Challenging Technologies of Diaphragm Wall and Bored Pile

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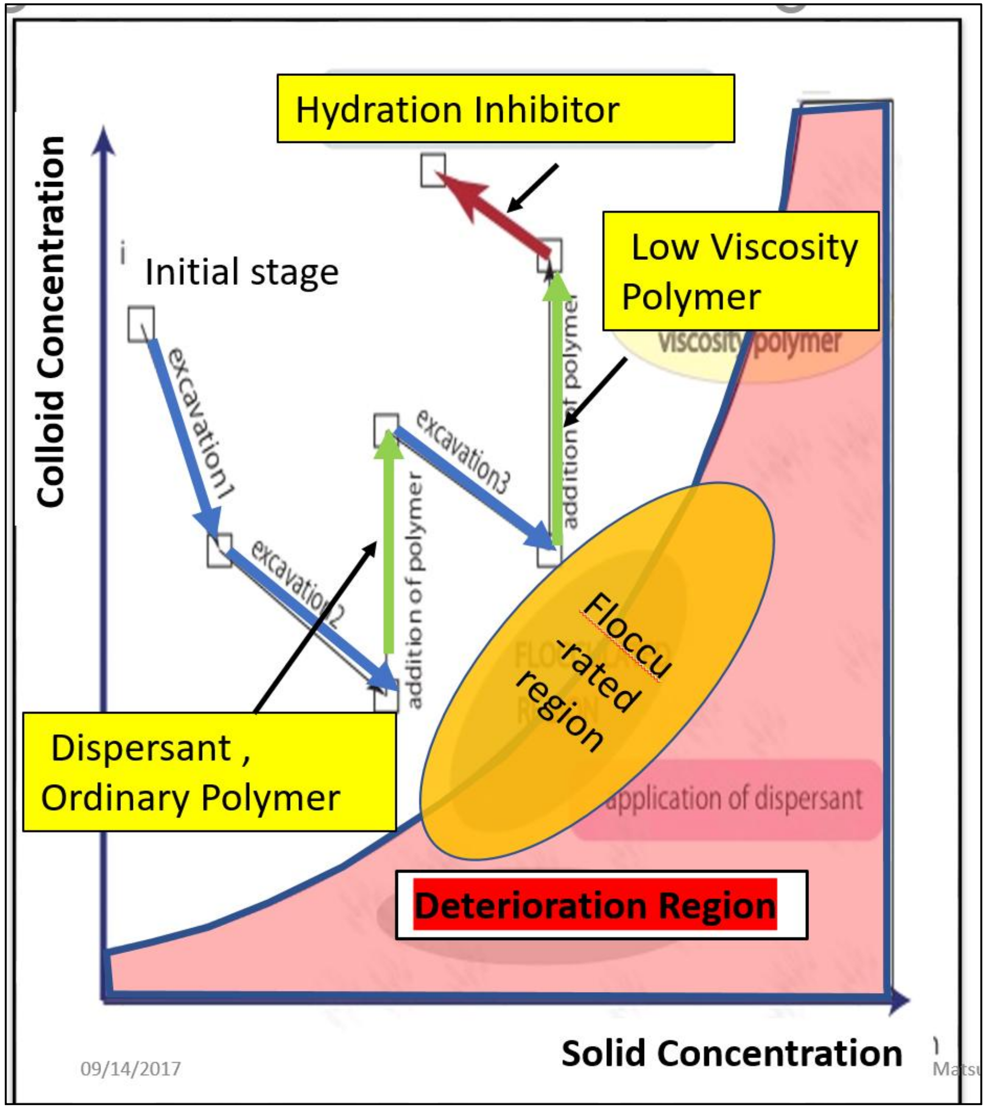
Highlighted Technologies for Diaphragm Wall and Bored pile

Excavation	Slurry	1	Slurry Quality Control
	Trench Stability	2	Local collapse caused by Excess Pore Water Pressure due to Excavation Machine
Concrete/Re-bar	Concrete		High Grade Concrete
			Auto Tremie Control System
	Re-Bar	3	Re-bar Movement in trench during Casting Concrete in the Trench
			Non-Welding Re-bar Cage
Large Scaled Diaphragm Wall and Bored Pile			Vertical Control Sytem of Excavation Machine
		4	Removal of Slime and Base Grouting
Varied Section		5	Enlarged Base Bored Pile /Nodular Bored Pile and Diaphragm Wall
		6	Application to Tokyo Skytree Tower Founation
Load Test/ Integrity Test			Pile-Toe Load Test /Dynamic Load Test
			Low Strain Dynamic Test /Sonic Logging Test
Alternative RC wall			Slurry -Cement Wall
			Soil-Cement Wall
Special Machine			Low Headroom Machine
			Under Structure Excavation Machine
Special Application			Diaphragm Wall Foundation
			Steel Diaphragm Wall

Concept of Slurry Quality Control



- Schematic figure shows change of slurry conditions
- As excavation progresses CC decreases SC increases
- At low density stage: Ordinary Polymer and or Dispersant are effective
- At high density stage: Low Viscosity Polymer and or Hydration Inhibitor to be added

Slurry Quality Control

- In order to achieve effective slurry control ,

a) Appropriate polymer for each stage

b)High-level monitoring system to confirm slurry conditions

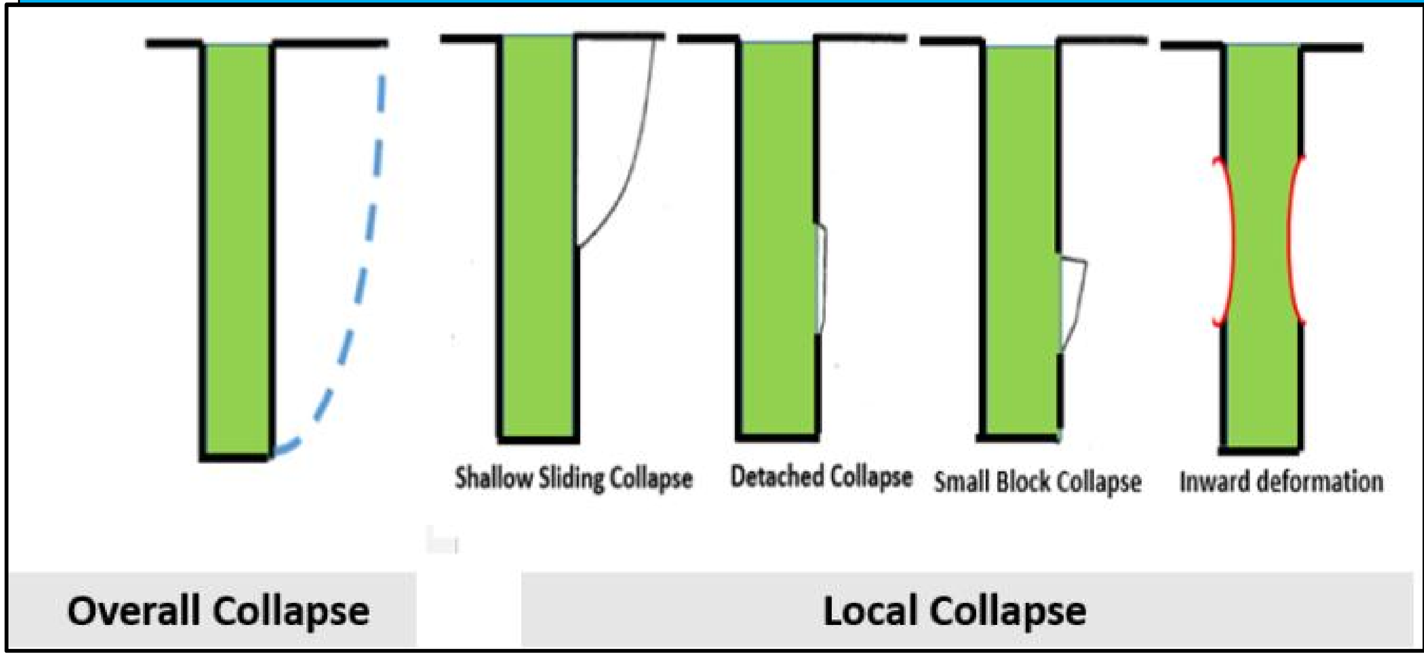
c)Integrated Automatic Slurry Control System

are essential

- Recently, much efforts are underway to develop

Slurry Quality Control Methods using new revised slurry such as “Super Slurry,” “Selective Flocculant Slurry “ and so forth

