Micropiling in Urban Infrastructure:
ADVANTAGES, EXPERIENCES & CHALLENGES

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Ennepetal

Introduction

Outlook

According to the United Nations (05/2018),

- 55% of the population lives in urban areas today
- by 2050, the number of people living in cities will increase to 68% of the global population. –
- Considering also the growth of the population over all the number of people living in urban areas will increasing by 50% or 2.5bill people.

The ongoing worldwide urbanization brings challenges to urban infrastructure (housing, public services, transportation, telecommunications, etc.).
Micropiling is one of the most successfully implemented deep foundation technologies in intra-urban interventions, which are often carried out in densely populated and built-up areas. The use of micropiles enabled the implementation of several solutions within **short time** frames, causing the **less possible disturbance** to the daily activities of the population.
Among the different micropile typologies, **self-drilling micropiles** have been proven to be a **very versatile** solution and are increasingly used in urban intervention projects, both for the construction of **new infrastructure** and as reinforcement to **retrofit existing** structures. The use of self-drilling micropiles allows a **flexible** use of the drilling equipment, enabling the installation of **long micropiles even in confined spaces**, obtaining high drilling performances associated to **very low vibrations**.
Self-drilling micropiles consist of continuously threaded hollow bars, made out of seamless steel pipes, installed via rotary percussive drilling. During the drilling process, the micropiles are **continuously grouted (dynamic injection),** building a rough **interlocking grout-soil interface, increasing the skin friction.**

The Selfdrilling System

As a **composite material**, the permanent use is limited by the corrosion protection of the steel elements. According to the European Standards that regulate the use of composite materials for geotechnical applications, such as micropiles (EN 14199) and soil nails (EN 14490), **the corrosion protection can be provided, among other measures, by an efficient encapsulation in grout.** Research has shown that crack widths controlled to **less than 0.1mm** can be considered to be self-healing, therefore, cement grout is considered acceptable as an impermeable protective encapsulation, provided that the crack width within the grout body can be demonstrated not to exceed 0.1mm (EN14490, 2010). In Germany, this requirement has been adopted by the German Institute of Building Technology to assess the structural behavior of self-drilling micropiles, as highlighted for example in the National Technical Approval Z.34.14-209 (DIBt, 2018).

