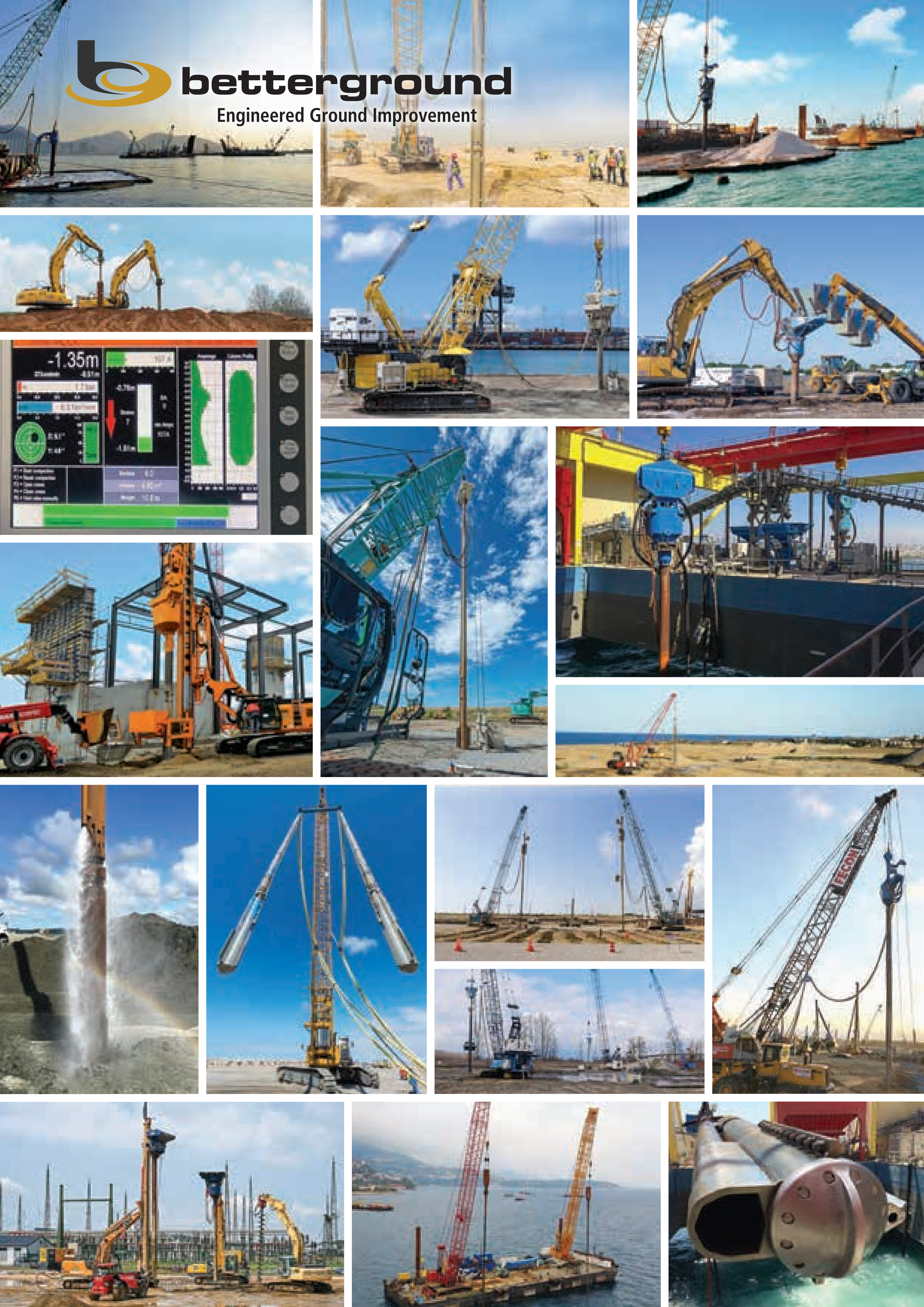
betterground

Engineered Ground Improvement



Betterground Group designs, manufactures, services and assembles specialized equipment for ground improvement, in particular equipment for Vibro Stone Columns and Vibro Compaction.

Betterground provides value engineering for clients' projects at an early stage. Knowledgeable in-house engineering teams draw on their vast experience with key international ground improvement projects over the last three decades.

For over 80 years the know-how of deep compaction Vibroflot design has been carried forward in the Degen family, the co-founders of Betterground.

Company Profile

Betterground enables construction companies to build up a sustainable business in the field of ground improvement by utilizing the best equipment in the world, competent services, and professional expertise, including equipment repairs, online spare part purchasing, site quality control, method optimization, and geotechnical design and supervision.

Betterground assists clients on major projects with customized state-of-the-art solutions in accordance with even their most stringent requirements. Our equipment design department provides project specific solutions for a wide range of complex scenarios.

Betterground's shareholders and employees have extensive experience in the field of ground improvement equipment, site methods, supervision and management.

The flexible business approach enables clients to choose any of the following services:

- Equipment rentals and sales
- Area licences
- Job-to-job joint ventures

History

Wilhelm L. Degen, the son of Johann Degen, was the co-owner of Johann Keller since 1920, and Managing Director and Chief Engineer of Keller until his death in 1970. He owned numerous patents, including the depth vibrator for Vibro Compaction (together with Sergey Steuerman), and various pioneering Stone Column related patents.

1901 - 1970

W. L. Degen invented the Stone Column method.

1958

Wilhelm F. Degen and Franz Eichkorn developed the first range of high performance electrical Vibroflots, utilizing revolutionary internal design, which facilitated a unique penetration capacity. This enabled their machines to reach numerous world record depths in the coming years.

Expansion of the Vibroflotation companies into Germany and Far East.

1978

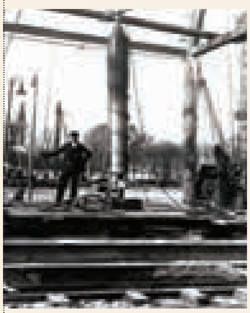
Together with their father, Wilhelm F. Degen, Alexander M. Degen and Wilhelm S. Degen set up Vibroflotation AG, an equipment manufacturing facility in Switzerland. They also developed the Gravel Pump, the Vibro Stitcher and the Marine Gravel Pump together with designers Franz Eichkorn and Beda Kälin.

