GOING UNDERGROUND

Engineers are completing a new five-storey basement underneath London’s Claridge’s, with no interruption to the hotel overhead. This extraordinary achievement has been made possible by a combination of traditional mining techniques and state-of-the-art structural and geotechnical engineering. Hugh Ferguson talked to engineers from McGee and Arup about the project, believed to be a world first for concurrent underground development and occupancy on such a scale.

Claridge’s hotel in Mayfair dates back to the 1890s in its current form. However, the building needed more space for its five-star facilities, including a spa and a swimming pool. With planning regulations removing the possibility of building upwards, a five-floor basement has been dug out below.
A FAMILY AFFAIR

In 2007, Wembly-based McGee was invited, along with several other civil engineering contractors, to submit a proposal to extend the basement beneath Claridge’s by two storeys. Managing Director Jim Mackey devised and proposed a scheme that would keep the hotel open throughout: all the other contractors required the hotel to close during the works. The project was once again live, only this time the hotel required five storeys instead of two: “We want to do it, and it starts next week.” Jim returned to London, where it was a clayey silt, it flowed like ‘running sand’, or ‘silt’, so extending downwards became the preferred solution. The real challenge came from the need to keep the hotel open and running, as it was already occupied by the Queen - a rare occurrence. The work had to be done without endangering the building overhead, the safety of the hotel and the hotel guests. The team was initially allocated just one small room overhead. The building’s columns, so relieving the loads on the raft. Gradually excavate downwards through the clay to create the basement levels, casting new walls and floors on the way. As if this was not challenging enough, the work had to be done with no noise or disturbance to the occupants overhead. The team was initially allocated just one small room on the lower ground floor (with a second room and a connecting corridor added later). All excavated material had to be removed, and all material and equipment brought in, through one window at the rear of the building, and lifted with a single hoist through one small hole in the raft. There was virtually no storage space, so all deliveries and removals had to be carefully planned on a ‘just in time’ basis. No noise, vibration or other disturbance to the hotel above could be tolerated. With a ‘live’ building overhead, the safety and stability of the structure at every stage was critical. The first two challenges were to gain an understanding of the existing concrete raft and how it would behave at every stage of construction until its eventual – very different – role as a suspended slab, and find a way to deal with the saturated silt immediately below the raft. A two metre by two metre hole was cut through the raft, both to provide initial access and to enable samples of the concrete to be analysed and tested. The hole was later doubled in size to provide the main access route for materials. With the raft, the concern was not so much whether it would sink or even tilt during the work, but whether it would bend and crack, and if so, where and how. Tests on the samples confirmed that the concrete was good quality. Desk studies

Claridge’s hotel in Mayfair, once described as the ‘fifth hotel in London’ and later as ‘an annex to Buckingham Palace’ because of its strong royal connections, opened in 1856 as an amalgamation of five terraced buildings. In the 1890s, it was built and redesigned in its current form, and a large extension, encompassing 60 new rooms and a ballroom, was added on the east side in the 1920s. However, in order to thrive as a top five-star hotel in the 21st century, the hotel needed more rooms and more facilities, including a spa and a swimming pool. For planning reasons, building upwards was out of the question, so extending downwards became the preferred solution. The real challenge was to keep the hotel open and fully functioning throughout the building works: a temporary closure would risk regular visitors changing their loyalties before the hotel reopened.

In 2015, the Maybourne Hotel Group asked engineering firm McGee to create a five-storey basement beneath the art deco extension. McGee was the only contractor to believe that the work was possible without closing the hotel (see family affair), but realised that help was needed to confirm that it could be done without endangering the building overhead. A small window was cut through the roof, and water was pumped into the basement to see if the building would bend and crack, and if so, where and how. Tests on the samples confirmed that the concrete was good quality. Desk studies

