MICROPILE INSTALLATION USING THE PREVENTER SYSTEM TO CONTROL THE INFLUX OF GROUNDWATER DUE TO A HIGH WATERTABLE

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ABSTRACT

An 8 storey building located in Dubai had undergone some form of movement within the basements leading to cracked columns, walls and slabs. Active water ingress penetrated through cracks in the basement slab and walls. Cracks to the columns were initially identified in 2012 and were repaired in mid 2014 and appear not to have re-cracked since.

A geotechnical and structural assessment of the building was carried out and concluded that structurally the building was within the limits of acceptance. However, the consulting engineer carried out a detailed design to enhance the stability of the structure, which involved a combination of grouting and micropiling.

Some, 312No. 15.0m TITAN 40/20 micropiles (4670m) and over 580No.3.0m tube a manchette steel grouting tubes were both successfully installed using the preventer system.

This paper examines construction processes involved in installing the micropiles using the TITAN preventer system.

INTRODUCTION

PROJECT BACKGROUND

The building is located in Deira, Dubai, approximately 500m from the Creek. The structure was built in 2007 and consisted of 8 stories and two basements. In 2012 cracks to the walls, columns and slab were identified and led to partial water ingress. As a result, the building was completed closed and has been for over 3 years. In mid 2014 the consulting engineer instructed repairs to be carried out on the building which seems to have worked, as they appear not to have re-cracked since.

A review of the geotechnical data suggested two potential mechanisms may have initiated the building movement. These were a variation in the rock head quality and elevation and disturbance of the rock quality close to the perimeter diaphragm wall.

Subsequently building movement and crack monitoring programmes were implemented, with data suggesting that movements were stable. However additional measures to further enhance stability were proposed. The design included grouting to enhance the strength and stiffness of the underlying soils and reduce the permeability. In addition to this, the design included underpinning, using micropiles.

The geotechnical report identified a water table at -1.46m, with the micropile installation level at -4.45m. This posed a significant risk of water influx during the micropile installation, once the water proof membrane under the slab was penetrated. The use of the preventer system successfully allowed the installation of the micropiles and TAM grouting tubes whilst controlling and restraining the water influx.

GROUND CONDITIONS

The geology of the United Arab Emirates has been substantially influenced by the deposition of marine sediments caused by numerous sea level changes during recent geological time. To the north-east the country is mountainous, but in the main the country is relatively low-lying, with near surface geology being dominated by Quaternary to late Pleistocene deposits made up of Aeolian dune sands and sabkha/evaporates.

