Newly developed SKK method for the improvement of soft ground

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The development of alluvial plain with constructing many infrastructures has been accelerated in many countries. One of the serious problems facing the construction of some big structures such as airports, highways and so forth on alluvial plains is improvement of soft ground to increase bearing capacity.

For the improvement of soft ground, drainage by a consolidation method is often used. In this method, the ground is compressed, and then density is raised and intensity is increased. Two techniques have been commonly used.
One is consolidation settlement by embankment surcharge and another is by vacuum consolidation. The compressive force in the former is the weight of the embankment, and in the latter it is negative pressure. In a typical case, the embankment surcharge method requires a longer time for consolidation. On the other hand, the cost of the vacuum consolidation method is higher than the embankment surcharge method. Due to this, a new method has been expected in order to accelerate the consolidation processes and to reduce the cost.

The SKK (Su-Kara-Kahn) method proposed here is one of the drainage by consolidation methods and the advantage of this SKK method is to considerably accelerate the consolidation processes.
In this method, the pore water can be rapidly drained by the combined use of vacuum pump, submersible pump, blower and compressor. At first the vacuum pump and submersible pump are used to lower the groundwater level, and then all of the equipment' are used to drain the pore water.

As a result, compressive forces obtained by this method are the new effective stresses due to lowering groundwater level and negative pressure. In addition, the combined use of the embankment surcharge method with this SKK method is possible to accelerate the consolidation processes and decrease the time and cost for the ground improvement.

In this study, the SKK method has been applied to soft ground in several countries such as Japan, Korea, Singapore, and etc. In conclusion, the SKK method is very preferable for the improvement of soft ground.

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1 Consolidation Dewatering Method

Definition of Consolidation

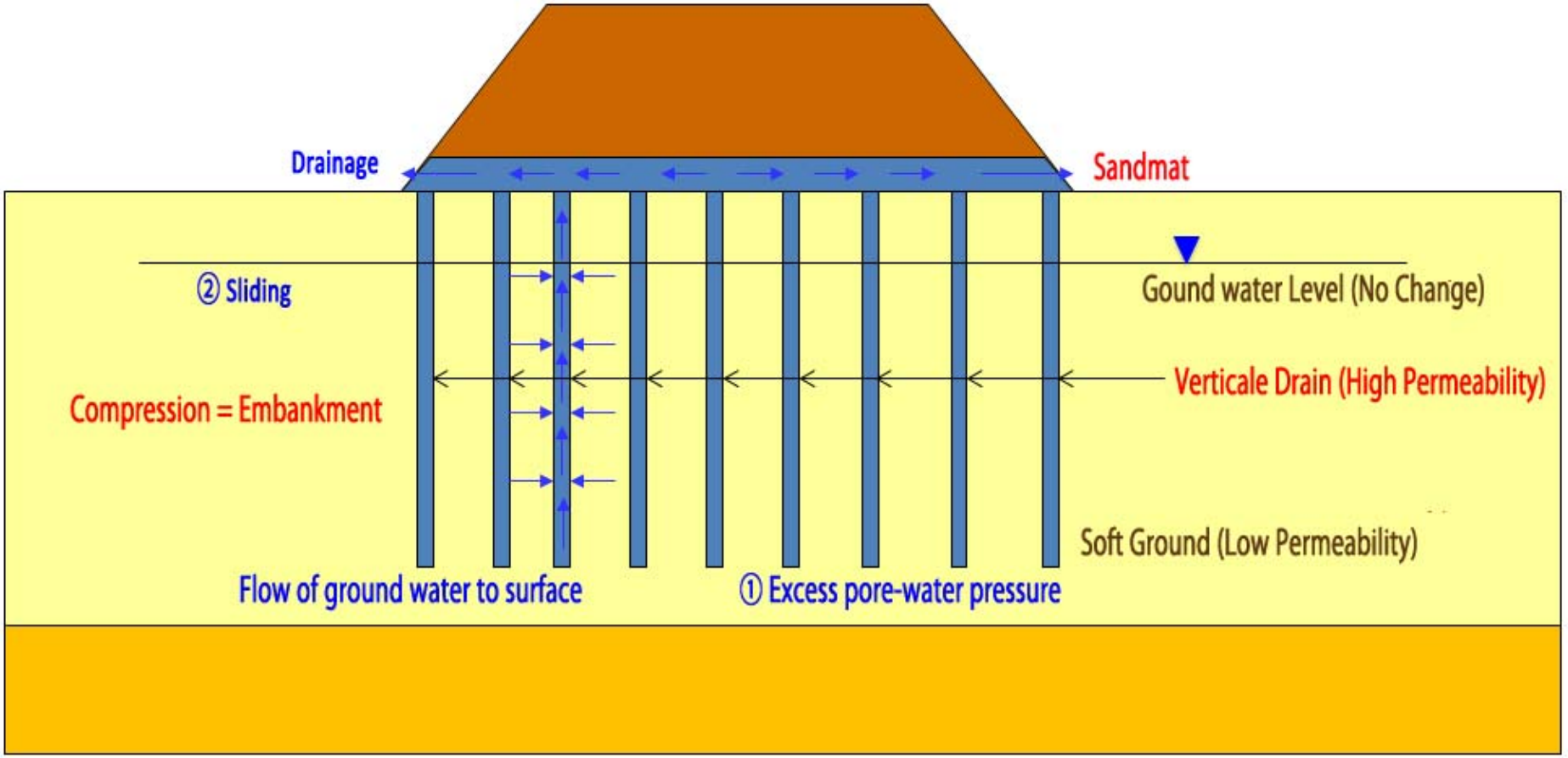
- Increase in strength of soft soil (clayey soil) due to artificial compression
- Dewatering of pore-water due to compression of soft soil (clayey soil) and replacement of voids with soil particles
- Increase in density of soil and consequently increase in strength of soil

① Embankment Surcharge Method

- The compression of the ground due to weight of the embankment
- Replacement of voids with particles due to compression

  ⇒ Increase in density and strength
- Long drainage time from clayey soil due to low permeability
- Embankment speed to be limited due to excess pore-water pressure (Without lowering ground water level)
- Shortening drainage time using vertical drain installation
- Drainage of pore-water to the surface ground through vertical drain
- More than one year is needed for completion of the drainage

