

Amsterdam Bangkok Bratislava Lille London Singapore Stockholm

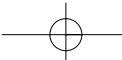
Ground improvement

MebraDrain® BeauDrain® AuGeo®



Cofra

Building worldwide on our strength



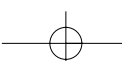
MebraDrain



BeauDrain



AuGeo





Ground improvement

Cofra specialises in ground improvement techniques that are used world-wide to improve the load bearing capacity and stability of soil, to enable construction of embankments and other structures. Given that the available space for infrastructure continues to decrease and construction time becomes ever shorter, the need for technologies that expedite the consolidation of soft soils become more necessary. Cofra offers the entire ground improvement process in-house, from design and manufacture to installation and construction, all in accordance with quality control procedures.



MebraDrain®

MebraDrain is a vertical drain, developed by Cofra to speed up the consolidation process in soft soils, MebraDrain has sophisticated mechanical and hydraulic properties, which guarantee that the system will function under the majority of circumstances. MebraDrain guarantees that consolidation is expedited and soil stability is greatly enhanced. It has proved its quality time and again in hundreds of projects throughout the world.



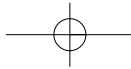
BeauDrain®

Cofra has recently developed vacuum drainage system, that has already been successfully applied to a large number of soil improvement projects. This is a system of horizontal drains connected to the vertical drains, which extracts the ground water by vacuum to a discharge point. This system can replace the need for surcharge layers, or be used in combination with surcharge to give a quicker rate of consolidation. The process uses the latest technology and best quality materials, which combine to give an efficient and effective design.

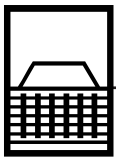


AuGeo®

The AuGeo pile foundation system eliminates any type of long term settlement. This enables embankments and other structures to be constructed immediately as instability as a result of increased groundwater pressure is avoided. The AuGeo system works by application of Cofra's patented installation techniques, with the proven construction of load transfer layers. Using Cofra installation methods it is possible to achieve hitherto unobtainable production rates, combined with an automatically recorded quality control.



Vertical Drainage



MebraDrain®

Where and when should vertical drainage be used?

Ground improvement using vertical drains is used where compressible soils are saturated, such as clay and peaty soils. These kinds of soils are characterized by a particularly weak structure and a large pore space, which is usually filled with water (porewater). When a heavy load, such as a road embankment, or other structure is placed on top of a clay or silty clay soil, considerable settlement may occur due to squeezing out of excess porewater, the soft soil consolidates. This kind of settlement often causes serious construction problems.

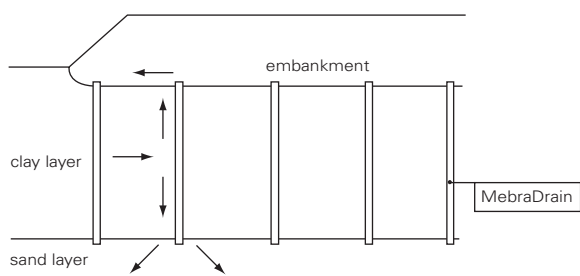
MebraDrain: a solid ground improvement

The load placed on the soil is initially carried by excess pressure in the porewater. This increases the porewater pressure. If the soil is not very permeable, the porewater pressure will decrease over a long period of time because the porewater is only able to

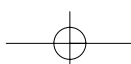
drain away very slowly. Increased porewater pressure can cause subsoil instability, which can lead to development of slip planes. This instability decreases the allowable rate of fill placement in embankments. A vertical drainage system reduces construction time, through giving improved dissipation of excess pore water pressure and reduces the risk of instability problems.

Vertical drains accelerate consolidation

In order to expedite the settlement process and reduce pore water pressure it is necessary to shorten the flow path of the pore water through the soil. This can be achieved by placing vertical drains at regular spacings in the soil. The presence of this drainage system enables the over-pressurised pore water to flow to the nearest drain horizontally and escape freely. By using vertical drains the time needed for the consolidation process can usually be reduced from decades to one year or less. Using a vacuum system the atmospheric pressure can be used instead of or in combination with a surcharge. Vacuum may also be used where a surcharge may cause instability due to the increased height.



Vertical drainage

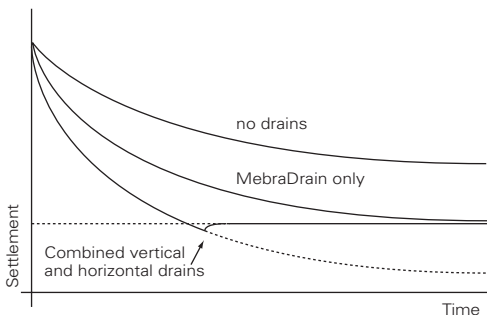




Soil improvement using vertical drains has already been used for many civil engineering projects.

