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Underground construction technology using new materials

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Content:

1. New underground construction technology using

 1) Super absorbent polymer material

 2) Air foam material

with the Toda Corporation.

2. Chemical grouting technology using

 3) High concentration silicate material

for the enhancement of sand liquefaction resistance with the Chemical Grouting company.

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1) Super absorbent polymer material

Super absorbent polymer material with water is employed in the Cast-in-place pile method-AWARD-Sapli Method.(AWARD is the name of novel construction method group.)



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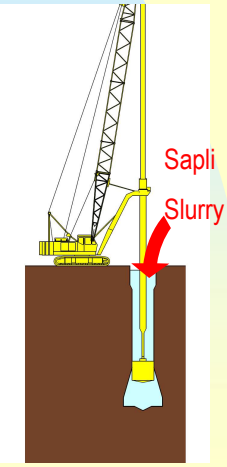
AWARD-Sapli Method
(AWARD-Super Absorbent-Polymer-Liquid)



- Method to use soil slurry (Sapli Slurry) using a super- absorbent polymer material instead of a conventional bentonite-based slurry
- Ensure quality of pile and reduction of waste volume

※Joint technology development among Waseda University, Toda Corporation and Magma Co.,Ltd.← Award is the common name of method.

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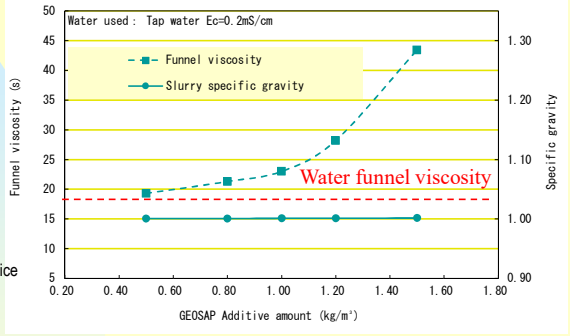
■Sapli Slurry

Viscosity measuring device
Funnel viscometer



Specific gravity
measurement device
Mud balance

Blending example		Properties of supplemental stabilizer		
Water	Superabsorbent polymer (GEOSAP)	Specific gravity	Funnel viscosity	Filtered water quantity
1000 kg	0.5 ～ 0.2 kg	1.00 ～ 1.01	20 ～60 s	5 ～30 ml

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Performance Requirements

a) Achieve the stability of pile hole wall even in highly permeable sandy soils.

b) Influence on quality of concrete pile can be reduced even in the case for a cohesive soil ground with a lot of fines tending to cause deterioration of the slurry and thick mud film on the pile hole wall.

c) Reduce the amount of industrial waste disposal by separating Slurry after use into water and mud.

d) Small amount of material used & costs reduction by reducing industrial waste disposal costs.

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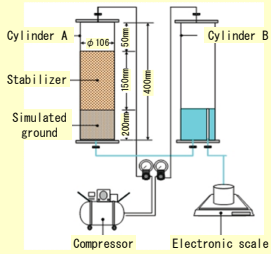
Slurry: Various performance confirmation laboratory tests

- Performance as drilling slurry (Hole wall stability and fluidity)
  - Water barrier test
  - Bottom expansion pile wall simulation
  - Flowability test (Table flow test)
- Impact on quality of concrete piles
  - Pressure filtration test (mud film thickness)
  - Rebar pull-out test
  - Concrete replacement test
- Separation characteristics
  - Separation Mechanism(movie)
- Environmental characteristics
  - Confirmation test of temperature, pH etc.



Water barrier performance confirmation test equipment


Pressure filtration testing device

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■ Slurry Separation characteristics

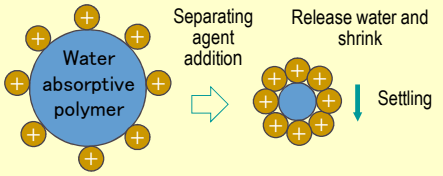
● Soil sapli Slurry :
Suspension during drilling process.

- Adding calcium chloride $CaCl_2$
→Absorbed water is released due to osmotic pressure.
Swelling gel → small

- Separation :
Sediment (soil mud) & water.
Sediment (soil mud) be treated as sludge,
Separated water be discharged to sewage.

➡ Reduction :
Amount of Industrial Waste Disposal

Separation image



Suspending polymer (small density)

Separating polymer (large density)

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■ Slurry Separation characteristics(movie)

Solid soil particle is easily separated and settled down to the bottom.

