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ISO 9001
ISO14001
Certified

Watch our video to find out more about Fudo Tetra ground improvement methods.

201912_500-DAT-101

Ground Improvement Brochure

TOTAL FOUNDATION ENGINEERING SYSTEM

Fudo Tetra Ground Improvement

FUDOTETRA

Ideas From The Land

Learning from the ground to create new spaces for people and the planet

Delivering ground that is safe and ideally suited for every type of built structure

The many structures such as buildings, bridges, and highways that we use unthinkingly every day are all built on the ground.
The character of the ground is not evident from simply looking at it. To avoid the damage that threatens built structures deriving, for example, from uneven subsidence or landslips, we need to understand the properties of the ground to ensure it is appropriate to the structure to be built on it.
Sixty years ago in a worldwide first, Fudo Tetra developed what remains to this day the most representative ground improvement method, the sand compaction pile method. Since that time research has continued unabated, and we have built up expertise so that we now have a wealth of design and construction technologies as well as implementation experience, through which we have gained an excellent reputation as a highly trustworthy company.
Through ground improvement technologies developed over many years and a further deepening of our understanding, our aim is to provide safe ground for all structures and create new spatial environments that are caring of the land.

Skillful fashioning of soils and ground

Ground creation that is highly reliable, safe, economical, and environment-friendly

Ground conditions → **Required structural performance** → **Implementation conditions**

TOTAL FOUNDATION ENGINEERING SYSTEM

- Planning ability
- Basic research
- Technical development
- Design technologies
- Construction technologies
- Implementation knowhow & experience

Proposals for ideal ground | **Guaranteed construction quality**

TOTAL FOUNDATION ENGINEERING SYSTM Resources

■Technical Development

We use a test ground at our research institute to undertake actual-size verification tests to validate effectiveness, for swifter and more reliable technical development.

■Design Technologies

Engineers with doctorates or similar qualifications develop our own technologies, bringing expert knowledge and a broad view gained from academic activities and public and private sector research institutions, to find solutions for every type of ground-related problem.

■Construction Technologies

We aim for construction reliability, flexibility towards changes in conditions, safety and cost savings through the use of ICT.

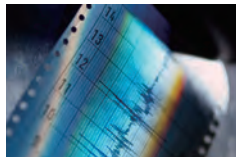
Ground born from the TOTAL FOUNDATION ENGINEERING SYSTEM is backed by factors guaranteeing reliability, and is ideal for the structure built on it and the people who will use it.

Technologies for all types of construction needs, delivering safe ground and better environmental design

Ground stability

We provide advanced methodologies making use of technologies nurtured over many years while constantly innovating. We work to boost trust by registering new methods with NETIS (New Technology Information System database) and obtaining technical accreditation from public institutions.

Updating, maintenance and repair



We develop ground improvement technologies for earthquake-proofing, reinforcement and updating of existing buildings.

Recycling of construction resources and industrial byproducts

Construction-generated waste soil, coal ash, concrete rubble etc. are re-used as ground improvement materials.

Meeting needs for building foundations and intensive use of urban space

As buildings and structures become larger and go deeper, our ground improvement technologies revitalize and empower buildings while maintaining urban functions.

Conservation, decontamination, restitution of soils and groundwater

Technologies to protect from contamination the soils and groundwater that provide the ecosystems for wildlife.

Development of construction technologies

Development of implementation equipment and technologies that can meet varied ground improvement needs and implementation conditions.

Implementation management using ICT

ICT-assisted implementation management of ground improvement methods saves labor and energy, in consideration of society's ageing and low birth-rate.

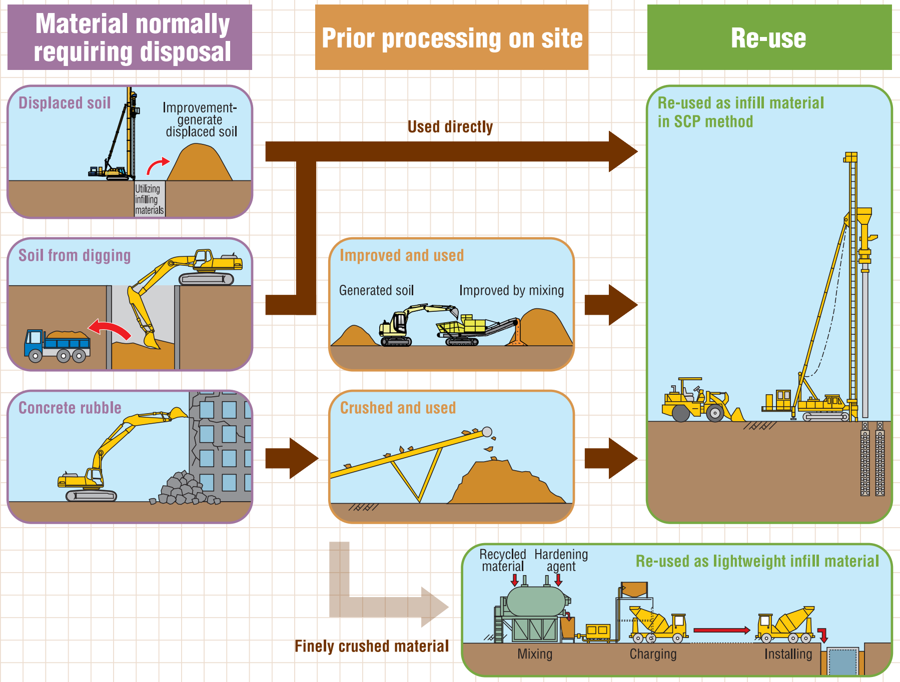
Patents

Through constant technical development we obtain between 10 and 20 patents every year, and we continue to top the ground improvement industry in terms of numbers of Japanese patents held.
Total of 340 patents as of March, 2018

Making effective use of construction materials and industrial by-products to conserve limited natural resources, while also developing new materials

Total Resoil System

Making use of construction-generated waste soil and concrete rubble from demolition work as a substitute compaction material in the SCP (Compozer and SAVE Compozer) methods, **the Total Resoil System** also contributes to zero emissions by utilizing material that normally has to be transported off site for disposal.



Recycled material

Eco-Gaia-Stone

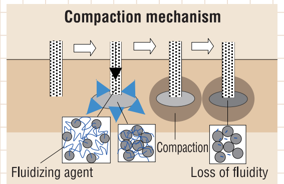
A new filling material for use in the sand compaction pile method, made from steel industry slag. Grain size and expansion rate are controlled.
Coastal Development Institute of Technology validation #10001
NETIS registration KTK-140002-A

Eco-Gaia-Stone Features

- Has the same compactability and ease of use as sand
- Possible to manage consolidation quality by hydraulic control
- Environment-friendly
- Controls expansion stability

Fluidized Sand

A material in which anion-type fluidizing agent L1, and cation-type plasticizing agent P1 that has the effect of aggregating the fluidizing agent, are mixed with sand. This material delivers fluidity due to L1's ability to hold water that allows passage through pipes and installation in the ground, the generation of an internal friction angle when compacted in the ground, and loss of fluidity after implementation. It has frequently been used as a liquefaction countermeasure in confined locations with the SAVE-SP method. It's also a material that can possibly be used for filling voids after pile extraction etc.



A range of specialized implementation rigs underpin ground improvement technology

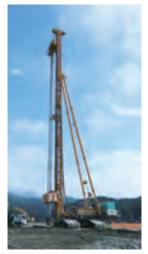
Our ground improvement technologies run to more than 50 methods. To meet a diverse range of needs, all sizes and shapes of rigs are available for safe, reliable implementation.

Land implementation rig:
SAVE Compozer

Vessel for offshore ground improvement work:
Pioneer 30 Fudomaru sand compaction vessel

Ultra small rig:
High-pressure jet mixing method

Large, long length rig:
Swamp type



Multi-purpose rig:
Large crawlers

Vessel for offshore ground improvement:
Deep mixing process vessel Fudo No. 7

Barge-type rig:
CI-CMC method

Barge-type rig:
FTJ-NA method

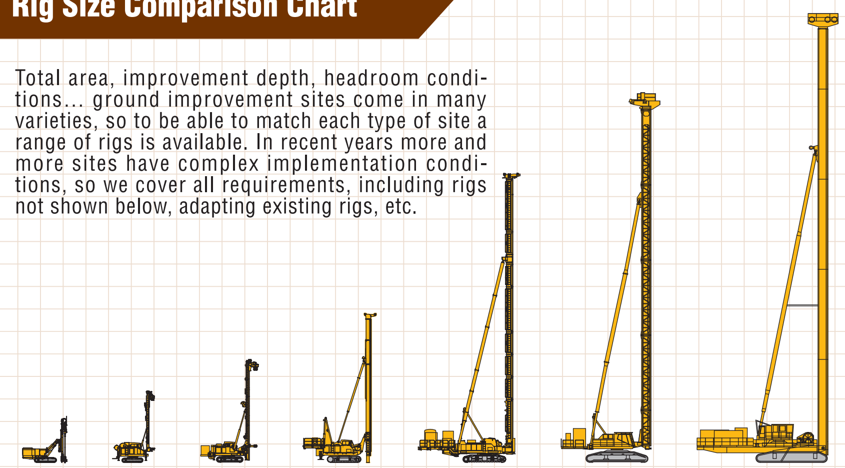
Ultra small rig:
SAVE-SP method

CI-CMC method:
Ejector discharge and mixing blades

Various types of CI-CMC mixing blades

Rig Size Comparison Chart

Total area, improvement depth, headroom conditions... ground improvement sites come in many varieties, so to be able to match each type of site a range of rigs is available. In recent years more and more sites have complex implementation conditions, so we cover all requirements, including rigs not shown below, adapting existing rigs, etc.