Trench Collapse /Trench Stability

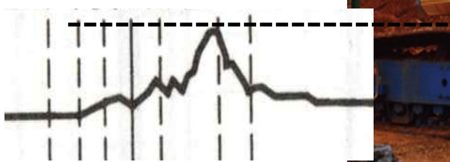


- According to past records, most trench collapse is Local Collapse, and it is classified into 4 types
- One of the main causes of Local Collapse is Induced Pore Water Pressure arising from the movement of excavation machine in the trench

Diaphragm Wall Machine

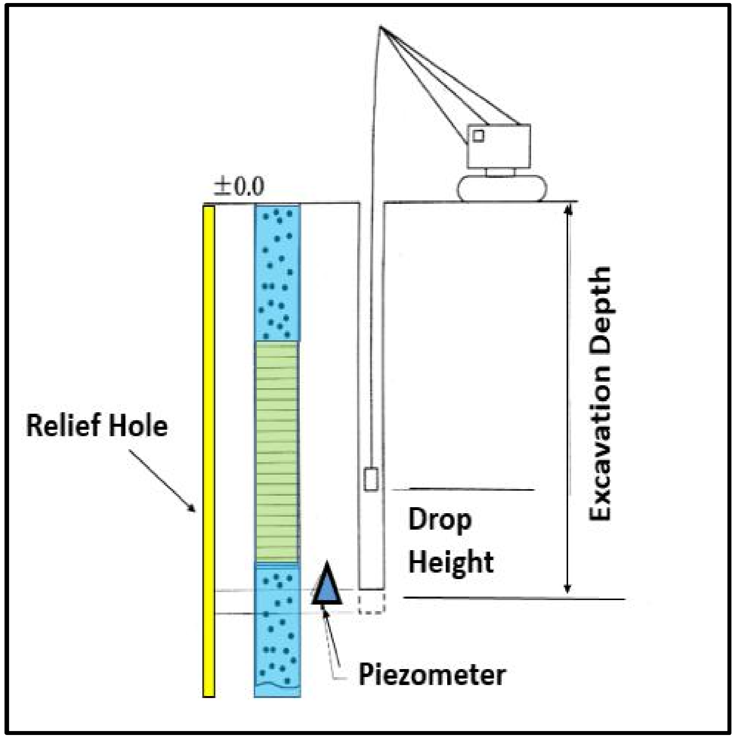
Grab Bucket Type

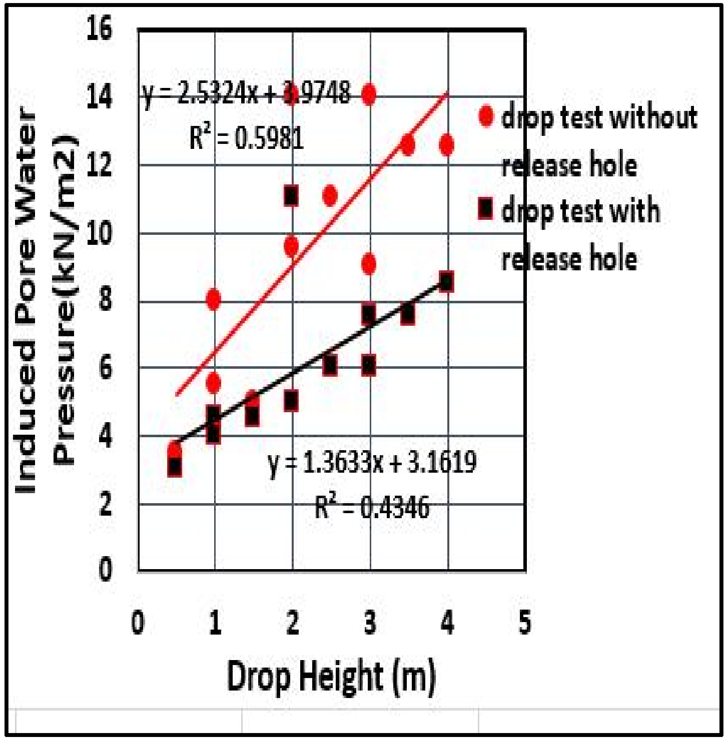
Trench Cutter Type



Excess Pore Water Pressure during excavation is induced by different causes: Impact by drop of bucket for Grab Bucket excavation and disturbance of ground by cutter rotation for trench cutter excavation

Grab Bucket Drop Test

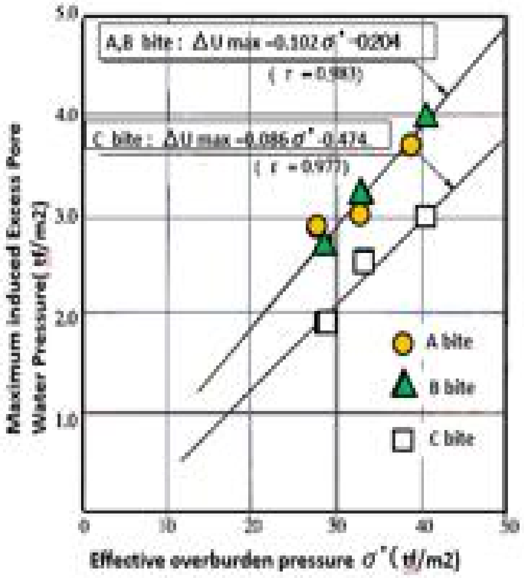




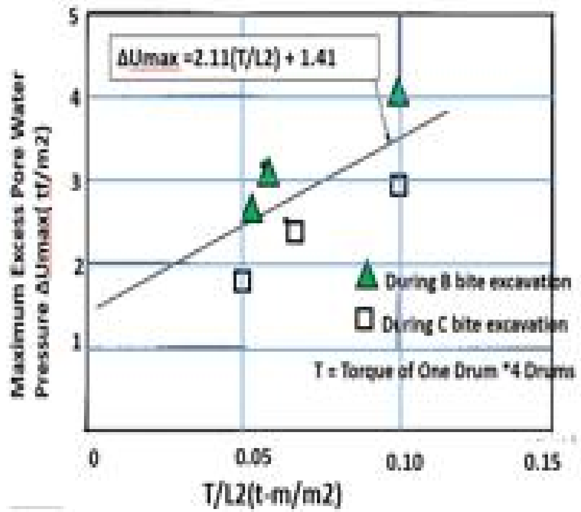
For Grab Bucket Excavation , Two Grab Bucket Drop tests were carried out in sand layer, with Relief Hole installed near trench and without Relief Hole. It can be found from test results:

1) Induced pore water pressure increases with Bucket Drop height
2) Relief Hole is an effective in reducing excess pore water pressure

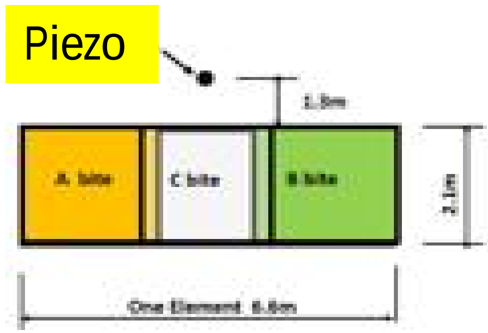
Trench Cutter Excavation Test



a) ΔU max－σ'



b) ΔU max－Trench Cutter Torque T



c) excavation bites

Diaphragm wall depth 150m
Element 2.1m * 6.6m

From tests 1) Induced pore water pressure increases with effective overburden stress