Embankment Surcharge Method

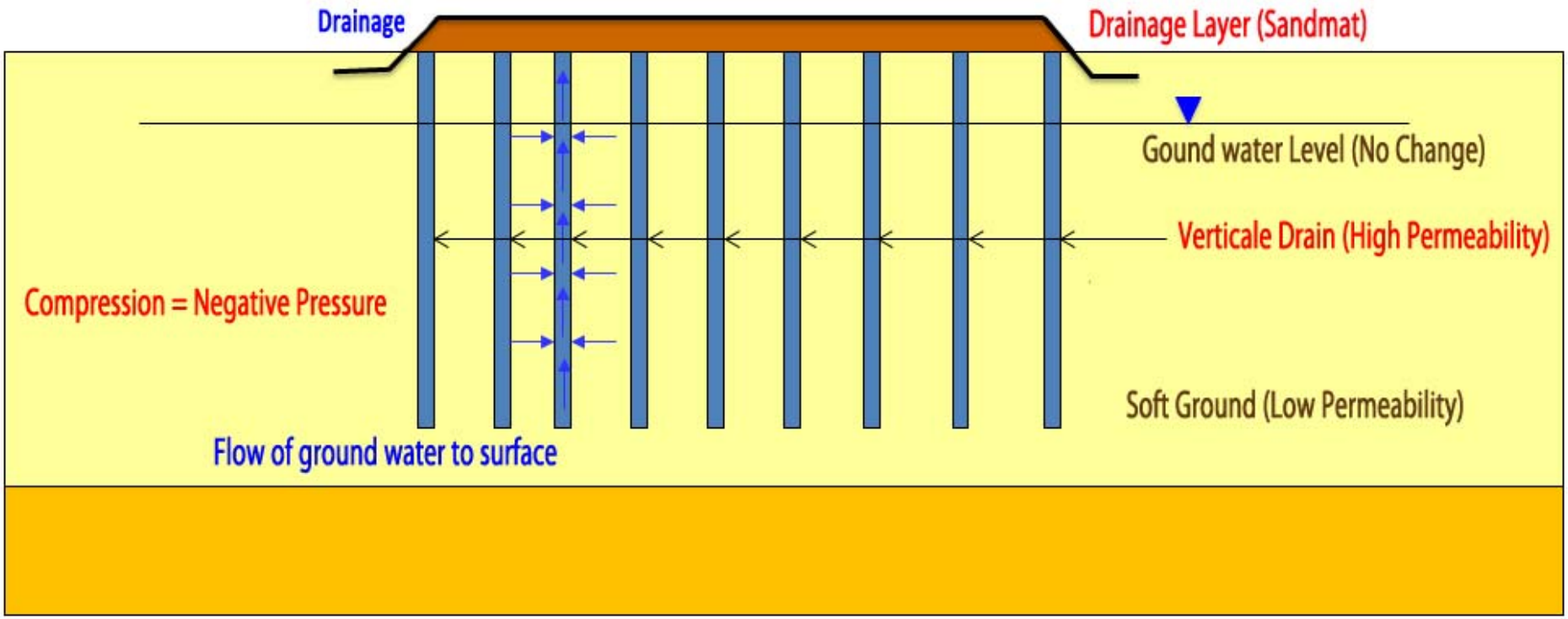


② Vacuum Consolidation Method

- Installation of vertical drain and drainage of ground water using vacuum pump and consequently compression of the ground due to negative pressure
- Drainage of pore-water pressure due to negative pressure and replacement of void with soil particles

  ⇒ Increase density of ground
- Necessity of closed surface using a sheet or impermeable soil in order to increase the negative pressure in the ground⇒ Recently development of method of increase in negative pressure
- No limitation of embankment speed because of no increase in negative pressure (without lowering the ground water level)
- Drainage of pore-water through vertical drain to surface ground (upward movement)
- More than six months is needed for completion of the drainage

Vacuum Consolidation Method



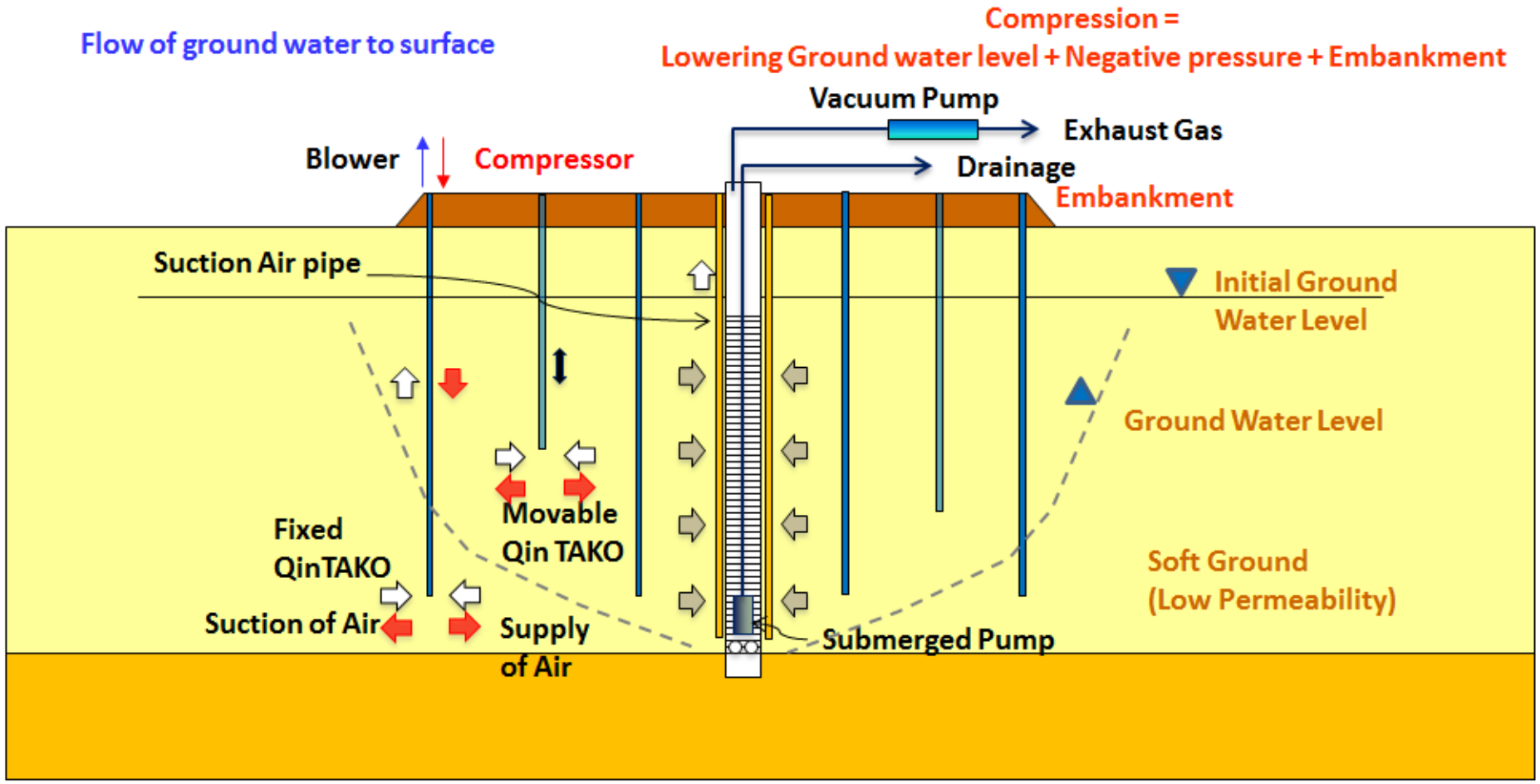
2　Su-Kara-Kahn（SKK）Method

Super-Well-Point Method（SWP Method）
・・・・・ Groundwater level-lowering method
・・・・・Uses Submerged pump and Vacuum pump