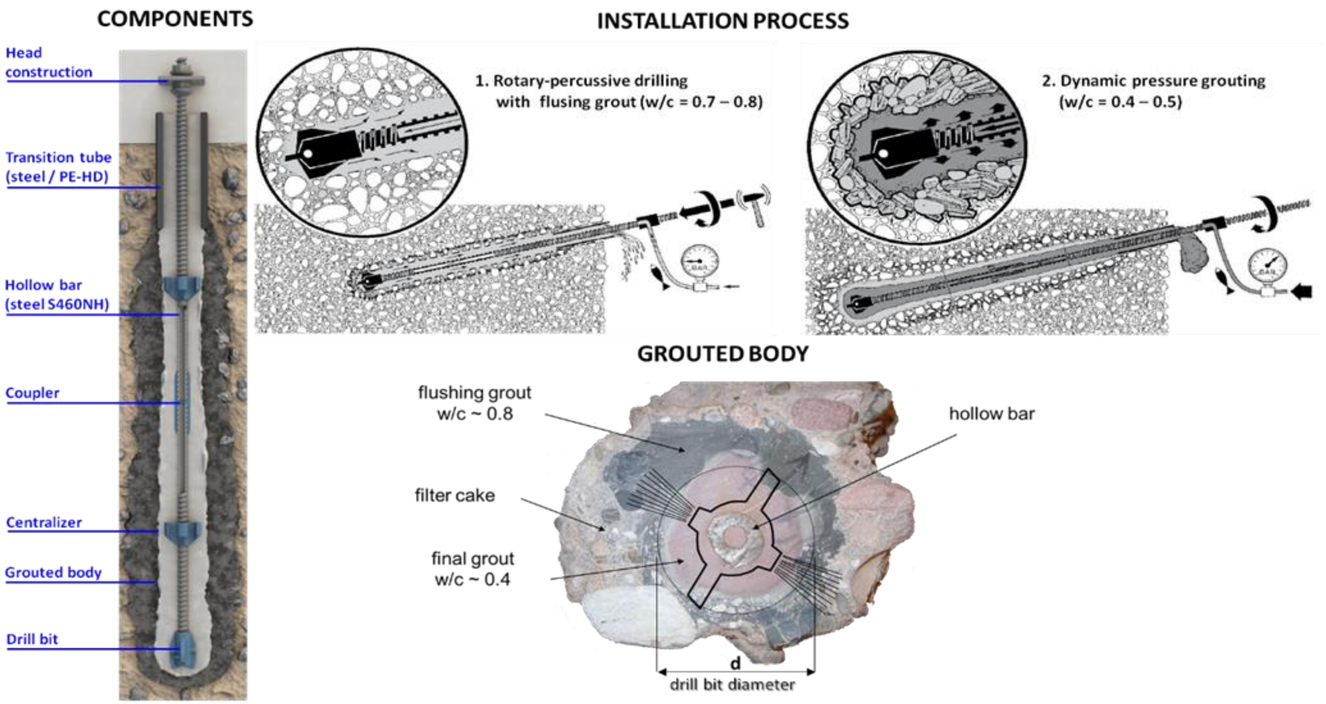


Figure 1: Self-drilling micropiles: components, installation and grouted body

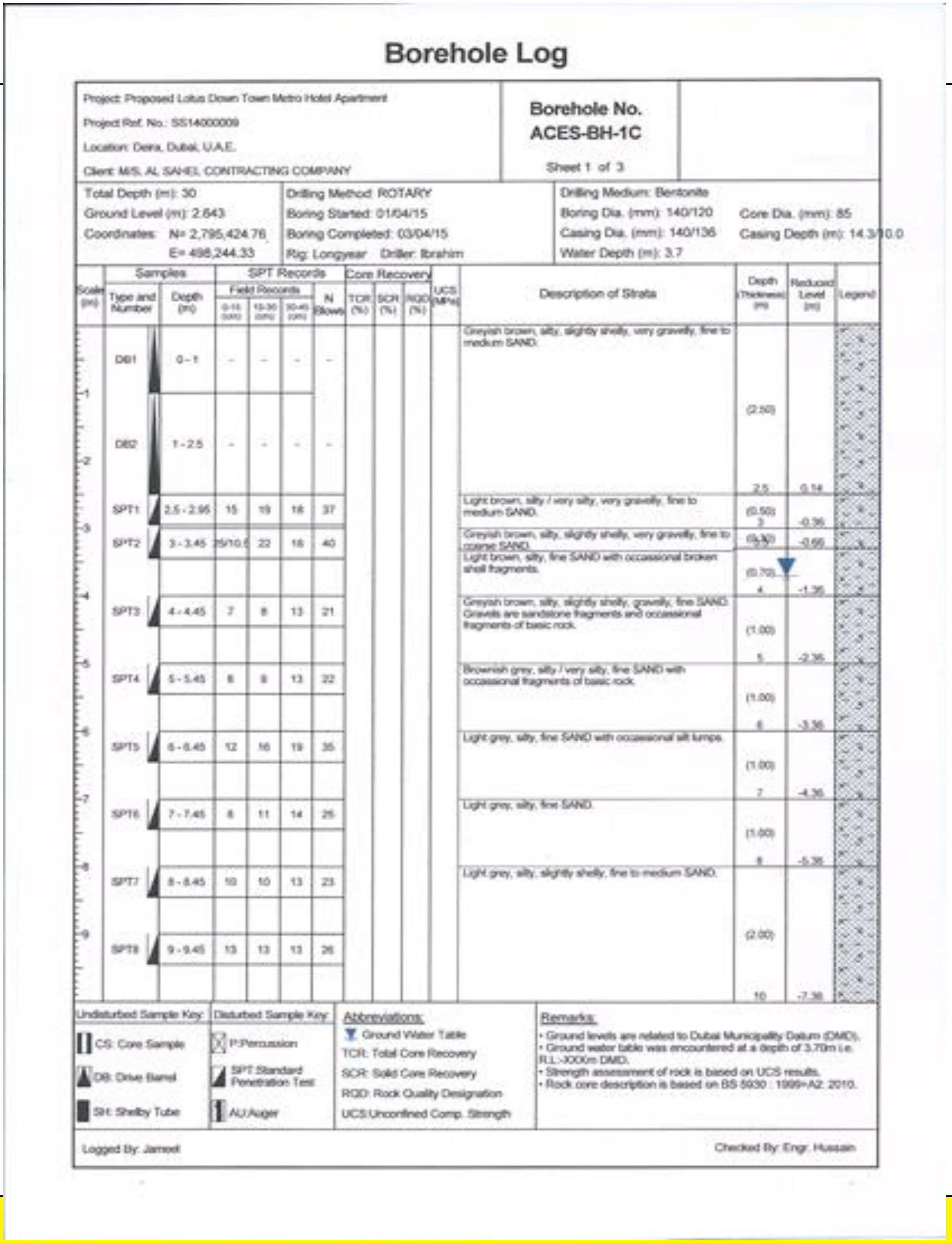
Typical soil condition in The UAE

Typical geology of Dubai:

Sand overlying calcarenite, which in turn overlies sand-stone.

The sandstone is weathered at the top meter or two.

- Water level – 3.70m
- TCR – 80 -100%
- SPT's – N values 20 -25



Borehole Log

Project: Proposed Lotus Down Town Metro Hotel Apartment Project Ref. No.: SS14000009 Location: Deira, Dubai, U.A.E. Client: M/S. AL SAHEL CONTRACTING COMPANY	Borehole No. ACES-BH-1C Sheet 1 of 3

Total Depth (m): 30 Ground Level (m): 2.643 Coordinates: N= 2,795,424.76 E= 498,244.33	Drilling Method: ROTARY Boring Started: 01/04/15 Boring Completed: 03/04/15 Rig: Longyear Driller: Ibrahim	Drilling Medium: Bentonite Boring Dia. (mm): 140/120 Core Dia. (mm): 85 Casing Dia. (mm): 140/136 Casing Depth (m): 14.3/10.0 Water Depth (m): 3.7

Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	UCS (MPa)
DB1	0 - 1	-	-	-	-				
DB2	1 - 2.5	-	-	-	-				
SPT1	2.5 - 2.95	15	19	18	37				
SPT2	3 - 3.45	25/10.5	22	18	40				
SPT3	4 - 4.45	7	8	13	21				
SPT4	5 - 5.45	8	9	13	22				
SPT5	6 - 6.45	12	16	19	35				
SPT6	7 - 7.45	8	11	14	25				
SPT7	8 - 8.45	10	10	13	23				
SPT8	9 - 9.45	13	13	13	26				

Description of Strata	Depth (Thickness) (m)	Reduced Level (m)
Greyish brown, silty, slightly shelly, very gravelly, fine to medium SAND.	(2.50) 2.5	0.14
Light brown, silty / very silty, very gravelly, fine to medium SAND.	(0.50) 3	-0.36
Greyish brown, silty, slightly shelly, very gravelly, fine to coarse SAND.	(0.30) 3.3	-0.66
Light brown, silty, fine SAND with occassional broken shell fragments.	(0.70) 4	-1.36
Greyish brown, silty, slightly shelly, gravelly, fine SAND. Gravels are sandstone fragments and occassional fragments of basic rock.	(1.00) 5	-2.36
Brownish grey, silty / very silty, fine SAND with occassional fragments of basic rock.	(1.00) 6	-3.36
Light grey, silty, fine SAND with occassional silt lumps.	(1.00) 7	-4.36
Light grey, silty, fine SAND.	(1.00) 8	-5.36
Light grey, silty, slightly shelly, fine to medium SAND.	(2.00) 10	-7.36