2) Induced pore water pressure increases with excavation Torque of machine

Mitigation Measures against Local Collapse

- Relief Holes installed near Trench is an effective method of reducing induced pore water pressure

- The following excavation methods are effective in mitigating trench collapse

➢ For Grab Bucket type Machine :

Reduction in drop height of Grab Bucket

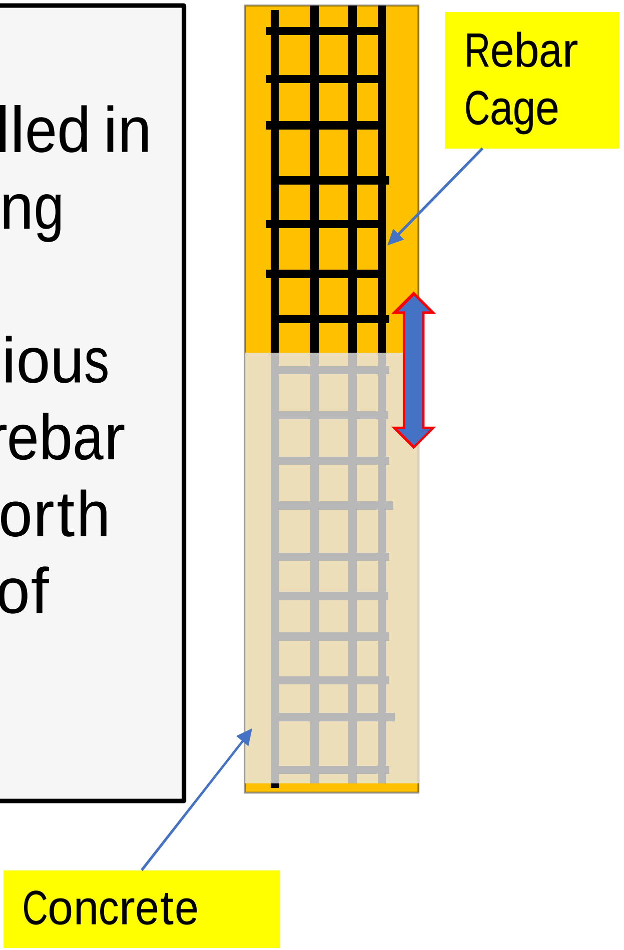
➢ For Trench Cutter type Machine

Smooth excavation with reduction in thrust force in order to decrease excavation Torque of machine

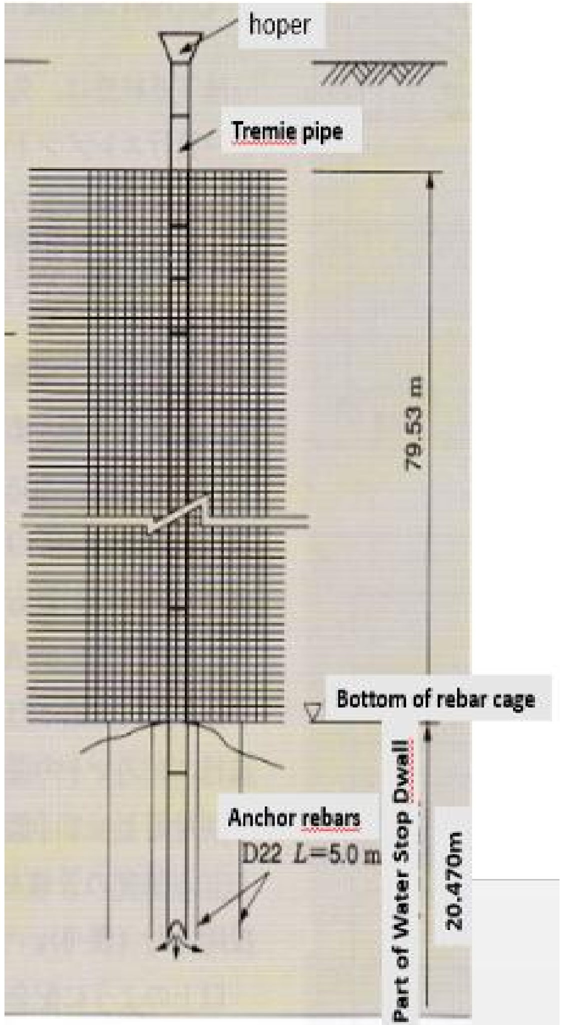
Movement of Re-Bar Cage in Trench

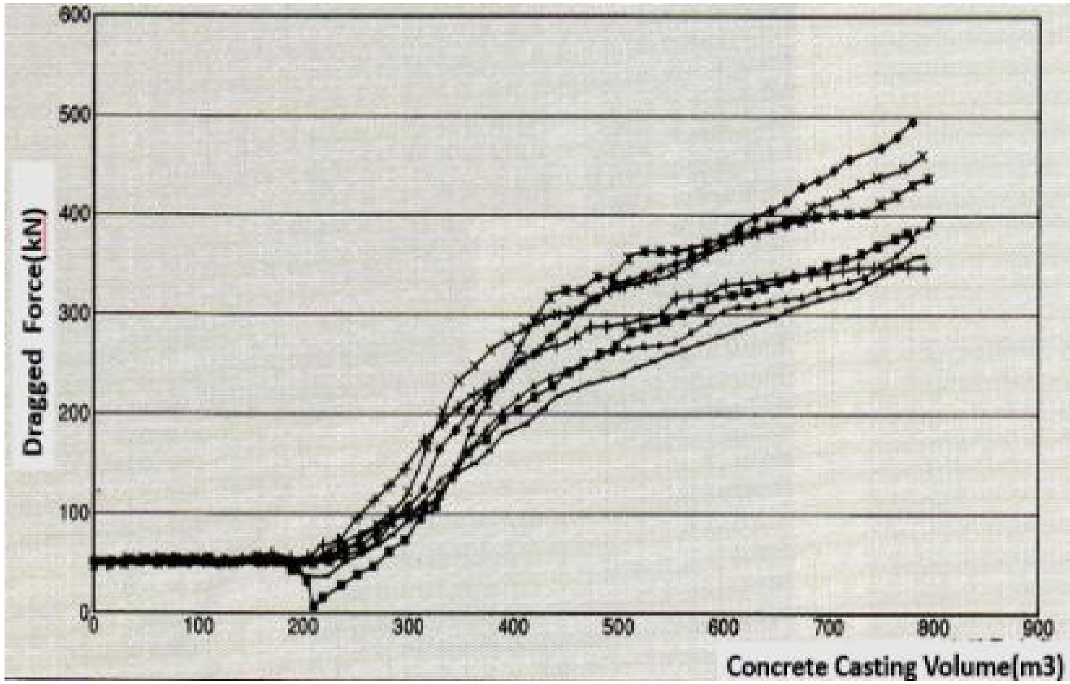
For Deep Diaphragm Wall ,

- It has been confirmed that Rebar Cage installed in the trench is lifted up and pulled down during casting of concrete
- Induced force in Rebar Cage depends on various factors: re-bar cage weight , re-bar density, rebar cage length, concrete casting speed and so forth
- Estimation of induced force and movement of Rebar Cage has not been established yet



