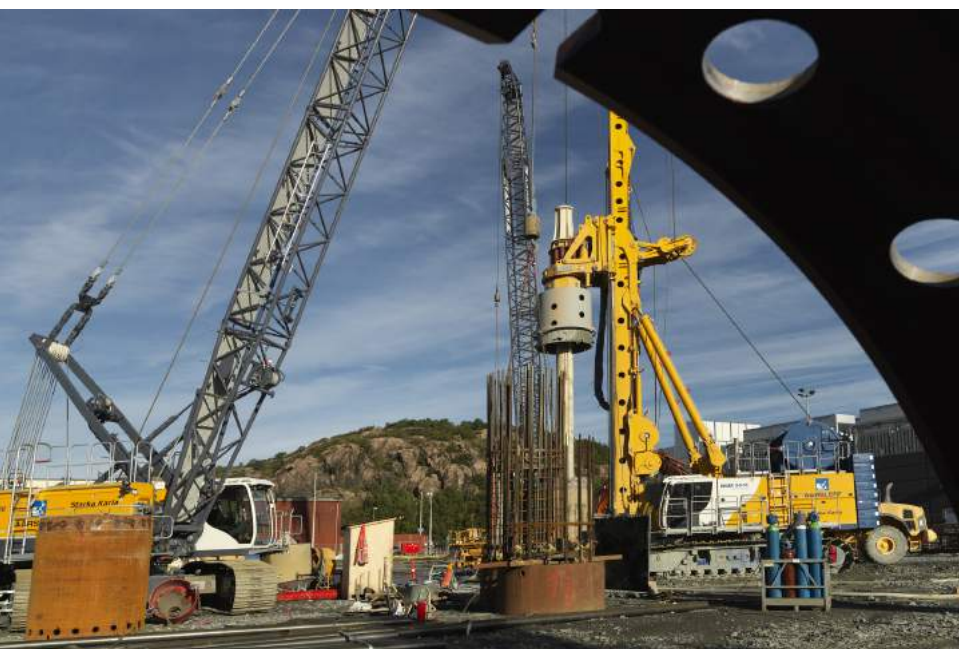


Aarsleff Ground Engineering Profile



AARSLEFF

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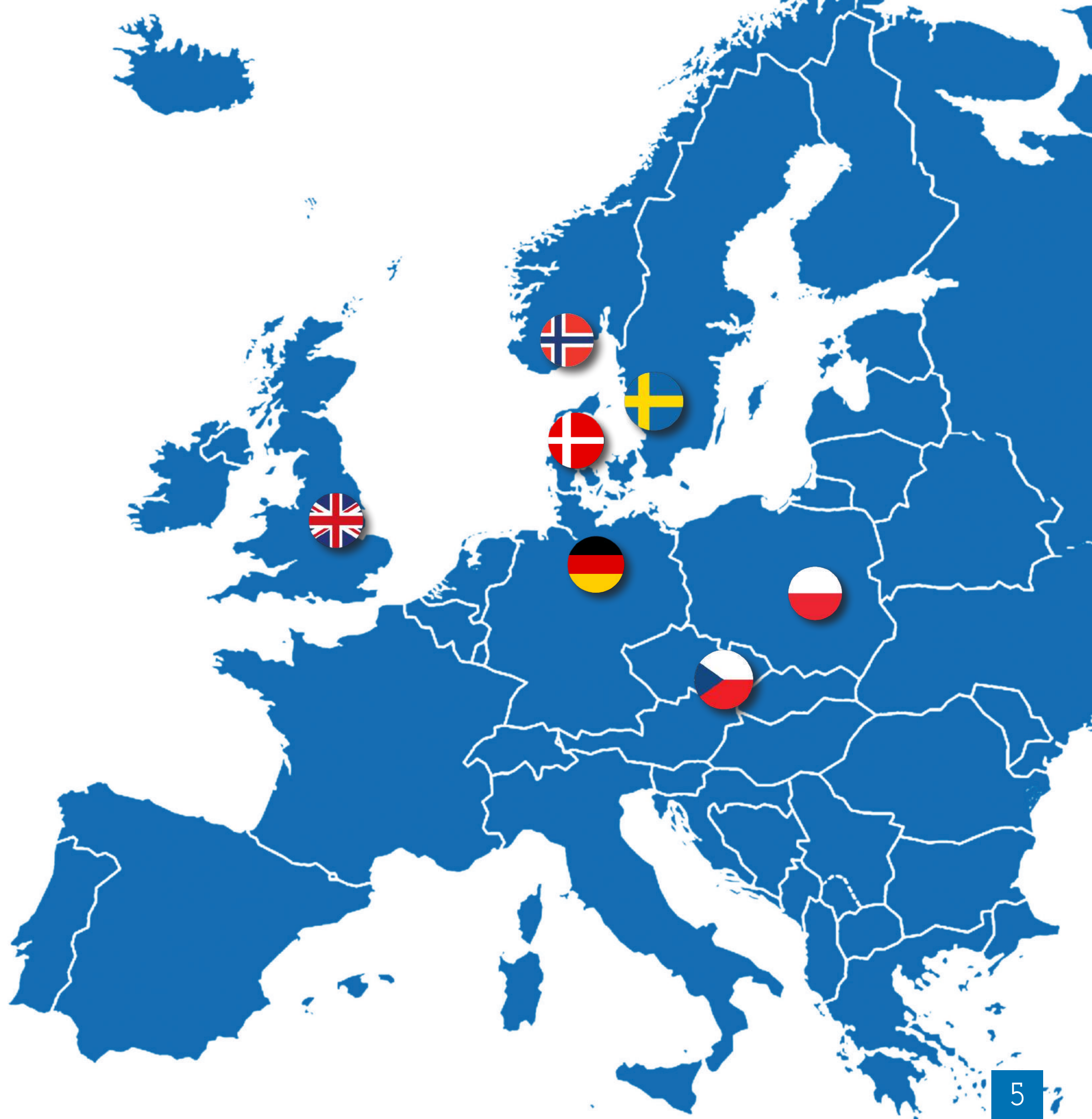
THE AARSLEFF GROUP

The Aarsleff Ground Engineering Group devises, plans and delivers a variety of projects across the infrastructure, marine, residential, rail, commercial and energy construction markets. Established in 1947, the Aarsleff Group is composed of three segments - Construction, Pipe Technologies and Ground Engineering. Specifically, the Ground Engineering division work together to solve technically challenging ground related problems in most parts of the world.

Aarsleff carries out a broad range of ground engineering works. In addition to driven and drilled pile foundations, they design and install construction pits with retaining walls such as sheet pile walls and combi walls, secant pile walls, diaphragm walls as well as driven and drilled king post walls. Their expertise also comprises anchoring, nail and injection work, ground improvement, drilling and grouting, geotechnical investigations and groundwater lowering systems - adapted to suit the needs of the individual markets.

Aarsleff has an impressive range of rigs and machinery and access to Europe's largest fleet of ground engineering rigs. They offer a comprehensive and detailed design facility, providing a full design service from placement of order to final installation.

With skilled, professional teams based in Denmark, Germany, Poland, Sweden, Czech Republic, Norway and the UK, the Ground Engineering subsidiaries are equipped to work on several types of site, delivering specialist ground engineering disciplines, all under one name and one specialist contractor for their clients' benefit. Speed and efficiency, both major considerations for today's built environment, are designed into operations, but always against a backdrop of safety and good working practice.



A PROUD HERITAGE

A quantum leap in the company's history came when Per Aarsleff A/S became listed on the stock exchange. Today, this success is reflected in the price of the shares; a sign of the investors' trust in the company.

On 4 January 1947, the 29-year-old Per Aarsleff, MSc in engineering, left a secure position with the Danish state. He borrowed 10,000 Danish Kroner from his father's life insurance, bought an excavator, rented two more and opened a lignite field near FASTERHOLT in Central Jutland.

1947

1984

1970s

In spite of general economic downturn, the 1970s were a very busy period for Aarsleff. There was a great demand for piling and Aarsleff were driving piles for large-scale projects, circa 10,000 running metres of piles.

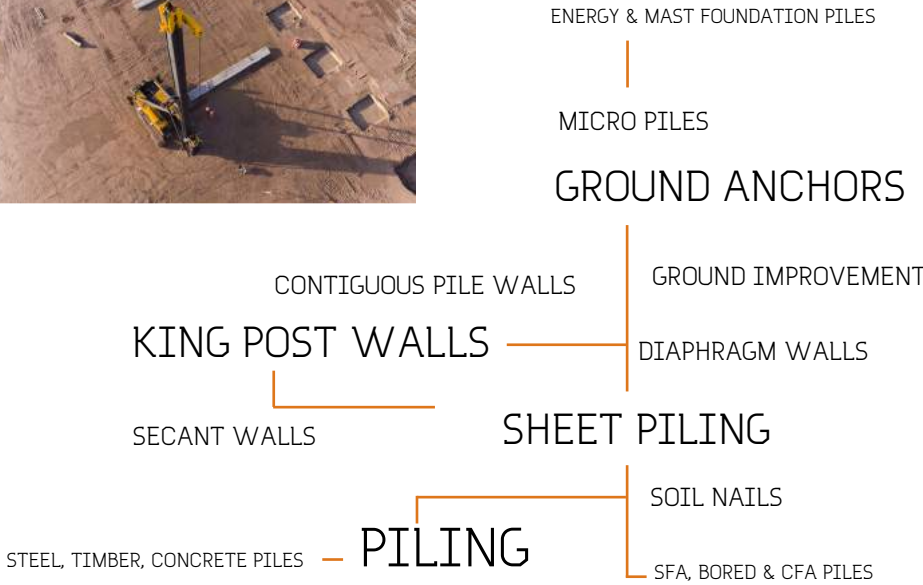


1990s

Aarsleff gained expertise within electrification of railways, and the piling division was soon very busy driving piles for the Danish rail network. The specially developed piling rigs then found their way to Spain, Germany and Poland. In addition to the Centrum pile factory in Denmark, Aarsleff Ground Engineering now have pile factories located in the UK, Sweden, Germany and Poland. Indeed, the Aarsleff Group is the largest pile producer in Northern Europe.



- Vejle, Denmark
- Newark, UK
- Kutno, Poland
- Kollanda, Sweden
- Germaringen, Germany



All subsidiaries diversified their product and services portfolio to offer a variety of pile types and specialist geotechnical solutions making the Aarsleff Ground Engineering segment a highly competitive expert in its field, growing rapidly to become one of Europe's most trusted and experienced ground engineering contractors.