Undisturbed Sample Key: CS: Core Sample; DB: Drive Barrel; SH: Shelby Tube

Disturbed Sample Key: P:Percussion; SPT Standard Penetration Test; AU:Auger

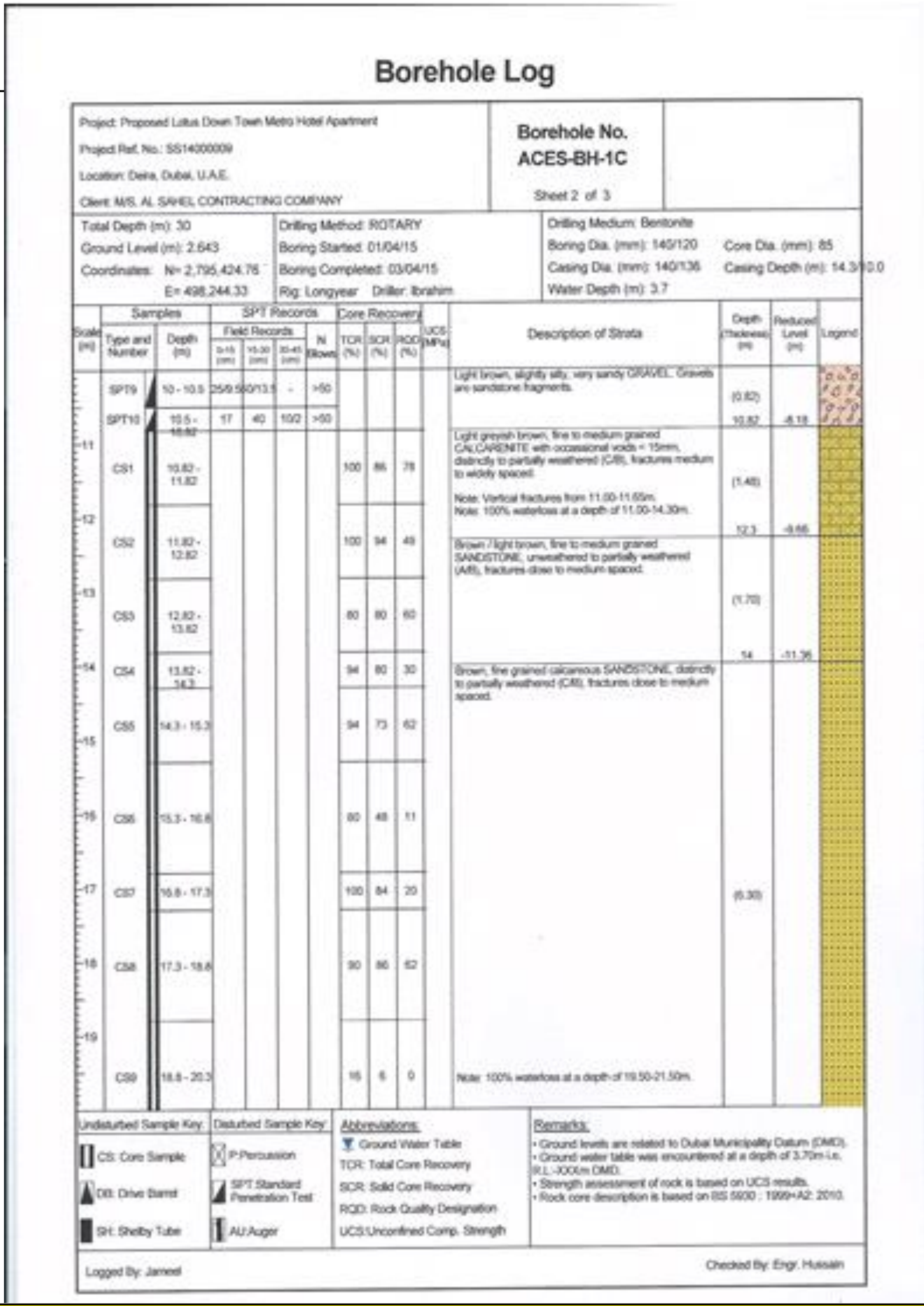
Abbreviations: Ground Water Table; TCR: Total Core Recovery; SCR: Solid Core Recovery; RQD: Rock Quality Designation; UCS:Unconfined Comp. Strength

Remarks:
- Ground levels are related to Dubai Municipality Datum (DMD).
- Ground water table was encountered at a depth of 3.70m i.e. R.L.-X.XXm DMD.
- Strength assessment of rock is based on UCS results.
- Rock core description is based on BS 5930 : 1999+A2: 2010.

Logged By: Jameel Checked By: Engr. Hussain

Figure 2: Typical soil condition borehole in Dubai

Typical soil condition in The UAE



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SPT9	10 - 10.5	25/9.5	50/13.5	-	>50				
SPT10	10.5 - 10.82	17	40	10/2	>50				
CS1	10.82 - 11.82					100	86	78	
CS2	11.82 - 12.82					100	94	49	
CS3	12.82 - 13.82					80	80	60	
CS4	13.82 - 14.3					94	80	30	
CS5	14.3 - 15.3					94	73	62	
CS6	15.3 - 16.8					80	48	11	
CS7	16.8 - 17.3					100	84	20	
CS8	17.3 - 18.8					90	86	62	
CS9	18.8 - 20.3					16	6	0	

Description of Strata	Depth (Thickness) (m)	Reduced Level (m)
Light brown, slightly silty, very sandy GRAVEL. Gravels are sandstone fragments.	(0.82) 10.82	-8.18
Light greyish brown, fine to medium grained CALCARENITE with occasional voids < 15mm, distinctly to partially weathered (C/B), fractures medium to widely spaced. Note: Vertical fractures from 11.00-11.65m. Note: 100% waterloss at a depth of 11.00-14.30m.	(1.48) 12.3	-9.66
Brown / light brown, fine to medium grained SANDSTONE, unweathered to partially weathered (A/B), fractures close to medium spaced.	(1.70) 14	-11.36
Brown, fine grained calcareous SANDSTONE, distinctly to partially weathered (C/B), fractures close to medium spaced. Note: 100% waterloss at a depth of 19.50-21.50m.	(6.30)	

Undisturbed Sample Key: CS: Core Sample; DB: Drive Barrel; SH: Shelby Tube
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Logged By: Jameel
Checked By: Engr. Hussain

Figure 3: Typical soil condition borehole in Dubai

CASE STUDIES

Lotus Hotel

Project: Hotel apartment building, Dubai
Product: TITAN Preventer System
Contractor: NSCC International
Consulting engineer: WSP
Date completed: 2017

Figure 4: Lotus Hotel

The challenge

A Dubai building had undergone some **structural movement within the basement**, leading to **cracked** columns, walls and slabs. **Water had penetrated through cracks in the basement slab and walls**. The building is located in **Deira**, approximately **500m from the creek**. The structure was built in 2007 and consisted of **8 stories** and two basements.

