

BAUER

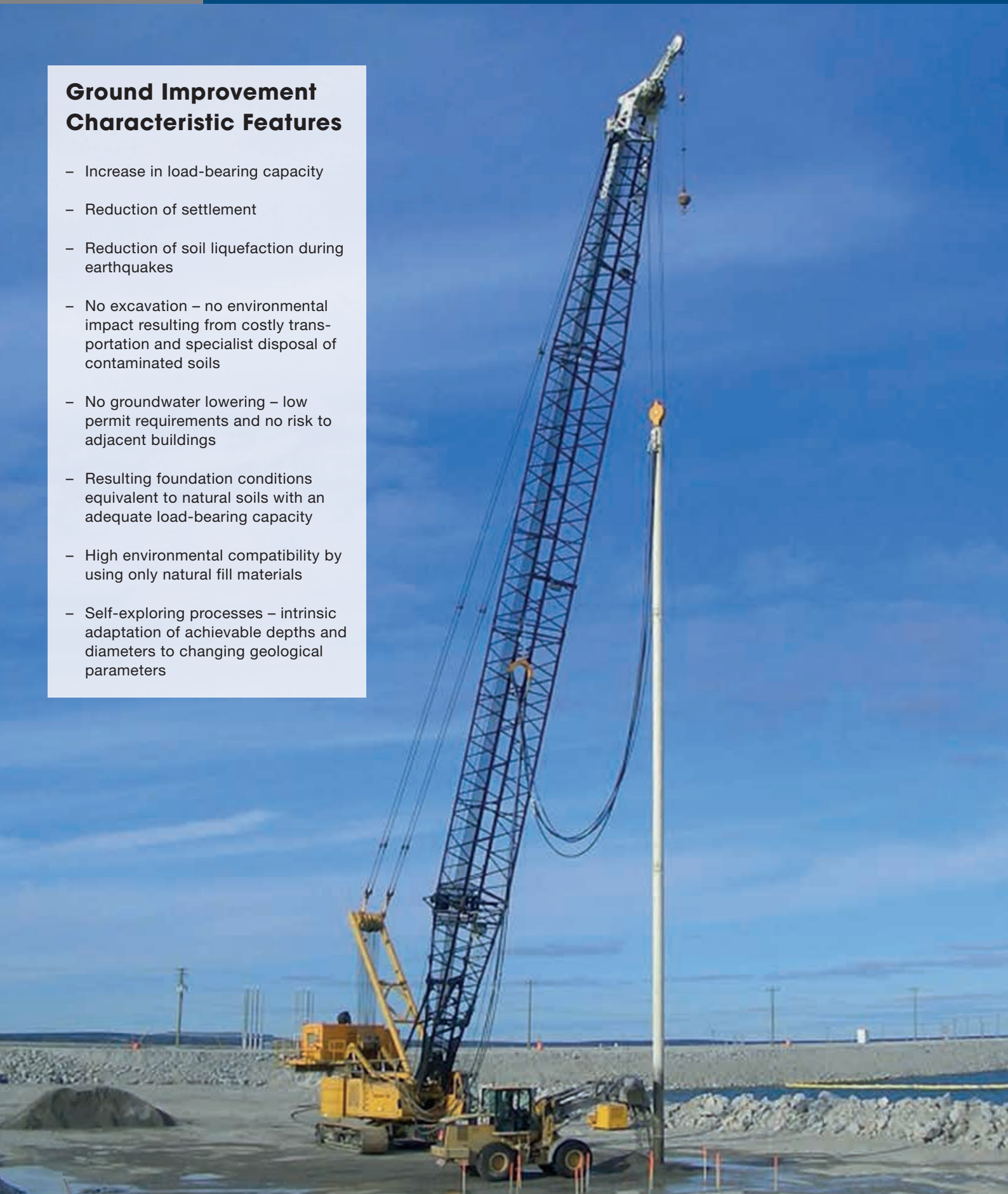
Ground Improvement

Process



Ground Improvement Characteristic Features

- Increase in load-bearing capacity
- Reduction of settlement
- Reduction of soil liquefaction during earthquakes
- No excavation – no environmental impact resulting from costly transportation and specialist disposal of contaminated soils
- No groundwater lowering – low permit requirements and no risk to adjacent buildings
- Resulting foundation conditions equivalent to natural soils with an adequate load-bearing capacity
- High environmental compatibility by using only natural fill materials
- Self-exploring processes – intrinsic adaptation of achievable depths and diameters to changing geological parameters



Milestones

- 1962** Bauer designed and built the first depth vibrator based on a hydraulic drive
- 1971** Collini-Center, Mannheim, Germany, vibrodisplacement stone columns 50,000 m³, depth up to 12 m
- 1975** Las Palmas, Gran Canaria, vibroflotation process 250,000 m³
- 1978** Thuwal, Saudi Arabia, vibroflotation process 160,000 lin m, harbour works – new quay wall, work carried out from pontoon
- 1988** Cardiff, Great Britain, vibrodisplacement stone columns 24,000 lin m, depth 9 - 10 m, road embankment
- 1990** Singapore, vibrodisplacement stone columns 230,000 lin m, depth 9 - 10 m, soil stabilization for a dam
- 1995** Vancouver, Canada, vibroflotation process 1,500,000 m³, depth up to 31 m, working from a pontoon
- 1999** Hohenwarthe Lock, Germany, vibroflotation process 28,000 lin m, depth up to 30 m
- 2004** Palm Jumeirah, Dubai, UAE, vibroflotation process 500,000 m²
- 2005** Peribonka Dam, Canada, vibroflotation process 700,000 m³, depth 35 m
- 2009** Cleveland Clinic, Al Sowah Island, Abu Dhabi, UAE, vibroflotation process 90,000 m², depth up to 10 m
- 2012** Davao City, Philippines, vibroflotation process 100,000 lin m, depth up to 18 m
- 2013** Ocean Reef Island, Panama, vibroflotation process 100,000 m², depth up to 15 m
- 2015** Santo Domingo, Dominican Republic, vibrodisplacement stone columns 100,000 lin m (freely suspended)