	Ultra small	Small	Small	Standard	Standard	Large	Ultra large
Height	6m	10m	15m	20m	36m	50m	60m
Weight	12t	15t	30t	60t	110t	150t	220t

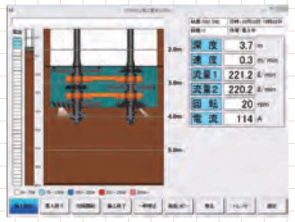
ICT Ground Improvement

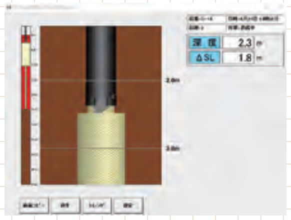
i-Construction

Following the i-Construction concept promoted by Japan's Ministry of Land, Infrastructure, Transport and Tourism, Fudo Tetra has brought together ICT and ground improvement technologies to create its 'Seeing More', 'Productivity, Safety, Quality Upgrade' and 'Technical Tradition' for improvement sites.

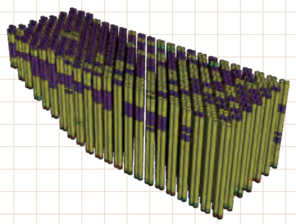
Visios-3D® (A real-time implementation management system + 3D modeling system)

An implementation management system that allows the operational status of the rig to be monitored from a remote location. Multiple staff can share the data simultaneously on tablet screens. Implementation records can be converted into 3D models conforming with the Ministry's CIM.


Tablet screen (CI-CMC)

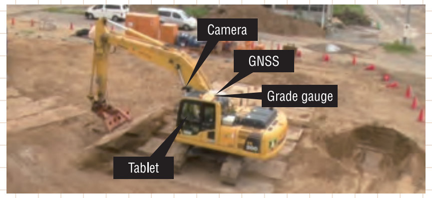

Tablet screen (SAVE-SP)


Remote monitoring

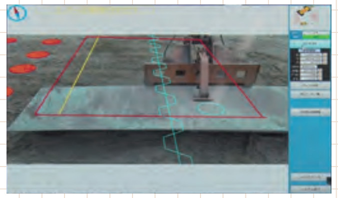

3D model of implementation records

Visios®-AR (Multipurpose implementation support using augmented reality)

An augmented reality (AR) system fitted to backhoes and excavators for supplementary support. Images captured by cameras are overlaid with data such as positioning for scaffolding or objects buried in the ground and displayed in real time. This supplementary support is possible even for sites where markers are no longer needed on the ground due to the use of GNSS.



AR fitted on machine


Tablet screen (AR)

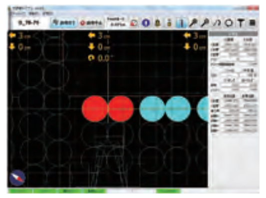

Tablet screen (2D)

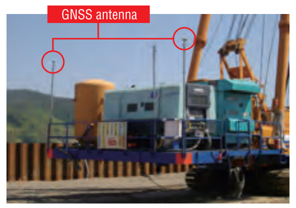
*Visios® is a registered trademark of Fudo Tetra and the series name for technologies making site operations more visible.

GNSS Ground Improvement Rig Guidance System

NETIS : CG-120020-VE

A system that displays pile driving position and rig position on the monitor in the operator's cab, so that guidance on positioning is no longer required on the ground. This saves on manpower and also has safety benefits, as personnel are not required to approach the rig.


Guidance screen



Fitted with GNSS antenna

*This system has been jointly developed by Fudo Tetra and Nishio Rent All Co., Ltd.

Working Vessel Location, Shipping Navigation Data System

A system to cover the whole of Japan that records and displays the current position and course of working vessels offshore. The position of a vessel can be checked at any time through the internet from a laptop or smartphone.


SCP barge working offshore


Screen of working vessel position data

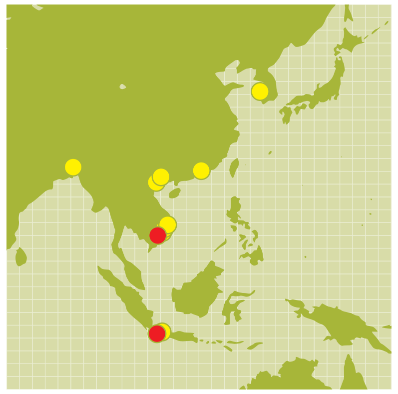
*This system is a service provided by All Japan Fishing Port Construction Association.

Overseas Activities

Our made-in-Japan
TOTAL FOUNDATION ENGINEERING SYSTEM
has been scoring high marks in construction work overseas, attracting attention from researchers and engineers in many countries.

Overseas Bases and Implementation Sites

South-east Asia



North America

● Overseas bases (subsidiaries, branch offices)
● Overseas implementation sites
Fudo Construction Inc. /www.fudo-const.com

Ground improvement work overseas resumed in 2004, and we have completed 27 assignments in South East Asia and USA using our renowned technical expertise built up in Japan. For ground stability and preventing subsidence in clay soils, offshore deep mixing methods were adopted for harbor structures in Vietnam and Hong Kong, and deep mixing methods were used on land in Vietnam in relation to harbor, power generation and railway construction work. In Bangladesh the SCP method was adopted to mitigate liquefaction in sandy ground in railway-related construction. In west coast USA the SCP and SAVE Compozer methods were used as liquefaction countermeasures close to buildings, and in rebuilding levees in New Orleans the CI-CMC method was used for ground stability and preventing subsidence. The vibro-tamper method was used for runway compaction work at a Florida airport.

Implementation Examples


In Hong Kong


In Bangladesh


In USA

At implementation sites overseas, work proceeds through cooperation between Fudo Tetra staff, the staff of our counterpart, and local personnel. With infrastructure construction growing in Indonesia, an increasing requirement for ground improvement is expected and in February 2016 we opened a branch office in Jakarta and employed a team of local staffs.


Local staffs


Morning exercises

Staff of Jakarta branch office

Various new technologies to meet all groundwork needs

Applications to Building Upgrading, Maintenance and Repair

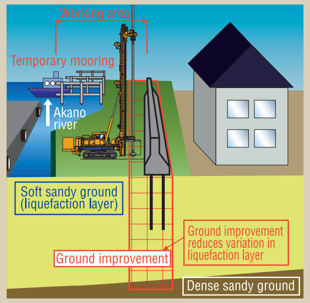
As existing buildings are earthquake-proofed or upgraded, we have practical, economical methods that fulfill a diversity of needs for ground improvement implemented close to existing structures, ground improvement directly beneath existing structures, and so on.

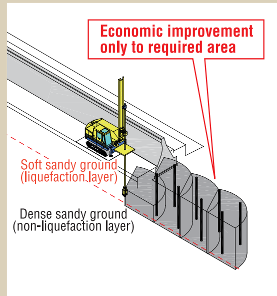
FTJ Method (Twin flow cement slurry jet mixing method) / FTJ-FAN Method (Swing type multi flow cement slurry jet mixing method)

NETIS: HR-140015-A

Example:

Ground was improved near a river estuary directly beneath a special revetment (existing concrete retaining wall) close to housing, to mitigate liquefaction in the event of an earthquake. The site was extremely confined, and as the existing wall was close to housing a combination of FTJ and FTJ-FAN methods was used to create a single improvement body that included the existing pile foundations.



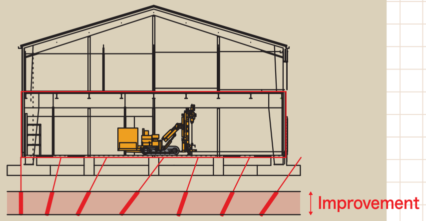


SAVE-SP Method (Non-vibratory sand compaction pile method)

NETIS: SKK-090002-VE 2016 Recommended Technology

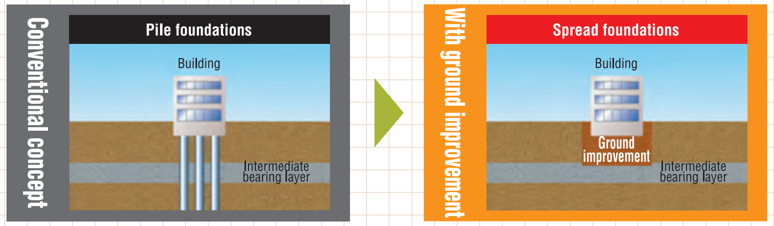
Example:

Liquefaction countermeasures implemented directly beneath an existing building. Some ground floor interior walls were removed, and the space served as a height-restricted, confined implementation space. Minimal removal of an exterior wall was made to allow rig access inside.