An assessment of the building was carried out and the consulting engineer compiled a detailed design to enhance the stability of the structure, which involved a combination of grouting and micropiling.

The issue was that the micropiles and tube a manchette steel grouting tubes needed to be installed in a basement area, subject to a **high water table**. This could have been achieved with **temporary dewatering.** However this was not the preferred option owing to the location of **a nearby underground metro station.**

CASE STUDIES

Lotus Hotel

The solution

The TITAN **Preventer System** was specified and employed to install the micropiles **instead of temporarily dewatering** the site. The Preventer allowed the successful installation of over **300 self-drilling micropiles and 580 Tube a manchette** steel grouting tubes and further soil tests. The micropiling was carried out at a level of -4.45m (ground water at -1.45m) without the need to temporary dewater.

How it works

TITAN Preventer is a **valve system** 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. When the rubber insert is in the closed position, it **restricts the ingress of water**, whilst pressing tight against the micropile, allowing the installation and grouting to be completed. The Preventer is fixed securely to the structure prior to commencing the installation. It is removed once the grout has completely cured, exposing the top of the micropile ready for the head detail to be constructed.

The result

The micropiles were installed and grouted using the Preventer, and implemented to strict Health and Safety procedures. The whole procedure enabled the contractor to **maintain an excellent production rate**, all to the satisfaction of the site engineer's as well as the client.

The real benefit of the Preventer system was that it allowed the installation and **grouting of the micropiles in a restricted working area – without the need for temporary dewatering**. It has been estimated that there was a **£350,000 saving achieved** on this project, by using the Preventer system instead of dewatering.

CASE STUDIES

Lotus Hotel

- This is Basement 2
- 312No. 15.0m TITAN 40/20 Micropiles – Epoxy Coated
- 587No. Tube a manchette
- Nearly 900No. coreholes
- Creek towards the SW
- Union Square Metro Station to NW