Deep Vibro Techniques

In many cases, deep vibro techniques offer a fast and economical method for improving the engineering characteristics of a prevailing subsoil.

**Vibroflotation
VF**



Applicable in non-cohesive to slightly cohesive soils such as sand and gravel, as well as in slag heaps. Suitable for carrying high loads on the improved subsoil, including dynamic loads. Very low foundation settlements. Particularly economical application in fully saturated soils below the groundwater table.

**Vibrodisplacement
VD**

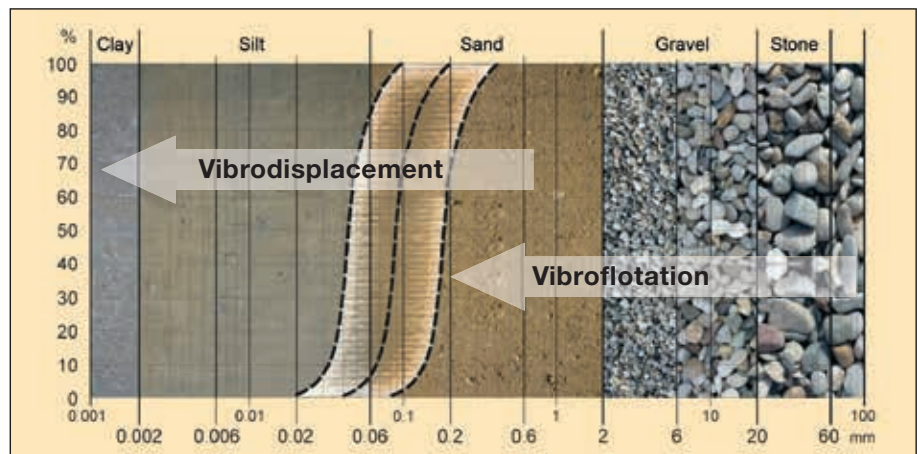


Applicable in mixed-grained soils, such as sandy silt, to cohesive soils with undrained shear strengths of 20 to 80 kN/m² with the introduction of coarse-grained fill material. Suitable for light to medium structural loads.

**Vibro Concrete Columns
VCC**



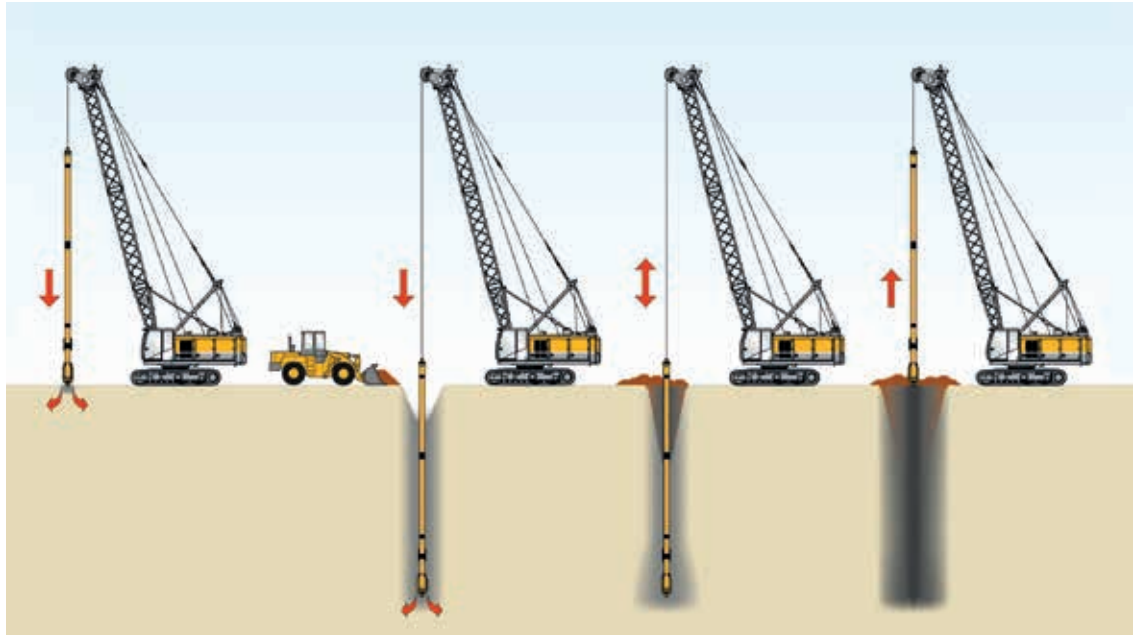
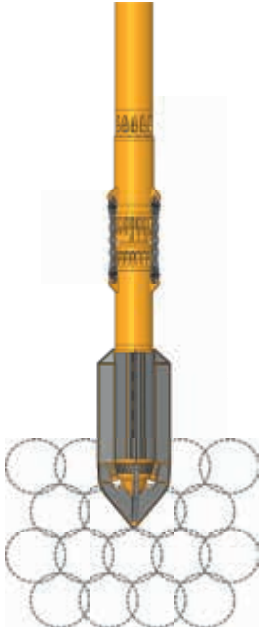
Applicable in soft superficial deposits, including organic material, overlying load-bearing subsoil formations. Suitable for light to medium structural loads. Very low foundation settlements.



