Shallow & Mid depth mixing in Japan

Masaki Kitazume
Tokyo Institute of Technology, Japan

Ground disasters on soft ground

slope failure by earthquake

excavation

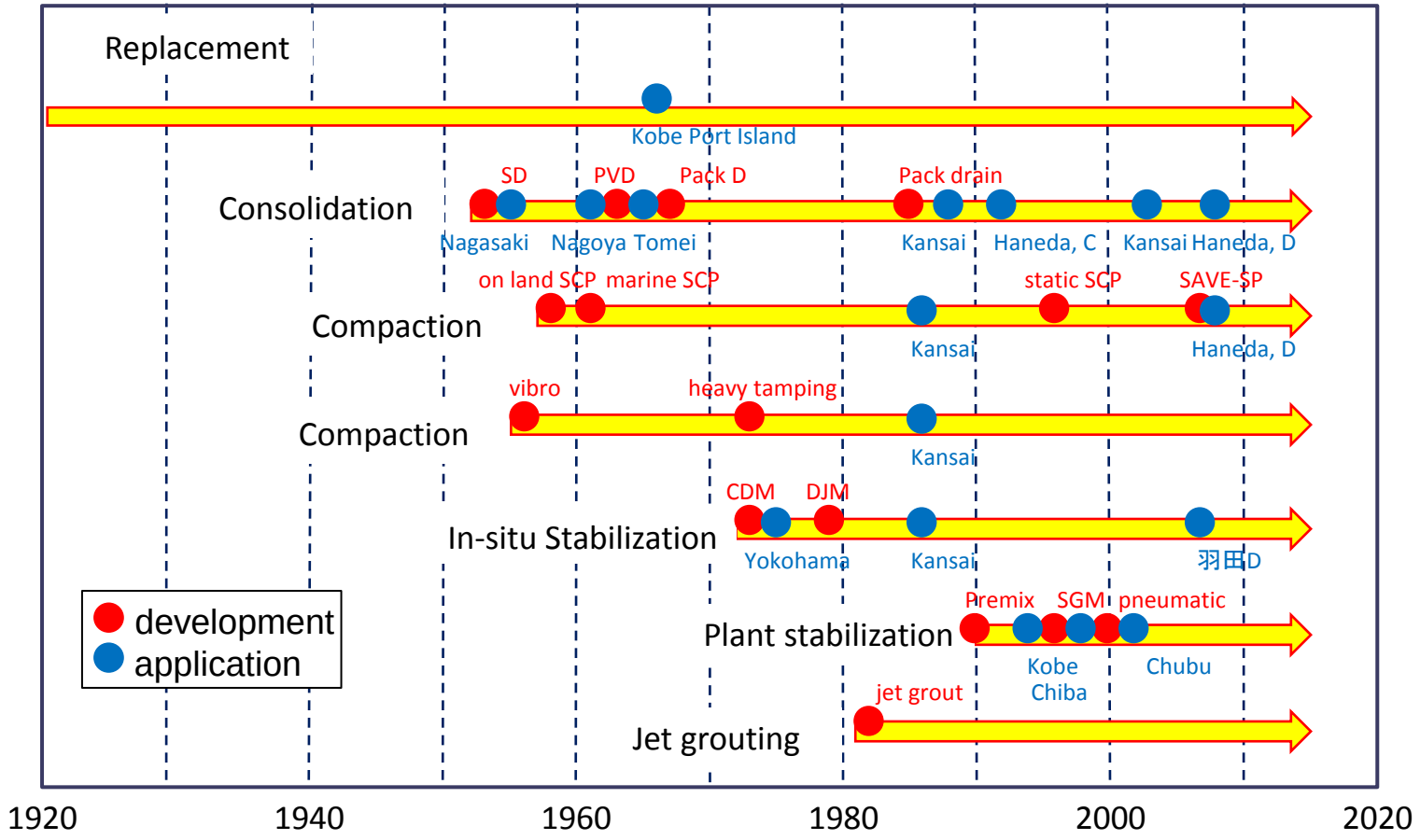
ground settlement

pile failure

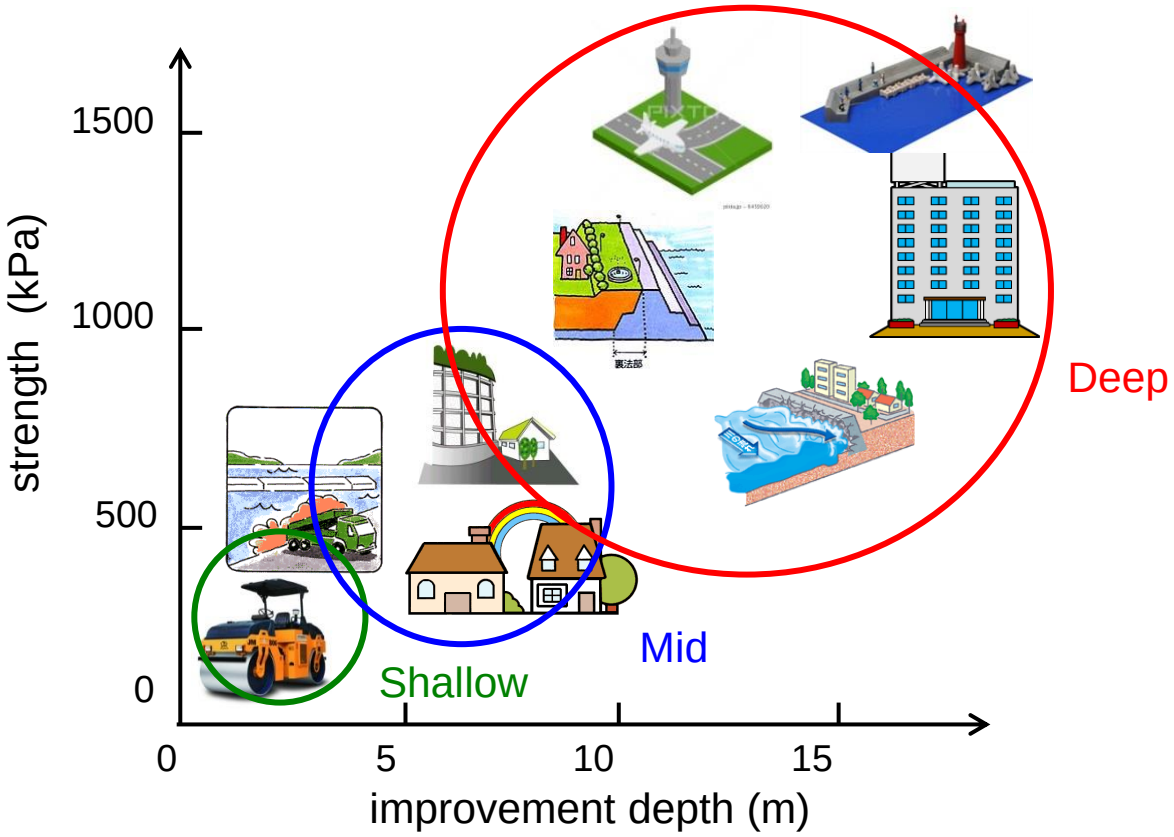
liquefaction in 1964

liquefaction in 1995

Development of ground improvement techniques



Classification and application



Purpose of shallow depth mixing

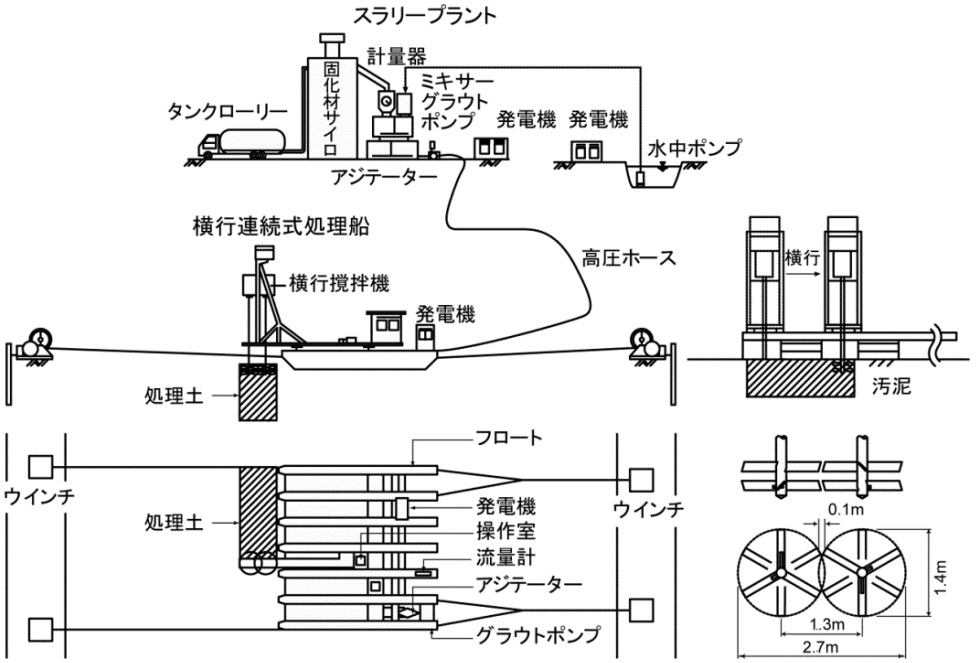
Purpose	required strength q_u (kN/m^2)	binder factor （kg/m^3）	W/C ratio
transporting soft soil	50～100		
improving roadbed		50～100	dry
beneficial use of soft soil	100～300		
barrier for contaminated soil, mitigating stench	100		