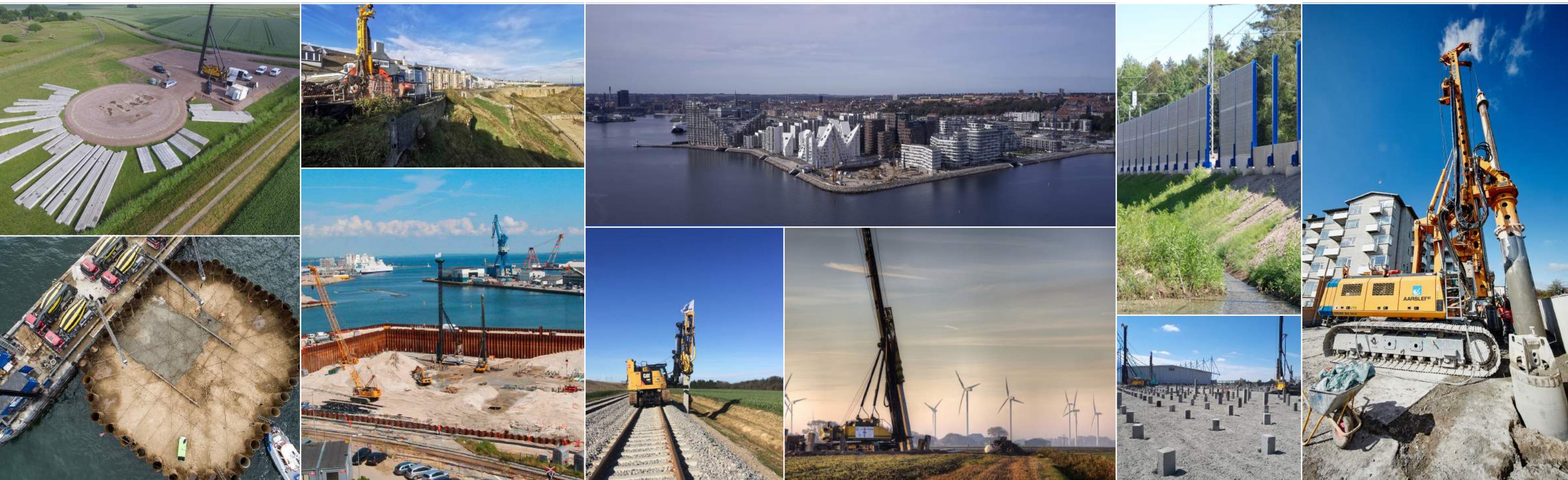
2000s



Experience and expertise are shared across Aarsleff's international companies with a view to continuing the development of pile types, machinery, as well as the innovation of new methods and geotechnical techniques. In this way, Aarsleff has built up specialist knowledge of the different countries' unique requirements enabling them to design and deliver smart, safe and sustainable ground engineering solutions.

OUR EXPERTISE

The population of the world is rapidly increasing, all of whom need housing as well as social, transportation and utility infrastructure. Ground engineering touches almost every aspect of modern life and Aarsleff's work has become a fundamental component in creating the modern landscape we live in and experience every single day. Aarsleff has earned a reputation for developing innovative solutions to improve the value, quality and sustainability of projects across the entire construction spectrum, from commercial sheds to railways and energy stations, benefiting clients, stakeholders and communities alike - both locally, nationally and internationally. Aarsleff Ground Engineering's extensive fleet ranges from mini piling rigs to large specialised machines, and covers fully hydraulic piling and drilling rigs as well as cranes and vibrators.



DESIGN & ENGINEERING



Design & Engineering is a fundamental part of every construction project. That's why, at Aarsleff, we have an in-house team of dedicated civil, structural, marine, mechanical, geotechnical and process engineers, who work at a high international level to design permanent and temporary works throughout Northern Europe.

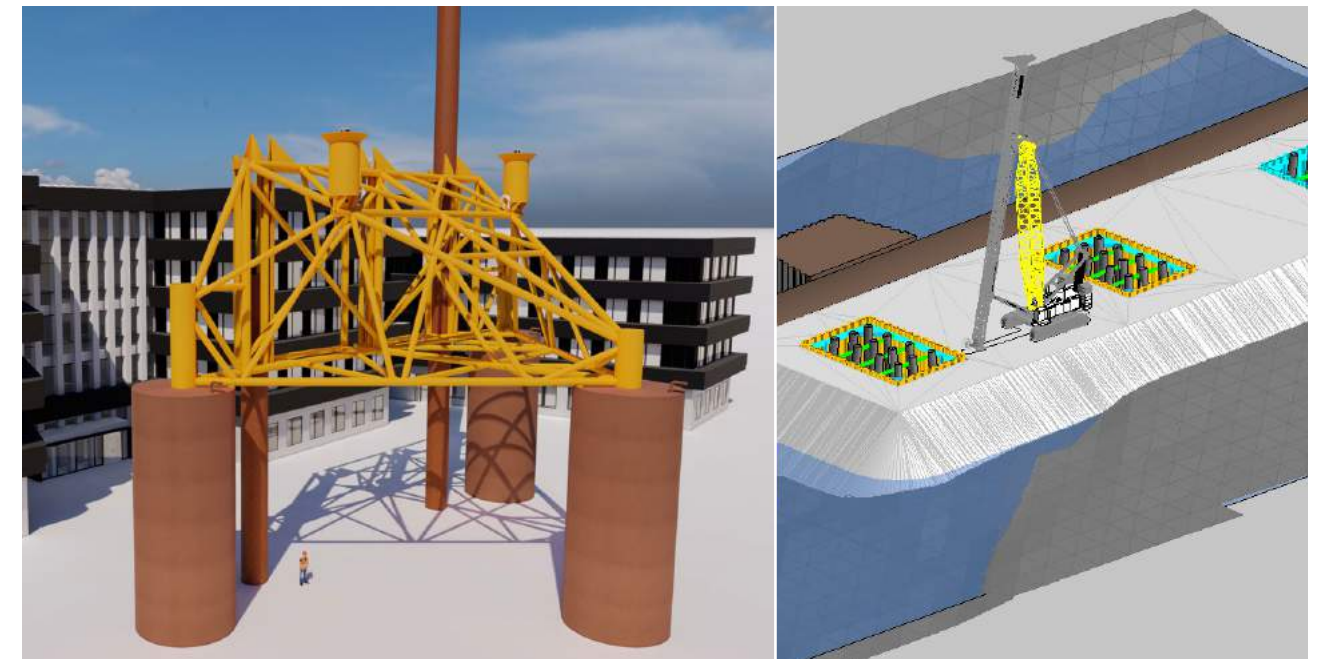
Aarsleff's team propose new and alternative solutions in connection with the design of foundation and ground engineering projects. Theoretical knowledge combined with a thorough and systematic gathering of experience allows them to contribute the best and most cost-effective solutions to complex construction work.

They provide consultancy not only in the design phase, but also if it is required during the practical execution of the work.

Design & Engineering implements and assists with development projects, both internally and in collaboration with universities in the form of examination projects and industrial PhD projects.

Aarsleff's expertise makes them highly competitive and ensures optimum implementation of the client's task. In addition, the close collaboration between the design and construction teams stimulates innovation that benefits not only clients but also the communities that the projects serve.

VIRTUAL DESIGN & CONSTRUCTION



If a picture is worth a thousand words, then a virtual model must be worth a million. Virtual Design & Construction (VDC) can significantly improve and transform the efficiency of projects by allowing fine-tuning before the main work begins. Aarsleff's VDC specialists offer many benefits for every building and construction project.

The use of VDC in some phases or on the entire project allows them to visualise and quantify the project, optimise the design, identify risks and improve buildability as well as plan and improve the efficiency of the building processes – before execution.

VDC is about more than creating models; it is also about creating a platform for collaborating on the models to create a more transparent project, a better understanding, safe execution and not least improved quality.

Different business areas require different skills and solutions. That is why Aarsleff do not offer a standardised concept but customised and bespoke solutions for each individual project. VDC gives Aarsleff the opportunity to be predictive and proactive, rather than reactive.

DRIVEN PRECAST CONCRETE PILES



Aarsleff Ground Engineering has established a longstanding and valuable partnership with Centrum Pile to bolster the production method of Driven Precast Concrete Piles. As well as having full quality control this means they are able to ensure the production processes are as sustainable as possible.

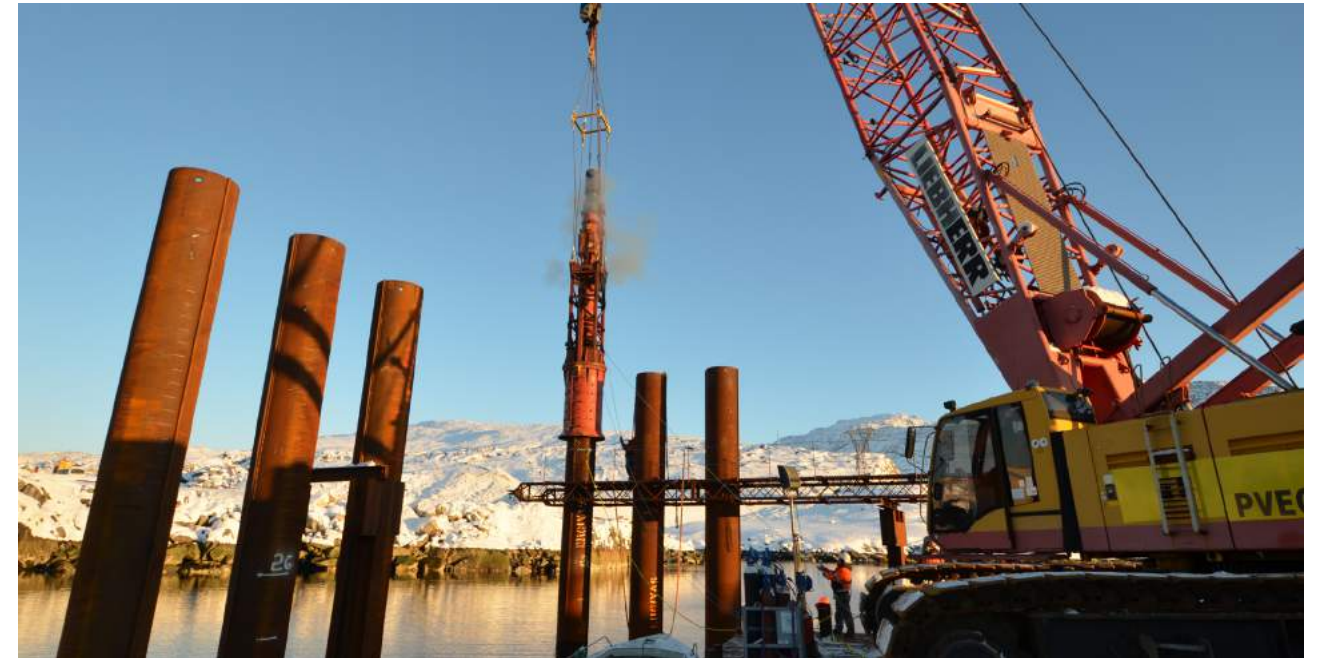
Sister company Centrum Pile manufacture reinforced precast concrete piles at their factories in Denmark, UK, Poland, Germany and Sweden, and maintain an extremely large stock at all times. In this way, they are very flexible and able to deliver from day to day. Due to the possibility of carrying vertical and horizontal loads as well as bending moments, precast piles are used as foundations for all sorts of engineering

structures in virtually every soil condition. They are particularly useful where there is a need for very deep piles, in soft ground or in aggressive or contaminated soils.