Range of applications

Vibroflotation Process – VF

The vibroflotation process (VF) is used to densify soil formations which do not have an optimum relative density - mainly naturally deposited or backfilled granular soils, such as sands and gravels. Under the influence of the horizontal vibrations generated by the oscillating vibrator, the soil particles are rearranged and adopt a denser packing. After reaching the final depth, supported by water jetting, the depth vibrator is gradually retracted creating a densified zone of 2 to 4 m in diameter. The reduction in pore volume is evidenced on the surface by the formation of a settlement crater around the compaction point which must be backfilled with suitable coarse material.



Work sequence for vibroflotation process VF

Backfill material/Flushing medium

Suitable backfill materials are silt-free quarry or river gravels, and silt-free sand-gravel mixtures. Fresh or salt water taken from groundwater or rivers is suitable as flushing medium. In certain ground conditions a combination of water and air flush has also proved successful.



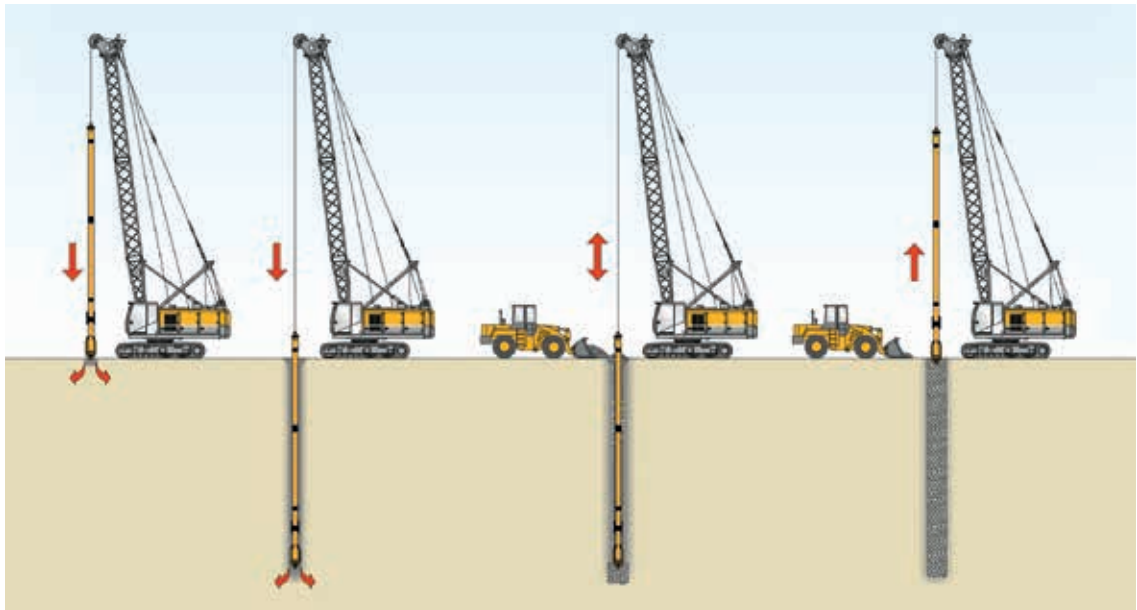
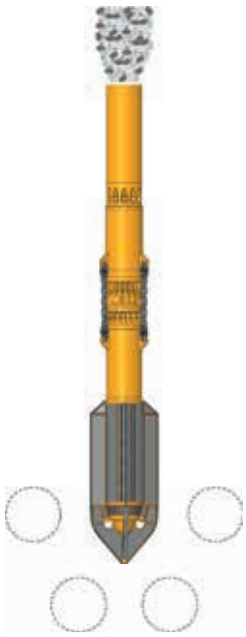
Formation of a crater



Placement of backfill material by a wheeled loader

Vibrodisplacement – VD “Top Feed”

Soils with fines content of more than 10 % can no longer be rearranged and densified by vibrations. Here, the achievable ground improvement consists in the construction of load-bearing stone columns. With the VD wet “Top Feed” process, the depth vibrator is lowered to the specified depth supported by water or water/air flush. Backfill material is then introduced at the ground surface to the annular space created by the vibrator and moves through the annular space to the vibrator tip. By repeatedly raising and lowering the vibrator in steps of around 0.3 to 0.5 m, the backfill material is densified and displaced radially into the surrounding soil until a pre-selected criterion (hydraulic pressure, volume of back fill material) is reached.



Work sequence for the construction of a stone column (vibrodisplacement – wet Top Feed)

Backfill material/Flushing medium

Gravels or crushed stone with a max. grading of 40/60 mm are suitable backfill materials. Water is used as flushing medium. In certain ground conditions a combination of water and air flush has also proved successful.