Frequently occurring examples are:

- construction of roads, railways, airports and dykes.
- land reclamation projects
- harbour construction
- residential and industrial sites
- pre-loading of sites for storage
- degassing land fills



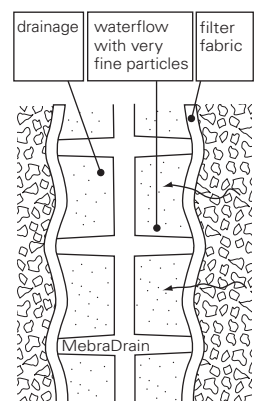
MebraDrain

MebraDrain is a pre-fabricated drain strip that is highly suited to vertical drainage. The flexible core is made out of high-quality polypropylene. Both sides of this core has grooves which run its entire length through which the water can flow unhindered. This core is wrapped in a strong and durable filter made out of non-woven polypropylene, which combines high water permeability with excellent filtration characteristics. MebraDrain is available with two different

cores. Type MD7007 has a crenellated core that is extremely resistant to high soil pressures. Type MD88 has a herringbone-shaped core that is highly flexible and is therefore well suited to areas where large relative settlement occurs. MD88 is made in a number of versions that are suitable for applications up to 65 m deep. Both types are available with a filter that can be adjusted to the soil condition. MebraDrain is constantly monitored for quality during the production process.

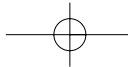
Ground stabilisation throughout the world

In a short space of time, MebraDrain has become one of the most frequently used vertical drainage systems in the world. The varied application of MebraDrain in large numbers of projects throughout the world provides clear proof of the faith that clients and consultants have in this product. World-wide, more than 300 million metres of MebraDrain have by now been installed. By applying MebraDrain you can be assured of high quality product.



Filter

Building worldwide on our strength



The advantages of the MebraDrain system are:

- small disturbance of the different soil layers
- guaranteed water drainage, even at high soil pressure and distortion
- core and filter membrane can be adapted to specific soil conditions
- shorten consolidation period by using small drain spacing
- fast installation: average of 8,000 metres per installation unit
- no water required for installation
- installation is possible to a drain depth of 65 m
- easy-to-monitor installation

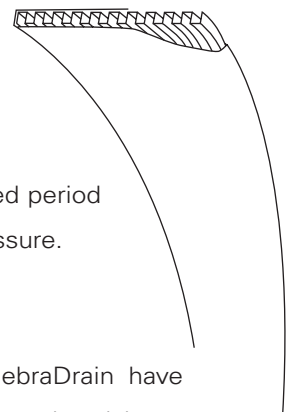
Filter membrane

The filter membrane has an important key function. It consists of thermally-bonded polypropylene fibres with a random structure, known by the tradename Typar. Contrary to woven materials that provide a straight passages through the filter structure, through which soil particles can force their way, the MebraDrain filter has a random structure which enables the filter to restrict the movement of the soil particles and to prevent clogging. In general a filter is required that prevents clogging by soil particles but that is sufficiently permeable. MebraDrain's filter structure meets these requirements. When the compressible subsoil contains horizontal soil layers that

are very permeable, pressurised pore water will seek out these layers and use this route to the closest drain. In order to optimise the use of these permeable layers the permeability of the filter must be at least as high as the permeability of these layers. MebraDrain has a filter with a high relative permeability level enabling effective drainage in layered soils.

Other important requirements that a filter needs to meet are:

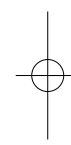
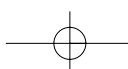
- high mechanical strength
- high resistance to bacteria and micro-organisms
- resistant to acids, solvents, etc.
- no loss of strength over a prolonged period
- creep resistant also under high pressure.



Laboratory tests

The properties and functions of MebraDrain have been researched in well-known independent laboratories. Reports of these tests, where the drainage capacity of the drain both in elongated and buckled form is recorded, are available. Extensive reports are also available of field tests and finished projects, as well as a calculation program for calculating the most economical drain spacing.

Building worldwide on our strength





Vertical Drainage

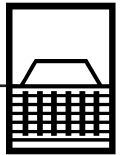
MebraDrain®

All mechanical Properties are average values. Standard variations in mechanical strength of 10% and in hydraulic flow and pore size of 20% have to be allowed for All information, illustrations and specifications are based on the latest product information available at the time of editing. The right is reserved to make changes at any time without notice.