assuring stability of structure	200～200		
improving traficability	100～200	100～150	100～130%
others			

Shallow depth mixing

- Horizontal mixing
  - Slurry type
    - Single shaft
      - Float Vertical Mixing method
      - Vertical Mixing method
    - Multi shafts
      - Triple I method, Float Aqua Mixing method
      - Float Slide Mixing method
  - Powder type
- Vertical mixing
  - Slurry type
    - Advanced Rotary Mixing Method
    - BH-RM method, Mud Reform method
    - Rotary Mixing method
  - Powder type
- Trencher mixing
  - Slurry type
    - Mud Mixer method, Mud Stabi method
  - Powder type
    - Mud Mixer method, Mud Stabi method
    - Power Blender method
- Bucket & vertical mixing
  - Slurry type
    - Mud Mixer method, New Soil Mixing method
    - Solid Cube method
  - Powder type
    - Mud Mixer method
- Bucket mixing
  - Slurry type
    - ESMIC mud method, ESMIC slurry method
    - Mud Mixer method, Mud Stabi method
    - Surface Compact Mixing method
  - Powder type
    - Chemico Lizer method, ESMIC base method
    - Mud Mixer method, Mud Stabi method
    - Rising method, SHK method
    - Surface Compact Mixing method
- Stabilizer mixing
  - Slurry type
    - SHM method, Soil Limer method
  - Powder type
    - Chemico Lizer method, EESMIC base method
    - Soil Limer method, STB method
    - STB-MC method

Floating mixing

Purpose of improvement:
improving traficability
surface barrier for contaminated soil
mitigating stench