Applications to Foundations Close to Built Structures

Foundation ground improved through compaction or solidification can be used to support spread foundations. It is of particular advantage to have an intermediate bearing layer several meters down from the bottom of the foundations. Bearing capacity is increased, liquefaction prevented, and settlement minimized, and the building can be directly supported.



CI-CMC Method (Large diameter, high quality deep mixing method)

Advanced Construction Technology Center certificate #2804

Example:

Ground improvement using the CI-CMC method was utilized to increase the bearing capacity of clay soil for an 8-story earthquake-proof building. The supporting ground of improved bodies was an intermediate diluvial sand layer, and columns 1,600mm diameter and 9m deep were installed for the whole area under the building's mat slab foundation. A study of consolidation settlement and instantaneous settlement was undertaken for the diluvial clay layer under the intermediate layer to confirm the safety of the building.

SAVE Compozer (Non-vibratory sand compaction pile method)

Japan Institute of Country-ology and Engineering Certified #38

Example:

A ground created with compacted sand piles can reduce liquefaction and also support directly and limit subsidence for a low-to-mid rise building, through the composite ground effect which is the ground created between the sand piles.

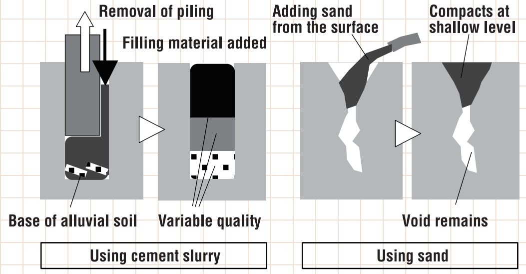
Filling Voids with Fluidized Sand

■ When the voids are filled after the removal of piling or sheet piles, the inferior quality of the filling can cause problems:

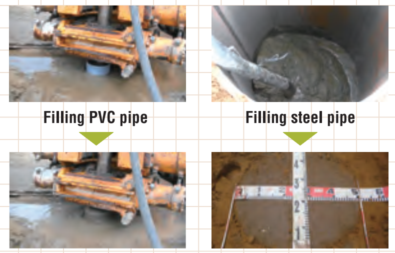
Problem:

With cement slurry, fluidized soil:	Mixing with soil from wall collapses lowers quality, creates inconsistency in strength, and hardened objects are treated as waste in the ground
With sand or locally generated soil:	Hardening at the surface can leave voids at deeper level.

■ Methods have been developed whereby the cement slurry mix is adapted and voids are filled at the same time as pile removal, but the development of a reliable filling method using sand was wanted for cases where filling with sand was preferable for subsequent procedures, and to avoid the problem of hardened cement lumps.
We have therefore developed a technology to fill voids uniformly with a sand material, using fluidized sand with the SAVE-SP method.



Problems of Conventional Void Filling



Tests Filling Voids with Fluidized Sand

Listing of Fudo Tetra Technologies

Category	Sub-category	Ground improvement method		NETIS registration	Page	Features	Stopping: Preventing subsidence	Stopping: Mitigating liquefaction	Stopping: Preventing slippage	Stopping: Soil/slope retaining	Stopping: Water cutoff	Stopping: Digging stability	Support: Increasing bearing capacity	Support: Increasing pile lateral resistance	Lightening, filling: Load reducing	Lightening, filling: Void filling	Protection: Soil decontamination	Protection: Containment
Consolidation, Drainage & Compaction		SAVE Composer	Non-vibratory sand compaction pile method		13	Offshore, Low vibration, Confined space, Re-used material, Certificates	●	●	●			●	●	●			▲	
		SAVE Composer HA	Non-vibratory sand compaction pile method	CB-160026-A	13	Offshore, Low vibration, Confined space, Re-used material	●	●	●			●	●	●			▲	
		SAVE marine method	Non-vibratory, low-noise offshore sand compaction pile method		14	Offshore, Low vibration, Re-used material	●	●	●			▲	●	●			▲	
		Compozer	Sand compaction pile method		13	Specialized rig, Re-used material, Certificates	●	●	●			▲	●	●			▲	
		Re-soil Compozer	Compozer utilizing construction-generated soil		14	Re-used material, Certificates	●	●	●			▲	●	●			▲	
Consolidation Acceleration		Sand drain method			15	Offshore, Confined space	●		▲			▲	▲	▲			▲	
		CF drain method	Partially covered sand drain method		15	Offshore	●		▲			▲	▲	▲			▲	
		Resoil drain method	Drain method utilizing construction-generated soil		15	Re-used material, Certificates	●		▲			▲	▲	▲			▲	
		Pack-drain method	Bagged sand drain method		15	Offshore	●		▲			▲	▲	▲				
		Plastic board drain method			16	Offshore, Low vibration, Certificates	●		▲				▲	▲			▲	
		CS drain method	Plastic drain method management system		15	Offshore, Low vibration, Certificates	●		▲				▲	▲				
		Vacuum consolidated drain method	Consolidated drain method using capped drains		16	Offshore, Mud, Low vibration, Certificates	●		▲				▲	▲				
		Fiber drain method	Natural fiber drain method		15	Offshore, Low vibration, Certificates	●		▲				▲	▲				
		PDF method	Floating type plastic board drain method		16	Offshore, Mud, Low vibration	●		▲				▲	▲				
Compaction		SAVE-SP method	Non-vibratory sand compaction pile method	SKK-090002-VE	14	Offshore, Low vibration, Confined space, Certificates		●									▲	
		Vibro-Rod method	Vibrating rod method		14		▲	●					●	●				
		Mammoth Vibro-Tamper method	Surface layer compaction method		14		▲	●					●					
		Compaction Grouting Denver system	Static compaction method by grouting	KTK-140005-A	14	Low vibration, Confined space		●										
Solidification	Mechanical mixing	CI-CMC method	Large-diameter, superior quality deep mixing method		17	Offshore, Low vibration, Low displacement, Confined space, Certificates	●	●	●	●	●	●	●	●			▲	●
		CI-CMC-HA method	Large-diameter, low displacement deep mixing method for hard ground	QS-160049-A	17	Offshore, Low vibration, Low displacement, Confined space	●	●	●	●	●	●	●	●			▲	●
		CI-CMC-HG method	Large-diameter, low displacement deep mixing method for ultra hard ground		17	Offshore, Low vibration, Low displacement, Confined space	●	●	●	●	●	●	●	●			▲	●
		CMC method	Cement deep mixing (CDM) method		17	Specialized rig, Low vibration	●	●	●	●	●	●	●	●				●
		CDM-LODIC method	Displacement-reduction type deep mixing method		18	Low vibration, Low displacement	●	●	●	●	●	●	●	●				●
		TOFT method	Grid type solidification method		18	Low vibration, Confined space, Certificates	●	●	●	●	●	●	●	●				●
		DJM method	Powder discharge mixing method		18	Low vibration, Confined space	●	●	●	●	●	●	●	●				●
		ALiCC method	Low improvement ratio cement column method		18	Low vibration, Certificates	●		●									
		Power Blender method	Shallow and intermediate layer mixing method		20	Mud, Low vibration, Low displacement, Certificates	▲	▲	●		▲		●	▲			▲	▲
	With compaction	HCP method	Hardening compaction method		18	Low vibration, Certificates	●	●					●	●				
		GCCP method	Gravel cement compaction pile method		18		●	●	●			▲	●	●				
	Composite mixing	JACSMAN	Cross jetting type composite mixing method		18	Offshore, Low vibration, Low displacement, Certificates	●	●	●	●	●	●	●	●				●
		PJ method	Cross jetting type composite mixing method using compact equipment		19	Offshore, Low vibration, Low displacement	●	●	●	●	●	●	●	●				●
	Jet mixing	FTJ method	Twin-flow cement slurry jet mixing method		19	Offshore, Low vibration, Low displacement, Confined space, Certificates	●	●	●	●	●	●	●	●				●
		FTJ-FAN method	Swing-type multi-flow cement slurry jet mixing method	HR-140015-A	19	Offshore, Low vibration, Low displacement, Confined space, Certificates	●	●	●	●	●	●	●	●				●
		Super jet method	High-pressure jet mixing method (large diameter)		19	Low vibration, Low displacement, Confined space	●	●	●	▲	●	●	●	●				●
	Surface layer mixing	Consolider method	Surface layer solidification method		20	Mud, Low vibration	▲	▲	●		▲		●	▲			●	▲
		V-mixing method	Surface layer solidification method (horizontal propelling trencher)		20	Mud, Low vibration	▲	▲	●		▲		●	▲			●	▲
	Premixing	Barge consolider method	Premixing method		20	Low vibration, Re-used material, Certificates	▲						●					▲
	Grouting solidification	Permeating solidification method			20	Low vibration, Low displacement, Confined space	▲	●					▲					
	Continuous diaphragm wall	TRD method	Continuous soil cement diaphragm wall method		20	Low vibration, Low displacement, Confined space	▲	▲	▲	●	●							●
Water cutoff		Sheet wall method	Special lightweight steel sheet pile water cutoff method		21	Low vibration, Low displacement, Confined space					●							●
		Geolock method	Vertical sheet pile method		21	Low vibration, Low displacement, Confined space					●							●
		Trinner method	Triple layer water cutoff wall method		21	Low vibration, Low displacement, Confined space				●	●							●
Fluidized Soil, Lightweight Soil		LSS method	Fluidized soil placement method		22	Low vibration, Re-used material	●	▲	●				▲	▲	▲	●		▲
		Georaft method	High-strength high-quality fluidized soil placement method		22	Low vibration, Re-used material	●	▲	●				●	●	▲	●		▲
		High-grade soil	Mixed strengthened soil method		22	Low vibration, Re-used material	●	▲	●					●	●	●		▲
		SGM lightweight soil method	Air bubble incorporated soil method		22	Low vibration, Re-used material	●	▲	●					●	●	●		▲
Drainage		Gravel drain method	Gravel drain method		21	Low vibration, Low displacement, Confined space		●										
		NUP gravel drain method	Gravel piling with compaction method		21	Low vibration, Confined space		●										
Others		Air-des method	Air-incorporated desaturation method		22	Low vibration, Low displacement, Confined space		●										