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Field Application

Site Location : Saitama City, Japan
Construction site : Distribution center

■Foundation piliing: Earth Drill Method
Pile diameter: φ 1.7 to 1.9 m (Enlarged base φ 2.2 to 3.4 m)
Pile length: 53.7m
Number of piles: 20
Total drilled depth: 55.5m
Amt. of drilled soil: 3,000m^3

■Application effect on site
・Reduction of Industrial Waste Disposal
Separate waste slurry (about 200m^3),
About 80% Reduction (separated water 160m^3, mud 40m^3)

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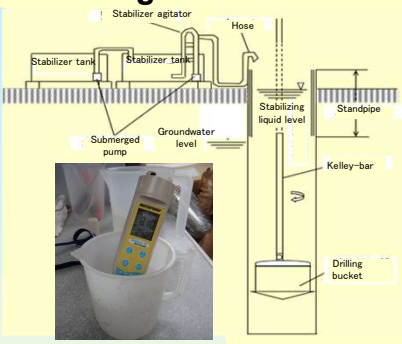
Site management test



Electroconductivity/pH meter

Test item	Test method	Control criteria	Remarks
Viscosity	Funnel	23 ～ 35 (s)	Reproducing outside the standard value (Geosap・Fresh water addition)
Specific gravity	Viscometer	1.01 ～ 1.10	
pH	pH meter	7.0 ～ 11.0	
Electrical conductivity meter	Electrical conductivity meter	1.000 (μS/cm) Or less	Adjustment required above standard

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■ Applicable Range

Superabsorbent polymers property:

If Seawater: high electroconductivity Ec (high ion conc.)

Water absorption performance ↘, Slurry viscosity ↘,

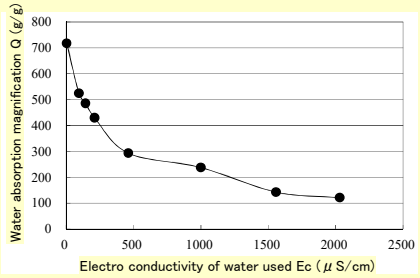
※Confirm properties of on-site groundwater and used water.

※Groundwater, Tap water Ec=100～300μS/cm

(Not affected by seawater, ground improvement, heavy metals)

＜Difficult Area to be used＞

- Landfill site and coastal area influenced by seawater
- Plant site: soil contamination
- Ground improvement with cement in the past
- Demolition site: foundation pile of existing structure left and remained in the soil.



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2) Air foam material

The aim of this technology development is to produce an air form suspension for use in stabilizing the trench wall surface during a diaphragm wall excavation using air foam, in stead of bentonite clay slurry suspension.

Air foam.

Air foam suspension with sand.

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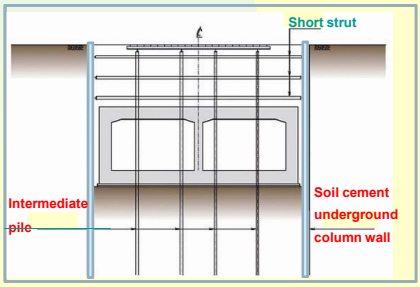
■ Soil Cement Underground Diaphragm Wall

Apply to soil-retaining wall when constructing underground facilities and building foundation.



Walls built mixed/stirred with in-situ soil and cement slurry.

≫Generation of the high amount of sludge
≫High machine/equipment ownership cost
≫Long term occupation of the site

[Social Request]

Reduction on Environmental impact and construction period

・Environmental impact reduction : Foam Drilling Method
・Reduce work period : New construction method needed

Conduct R&D on New Constrution Method

Featuring Air-Foam Drilling Method

AWARD-Para Method

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Foaming agent (Synthetic surfactant)

Dilution and Foaming

Air foam

Excavated Soil+Water

Mixing

Air foam suspension

Production of air foam suspension.

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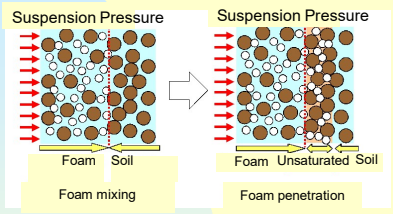
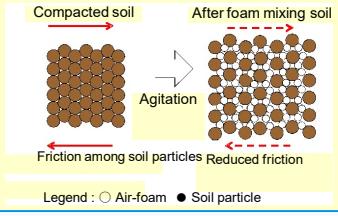
1)Stabilization of Trench Wall

Rapid formation of unsaturated layer on trench wall.



2)Bearing Effect

Fluidity increase by Bearing Effect among soil particles..



3)Defoaming and Volume Reduction

Deforming by adding antifoaming agent and volume reduction.