Precast concrete piles are installed in the ground by using various pile driving rigs and hydraulic hammers. All dimensions can be supplied in lengths from 6 metres, at intervals of 1 metre, and up to 18 metres as standard. For piles longer than 18 metres, Centrum Pile can joint the piles and in this way are able to supply piles in any length.

Manufactured off-site, they are unaffected by ground water, produce no spoil and can be used for immediate follow-on construction.

STEEL & TIMBER PILES



Steel Piles, such as tubes and H-Sections, are usually installed for marine structures or as foundations for temporary structures, permanent bridges, acoustic screens and buildings with underground floors. Depending on soil conditions, Aarsleff can install steel piles using two technologies - or a combination of both:

1. Driving with hydraulic hammers
2. Vibrating with vibratory hammers

As with all of Aarsleff's driven piling solutions, steel bearing piles provide a proven and tested pile, eliminating guesswork to produce a cost effective product that can accommodate a wide variety of subsurface conditions.

Timber Piles have been utilised around the world for thousands of years. Responsibly sourced timber piles are installed for many project types – mainly within marine working environments and low loaded structures with a lifespan of up to 30 years.

Timber piles are designed as columns to support loads by end bearing, shaft friction or combined end bearing and friction depending on the nature of the strata into which they are inserted.

The main advantages are potential low cost, use of sustainable material and carbon sequestration because off-cuts can be used for fuel.

BORED PILES



Aarsleff offer Bored Piles as an ideal solution for noise, vibration and environmentally sensitive sites for both load bearing piles and excavation support. Suitable for all soil conditions, the pile type is fast to install and poses limited risk to adjacent structures.

A bored pile is a cast in-situ concrete pile where the bored pile has to be cast in the borehole on the construction site. Bored piles can be executed as:

- CFA piles (Continuous Flight Auger)
- FDP piles (Full Displacement Piles)
- VDW piles (Vor der Wand)
- Kelly piles

Aside from building foundation piles, the bored piling method is also used to form contiguous and secant bored pile walls for earth retention.

The VDW method is a noiseless execution method with no vibrations and can be used in even the most challenging soil conditions which would otherwise require hard pile driving. Boring is carried out to the required depth by means of either a crawler crane-mounted rotary boring unit or a purpose-built hydraulic drilling machine. In unstable soil strata, Aarsleff would use bentonite fluid to assist in stabilising the bore especially in large diameter deeper piles. This also allows the insertion of heavy reinforced steel cages. Depending on the casing or lining that is used, permanent or temporary casing may be used for supporting the pile.

MAST FOUNDATION PILES



Mast Foundation Piles are precast piles specifically designed for the masts of the railway electrification system, as well as special anchor piles. They are driven with a special rig, able to move on railway tracks and equipped with a hydraulic hammer; the frequency and height of which are electronically controlled. The machine can also safely work under the existing electrification system.

The geotechnical design of the piles is based on a soil-pile interactive model with elastic springs, representing the soil stiffness in different layers, for which a bespoke piece of design software has been developed.

The system is on precast, reinforced concrete piles with integral stainless steel bolts for subsequent mounting of masts.

The piles are adapted for the electrification application by an enlarged upper part of the pile section. This increases the moment capacity perpendicular to the orientation of the rail.

The product is manufactured in the Centrum Pile factory, a controlled environment that ensures the highest quality is achieved. It has a design life of up to 120 years, resulting in no disruption for maintenance. The product provides a cost effective, efficient and sustainable solution for the rail electrification market with full traceability of all components.

Aarsleff Ground Engineering is one of the leading specialist contractors in Europe within pile production and pile installation. Aarsleff installs complete reinforced precast concrete piles supplied by its sister manufacturing facilities across Denmark, Sweden, Poland, Germany and the UK. Under the Centrum Pile logo, the pile factories work in a strong partnership according to a uniform system, providing high reliability in all phases with a constant focus on quality, transparency, production costs and efficient delivery.



ENERGY PILES BY CENTRUM PILE

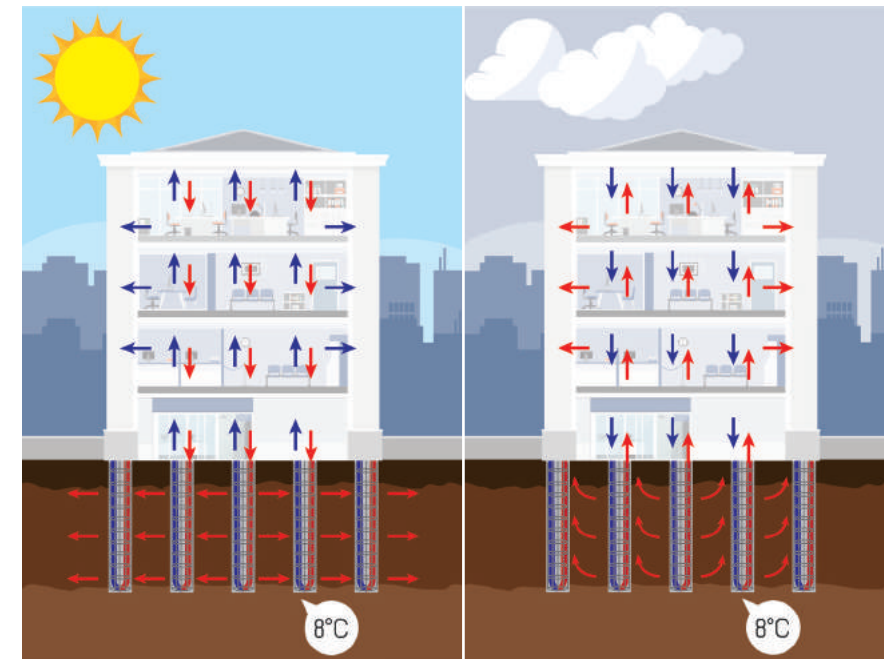


Sister manufacturing facility Centrum Pile has taken great steps to reduce its carbon footprint. After solar energy, geothermal energy is the second most abundant source of heat on earth. In this case, it is used in conjunction with Energy Piles, which are equipped with individual or several pipe circuits to enable the exchange of heat with the surrounding soil.

This means two-fold sustainability: the pile provides a static bearing capacity and supplies sustainable energy as well. When a building needs to be piled due to the low soil strength in the site, the foundation can serve both as a structural and a heating-cooling component. Ground source heat pump systems produce renewable thermal energy that offers a high level of efficiency for space heating and cooling and

has the potential to be used anywhere in the world.

With increasing energy costs and the introduction of greater renewable energy requirements for new buildings, energy piles are becoming more and more in demand. Centrum Pile's extensive research into energy piles is a testament to their ethos as a market leader; inciting innovation as a key factor for reaching cost-effective development. An industrial PhD thesis enlightening and supporting the long-term feasibility and performance of energy piles has been presented by Centrum Pile. The thesis titled "Design and performance of energy pile foundations" was carried out in close collaboration with Centrum Pæle A/S, Aalborg University and VIA University College in Denmark.



The PhD research resulted in hitherto unknown knowledge regarding the forecasting process when seeking to install energy piles; the main outcome of the project being the development of a tool which estimates the optimal amount of energy piles needed to obtain maximum performance. The tool eliminates the risk of depleting the ground heat by stimulating the long-term effect of energy piles in any specific area, thus granting a basis upon which to decide how to alter the dimensions of the energy piles to accommodate the heating and cooling demands of any building.

In combination with other renewable energies, Centrum energy piles have great potential for realising the transition from fossil fuels to renewable energy resources. As an offsite method of construction, precast concrete piles offer known advantages: improved construction programmes, better budget controls and improved quality.

KING POST WALLS



Aarsleff can design and construct King Post Walls for significant retained heights, very large dimensions and by different installation methods. They can be constructed as free standing cantilever walls, propped or as anchored structures offering numerous applications including basements, embankment and highway retention.

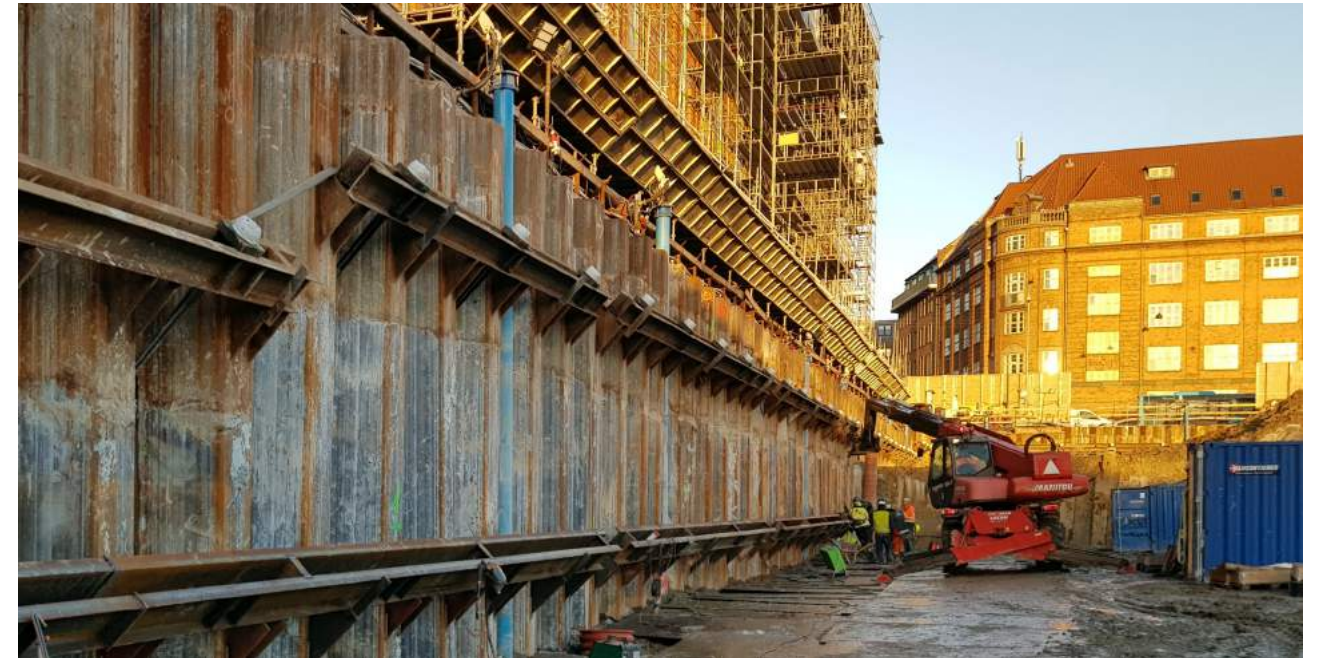
Typically, the method involves drilling a hole with a high powered CFA, large diameter or mini piling rig and then filling it with concrete and installing an H beam. This allows e.g. concrete prestressed panels to be inserted between the webs of the H sections, which, after excavation, results in the finished embedded retaining wall. The isolated steel columns are typically installed at predetermined centres. The flexible installation

allows top-down or bottom-up construction. For bottom-up construction, back-filling would then take place.