Specialized rig for offshore work available · Offshore implementation possible · Can handle implementation over mud · Low vibration, low noise · Low displacement implementation · Rig available for confined space /height restrictions · Can handle re-used material · Technical certificates by official organizations available · ● Applicable or effective · ▲ Applicable or effective depending on conditions

Consolidation, Drainage & Compaction

SAVE Compozer / SAVE Compozer HA
(Non-vibratory sand compaction pile method)

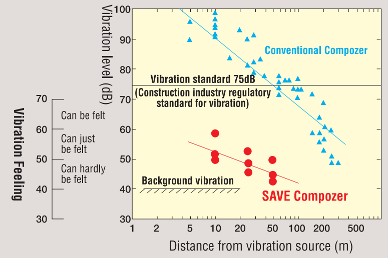
SAVE Compozer : 2010 Recommended Technology
SAVE Compozer HA: CB-160026-A NNTD registration number: 1253

The SAVE Compozer is a quiet, non-vibratory compaction method that uses a forced driving/lifting device with rotation for ground penetration, for wave-type implementation. It can therefore be used close to existing structures, widening the scope of compaction for ground improvement. The SAVE Compozer HA exhibits the same outstanding benefits of the SAVE Compozer with increased penetration force, and the digitalized implementation management boosts reliability.

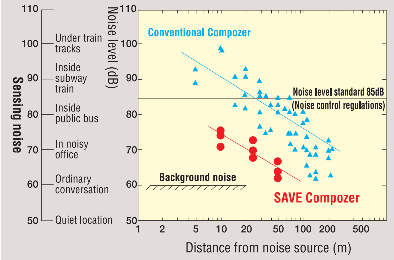
Features:

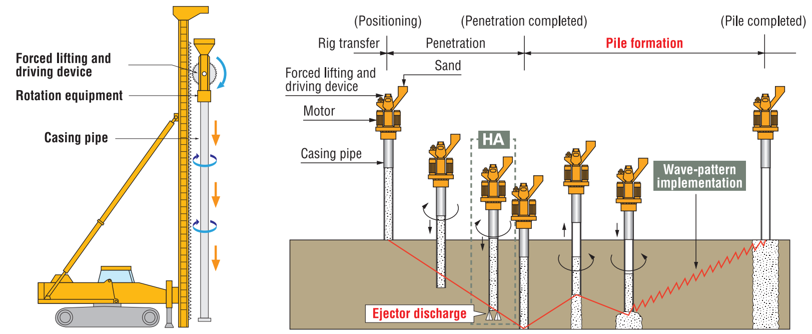
- This non-vibratory, low noise method causes minimal impact on the surrounding environment and so can be implemented close to existing structures.
- This method can be used for all types of ground, from sandy to clay.
- It can be used for the same improvement objectives as conventional sand compaction pile methods, and gives the same improvement effect
- CONOS is a new system used for implementation management. The CONOS system provides the operator with specific instructions and is a trustworthy system for creating sand piles with precision.
- Other types of material besides sand, such as crushed stone/concrete or slag, can be used as the pile material. The pile diameter can easily be changed using the same installation rig, so composite piles with sand drains can be installed.
- Implementation is economical compared with other types of environment-friendly ground improvement methods.
- By using an ejector discharging device that mixes in compressed air and water, it's possible to use in sand layers with N values around 35 included within soft ground that conventionally require prior boring with an earth auger or similar. (SAVE-HA)
- A message displayed on the monitor screen indicates that the bearing layer has been reached, for highly reliable implementation management. (SAVE-HA)

No Vibration
No vibration can be felt even close up to the rig



Low Noise
Ordinary conversation possible at only 10m from rig



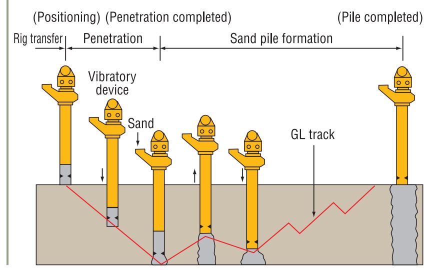


Compozer
(Sand compaction pile method)

The Compozer method uses a vibrating hollow pipe for repeated driving and lifting to create large-diameter, well compacted sand piles in soft ground for ground stabilization. It is the most representative of the sand compaction pile methods and is the most widely used. This method was developed and commercialized by Fudo Construction as a world-wide first. It has been used in all parts of the world and the total length of all installed piles exceeds 380,000 km.

Features:

- Suited to wide range of ground types
- Can meet wide range of improvement objectives
- Creates reliable Compozer piles
- Highly reliable implementation management and quality control
- Most widely used method to counter liquefaction
- Can be used for deep water and deep ground improvement
- Economical implementation
- Highly versatile
- Construction-generated material can be used effectively



Resoil Compozer
(Compozer utilizing construction-generated soil)

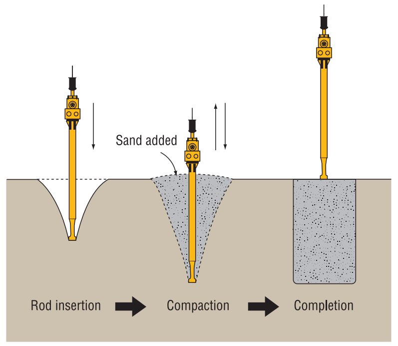
This method utilizes construction-generated soil as an alternative to natural sand, the conventional filling material. Installing both construction-generated soil and artificial drainage material in the ground gives the same improvement effect as a conventional method. This is an environment-friendly ground improvement method that saves on natural resources and makes use of construction-generated soil which otherwise must be disposed of.

SAVE Marine Method
(Non-vibratory, low-noise offshore sand compaction pile method)

This is a non-vibratory, low noise method of installing sand compaction piles using a forced lifting and driving device and rotation equipment without the use of vibration energy. It is suited to foundations work for coastal embankments etc.

Vibro-Rod Method
(Vibrating rod method)

The Vibro-rod method is a compaction method for loose sandy ground in which vibratory insertion is used for various types of rods featuring special-shaped tips or side surfaces.

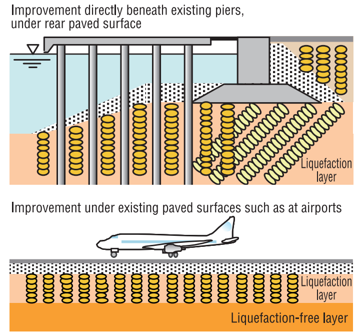


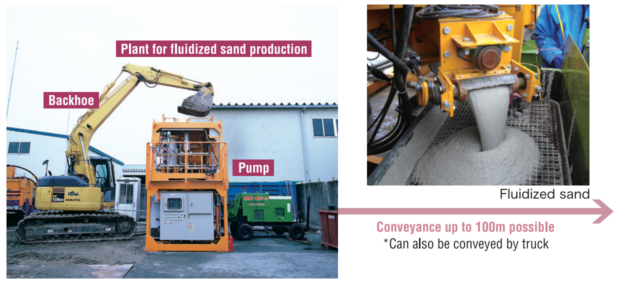
Compaction

SAVE SP Method
(Non-vibratory sand compaction method)

SKK-090002-VE 2016 Recommended Technology
NNTD registration number：1252

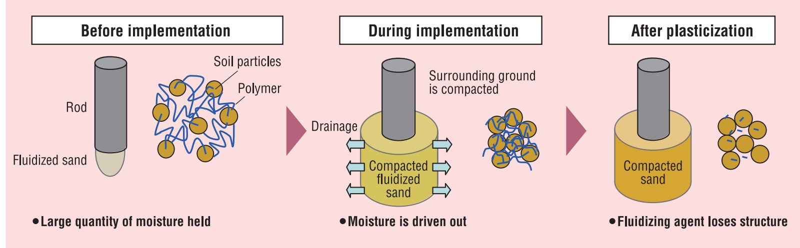
The SAVE-SP method achieves compaction with a very small rig through pumped conveyance of fluidized sand. Sand mixed with fluidizing agent is pumped into the ground through a rod installed to the required depth and the surrounding ground is compacted. The fluid state of the sand is terminated by draining when discharged, and through the use of an added slow-acting plasticity agent.