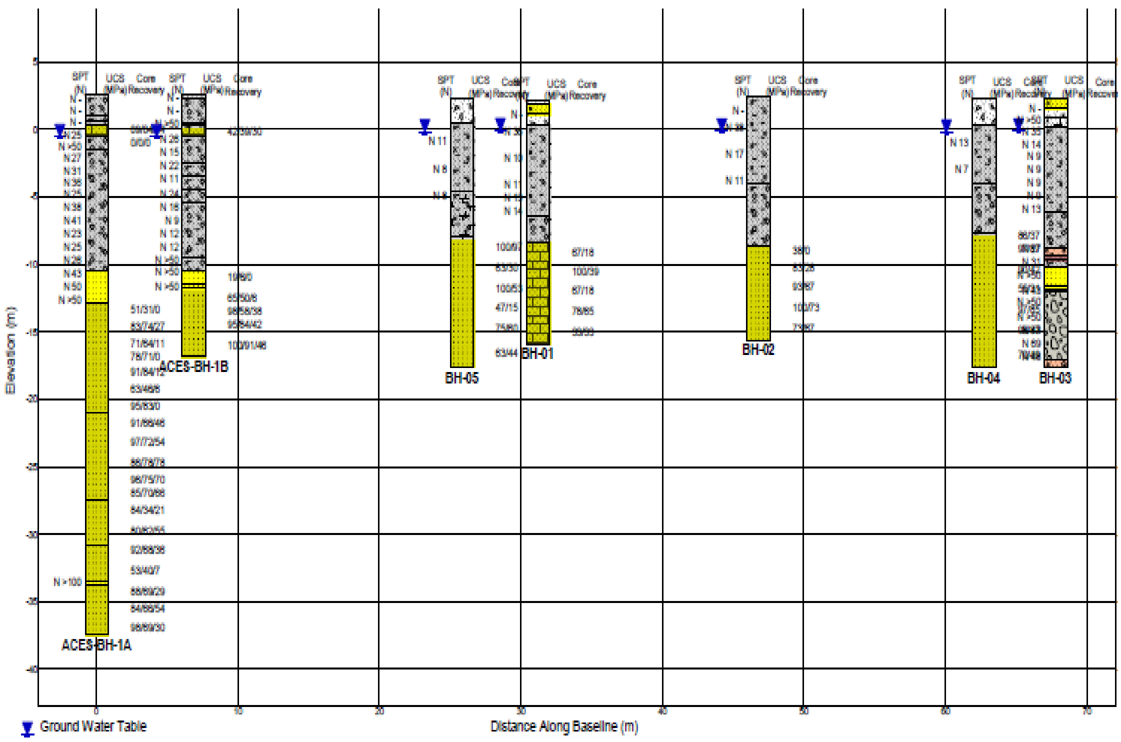

Figure 1 - Typical Boreholes

In Dubai the ground conditions essentially consist of superficial deposits of beach dune sands together with marine sands and silts. These superficial deposits are underlain by alternating beds of calcarenite, carbonate sandstone, sands and cemented sands.

The ground conditions on site in Dierra are typical and consisted of approximately 9.0m of sand overlying 1.5m thick bed of Calcarenite, which in turn overlaid the calcareous sandstone. At basement 2, the installation involved drilling through 2.0 – 3.0m of sand before the calcarenite/calcareous sandstone was encountered.

DESIGN

The micropile design was carried out by the Piling Contractor, however at the time of writing this paper the detailed design was unavailable as a reference.

The working load of the micropile was T_w = 256kN and to accommodate the load for a permanent design case the 40/20 was adopted (Yield Load = 425kN Ultimate Load = 540kN). The overall length of the micropile was 15.0m (allowing for the 400mm slab) and was installed using a 115mm cross cut drill bit. This allowed for an approximate 12.0m bond within the calcarenite and calcareous sandstone.

Due to the groundwater containing sulphate, corrosion protection of the micropile tendon was provided by an epoxy/galvanised coating, which met the permanent design life required.

INSTALLATION

Prior to commencement of the installation of the micropiles all drilling positions where marked on the basement concrete slab. Once this was completed the micropile positions where diamond core drilled using a 150mm diameter barrel, by rotation, using a water lubricant. The 400mm thick concrete slab was core drilled to a depth of 350mm, passing through the last row of steel reinforcement. As a precaution a mechanical packer was positioned close to the core hole to control any groundwater as a result of over coring.

Figure 2 – Mechanical Packer

Figure 3 – Diamond Core Drilling Set Up

Once the core drilling was completed, the walls of the core hole were roughened up using an electric hammer. This was carried out to improve the friction/bond capacity between the existing concrete slab and the new head detail. Once this was completed the core hole was cleaned of any resultant concrete debris.

The next procedure involved the set up of the preventer. First, four mechanical anchor bolts were installed into the concrete basement slab. A rubber gasket was then positioned over the four bolts, sitting directly on to the concrete slab. With this in position, the flange head plate and gate valve were installed directly over the core hole and bolted to the slab with the anchor bolts. The gate valve acted as a secondly preventer, sealing the core hole after installation. This allowed the preventer to be removed at an earlier stage, freeing it up for another micropile installation.

Figure 4 – Flange Head Plate & Gate Valve

Once the gate valve was successfully installed, the preventer was then fixed and secured to the flange plate using four M12 bolts.