Backfilling at ground surface wet “Top Feed”

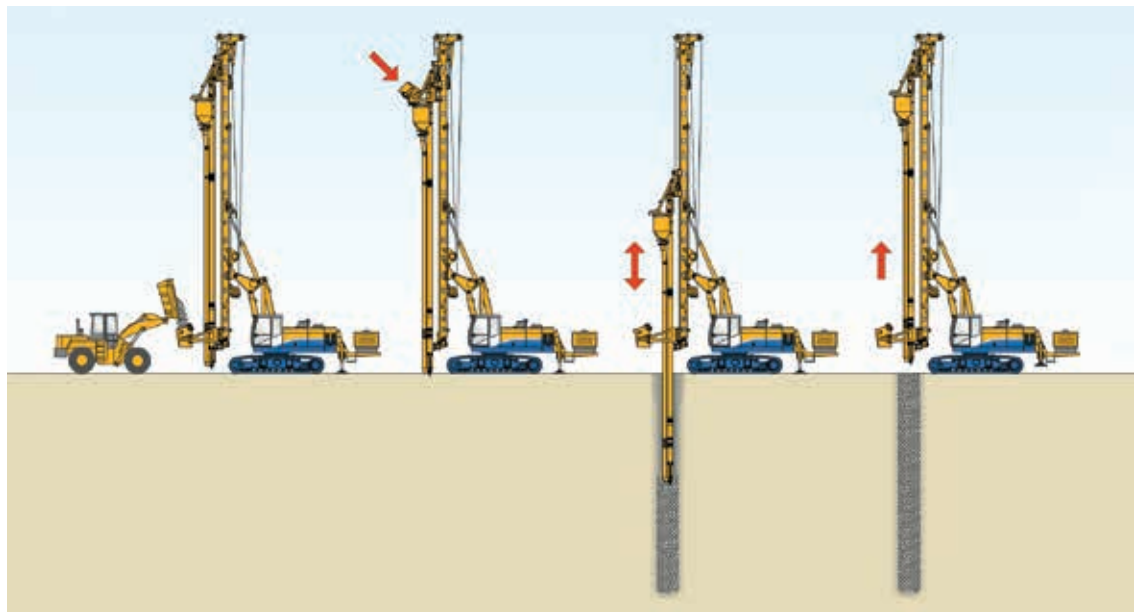
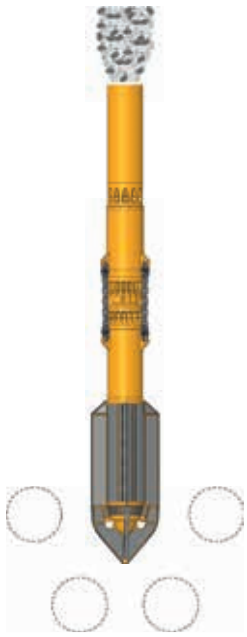


Annulus around vibrator



Vibrodisplacement – VD “Bottom Feed”

Soils with fines content of more than 10 % can no longer be rearranged and densified by vibrations. Here, the achievable ground improvement consists in the construction of load-bearing stone columns. With the VD dry “Bottom Feed” process, a leader-mounted bottom-feed vibrator is lowered to the specified design depth assisted by air flush and positive crowd pressure. The surrounding soil is displaced laterally as a result. The coarse granular backfill material is delivered directly to the tip of the vibrator via a material transfer hopper and a material transfer pipe attached to the front of the vibrator. By repeatedly raising and lowering the vibrator in steps of around 0.3 to 0.5 m, the backfill material is densified and displaced laterally into the surrounding soil. The backfill criterion (volume, pressure) is determined and monitored on an individual basis.



Work sequence for the construction of a stone column with dry bottom-feed vibrator

Backfill material/Flushing medium

Gravels or crushed stone with gradings of 8 - 32 mm and 16 - 32 mm, conditionally also 4 - 32 mm are suitable backfill materials. Air is used as flushing medium.

Pre-boring

For hard desiccated surface layers or highly compacted layers of fill, which may not readily be penetrated by the bottom-feed vibrator, it is recommended to loosen the surface layer with an excavator. If necessary, an auger has to be used to pre-bore at each column position.



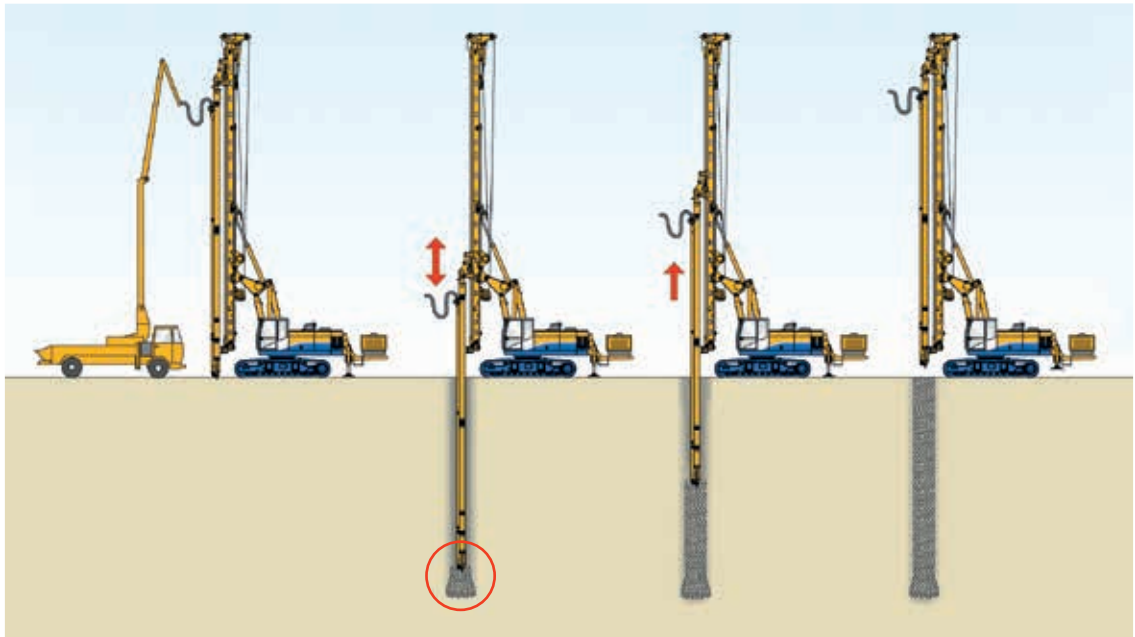
Backfilling via the material transfer unit