Look for the most recent information at www.cofra.com

*) These type of drain are produced in the Netherlands under the KOMO-certificate

***) Test machine 2 was used (sample with a cell membrane) during 7 days



MebraDrain Technical Specifications

Characteristics		Test method	Unit	MD7007*	MD88M*	MD88H*	MD88HD
Core	configuration						
	Raw material			PP	PP	PP	PP
Filter	spunbonded nonwoven			PP/PES	PP/PES	PP/PES	PP/PES
Weight		ASTM D3774	g/m	75	70	85	110
Width			mm	100	100	100	100
Thickness		ASTM D5199	mm	3.0	3.0	3.5	5.0

Mechanical Characteristics

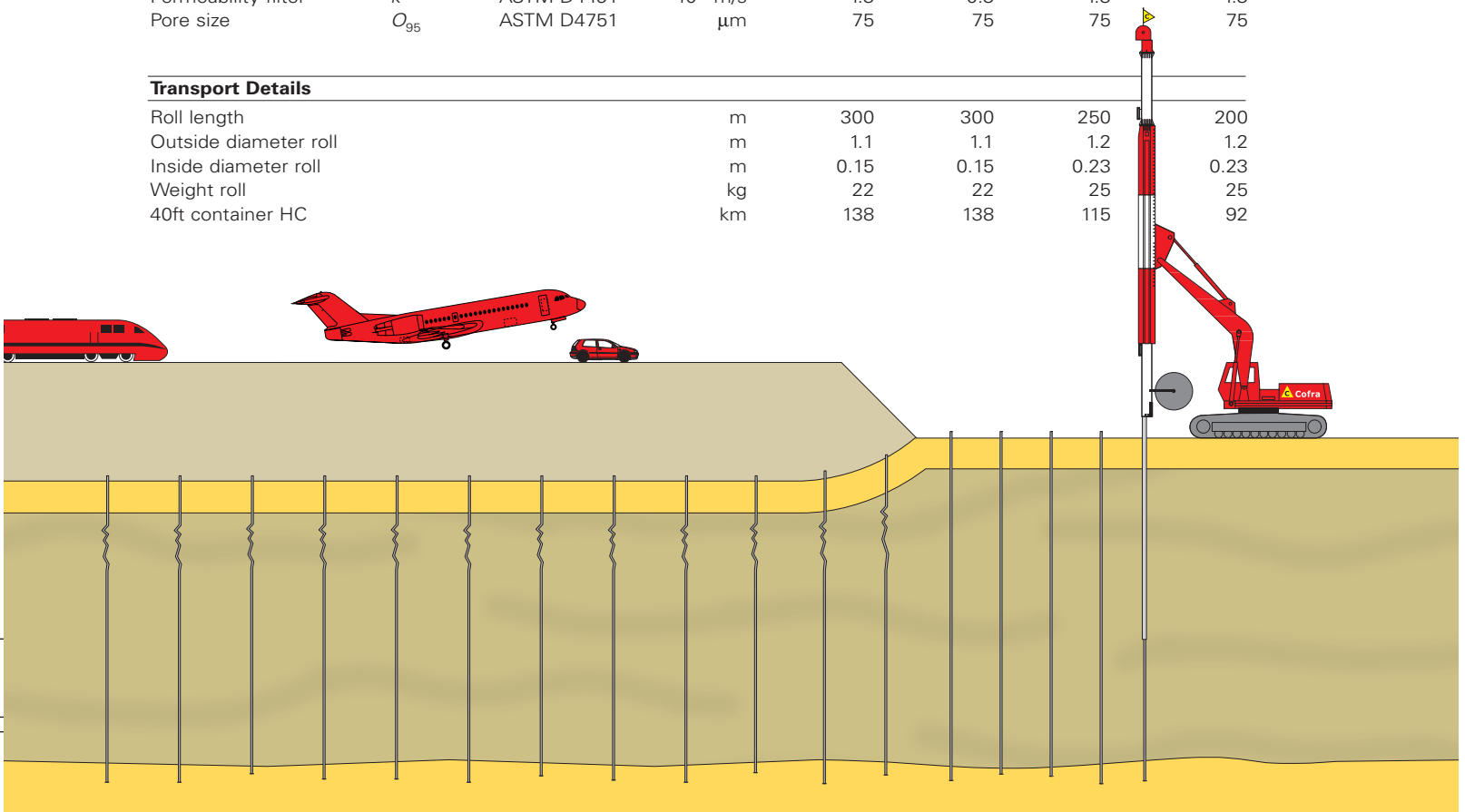
Tensile strength drain	F_d	EN/ISO 10319	kN	2.2	1.8	2.2	4.2
Strain		EN/ISO 10319	%	60	40	60	60
Strain at 0,5 kN	$\epsilon_{0,5 \text{ kN}}$	EN/ISO 10319	%	2	2	2	1.5
Grab strength filter		ASTM D4632	N	970	580	970	970
Bursting Strength		ASTM D3785	kPa	1000	900	1000	1000
Tear strength filter		ASTM D4533	N	270	180	270	270