1986

1900

Johann Degen bought the Johann Keller Company in Germany in 1900 and managed its rise from a local well drilling company to a regional market leader, expanding into the surrounding countries. After his early death in 1903, his wife, old Mr. Keller and Johann Degen's brother Wilhelm managed the company through hard times until its transition to sons Johannes and Wilhelm in 1920.

1938



Mr. Sergey Steuerman, co-inventor of the Vibroflot, left Germany and set up the Vibroflotation Foundation Company in Pittsburgh, PA, establishing Vibro Compaction in the USA.

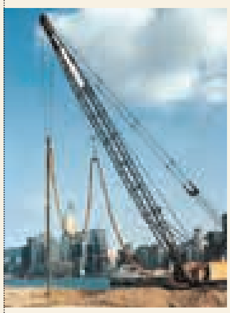
1974

Johannes Degen and the children of Wilhelm L. Degen sold their share in the Keller Group after continuous years of expansion. Wilhelm. F. Degen (son of Wilhelm L. Degen) bought the Vibroflotation Foundation Company of Pittsburgh, PA, from Sergey Steuerman.

1980

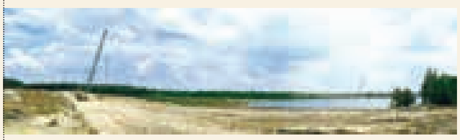
World record for deep vibro compaction by Vibroflotation at Jebba Dam, Nigeria.

1990 - 1996



Licence agreements between Soletanche S.A., in France and Vibroflotation AG and a Joint venture between Vibroflotation AG and Bachy-Soletanche were established in Hong Kong.

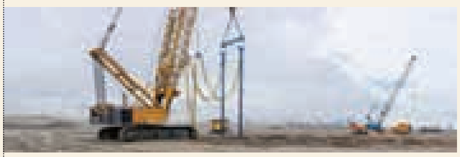
Vibroflotation equipment dominated the Vibro Compaction market in Germany for lignite mining slope stability projects of over 70 m in depth, with a total volume of over 1 billion cubic meters.



1994 - 2001

Betterground supported China Harbour Engineering Co. with low headroom offshore stone column equipment and site support on the HKBCF project, which included over one million meters of marine Stone Columns. It was the largest project of its kind in history.

Three Double Lock Bottom Feed Stone Column rigs worked simultaneously off a jack up platform to found the new breakwater for the Port of Ashdod.



Betterground supported Jan De Nul with Tandem Vibro Compaction equipment for the compaction of the land reclamation at the Port of Calais.

Betterground and Wurster Engineering & Construction Inc. form together a 50/50 joint construction company in the USA called Wurster Betterground.

2012 - 2017

2001 - 2009

Soletanche Bachy took a 70% share in The Vibroflotation Group and in 2006 took over the company entirely. The relationship ended in a three year non-competition undertaking by Wilhelm and Alexander Degen during which both brothers were consulting The Vibroflotation Group on numerous key international projects.

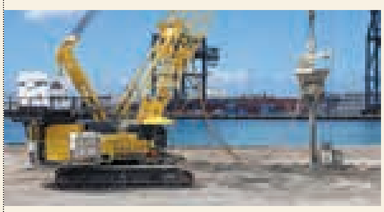
2009

Betterground Ltd. (Switzerland) was founded in early 2009 and was immediately joined by the most experienced technical experts in the world.

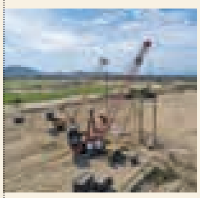
One of the first projects was Palm Deira in Dubai, the largest Vibro Compaction project in history.

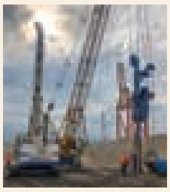
2018 - 2022

Wilhelm G. F. Degen, the fifth generation of the Degen family, joins Wurster Betterground and as Operations Manager executes the company's largest Bottom Feed Stone Column project near Tampa Airport.

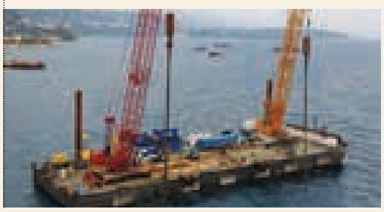


Kiewit Corporation uses Betterground BD1 Bottom Feed equipment on Kapalama Port, Hawaii.





Betterground stone column equipment becomes very busy during Covid times in Mexico, for the Amanvari Hotel and Resort project in Baja California and for the Port of Manzanillo.



Betterground supports Bouygues in the offshore vibro compaction of a 30 m thick rubble fill in Monaco.

Services

Catalina Power Plant: Dominican Republic (2015)

"Engineered Ground Improvement"

We help customers find the right ground improvement solution for their projects from an early point in the design stage.
We assist in the design of favorable solutions, including stability calculations, liquefaction mitigation assessments, settlement estimations and optimization of methods as well as custom equipment design for dedicated applications.

Our strength lies in the field of Stone Columns and Vibro Compaction, but we combine and complement these techniques with vertical drainage, soil mixing or dynamic compaction whenever advantageous to our clients.

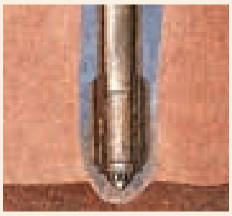
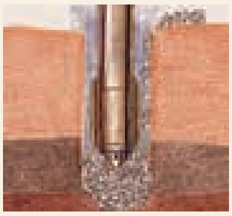
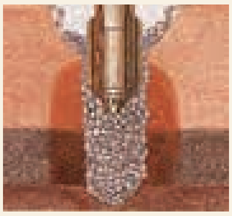
A mix of ground improvement techniques is often the key to a successful design-build approach.

We offer the whole range of services, from equipment rentals or sale, repair services, site supervision, compaction methods optimization, tender design assistance, and on-site assistance to full scale joint ventures.

These services are offered globally through our regional offices in Munich, Dubai, Hong Kong and Dallas.