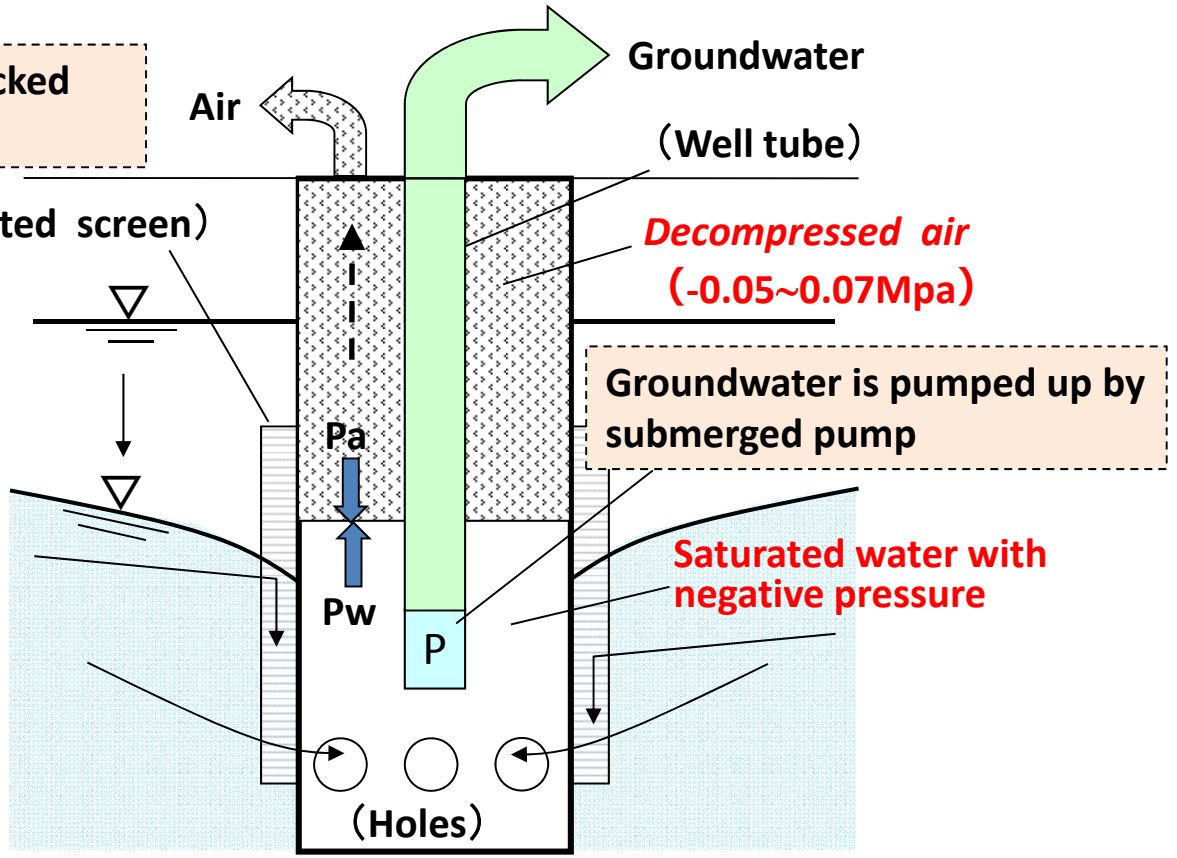
Strengthens collection power of the groundwater

Su-kara-kan Method（SKK Method）
・・・・・　Ground consolidation method
・・・・・　Uses Blower pump and Compressor in addition to Submerged pump and Vacuum pump

SKK Method


Flow of ground water to surface
Compression =
Lowering Ground water level + Negative pressure + Embankment
Vacuum Pump
Exhaust Gas
Blower
Compressor
Drainage
Embankment
Suction Air pipe
Initial Ground
Water Level
Ground Water Level
Movable
Qin TAKO
Fixed
QinTAKO
Soft Ground
(Low Permeability)
Suction of Air
Supply
of Air
Submerged Pump

Principle of SWP Method



Groundwater flows toward the holes at the lower part of well

Air pressure and water level is controlled to prevent air coming into the well

A large amount of groundwater can be pumped up

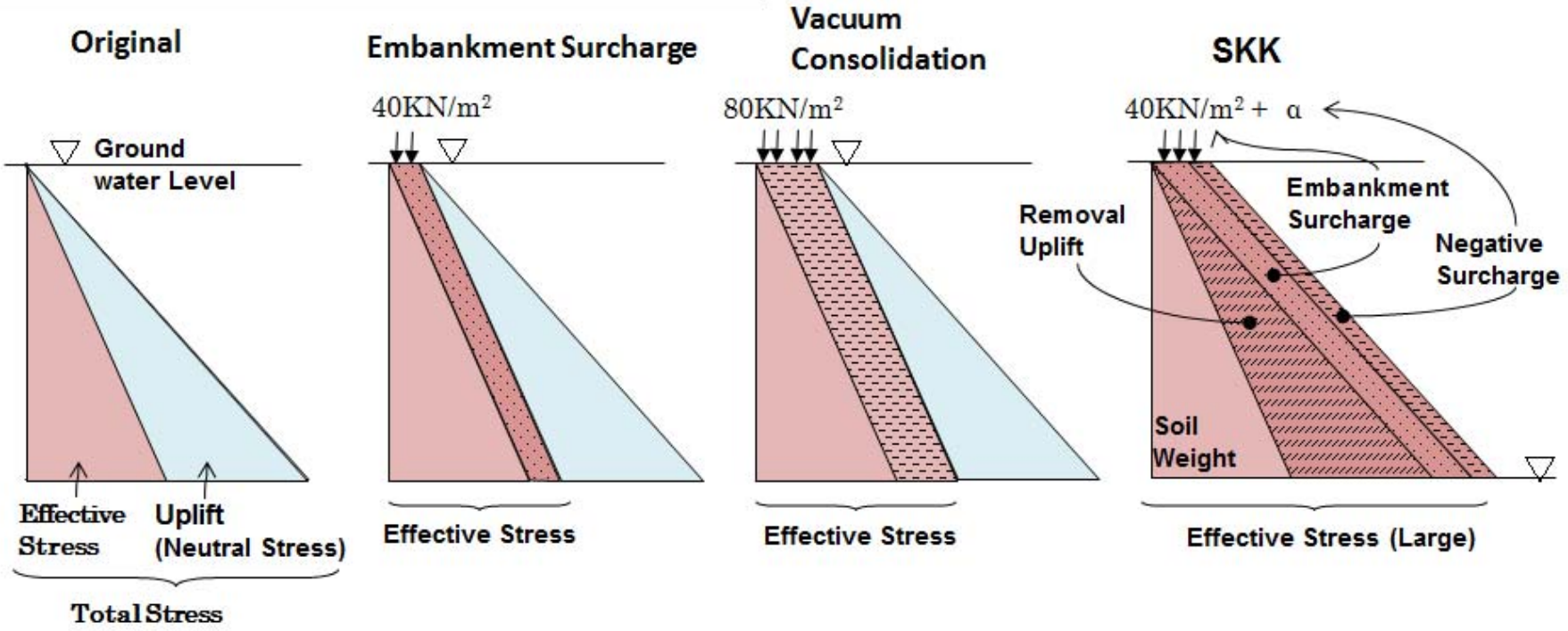
Rapid groundwater drawdown

“ In the SWP method, groundwater flows toward the bottom of the well due to negative pressure and gravity, and is then pumped up by a submerged pump”