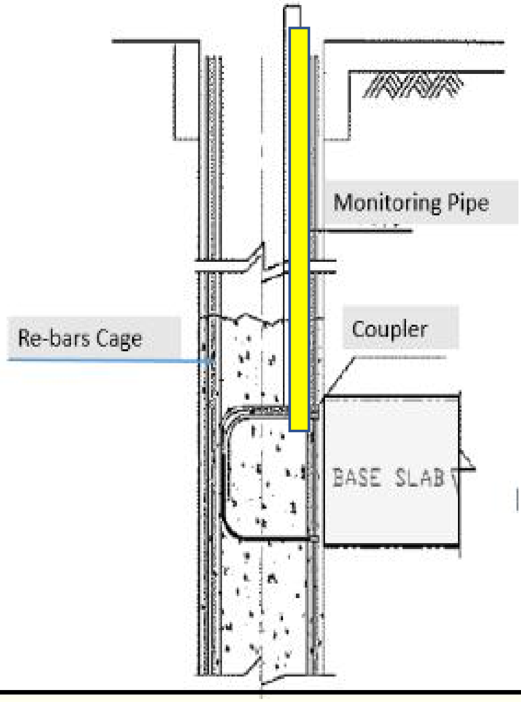
Monitoring of Induced Force in Re-bar Cage during Casting Concrete





Diaphragm wall length: 100m(lower part : water stop Diaphragm Wall without re-bar , length of Rebar cage: 80m), 2.1m *3.8m element , Induced Force max 500kN

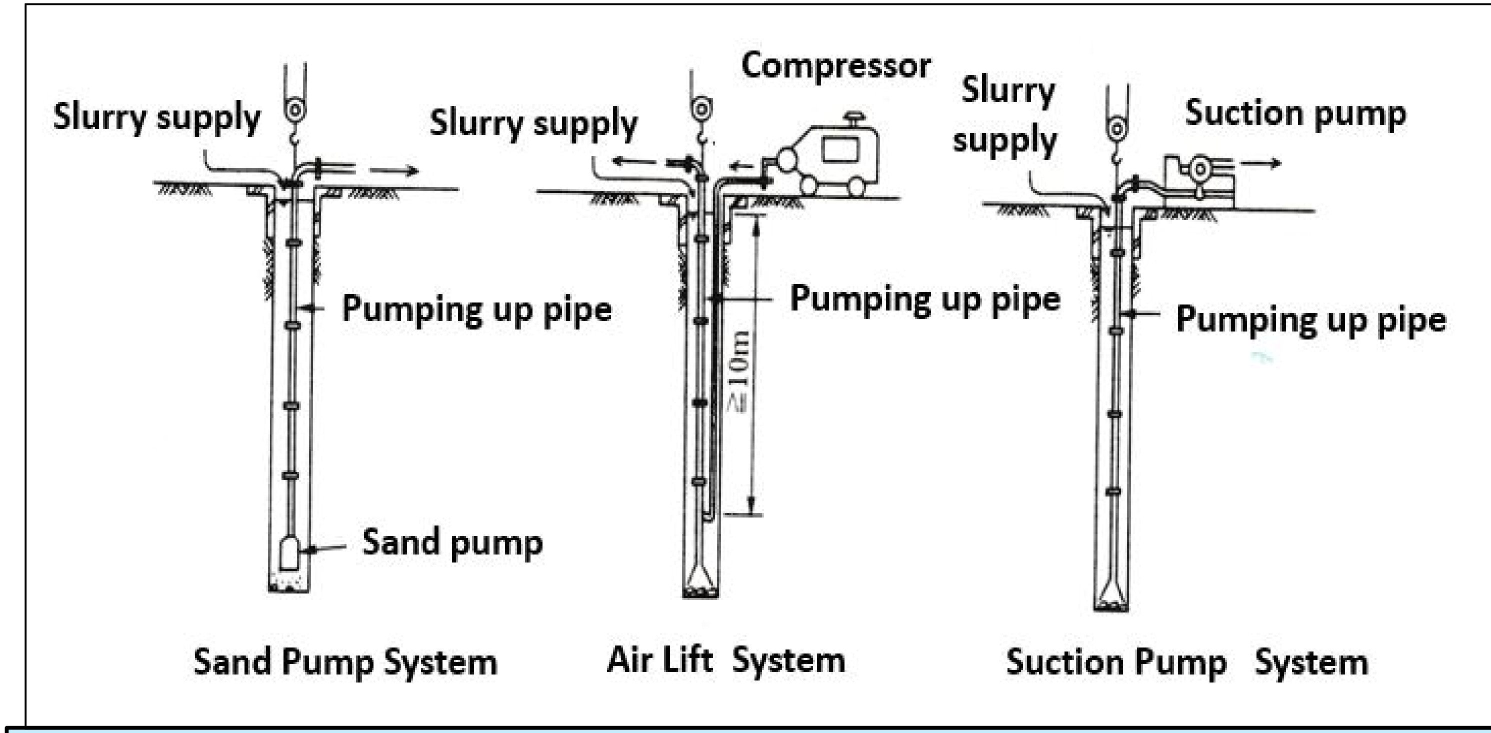
Monitoring of Rebar Movement due to Casting Concrete



Coupler Level Before Intalllation of RE-bar Cage (A)	Coupler LevelAfter Intallation of Re-bar Cage	Coupler Level After Casting Concrete (B)	Difference =A-B (mm)
83.098 0	83.097 -1	83.058 -40	40

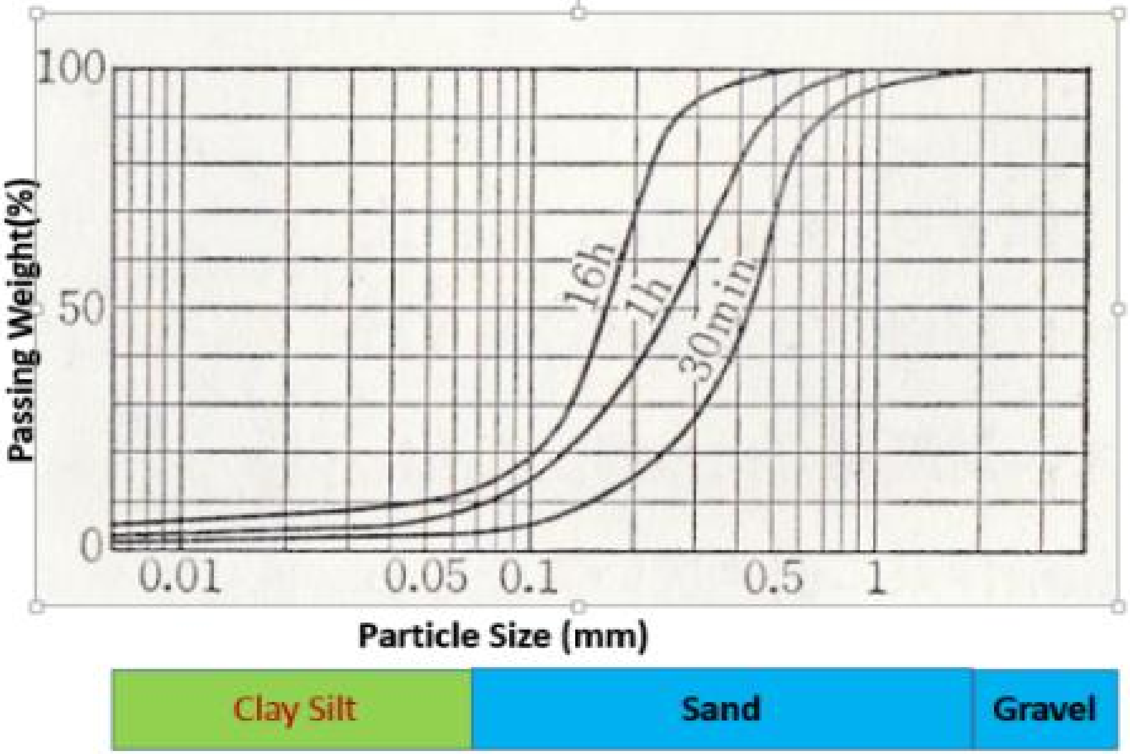
Monitoring was carried out to confirm the change in coupler's level of Base Slab of underground station (Diaphragm length 50m, width 1.5m, Re-bar cage 50m length , Couple's setting level : GL-20m).Coupler's level was settled by 40mm after casting concrete