For silty and clayey soils

Top Feed Stone Columns

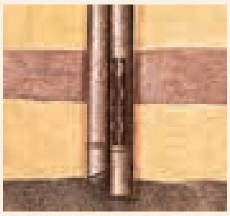
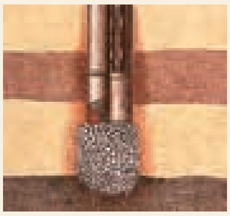




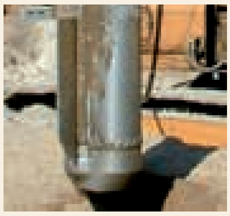

Penetration
The vibroflot penetrates and 'washes' the hole in preparation for the stone transport within the hole.

Installation
During the introduction of the stones, water and air are flushing in order to create a positive flow for the stone transport.

Completion
The vibroflot is frequently moved up and down in order to form and compact a column. Thereby, the surrounding ground is horizontally compressed and improved. The column is able to support high vertical loads.

Bottom Feed Stone Columns



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The vibroflot penetrates with the help of vibration and air flushing. (Sometimes minimal water lubrication is useful to overcome high friction from the soils).

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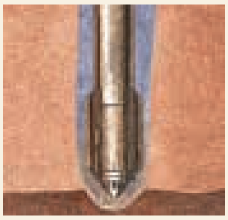
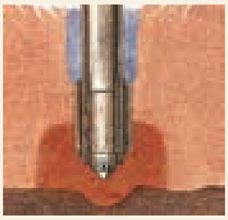
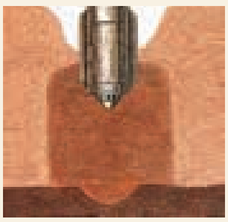
For clean granular soils

Vibro Compaction Procedure

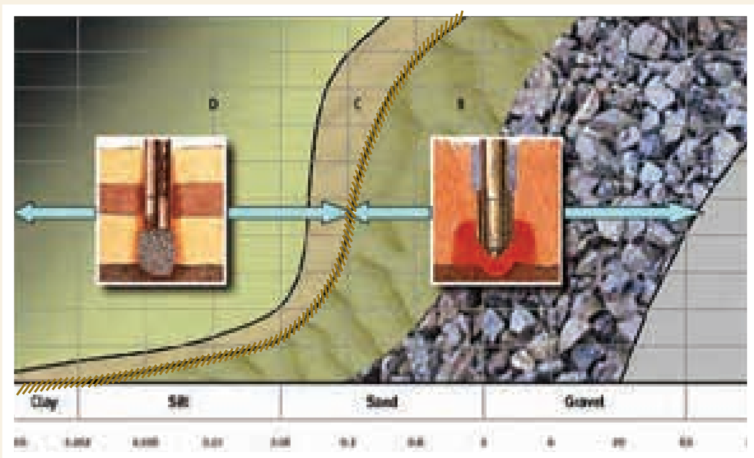



Penetration
By vibration and the flushing of water and/ or air, the vibroflot penetrates to the desired depth.

Compaction
The vibroflot is recovered from a certain vertical distance after a verified holding time or buildup of resistance from the compacted ground.




Completion
Immediate top layers may be leveled or impact compacted or roller compacted to ensure a ready-to-build surface.



Vibro Compaction

The method of soil improvement whereby granular soils are compacted using depth vibrators is known as "Vibroflotation".

Naturally deposited soils as well as artificially reclaimed sands can be compacted to great depths. The current depth record lies at 70 meters for reclaimed sands and at 53 meters for naturally deposited sands.

The intensity of compaction can be varied in order to achieve the desired effect depending on the foundation or ground improvement purpose.

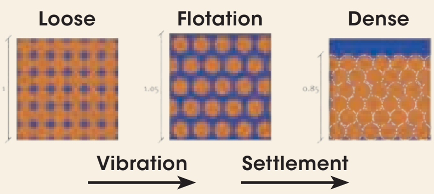
Palm Deira Vibro Compaction Dubai 2008 - 2009
Up to 85 Vibroflots supplied and serviced by Betterground teams.

Compaction effects:

- The sand and gravel particles rearrange into a denser state
- A significant increase in the horizontal to vertical effective stress ratio
- The permeability of the soil is significantly reduced
- Increased friction angle
- Settlements of the compacted soilmass (between 2% and 15%)
- Increased stiffness modulus

Compaction Process:

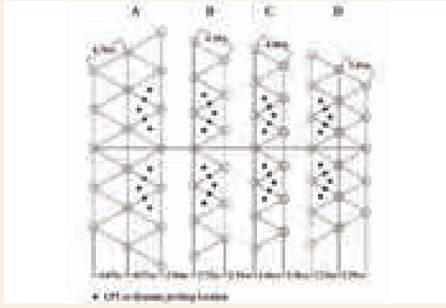
The compaction process consists of a flotation of the soil particles as a result of vibration, which then allows for a rearrangement of the particles into a denser state.



Improvement effects:

- Increased bearing capacity
- Settlement reduction under loads
- Near-elimination of differential settlements for large foundations
- Liquefaction mitigation
- Prevention of lateral spreading
- Prevention of settlements, due to rearrangement of particles from impacts
- Prevention of (inundation) settlements
- K-value reduction (permeability of soils).

Method optimization:
At initial trials, the application of side sprayers for homogenous compaction results is optimized

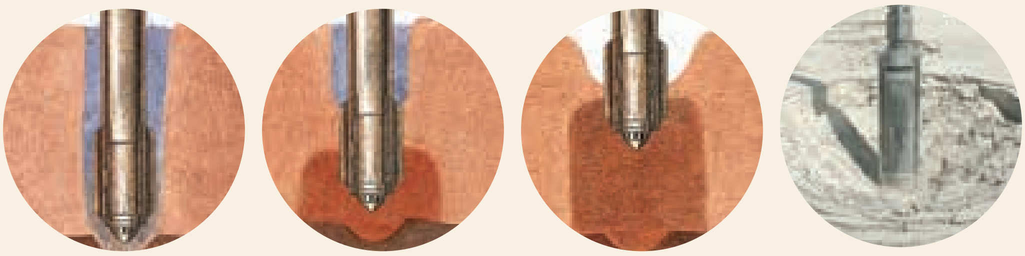


Compaction trials:
For the selection of different patterns, holding times and methods, a field test is performed.