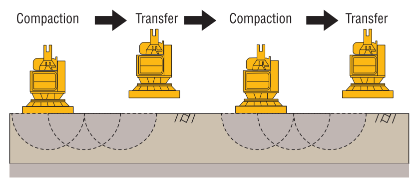
Pipe conveyance to about 100m is possible, so production plant can be sited separately if the implementation site has limited space.

Behavior of Fluidized Sand



Mammoth Vibro-Tamper Method
(Surface layer compaction method)

The mammoth vibro-tamper combines powerful vibration and a large-size tamper plate for surface compaction. It is supplied in two sizes: 4m² and 9m².



Compaction Grouting Denver System
(Static compaction method by grouting)

KTK-140005-A

The compaction grouting Denver system is a non-vibratory compaction method in which extremely low fluidity mortar of less than 5cm slump value is installed in the ground without applying vibration or shock. It is particularly effective for implementation in confined spaces or at facilities that are in use and that other methods therefore cannot cover.

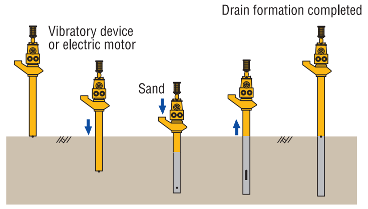
Consolidation Acceleration

Sand Drain Method

The sand drain method is one of the most common vertical drain methods and has long been utilized in Japan. Vertical sand columns are formed in soft ground and their drainage effect leads to consolidation of soft clay ground. Continuity in the sand columns is essential, and implementation management gauges ensure reliable formation.

Features:

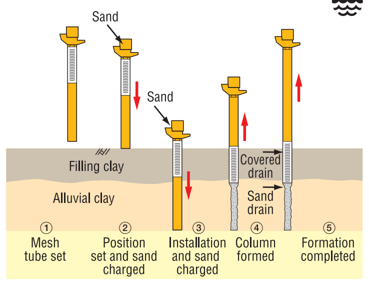
- **Many applications**
  The most common vertical drain method used for many different purposes.
- **Suitable for a wide range of sites on land and offshore**
  The method with the longest history both on land and offshore, it can be implemented at great depth of water or at great land depth.
- **Thorough implementation management**
  Gauges indicate the quantity of charged sand, the depth of the casing pipe, the changing level of the sand inside the casing pipe during withdrawal, etc.



CF Drain Method

(Partially covered sand drain method)

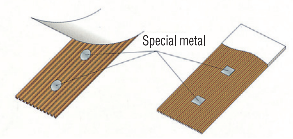
This method aims at reducing costs by exploiting the merits of both the bagged sand drain and the sand drain methods, covering only the necessary sections with mesh tubes. There is no loss of continuity in loading during and after implementation and the consolidation drainage effect is maintained.

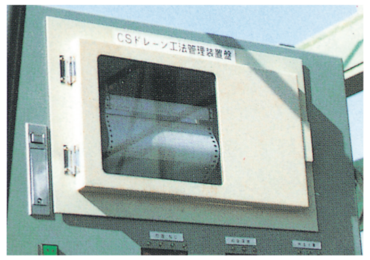


CS Drain Method

(Plastic drain method management system)

This system accurately gauges implementation status of plastic drains that cannot easily be assessed from above ground, for high quality implementation management.





Resoil Drain Method

(Drain method utilizing construction-generated soil)

This method utilizes construction-generated soil as an alternative to natural sand, the customary improvement material. The drain effect is obtained through man-made drainage material combined with bagged man-made drainage material, and the method can be used for the same purposes as conventional methods. It is a highly economical and environment-friendly method, saving on natural resources while at the same time solving the disposal problem of construction-generated soil.

Pack-Drain Method

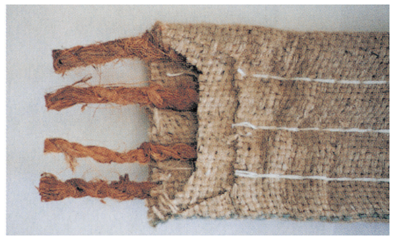
(Bagged sand drain method)

To maintain continuity in sand columns during and after installation, flexible synthetic fiber bags filled with sand are used as the drain material, to form reliable sand columns within the ground. Multiple sand columns (2 or 4) can be installed simultaneously.

Fiber Drain Method

(Natural fiber drain method)

An environment-friendly method that uses natural fiber as the drain material. After fulfilling its drainage role it decomposes and is assimilated into the soil.



▲Appearance

Plastic Board Drain Method

In principle identical to the sand drain method, this method uses plastic as the drain material. Being an industrial product, plastic is consistent in quality, lightweight and easy to handle, making it easy for installation.
There is also a biomass drain material that utilizes unsaleable stale rice as its core material. After consolidation is complete the strength declines, making it advantageous for subsequent work.

We also offer a power boost drain method designed for hard ground penetration that uses a special pressurized drive device.

Special pressurized drive device

PDF Method

(Floating-type plastic board drain method)

Special floats are used on very soft ground or in shallow water over soft ground for direct installation of plastic drains. A special plastic material is used for the horizontal drain layer, making conventional sand mats unnecessary. This technology is suited to extending the life of landfill disposal sites by reducing the volume of waste soil

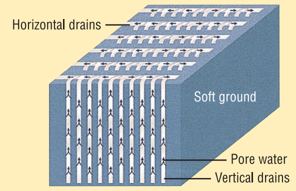
Features:

- Shortened schedules
- Conventional sand mats not required
- Implementation possible on shallow water/marshy ground
- Increases volume of dredged soil that can be accepted
- GPS used
- Non-vibratory, low noise method
- Environment-friendly

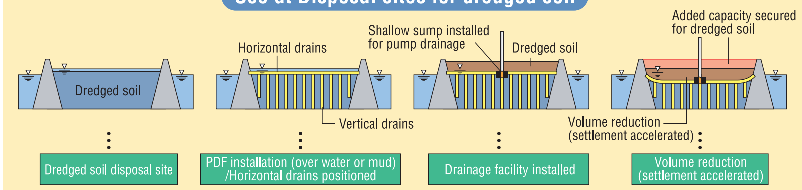
Improvement using PDF method

<In Combination with Horizontal Drains>

In the PDF method, vertical plastic drains can be installed over water or mud by utilizing linked floats. Implementation over mud requires neither solidification work nor sand mats to ensure trafficability. Horizontal drains can substitute for sand mats.



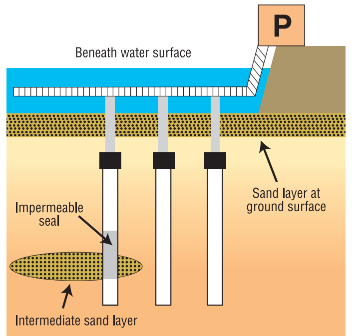
Use at Disposal sites for dredged soil



Vacuum Consolidated Drain Method

(Consolidated drain method using capped drains)

The vacuum consolidated drain method is a consolidation improvement method in which drains fitted with caps with drainage hoses are installed at a specific depth in a clay layer, using the clay layer above as a negative pressure seal layer, making use of the negative pressure in the soft ground.



Compared with conventional methods:

Sealed sheets are not needed, and so it can be used in circumstances where conventional methods are difficult to apply, as follows:

- Improvement where there is a sand layer on the surface
- Improvement beneath water surface
- Improvement where an intermediate sand layer interposes

Solidification

CI-CMC / CI-CMC-HA Methods

(Large-diameter, superior quality deep mixing method / Large-diameter, low displacement deep mixing method suited to hard ground)

CI-CMC-HA method: QS-160049-A
NNTD registration number: 1250

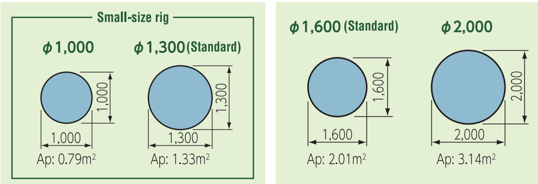
The CI-CMC and CI-CMC-HA methods are deep mixing methods that form large-diameter high quality improvement columns through the use of an "ejector discharge" device that uses compressed air to spray slurry as a mist.
Displacement in the surrounding ground is greatly reduced, allowing implementation close to existing structures in urban areas. Large-volume implementation maintaining high quality reduces costs.

Features:

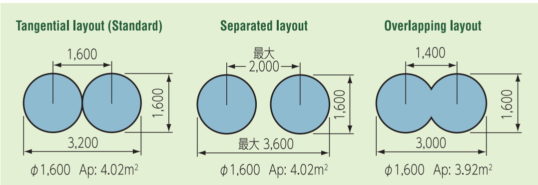
- **High quality large-diameter columns**
  Improved mixing effectiveness delivers large-diameter, highly uniform columns.
- **Outstanding driving capability**
  Greater driving capability makes mixing possible in ground where penetration resistance is high.
- **Low displacement method**
  Using compressed air significantly reduces displacement in surrounding ground.
- **New Visios®-3D implementation management system**
  Makes implementation status visible, following record files and CIM (Concrete Information Modeling) allows mapping as 3D model.
- **HA: Reduced costs and shortened schedules**
  No advance boring is needed in hard ground, reducing costs and shortening schedules.
- **HA: Consistent strength in improved columns**
  Controlling the volume of compressed air used in ejector discharge limits strength variations in improvement columns.
- **HA: Implementation possible in hard ground**
  With more advanced mixing blades, implementation possible from hard ground (N value 50) to soft soil (N value 15).

