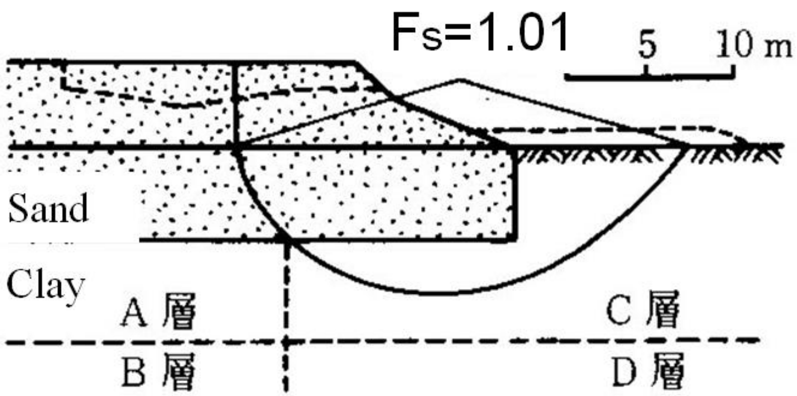
c_1 = 1.0(perfect sample)／0.7(average disturbance)

c_2 = {1.0(compression) +0.7(extension)} ／2 = 0.85

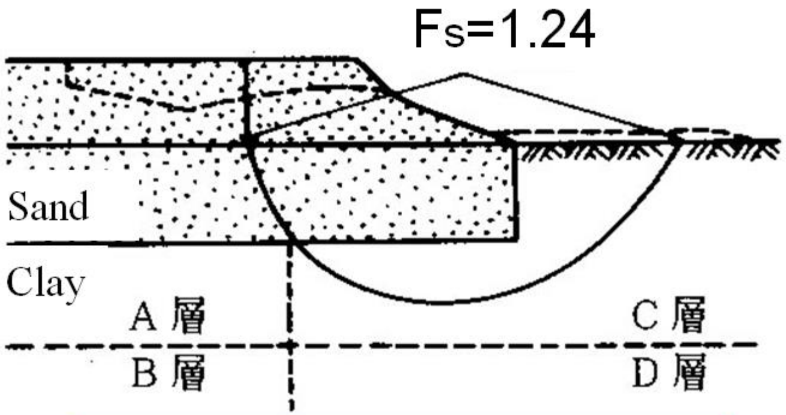
c_3 = 0.85(ε=1.0%／min and 0.01%／min)

$c_1 \times c_2 \times c_3 \rightarrow 1$

Effect of data variation on the design

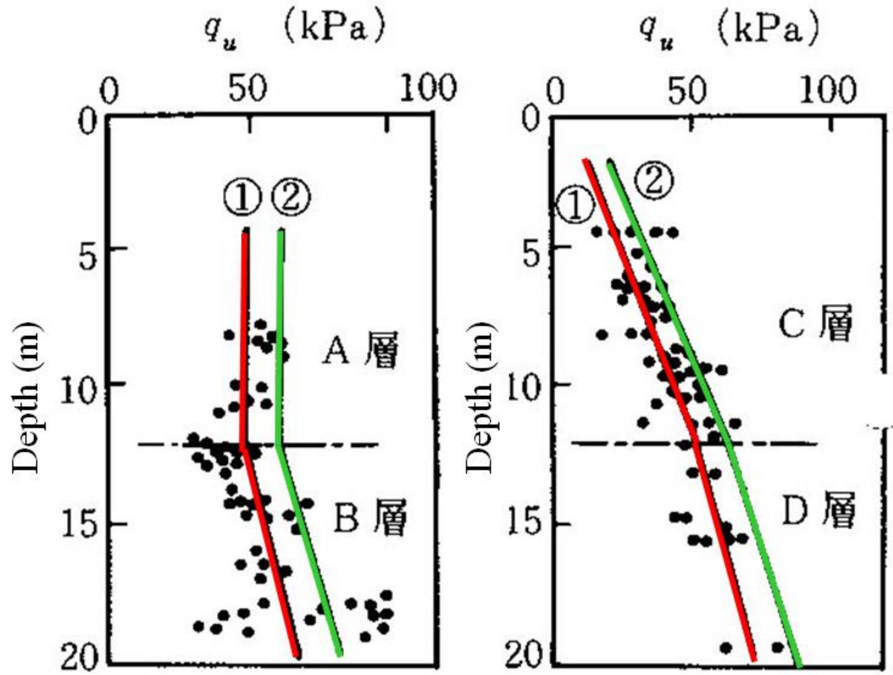


Circle arc failure on the profile ①



Circle arc failure on the profile ②

An analysis of the embankment. (Nakase, 1967)



Prerequisite for UC test

- **Sampling by thin-walled tube sampler with fixed piston → moderate disturbance (= slight disturbance)**

  Followings cause "too much disturbance"