Application of the technology in an optimal manner is an art!

The challenge of optimization lies in the multiple parameters that can be varied and the narrow band in which those parameters need to be adjusted to deliver the desired results. Some of the parameters that can be varied include:

- Type of vibroflot used
- Distance between compaction points
- Hold time per depth interval
- Water pressure
- Location and type of water jets required



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Completion
Immediate top layers may be leveled or impact compacted or roller compacted to ensure a ready-to-build surface.

The world's largest Vibro Compaction project before Dubai's Palm islands: 40 million m3 marine sand, with compaction depths up to 40m. Hong Kong Penny's Bay project (Disney Hong Kong) 2001-2003

Equipment configurations for Vibro Compaction Applications

1 Tandem Suspension

The tandem suspension configuration utilizes two vibroflots suspended from the same crane. This set up has been used extensively in the last 30 years and has proven to be industrially superior to the conventional single rig. It is suitable for penetration depths of up to 25 meters and a hydraulic crawler crane of minimum 150 tons is recommended.

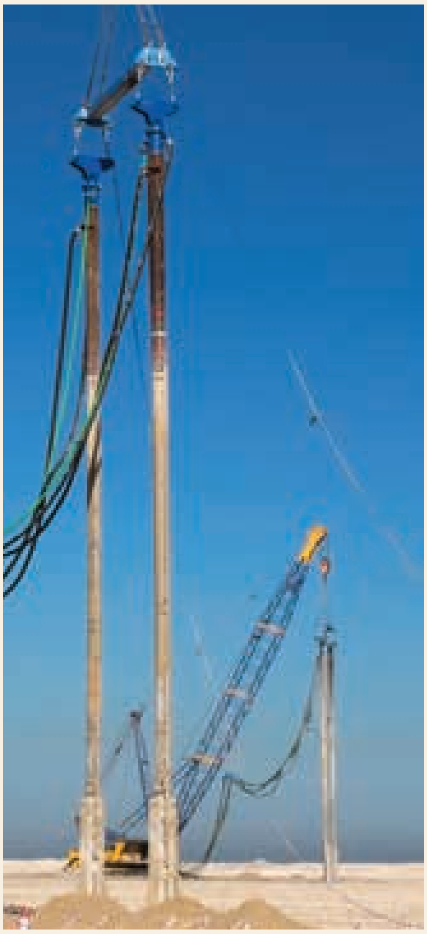
2 Single Suspension

The single crane configuration consists of the same interchangeable components as the tandem setup. The single setup is ideal for great depth and for medium and small volume of works per site. It is particularly suitable for sites where the large crawler cranes needed for tandem are not available. Betterground supplies all the components as well as the technical expertise required.

3 Excavator Suspension

The excavator configuration is the most economical application available for vibro compaction. It offers up to 9 meters treatment depth while having an extremely cost efficient carrier with the ability to support penetration through push down force. It can be transported without disassembly of the components. The same configuration can also be used for shallow Top Feed Stone Columns.

Tandem



Single

Excavator

Compaction of reclaimed land, off-shore and on-shore

Port of Calais, France: Vibro Compaction in Tandem arrangement.

Vibro Compaction of 30 m thick rubble fill from a barge in over 20 m deep water off the shore of Monaco

Two Vibro Compaction rigs have been deployed on the same barge.
Extra dead weights and the high performance of the B41 vibroflot assure reaching the required depth in these difficult conditions.

The following globally recognized projects, as well as many similar medium size projects, were performed by the members of Betterground in either joint ventures or equipment supply and service arrangements.

Dubai: Palm Jumeirah, Palm Jebel Ali, Dubai Maritime City, Palm Deira, World Dubai Heart of Europe and Iceland (2004 and 2010), Pearl Jumeirah Island (2012), SARB Island (2013), Container Terminal 4 (2016)

France: Port of Calais (2017)

Germany: Lausitz (eng. "Lusatia") coal mine restoration slope stability projects (1994 to 2006)

Hong Kong: Chek Lap Kok Airport (1995), Central Reclamation (1994 and 2006), West Kowloon Reclamation (1991-1992), Penny's Bay (2001-2003)

Singapore: Pasir Panjang Container Terminal (1998 - 2000)

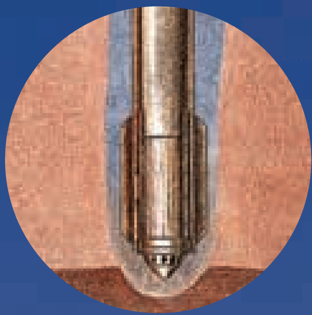
Top Feed
Stone Columns

Top Feed Stone Columns

The use of Stone Columns can be split into two distinct categories; as foundation elements ('stone piles') or as ground reinforcement.

As a foundation element, Stone Columns can be used for a wide range of building types from multi-storey buildings to oil tank foundations. They can function under multiple foundation types including single footing, strip footing and raft.

As ground reinforcement, Stone Columns can prevent liquefaction, provide embankment stabilization, slope stabilization, as well as other ground improvement applications via the combined effects of soil compaction, reinforcement and drainage.



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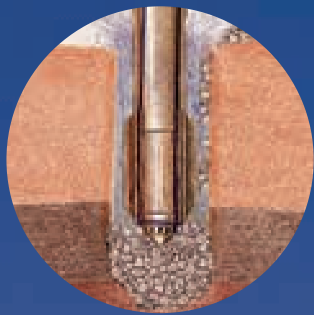

Installation
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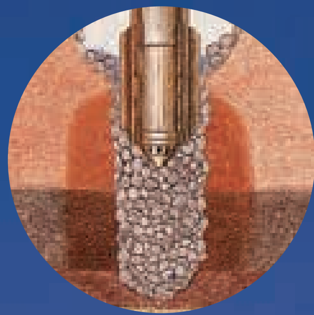


Completion
The vibroflot is frequently moved up and down in order to form and compact a column. Thereby, the surrounding ground is horizontally compressed and improved. The column is able to support high vertical loads.

Citywalk Development, Dubai (2013)

A Green Product

Stone Columns represent the most natural and ecologically neutral foundation system in existence due to consisting entirely of natural stones.