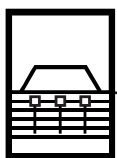
Hydraulic Properties

Discharge capacity	$q_{w(10,0.1)}$	EN/ISO 12958**	$10^{-6} \text{ m}^3/\text{s}$	1.1		0.8	2.7
Discharge capacity	$q_{w(300,0.1)}$	EN/ISO 12958**	$10^{-6} \text{ m}^3/\text{s}$	49	50	70	155
Discharge capacity buckled	$q_{wb(200,0.1)}$	EN/ISO 12958**	$10^{-6} \text{ m}^3/\text{s}$	60	55	82	130
Discharge capacity	$q_{w(500,0.1)}$	EN/ISO 12958**	$10^{-6} \text{ m}^3/\text{s}$	1	14	20	25
Permitivity filter	ψ	ASTM D4491	s^{-1}	0.3	0.3	0.3	0.3
Permeability filter	k	ASTM D4491	10^{-4} m/s	1.3	0.3	1.3	1.3
Pore size	O_{95}	ASTM D4751	μm	75	75	75	75

Transport Details

Roll length		m	300	300	250	200
Outside diameter roll		m	1.1	1.1	1.2	1.2
Inside diameter roll		m	0.15	0.15	0.23	0.23
Weight roll		kg	22	22	25	25
40ft container HC		km	138	138	115	92





BeauDrain[®]

v a c u u m c o n s o l i d a t i o n



Vacuum consolidation was introduced for the first time by W. Kjellman, the inventor of the vertical pre-fab drain. In a report that was presented during a soil mechanics conference (1952), he describes how this kind of system works. Since then, vacuum drainage has been used with varying degrees of success, particularly with constructions where there was a high risk of instability. The system works as follows: instead of applying and then removing a fill surcharge, surcharge is created in the soil using a vacuum pump. This relative surcharge, that can reach 80 kPa, simulates a load that corresponds with the load of a 4-metre thick sand fill. The increase in costs associated with the supply and removal of sand have resulted in vacuum consolidation providing a competitive alternative.

Operating principle

Settlement is created by an increase in the particle tension as a result of increased loads or a lowering of the groundwater table. The decrease of the water pressure is equal to the increase of the particle pressure. The total soil pressure remains the same for vacuum drainage so that instability does not occur. In the case of traditional embankments, the pore water present in the soil initially carried the load. A certain amount of instability occurs leading to distur-

tions of the subsoil and increased settlement. Vacuum drainage is created by providing the soil with an intricate drainage system that is connected to a vacuum pump. The soil that needs consolidating is isolated from its environment by fitting an impermeable liner or a layer of impermeable soil at ground level. The surcharge simulates an active atmospheric pressure that can rise to a maximum of 80 kPa. This surcharge is only active up to the installation depth of the vertical drains. Beneath it there will be no change at all in the sub soil. An advantage of vacuum drainage against surcharge is avoiding instability during construction. Embankment construction causes soil movements which are the result of high water pressures. Soft soil is pressed to the outside, leading to a large amount of settlement and the necessity for more fill material.

Vacuum consolidation sucks the substrate together like a vacuum pack of coffee. Excess water pressure is avoided. Active pressure will not increase through the atmospheric pressure, but because of a surcharge from the groundwater outside the vacuum zone, soil from outside the area that has to be consolidated will move inwards rather than outwards. The consequence will be that reduced amounts of settlements are accompanied by a larger increase in the



sliding resistance of the soil. Combined with a pre-load, vacuum drainage provides a powerful soil improvement technique, which makes it possible to carry out soil construction quickly and safely.