  Sampling in slipshod manner
  Using poor sampler
  Shock in the transportation
  Careless trimming
  Shock into the specimen

  Smaller strength is obtained → Overdesign

Application of UC strength to design

Stability analysis by using UC strength

Common sense in Japan, but

Not common in other countries

UU-test ← valid for crack type disturbance

CU-test (Consolidation with σ'_{v0})

← valid for remolding type disturbance

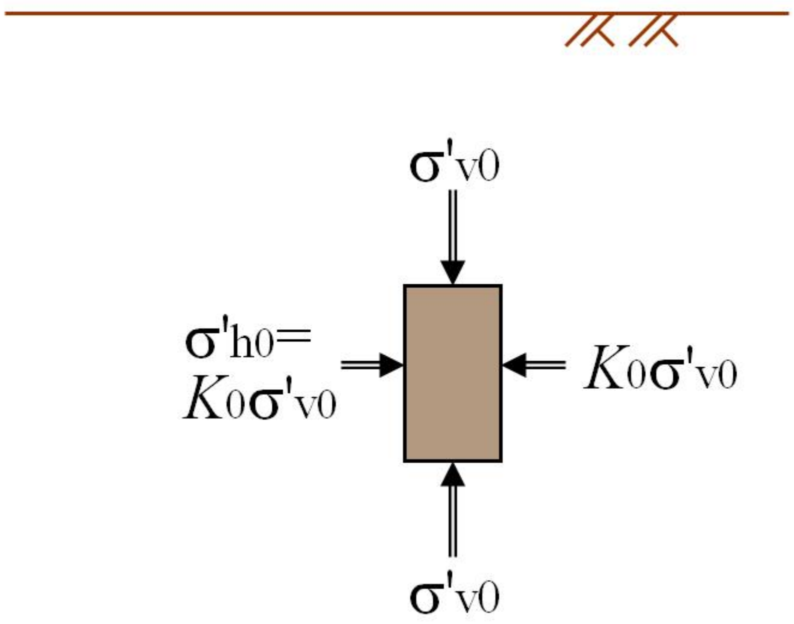
with different characteristics

(disturbance, anisotropy, strain rate effect)

To obtain a reliable test result …

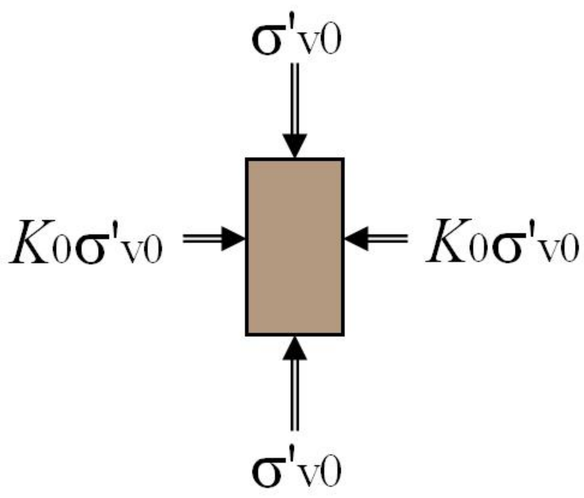
- Recompression method
  → Minimize the effect of disturbance