STABILISING THE BUILDING

The 1920s eight-storey extension is supported by 61 steel columns resting on a 1.1-metre-thick, 50 metre by 25 metre reinforced concrete raft (a slab spread out under the entire building) directly below the lower ground floor, with no pile foundations beneath. Some distance beneath the raft was firm London Clay, but unfortunately in between the raft and the clay were treacherous, uneven layers of gravel, up to half a metre thick, overlain by a layer of saturated silt with a high water content up to two metres thick, which was an alluvial flood plain feature of the former course of the River Tyburn. In its contained state, this silt had a high bearing capacity and could satisfactorily support the building overhead. However, once disturbed, below the table water the material flowed like ‘running sand’, so extending downwards became the preferred solution. The real challenge was to keep the hotel open and running, as it was already occupied by the Queen - a rare occurrence. The work had to be done without endangering the building overhead, the safety of the hotel and the hotel guests. The team was initially allocated just one small room overhead. The building’s columns, so relieving the loads on the raft. Gradually excavate downwards through the clay to create the basement levels, casting new walls and floors on the way. As if this was not challenging enough, the work had to be done with no noise or disturbance to the occupants overhead. The team was initially allocated just one small room on the lower ground floor (with a second room and a connecting corridor added later). All excavated material had to be removed, and all material and equipment brought in, through one window at the rear of the building, and lifted with a single hoist through one small hole in the raft. There was virtually no storage space, so all deliveries and removals had to be carefully planned on a ‘just in time’ basis. No noise, vibration or other disturbance to the hotel above could be tolerated. With a ‘live’ building overhead, the safety and stability of the structure at every stage was critical. The first two challenges were to gain an understanding of the existing concrete raft and how it would behave at every stage of construction until its eventual – very different – role as a suspended slab, and find a way to deal with the saturated silt immediately below the raft. A two metre by two metre hole was cut through the raft, both to provide initial access and to enable samples of the concrete to be analysed and tested. The hole was later doubled in size to provide the main access route for materials. With the raft, the concern was not so much whether it would sink or even tilt during the work, but whether it would bend and crack, and if so, where and how. Tests on the samples confirmed that the concrete was good quality. Desk studies

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judgements to be made about ‘additional’ reinforcing steel is probable explanation was that reinforcement found in the construction unearthed reports backfilled with concrete to form a new basement where it was taken advantage of the non- and an arching model, which could be measured – and that the chosen approach was feasible and safe. A 3D finite element geotechnical model of the raft’s interaction with the ground was subjected to different excavation activities (tunnel excavation, shaft construction, removal of temporary steel, and soil removal beneath the raft) to predict possible raft movements. This was vital to informing structural models and analysis. This is a project where the structural and geotechnical engineers relied on an integrated approach to design to provide a unique solution.

Quick Excavation

Several methods of dealing with the soil were considered. Grout injection, which is usually used to fill accessible pores between the solid particles in a soil to strengthen it, was not suitable because the material was too dense and clay-like to inject. Ground freezing to stabilise the saturated silt was also rejected because it would have required access to occupied hotel rooms, meaning that the hotel would need to be closed and was therefore outside the client brief. Tests showed that the silt, once dried, formed a remarkably stable clay-like material, so engineers decided to drain the silt using vacuum pumps from several bored wells. First, the perimeter of the site had to be sealed on all four sides to stop any water flowing in. The most challenging part was the north side along the front of the hotel, where no external construction work could be permitted. The solution was a ‘water cut-off beam’ beneath the edge of the raft, 1.2 metres wide by 1.8 metres deep (to connect into the impermeable clay below) and 25 metres long, created by digging a tunnel using vacuum drainage along the edge of the raft, and then filling with reinforced self-compacting concrete.

A diagram shows the three main tunnels (in blue) – named Tom, Dick and Harry – beneath the concrete raft, with tunnels of access tunnels in context to the levels of soil of the E1 caissons.

A hotel floating on hydraulic fluid

Key to the safe construction of Claridge’s new basement was the close monitoring of loads and deflections of the existing hotel at every stage of the work, together with the ability to make adjustments to the load distribution if the measurements approached a critical level.

One of the 61 hand-dug caissons with a temporary steel lining, outlined out below the bottom of the new basement where it was eventually chosen. The diameter of the caissons segments as they progressed. One-metre-deep bolted steel columns, from where the caissons would be sunk.

Two mine used pneumatic spades to hand dig each circular caisson through the dried silt and clay, installing a temporary lining formed of one-metre-deep bolted steel segments as they progressed. The diameter of the caissons was a critical decision: miners needed sufficient space to work and, at a later stage, to install the formwork and reinforcing steel for the new concrete columns, working in the cramped annular space between the columns and the caisson walls. However, the span of the raft that could be opened up to form the top of the caisson had to be kept to a minimum. A ‘sweet spot’ of 1.8 metres diameter was eventually chosen.