Removal Method of Slime



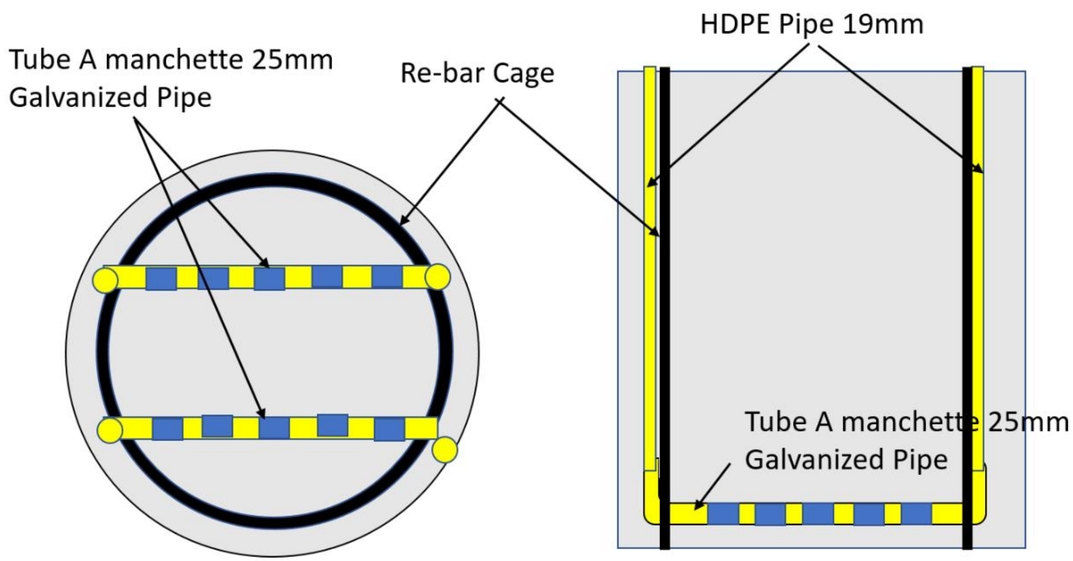
- After trench excavation fine soils in the slurry accumulate at the bottom of trench (Slime)
- Slime is removed using Sand Pump or Airlift or Suction Pump or Excavation Machine

Particle Distribution Curve of Slime with Time at Trench Bottom



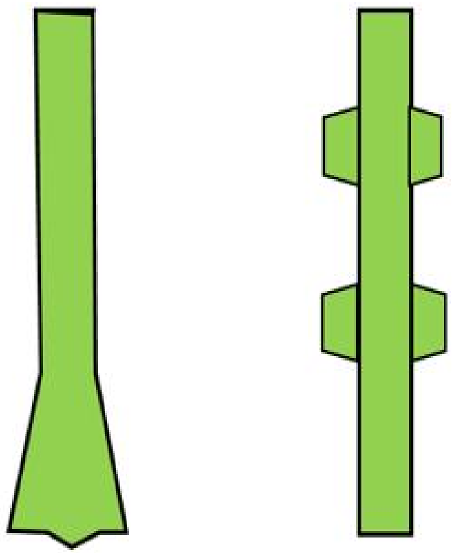
- Particle distribution curve of accumulated slime at trench bottom with time
- At 16 hours after trench excavation fine slime still accumulates at the bottom of trench
- It is difficult to remove slime at trench bottom perfectly

Base Grouting System

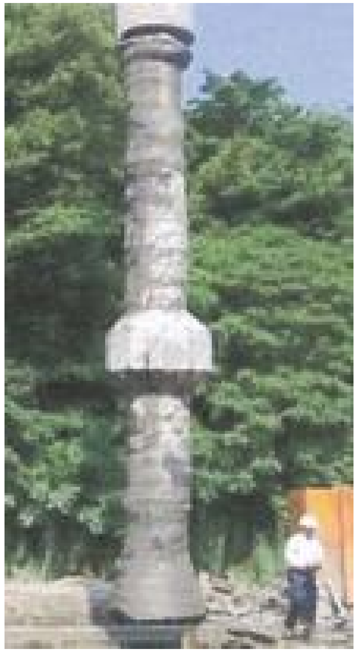


- In order to compensate removal of slime , Base Grouting System has been applied to various projects
- SL Lee/KY Yong (NUS)proposed this method (1992).
- Grouting pipes are attached at bottom of Rebar Cage and installed together with Rebar Cage.
- After casting concrete, grouting at the bottom is carried out