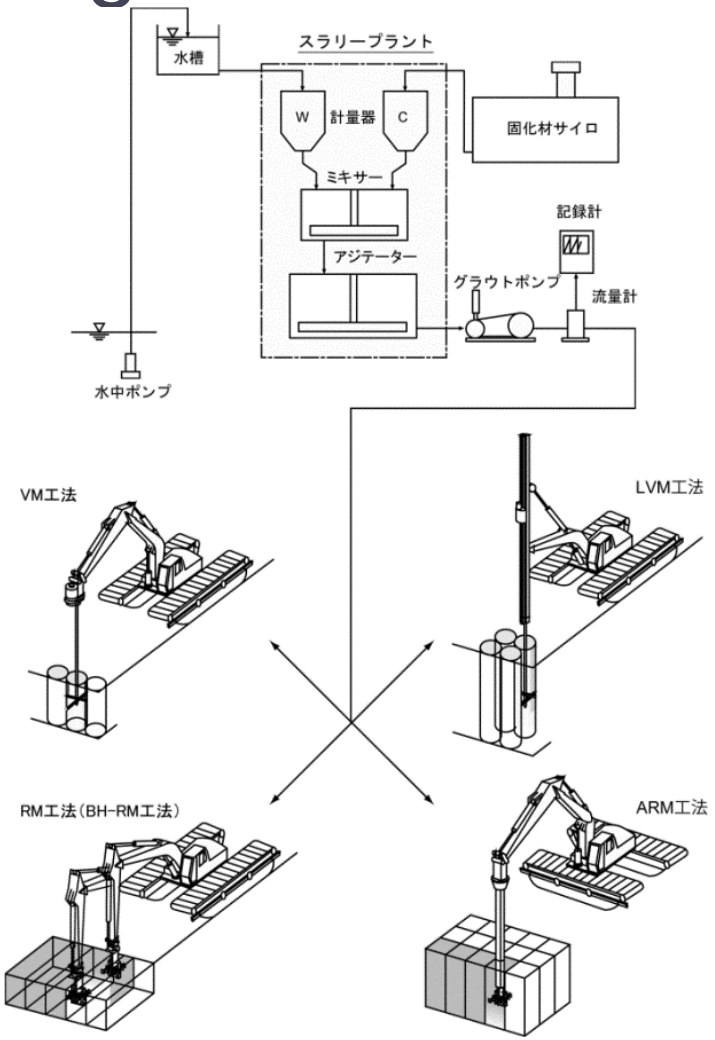


design strength : 100～300 kN/m^2
binder factor : 100～150 kg/m^3
W/C ratio : 100～130 %

Horizontal & vertical mixing

Purpose of improvement:
- improving traficability
- surface barrier for contaminated soil
- mitigating stench

design strength : 100～300 kN/m^2
binder factor : 100～150 kg/m^3
W/C ratio : 100～130 %



Stabilizer mixing

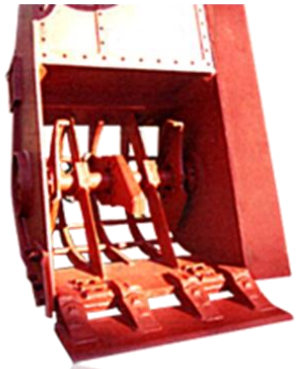
Purpose of improvement:
improving roadbed

design strength
upper roadbed: q_{u7}= 2.9 MN/m²
lower roadbed: 0.98 MN/m²
binder factor: 50～100 kg/m³ (dry)

Bucket mixing, bucket & vertical blade mixing

Purpose of improvement:
- transporting soft soil
- beneficial use of soft soil
- surface barrier for contaminated soil
- improving traficability
- mitigating stench

