

» 1990

Connection is made on the service tunnel of the Channel Tunnel project, making it possible for the first time in about 10,000 years to walk between England and France.

» 1991

Work begins on placing steel cabling around the most stressed section of the Leaning Tower of Pisa. UK government chooses Arup route for CTRL with terminal at Waterloo.

» 1992

Crossrail heralds one of the most sophisticated site investigations ever carried out in London. The investigation is a success, but the project fails to secure funding.

FOUNDATIONS AND PILING

CORE VALUES

Bigger and deeper piles have dominated developments in piling technology in the last 40 years, discovers **Damian Arnold**.

The story of piling and foundations since the early 1960s has been one of continuous pushing of boundaries towards bigger and deeper foundations facilitating higher and more heavily-massed buildings and more cavernous basement spaces.

"With each job completed, you see where you can go a bit further and, as a consequence, buildings get higher, heavier and deeper," says Geotechnical Consulting Group director Professor Hugh St John.

One of the most important innovations of the 1960s was the development of large-diameter piles with under-reams mechanically shaped in an inverted cone at the base of the pile, by as much as 6m in diameter, which allowed for very high load-bearing capacities.

"The dry and stable London Clay was a very good medium for under-reamed piles and we did an enormous amount in the 1970s," says Cementation Skanska foundations and piling key account manager Dick O'Driscoll. "It's still a very effective solution and we've just done some for the preliminary groundworks for the Heron Tower in London."

St John adds: "We started doing large-diameter piles in the 1960s and 1970s with the big rotating rigs initially brought over from the US, but to limited depth. In the mid-60s we started doing under-reamed piles bored much deeper."

The next innovation was the introduction of bentonite fluid through the auger to stabilise the ground around the pile. This gave contractors the ability to drive far deeper piles of up to 60m.

O'Driscoll takes up the story of how Cementation started to use bentonite in the mid-1960s. "It allowed us to put piles into the water table which was essential for some of the taller buildings starting to happen in London in those days.

"It enabled us to drive piles without having to put in very long

temporary casings which were very expensive. By using bentonite as a drilling fluid we could stabilise the wall of the hole and stop the gravels and loose soils from falling in."

The introduction of bentonite then led to the development of the diaphragm wall, often excavated with a grab. The concrete was pumped in, displacing the bentonite and the reinforcement cages placed. Once complete it would effectively act as a massive retaining structure to facilitate basement excavation.

Cementation built its first diaphragm wall for a sewerage plant in Eastbourne in the 1960s and the construction of the Hyde Park Corner underpass in the early 1970s was another early application. Professor John Burland of Imperial

"By using bentonite as a drilling fluid we could stabilise the wall of the hole and stop the gravels and loose soils from falling in."

Dick O'Driscoll
Cementation Skanska

College cites the deep basement car park for the Palace of Westminster, known as New Palace Yard, in 1975 along with the basement for the Pompidou Centre in Paris, completed in 1977, as landmark projects in terms of unprecedented size and depth of the basement.

"In the 1980s we started »

MINIPILING

The history of minipiling in the UK can be traced back almost 40 years to when Fondedile first brought its specialist Pali Radice (root pile) techniques to this country, says *Jim Martin*.

The fledgling domestic underpinning minipile market then developed in earnest after the dry summer of 1976 when companies like Bullivant and Cementation set up their own mini-piling divisions. Over recent decades, there have been major developments and growth in the use of minipiles and they now represent a substantial proportion of the piling and ground engineering market.

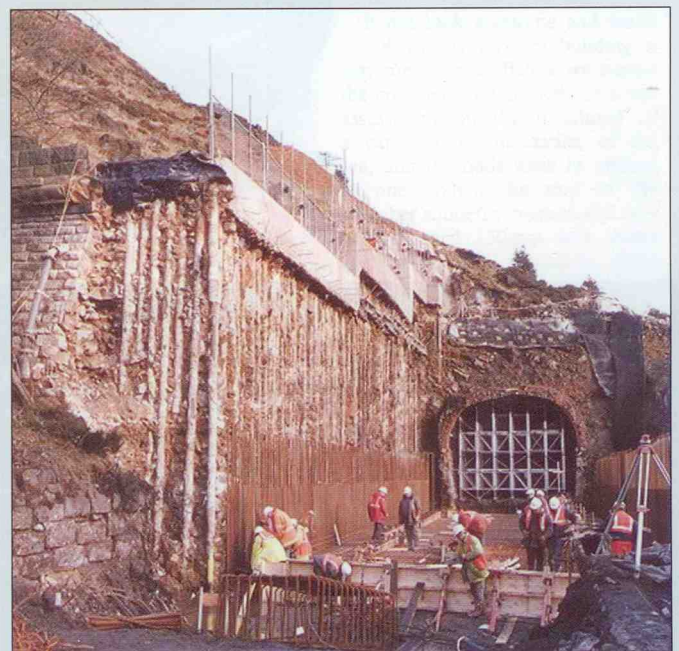
The use of minipiles has grown from simple driven tube domestic minipiles to high strength heavily reinforced concrete and grout piles used in many areas of civil engineering. This is due to significant improvements in the capabilities of minipile drill rigs and drilling systems (case and auger, rotary duplex, rotary percussive and down the hole hammer).

While minipiling does not profess to be the cheapest form of piling, it may offer the best value option where there is difficult drilling involved in rock,

concrete or masonry, difficult access to the site or permanent casings are required. Minipiles may also be the preferred option where there are high-tension loads (primarily shaft friction piles) and or inclined drilling is required. Self-drilling hollow bar and hollow stem auger now form part of the minipile armoury and are a growing percentage of the market due to the speed of installation and competitive cost.