- ◇ Trench Wall stabilization
- ◇ High Water Barrier
- ◇ High Liquidity
- ◇ Easy Volume Reduction

⇒Airfoam Drilling Method

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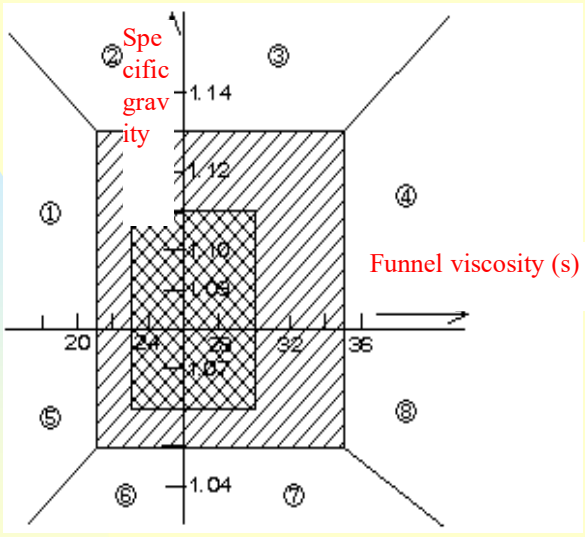

Management chart for bentonite clay slurry suspension.

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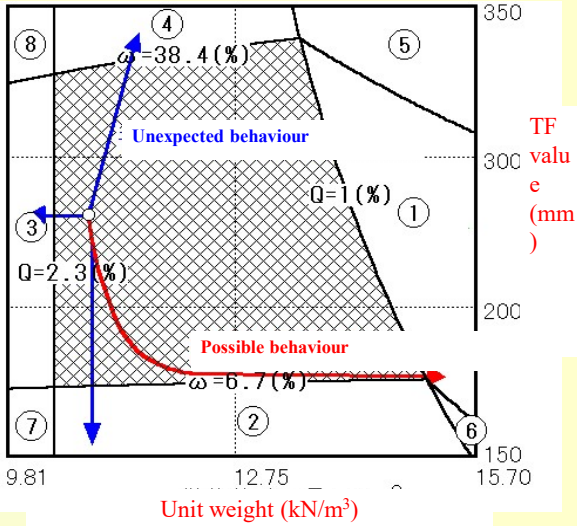

Management chart for air foam suspension.

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Table flow (T.F.) testing device.

Model test apparatus for air foam suspension performance.

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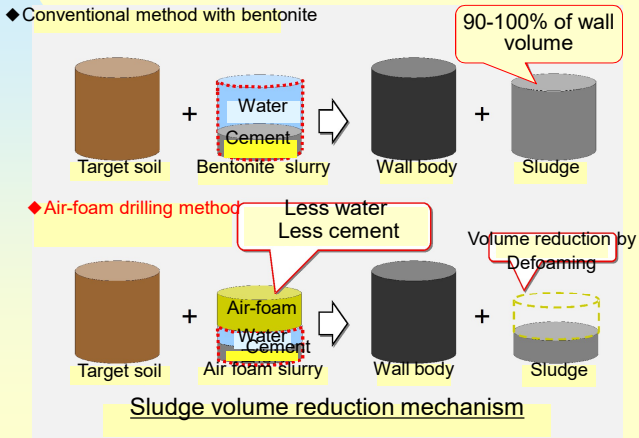
Implement a new construction method to make use of features of air foam drilling method and reduce the work period and the environmental impact.



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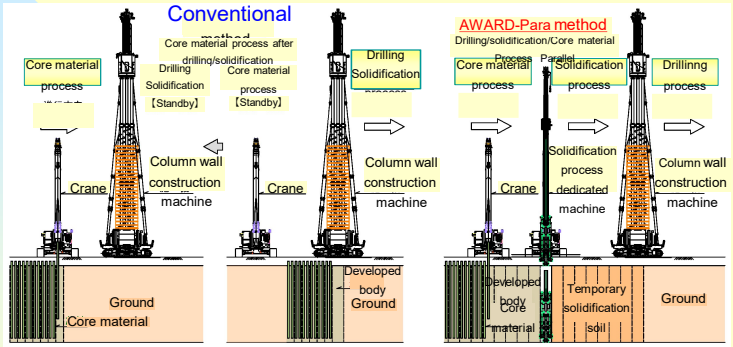
Work Period Reduction	Improvement of operation rate of construction machine, increase of construction amount of panel per day → Construction period is reduced to approx.1/2



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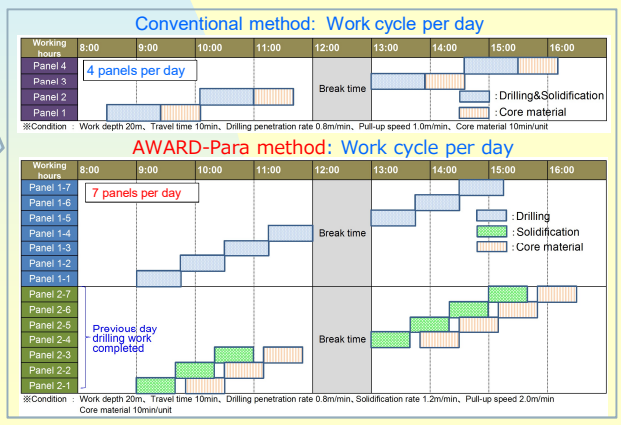
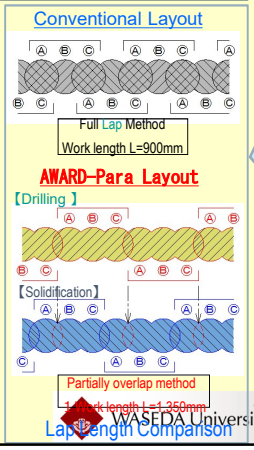
■ **Comparison with Conventional Construction Method**