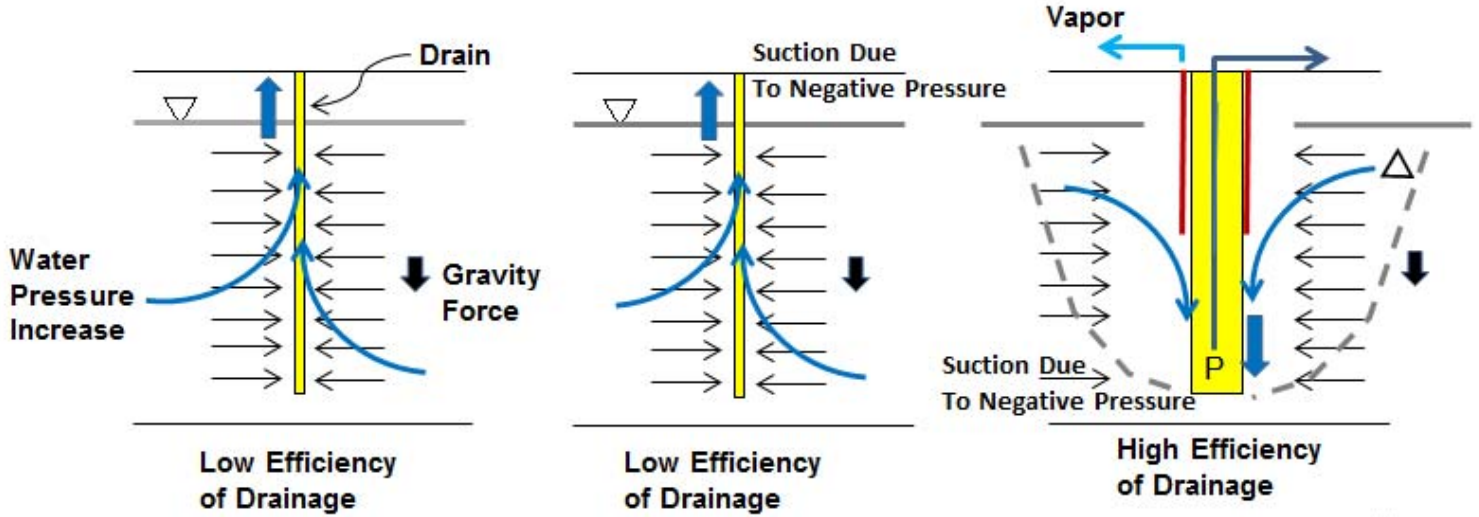
Comparison of Methods

Method	Embankment Surcharge Method	Vacuum Consolidation Method	SKK Method
Compression Force	Embankment	Negative Pressure	Embankment, Negative Pressure, Reduction of Uplift (Increase in Effective Stress)
Drainage	- Improved Permeability using particle drain - Drainage upward	- Improved Permeability using particle drain - Drainage upward	- Improved Permeability due to formation of drainage root by Qin-TAKO - Drainage downward
Problem	- Increase in pore-water pressure - Possibility of sliding - Limitation of embankment speed	- No increase in pore-water pressure - No possibility of sliding - No Limitation of embankment speed	- No increase in pore-water pressure - No possibility of sliding - No Limitation of embankment speed
Construction Period	More than 1 Year	6 Months ~ 1 Year	3 Months ~ 6 Months
Cost	A	>A	<A