King post walls are quick to install and hand over for follow on trades compared to other techniques. They generate minimal spoil on site and with options for various types of infill panels or complimentary cladding systems, the king post wall finish can be an aesthetic one.

It is a relatively silent and vibration free installation and adjustments can easily be made in the field to accommodate changes. Furthermore, king post corners can be fabricated off-site so that no on-site hot works are required on site. This reduces risk on site as well as saving time and money.

SHEET PILING



Aarsleff's in-house capabilities enable it to design, supply, install & extract Sheet Piles whether for temporary or permanent works. Sheet piles can be used for a variety of applications including cofferdams, retaining walls, seawalls, bulkheads, access jetties or other applications where earthworks support is required. Additional support can be provided via hydraulic or in-situ frames, tie-rods or anchors.

Working closely with clients, developers and principal contractors, Aarsleff's team design and deliver successful projects built on reliable and relevant methodologies. Each project is evaluated and appraised to develop the optimal engineered solution. Methodologies include the use of techniques such as silent, vibration-free

piling and telescopic leader rigs, as well as conventional driving equipment. Sheet piling solutions are installed for a wide range of sectors including industrial, commercial and residential: permanent steel sheet pile basements and retaining walls, temporary works and bracing and rail and road infrastructure.

Aarsleff also has significant experience working in both tidal and intertidal and land based zones in the design and installation of sheet piling for marine works including dock wall stabilisation, quay walls, jetties, slipways, tubular piles, ports, harbours and mooring dolphins. Once installed, sheet piles have an immediate and structural capacity allowing excavation to commence immediately and no spoil is generated.

CONTIGUOUS PILE WALLS



Aarsleff Ground Engineering has the specialist plant and team to install Contiguous Pile Retaining Walls. The walls are constructed with nominal gaps between adjacent piles, depending on retained heights, installation tolerances and allowable deflections.

These walls can be constructed to provide load bearing capacity as well as a retaining structure where line loads can be applied to the wall or additional piles to form caps.

Contiguous pile walls are ideal when groundwater ingress is not an issue for the finished wall. This type of retaining wall is used on a wide range of engineering projects such as ground stabilisation, underpasses and basement walls.

Aarsleff has significant experience in designing, installing and testing contiguous piled retaining walls in a variety of diameters and locations across Northern Europe.

SECANT PILE WALLS



Aarsleff use the latest technology and best practice measures developed over many years to ensure position, verticality and structural integrity of their Secant Pile Walls.

Secant pile walls are formed using interlocking primary and secondary piles. The secondary piles are first installed with the primary pile cut in to the secondary pile. The secondary pile can be described as soft, firm or hard depending on the design requirements. A soft and firm pile resists the loss of ground between the structural piles along with reducing the potential flow of ground water.

A hard pile is cast with both structural concrete and reinforced with a steel cage adding to the walls' capacity.

Aarsleff can deploy various drilling methods when constructing secant pile walls. One in particular is known as Vor der Wand drilling (VDW). VDW stands for "in front of the wall" and is a vibration-free and low noise procedure well suited for drilling in areas with limited space.

This type of drilling offers optimum utilisation of the space available on the construction site.

DIAPHRAGM & SLURRY WALLS



Diaphragm Walls are designed to reach great depth and provide the required structural capacity to facilitate certain construction activities such as retaining walls, underground structures, or as a form of foundation.

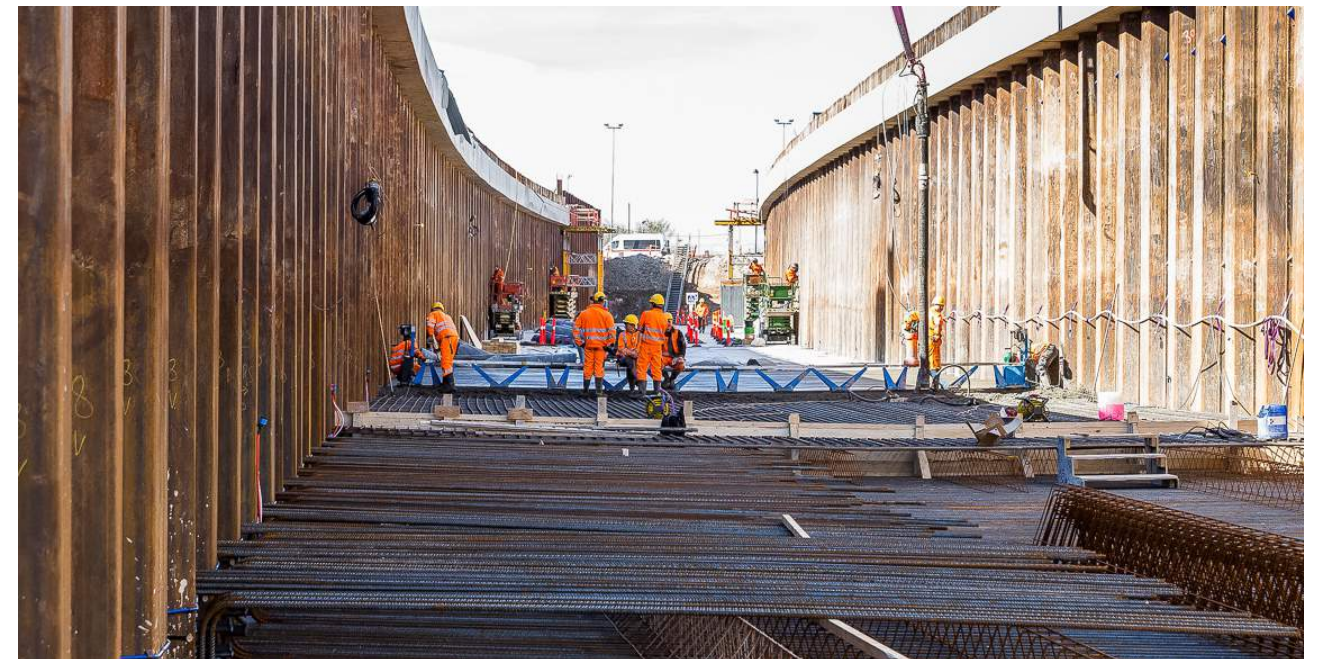
They are excavated in panels by duty-cycle cranes using suitable diaphragm wall grabs or cutters, either alone or in combination. To protect the excavation against collapse, stabilisation is carried out on an ongoing basis by means of bentonite suspension. Reinforcement cages are installed and the concrete casting is carried out.

Slurry walls are constructed using a cement-bentonite suspension to stabilise the trench

during excavation. The final stabilisation of the construction pit is made with sheet piles or prefab elements which are lowered down into the cement-bentonite. Slurry walls benefit from very low permeability of the cement-bentonite obtained after curing. When combining the impermeability with a trench of a bigger depth than statically required, a cut-off effect on the groundwater inflow can be obtained. This means that you can reduce the groundwater lowering – and the project costs – considerably.

A great advantage of both is the method's very low level of noise and vibration, which means that it can be carried out in most soil types.

CONSTRUCTION PIT / COFFERDAM



Construction Pits/Cofferdams will most often consist of a relatively impermeable wall built around the periphery of the proposed excavation. Sheet pile walls are widely used in construction pits, but secant piles, diaphragm walls and other structures can also be used.

If sheet pile walls have been utilised, such structures may be dismantled after the ultimate work is completed and are constructed to allow the enclosed area to be pumped out, although in the majority of cases, the walls are left in the ground.

The pumping creates a dry working environment for the major work to proceed. This is generally

required for foundations of structures, such as bridge piers, marines, harbours, ports, docks, locks, and dams, which are built in open water or used on land where there is a high groundwater table.

The pit can be constructed in almost any desired shape. However, for practical and reasons of economy, most cofferdams are either rectangular or circular.

Several of Aarsleff's core competencies are involved in the installation of construction pits, namely sheet piling and earthworks, piles, ground anchors, and groundwater lowering.

SOIL NAILS



Aarsleff takes pride in being fully proactive with their clients to offer a one-stop design and build Soil Nail solution to enable their clients to rest easy in the knowledge that their contract is in safe hands.

Soil nails are a cost-effective method for long or short-term stabilisation of steep existing or proposed slopes. They are particularly well suited to excavation applications for ground conditions that require vertical or near-vertical cuts.

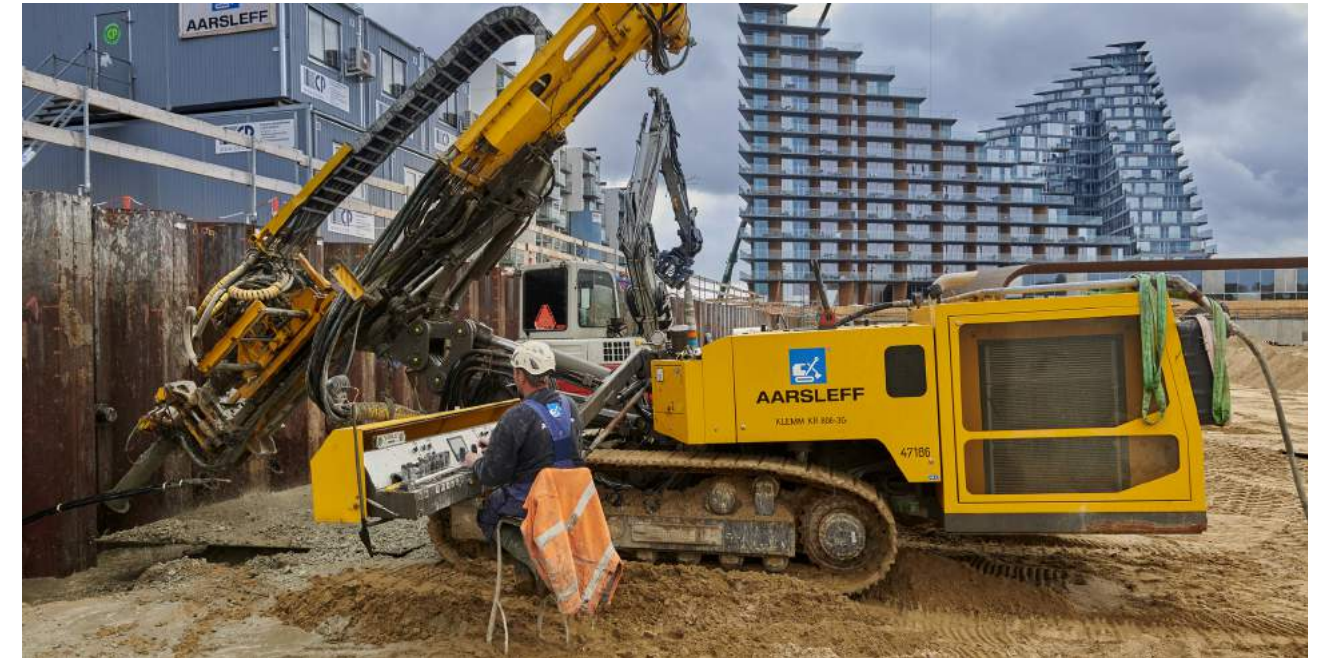
The process consists of drilling a series of steel or fibreglass bars into the ground. The nails are typically fully grouted in place to secure the inclusions and provide additional pull-out resistance.