Improved work cycle	Separate three processes → Reduce loss of construction work time → Improve operation rate of construction machine
Reducing Lap Length between Panels	Change panel layout (partially overlap circle method) → Increase the amount of construction work





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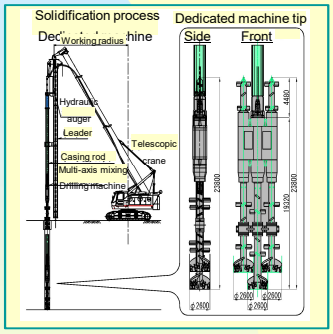
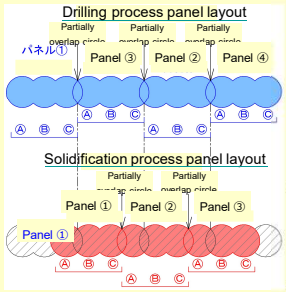
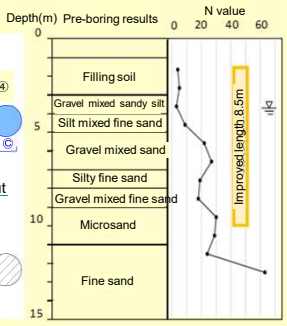
■Award Para Method: Field Test Construction



Machine (Solidification process used only)



Panel layout



Field soil profile

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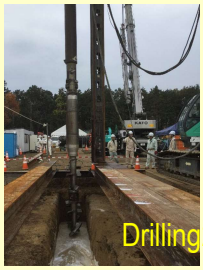
■Field Test Construction



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Field test construction results.

◇ Reduction of Cement Material : approx. 30%

◇ Reduction of Sludge Volume : approx. 30%

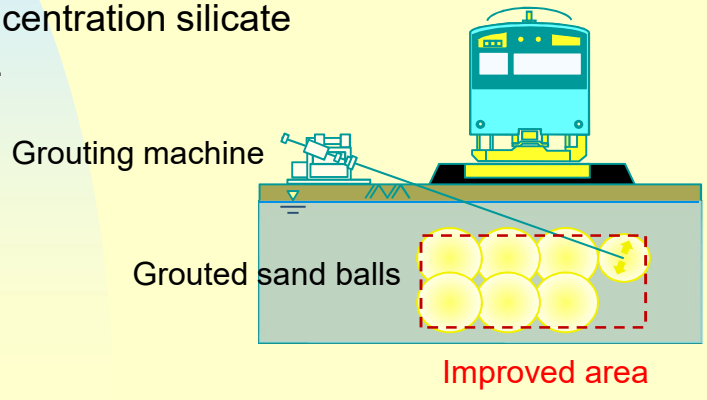
◇ Achieving Construction Period Reduction : 50%

Verification High-speed construction with the machine dedicated solidification process.

◇ Ensuring construction quality : Trench Wall Stability, continuity of wall body, ensuring vertical accuracy, and verification of constructed body strength.

3) High concentration silicate material

Aim: Enhancement of sand liquefaction resistance under the strong earthquake ground motion by injecting the liquid glass with a high concentration silicate material.



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■ What is the chemical grouting? …

・Chemical grouting is one of the soil improvement method, which is grouting material controlled hardening time in the void of the soil.

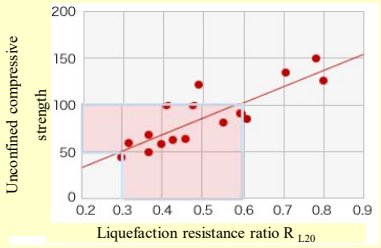
・Grouting material replaces the water in the void and the soil strength increases and the permeability decreases.

■ The strength after soil improvement using the standard grout is as follows.

・Liquefaction resistance ratio：0.3～0.6(⇒Unconfined compressive strength：50～100kN/m^2)⇒Strength is not enough, if subjected to the strong earthquake.

・Higher strength chemical grouting is required for the countermeasure against the liquefaction under the strong earthquake.