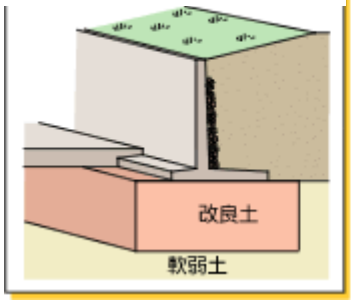
improvement depth: 2 m



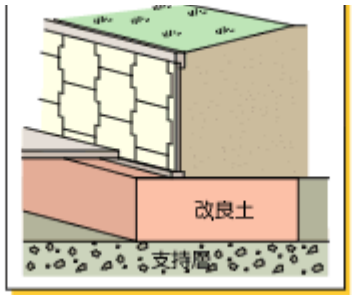
bucket & vertical blade mixing

Purposes of mid mix improvement

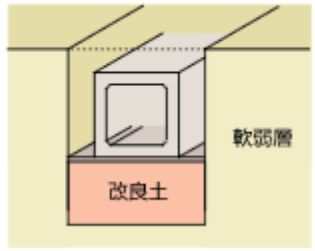
retaining wall foundation



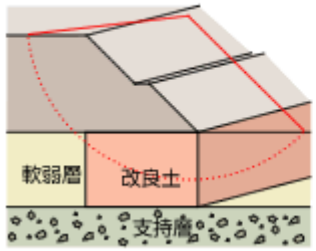
retaining wall foundation



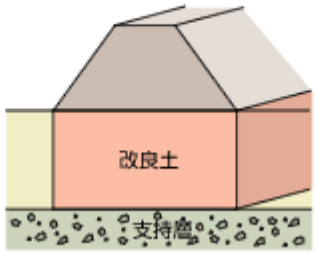
box culvert foundation



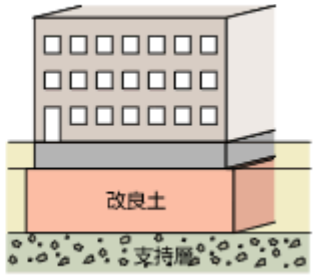
slope stability



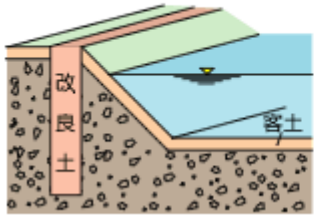
embankment stability



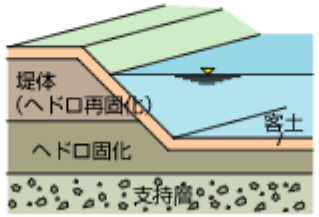
building bearing capacity



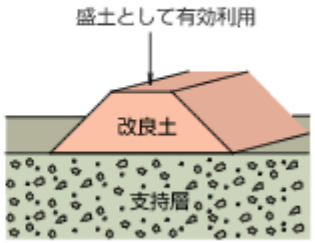
shut off wall



stabilization of mud



beneficial use of subsoil



Mid depth mixing

Horizontal mixing	Slurry type	Single shaft	Column Z method,	Cross wing column method
			Double mixing method,	Earth column Type II
			ECM method,	Fine pile method eco
			HITS column method,	I mark method II
			L column method,	LVM method
			MITS method,	MS column
			NSV column method,	REC method
			S-Max column method,	SS column method
			ST column method,	TSC method
			Super I mark method II ,	Tiger pile method
			Ultra column method,	Ultra wood column method
			USP method,	VMS method
			WinBLADE method	
		Multi shafts	MRC method,	MR method Type I
			MR-IIC method,	TenoColumn method
	Powder type			
Vertical mixing	Slurry type		In Situ Mixing method,	Mud Reform method
			SCM method,	Twin Blade Mixing method
			WILL method	
	Powder type		SCM method,	STB-PMX method
Horizzontal & Vertical mixing	Slurry type		3DM method	
Trencher mixing	Slurry type		Power Blender method,	V-MIXING method
Bucket mixing	Powder type		KR pile method	
Bucket & vertical mixing	Slurry type		EI Mud S method,	Multi Mixing Backet method

Horizontal mixing

mixing blade:	0.4 to 1.6 m
depth:	2 to 16 m
slurry:	penetration injection
design strength:	600～1000 kN/m^2
binder factor:	200~350 kg/m^3

quality control

$$T = \Sigma M\left(\frac{Nd}{Vd} + \frac{Nu}{Vu}\right)$$

where

- T : blade rotation number (N/m) >450 to 650/m
- ΣM : number of mixing blade (3)
- Nd : rotation speed during penetration (10 rpm)
- Vd : penetration speed (0.5 m/min)
- Nu : rotation speed during withdrawal (30 rpm)
- Vu : withdrawal speed (1.0 m/min)

Vertical mixing

diameter: 1.3 to 1.5 m
shape: rectangular solid column

quality control

$$N = \sum M \cdot n\left(\frac{1}{V_u} + \frac{1}{V_d}\right)$$

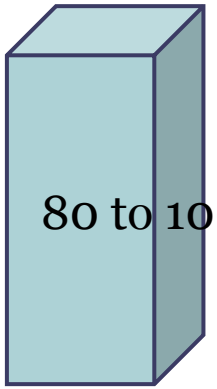
where

- N : blade rotation number (N/m) >230/m
- $\sum M$: number of mixing blade (4)
- n : rotation speed (rpm)
- Vd : penetration speed (m/min)
- Vu : withdrawal speed (m/min)