Figure 5: Micro Pyle Layout

Lotus Hotel

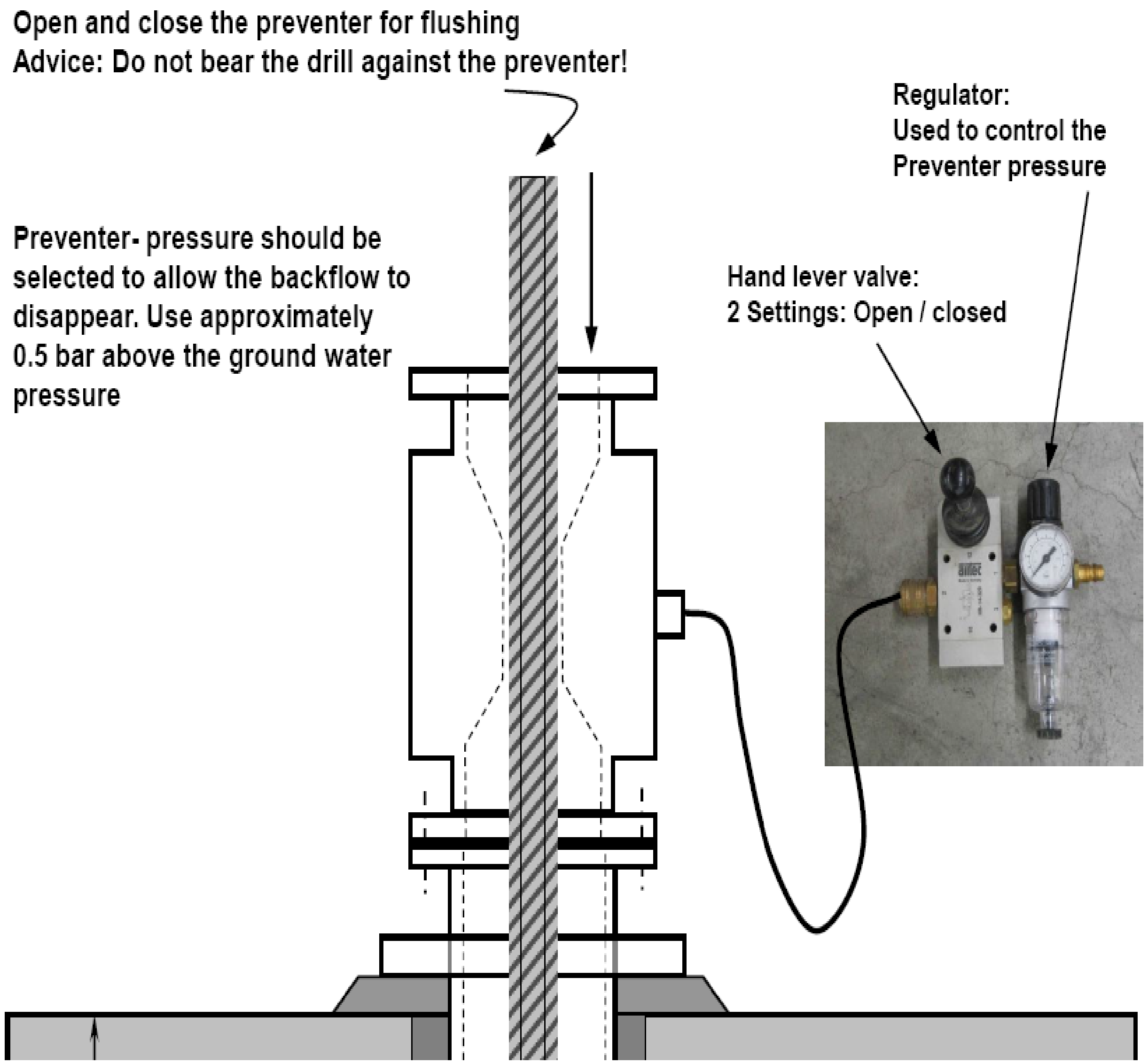

Figure 5: Preventer

CASE STUDIES

Lotus Hotel

Figure 6: Preventer is installed

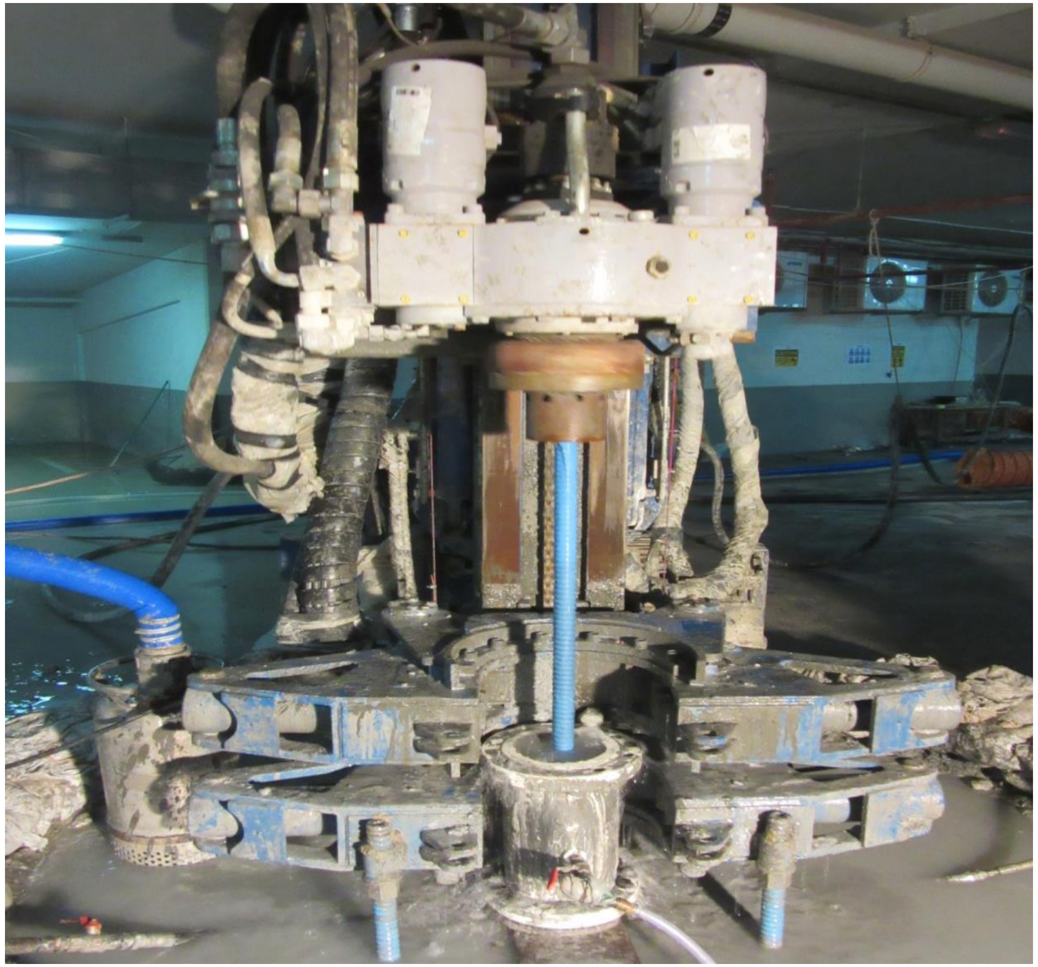

Figure 7: Start to install the hollow bar

CASE STUDIES

Lotus Hotel

Figure 8: hollow bar almost finished

CASE STUDIES

Lotus Hotel

Figure 9: monitoring of cracks installed monitoring equipment

A: Crackmeters

B: Optical Targets

CASE STUDIES

Lotus Hotel

Figure 10: visible cracks and monitoring of cracks

CASE STUDIES

Lotus Hotel

Crackmeter

Electrical and vibrating wire crackmeters (jointmeters) are intended to monitor movement across surface cracks and joints in concrete structures or rock

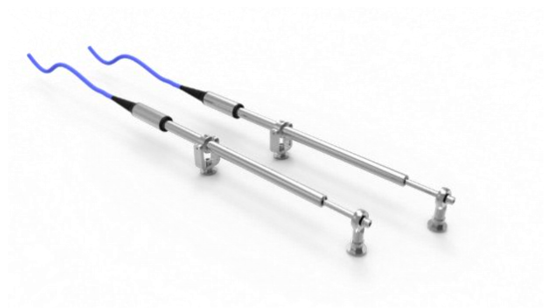

Figure 11: visible cracks and monitoring of cracks

Digital Portable Tiltmeter are used to measure the angular difference between the sensors axis when held or placed on the X and Y planes of the tiltplate.
Tiltplates are installed either horizontally or vertically on the structure to be monitored and a datum reading is taken from which all subsequent are then compared.

Housed within the unit is a MEMS accelerometer that measures the angular position of the Tiltplate and a Bluetooth transmitter that transfers data to the Field PC, resulting in a wireless connection between the instrument and the Field PC

Figure 12: portable tilt meter

CASE STUDIES

Lotus Hotel

Optical targets for quick and easy assessment of cracks.

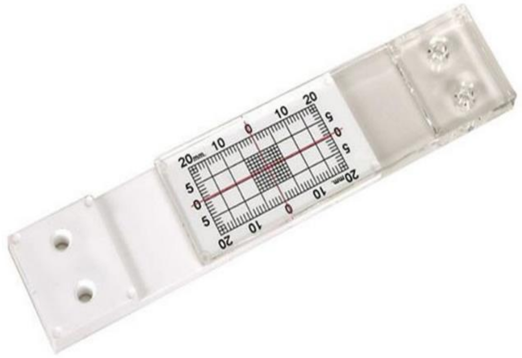

Figure 13: optical targets

CASE STUDIES

Mövenpick Hotel, Ibn Battuta Mall

Project: Mövenpick Hotel Ibn Battuta

Location: Dubai, UAE

Contractor: Swissboring Overseas

Consulting engineer: PJSI Consultants DMCC

Date completed: July 2017

Figure 15: Ibn Battuta Mall, Mövenpick Hotel

The Background

The Mövenpick Hotel located at the Ibn Battuta Mall in Dubai required some **retrofitting**. The foundation was at B-3 Parking level and had **height of 2.4m**. The original design was asking for **25 piles with a diameter of 500mm**. The ground **water level** was at about **4 m**

The Solution

The original design was changed to **90no of 52/26 micropiles** with a length of **10m**. Due to the high ground water table, a preventer was used to avoid having to dewater. Unlike the previous project in this report the grade slab was not able to take additional forces. The slab was cut out in various areas to expose the footing. The footing was than extended to create pile caps for the micropiles.