1 Comparison of Effective Stress (Compression Force)



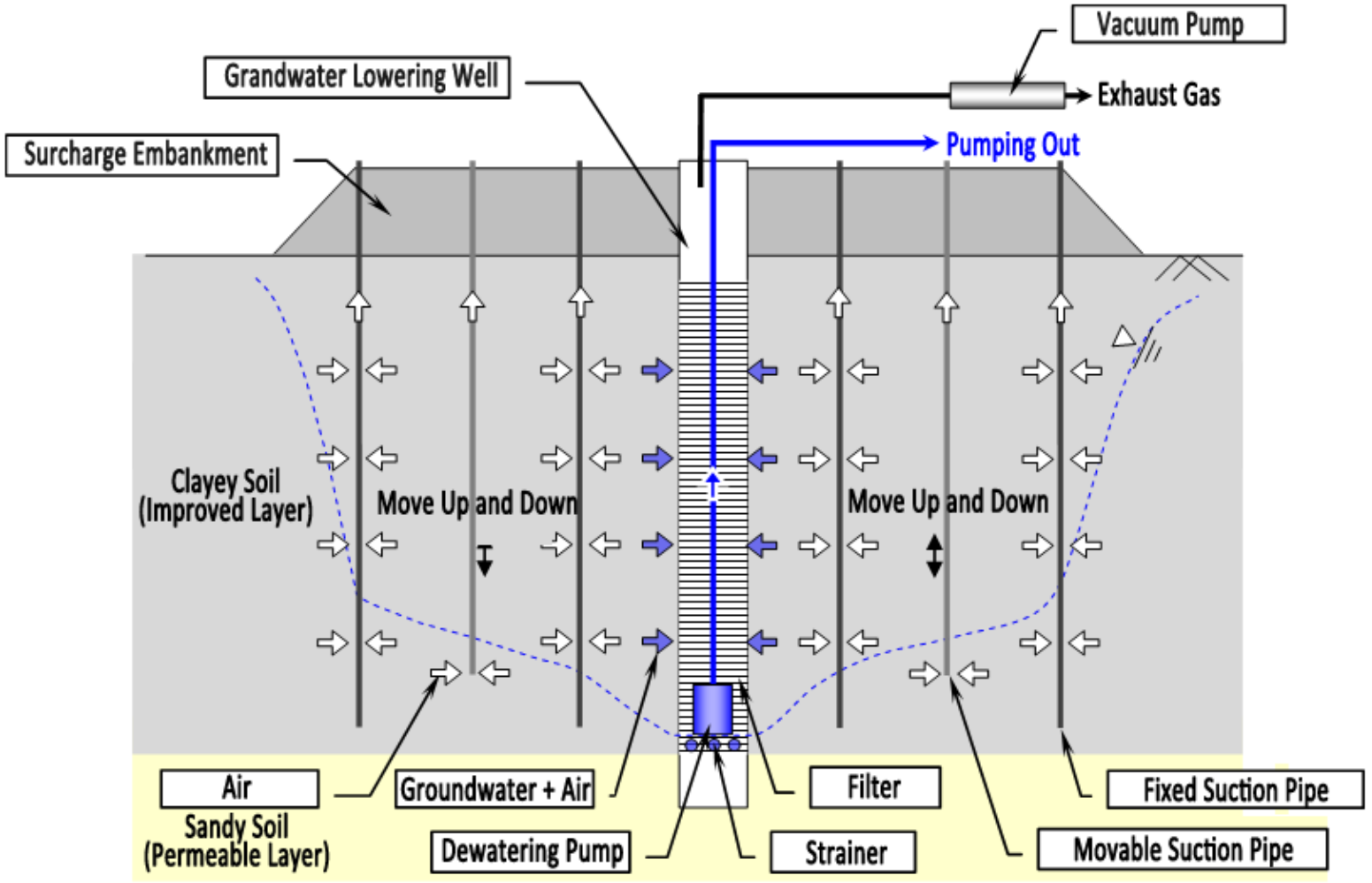
2 Comparison of Drainage



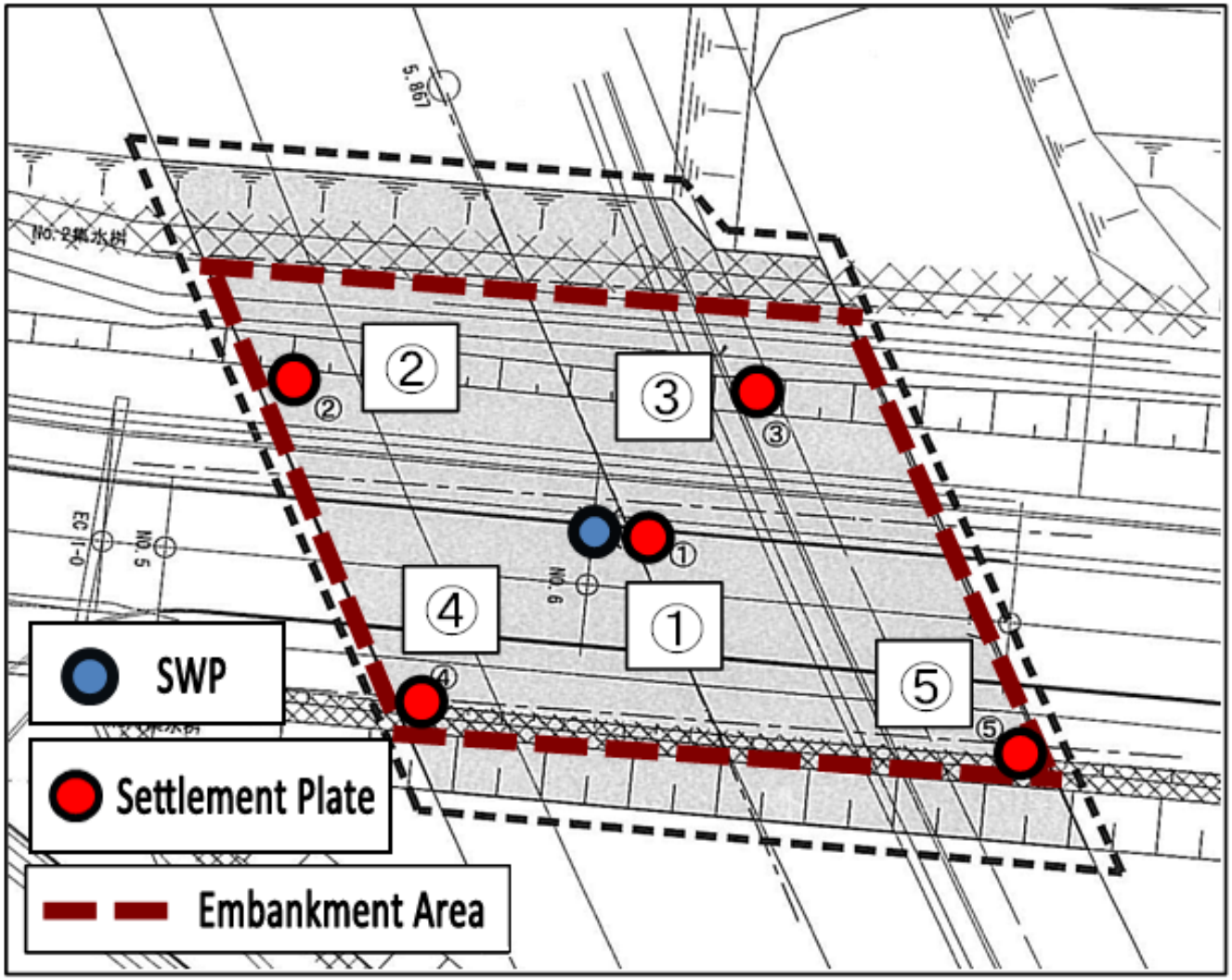
3 Example of Consolidation Dewatering using SKK Method

- **Place: Kanto region,**
  independent houses planning area
- **Year: 2012**
- **Objective: Ground improvement**
- **Geology : Alluvial cohesive soil layers**
  Depth around 30m
- **Improved area: Around 1050m^2**
- **Construction Method SKK Method**

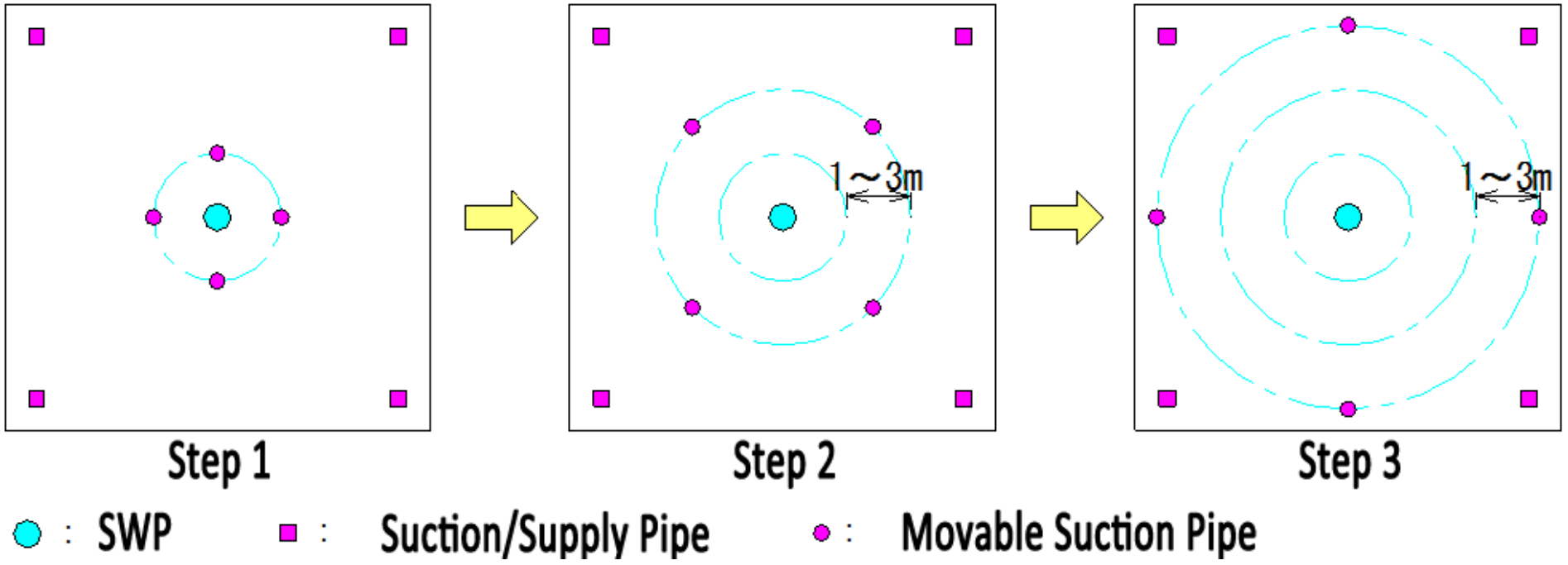
Outline of Method



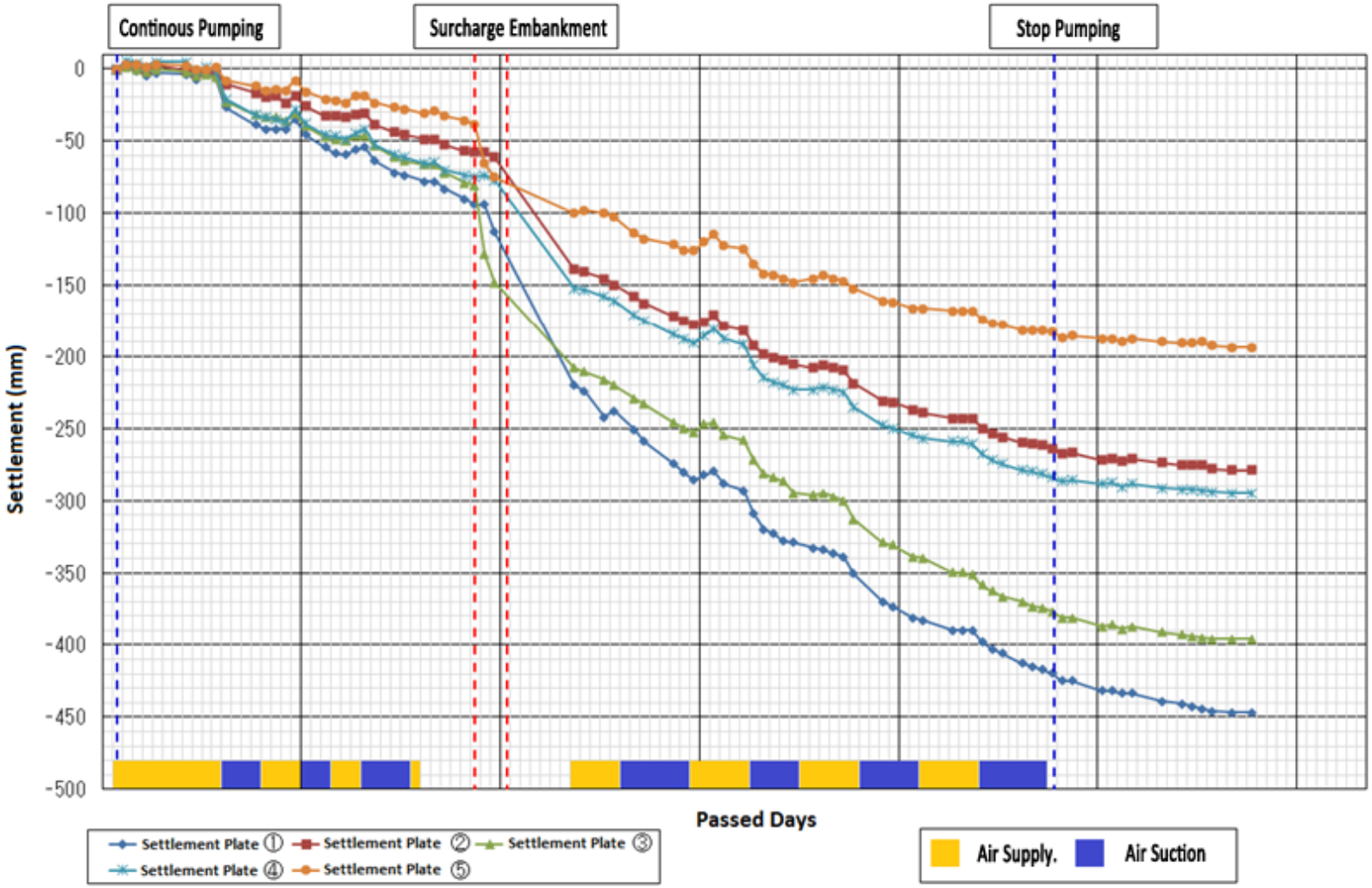
Position of SWP / Settlement Plate, Surcharge Embankment Area



