

## Wind farms

- Earthworks
- Deep foundations
- Ground improvement
- Base slab



## Wind turbine foundations

Keller has delivered wind turbine foundations over decades, safely applying a variety of advanced foundation and ground improvement technologies. We provide custom design and build solutions, always taking into consideration the cost and environmental impact.

## Challenges we can solve

Preparing the ground for the construction of wind turbines can be challenging and costly. Wind turbines are often located close to the shoreline, where soils are weak and compressible or are built in higher, more remote areas often with a variety of different soil conditions. Constructing the foundations on hillside locations and inclined soil layers or fissures can be difficult. It is also important to consider dynamic, eccentric and peak load requirements, as well as servicing and maximum inclination, demands.

Keller has the know-how and capability to design and build state of the art foundations for the largest wind turbines under any condition, based on a track record over decades.

## Health and safety

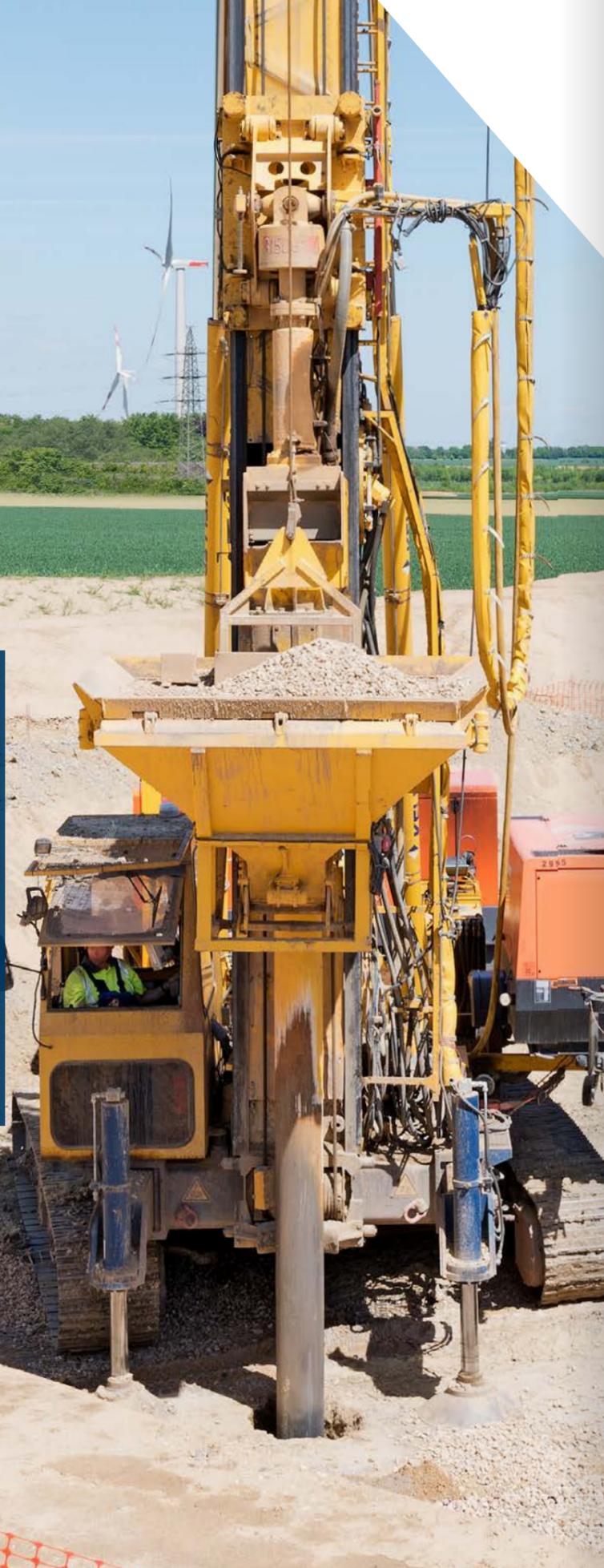
Health and safety is a priority for Keller and we have a proven track record of one of the lowest accident frequency rates in our industry. The commitment of leaders and employees to our Think Safe programme has earned us awards and recognition from industry bodies as well as our clients.

We believe no one should be harmed as a result of any work we do and our ultimate goal is zero incidents.

## Ground improvement Eschweiler Fronhofen, Germany

RWE Innogy awarded Keller Grundbau the contract to construct 18m-deep vibro stone columns for nine wind turbines up to a height of 143m.

The turbines had to be built on a former brown coal open pit mine reaching depths of up to 100m. Backfilling was completed using finely-sieved, slightly silty and gravelly, homogeneous sands.