CASE STUDIES

Mövenpick Hotel, Ibn Battuta Mall

Figure 16: Slab prepared

Figure 17: Preventer installed

CASE STUDIES

Mövenpick Hotel, Ibn Battuta Mall

Figure 18: First Bar almost fully installed

Figure 19: Pile testing set up

Mövenpick Hotel, Ibn Battuta Mall

Figure 20: Micropiles ready for reinforcement

CASE STUDIES

One Za'abeel

Project: One Za'abeel
Location: Dubai, UAE
Contractor: APCC
Consulting engineer: WSP
Date completed: October 2018

The Background

The **One Za'abeel** project consists of two commercial and residential towers located on the Sheik Zayed Road, Dubai, between the Dubai World Trade Centre and Za'abeel Park.

The two towers are **67 and 57 stories high** respectively, constructed on top of a retail podium and are linked by a suspended bridge. The project includes residential units, two hotels, office space and a 3-storey retail podium at ground level. One Za'abeel will also feature the world's largest cantilever. **The Linx, which will float 100m above ground** and offer fine restaurants and lounges.

The Challenge

Our scope was to provide permanent tension **micropiles to resist uplift** in **two tunnels** that linked the basements of the two towers. The purpose of the micropiles is to ensure the stability of the superstructure against uplift pressures due to the presence of the ground water table.

The Solution

Each micropile is subjected to a maximum **795kN service load** in tension and **250kN service load** in compression. In total **99 x TITAN 103/51 micropiles** were installed using a **220mm Cross Cut Drill Bit to a depth of 11.0m** into the sandstone.