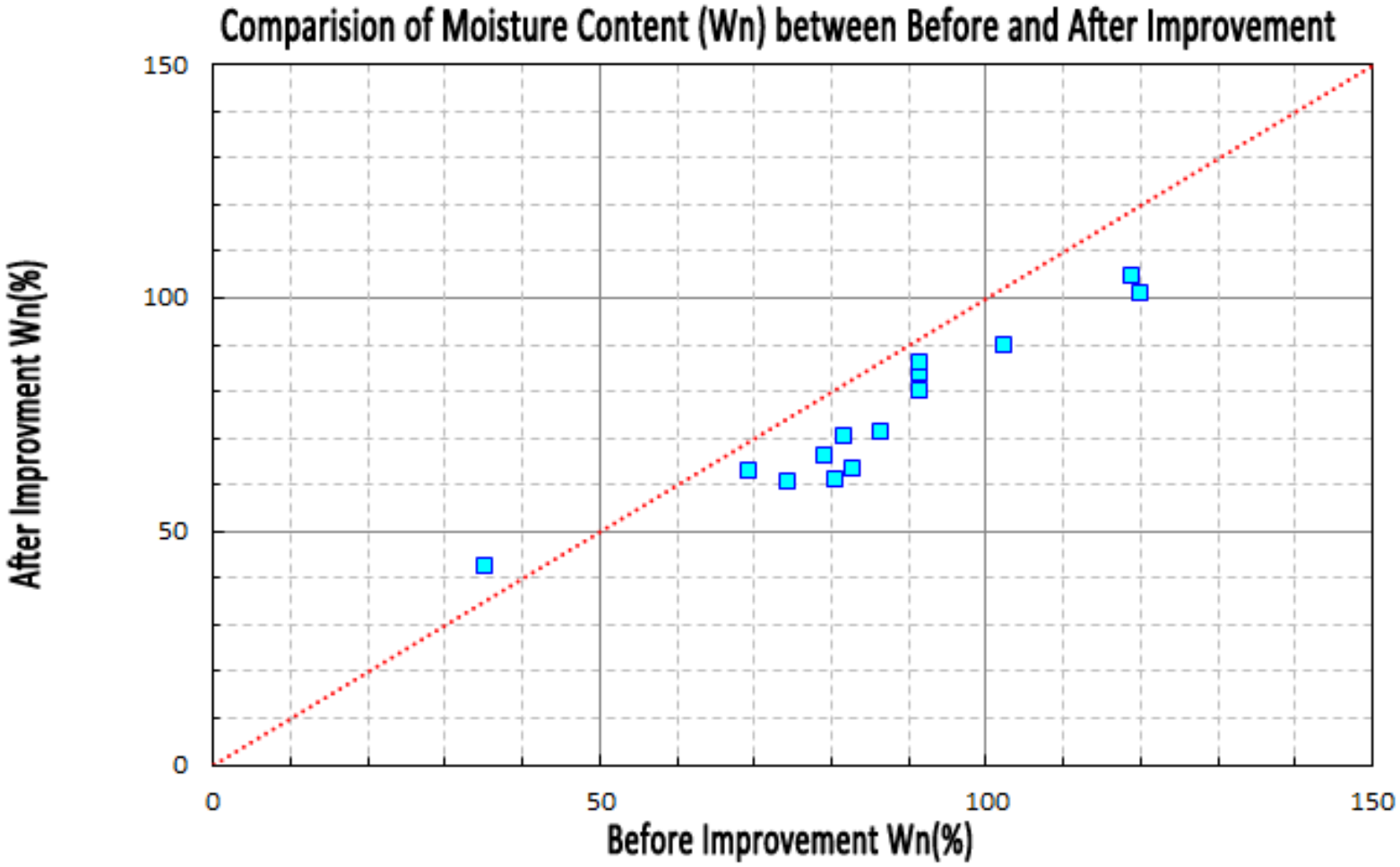
Arrangement of Suction Pipe / Supply Pipe