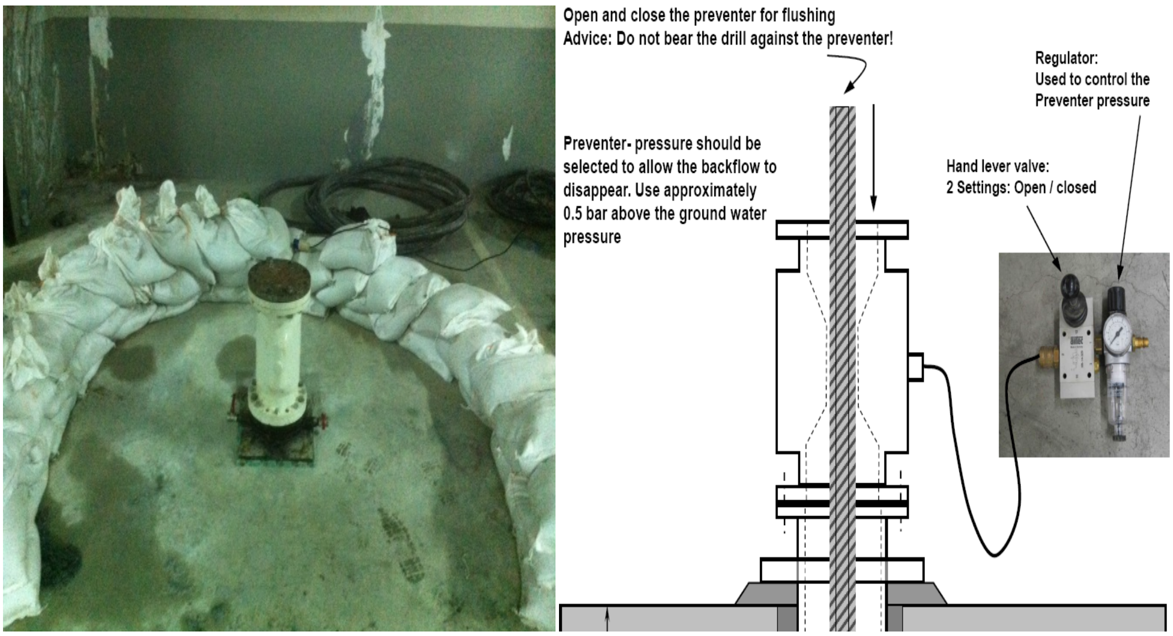

Figure 5 - Installed Preventer

The preventer is essentially a valve system, fitted with a 19mm thick rubber tube insert, which is connected to a compressor via an air line. The system is operated by opening and closing the rubber insert, by applying air pressure to inflate (close) or deflate (open) the rubber insert. The air line supplies an air pressure of between 3 to 6 bar.

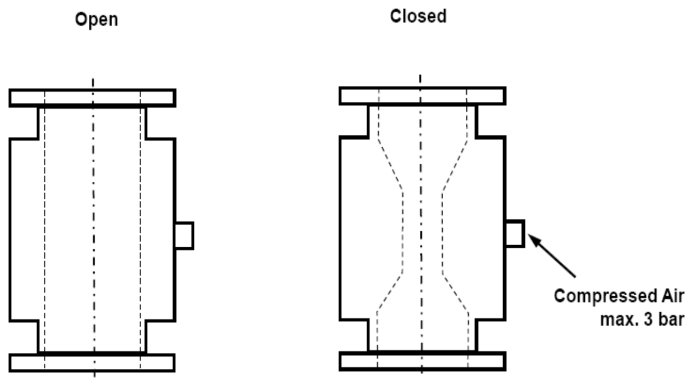

Figure 6 - Preventer Positions

Micropile installation

Installation through the preventer involved adjusting the pressure to allow a “gentle” backflow, which is essentially employed to lubricate the rubber insert. It is the responsibility of the preventer engineer to determine the required pressure during the installation process. During this project the pressures required were typically 1.5 bar during drilling and 3 to 4 bar when closed.