BeauDrain, an innovative method

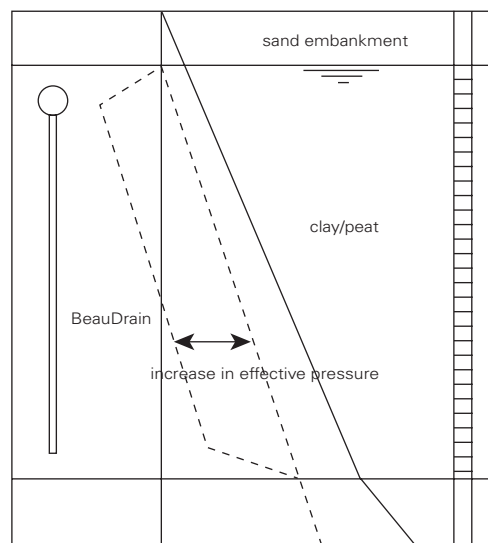
The new BeauDrain concept is an innovative combination of the already proven techniques mentioned below for consolidating highly compressible layers, namely:

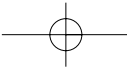
- vertical drainage
- vacuum consolidation
- surcharge (optional)

The BeauDrain system consists of a series of drainage screens. Each screen consists of a row of vertical drains, of which the top part is directly connected to a horizontal collector drain. A liner placed on the top of the horizontal drain assures a seal between the atmosphere and the drainage screen. Each collector drain is situated 1-2 m under the top of the compressible layers and is connected to a vacuum pump. In order to install the BeauDrain system a multi-functional plough has been developed that cuts through the soil with minimal disturbance.

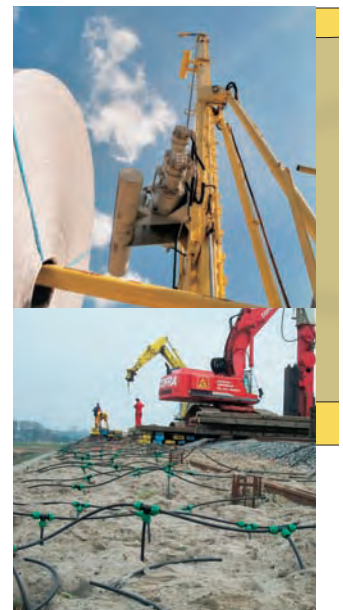
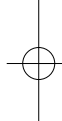
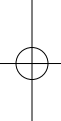
There are many advantages to the BeauDrain system:

- a short installation period and a clean work platform after installation
- no soil is dug out, which avoids any potential damage resulting from horizontal soil deformation as a result of de-pressurising and insufficient fill
- no supply of drainage sand or removal/storage of withdrawn soil
- installation can be at various working depths.
- an increase of the effective pressure occurs as a result of the vacuum pressure, decreasing the risk of instability when continuously filling

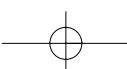


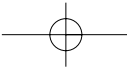


- the existing soil body is used as a sealing medium, making the use a surface liner redundant.
- the work platform is immediately and permanently accessible for other operations after installation
- the screen configuration can be adapted to the soil type that is to be consolidated
- horizontal influence with ongoing filling decreases considerably
- considerable reduction in secondary and uneven settlement forms part of the benefit of the BeauDrain system.