Sufficient quality gravel or crushed rock for producing quality Stone Columns are widely available in many areas. The ecological balance can be further improved through the use of recycled concrete material. A smaller friction angle for the stone column has to be applied if recycled concrete is used.

Where To Use The Top Feed Stone Column Method?

- Where the working platform allows the flushing water to flow towards settlement ponds.
- Wherever the treated soil type doesn't lead to problems handling the mud in the process water.
- Where space is available for a 500 sqm sedimentation pond.
- Where the installation crew has sufficient experience in the more demanding installation methodology.

Stone Columns And Liquefaction Prevention

It is well known that loose sandy soils below the water table turn liquid (liquefaction) during an earthquake. This causes excessive settlement of the ground, leading to damage to structures and services. To prevent this from happening, Stone Columns can be installed and have a threefold effect:

- Compact loose sand and gravel layers.
- Reinforce layers that cannot be compacted (as silt and clay).
- Facilitate drainage in silty and clayey soils.

Bottom Feed Stone Columns

Advantages of the Bottom Feed Stone Column Method

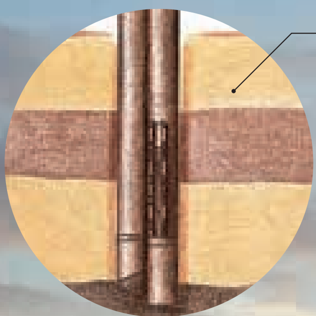
- **The flow of stones to the column is mechanically controlled and automatically recorded.**

- **The material volumes installed can be doubtlessly allocated to precise depth levels.**

- **Minimal soil is transported to the surface, which results in a lower stone consumption, since the necessary lateral confining pressure around the stone column can be reached with less gravel.**

- **No mud handling is necessary on the site.**

- **Surface loss of gravel is reduced to a maximum of 2%, compared to around 5% for the wet method.**



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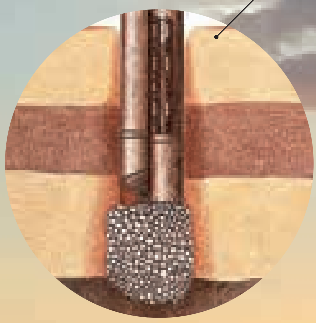

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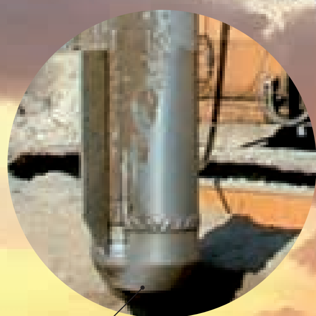

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Leader Mounted Bottom Feed Rig

The Bottom Feed Vibroflot is connected to a sled that is moved along the mast by a hydraulic winch. A hopper on top of the rig is filled with gravel by a bucket, which is moved along the mast by an auxiliary winch independent of the Vibroflot. The bucket is mounted to a frame and tilts into the hopper by the use of hydraulic cylinders. A stone gate below the hopper ensures the necessary buildup of air pressure in the oval stone tank and silo tube. From the silo tube, the gravel flows in a separate tube alongside the vibrator to its tip where it is ultimately discharged.

In an advanced option, the auxiliary winch for the bucket can be integrated into the main sled. This allows using a carrier rig which only requires one winch. It also allows for a completely synchronized movement of the bucket and penetration unit during the filling process, speeding up production.

Excavator Mounted Bottom Feed Rig

The penetration unit is suspended from the excavator's bucket mounting pin. The compact rig can work in the smallest lots, like here in Christchurch, New Zealand, for retrofitting land after an earthquake.

The stone receiver hopper is filled by a specially designed shovel, lifted by a standard telescopic loader.

Bottom Feed Stone Columns

Foundations for railroad-road flyover Mue30, Schwindegg, Germany (2015): BL3 Bottom Feed Stone Columns rig, attached to BAUER BF12

Suspended from Crawler Crane or Drill Rig (leader mounted)

When to use a drill rig as carrier:

- On sites with limited space. Drill rig based carriers are more compact than crawler crane based rigs.
- When treatment depth is limited to about 20 m.
- For small sites, where quick mobilization is important.

When to use a crawler crane as carrier:

One reason to suspend a Bottom Feed Stone Column rig from a crawler crane is the great flexibility in reaching the compaction point. Another advantage is the ability to rent a crane in nearly every corner of the world, therefore removing the need to transport special leader rigs across large distances. Paramount is the much higher production rate which is achievable in many cases.

Flyover Heldenstein, Highway A94, Germany (2016): Dry Bottom Feed Stone Columns installed with BL1 attached to Liebherr drill rig carrier

Variations of the crawler crane suspended rig:

Skip Bucket Rig (BC1)

(Left, and middle of page) Rig with bucket stone transport. This rig is preferred when the stones can be fed by a wheel loader into the tilting bucket. The bucket is either hoisted by the additional crane winch or suspended from a separate winch, attached to the unit itself. The bucket fills into a hopper on top of the rig, from where the stones fall into a receiver tank and silo tubes, and finally reach the tip of the vibroflot.

Pneumatic Stone Transport Rig (GP1)

(Bottom of page)
For slope stabilizations and offshore, if a wheel loader can't reach the rig. The stone transport can be accomplished also by water in lieu of air, if the rig is used offshore.