## Project examples

### Deep foundation Hannut, Belgium

EIFFAGE Energia contracted Keller to install deep foundations, using CFA piles, for the construction of nine wind turbines. In total, Keller installed 163 piles with a total length of 3,250m.



## Ground improvement Monts de Maisnil Audincthun, France

Keller Fondations Spéciales completed ground improvement work using a rigid inclusion system on the foundation of a series of wind turbines. CFA piles were used, partly displacing the soil, and a load transfer layer was installed between the rigid inclusions and the turbine base slab to reduce horizontal forces.



## Project examples

### Ground improvement Grossheide-Arle, Germany

ENERCON awarded a joint venture, headed by Keller Grundbau, to build foundations for eight wind turbines.

Four wind turbines were founded on 108 driven cast in situ piles and the other four with 233 vibro stone columns.

The vibro stone columns and driven cast in situ piles at up to 33m deep were installed in dense to very dense sands. The bearing layer was overlaid by clay, silt, alluvial sands and peat.

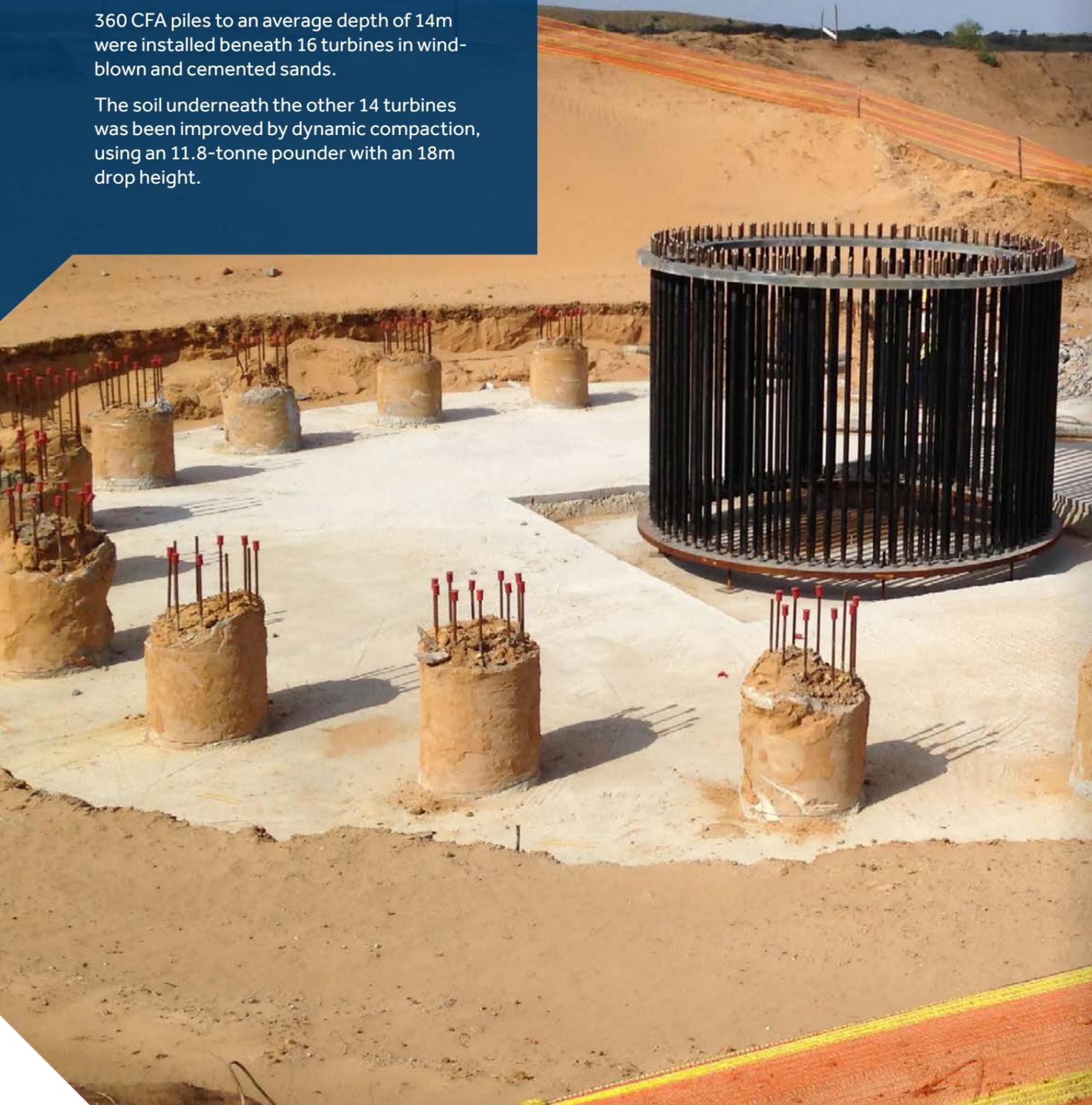


## Deep foundation & Ground improvement Gibson Bay, South Africa

Franki Africa, a Keller company, provided two geotechnical methods for the foundation of Gibson Bay Wind Farm.