Pre-boring operation with auger

Vibro Concrete Columns – VCC

Vibro concrete columns are used when fine-grained soils are unable to form a load-bearing bond with stone columns or the lateral support is too low. The surrounding soil is not, or only marginally, compacted. Non-load-bearing soil layers are “bridged” by rigid load-bearing elements. After reaching a load-bearing foundation level, the vibrator is partially retracted and concrete is placed under constant pressure through the concrete feeder pipe attached to the front of the vibrator into the cavity formed by the vibrator. The column diameter is broadly equivalent to the diameter of the vibrator, but it is also possible to form an enlarged base by surging the vibrator up and down to displace concrete horizontally. VCC columns are classified and designed as unreinforced piles.



Work sequence for the construction of a vibro concrete column VCC

Backfill material

For the construction of VCC columns pumpable concrete is generally used with a consistency range of KR to KF and the strength classification C20/25.



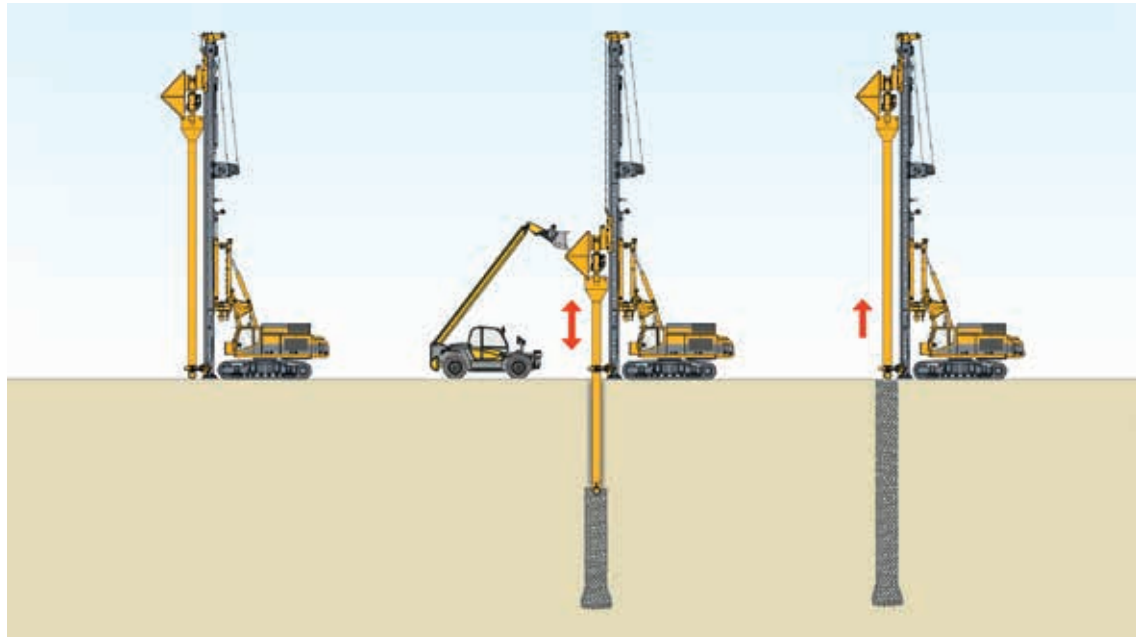
Excavated VCC column



Concrete placement for VCC column

Crushed Stone, Sand and Gravel Columns – VIPAC

The VIPAC process is a technique for constructing sand and gravel columns simply and economically. The displacement work is carried out by vertical vibrations that are generated by a vibro hammer. The high hydraulic power required for this process is provided by the base machines of the RTG RG series and BG PremiumLine machines with auxiliary power pack. The process involves repeated raising and lowering of the vibrator tube. The resulting column diameter is generally slightly larger than the diameter of the tube. A telescopic loader can fill the Vipac system with backfill material even as the tube is vibrated into the ground. A telescopic loader can fill the Vipac system with backfill material even as the tube is vibrated into the ground.



Work sequence for the construction of a stone column with a vibro hammer (VIPAC)

Backfill material/Flushing medium

Gravels or crushed stone with a grading of 0 - 56 mm are suitable backfill materials. For tube lengths in excess of 20 m, air flush can be used to improve the flow of the backfill material.