Catalina Power Plant, Dominican Republic (2015)

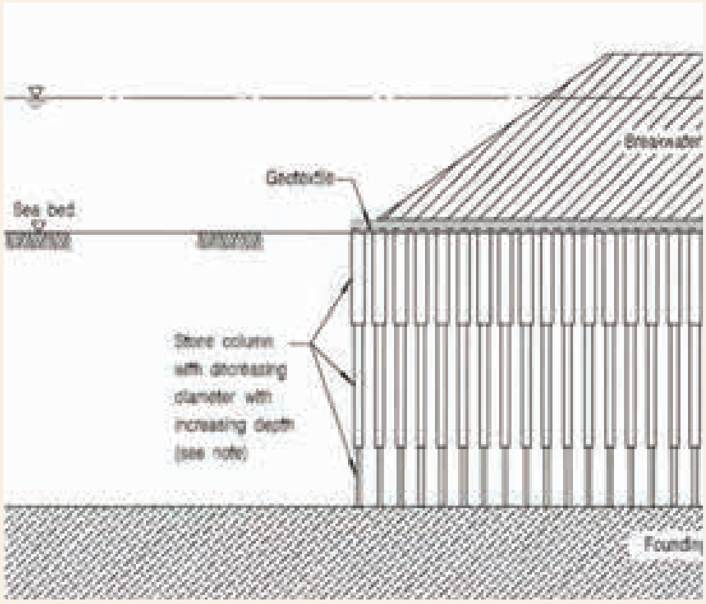
Cannelton Lock, USA (2011): Dry Bottom Feed Stone Columns installed with GP1 peneumatic stone transport rig

Offshore Ground Improvement

Marine Stone Columns

Offshore stone columns have been installed for many years.
The critical aspect of this product was always quality control or the lack thereof.
The finished product can be visually inspected only by divers and full scale load tests on offshore stone columns are unheard of.
It is therefore of paramount importance to rely on a column installation method that leaves no room for defective columns.

A large step to improve the quality of the installed columns was made with the introduction of the predecessor of the Betterground Pressure Chamber Injection System (PCIS) at the Port of Patras, Greece, in 2001.
Since then the number of projects as well as their technical challenges have increased. Today millions of meters of offshore stone columns have been installed in over 38 m water depth, with column length of over 25 m and diameters that can both be constant over depth or follow a tapered design, with the largest column diameters installed directly below seabed where marine deposits typically exhibit the lowest strength.



Tapered Stone Columns, after Hong Kong Port Works Design Manual, Part 4

Patras Phase III
Greece

Richard's Bay,
South Africa

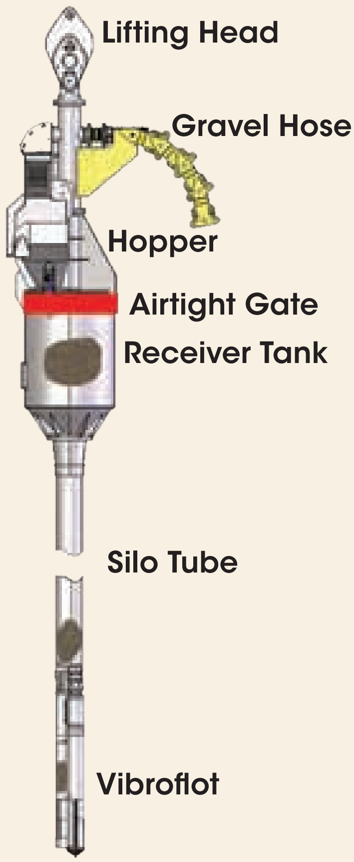
Pressure Chamber Injection System (PCIS)

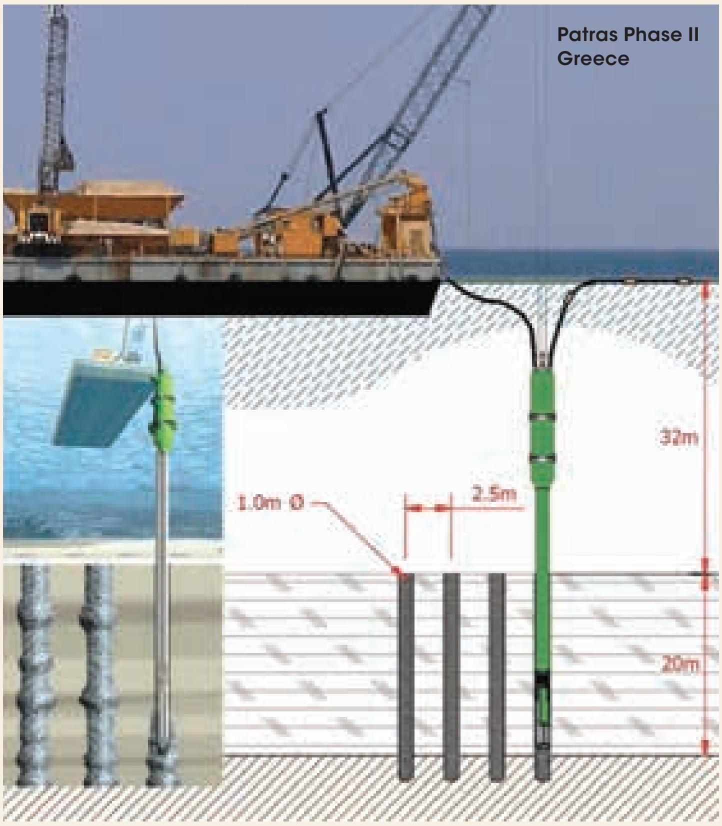
The Betterground PCIS is the latest evolution of marine bottom feed stone column installation equipment.
As shown in the illustration, gravel is transported via a 6-inch gravel hose. In a variant of this system, the gravel can alternatively be placed into the hopper by a bucket.

Key to the PCIS is the airtight gate on the top of the receiver tank that locks the gravel from atmospheric pressure and puts it under an over-pressure that ranges between 2 to 6 bars, depending on the operating depth of the rig.

Under the applied excess air-pressure in the interconnected chamber consisting of receiver tank, silo tube and tremie pipe, gravel is injected into the soil at the tip of the tremie pipe near the Vibroflot's nose, hence the name "Pressure Chamber Injection System".

Compared with a Single Large Tank System, the advantage of the PCIS is that below the gate there is always exactly one full batch of gravel filled in with each opening of the airtight gate. This not only allows for few open-close cycles of this gate, but also for a most accurate recording of gravel batches placed in the ground at defined depths. In an aptly named "Double Lock" variant of the same system, two airtight gates enclose the receiver tank on its top and bottom end.





Patras Phase II
Greece


BART Trans Bay Tube
Oakland

Offshore Ground Improvement

Marine Stone Column works under very strict Airport height restrictions.

Hong Kong Boundary Crossing Facility (HKBCF)

The project target was to install 500,000 lineal meters of 1.0 m diameter marine Stone Columns in under one year of construction time.