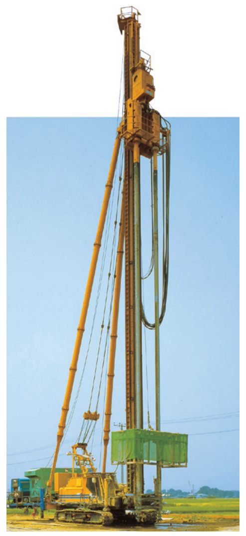
Improvement design

Single-axis installation



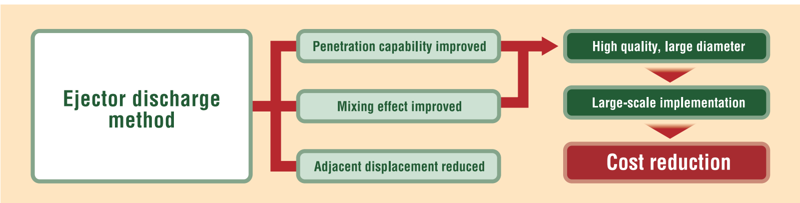
Twin-axis installation





Ejector discharge method

A discharge method in which compressed air and hardening agent are sprayed as a mist, to give a finer and more uniform mixing effect.



CI-CMC-HG Method

(Large-diameter, low displacement deep mixing method for ultra hard ground)

The CI-CMC-HG method utilizes a high-torque inverter motor with twice the torque of a regular auger motor, to boost driving capability and make applications possible in gravel ground with N value exceeding 50.

CMC Method

(Cement deep mixing (CDM) method)

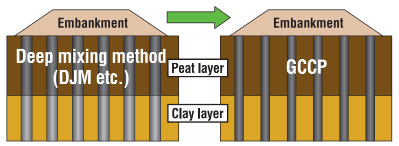
The CMC (clay mixing consolidation) method is the most common deep mixing method, utilizing chemical bonding for ground improvement. Improvement agent such as cement milk or cement mortar is mixed in situ into soft clay soil. It is widely used on land and offshore.

GCCP Method

(Gravel cement compaction pile method)

The GCCP method uses gravel into which cement has been mixed in place of the conventional sand in the sand compaction pile method, to form high strength gravel cement piles. Due to this the texture of the soil for improvement (highly organic soil) is not affected as in deep mixing methods, and gravel cement piles can be formed that are very strong and of consistent quality.

Costs reduced and schedules shortened



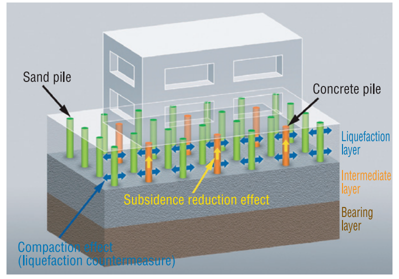
<Deep mixing method>
Improvement diameter φ1,000mm
Improvement ratio 50%
Hardening agent: special cement (high price)
Quantity of hardening agent added: high for peat, low for clay

<GCCP>
Improvement diameter φ700mm
Improvement ratio 25%
Hardening agent: regular cement (low price)
Quantity of hardening agent added: low throughout

HCP Method

(Hardening compaction method)

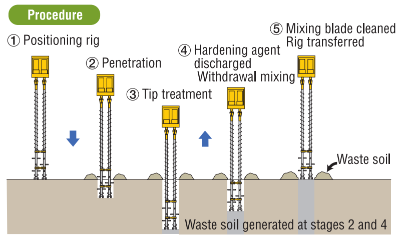
This is a practical piled raft foundations method for ground prone to liquefaction, in which a SAVE Compozer rig alone is used for ground improvement as a countermeasure to liquefaction and to form concrete piles to reduce subsidence of buildings.



CDM-LODIC Method

(Displacement reduction type deep mixing method)

To limit displacement occurring in the adjacent ground due to injection of the hardening agent, in the CDM-LODIC method a screw is fitted to the mixing axle to remove the equivalent quantity of soil to that injected during implementation.



DJM Method

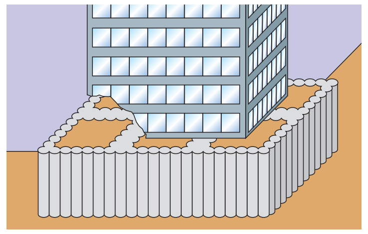
(Dry Jet mixing method)

The DJM dry jet mixing method is a deep mixing method that boosts the strength of soft ground by mixing into it improvement agent such as lime or cement in powder form. It has the same features as the CMC method that utilizes cement slurry. This method was adapted for commercial use from technology developed as part of a 1970s Ministry of Construction development project for new ground improvement methods. Standard mixing blades are 1,000mm but currently larger 1,300mm implementation is being studied.

TOFT Method

(Grid-type solidification method)

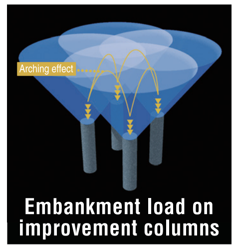
A grid pattern of deep mixing columns is formed in the ground to prevent liquefaction by binding the soil.



ALiCC Method

(Low improvement ratio cement column method)

The ALiCC method reduces consolidation settlement directly beneath a raised embankment by installing cement-hardened improvement columns throughout the whole area directly beneath the embankment with large spaces between them. It allows a lower improvement ratio than is conventional, for lower costs and shortened schedules.

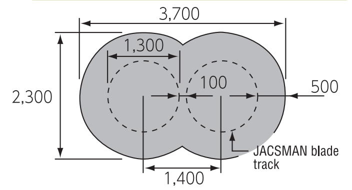


JACSMAN

(Cross jet type composite mixing method)

This method combines the merits of conventional mechanical mixing with high-pressure jet mixing. It forms soil cement blocks leaving no unimproved part.
Through the development of cross-jets, the extent of improvement can be contained compared with usual high pressure jet mixing methods, so the diameter of the improved body can be controlled without affecting the ground.
A better mixing performance efficiently creates uniform improvement bodies.
By stopping the cross jets it's possible to change the diameter of the improved body at a chosen depth.

Improvement body section example



Improvement area Formation speed up to 1.0m per minute

Solidification

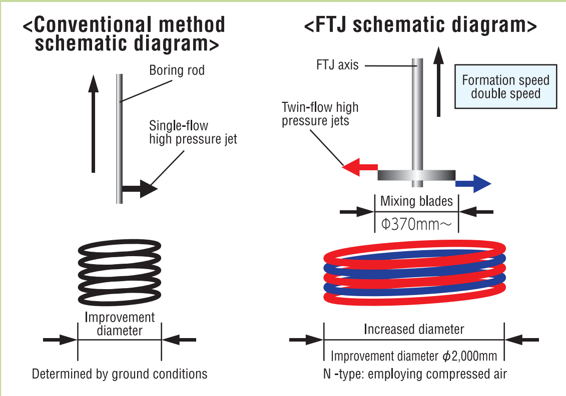
FTJ Method/ FTJ-FAN Method

(Twin-flow cement slurry jet mixing method) / (Swing-type multi-flow cement slurry jet mixing method)

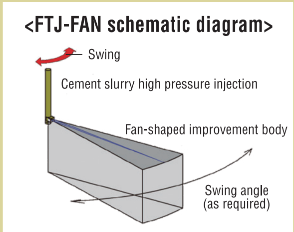
FTJ-FAN method: HR-140015-A
NNTD registration number: 1251

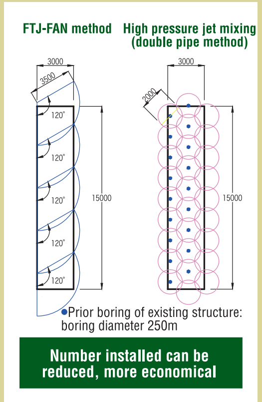
In the FTJ method, cement slurry is injected at high pressure from twin nozzles at the tip of the mixing blades, to form large cross-section of improvement all at once, allowing installation at more than twice the usual speed, and resulting in cost savings and shortened schedules. By employing compressed air the loosened soil can be discharged at the surface, avoiding the effects of displacement on existing structures.
The FTJ-FAN method is a swing-type multi-flow cement slurry jet mixing method. The direction of injection can be controlled in order to form fan-shaped or rectangular improvement bodies. Greater freedom in forming improvement bodies allows improvement directly under existing structures, and improvement that can be limited in scale as required, for more efficient and more economical groundwork.

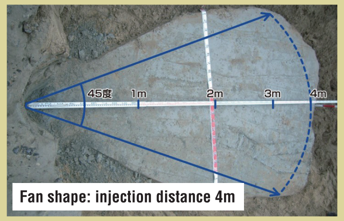
FTJ method



FTJ-FAN method







PJ Method

(Cross jet type composite mixing method using compact equipment)

This deep mixing method uses both mechanical mixing and jet mixing, for easy implementation close to sheet piles and also overlapping implementation. With two types of mixing blades the same rig can implement both large-scale and close-up installation. With a compact size rig and a smaller power plant this method of ground improvement is suited to confined sites in urban areas.