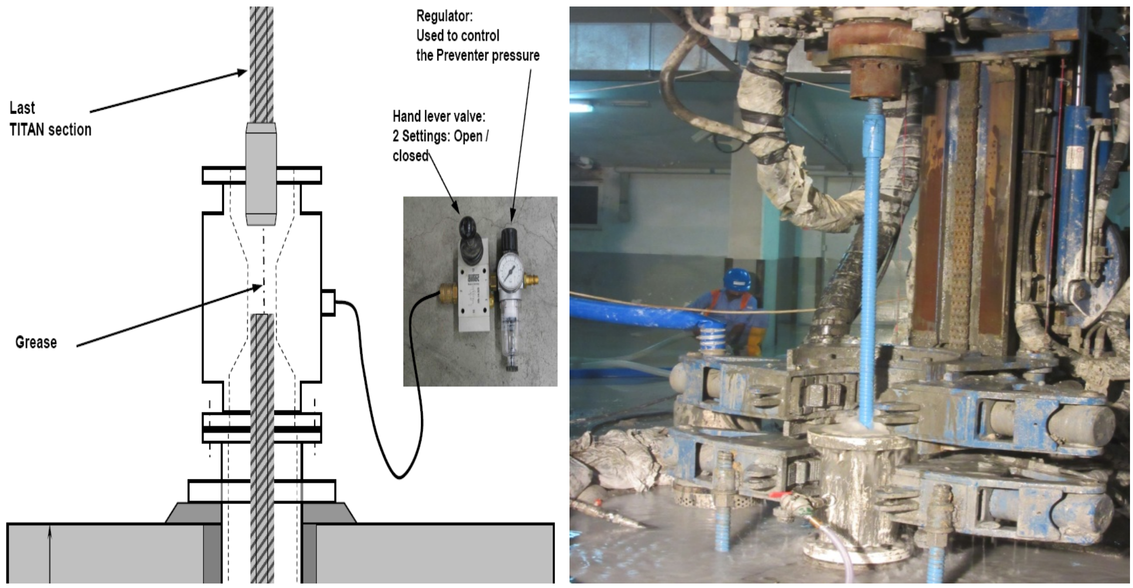

Figure 7 - Micropile Installation

The micropile installation used a water flush, due to the proximity of the rock head, however on occasions a cement grout, with a water cement ratio of 1 (by weight) was used as a flushing fluid.

The quality of the cement grout body and bond were improved by adopting a slower drilling rate and frequently cleaning out the drill hole. This process known as reaming, involved repeatedly extracting and reinserting the drilling rod/micropile, while continuing to rotate the rod and flushing out the drill hole. This procedure allowed the debris to be flushed from the drill hole to the surface and was continually monitored by the drilling operative.

<u>Grouting</u>

Once the micropile had reached the 15.0m design depth, dynamic pressure grouting was carried out. Dynamic pressure grouting is the term given to the simultaneous process of injecting grout, whilst rotating the micropile tendon, resulting in a dense grout body encapsulating the tendon. The cement grout used for the micropile had a water/cement ratio of 0.35 to 0.4, with a strength = $35N/mm^2$ after 28 days. Due to the proximity of the Creek, the cement grout used was a high sulphate resistant cement. In addition Epsilone was added to improve the pumping of the cement grout.

The stiff grout mix displaces the thinner flushing medium used to support the drill hole, encouraging it to return to the surface.

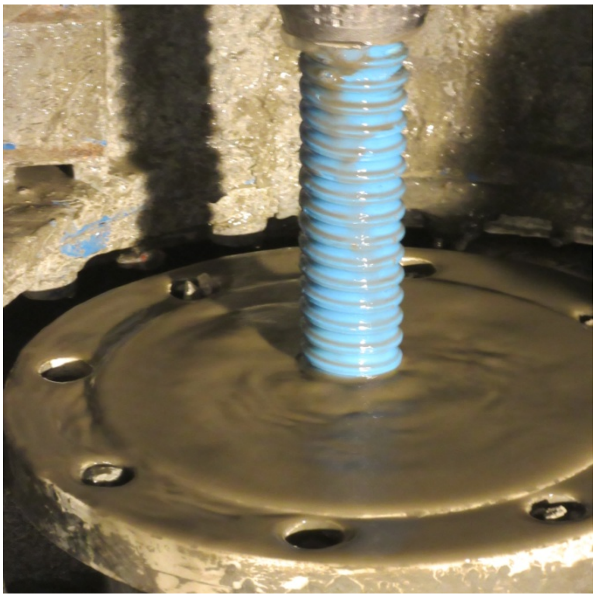

Figure 8 - Grout Return

The drilling operator monitored the consistency of the grout mix and was responsible for determining when the dynamic grouting process should be stopped. Typically 12 bags (50kg each) of cement grout were used per micropile and injected at about 20 bar pressure.

The micropile was installed to its final design depth by using a recoverable extension bar and coupling nut. The assembly was loosened and flushed with water, inside the preventer to clean it. The last section of the micropile was then pushed 5cm below the top of the basement slab.

On completion of this operation, the gate valve was closed and the injection of the non-shrink grout began, in order to fill the micropile head, providing contact to the existing concrete slab. A minimum of 20 litres of grout was pumped, with a water cement ratio of 0.35. In order to obtain a compressive strength of 45Mpa at 28 days, high range water reducers and expansive admixtures where used. To increase the curing time of the grout, 5 litres of Sodium Silicate Liquid was simultaneously pumped with the grout, through the gate valve.