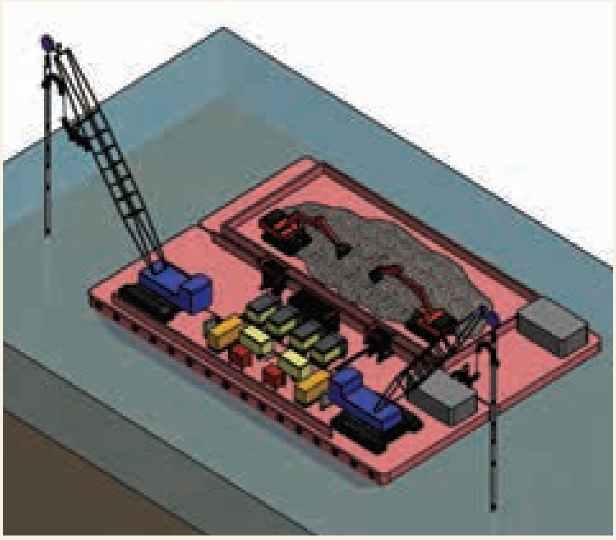
The biggest challenge, besides a very tight time schedule, is the height restriction imposed on the rigs due to the nearby airport. The land based rig with filling bucket loses over 5 m on the top that cannot enter the ground and hence add to the total required length of the rig. The Betterground team designed from scratch and under enormous time pressure, a dedicated low headroom rig that can partially submerge with its upper section into the Marine Deposit and thereby reduce the lost length to zero.

A 1.5 km x 1.5 km non-dredged island is created just east of Hong Kong's Chek Lap Kok airport as part of the Hong Kong -Shenzhen-Zhuhai corridor.

The island is constructed from sand fill placed on top of 15 m to 25 m soft marine deposit. Most of the island is surrounded by a sloped sea wall, with the crest of the sea wall additionally protected by up to 31 m diameter caissons formed by sheet piles.

The inside of the caissons as well as large parts of the slope are reinforced by 1 m diameter stone columns. These columns increase the shear strength of the soft clay and accelerate consolidation, i.e. the dissipation of excess pore pressures in the soil upon loading.

Bottom Feed Stone Columns inside 31 m diameter caissons. 57 columns are installed in each caisson.



Typical barge setup twin rigs Double Lock Bottom Feed under height restriction.

Port of Ashdod Breakwater

The project comprised the installation of over 3000 in average 1.0 m diameter and up to 25 m long marine Stone Columns for the foundation of the extension of the exisiting breakwater in the Port of Ashdod and some additional quay walls inside the port.

The project challenge was a tight construction schedule combined with difficult wind and wave conditions. This led the contractor to select as carrier for the three Betterground offshore stone column rigs a 4000 ton custom built jack up platform in lieu of floating barges that could have only worked during parts of the year.

Betterground provided not only the specialized equipment but their mechanical and soil mechanical departments also helped design many details of the platform setup in close cooperation with the platform builders of the contractor.

During the works Betterground consultants were present on the platform to supervise both the rig operation and its service and preventive maintenance.

The installation trials at the beginning of the project were supervised geotechnically by Soilmechanics GmbH and two experienced installation method experts of Betterground.

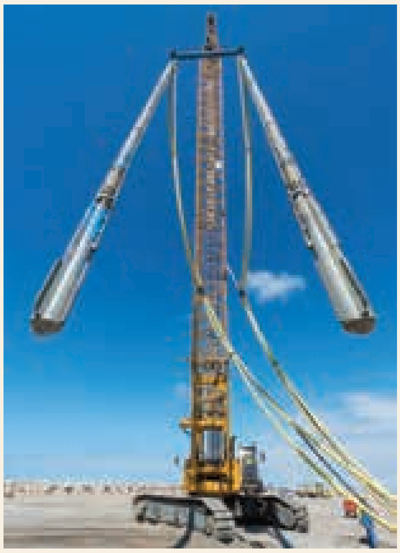
The project was finished within budget and ahead of schedule.

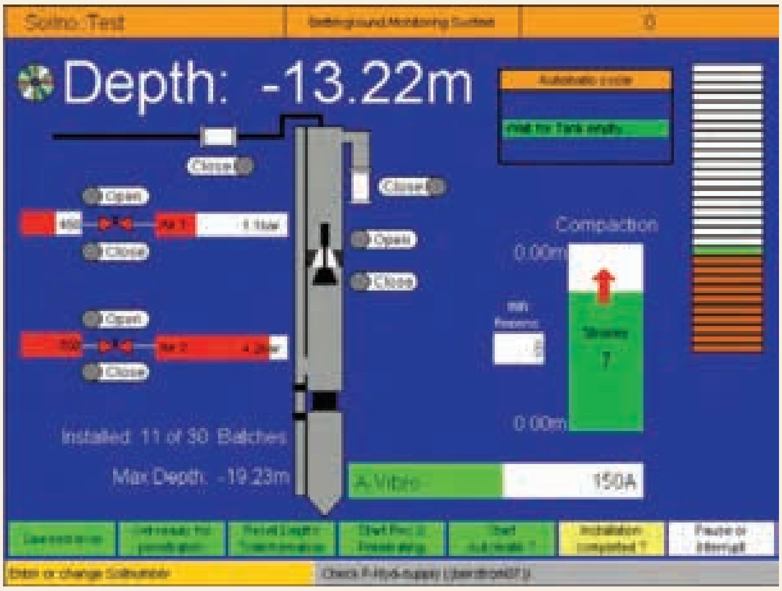
Betterground has experience with alternative setups for Double Lock Marine Stone Columns and skip bucket feeding systems when projects have no Airport Height Restrictions.

Quality Control Recorder

Installation Monitoring

Betterground quality monitoring and control system





The quality control recorder is a touchscreen unit located in the rig operator cabin (pictured right).

The unit can act as a remote control for regulating the pressure or flow of water, air, or even cement grout. This regulation can be programmed to follow an automatic or semi-automatic rule where these flows are regulated depending on depth level.

Operator guidance system

The software guides the operator to install a specified column diameter or achieve the necessary ampere layer by layer as required.