⇒Liquefaction resistance ratio : more than 1.2 and unconfined compressive strength at lab.: 400 kN/m^2 and in the field : 200 kN/m^2,



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Selection of chemical solution type

Required performance

■ $\sigma_{28} \geqq 400$kN/m^2

(Ratio of lab./site strength is 2)

■ Gel time：about 6 hours

■ Less Permeability

Specimen

Items		Unit	Value
Soil	-	-	Keisa No.7
Density of soil particle	ρ_S	g/cm^3	2.62
Maximum void ratio	E_{max}	-	0.931
Minimum void ratio	E_{min}	-	0.613
Relative density	Dr	%	60
Size of specimen	Φ,h	㎝	Φ5.0,h10.0
The method of making specimen	-	-	dropping in the grouting material

Test result

Items	Unit	Special neutrality-acid silica	Special silica		Organic compound
Concentration : w/w(w/v)	%	10.29 (11.78)	13.25 (15.44)	10.74 (12.09)	14.28 (16.77)
Unconfined strength (28 days)	kN/m^2	582～698	557～674	557～753	926～1,127
Gel time		6 hour	6 hour	6 hour	2~5 min.
Permeability		○	×	△	×
Result		◎			

Special neutrality acid silica material is the best !!

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Strength characteristics : laboratory test

The evaluation method

■ Unconfined compression testing (JGS 0511)

Curing period : 540 days

Condition : Same of the test of selecting chemical solution type.

Curing method : In the air

Test result

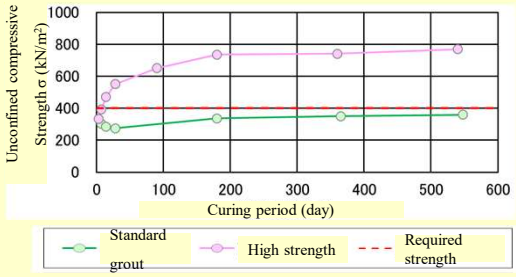
	28 days	540 days
Required strength	400 kN/m^2	400 kN/m^2
Standard grout	275 kN/m^2	360 kN/m^2
High strength	551 kN/m^2	770 kN/m^2

Required strength characteristics

■ $\sigma_{28} > 400 kN/m^2$

(ratio of lab./site strength is 2)

■ Strength is kept constant.



Target value is achieved by high strength grouting material !!

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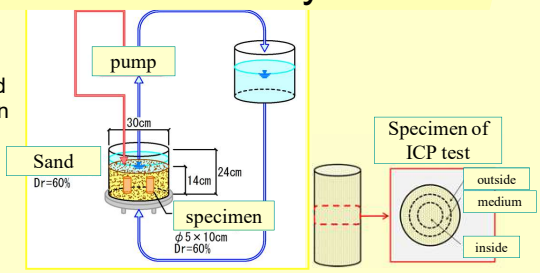
Durability characteristics : laboratory test

Leaching test

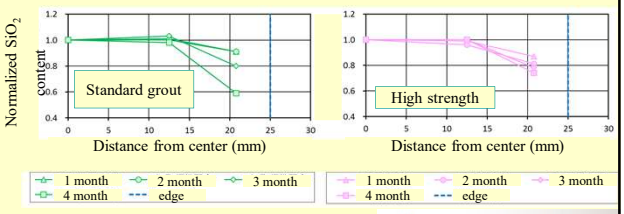
Grouted sand specimen was embedded in the sand, and grouted sand specimen is exposed to water flow to leach the silica material within the grout.
Silica (SiO_2) content within specimen is measured by ICP test.



Experimental condition

Tank size	Φ,H	cm	Φ30,24
Hydraulic gradient	i		1.00
Coefficient of permeability	k	m/sec	1.0×10^{-3}
Flow rate	Q	cm^3/sec	1.77
Period	1, 2, 3 and 4 month (4 case)		

Silica content distribution within grouted sand after leaching test
(normalized value : silica content / initial silica content)



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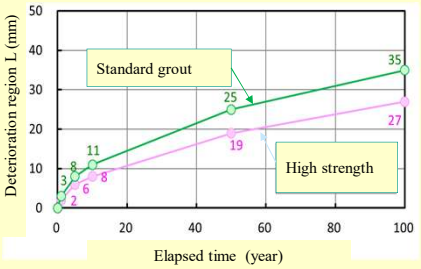
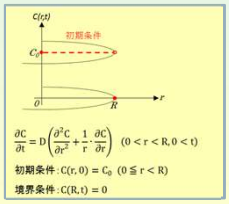
Durability characteristics : Numerical simulation

item		unit	standard	high
Diffusion coefficient	D	mm²/year	21	24
Initial silica amount	C_0	mg/g-dry	19.5	27.0
Analysis region length	B	mm	1,000	
Limit silica amount at diffusion	C_{limit}	mg/g-dry	8.2	

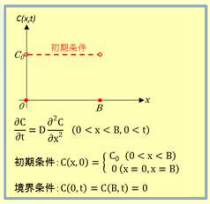


Axial symmetric diffusion equation



Prediction of deterioration depth using axial symmetric model.

1D Diffusion equation



Prediction of deterioration depth using 1D model

Prediction of deterioration depth from the surface for 100years.