Filling process



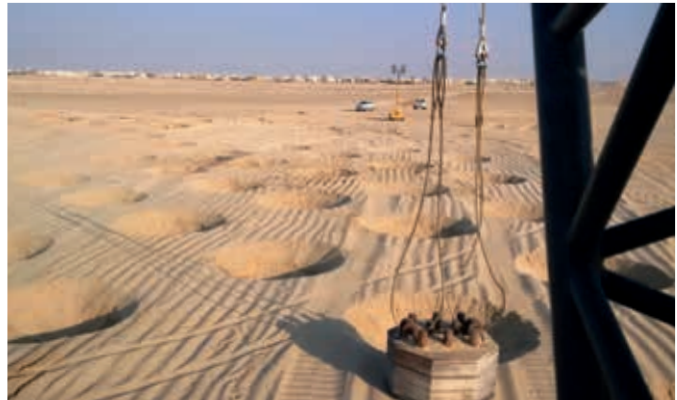
Flaps at the tip of the vibrator tube

Bauer Dynamic Compaction – BDC

BDC (Bauer Dynamic Compaction) is particularly suited for increasing the relative density of non-cohesive granular soils and loose mixed soils with low fines content. The process involves dropping a heavy weight (pounder) repeatedly on the ground at regularly spaced impact points. The kinetic energy released on impact penetrates into deeper soil formations and, as a result of the forced rearrangement of the soil particles, leads to compaction. The degree of compaction depends on the mass of the drop weight, the drop height and the spacing of the impact points. BDC is mainly used on fill, demolition waste and building rubble, as well as soil formations with large voids (karst).



MC 96 duty cycle crane



Compaction point



Drop height 25 meter, pounder weight 20 tonnes

When using MC duty-cycle cranes, fully automatic control of the winch functions in both single and double rope operation is possible, as well as the selection of the number of impact cycles and/or the criteria for the required compaction target.

Treatment depth

It can be estimated using the following formula:

$$\text{Depth [m]} = \alpha \times (W \times H)^{0.5}$$

α = correction factor 0.3 ... 0.6

W = pounder weight in tons

H = drop height in meters

Pounder weights range from 6 – 40 tonnes

Drop heights range from 10 – 30 m

Impact cycles

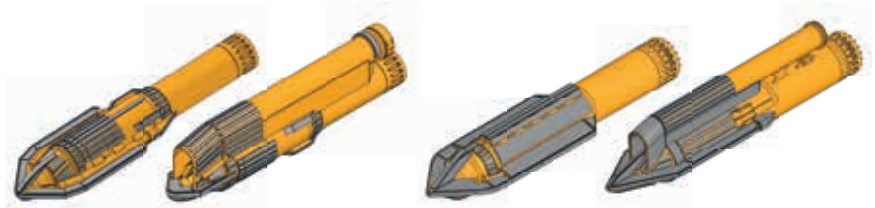
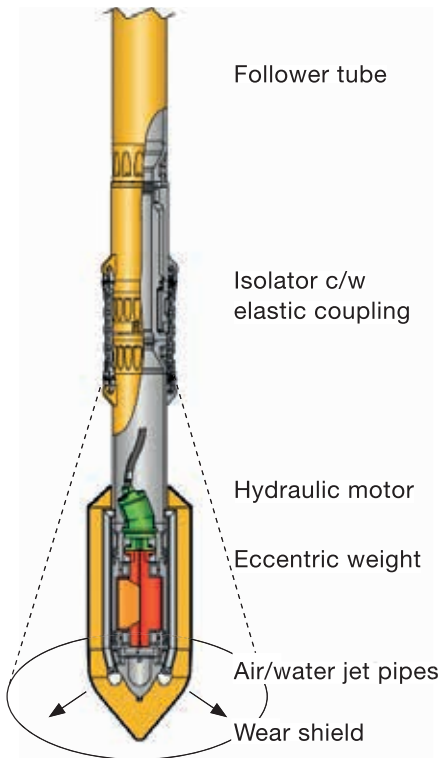
The drop weight can be dropped in a primary, secondary and frequently also tertiary impact grid. The primary grid (largest grid spacings) is used for deep compaction.

The secondary and tertiary grids are used for the compaction of shallower soil formations. The process is completed in a final pass (“ironing pass”) by pounding the layers at the surface.

Technical Specifications

Depth Vibrator TR 17 and TR 75

		TR 17	TR 75
Centrifugal force	kN	193	313
Eccentric moment	Nm	17	75
Amplitude at tip of vibrator	mm	± 6/12	± 11/22
Speed/frequency	rpm/Hz	3,215/53	1,950/32
Power output	kW	96	224
Overall weight incl. follower tube (VF)	kg	ca. 6,700 (25 m)	ca. 15,300 (50 m)
Penetration depth	m	up to 25	up to 50
Diameter of pre-bore if required	mm	~ 550	~ 750



Depth vibrator TR 17 Standard / c/w material transfer pipe **Depth vibrator TR 75** Standard / c/w material transfer pipe

The horizontal vibrations of the depth vibrator are generated by a hydraulic motor driving an eccentric weight, housed inside the vibrator section. The length of the depth vibrator can be adjusted to suit the prevailing site conditions by the addition of follower tubes. Fully customized BAUER base machines provide the necessary hydraulic power without the need for auxiliary power packs. For use with external base machines, a suitably sized BAUER hydraulic power pack is recommended.