When the miners reached the basement, the caissons – up to 1.8 metres diameter and more conventional, permanent precast concrete linings of up to four to six metres in depth were installed for the next section. Finally, the bottom of the excavation was ‘belled out’ to a diameter of up to 4.6 metres to form a broad, flat base for the new piles. The level of the bottom of each pile was carefully chosen to avoid going below the impermeable London Clay, which would have allowed groundwater to enter and required compressed air working. Reinforcing steel was placed and the caissons were then concreted to form solid

The jacks are still in place and active, and will be until all possibility of unacceptable movement has passed. In the meantime, the whole art deco extension on the east side of Claridge’s remains floating on hydraulic fluid.

One of the 61 hand-dug caissons (left), while another places a reinforcing bar for a new structure within the tight space of a hand-dug caisson (right).

In the existing masonry walls, particularly concern, including the effects of load redistribution in the existing masonry walls. Overall, the analysis gave confidence that loading at every stage could be kept within the acceptable ultimate loads – provided that deficiencies due to excavation were controlled and could be measured – and that the chosen approach was feasible and safe.

Given the uncertainties, the design criterion in modern raft design, which is the tendency of the column with its large post load to ‘punch’ a hole through the raft – was less of an issue because of the ability of the existing gullies (an arrangement of metal beams to create large steel feet) at the base of each column to spread the concentrated column loads. The main strength analysis methods adopted were Johansen yield line analysis and an arching model, which took advantage of the non-simultaneous excavations to develop thrusts through the surrounding raft. Engineers assessed deflections using tools ranging from simple geometrical models of strain (for the new piles) taking into account the high ductility found through testing the mild steel rebars) through to sophisticated 3D finite element cracked concrete time-history analysis. The edges of the slab were a particular concern, including the effects of load redistribution in the existing masonry walls.
piles, up as far as the bottom of the new basement.

Working upwards from here, formwork and reinforcing steel were installed and the concrete poured for the 600-millimetre diameter permanent columns, founded on the new piles and running up the centre of the caissons. At the top of each new column, engineers installed twin 800-tonne hydraulic jacks and used them to start transferring the load from the existing building into the new foundations. The jacks, together with associated measuring equipment, were used to monitor loads and movement, and to make adjustments when necessary (see A hotel floating on hydraulic fluid).

The first six caissons and columns were treated as ‘trials’ to prove the feasibility of the proposed method, and only after their successful completion did the project turn into a full-blown contract. Tunnelling beneath the raft was extended, with three main tunnels – named Tom, Dick and Harry after the tunnels in The Great Escape – running most of the length of the raft, and with passageways connecting to the heads of all 61 caissons. There were so many tunnels and so much activity that it reminded those on site of an Indiana Jones movie.

With all 61 columns complete, the jacks were operated to transfer an additional load into the columns, equivalent to about three quarters of the dead load of the building. With the building’s load now removed from the raft, the network of tunnels and passageways could be removed and excavation of the basement could commence, dismantling the temporary steel caisson rings and adding new concrete walls and a basement slab linked into the new columns. The first basement was completed in February 2018.

An ingenious modified piling rig was used to create adjoining concrete walls around the perimeter of the new basement below. The rig was converted to electric operation to reduce noise and pollution, and had a reduced height mass to fit within the basement, but was still capable of drilling to a depth of 20 metres. Excavation and construction of the remaining basement levels then proceeded using fairly conventional top-down construction.

Health and safety management was paramount throughout. There were no reported injuries or accidents from any of the tunnel and shaft mining or the top-down construction, and no incidents involving loss of time for workers.

With construction of the ‘shell’ of the new basement completed at a cost of £35 million, all the machinery that services the hotel will be transferred from the top floors to basements four and five, the lower levels of the new basement, which will also be used for storage. This frees up space for up to 40 new bedrooms. Basements one and two, at the higher levels, will be fitted out to include two swimming pools, a restaurant, a spa and meeting rooms. Basement three will house operational space for hotel services, including food preparation.

This remarkable project has demonstrated that – with factors including the right site conditions, client and approach to risk – almost any historic building can be expanded downwards, without the need to shut down operations during construction. Most importantly, it requires a collaborative working relationship between the contractor and consultant, with experienced and knowledgeable engineers to do this type of work.

**BIOGRAPHIES**

Jim Mackey is Project Director for McGee.
Michelle Mackey is Project Engineer for McGee.
Dinesh Patel is a Director and Geotechnical Engineer at Arup.
Andy Pye is an Associate Director and Structural Engineer at Arup.