CASE STUDIES

One Za’abeel

Figure 21: One Za´abeel

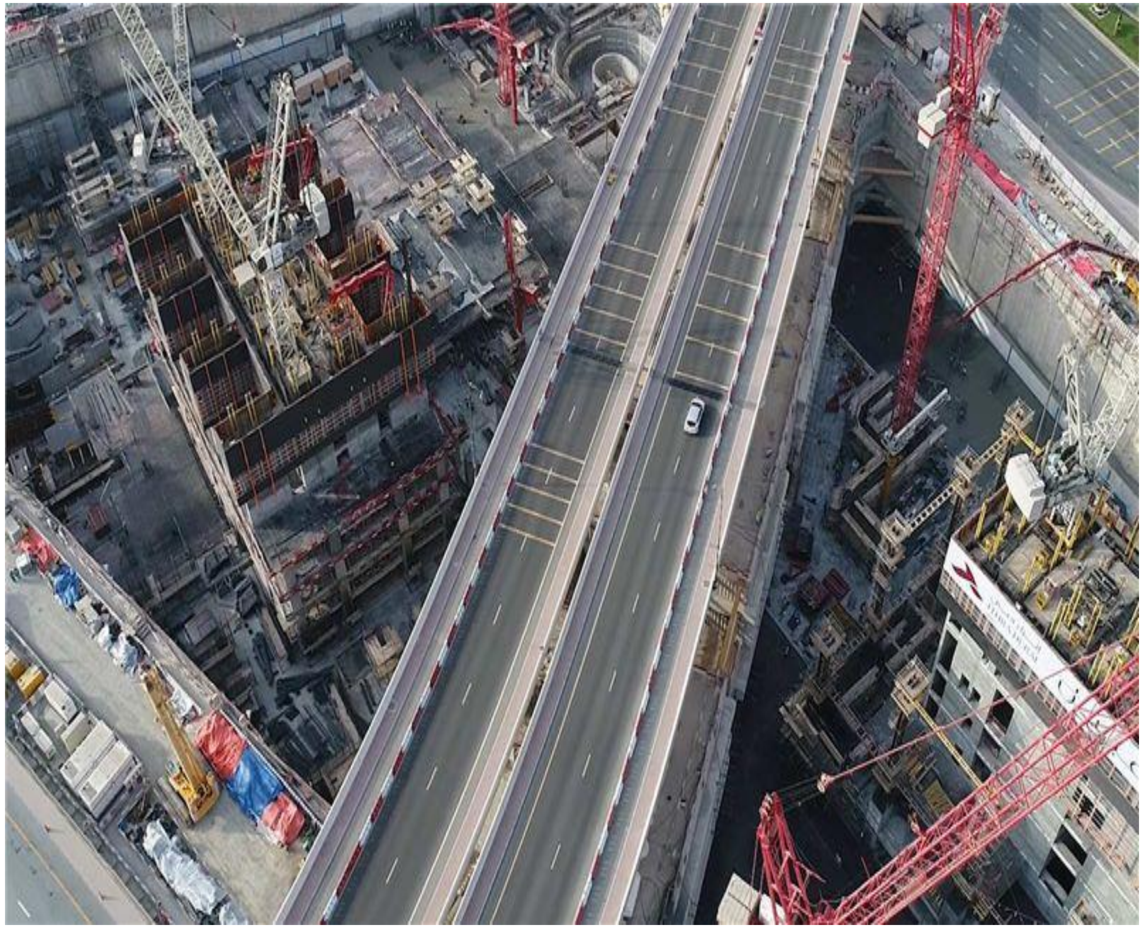

Figure 22: One Za´abeel in construction birds view

CASE STUDIES

One Za’abeel

Figure 23: Drilling with limited head room

Figure 24: Drilling underneath fully operational road

CASE STUDIES

One Za’abeel

Figure 25: Pile testing set up

Figure 26: Piles comleted

One Za'abeel

Figure 27: blinding, pile heads, conecting dowels, water stopper

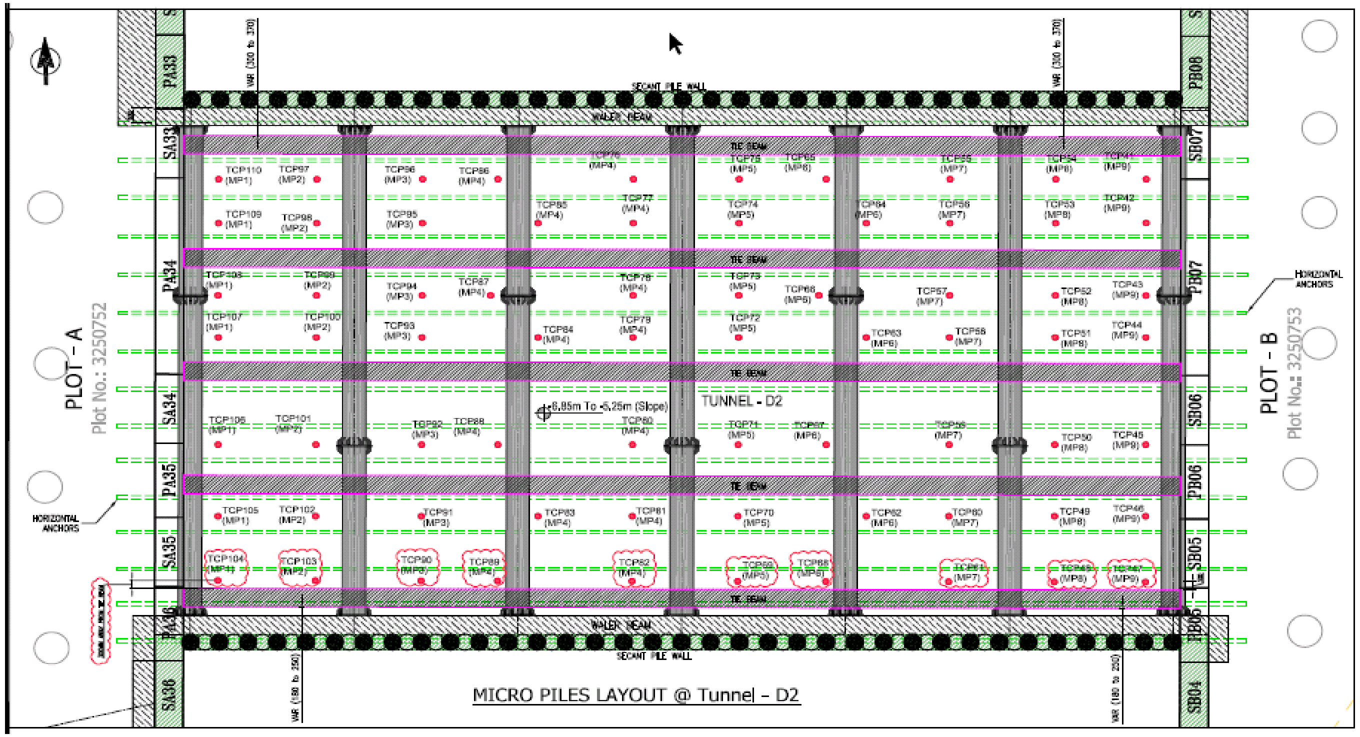

Figure 28: pile layout for one of the 2 tunnel

Sky Views Tower

Project: Sky View Tower
Location: Dubai, UAE
Customer: NSCC International
Project completed: March 2018

Figure 29: Sky View Tower under construction

CASE STUDIES

Sky Views Tower

The Challenge

The client wished to **extend the basement of a pair of towers whilst they were still being constructed**. The location of the extension was directly under the metro travellator, very near to the Burj Khalifa Metro Station. The restricted site conditions were very challenging. In total the length of **the extension was 52.0m, with a width of 3.0m and headroom of only 5.5m**. In addition, the metro station was only a few meters from the proposed **5.0m excavation**.

The Solution

The project included two elements which utilized Ischebeck Titan products. Firstly, the temporary shoring structure and secondly, 21 groups of main and permanent micropiles.

The shoring involved the installation of **229 No. 12.0m T103/51 micropiles**. These were restrained using two rows of **T52/26** tie back anchors. The upper row of anchors were **18.5m long, with second row being 17.0m**.

In total there was **168 No**. permanent micropiles installed in two lengths – **40 No. at 15.0m and 128 No. at 12.0m.**

The self-drilled option was adopted due to the limited headroom, which allowed 1.5m sections to be installed at a single time. With the presence of sand, the self-drilled option, eliminated the need for temporary casing.

The Result

Due to the proximity of the metro station extensive monitoring was carried out during construction, these included ground **settlement markers, miniprisms/reflectors, tiltmeters, inclinometers, piezometers and anchor load cells**.The project was completed on time and to the satisfaction of the client and their construction team.

CASE STUDIES

Sky Views Tower

Figure 30: drill rig

Figure 31: drill rig underneath the metro travellator

CASE STUDIES

Sky Views Tower

Figure 32: temporary shoring wall

Figure 33: preparation of temporary shoring wall top beam and the sleeve for the anchor to avoid drilling through the reinforcement steel

CASE STUDIES

Sky Views Tower

Figure 34: temporary shoring wall

Union Steel

Project: Union Steel, new footings in welding area
Location: Abu Dhabi, UAE
Customer: Universal Piling
Project completed: March 2017

The challenge

The Union Iron & Steel company in Abu Dhabi was planning to do some structural changes in the welding machine area. The major challenge was that the entire factory had a lower ground floor and a ground floor. The position of some piles were on the lower ground floor and only accessible via an opening in the slab and on the ground floor without much restrictions. Also the head room of the lower ground floor area was very limited.

The solution

The very restricted space and the short program made the use of micropiles the best option. The drill rig was placed on site by crane. The production of the factory could not be stopped and the drilling of the piles should not have an impact on their daily routine.

The result

After about 2 days of preparation such as core drilling through the grade slab, installation of grout station and preparation of the material the actual drilling time only took 4 days. During those 4 days the contractor installed **25piles T73/56 with a total length of 17m**.