Soil nail walls may be “finished” with reinforced shotcrete, precast panels, heavy steel mesh, or vegetated “cells”.

Nail location, inclination and lengths can be adjusted easily when obstructions are encountered. They are relatively fast to install and maximise available land usage. It is ideal when working on sites which have a limited amount of space, as there is little need for room to manoeuvre.

Aarsleff have been installing soil nailing techniques for many years, deploying highly specialised equipment and experienced crews to ensure uniform and consistent results, time and time again.

GROUND ANCHORS



Aarsleff has extensive experience installing Ground Anchors for a wide variety of projects across Northern Europe.

A ground anchor is a load transfer system designed to transfer the forces applied to it to a competent stratum. They can be installed either vertically or in an inclined position. The main purpose of geotechnical ground anchors is to prevent horizontal movement, while stabilising retaining structures, including sheet piles, bored concrete piles and steel tubular walls.

Aarsleff also has considerable experience of drilling against water pressure, where approved special structures are used to secure both construction pits and other structures. For large

projects, it can be a financial advantage to carry out more preliminary investigations and install test anchors. The test anchors make it possible to optimise the project further.

The anchor section of Aarsleff comprises several drill rigs. The rigs are equipped with flexible leaders which means that they can perform almost every kind of drilling work in every angle possible.

In addition, Aarsleff has the competencies and the expert staff to price and carry out every kind of waling or cantilever construction as part of a ground anchor system.

GROUND IMPROVEMENT



Ground Improvement methods are used to improve the existing soil formation by changing the soil properties. They can increase the bearing capacity, provide settlement control for new construction, or remedy an existing issue.

Deep compaction is a method that Aarsleff uses for compaction of loose sand fill below groundwater level at depths up to 20-25 metres.

Where it is necessary to provide reinforcement and strengthening of low-bearing soil for the purpose of direct foundation of buildings and constructions, soil-cement columns are installed using the Deep Soil Mixing (DSM) technology.

Dynamic compaction involves the controlled impact of a crane hoisted weight, falling in a pre-determined grid pattern to improve loose, granular and mixed soils and fills.

Among soil improvement methods aimed at enhancing bearing capacity, stability and/or limitation of settlement, Aarsleff can also execute the following type of concrete columns:

- Displacement columns formed in the soil with no excavation and spoil
- Non-displacement columns formed with Continuous Flight Auger (CFA) with spoil removal.

DRILLING AND GROUTING



Aarsleff has the specialist plant and labour to carry out all types of Drilling and Grouting works. It can be used for soil stabilisation, waterproofing, soil mixing to increase the strength of soil and many other applications.

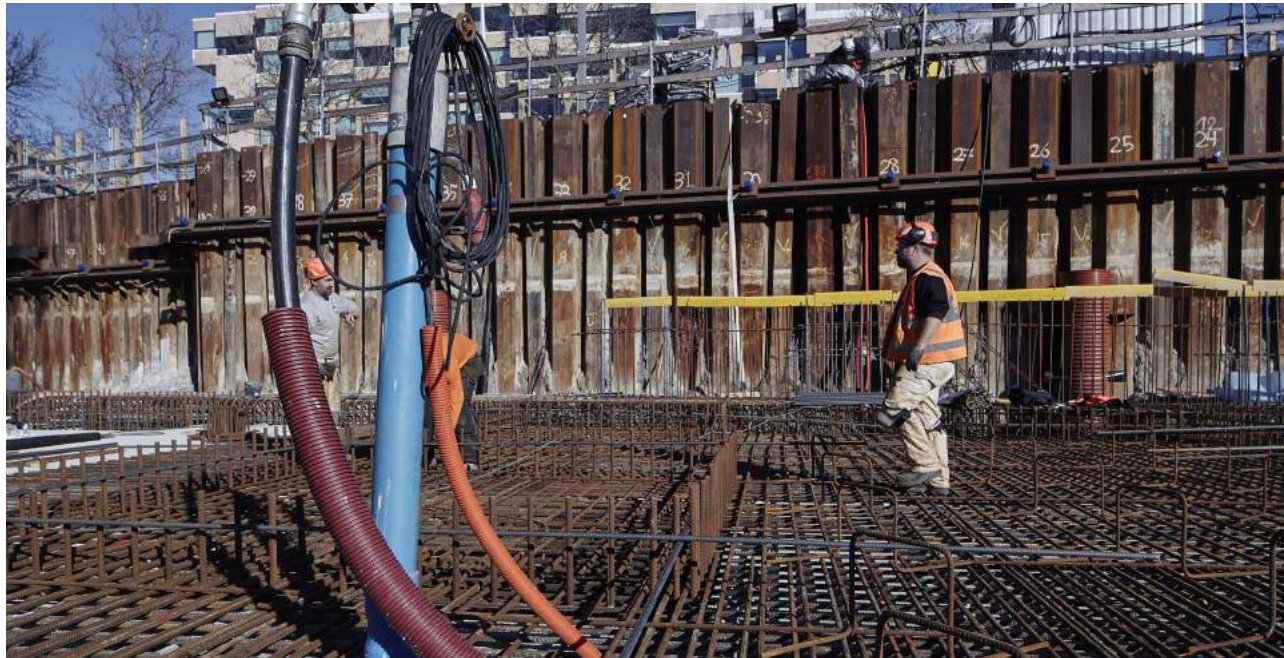
Compaction grouting is a technique that displaces and densifies loose granular soils, reinforces soils and stabilises subsurface voids or sinkholes, by the staged injection of low-slump, low mobility aggregate grout.

Shallow voids pose a risk to surface buildings and sub-surface infrastructure because collapse of the ground overlying the voids can result in voids migrating to the surface, leading to crown-hole development.

One option for remediation is bulk filling of these voids by drilling and grouting. The drilling process involves rotary percussive rigs, firstly installing casing seated into rockhead, then drilling to 1m below the base of the seam. Commencing at the lowest dip side, grout is injected through a flexible tube called a tremie from the base of the drilling hole to the surface.

The jet grouting method is used for improving soil parameters or sealing ground surfaces. It uses a high-pressure jet of grout to break up the natural structure of soil, to loosen and partially replace it and then to bind with soil fractions and form a soil-cement composite.

GROUNDWATER LOWERING



When a client is to build in an area with a high water table, it might be necessary to carry out Groundwater Lowering in order to prevent significant groundwater seepage into the excavation and to ensure stability of excavation side slopes and base.

Aarsleff's extensive range of equipment comprises several types of drilling rigs with different kinds of drilling methods. They are able to carry out drillings with filters in diameters ranging from 150 to 400mm. In connection with the drilling work, Aarsleff also take soil samples. After the drilling work, the filter well is cleaned and a pumping test is carried out. The test results are monitored, stored and then processed in specially developed software determining the efficiency and transmissivity of the filter well.

Aarsleff carries out all types of works in connection with groundwater lowering including filter, bleeding and monitoring wells, reinfiltration systems and well points.

Aarsleff carries out operation and maintenance work of the installed groundwater lowering systems and reports the measured water levels on a weekly basis. The specialists of Aarsleff's design department carry out calculation of the expected water volumes and are well placed to provide a complete design and installation service to control the groundwater problems at a given site.

GROUND INVESTIGATIONS



Ground Investigations are the method of determining the condition of the ground, typically before carrying out the main construction works. Aarsleff specialises in all types of geotechnical and hydrogeological investigations.

Aarsleff's work comprises:

- Geotechnical drilling
- Environmental drilling
- CPT testing
- Core drilling
- Monitoring wells and pump tests

Aarsleff also specialises in seabed investigation for marine construction. Aarsleff has participated in several offshore wind projects and a large number of harbour projects.

They carry out investigations with their own specialist drilling rigs of varying sizes and with different equipment. The drilling rigs are mounted on Aarsleff's own barges and jackups, which provides great flexibility, allowing it to carry out work in lakes, harbours and at sea at great water depths.

Aarsleff are able to take undisturbed samples (A-tubes and B-tubes) and core samples as well as carry out in situ tests, including field vane tests, SPT tests and cone penetration testing for measurement of the soil strength.