Building worldwide on our strength



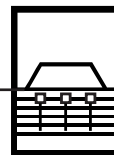


BeauDrain®

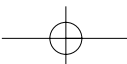
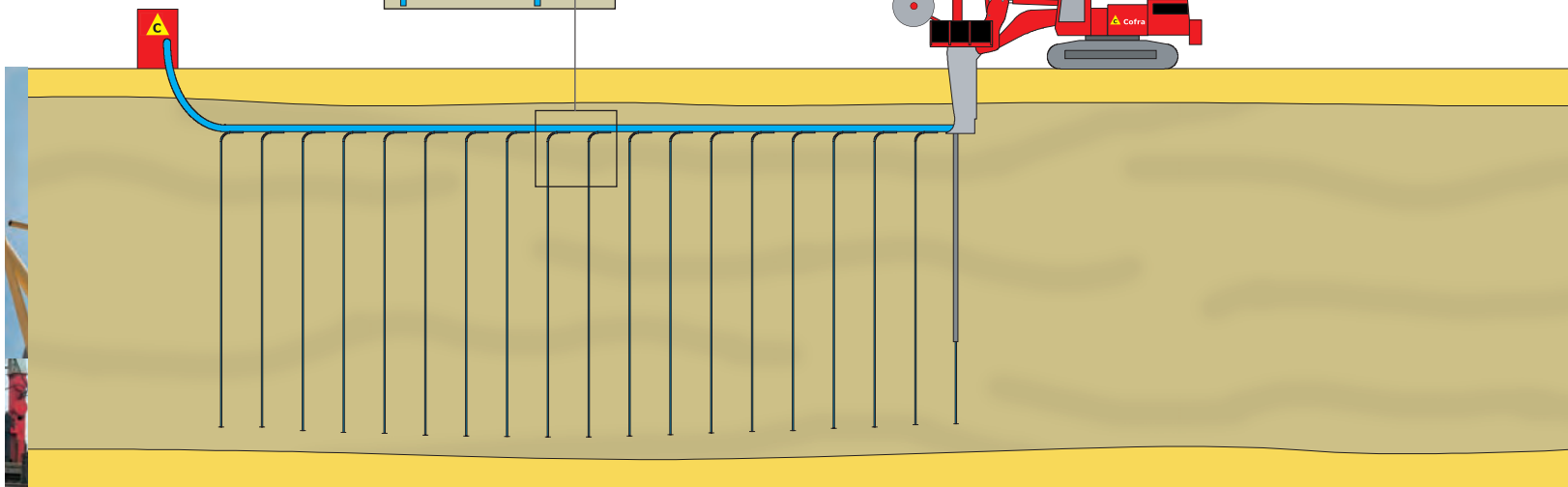
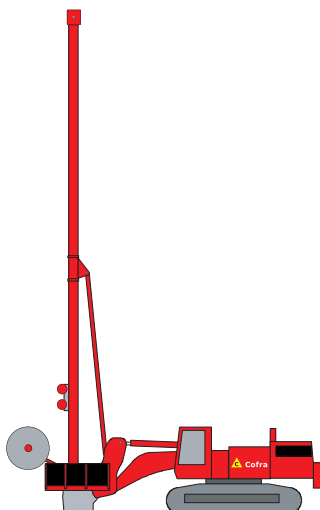
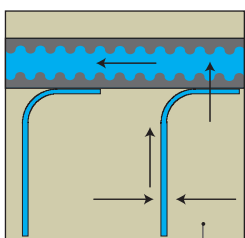
All properties are average values. Standard deviation is 10% for mechanical properties and 20% for hydraulic properties.

All information, illustrations and specifications are based on the latest product information at the time of printing. We reserve the right to make any changes at any time without notice. Please visit www.cofra.com for the most up-to-date information.

BeauDrain technical specifications



Characteristics	Unit	Value
Horizontal drain material		PE
External diameter	mm	100
Internal diameter	mm	80
Filter material		PP 7000
Vertical drain material		PP
Drainage capacity	10 ⁻⁶ m ³ /s	70
Fill	m	1 to 15
Effective vacuum	kPa	50 to 150



embankment on piles



AuGeo[®]

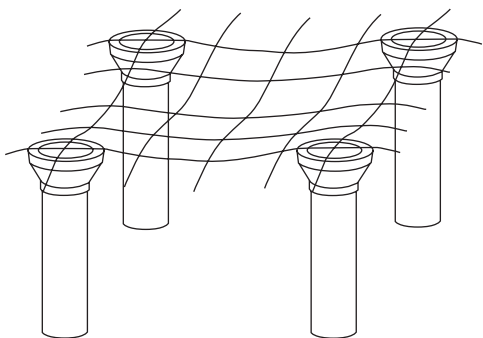


New foundation technology

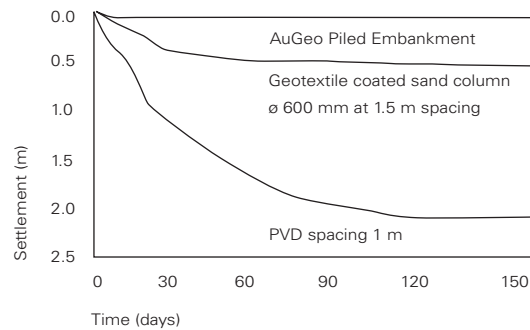
The rapid construction of low-maintenance infrastructure on highly compressible soils requires new foundation techniques, which can be applied in an economically viable way and on a large scale. Cofra's AuGeo system was developed to meet this requirement, making it possible to deliver settlement-free soil foundation in a very short period of time. This concept has been successfully introduced internationally.

AuGeo, a settlement-free solution

The AuGeo system consists of a large number of piles formed in the ground, they are set out in a square or rectangular grid. The piles are provided with an enlarged pile head and foot bearing on the deeper load bearing strata. The pile head takes the load from a "load transfer layer" which consists of a layer of aggregate packed between two layers of geogrid with very low elasticity. This load transfer



layer ensures an even distribution of forces over the piles. Pile intervals are dependant upon the applied top load. Piled embankments are often used in projects where the construction must be delivered free of settlement to a tight time schedule.



Test field AuGeo system

The settlement-free character of the AuGeo system is very important, especially in areas where buildings or other infrastructure are present which must not experience vibration and settlement damage.