Enlarged Base /Nodular Bored Pile

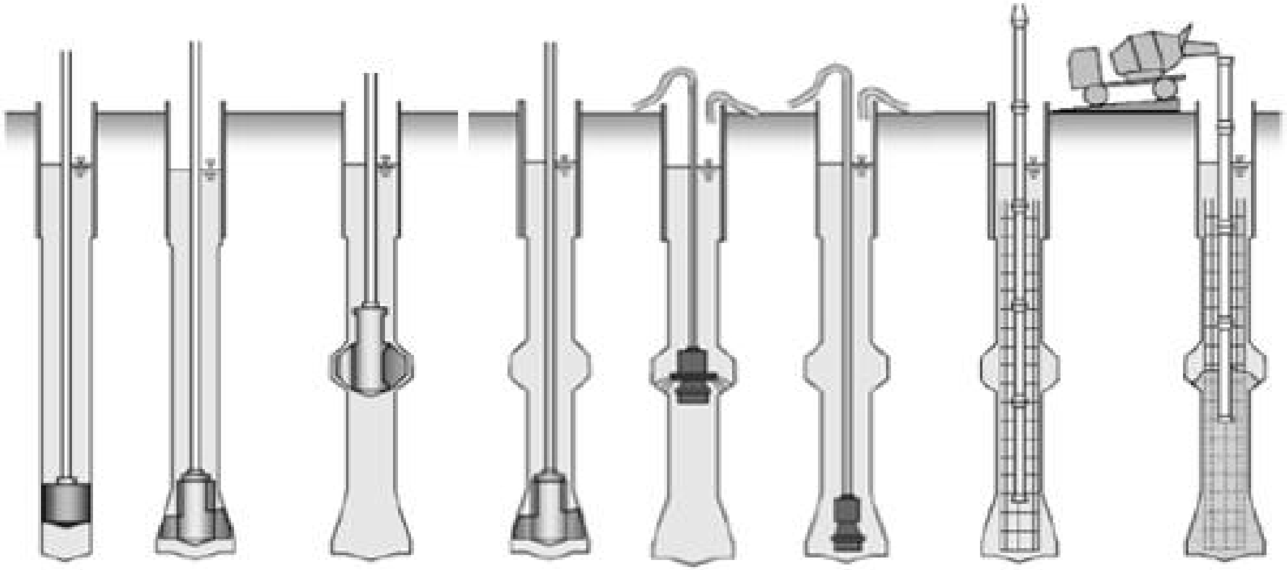


a)Enlarged Base Bored Pile   b)Nodular Bored Pile



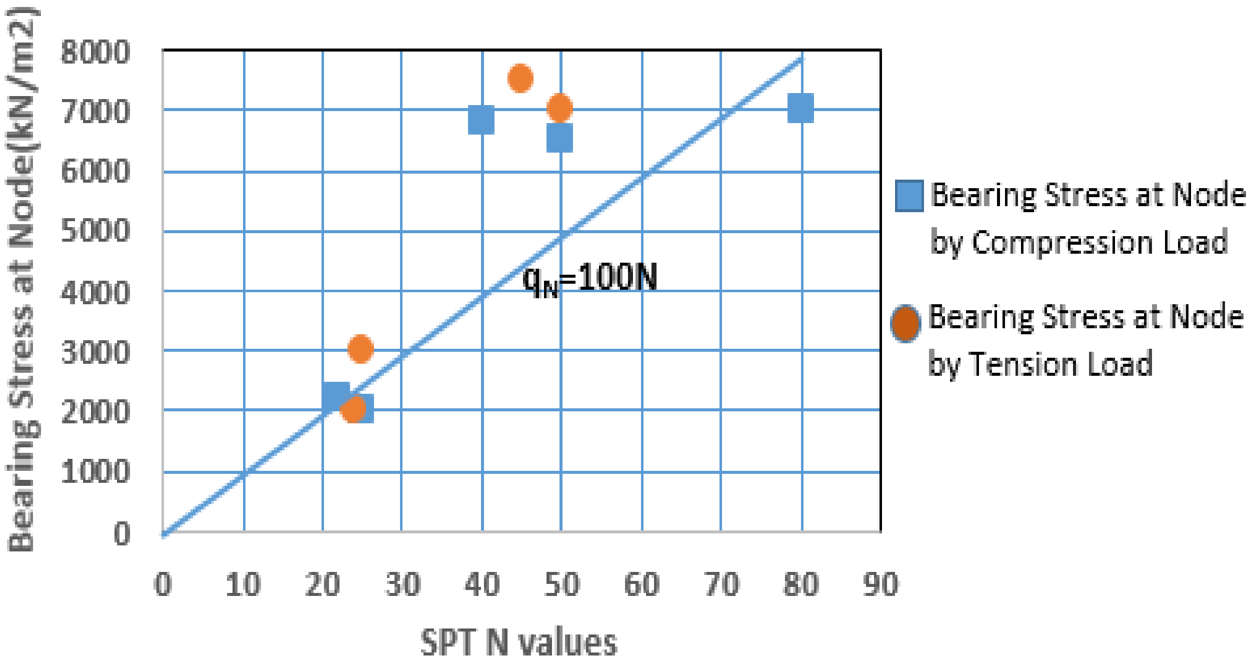
- In order to improve Bearing Capacity and Shaft Resistance, Enlarged Base Bored Pile and Nodular Bored Pile have been developed.
- For Enlarged part and Nodular Part, Bearing Stress is resisted by Concrete Shear Stress without Rebars

Construction Sequence of Enlarged Base and Nodular Bored Pile



Step1: excavate Shaft , Step2 : ream at base using special machine
Step3: ream at Node using special machine
Step4: remove slime at Base, Step5: clean at Node,
Step6 : remove slime ,replace slurry with new slurry and monitor
Step7: install re-bar cage/ and carry out secondary removal of slime, Step8: cast concrete

Bearing Stress at Nodular Parts

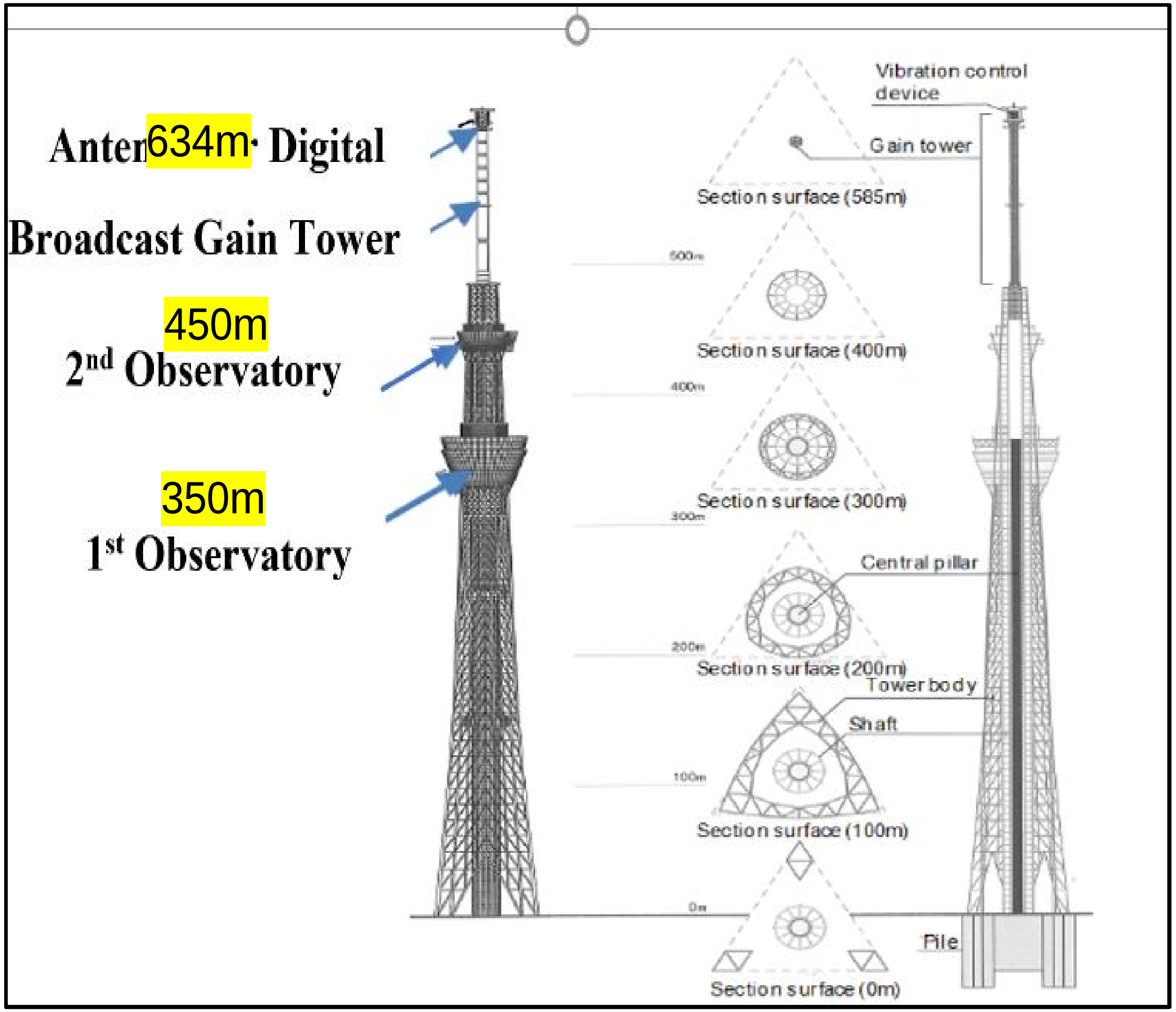


It can be confirmed from Load Tests that :