In-situ

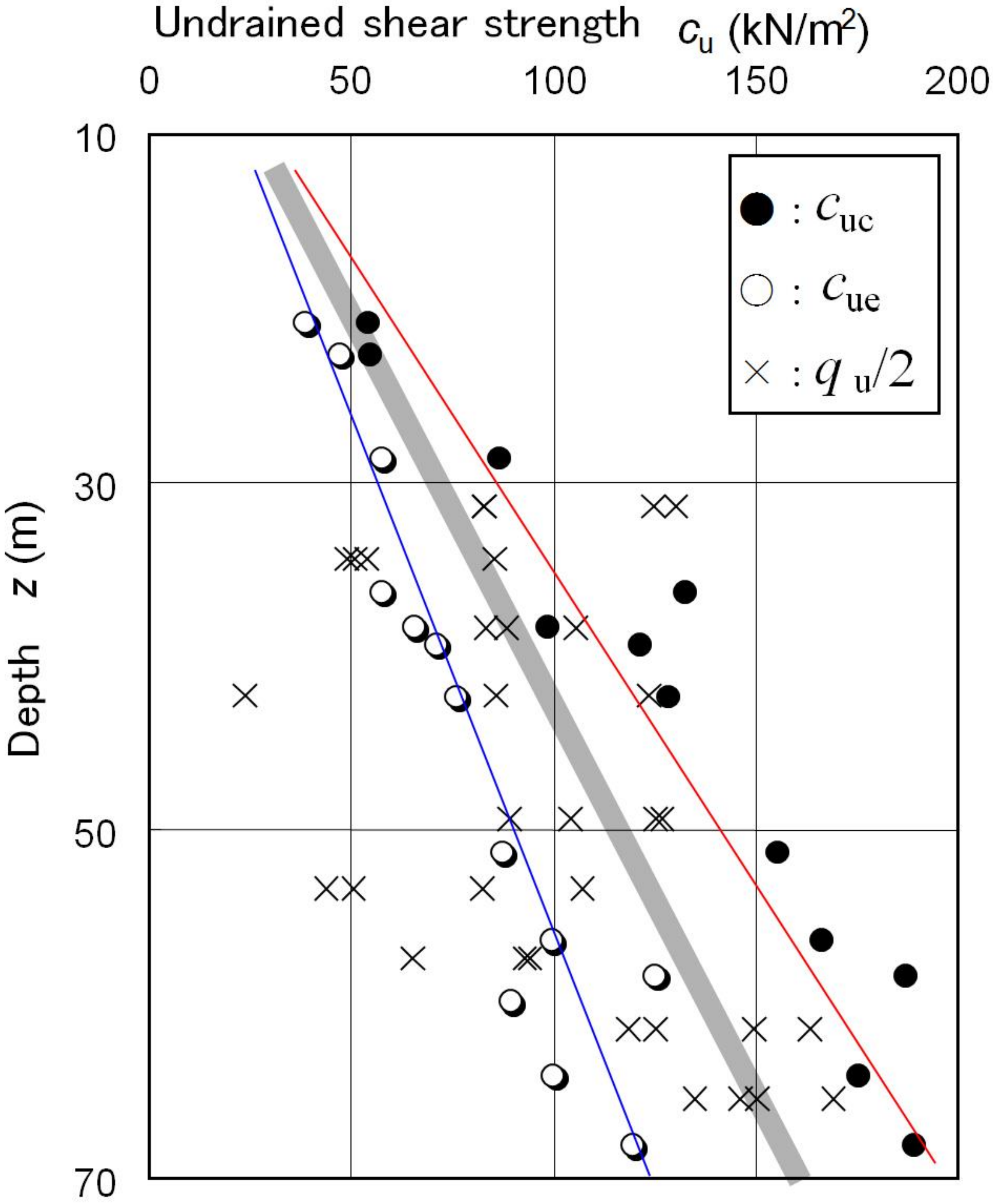


K_0 : Coefficient of earth pressure at rest

Recompression



Triaxial CU compression and Extension test



UC strength and Triaxial compressive & extensive strengths

- The undrained shear strength ($q_u/2$) obtained from UC test varies much, but the average value agrees with the mean value of the triaxial compressive and extensive strengths with recompression method

This balance is only achieved by standardized sampling and laboratory tests

How the careless geotechnical investigation (scamp work) affects on the design?

- Disturbance in sampling caused by

  Forceful boring
  Non-removal of slime at bottom of borehole

  A boring operator who can conduct quick boring (many number of sample can be collected in a day) is not the meaning of "excellence".

Results in
→ Smaller strength and modulus

→ Underestimation of the stability

→ Useless soil improvement and **overdesign**

A scene of boring investigation in ?????

Consolidation test apparatus in ?????

Standardization is very important!

Flowchart in determination of soil parameters

Measured value in the soil test

↓ Primary treatment with empirical/theoretical equation

Derived value as the soil parameter Z

↓ Depth profile modeled in each soil layer

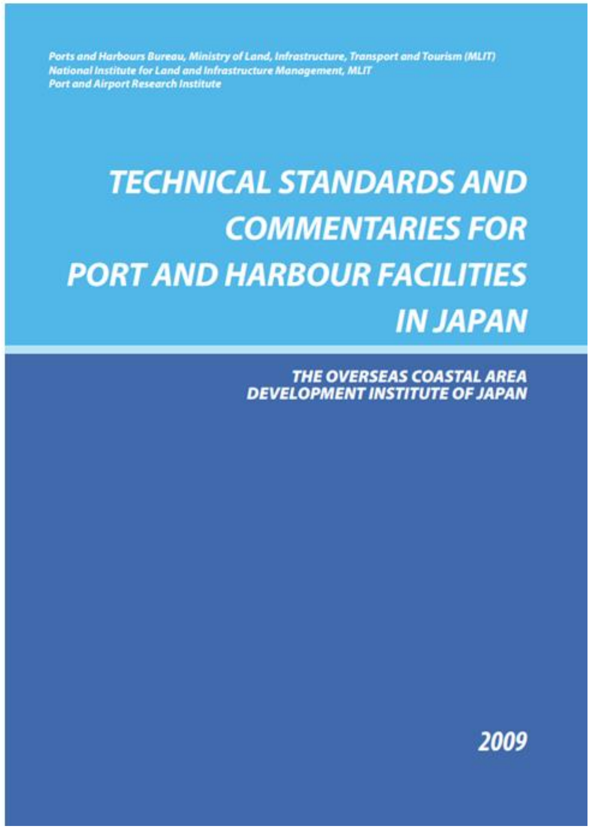
Estimated value Z^*

↓ Statistical treatment in consideration of the data variation (To be minimized)