This is accomplished by the green bar graph on the right of the display (titled “Compaction”). As the operator moves the Vibroflot up and down to install the column, this green bar empties or fills and at both ends the red arrow reverses direction to indicate to the operator to also reverse direction from, say, upward movement to downward movement.

The bar on the far right shows in orange the already installed column, green the present depth interval, and white the remaining intervals till completion of this column.

The valve controllers for the various air lock chambers of the Double Lock rig are shown in the left part of the display, indicating status of the valve, flow rate and pressure.

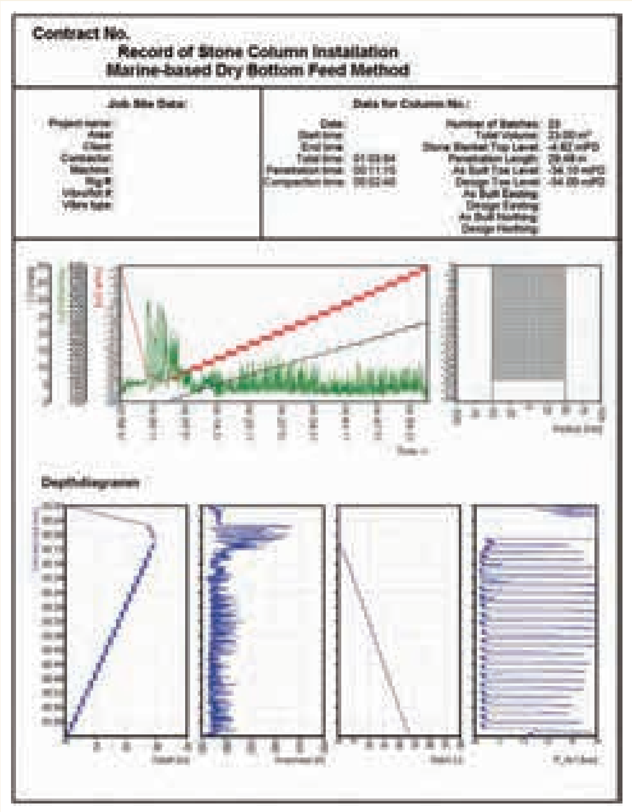
At the bottom of the screen a row of buttons (green, last one yellow) shows the present position of the control computer in the process of installing an offshore stone column. The operator works sequentially from the leftmost to the rightmost button during the installation process, with the presently available selection in Yellow and the already completed steps Green. This way, most operators learn to run the system error free without ever needing a manual.

Stone Column Monitoring Printout

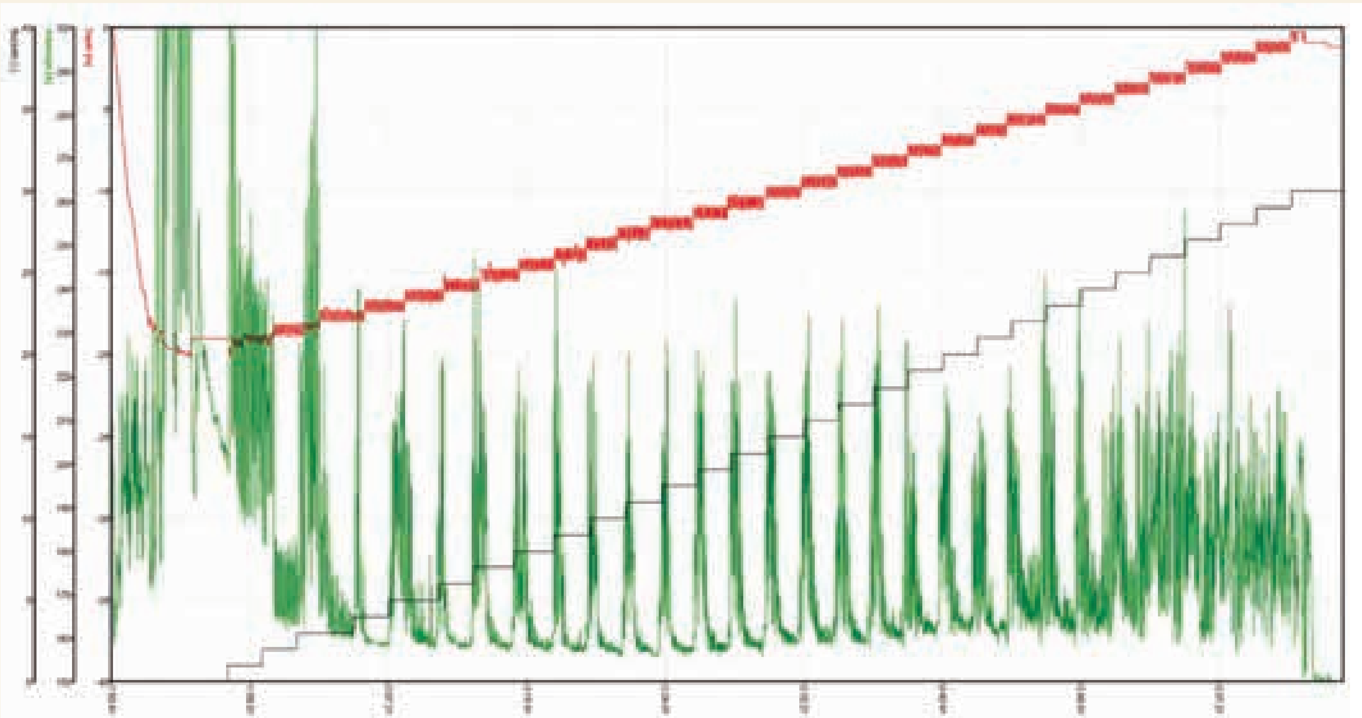
Continuous Recording of:
- Depth
- Amperage
- Air pressure in double lock system
- Inclination

The recorder can be connected to sensors for
- Depth (with deflection rollers or laser)
- Hydraulic pressure (crowd force)
- Concrete, grout or water pressure
- Flow rate
- Inclination of mast in x- and y- direction
- Frequency measurement at the vibroprobe

Below: The output can be analyzed in a custom made software or in Excel. Seen below, a magnified plot was created to better study the build up of Ampere during rig penetration and subsequent column installation.



Output for Stone Columns



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