Hydraulic power packs

		HD 250	HD 470
Depth vibrator		TR 17	TR 75
Power output	kW	176	261/298
Hydraulic pressure	bar	320	330
Oil flow	l/min	250	470



Hydraulic power pack HD 250

Vibroflotation VF



MC Duty-cycle cranes



Crane with power pack



BG



RG

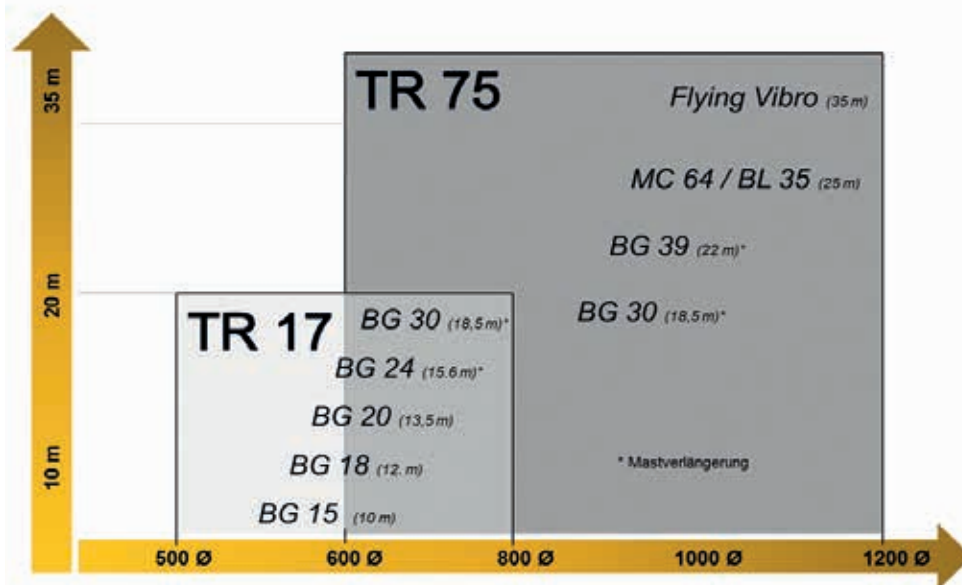
	MC 64	MC 96	MC 128
Depth vibrator	TR 75	TR 75	TR 75
Penetration depth max.	27 m	38 m	47 m
Boom length	33 m	45 m	54 m
Engine power	455 kW	570 kW	709 kW
Line pull	see load charts (MC Series brochures)		
Water pump	1,200 l/min. @ 20 bar		

Vibrodisplacement VD



Examples with BG PremiumLine

	BG 15 – BG 39
Depth vibrator	TR 17 – TR 75
Penetration depth max.	10 m – 22 m
Engine power	205 – 433 kW
Crowd pressure max. (approx.)	110 kN
Line pull	140 – 460 kN
Compressor (recommended performance)	20 m ³ /min @ 15 bar



Operating conditions for vibrodisplacement VD (stone columns)

"Flying Vibro" on MC 96

B-Tronic

As a central control unit, the B-Tronic monitor supports the machine operator with real-time visualization of all relevant production and machine operating parameters. The locally stored data can subsequently be downloaded for evaluation in the B-Report. For operation on external machines a mobile version is available.

Production data:

- Production time
- Depth
- Volume of backfill material
- Energy consumption (hydraulic pressure of depth vibrator)

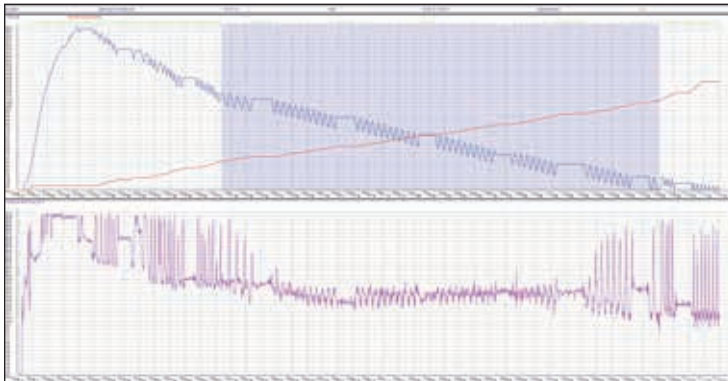
The stored data can be downloaded onto a storage device or transferred by radio transmission (DTR module - software Web-BGM).

B-Report

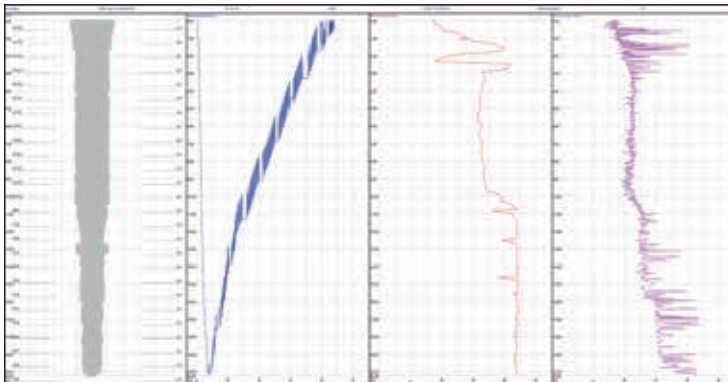
The evaluation and display of production data sets can be produced in the B-Report for each column or compaction point. Depth or time diagrams, as well as daily and weekly reports are available.