Super Jet Method

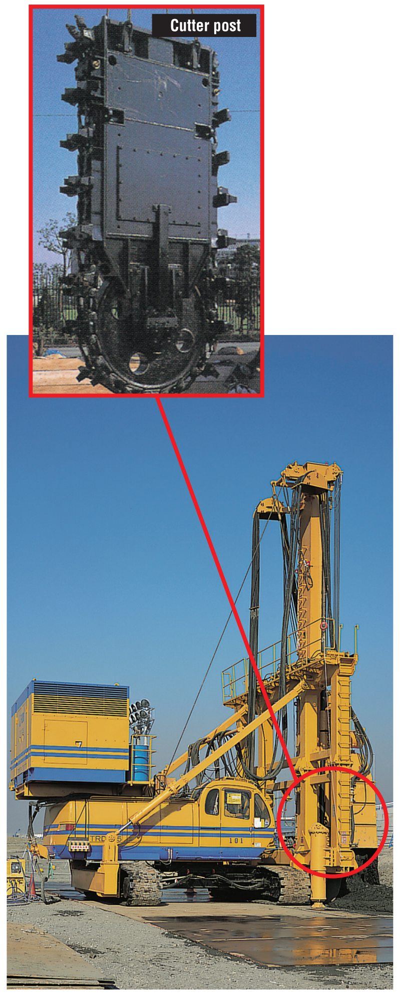
(High-pressure jet mixing method – large diameter)

This ground improvement method uses ultra high-pressure jets to spray hardening agent forcefully through ground to form large-diameter soil cement piles. This high-speed installation is 10 times faster than conventional methods.

TRD Method

(Continuous soil cement diaphragm wall method)

The TRD method forms a wall in the ground by using a chainsaw type of cutter connected to a base machine. The cutter is moved laterally through the ground, digging a trench and adding hardening agent, which is mixed with the soil in situ to form a continuous wall.



Consolider Method

(Surface layer solidification method)

This method hardens the top layer of soft ground, providing enough ground strength for the passage of personnel and vehicles.

Power Blender Method

(Shallow and intermediate layer mixing method)

A trencher-type mixing device is attached to a backhoe base machine, and improvement agent such as cement or other hardening agent is mixed to a slurry, injected into the ground and forcibly mixed with the existing soft soil to harden it.

V-MIXING Method

(Surface layer solidification method – by horizontal propelling trencher)

This is a revision of an earlier solidification method in which level mixing blades are raised and lowered during horizontal movement. An upright composite mixing rig called a trencher is loaded onto a floating deck. Once it has been driven into the ground it is moved continuously horizontally, to improve soft ground.

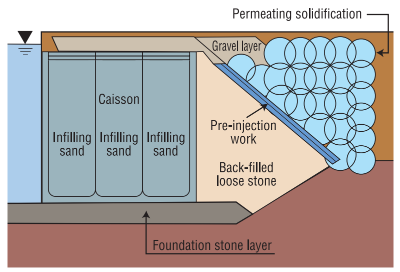
Barge Consolider System

(Premixing method)

The barge consolider system uses a barge equipped with a vertical mechanical mixing device and a cement slurry plant. Dredged soil is mixed with cement slurry in the barge and the hardened material is transported to landfill sites.

Permeating Solidification Method

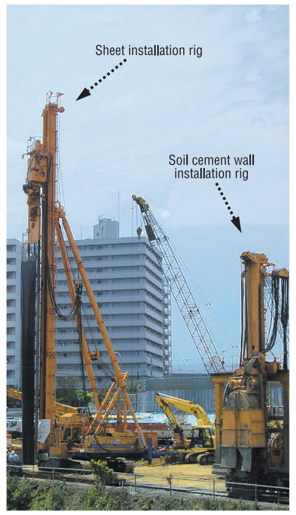
The permeating solidification method is adapted from the fluid chemical agent injection double packer method, and special silica is introduced by permeation into soft sandy ground. The compact installation rig uses fine injection pipes, and by injecting a highly permeable permanent fluid agent, pin-point improvement is possible at sites where countermeasures to liquefaction are needed.
Due to these characteristics, installation has little impact on structures and is possible at facilities that continue to operate, making it a highly economic method.

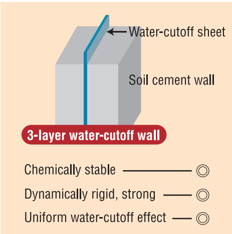


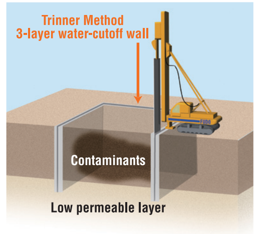
Water Cutoff

Trinner Method
(Triple layer water-cutoff wall method)

The Trinner method is a vertical water-cutoff wall technology that prevents contaminants from leaching into surrounding soil and groundwater by using blocking and seepage control work to contain the contaminated soil. The Trinner method combines two techniques that have been well used: the diaphragm wall water-cutoff method (soil cement wall) and the sheet-type water-cutoff method. Using the merits of each makes for a highly reliable water-cutoff wall method.

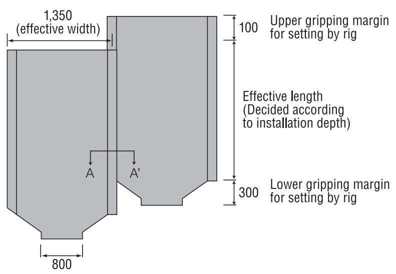


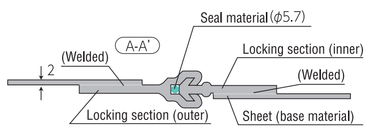




Geolock Method
(Vertical sheet pile method)

A water cutoff method using high-density polyethylene sheet. The material is highly durable and resistant to chemicals and so is ideal as a water cutoff method for waste disposal sites.





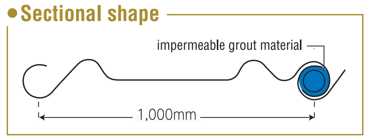
Sheet Wall Method
(Special lightweight steel sheet pile water-cutoff method)

The sheet wall method cuts off water by forming a continuous wall in the ground using thin steel sheets that couple together.

Features:

- Reliable water cutoff effect
- Economical
- Easy installation

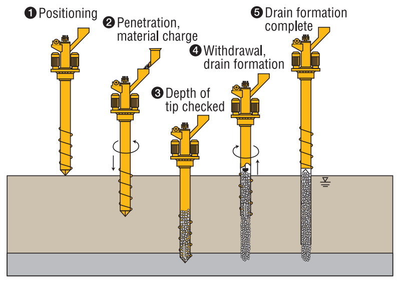
● Sectional shape



Drainage

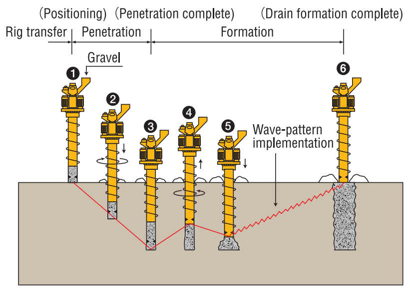
Gravel Drain Method

The gravel drain method is a liquefaction countermeasure that can be implemented close to existing structures or in urban environments where vibration or noise are a concern. Forming gravel piles in sandy ground shortens horizontal draining distance and prevents liquefaction by stopping the rise in pore water pressure that occurs during earthquakes.



NUP Gravel Drain Method
(Gravel piling with compaction method)

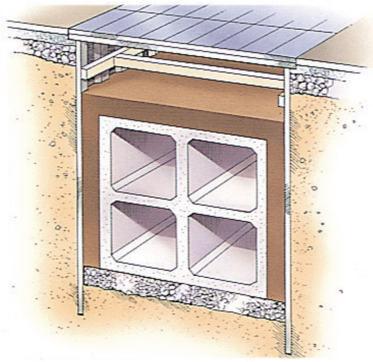
By adding compaction to the draining effect of gravel drains, this method is an efficient countermeasure to liquefaction that cuts costs and reduces schedules. With a small sized rig and the use of natural materials, it is ideally suited to liquefaction mitigation in residential areas.



Fluidized Soil, Lightweight Soil

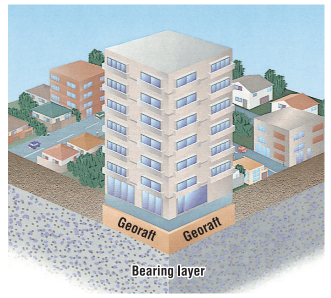
LSS (Fluidized Soil Placement) Method
(Fluidized soil placement method)

The LSS method uses a highly fluid processed soil for backfilling, embankment work and to fill voids under structures etc. in locations where compaction is difficult. All types of construction-generated soil can be re-used as the base material.



Georaft Method
(High-strength high-quality fluidized soil placement method)

The Georaft method is a new environment-friendly method developed as a substitute for rubble concrete in structural foundations. Using soil generated during construction work as a re-usable resource in compliance with legislation promoting the use of recycled materials, a high-density mud soil is created, to be used as a highly reliable solidification-treated soil. This method can be widely used, not just for foundation work, but in slope retaining work, and for all types of backfilling.