- Standard grout:35mm
- High strength:27mm

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Field testing

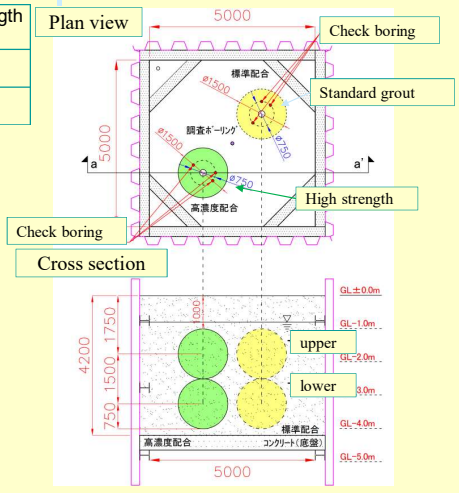
Overview of grouting test

Purpose	Verification experiment of High strength grouting material
Place	Kanagawa prefecture in Japan
Size	L×W×D=5.0×5.0×4.7m

Soil properties

item		unit	value
Density of soil particle	ρ_s	g/cm³	2.74
Wet density	ρ_t	g/cm³	1.90
Void ratio	e	-	0.68
Fine content	F_c	%	3.8
Liquefaction resistance	$R_{L20,5\%}$	-	0.206
SPT N value	-	-	less than 10

Plan view and cross section



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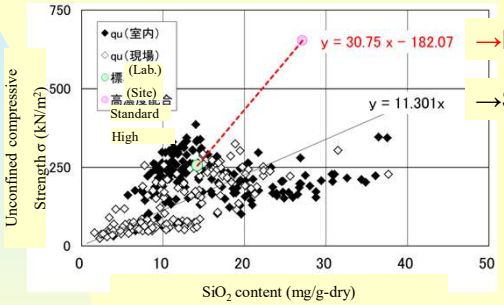
Field testing

General relations between unconfined compression strength and silica content



→High strength grout

→Standard grout

Unconfined compression strength (28 days)		amount of silica content
Target value	400 kN/m²	–
Standard grout	255 kN/m²	14.22mg/g-dry
High strength	652 kN/m²	27.13mg/g-dry

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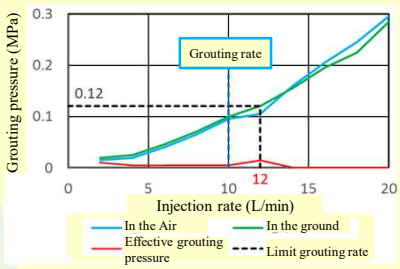
Field testing

Injection rate decision by water injection test→<12(L/min)



Grouting specification.

	Silica concentration	Diameter	Injection rate	Injection total quantity
	%(wt)	m	L/min	kL
Standard grout	6.19	1.50	10.0	0.800
High strength	10.29	1.50	10.0	0.800

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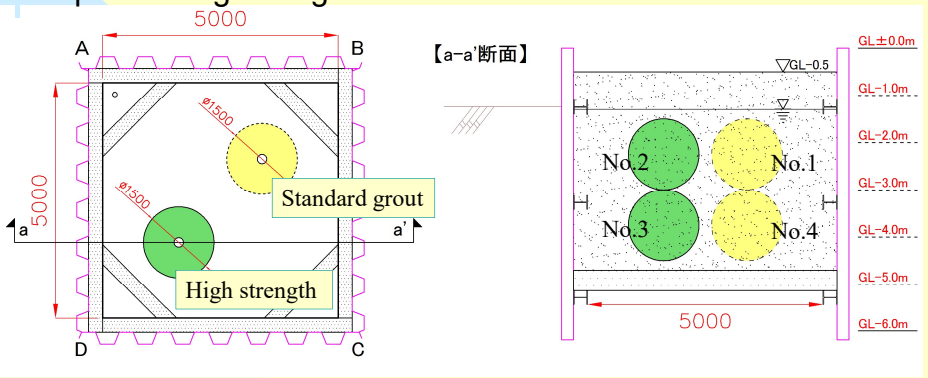
Field testing

Sequence of grouting



No.1	Shallow point of standard grout
No.2	Shallow point of high strength
No.3	Deep point of high strength
No.4	Deep point of standard grout