360 CFA piles to an average depth of 14m were installed beneath 16 turbines in wind-blown and cemented sands.

The soil underneath the other 14 turbines was been improved by dynamic compaction, using an 11.8-tonne pounder with an 18m drop height.



## Project examples

### Deep foundation Ellwangen, Germany

ENERCON contracted Keller Grundbau to provide the foundation for three wind turbines.

The 149m-high structures required 26 reinforced concrete bored piles (1000mm diameter) below each slab up to a depth of 13m.



## Ground improvement Trairi, Brazil

Tractebel Energia awarded Keller Tecnogeo a project to construct a total length of 3,317m of vibro stone columns (800mm diameter, up to 16m depth) beneath 36 wind turbine slabs.



## Project examples

### Deep foundations Nowy Staw, Poland

BUDIMEX contracted Keller Polska to design and build deep foundations for 37 wind turbines type REpower MM92 and MM100 in challenging ground conditions. The subsoil consisted of organic layers at the surface and interbedded in fine and medium sands.

Our solution comprised 32 precast piles (400x400mm) for each turbine foundation, including 16 vertical and 16 inclined piles (8:1), 9 to 17m long. For 14 turbines located in very soft spots, additional seven piles, 300x300mm and 9 to 12m long, were added to support each tower. In total, 16,512m and 931m of precast piles made of reinforced concrete C40/50 were installed.



## Ground improvement Santo Domingo, Mexico

6,200 lm of vibro stone columns were installed to improve the ground beneath 17 wind turbines.

The challenge of this ground improvement method was preparing the ground to withstand seismic forces should an earthquake occur, including any subsequent effects of liquefaction.

The tough time constraints given by the client were fulfilled using most modern equipment provided by Keller Cimentaciones.

## Project examples

### Ground improvement Kassiek-Lindsted, Germany

For Enercon, Keller Grundbau constructed vibro stone columns for 10 wind turbine foundations.

The main challenge faced was the variation in ground conditions under the foundation slab. In one half of the area, the ground was dense and suitable, but the other needed ground improvement using 52 vibro stone columns up to 11.5m of depth to prevent differential settlement. Predrilling was partly used to aid poker penetration.

## Ground improvement Königshovener Höhe, Germany

RWE Innogy awarded Keller Grundbau the construction of vibro stone columns for 21 wind turbines, 143m high.

The turbines had to be built on up to 160m-deep former brown coal open pit mine. Backfilling was completed using finely-sieved, slightly silty and gravely, homogeneous sands.

With the installation of vibro stone columns up to 20m deep, homogeneous ground condition could be achieved.



## Project examples

### Ground improvement Reinaco, Chile

Keller Cimentaciones Chile completed the foundation for 15 wind turbines on very poor quality soils. The natural ground was highly compressible.

For settlement control, an in-house solution, provided by Keller Chile, proposed 1,485 vibro stone columns up to 10m deep.



## Deep foundations Shoreham By Sea, UK

To provide the Shoreham Port facilities with a form of green energy, two wind turbines needed to be built on the shoreline. Keller UK installed micro piles to provide foundation support beneath the tower slabs.

The main challenge was installing micro piles on a small restricted site between the edge of rock armoured sea defences and the concrete wave wall.

Twelve micro piles were installed at each wind turbine location up to 25m depth.

Keller Getec Azimuth Aligner was used to ensure the correct alignment and inclination.