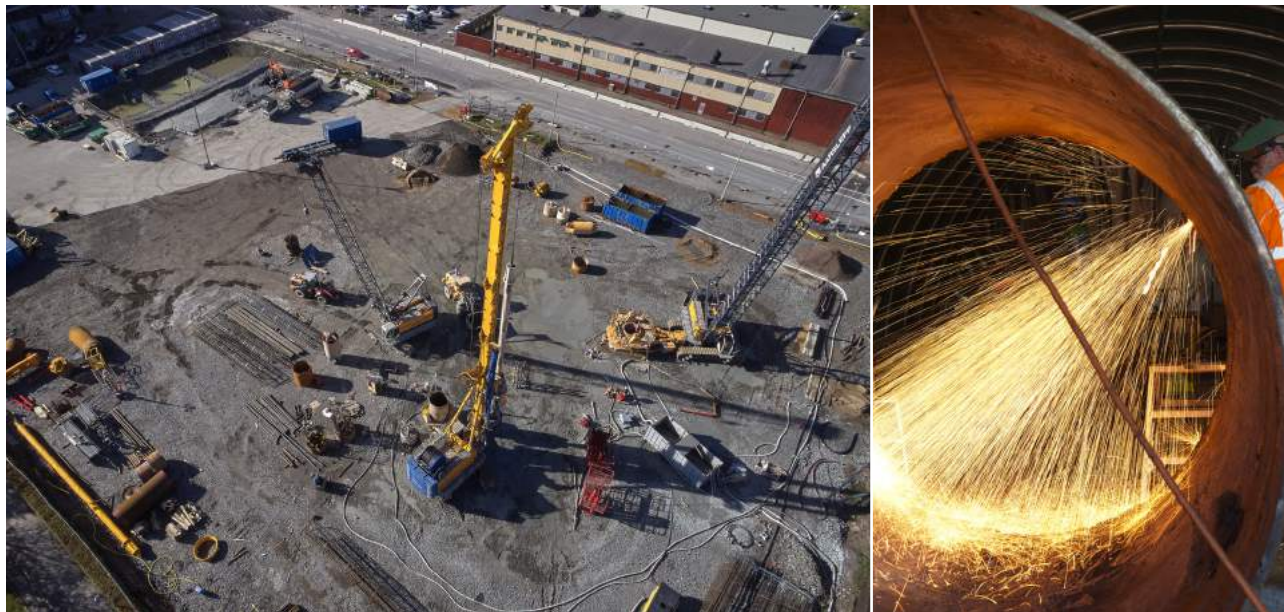
SPECIAL PROJECTS





HIGH-RISE BUILDING IN SWEDEN

Bored piles for the tallest building of the Nordic countries in Gothenburg.

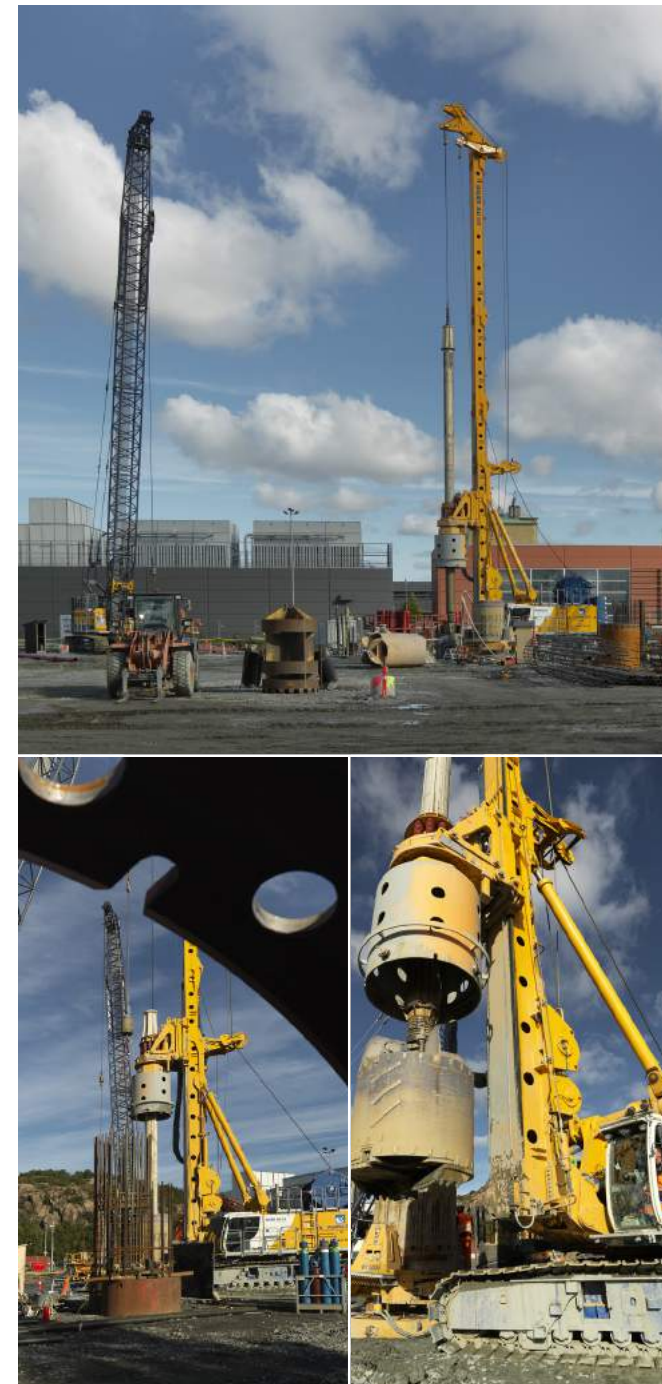


Aarsleff carried out the ground engineering work for the 245m skyscraper Karla Tower – the tallest building of the Nordic countries once complete. The contract with Serneke Group comprised the execution of 57No. bored piles: 1 No. test pile and 56No. production piles. The piles were installed by drilling a casing pipe down to the rock and from there drilling an additional seven metres into the rock. The project was carried out by ground engineering specialists from Aarsleff in Sweden and in Denmark.

When completed, Karla Tower will have 593 flats on 73 storeys. In addition, eight to ten other buildings will be constructed, and three of them will be more than 100m tall. Karlastaden, which is the name of the new district, covers 33,000m² and will consist of more than 2,000 flats as well as businesses, schools and kindergartens. Aarsleff

were first involved in the project at the beginning of 2015 when they were contacted by the project group. They wanted to find out if it was possible to support a building of such height in one of Gothenburg's most difficult places in terms of geotechnical conditions. From the bottom of the tower, there is approximately 55-75m down to bedrock; and in between, the underground consists mainly of Gothenburg clay characterised by a very low strength and a high sensitivity during excavation. In addition, there is a layer of frictional materials above the rock and a general risk of encountering large stones.

The 57No. bored piles of a diameter of DN2000mm were installed by means of the Kelly method. The piles were led down to and into the rock until there was full contact to protect against leaks and inflow of materials. Then the drilling



tool was replaced, and drilled up to seven metres into the rock, depending on the location and function of the pile. The casing pipe was constantly filled with water to protect against heave in the pile during production. After completion of the drilling work, the hole was cleaned by means of airlifting, and the reinforcement was lowered down into the casing pipe. To optimise the installation, the reinforcement was mounted in advance in three installation pipes driven 30m into the ground.

For the concreting process, a concreting pipe was led down to the bottom of the pipe and withdrawn together with the casing pipe. Initially, a test pile was installed to document compliance with the strict quality requirements of the tender documents. According to the requirements, a maximum of two millimetres of unwanted material was allowed in the transition between rock and concrete casing at the bottom of the pile.

Aarsleff had to document that the method used for verification of the concrete curing, Thermal Integrity Profiling (TIP), worked and that the pile had the required profile. The test pile was approved after supplementary injections into the transition between rock and concrete. During this project, Aarsleff discovered that it was possible to leave the casing pipe in the clay for up to 13 days without a problem. Also, Aarsleff's use of large casing oscillators contributed to a good and stable working process. As the rock was extremely hard, Aarsleff tested different tools to increase the production.



WIND FARM IN GERMANY

Deep foundation of wind turbines and crane sites at the WP Wetterdeich.



Aarsleff was appointed to install the pile foundations for wind turbines including foundations for the assembling crane at the Wetterdeich wind farm in Lower Saxony. 7 WEA of the type ENERCON E-115 were built for Bürgerwindpark Oederquart GmbH and Denker & Wulf AG.

For the foundation of each of the wind turbines, 84No. piles with lengths of 28-38m were driven. In the case of the crane sites, 64No. piles with lengths 28-38m were utilised.

At some locations, test piles were driven and tested using dynamic test loads to determine the required pile lengths and load-bearing capacities as precisely as possible. This allowed for a high degree of planning security.

The load-bearing layers were present at depths of 16-21m, below thick soft layers. The load-bearing subsoil differed between the individual locations and was characterised by sand and sliding marl.

The Centrum precast pile system, with a cross-section of 45x45cm, was used at all locations. Due to the composition of the subsoil, piles with greater reinforcement contents were driven. Additionally, some of the piles were equipped with inclinometer tubes in order to monitor potential deformation caused by the subsoil encountered.

The execution of the piling works was carried out with 2 piling rigs, a Junttan 26 and a Hitachi 180. This project represents a typical project for Aarsleff Ground Engineering in Germany.



Indeed, over the last three decades, the company has successfully installed the Centrum pile system for over 5000 wind turbines.

With access to an extensive selection of pile sizes to ensure an optimum design solution, Aarsleff can draw on extensive experience and resources to ensure successful project delivery.

Aarsleff's pile system has proven time and time again to be of great quality and time and cost efficient. It has now become one of the preferred pile systems within the wind energy industry.



METRO STATION IN DENMARK

25,000m of drilled piles for the South extension of The Copenhagen Metro.

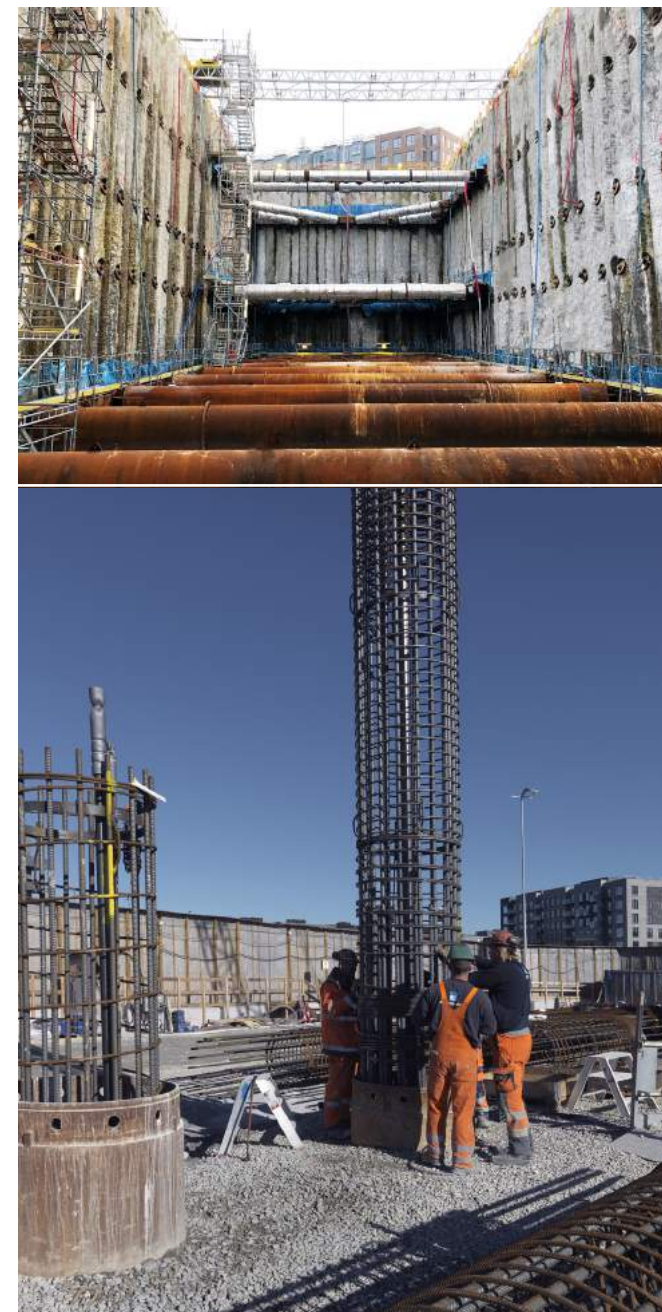


In Copenhagen's South Harbour, six large drilling rigs from Aarsleff Ground Engineering worked on three future metro stations. Aarsleff Ground Engineering won two out of three contracts for the establishment of shafts for three of the five metro stations on the future Sydhavn Metro Line in Copenhagen.