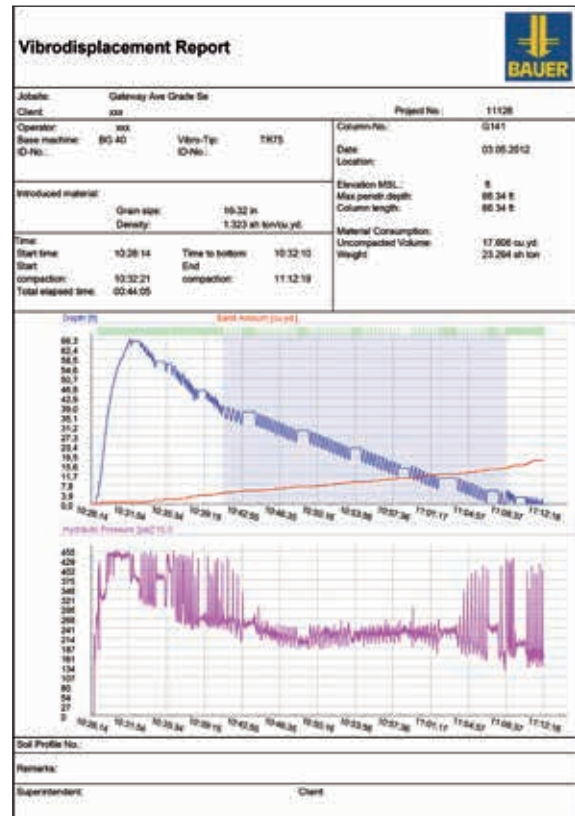
B-Tronic monitor



Time diagram



Depth diagram



Individual column report

The relative densities achieved on completion of the ground improvement works can be verified either by dynamic or static cone penetrometer tests or by plate bearing tests.

The load-bearing capacity of vibro concrete columns is generally verified by load tests on individual columns.

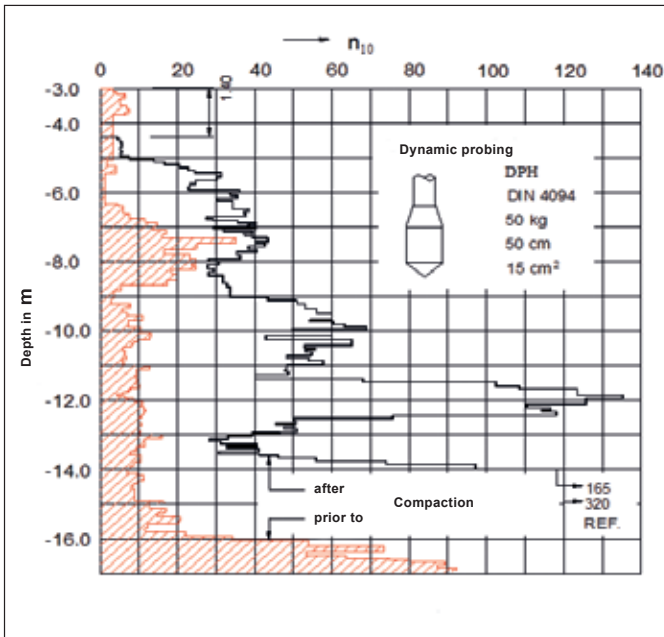
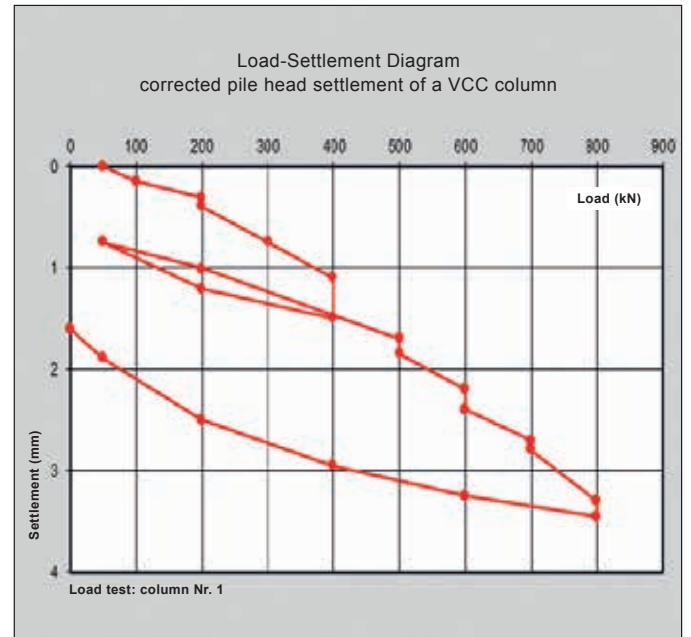


Diagram Dynamic Sounding



Load-Settlement Diagram



Load test



Mobile static cone penetrometer unit



Process



bma.bauer.de



BAUER Maschinen GmbH
BAUER-Strasse 1
86529 Schrobenhausen
Germany
Tel. +49 8252 97-0
bma@bauer.de
www.bauer.de

Design developments and process improvements may require the specification and materials to be updated and changed without prior notice or liability. Illustrations may include optional equipment and not show all possible configurations. These and the technical data are provided as indicative information only, with any errors and misprints reserved.