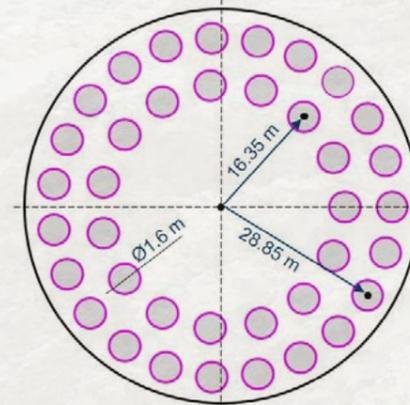


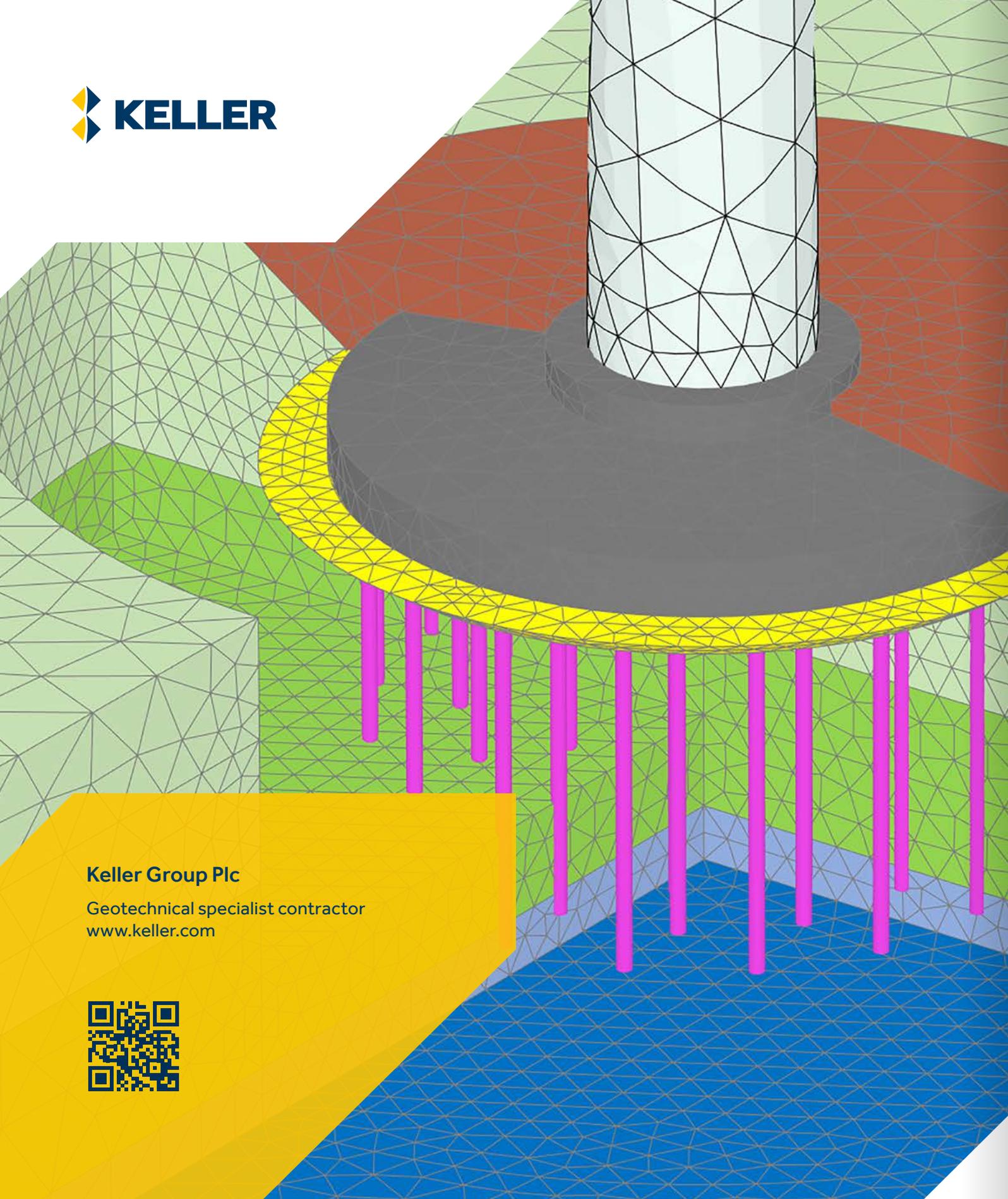
## Project examples

### Ground improvement Pağów, Poland

Since 2007 more than 400 wind turbines have been founded on deep soil mixing columns in Poland, and the solutions adopted turned out to be reliable, quick to execute and competitive.

The project comprised nine wind turbines at 119m in height, built by PBDI S.A. and ERBUD S.A. for GDF SUEZ Energia Polska S.A. Keller Polska designed and installed 38 DSM columns for each turbine foundation. The columns were 1.6m in diameter, and 6 to 12m long. The adopted characteristic compressive strength of soil-mix was 2.2 MPa.





**Keller Group Plc**

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