The work comprised a total of 1,213No. drilled piles for the stations Fisketorvet, Mozarts Plads and Sluseholmen at a total contract value of DKK 105 million. Aarsleff Ground Engineering was a subcontractor on the project, meaning that work related to the construction site, design and communication with the authorities fell outside the scope of their contract. In general, their contract concerned the execution work only; specifically, to drill 1,213No. piles in lengths of up

to 28m and in diameters of up to 1.2m, a total of 25,000lm of drilled piles. The piles were primarily used in the construction pits for the shafts as well as for the main staircase, the escape staircase and a technical room on one of the stations. A secant pile wall was installed. This meant that Aarsleff drilled a hole using a casing pipe, then filled it with concrete (primary piles); afterwards they drilled another hole and placed a reinforcement cage inside it before filling it with concrete (secondary piles) and so on. The two types of piles were established with overlap, thus forming a wall.

Aarsleff Ground Engineering supplied about 1,300 t of reinforcement for the secondary piles and used a total of about 25,000m³ of concrete. Even though the work was a pure execution contract,



there were still challenges, e.g. more stringent requirements to quality and safety. When the Cityringen Metro Line was established, the client, Metroselskabet, experienced difficulties with both pile type and safety, so of course this project required increased focus on these issues.

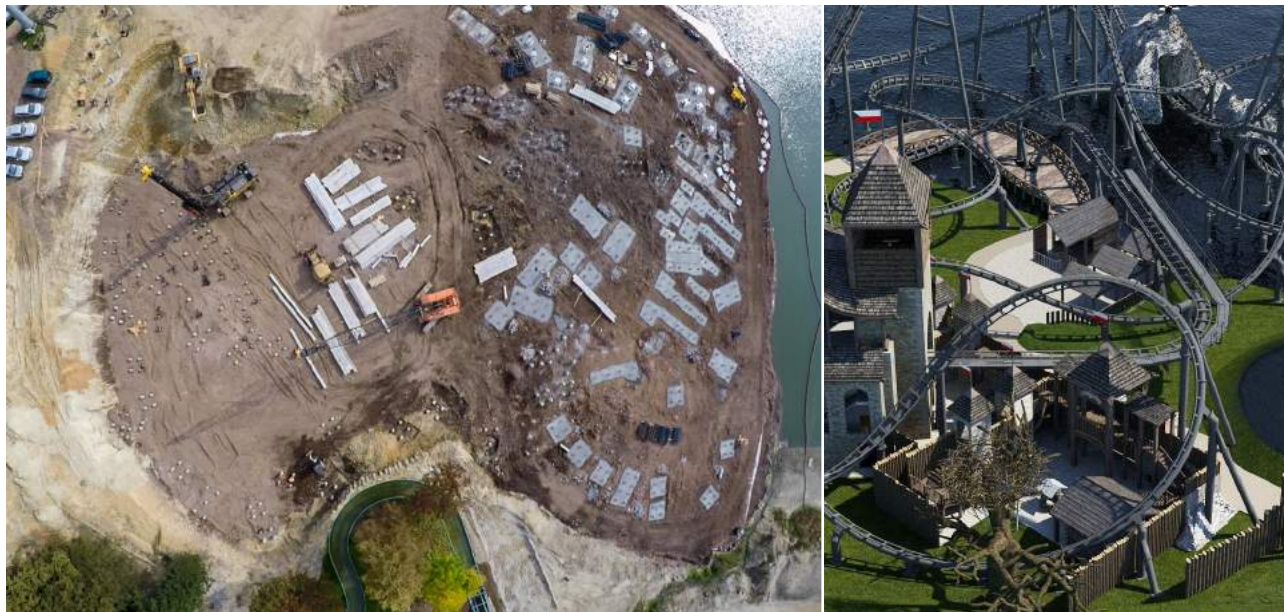
In terms of safety, all employees wore an extended set of safety equipment on the sites and each morning signed a document stating that they had been introduced to today's work. In addition, there were weekly toolbox meetings on the sites. In terms of quality, it was a requirement that Aarsleff always lead the casing pipe all the way to the bottom. This reduced the risk of directional changes and the risk of lack of overlap between the two piles which may have led to penetration of groundwater into the construction pit. It slowed down the process somewhat but ultimately provided the client with a better product. Aarsleff also carried out inclination measurements of the casing pipe on every fifth pile which is also more comprehensive.

They used Denmark's largest fleet of machinery – Aarsleff's own. Six large drilling rigs, including Bauer BG55 and Bauer BG45, which are some of the largest drilling rigs in Europe, constantly worked on one of the three stations.



AMUSEMENT PARK IN POLAND

Construction of Lech coaster in Chorzów Amusement Park.



Chorzów Amusement Park, rebranded as "Legendia", boasts the largest rollercoaster in Central Eastern Europe. The ride reaches a height of 40m, has a maximum speed of 95kph, and has a track length of 908m. The ride also features three inversions. The structure was designed to have 187 foundations, with 12 types of foundation solutions.

Due to the character of loads, specific location and water and soil conditions, it was decided to apply the pile technology. The original version of the design assumed onshore and offshore (from a working platform erected in a water reservoir) installation of drilled piles with a diameter of 50mm, made of C40/50 concrete and reinforced with steel $f_y=355\text{MPa}$.

Due to a relatively short time (3 months) of completion of the working platform, pile installation, test loading and construction of reinforced concrete caps, Aarsleff analysed and optimised the design solution, taking into account such factors as high sulphate aggressiveness of water and soil, necessity of using high-class concrete (C40/50) and locations of pile foundations both on land and in water.

Upon an in-depth analysis, the precast pile technology was chosen. This pile type overcame the challenges commonly associated with drilled piles including the possibility of polluting the water reservoir with concrete mix, the long curing time and the required high concrete class.



Along with the installation of 39No. precast piles with various cross-sections, lengths and reinforcement, Aarsleff both constructed and disassembled access roads and a temporary working platform on land and in water, using 17,800 t of red-burnt shale. They also constructed monolith pile caps for 12 foundation types as well as performed 22No. dynamic load tests.

All in all, 410No. piles with a cross-section of 30 x 30cm and 88No. piles with a cross-section of 40 x 40cm and lengths from 5 to 15m were installed for the foundation of the structure, reinforced with 12, 16 or 20 main bars with a diameter of 12mm. Pile cross-sections and lengths were adjusted

to transfer the expected loads. The piles were designed for axial loads ranging from 200 to 1000kN in difficult and varied soil conditions. The foundation was designed and constructed using prefabricated elements made of C40/50 concrete and HSR cement (sulphate-resisting), resistant to highly aggressive soil and water. Installation of piles in adverse soil conditions was carried out meeting the high requirements for pile driving accuracy.

Aarsleff completed the piling works in 21 days and in close proximity to the amusement park which remained operational throughout.



WAREHOUSE IN THE UK

Soil nails, grouting and mixed pile solution for contract off the M1 in Leeds.



Aarsleff were awarded the ground engineering contract to construct a 112,000 square metre state-of-the-art distribution hub for Premier Farnell - a global technology leader - and which is to be the largest ever warehouse development in the city. As the site was located to the north of the Wyke Beck and firmly within its valley, a substantial ground engineering scheme had to be put in place to facilitate the construction of the commercial development.

Aarsleff offered their client the option of a value engineered solution on several aspects of the substructure. Aarsleff redesigned a large gabion wall into a slim 7.5m high soil nail retained slope - that involved the installation of 1,151No. Soil Nails between 6m and 13m in length. This removed 4.5m of excavation and saved six weeks on the overall construction programme.

Standard grouting works were also undertaken using Aarsleff's own Klemm 806-3G rig to facilitate the construction of a road - also adding a series of consolidation grouting behind the soil nailed wall - totalling 2,000 t in all.

The client introduced an over dig below the toe of the wall, which was an extra 4.9m in places. Aarsleff therefore, designed the soil nail wall to continue to a greater depth, whilst taking into account the reduction in capacity of the fill material in the long term. The grouting behind the line of the wall was therefore taken deeper to stabilise over the rig.

Aarsleff's Klemm 806-3G rig is compatible for use with powerful double head drilling units, hydraulic drifters or rotary head, whilst the drive train is based on a 160kW diesel engine including SCR-



only emission technology. The drill rig can be equipped with drill masts either with feed gear or cylinder feed systems with the option of fitting lattice mast extensions. The modularity of the drill mast allows the adaption of a variety of options which makes it universally applicable for anchoring, micro piling, jet grouting and of course drilling.

Aarsleff also offered a radically different approach to the original option on the actual foundations, which also saved the main contractor time. Due to the ground conditions comprising an

overburden of fill overlying mudstones, Aarsleff proposed a driven piled solution as opposed to standard CFA piling and installed 1,199No. 300mm² precast piles to depths of between 6m and 14m and 210No. 244mm diameter steel tubular piles down to between 8m and 18m in depth, using a combination of two rigs - a Junttan PMx22 and a Junttan PM20.



RAILWAY BRIDGE IN NORWAY

Steel foundations for the railway bridge over Minnevik.



Aarsleff Ground Engineering delivered the pile foundations for a new railway bridge at Minnevik, an hour's drive north of Oslo. As part of developing the Norwegian railway infrastructure, Bane NOR had several projects with dual track extensions in the east and west of Norway. Approximately 4.5km spanning from Eidsvoll North to Langset on the Dovre Line was constructed. The Minnevik railway bridge is 836m long, and formed one of the main elements in Aarsleff's challenging, multidisciplinary construction work.

Aarsleff Ground Engineering was subcontracted to execute the piling works for the bridge in a joint venture between the Norwegian Hæhre and the Norwegian PNC whose parent company is Austrian Porr.

The Minnevik bridge, crossing the river Vorma close to Eidsvoll, is a concrete bridge, which to the south at the Kråkvål Peninsula, is rising from filled ground in the Vorma and towards north cutting into the terrain of Langset. The central span of some 100m will be constructed with an overlying arch carrying the bridge deck, which has a clearance of approximately 14m from the water table in the Vorma, enabling vessels to pass underneath in the future.

