**» 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 cases 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 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 »

> "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**

## 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***