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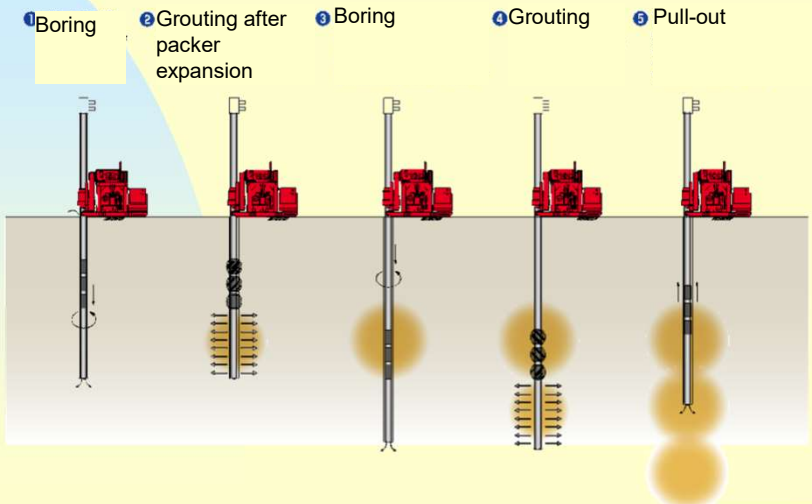
Field testing

Procedure of grouting



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Field testing

Photo of field test

Transporting soil

Compacting ground

Standard penetration test (SPT)

Chemical grouting method (boring and grouting)

Grouting plant

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Field testing

Photo of field test

Check boring

Core sample of grouted soil

Excavation

Measuring grouted soil

Block sampling

Needle penetration test

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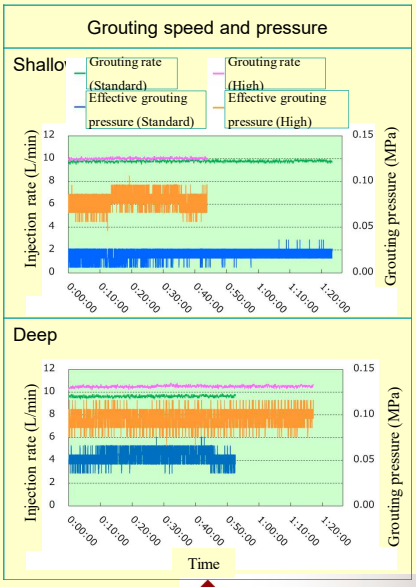
Field testing

Recorded data during grouting

	Unit	–	Standard	High
Grouting volume (design)	kL	upper:	0.800	0.800
		lower:	0.800	0.800
		total:	1.600	1.600
Grouting volume (result)	kL	upper:	0.815	0.439
		lower:	0.488	0.810
		total:	1.303	1.249
Grouting pressure	MPa	upper:	0.020	0.079
		lower:	0.054	0.096

■ In the case of high strength grouting, viscosity is high and grouting pressure is high.

■ In the case of high strength at shallow and standard grout at deep, grouting material was observed to leak.



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Field testing

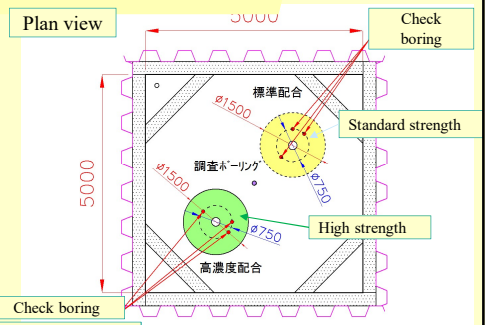
Compressive strength of grouted sand

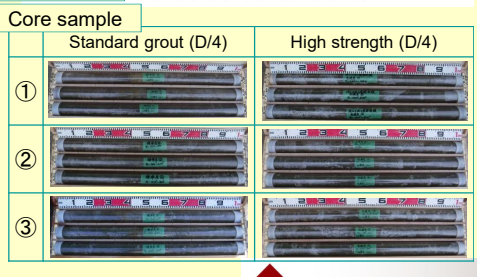
	Unit	standard	high
No. of Samples	-	12	18
Average(site)	kN/m²	106	306
permeability	m/sec	2.75×10^{-8}	7.15×10^{-10}

Strength ratio of lab./site

	unit	required	standard	high
Laboratory	kN/m²	400	255	652
Site	kN/m²	200	106	306
Strength ratio		2.00	2.41	2.13

■ Compressive strength of high strength is greater than the required value.





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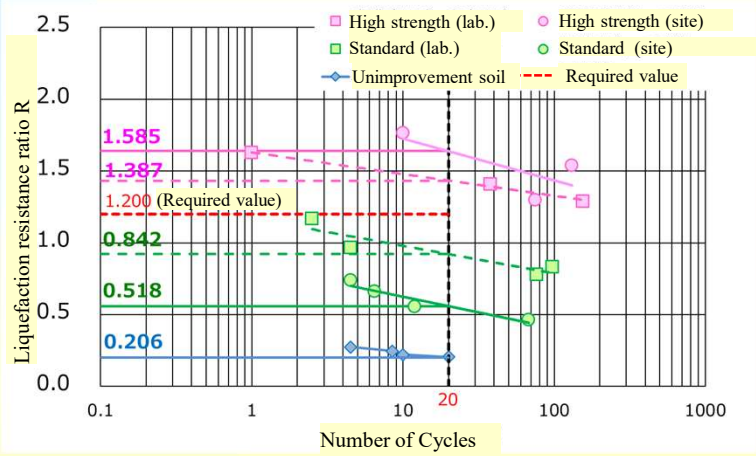
Field testing

Liquefaction resistance ratio



■ $R_{L20.5\%}$ of high strength grout is greater than required value.