Bucket mixing, bucket & vertical blade mixing

bucket & vertical blade mixing

Trencher mixing



Trencher width:	1.0 m
W/C :	150 to 200 %

quality control

$$N = \frac{R}{A \cdot B/W}$$

$$R = \frac{Dc}{Pm} = \frac{Vc \cdot T}{Pm}$$

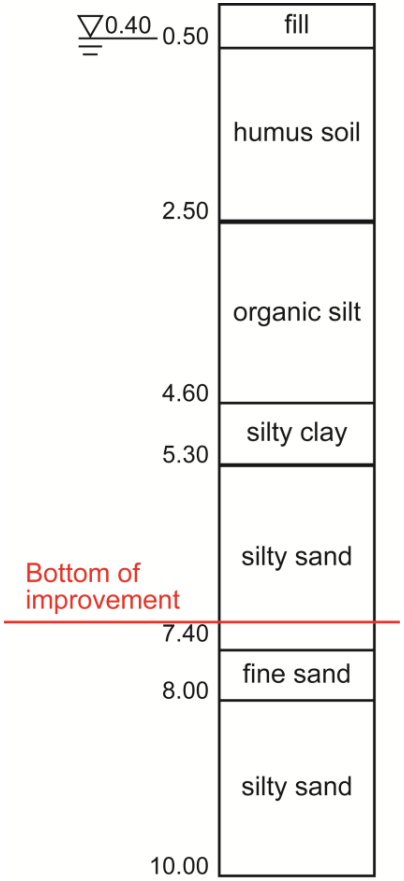
$$A = L \cdot H$$

where

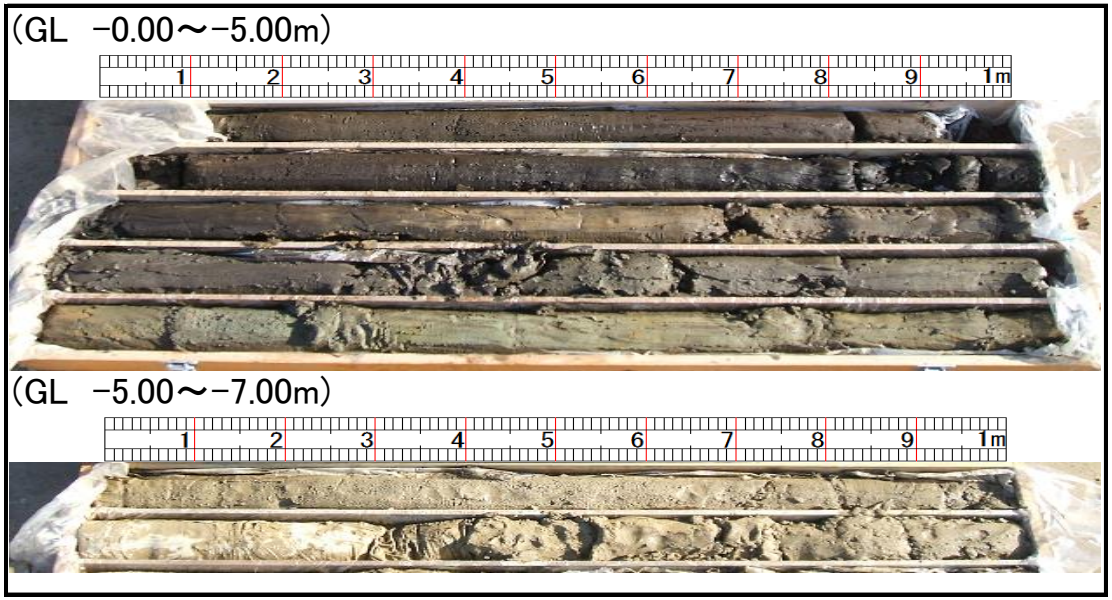
- N : blade rotation number (N/m^2) >50
- R : total mixing number (N)
- A : improvement area (m^2)
- B : improvement width (m)
- W : width of trencher (m)
- V_c : speed of chain (m/sec)
- T : mixing time (sec)
- D_c : total distance of chain movement (m)
- P_m : pitch of mixing blade (m)
- L : improvement length (m)
- H : improvement depth (m)