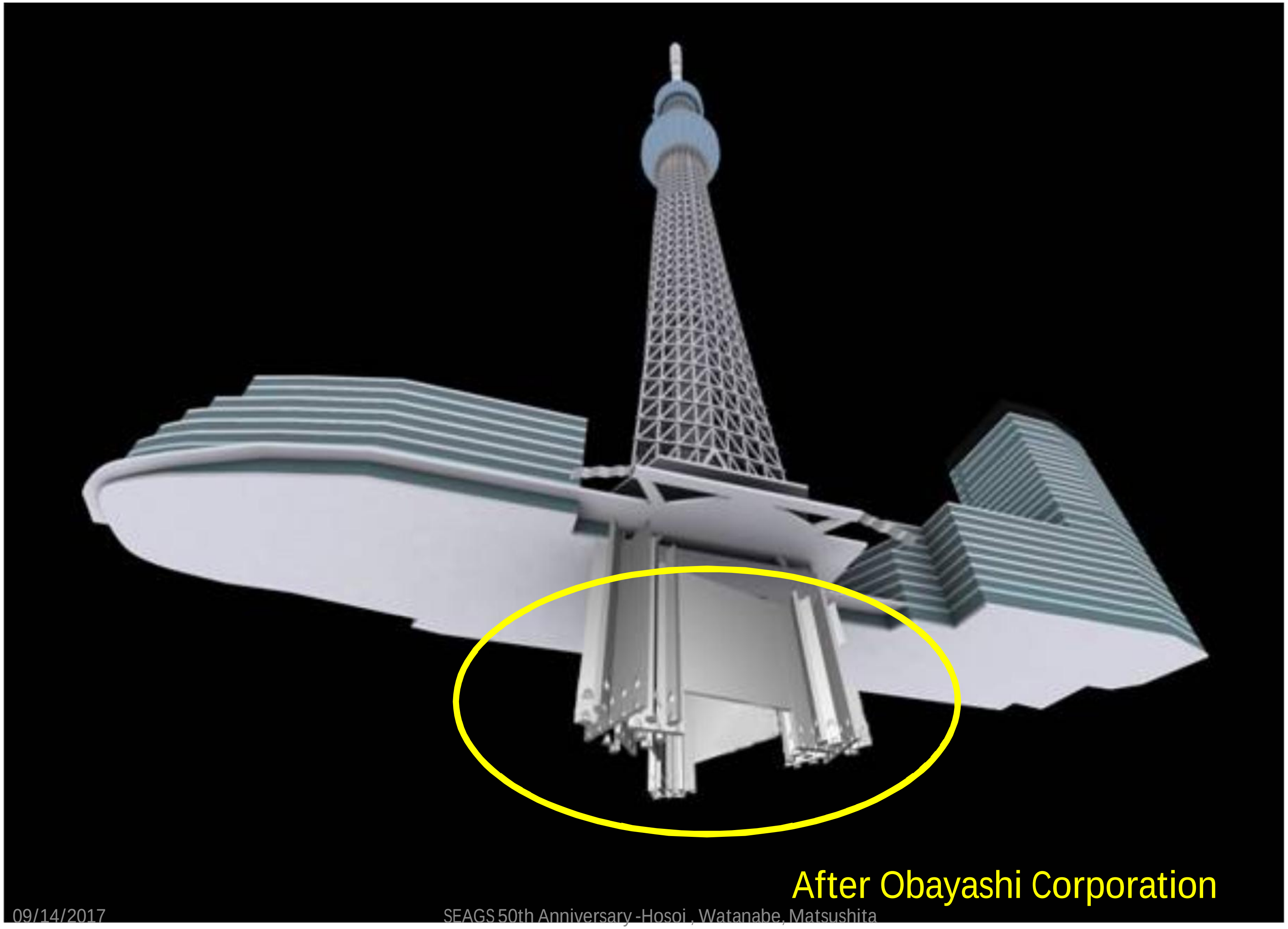
- Ultimate Bearing Stress at Node by tension load and compressive load are approximately 100N

Application of Nodular Diaphragm Wall/Enlarged Base Bored Pile to Foundation of Tokyo Skytree Tower

Schematic View of Tokyo Skytree Tower

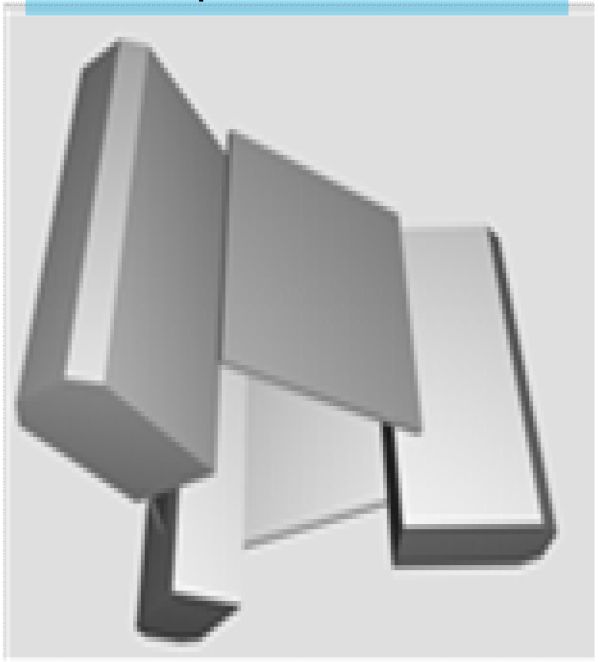


Overview of Foundation of Tokyo Skytree Tower



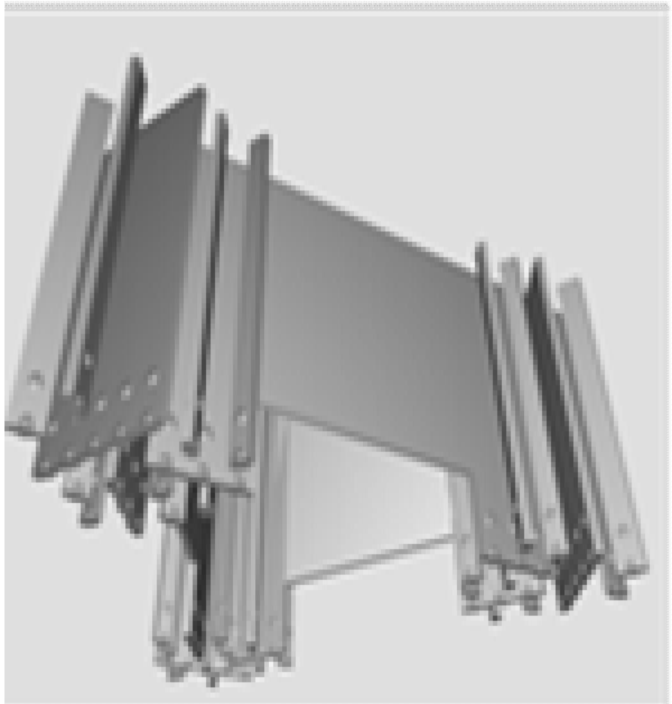
Two Options of Foundation

Open Caisson



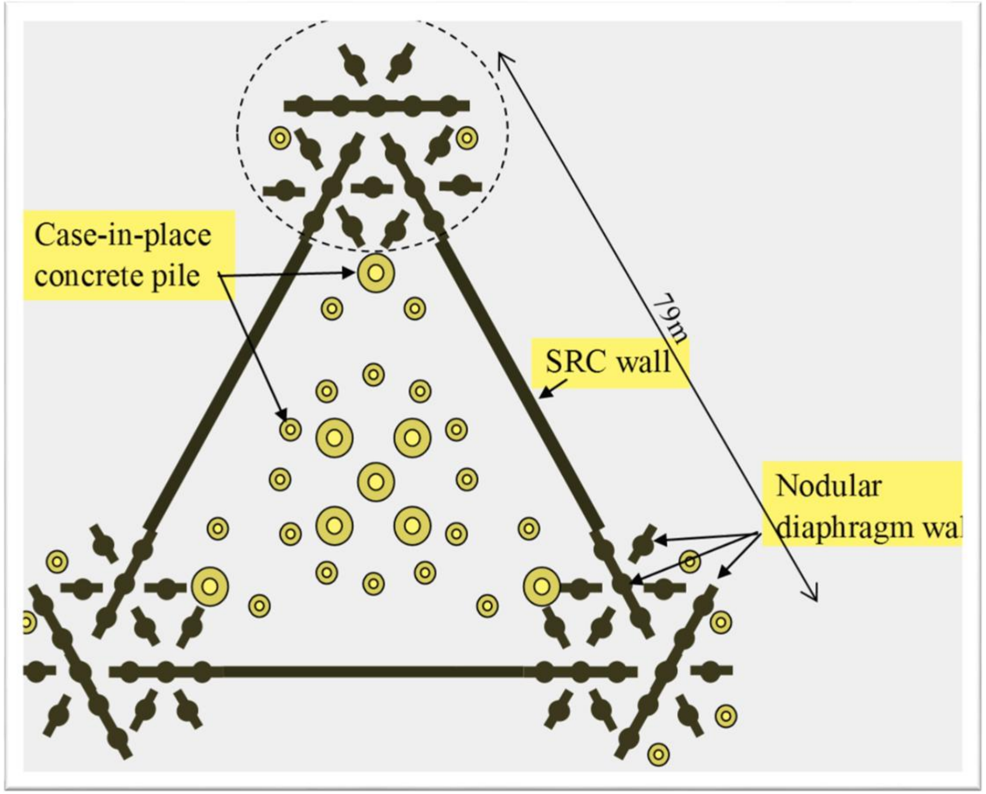
- Open Caisson Method is to resist tensile load by large Caisson dead-weight
- Construction of Caisson would have impact on the neibouring structure