The bridge had a layout of 20 pier shafts, and they all required piling. The piles were designed as friction piles - which the Norwegians refer to as "svepeler" - floating piles - as the shaft and not the tip of the pile provides the main part of the bearing capacity.



The foundation of the Minnevik bridge consisted of 268 No. driven piles in total, all with a diameter of 1016mm and installation lengths of up to 58m. All piles were set out in a tight scheme, thus arranged with an inclination of 1:10 - 1:5 in order to resist ice loads, brake forces etc. In addition to the piling works, Aarsleff also installed 17 cofferdams (up to 20x24m²) using sheet piles with a length of 19m allowing for excavation to a depth of approx. 10m.

Since the construction site was not connected to open sea by the river, the transportation of the heavy piling equipment and the piles called for special solutions. Designated barges for the river works were therefore provided from Aarsleff's fleet, transported by road to the site and assembled locally. Due to the inland location of

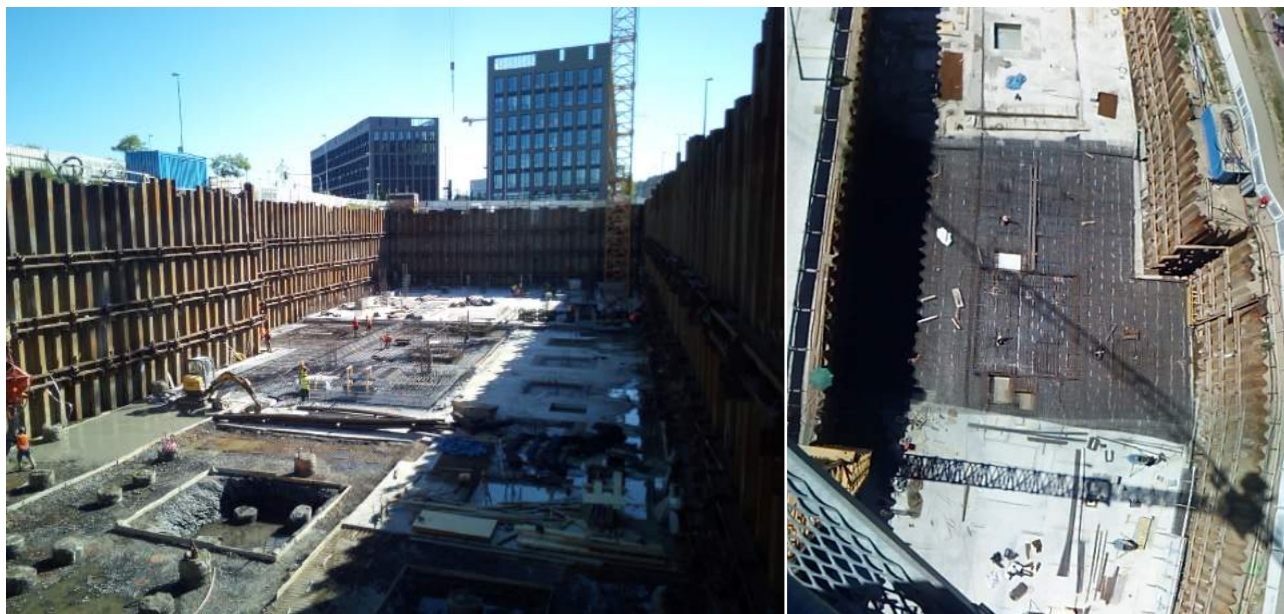
the construction site - the long steel piles had to be assembled on-site before they could be driven into the ground. The piles were manufactured in Turkey in smaller sections of 11.9m and shipped to Minnevik in 40' containers by ship and trucks. The final assembly was carried out on site, where Aarsleff had established an indoor welding factory, which enabled robot welding regardless of weather conditions.

In the bridge location the river Vorma was only 14m at its deepest, but diving assistance was still needed. The driving of the long and heavy steel piles was performed with a Liebherr LRH600 piling rig, one of the largest piling rigs in Europe. The rig was equipped with a Junttan HHK18S hammer with a total weight of 35.5t and 18t drop weight, respectively.



OFFICE IN CZECH REPUBLIC

Construction pit for new office building in Prague.



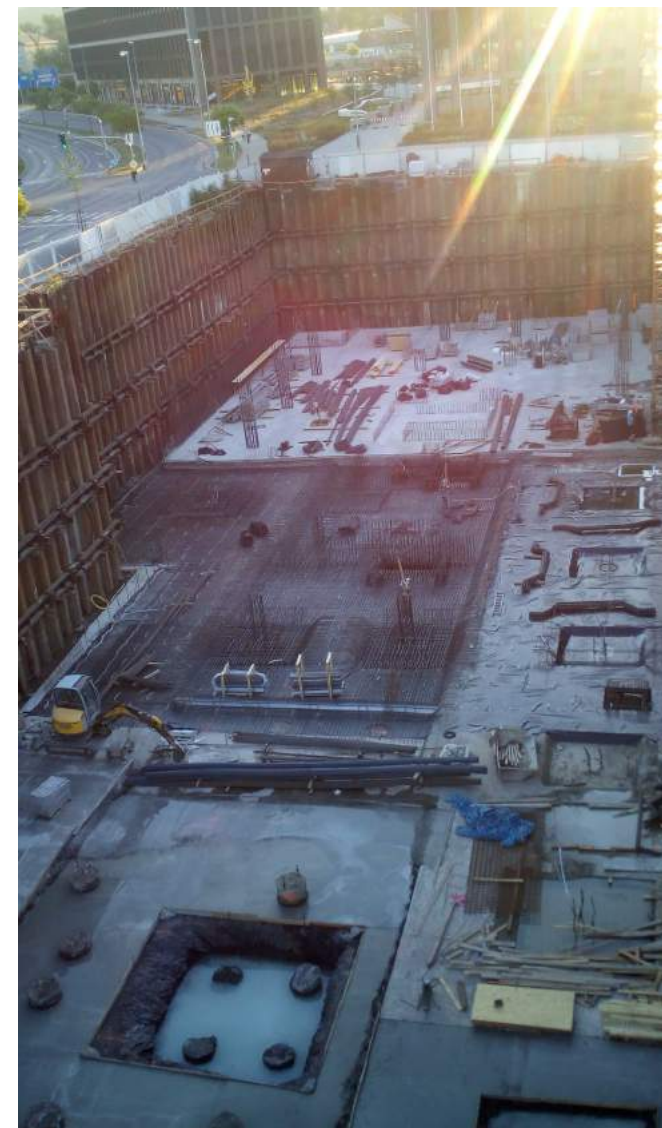
Aarsleff was commissioned to carry out the securing of a construction pit for the new J&T Bank office building in the Rustonka business centre, Prague.

The substructure had the dimensions of approximately 120m x 40m on land between busy roads, extending to a depth of about 12m below the existing terrain.

The building is located in the area of the city district of Karlín, where there were relatively straightforward if unfavourable geological conditions for deep excavations. Made up of Ordovician shales, the rock surface is at a depth of approximately 12m, on which a quaternary cover of 7m gravel sediments, fully saturated with groundwater, (subsidised from the Vltava

River) is mounted. This layer is highly cohesive and permeable and functions as an almost perfect collector for groundwater. The upper layers then form fluvial sediments and anthropogenic fillings with the remains of masonry and building rubble from the former industrial development.

Due to the boundary conditions, the preferred retaining wall in the locality is usually by diaphragm or secant pile wall. The use of a temporary sheet pile wall was rejected by designers and investors – sheet piles would have to be driven into the bedrock to ensure impermeability, and this was of course impossible using only the usual vibratory technology. Everything changed in 2015 when the company designed and successfully implemented sheet pile walls for the first time in the region of Karlín.



The Rustonka was their third technically successful project there.

Before installation, it was necessary to loosen the bedrock, which in this case was done by a system of boreholes with a continuous auger of 630mm diameter in the location of future clutches of sheet piles without excavating the material. Subsequently, the 14m long sheet piles were installed by Bauer RG 21T into the prepared subsoil.

The stability of the structure was ensured by temporary anchors located at three levels. Due to the significant inflow of groundwater in the gravel layer, it was necessary to use watertight heads for anchors.

After the actual construction of the pit, the space between the sheet pile and the monolithic construction was backfilled and the anchors were gradually deactivated, the bracing removed, and all sheet piles were extracted.

The design in Aarsleff's submission saved a considerable amount of time and money compared to the commonly used practices, due to the possibility of reuse of sheet piles which is the more environmentally friendly option.



ONE COMPANY

The Aarsleff Group is organised in independent, competitive divisions and companies each with their own specialist expertise. We refer to teamwork and collaboration across divisions as 'One Company', meaning that we seek and exploit synergies. The synergies develop when specialist contractors contribute expertise to reach the best solution.

All large-scale projects are undertaken in collaboration between several of Aarsleff's divisions and companies. This allows us to

utilise and share experience gained through intercompany projects, with priority to joint management because it creates value to the customer in the form of flexible and efficient processes – and not least results of the highest quality.

By drawing on the companies' versatile contracting expertise, Aarsleff is able to undertake work of any scale in turnkey projects with a high degree of own production. This provides security for the client – financially as well as professionally.

SUSTAINABILITY

We're ready to meet the demand for and the requirements of sustainable buildings. It's in our DNA to be flexible and agile and look for new innovative solutions in our work, and we'll continue doing so - Jesper Kristian Jacobsen, CEO

- 1

The Aarsleff Group are aware that all of our activities and operations influence the environment. We ensure our manufacturing and operation processes are planned and executed with the least possible impact on the environment.
- 2

We continuously monitor and adapt working practices and equipment to improve the environmental impact of noise and vibration on site.
- 3

The offsite manufacture of Aarsleff's precast products provides several benefits with respect to QA, reduced energy and carbon consumption, durability and low waste, while their driven installation benefits from low spoil production.
- 4

Aarsleff's geotechnical engineering practices include the use of alternative, environmentally friendly materials, and the reuse of waste materials where possible.
- 5

Through research projects and close collaboration with academic institutions, the Aarsleff Group makes sure its techniques are at the forefront of innovation, so that it can offer the most effective solutions for our customer's challenges.
- 6

We collaborate with our customers to include measures and procedures from the start which can minimise the environmental impact. The use of Virtual Design & Construction in particular allows us to improve buildability as well as plan and improve the efficiency of the building processes – before execution.



As part of the Aarsleff Group, we have participated in many 'One Company' projects, and we think that the concept is quite unique. When we work according to the One Company principles, we strive to make the client feel secure and to supply high quality on time and at an attractive price. Discover more by visiting: www.aarsleff.com/about-aarsleff/one-company-collaboration

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