Trencher mixing

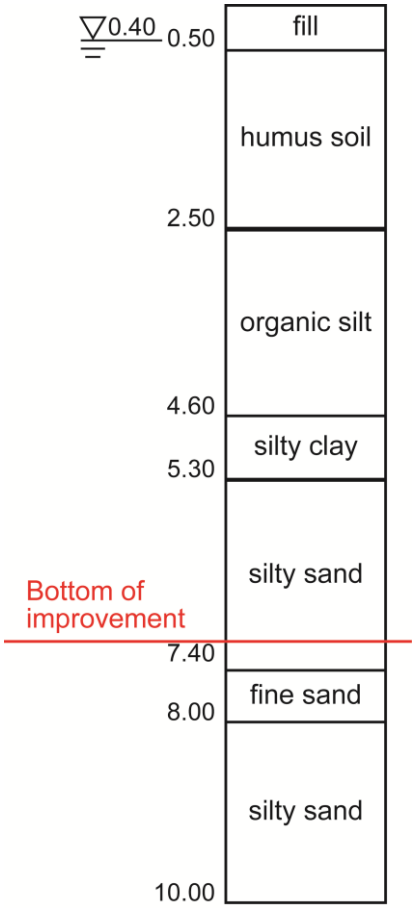
Original soil

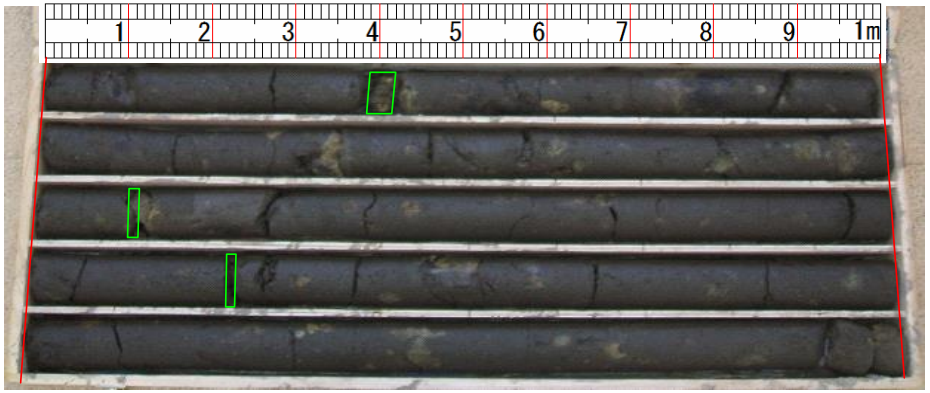


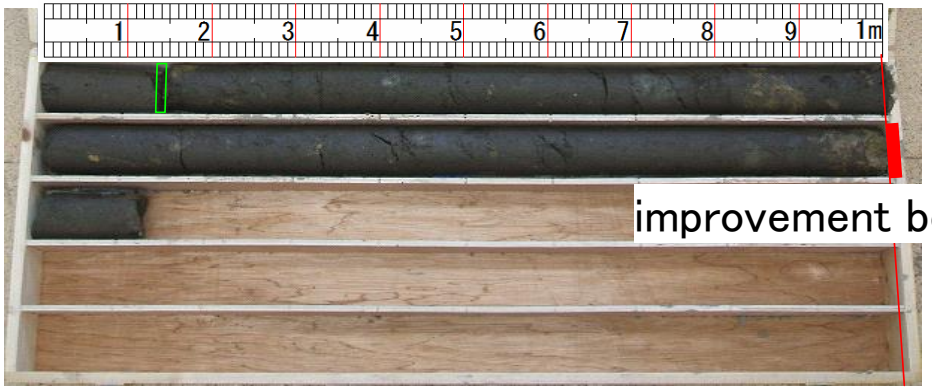
Original soil



Core sample of stabilized soil

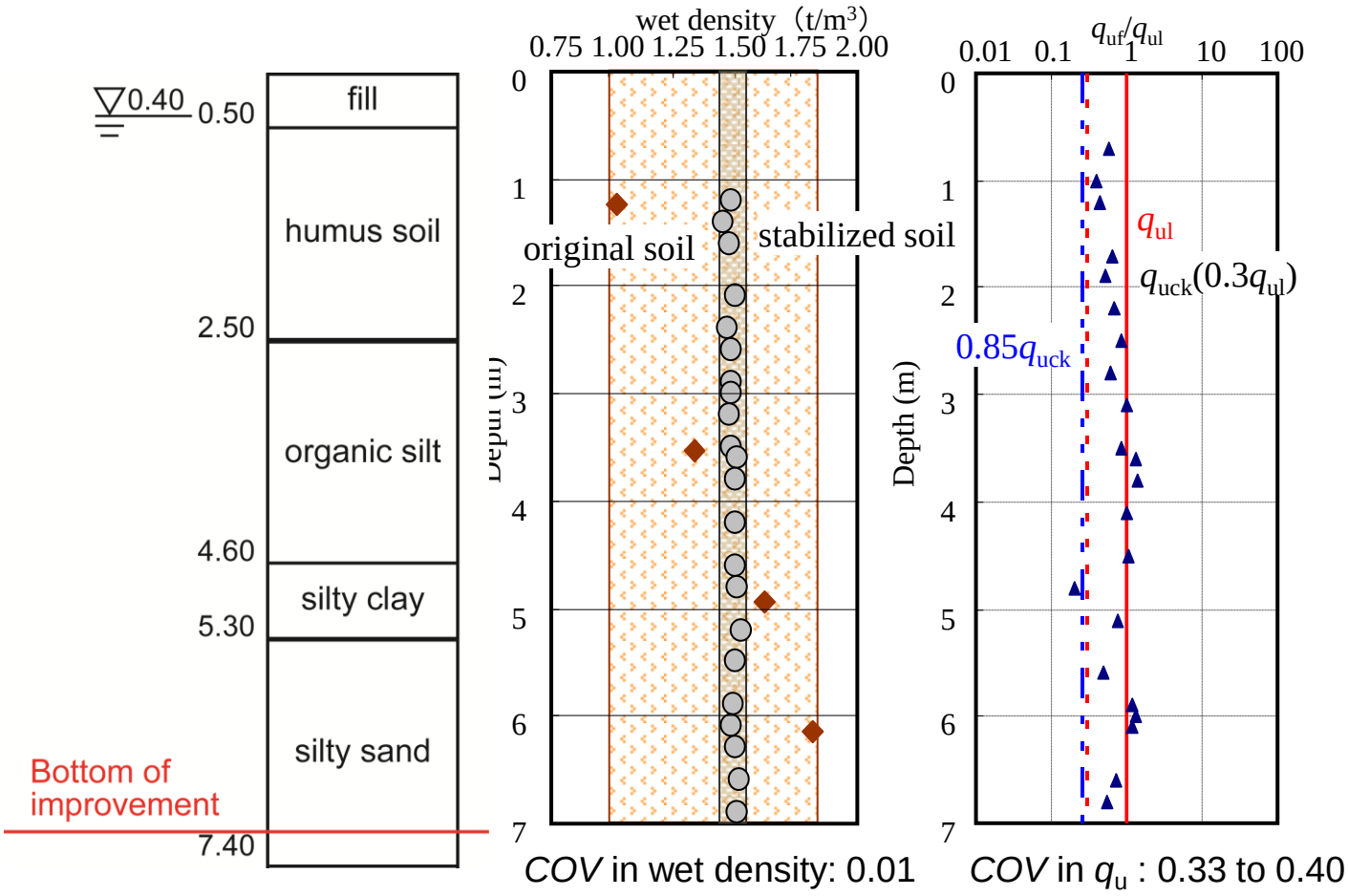






RQD=98.1%

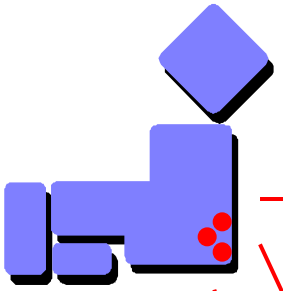
Properties of stabilized soil



Quality control and assurance

- monitoring during execution
  - binder content
  - position of blade
  - blade rotation number
- quality assurance
  - core sampling
  - wet grab sampling
  - qu test, needle penetration test

Performances of CDM improvements



River embankment

unimproved ground

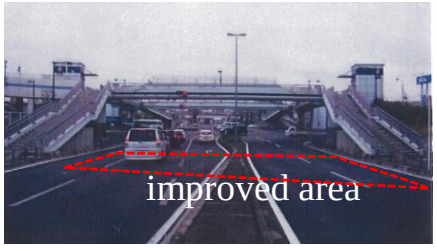
improved ground

block type improvement
as=100%
q_{uck}=100 kN/m^2

River embankment

block type improvement
as=100%
q_{uck}=1,000 kN/m^2

Road embankment



grid type improvement
as=50%
q_{uck}=200 kN/m^2

Earthquake attack in 1995 earthquake

slope failure in 2007 earthquake

Liquefaction in 1964 earthquake

Tsunami attack in 2011 earthquake

Concluding remarks

- brief explanation of shallow & mid depth mixing in Japan, purpose, machine, execution, quality control and assurance
- Cement mix techniques, shallow and mid depth, are essential in infrastructure development for mitigating disaster.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