Nodular Diaphragm Wall



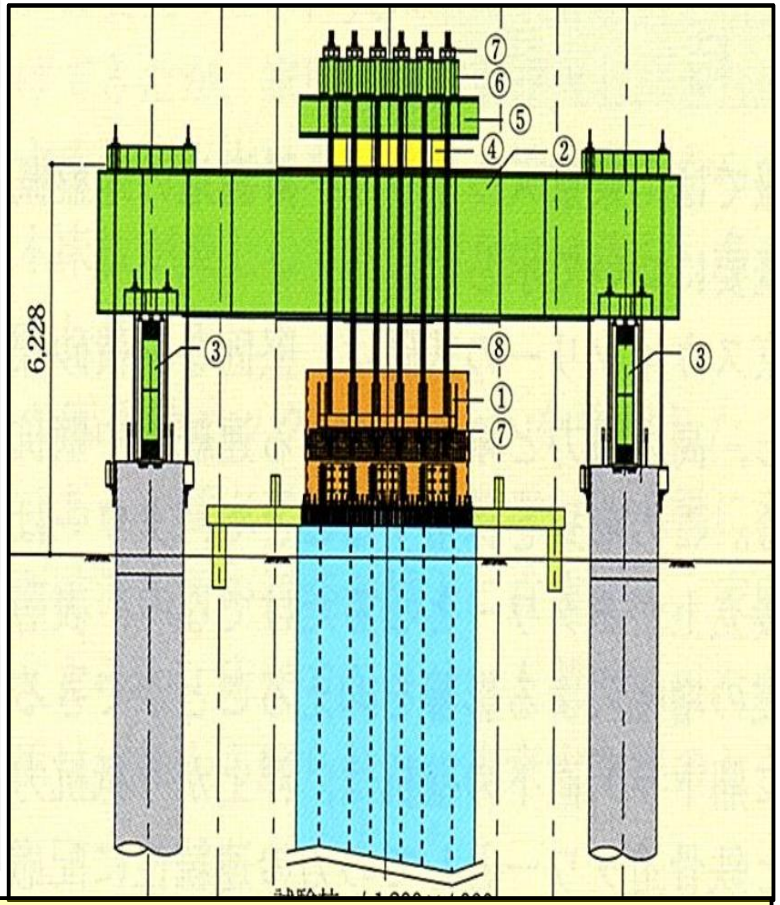
- Nodular Diaphragm Wall Method mobilise Shaft friction and Tip resistance at Nodular Parts
- No influence on neighboring structure

Triangular Foundation:



- Side length of triangular foundation : 79m,
- At Apexes Nodular Diaphragm Walls are installed.
- Between Apexes SRC Diapfragm Walls are installed.
- Inside Triangular Enlarged Base Bored Piles are arranged

Full Scaled Load Test

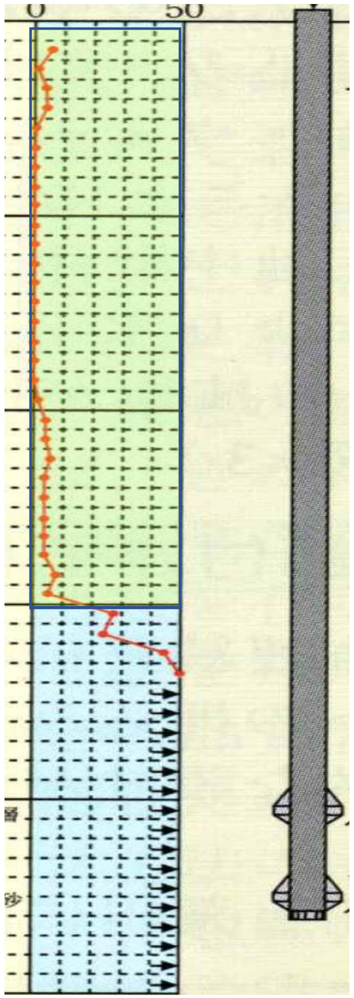


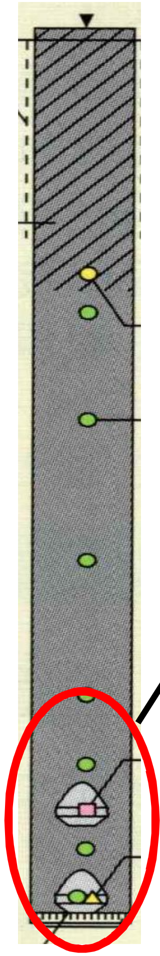
40,000kN Full Scale Tensile Load Test was carried out successfully

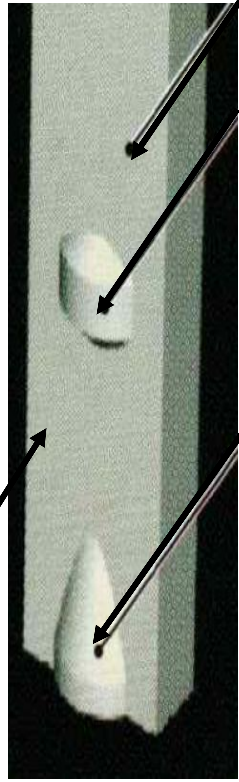
Full Scaled Load Test of Nodular Diaphragm Wall

GLtoGL-30m: Yuraku Alluvium

GL-30m deeper : Diluvial N>50







- Test Pile 4m*1.2m *46m
- Node at upper part (2.14m wide)
- Node at Toe part (2.16 wide)
- Design Load and Stiffness can be confirmed.

Summaries (1)

- **Slurry quality control**

Appropriate polymer slurry to meet slurry conditions should be used. It is anticipated that Automatic Slurry Control System with accurate monitoring slurry quality will be developed

- Trench stability

Introducing Relief hole near the trench is an effective method to reduce excess pore water pressure due to excavation

- Re-bar movement in trench

For deep Diaphragm wall construction upward and downward movement of re-bar cages has been confirmed. Setting Level of connection couplers should be considered. Theoretical analysis has not been established yet.

- Removal of Slime

In order to compensate removal of slime, Base Grouting System has been applied to many projects

Summaries (2)

- Enlarged base bored pile

➢Enlarged base bored pile have been developed and applied mainly to building foundation.

- Nodular Diaphragm Wall and Bored Pile

➢ Bored Pile with nodes has been successfully developed based on full scaled load tests and applied to high-rise building projects.

➢Diaphragm wall with node (Nodular cast-in-place diaphragm wall) was successfully applied to the foundation of TOKYO SKYTREE TOWER based on full scaled load test.

- Others

High-grade concrete: Grade 100 grade,/Non-welding rebar cage

Vertical Control of Machine : 50mm at 150m/

Slurry-Cement /Soil-Cement /Steel-Concrete Diaphragm Wall/

Special Machine :Low Headroom/under-structure

THANK YOU
for your
ATTENTION!