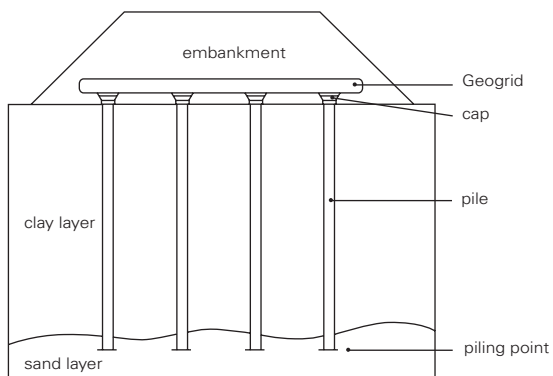
The AuGeo systems is typically used when:

- laying new roads and railways
- widening of existing roads and railways
- making road foundations in areas of expansion
- making production floor foundations that carry with high surface loads



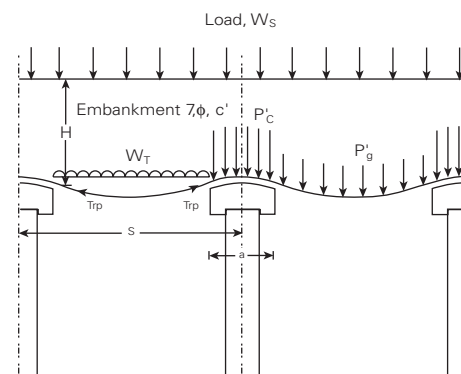
Calculation of the AuGeo system

In calculating this top load Cofra leaves nothing to chance. All possible loads are calculated precisely and checked. In order to calculate the geogrid a combination of a number of tried-and-tested calculation methods are used. The geogrid can be designed using the CUR report 2002-7 *“Strengthened aggregate layer on piles”* and the British requirements set out in BS8006, *“Code of practice for strengthened/reinforced soils and other fills.”* In addition, recommendation 6.9 of the EBGEO *“Bewehrte Erdkörper auf punkt- oder linienförmigen Traggliedern”* provides assistance in how the geogrid can be calculated. Furthermore, the end element method (Plaxis) is used to perform checking calculations. Cofra can provide the BS8006 calculation method in the form of an Excel spreadsheet.

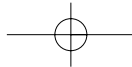


Installation of the AuGeo system

The AuGeo system piles are installed from ground level. A Cofra MY-200 stitcher is used to drive a 220 x 10 mm steel tube into the ground including a foundation plate which serves as an enlarged pile toe.



Placement of the tubes is carried out at a steady speed, minimizing disturbance to the substrate and the piles already installed. Within the steel tube a synthetic tube is placed. AuGeo pillings can be used to depths of around 25 m. For three-fourths the synthetic tube is pumped full of concrete. The synthetic tube remains in the soil when the steel casing tube has been withdrawn. It is cut to length, fitted with a basket of reinforcement and a circular pil head. The tube is then pumped filled with concrete. The space between piles is filled with sand. Compressing



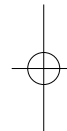
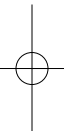
between pillings is not necessary. Given a good and stable production floor it is possible to produce up to 20 piles per hour.

As well as continual visual inspection, quality control is provided during the installation process. During installation of the casing, the penetration depth and the penetration resistance are automatically recorded in the Stitcher. This data is printed out and creates a record for each pile, which makes it possible to determine whether or not the pile is in fact resting on the load-bearing layer.

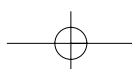
Advantages of the AuGeo system:

- relatively cheap
- fast installation
- vibration-free and low-noise installation
- no environmental influences
- no settlement time
- high production rates possible
- no instability risk

AuGeo: a unique product for a range of application possibilities, with the quality guarantee of skilled installation.