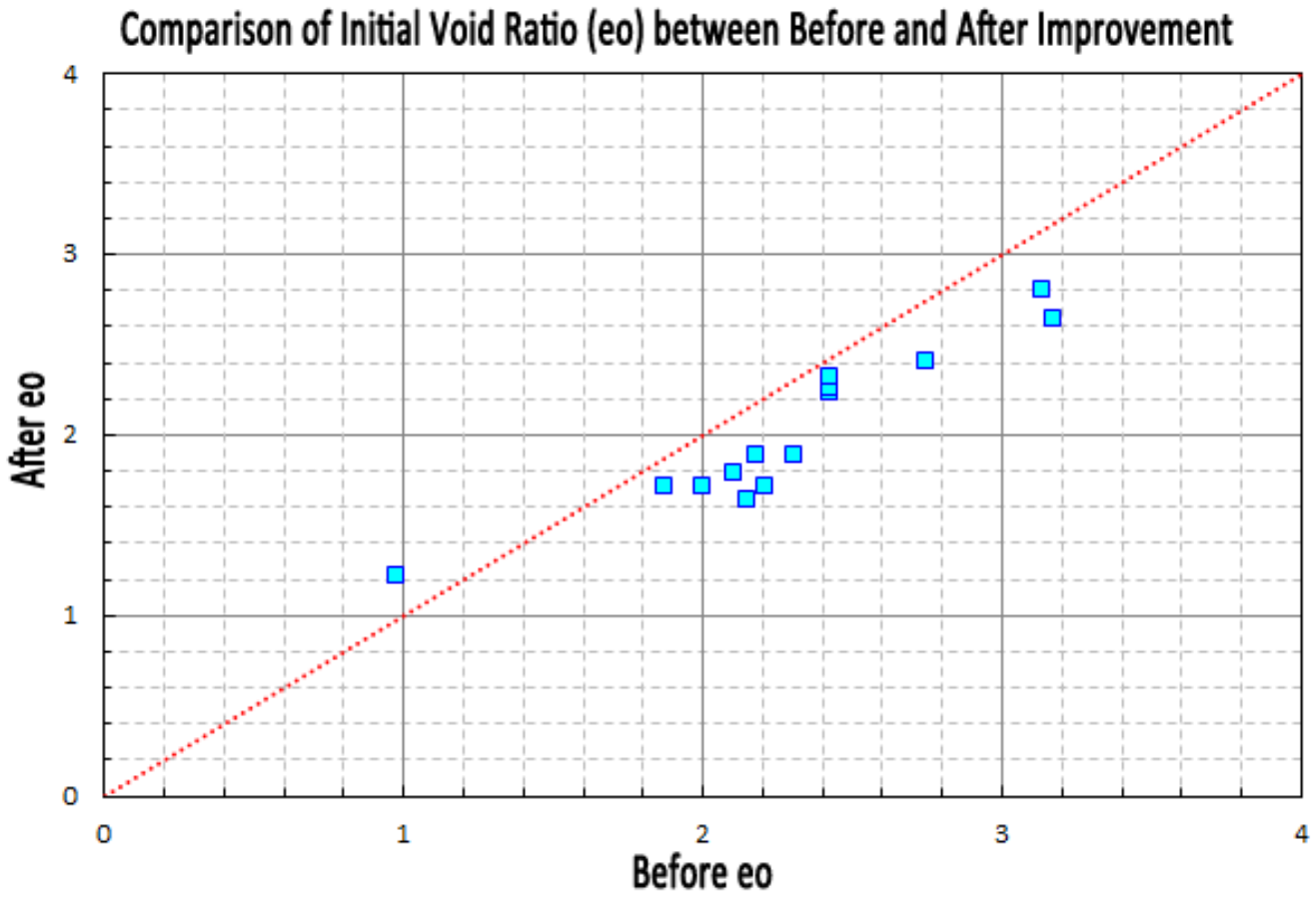
Settlement Curve



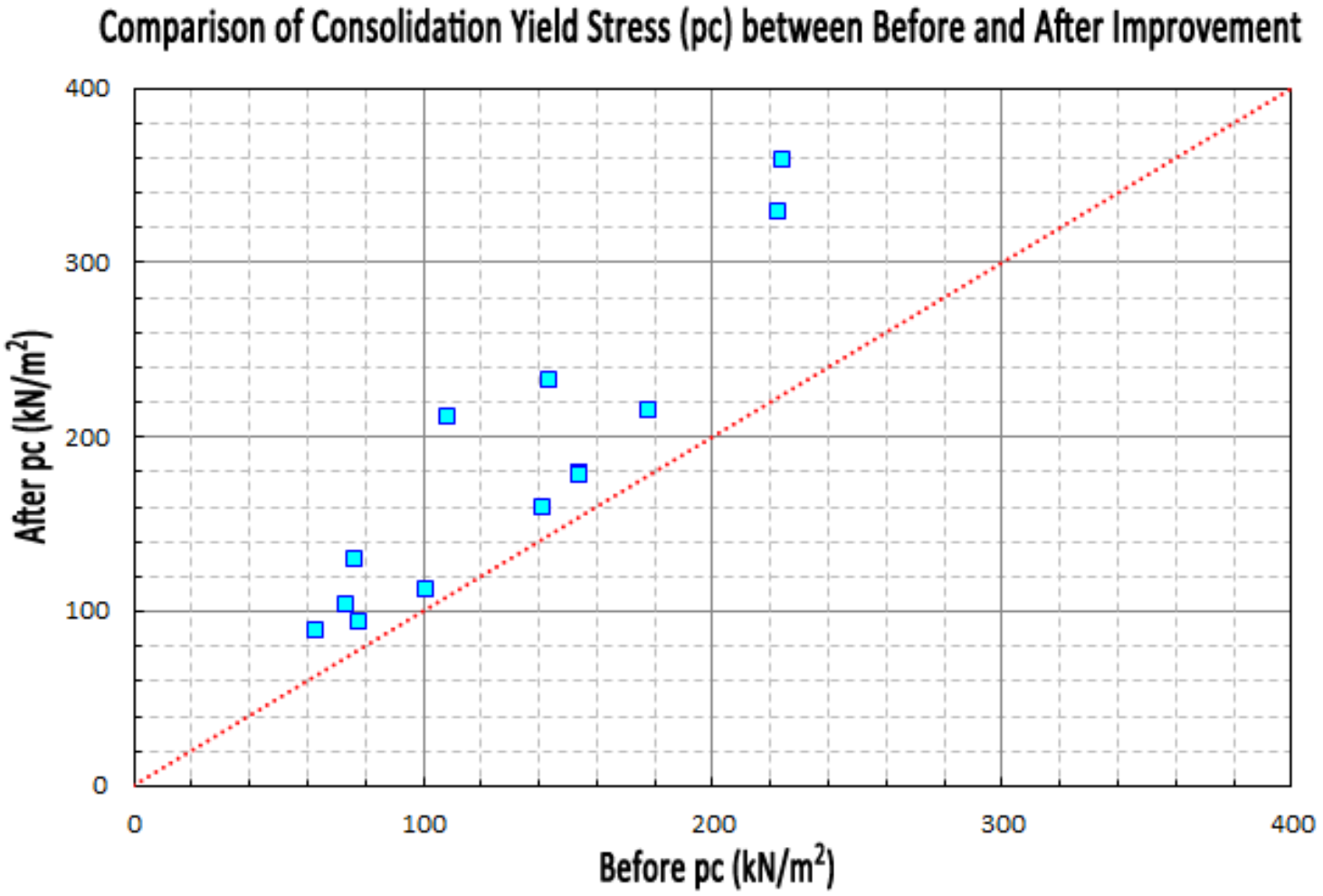
Comparison of Moisture Content (Wn) Before and After Improvement



Comparison of Initial Void Ratio (eo) Before and After Improvement

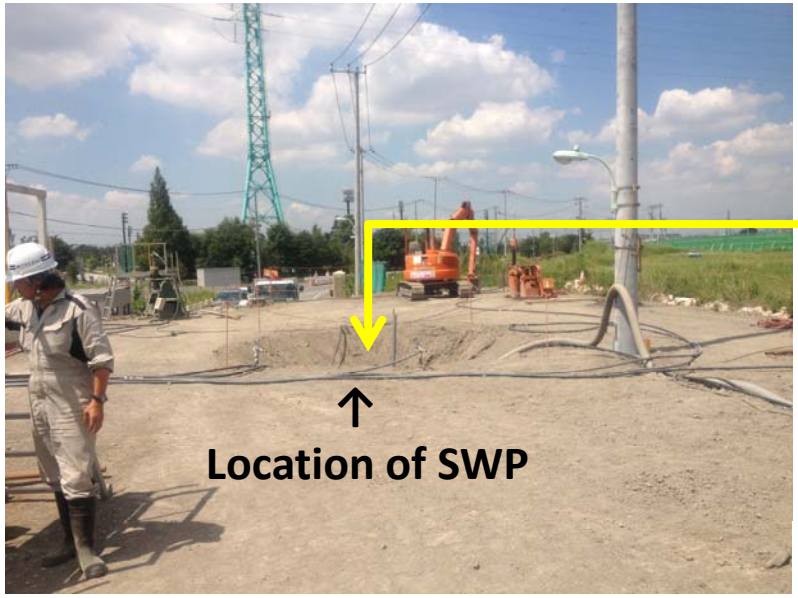


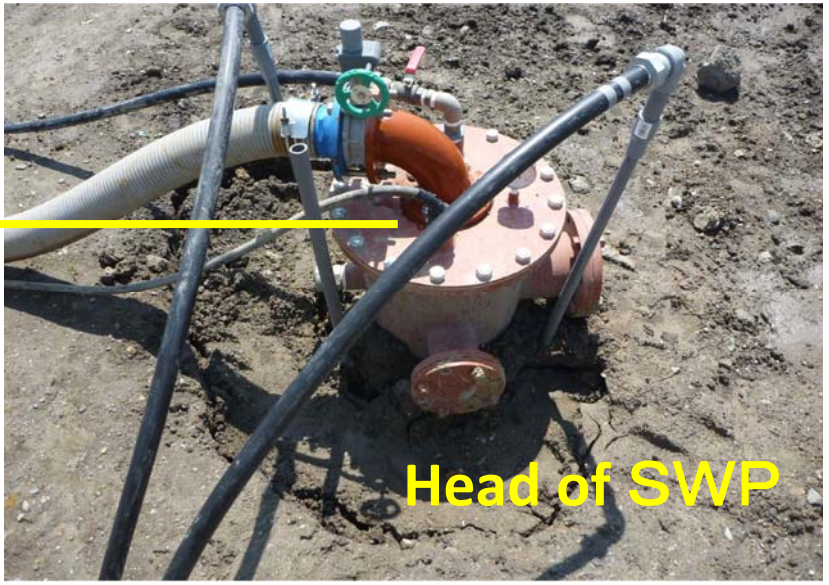
Comparison of Consolidation Yield Stress (pc) Before and After Improvement