Some modern minipile rigs can now install piles of up to 600mm diameter, which makes the definition of a minipile as a pile with a diameter of 300mm somewhat misleading. The load carrying capacity of minipiles has grown from around 100kN or less in compression to approximately 1,400kN in compression or tension for minipiles reinforced over their full depth founding in strong bedrock.

A major growth area for minipiles is the upgrading of existing structures via the use of retrofitted minipiles. At Newcastle United's football ground, retrofitted minipiles were used to allow the addition of another level to the North Stand. Similar



Stabilising the railway embankment at Todmorden for the Horsfall tunnel, 1997-98 (above) and minipiling at the same project

» 1993

The Ground Forum is formed to offer a co-ordinated industry voice and raise awareness of the importance of geotechnics in construction. David Sherwood of Bachy is the founding chairman.

» 1994

Heathrow Express tunnel collapse causes havoc at one of the world's busiest airports. The Channel Tunnel opens and is proclaimed one of the great engineering projects.

» 1995

London's largest diameter and longest concrete bored piles are sunk at Westminster Station on the JLE. Foundations include just nine main loading piles, each 3m diameter and up to 52.5m long.

techniques have been used in many urban developments to allow the construction of extra floors.

Embankment stabilisation and associated works on the railways have been another large market for minipiles over the past two decades, with thousands of minipiles installed along LUL embankments. In the late nineties, a 15m high-reticulated minipile was constructed at Horsfall Tunnel near Todmorden, where the access and ground conditions were particularly difficult and it was not possible to use a conventional piling rig.

The recent growth in deep basements has created a big market for antiflotation tension minipiles. Several thousand of these have been installed in Dublin alone, where the limestone bedrock at shallow depth makes them particularly suitable.

In addition to restraining the basements from flotation, they also reduce bending moments in the slab, thus allowing significant reductions in the slab thickness and reinforcement.

Jim Martin is director of Byland Engineering



BIG PILES

In the last 40 years, some piling techniques have disappeared while others are resurgent. Arguably most of these changes have been driven by developments in piling equipment, says Alex Cartwright.

In the 1960s the foundation market began taking inspiration from Italian improvements in diaphragm walling techniques. Diaphragm walls allowed deeper basements and engineers were quick to take advantage of this new technology, spawning a persisting trend for deep basements.

In the 1960s vast numbers of tripod rigs commonly worked in close formation on construction sites, but by the end of this decade they were being slowly replaced by crane-mounted drilling rigs. It was quickly apparent that turning an auger into soil was more efficient than dropping a hollow tube into it and the demise of tripod piling began. The new rotary piling rigs made the construction of under-reamed piles an efficient prospect.

From the 1960s under-reaming boomed, until in the 1990s, new legislation prohibiting manned descent of un-lined pile boreholes prevented the cleaning of under-reams. This rendered much of the under-reaming technology of the day instantly redundant.

Just as the crane-mounted piling rig had replaced the tripod rig, so in the 1980s a new breed of more powerful hydraulic piling rigs began to supplant the crane-mounted piling rig.

In the 1980s, as the diaphragm wall basement market reached its zenith, powerful new machines were beginning to restore the balance of economies for deep basement construction in favour of the piling rig. In the 20 years since the British Library project demonstrated the economic benefits of deep secant piled walls over diaphragm walls, the diaphragm walling market has waned noticeably and it is the modern piling rig that has driven this change.

Alex Cartwright is director of AC DEVCO



Piling in the 1970s. Photo courtesy of Cementation Skanska.

» putting in more retaining walls using bored piles to form secant/contiguous bored piled walls," says St John. "It was a dramatic change that made everything cheaper. It created deeper and deeper basements."

In the early 1980s, continuous flight auger (CFA) piles were used for the first time and would go on to become the most popular piling technique, accounting for about 40% all piles, according to O'Driscoll.

"We now have a wide range of techniques developed over the last 40 years. The thing is now making sure we choose the right method for the right situation."

Professor Hugh St John, GCG

The technique transformed the piling industry because the rig would drill the hole and inject the concrete through the auger simultaneously, leading to big time and cost savings. It also enabled the pile to be formed in difficult ground before its hole started to cave in.

By the 1980s basement

constructions, such as the car park for the Aldersgate office block in the City of London, completed in 1988, were becoming deeper still. More recent projects included a 27m basement car park underneath the Harrods department store in London, completed in 2000, the 30m basement for Westminster Jubilee Line underground station (1999) and a massive diaphragm wall built for the Channel Tunnel Rail Link Stratford box (2002).

Such large retaining structures facilitated "top-down construction" whereby steel columns could be plunged into the piles before basement excavation began, enabling the work on the structure to begin to take place above.

A more recent landmark project is the Moorhouse office scheme, in the City of London, completed in 2004 and where Arup Geotechnics, Cementation Skanska and Skanska UK worked together to install large-diameter driven piles 60m into the Thanet Sands. The piles were sleeved and protected by a bentonite layer to reduce the downward drag that could occur when the Crossrail tunnels are later bored within 3m of the building's foundations.

And with a new range of tall buildings in the pipeline: the Shard; the Pinnacle; the Cheese Grater; and the Walkie Talkie, to name but a few in London, the industry will develop further, says St John.

"We now have a wide range of techniques developed over the last 40 years. The thing is now making sure we choose the right method for the right situation."