Building worldwide on our strength





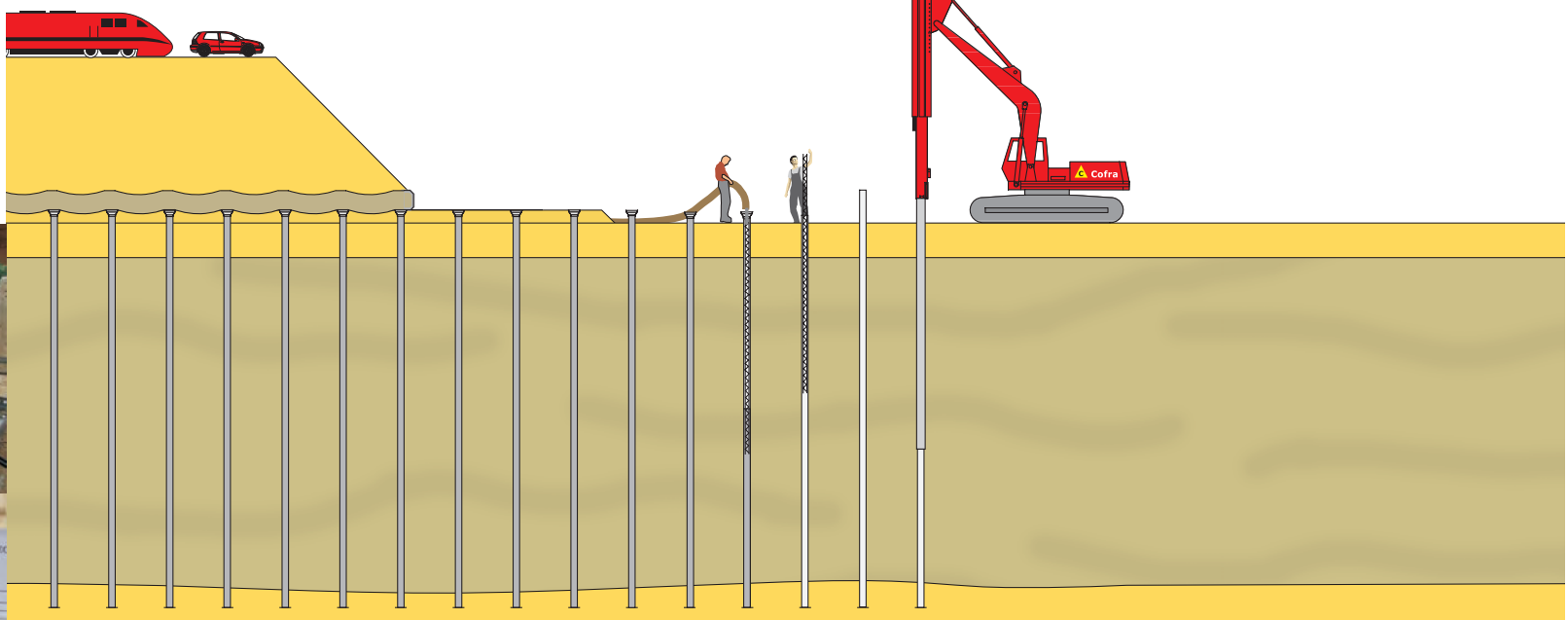
All properties are average values. Standard deviation for mechanical properties is 10% and 20% for hydraulic properties.

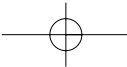
All information, illustrations and specifications are based on the latest product information at the time of printing. We reserve the right to make any changes at any time without notice. Please visit www.cofra.com for the most up-to-date information.

AuGeo technical specifications



Characteristics	Unit	Value
Tube material		PE
External diameter	mm	178
Internal diameter	mm	150
Pile length	m	2 to 15
Pile head	mm	Ø 300
Pile tip	mm	230x230
Embankment height	m	1 to 7
Pile load bearing capacity	kN	150
Maximum load	kN	350
Geogrid tensile strength	kN/m	50 to 350
Geogrid strain	%	< 4
Reinforcement Fe52	mm	Ø 6
Reinforcement length	m	1 to 6
Concrete		B25





Ground improvement

MebraDrain[®], vertical drainage



Ground improvement sophisticated and proven, using sophisticated drainage technology;

- Fast and clean installation
- Effective drainage even at high soil pressure and distortion
- Small disturbance at the foundation level.
- Installation to great depth possible
- Installation at small spacings gives rapid consolidation
- Prevents future settlement damage

BeauDrain[®], vacuum consolidation



Innovative vacuum consolidation through advanced use of materials gives;

- Short consolidation time
- Reduced porewater pressure during the embankment construction
- No pollution during the installation (this does also apply for ordinary vertical drainage)
- Horizontal drainage layer in embankment is not necessary (N.B. This layer is substituted by the drainage tubes)
- No geomembrane cover necessary

AuGeo[®], embankment on piles



Fast embankment construction with the AuGeo system has many advantages;

- No stability problems during placement of embankment.
- Maintenance free, with no secondary settlement.
- Sound and vibration free during installation.
- An ideal solution when used together with reinforced earth embankments.

09/05



Cofra BV

Zuider IJdijk 58, 1095 KN Amsterdam - The Netherlands

Postbus 94900, 1090 GX Amsterdam - The Netherlands

Tel: +31 (0)20 693 45 96

Fax: +31 (0)20 694 14 57

E-mail: mail@cofra.com

www.cofra.com