Characteristic value Z_k

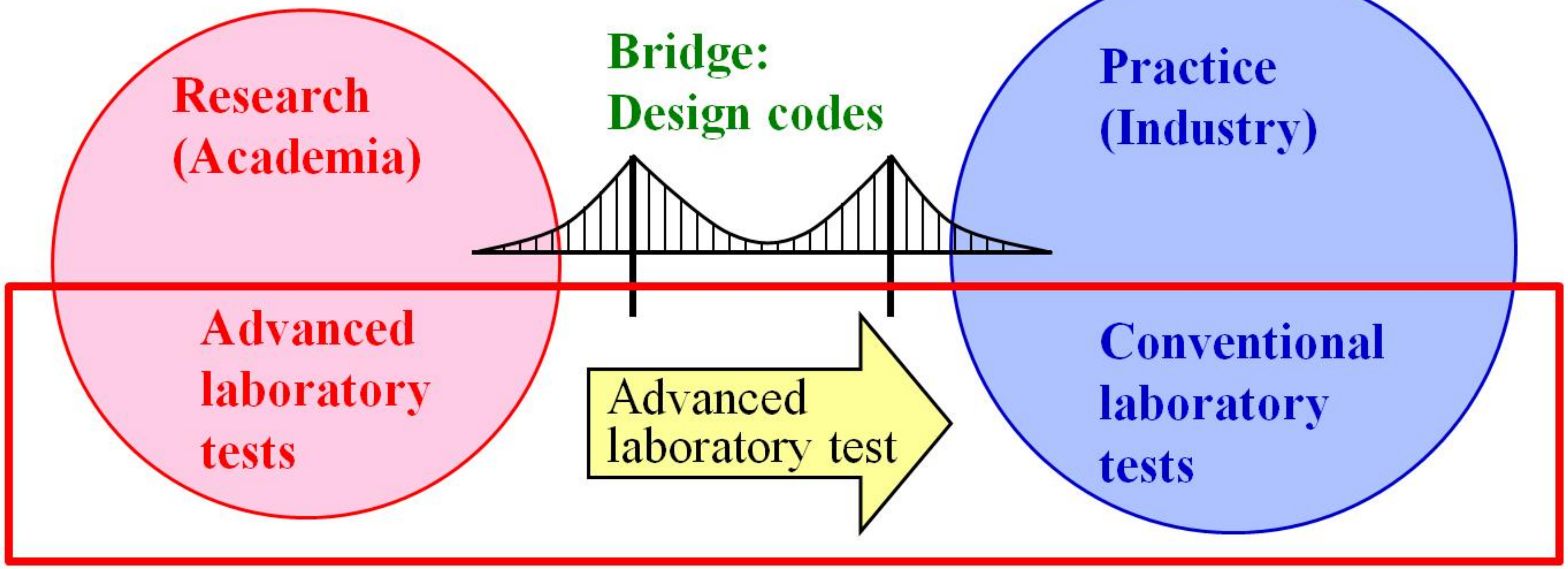
↓ Partial safety factor

Value for the design



This is a new challenge that will take a role as a bridge (for constructing reliable design codes) between
the industry (for the determination of soil parameters in practical designs) and
the academia (for performing advanced laboratory tests).

The design code aims to introduce advanced laboratory tests to the practice.

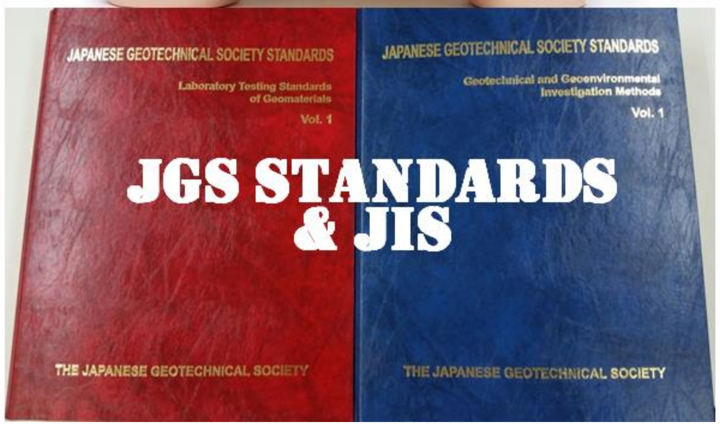


Standardization is very important!

Major Japanese Foundation Codes

for Highway Bridges
Port and Harbor Facilities
Railway Structure
Buildings

www.artbank.co.jp



Japanese Geotechnical Society