Embankment（H=2m）


Fixed Qin TAKO
Movable Qin TAKO

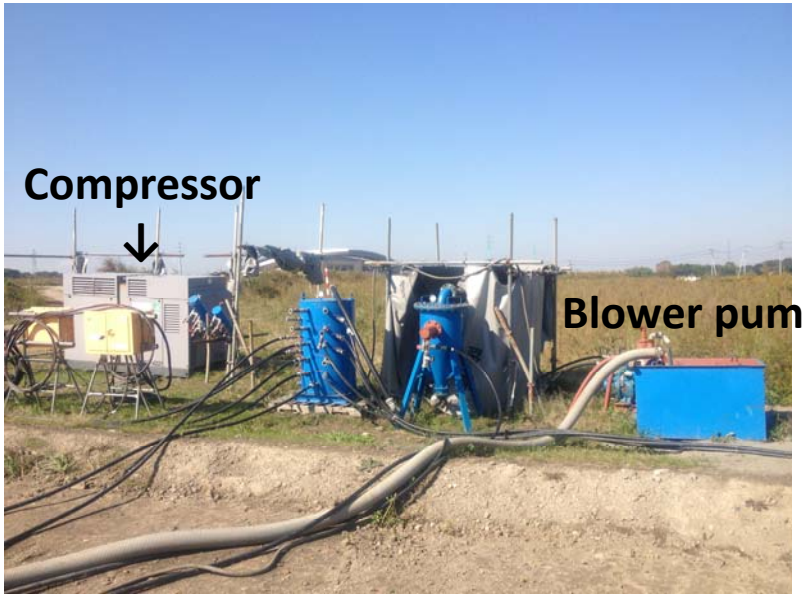

Location of SWP


Head of SWP


lifting pipe


Notch tank


Vacuum pump

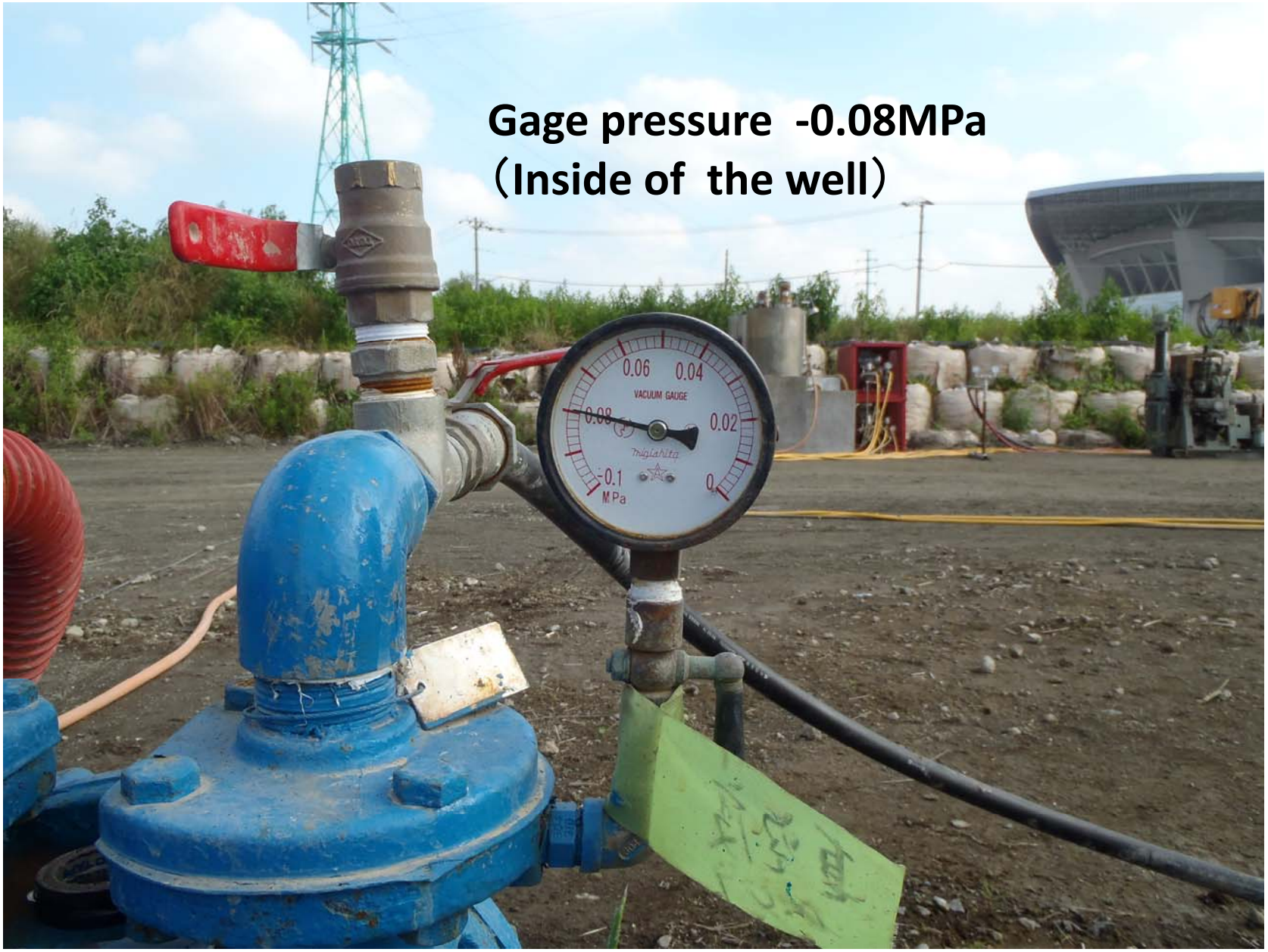

Compressor
Blower pump


工事名 湘和東部第二地区U-79街区外整地他工事
工事場所 U-2-8
SWP工
スクリーンパイプ取付状況
(1本目~2本目)
清水建設㈱
Installation of well tube


Fixed Qin TAKO
工事名 湘和東部第二地区U-79街区外整地他工事
工事場所 U-2-8
固定式吸引管工
固定式吸送気管 No.2
設置完了
清水建設㈱


Movable Qin TAKO


工事名 湘和東部第二地区U-79街区外整地他工事
工事場所 U-2-8
計測工
沈下板設状況
No.4
清水建設㈱
Settlement plate


Gage pressure -0.08MPa
（Inside of the well）
0.06
0.04
VACUUM GAUGE
0.08
0.02
-0.1
MPa
0

4 Highlighted Items

1 Finding the mechanisms of consolidation

- Comparison of the effect of compression forces
- Mechanisms of drainage

2 Construction methods

・Using the alternative compression force instead of embankment（ex. Vibration roller）

・Rationalization of Qin-TAKO（position, moving, lifting）

・Using the vertical drain for drainage