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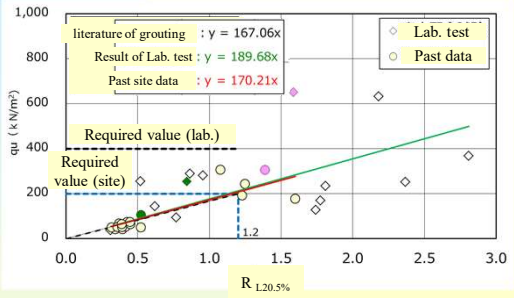
Field testing

Test result summary of grouted sand

(Liquefaction resistance ratio & unconfined compressive strength)



High strength grout achieved the required value.

Liquefaction resistance ratio
: greater than 1.2
Unconfined compressive strength: greater than 200 kN/m²

	σ_{28} (lab.)	σ_{28} (site)	Lab./site	$R_{l20,5\%}$ (lab.)	$R_{l20,5\%}$ (site)	permeability
	kN/m²	kN/m²	–	–	–	m/sec
Required value	400	200	2.0		1.200	1.00×10^{-7}
Standard grout	255	106	2.41	0.922	0.559	2.75×10^{-8}
High strength grout	652	306	2.13	1.432	1.639	7.15×10^{-10}

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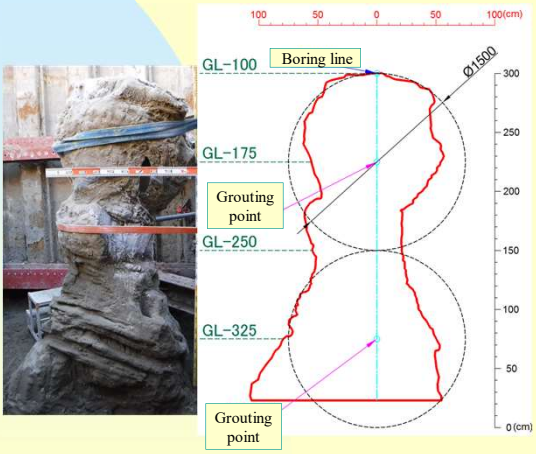
Field testing

Shape of standard grout



The result of grouting test

		unit	Standard strength
Grouting volume	A	kL	upper : 0.815 lower : 0.488 total : 1.303
Grouting pressure		MPa	Upper : about 0.02 Lower : about0.05
Volume of actual improvement	B	m³	2.70
Calculated volume (grouting volume and porosity)	C	m³	3.26
Volume ratio	B/C		82.9%

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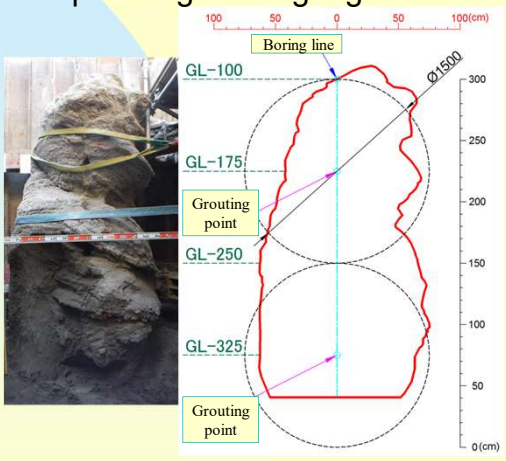
Field testing

Shape of high strength grout



The result of grouting test

		unit	High Strength
Grouting volume	A	kL	upper : 0.439 lower : 0.810 total : 1.249
Grouting pressure		MPa	Upper : 0.05-0.08 Lower : 0.06-0.10
Volume of actual improvement	B	m³	2.65
Calculated volume (grouting volume and porosity)	C	m³	3.12
Volume ratio	B/C		84.9%

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Summary

■ Laboratory test

1) Unconfined compressive strength of lab. specimen is greater than 400 kN/m^2.

2) Durability : prediction of deterioration region is 27mm/1000mm during100 years.

■ Field test

1) $R_{L20.5\%}$ of core sampled specimen is greater than 1.2.

2) Unconfined compressive strength of core sample is greater than 200 kN/m^2.

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Concluding remarks:

1. New underground construction technology using

1) Super absorbent polymer material

2) Air foam material

has been successfully demonstrated.

2. Chemical grouting technology using

3) High concentration silicate material

for the enhancement of sand liquefaction resistance has been successfully demonstrated.

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Thank you!

(at Waipara winery, NZ, August, 2006)

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