Figure 35: drill rig hanging on the overhead crane

Union Steel

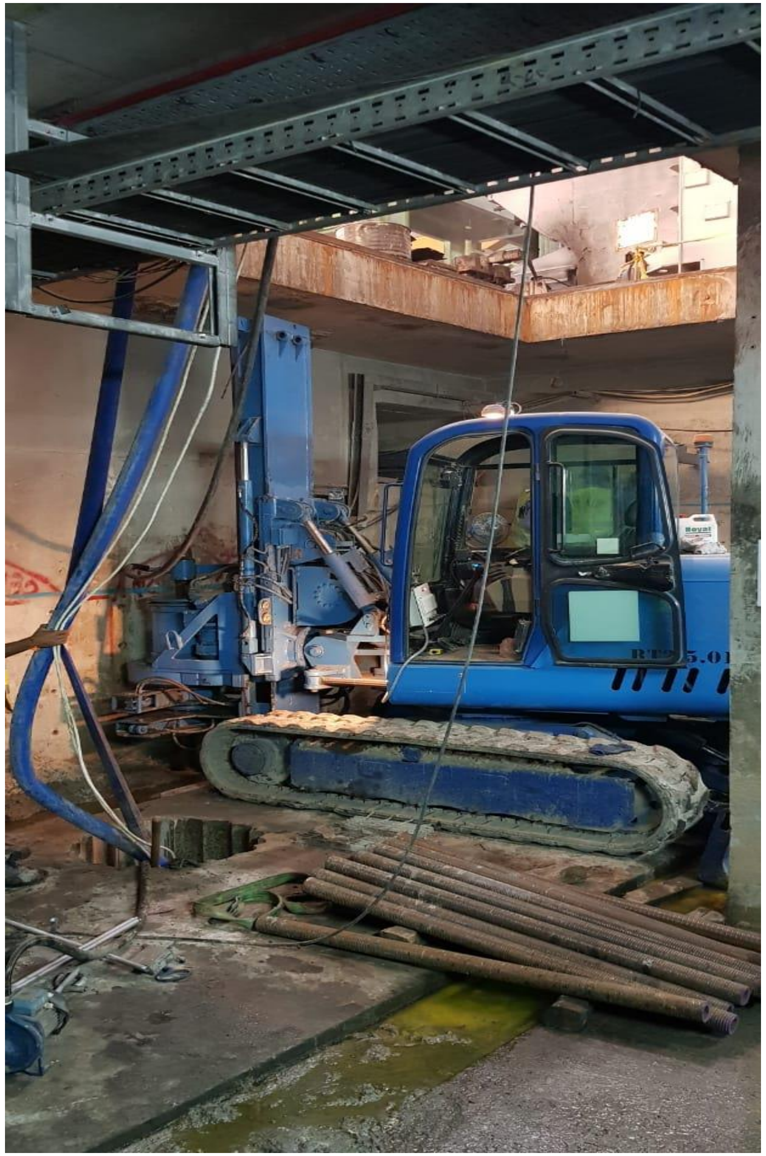

Figure 36: drilling rig in position

CASE STUDIES

Union Steel

Figure 37: drill rig on lower ground floor from the top

CASE STUDIES

Union Steel

Figure 38: piles on the ground floor after execution

Union Steel

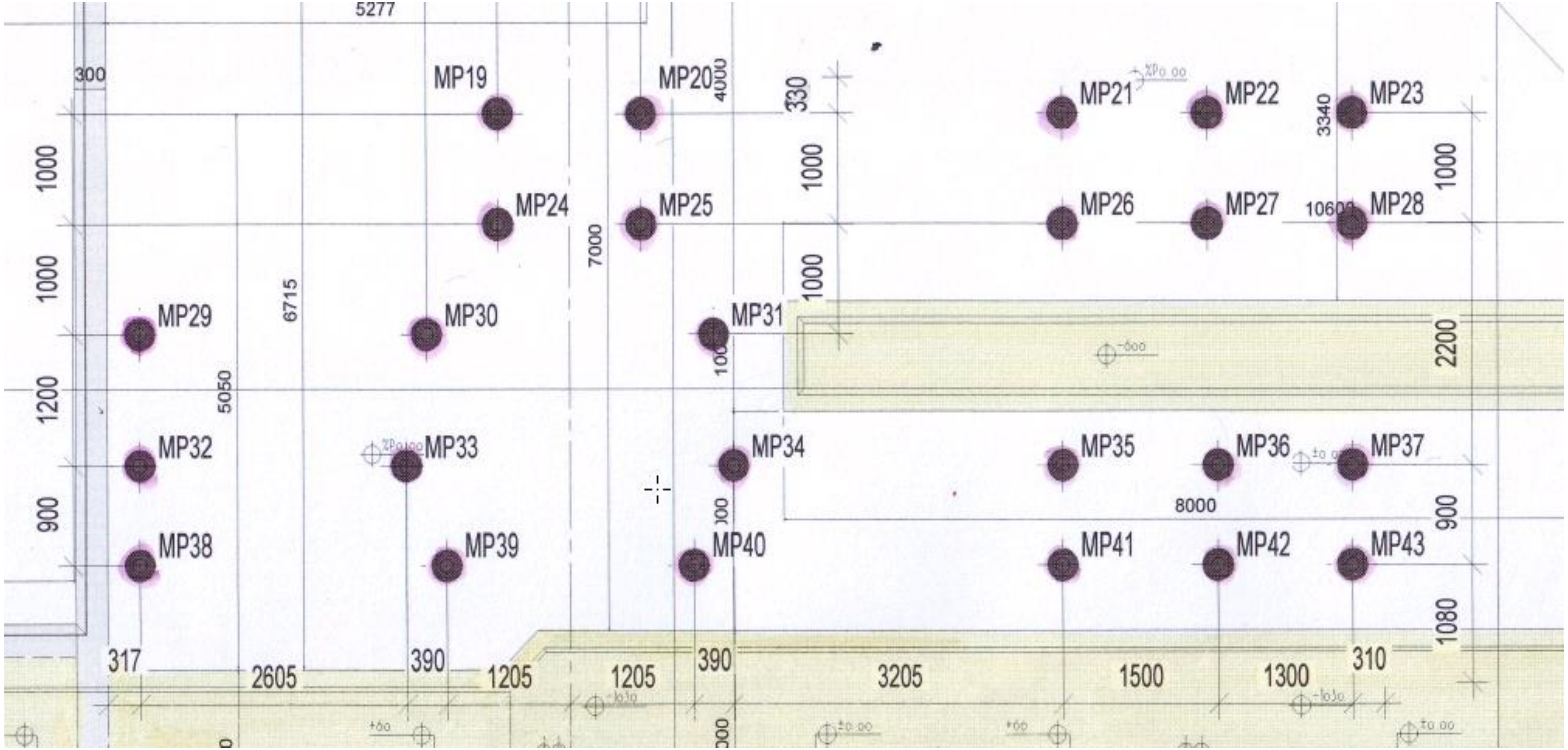

Figure 39: pile layout

Thank you for your attention

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