Once the grouting procedure was completed a blank flange plate and gasket was bolted to the top of the preventer to close the unit completely. The compressed air was set to allow the disassembly and cleaning process. Between 6 – 12 hours after the installation the preventer was removed, leaving the flange and gate valve in place. With the grout cured, the flange/gate valve assembly was removed. The local slab area was cleaned and non-shrink grout was injected into the core hole up to the slab surface.

The head detail arrangement consisted of a 100mm pipe with a welded helix on the outside, a spherical collar nut and washer plate.

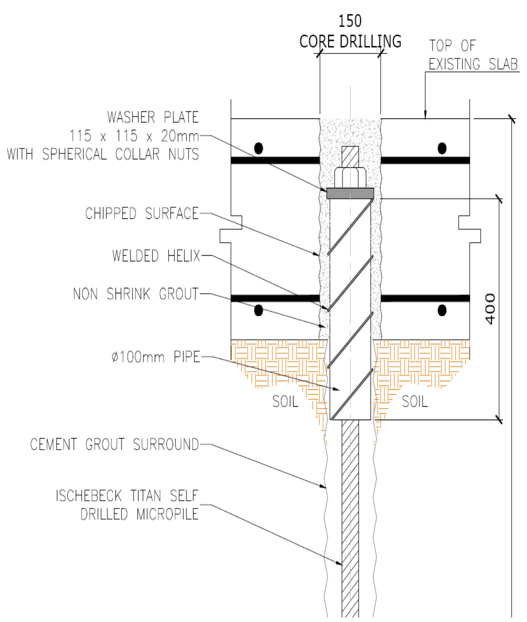

Figure 9 - Micropile Head Detail

SITE CONSTRAINTS

The installation of the micropiles was carried out in basement 2 and presented a number of constraints to the drilling contractor. Firstly the headroom was limited to 2.4m and resulted in the micropile tendons being cut and coupled in 1.0m sections. In addition the restricted headroom, only allowed the use of one preventer due to their height measuring 450mm. Additional security was offered by the gate valve, which measured only 100mm in height.

Figure 10 – Electric Drilling Rig

The confined space also led to the drilling contractor using an electric drilling rig to eliminate any fumes. The drilling rig worked almost continuously for 3.5months, amassing a total of more 1700 drilling hours in an incredibly humid environment..

Figure 11 - Ground Water Back Flow

An issue that needed to be addressed was the back pressure of water. Because the micropile tendon is hollow, the ground water found its way up the centre of tendon. A no return valve system was proposed and used on occasions to limit the return of ground water. The no return valve was fitted in to the hole of the hollow bar, at the drill bit end of the micropile. This allowed the flushing and grouting process to continue whilst stopping the flow of ground water up through the hollow micropile

TESTING

Grout Tests

The quality of the grout was tested for density, viscosity and bleeding. Cube samples were taken of the production grout, by the grout mixer operator. The samples were taken at a frequency of three cubes per shift and tested at 28 days. The grout cubes were cast, cured and tested to ASTM C109, in an independent accredited laboratory.

In addition the compressive strength of the micropile production grout was tested according to DIN EN 445.

Tension Test

Preliminary micropile tension tests were carried out as per the project specification, in order to verify the design of the micropile system and construction methods. The preliminary tests were performed outside of the project area to avoid any risk to working micropiles or damage to the slab.

In total 16 proof tension tests were carried out, in line with the consulting engineer's specifications, which included the following test load schedule.

Table 1 – Testing Regime

Stage	Load	Hold Time
1	AL	1 minute
2	0.25 DL	1 minute
3	0.50 DL	1 minute
4	0.75 DL	1 minute
5	1.00 DL	1 minute
6	1.33 DL	60 minute Creep Test
7	1.67 DL (Max. Test Load)	1 minute
8	AL	1 minute

All the tests followed the project specifications, with all 16No. tension tests passing the design criteria

Figure 12 – Test Set Up

Push out tests were also carried out on the micropile head arrangement to test the connection at the grout/concrete slab and grout/steel bond interfaces.

CONCLUSIONS

In total 312No. 15.0m 40/20 micropiles and over 580No.3.0m tube a manchette steel grouting tubes were successfully installed using the preventer system. The system eliminated the need to temporarily dewater the site, which was an advantage to the client, considering the close proximity of a major underground metro station. It is estimated that the use of the preventer saved the project nearly AED 2,000,000 in temporary dewatering costs. The preventer provided a safe, economical and fast method of micropile installation for a confined, complex project that had a high water table.

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