High-Grade Soil
(Mixed strengthened soil method)

High-grade soil is a value-added construction-generated soil material for civil engineering uses that meets sophisticated and multi-purpose requirements. Used in 4 methods: air bubble incorporated soil method, foam beads method, pack-drain method and fiber mixed soil method.

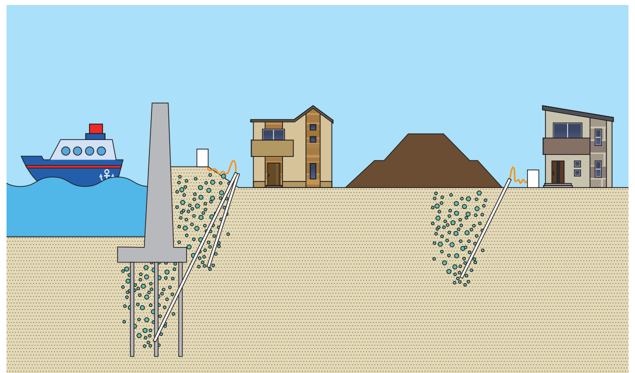
SGM Lightweight Soil Method
(Air bubble incorporated soil method)

A processed soil made by mixing clay or similar soil with cement or other hardening agent, and with air bubbles. Used as a landfill or backfilling material in ports and marine environments, it forms a stable, lightweight ground.

Others

Air-Des Method
(Air-injection desaturation method)

Direct injection of air into the ground to make it desaturated is a ground improvement method that boosts resistance to liquefaction. Using only air, it is low-cost compared with other liquefaction countermeasures and the environmental impact of implementation is lighter. It can be used for ground directly beneath existing structures and implemented while buildings are in use, and also in very limited spaces.



Implementation Examples

Tokyo International Airport (Haneda)

Haneda Airport is the gateway to the skies of Japan. At the start of the 1st phase of Haneda expansion in 1984, Fudo Tetra's proposals for various ground improvement technologies for both land and offshore were adopted. These included the Compozer (sand compaction pile method), Sand drain, CF drain and CMC methods. The Compozer was also used offshore for stabilizing the embankment of reclaimed ground for D runway, and the SAVE Compozer for liquefaction-proofing of the apron facing the gates for international flights. In recent years, SAVE-SP method has been used for earthquake-proofing of existing taxiways, with implementation undertaken at night, taking care not to create unevenness in the paved areas as the airport is in use during the day.


Offsore Compozer

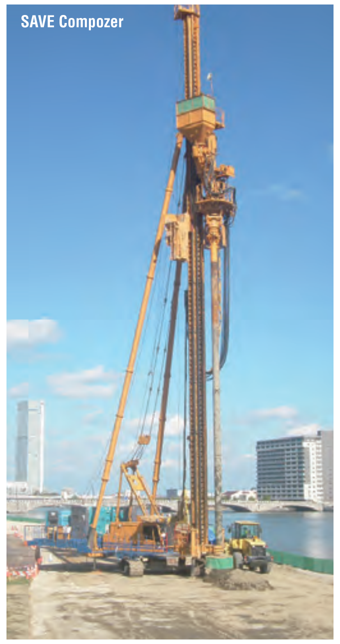

SAVE Compozer


SAVE-SP Method

Atsugi Minami Interchange

The Atsugi Minami Interchange, on the Shin Tomei Expressway that links Tokyo and Nagoya, is located on the first section to be opened in Kanagawa prefecture (28 January 2018). The CI-CMC method was adopted with the aim of ensuring embankment stability to prevent slippage, and curbing settlement and lateral shift. The maximum length of improvement was 31m and about 450,000m^3 of soil was improved.

Photo: NEXCO Central


SAVE Compozer


CI-CMC Method (Small rig)


SAVE-SP Method

Yasuragi Waterfront, Shinano River

Central Niigata City is low-lying, with some sections at sea level, and in the Niigata earthquake of 1964 large areas suffered flooding. The lower reaches of the Shinano river flowing through central Niigata have long been popular as a valued waterfront amenity in the middle of the city. To prevent bank collapse from liquefaction in an earthquake and flood damage due to a tsunami, works were undertaken to counter liquefaction in the banks using the SAVE Compozer, SAVE-SP, CI-CMC and FTJ methods. The improved sections on the left and right banks of the Yasuragi waterfront total 7km in length, and serve as disaster-prevention measures for the city.


FTJ Method (NA type)


FTJ Method (SA type)

Nagasaki Prefectural Government Building

The new Nagasaki Prefectural Government building, adjacent to Nagasaki Station, was completed in November 2017 and meets all safety performance standards as a major disaster prevention facility. The Compozer (sand compaction pile method) and SAVE Compozer (non-vibratory compaction pile method) were used to proof the site against liquefaction in the event of an earthquake. Ground improvement was undertaken for the administrative wing, the prefectural assembly building, the car park and the police headquarters building, as well as the harbor highway area. At the height of the implementation period 7 rigs were working simultaneously, and in total about 10,000 ϕ700mm sand piles were installed for 90,000m of improvement.

Implementation Examples

■ Kanazawa Port, Muryoji Sea Wall

Since the opening of the Hokuriku Shinkansen bullet train line in 2015, the old city of Kanazawa has seen great change. Renovation work was undertaken at Kanazawa port, the city's approach from the sea. Nearly 50 years have passed since the port was opened in 1970, and the deteriorating sea wall was rebuilt to be earthquake-resistant. To ensure it functions both as a port of call for growing numbers of cruise ships, and as a transit point for supplies in emergencies, the FTJ and CI-CMC methods were used on the back slope of the sea wall, and the offshore CMC method was used on front facing slope.


FTJ Method/CMC Marine Method


CI-CMC Method


FTJ Method

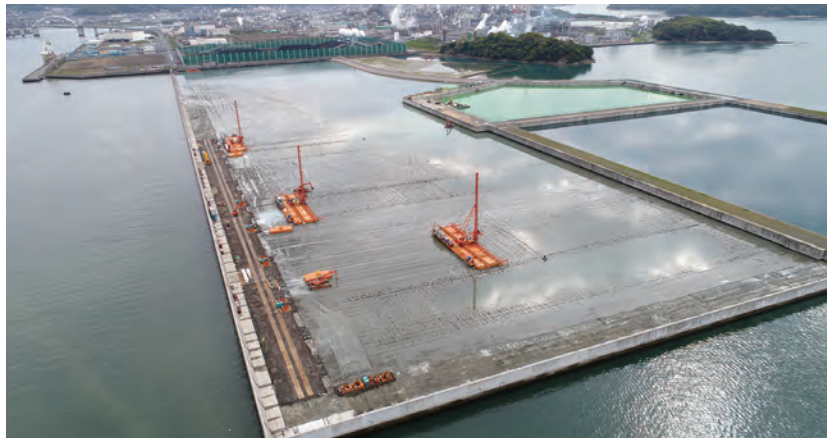
■ Tadano Co., Ltd Kasai Plant Site

Tadano Co., Ltd, a manufacturer of large cranes and other industrial machinery, planned the construction of its Kasai Plant to be one of the largest industrial plants in Japan, on an extensive site of about 20 hectares of reclaimed land situated to the west of Takamatsu City on Shikoku Island. Ground improvement was undertaken at the site to protect against liquefaction and prevent ground settlement, with the aim of ensuring long term bearing capacity. For this the Compozer (sand compaction pile method) was adopted, the method that Fudo Tetra was first in the world to develop for commercial use. Selecting this method involved an analysis of the state of the extensive ground to ensure the required performance could be met, and the cost and schedule were also studied. For the Compozer implementation, a maximum of 8 rigs were deployed for a total improvement length of about 200,000m, as 23,400 piles.


Photo: Tadano Co., Ltd
Construction of new plant from the east, February 2019.

■ Tokuyama Kudamatsu Port (Shinnanyo) Waste Soil Disposal

In 2011 Tokuyama Kudamatsu was selected as an 'international bulk strategic port (coal)', a major industrial port supporting a petrochemical complex and other facilities along the coastal industrial belt. It was thus designated an international base port.
Work has progressed with the construction of an international cargo terminal that can handle larger vessels, and a shipping lane and berths of -12m were created to ensure an adequate depth of water. A waste soil disposal area was secured in Shinnanyo for the disposal of the dredged soil. With its remaining capacity there at 2.1 million m^3, roughly 500,000m^3 short of the 2.6 million m^3 required, the Floating Plastic Board Drain (PDF) method was adopted for consolidation acceleration in order to expand capacity by reducing volume. Three linked PDF vessels were used to install 62,000 vertical drains for a total length of drains of about 1.3 million meters.



■ Ozawa Fishing Port

Iwate Prefecture suffered tsunami damage after the Great East Japan earthquake of 11 March 2011, and sloping sea walls were planned for restoration of its shoreline of fishing ports. Ozawa formed part of this, and the Compozer (sand compaction pile method) was used for proofing the sea wall against liquefaction. Because the site was close to where local people had set up new homes, the non-vibratory SAVE Compozer method was used to minimize noise and vibration. This work was undertaken at the same time as other restoration projects for highways and so on, which made it difficult to obtain gravel, so Ecogaistone was used as a substitute. As a result, the disaster recovery work for Ozawa fishing port contributed to the region's reconstruction without any delay.