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# Tunnelling towards 2022

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# LAYING THE FOUNDATIONS

by Dr Heinz Plum, General Manager, Bohrtec

As part of its preparations for the 2022 FIFA World Cup, Qatar is in the midst of an unprecedented level of construction in the leadup to the event. With some reports suggesting it is spending as much as US\$500 million a week on construction, including a state-of-the-art subway system in its capital city, Doha, to transport hundreds of thousands of fans from all around the world in attendance.

Qatar, and its capital city Doha, has benefited from plentiful oil and gas resources to make it one of the wealthiest countries in the Middle East. With a view to hosting the FIFA World Cup in Qatar, a masterplan was developed for a completely new and modern public transport system, the Doha Metro.

After Qatar won the bid for the 2022 World Cup, the country decided to tender the construction works for this huge project.

At the moment, the Doha Metro project is the major project in the capital city. The metro system will be built in two phases: the first phase comprises the construction of three metro lines – Red, Gold, and Green – and 37 stations.

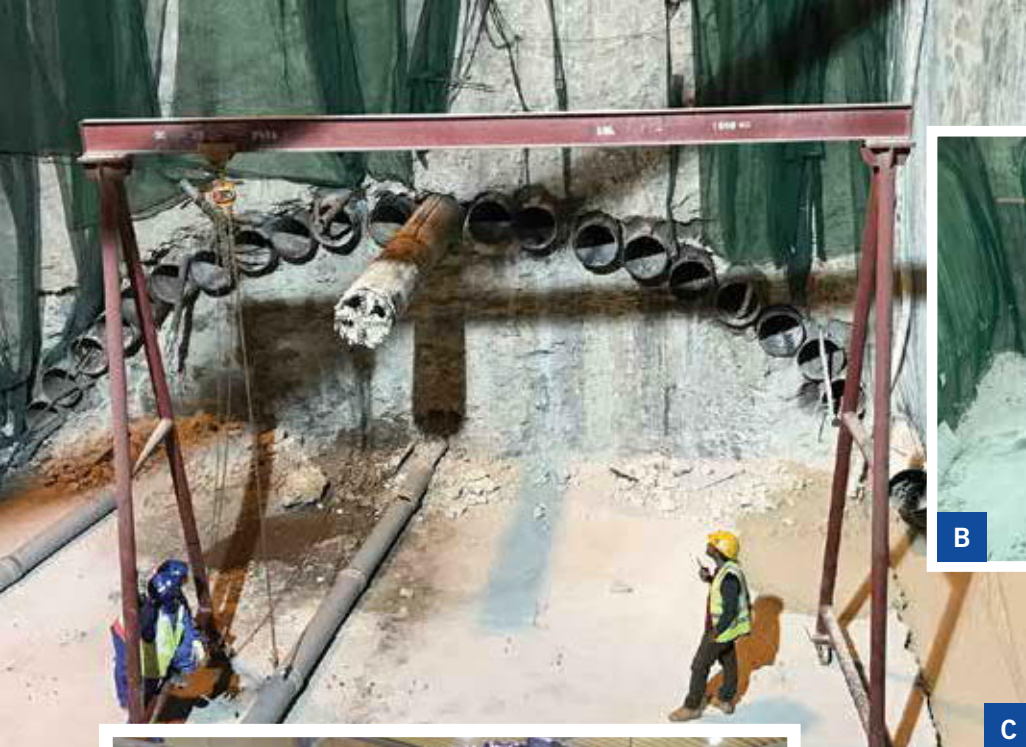
The second phase involves the expansion of the phase one lines and the construction of one additional line – the Blue Line. Another

72 stations will also be built. For the southern part of the Red Line, Qatar Rail, the owner of the project, awarded the design-build

Pedestrian tunnel project (current name)	Tunnel length as per tender document dated 16.04.2015	Tunnel length due to modification of design and constraints around the shafts
MTB 1-2 (AMB 2-1)	56 m	
MTB 1-3 (AMB 3-1)	49 m	
MTC 1-5 (AMC 5-1)	69 m	
MTC 1-2 (AMC 2-1)	72 m	74 m subcontracted to Bauer
MTC 3-4 (AMC 4-3)	78 m	72 m subcontracted to Bauer
MTD 1-2 (AMD 2-1)	88 m	
MTD 1-4 (AMD 4-1)	81 m	
MTD 3-4 (AMD 4-3)	81 m	64 m subcontracted to Bauer

Table 1: tunnel lengths for the pedestrian tunnel project.





A: The Bohrtec BM600LS working on the pipe arch for tunnel 3.  
 B: Pipe arch tunnel 1. Starting shaft.  
 C: Pipe arch tunnel 1. Receiving shaft.  
 D: The flat drilling head of the FS609.  
 E: The retractable drilling head of the FS609.

contract to the consortium led by QDVC, a joint venture between Qatari Diar and Vinci Construction Grands Projects. The major tunnelling works and the construction for the metro are highlights of construction works worldwide, but there are also some works that do not attract attention at first glance that are worth noting.

One of these works is the construction of the access tunnels to the metro stations underneath the major roads of Doha. Due to massive traffic activity both day and night, these access tunnels cannot be built by open trench methods.

Doing this work trenchless is easier said than done. Within the southern Red Line project there were a total of eight pedestrian tunnels to be built.

All tunnels had to be constructed in Simsima Limestone with different grades of weathering and investigated UCS values of

around 20 MPa. The coverage wasn't high enough that the tunnel works could have been done without intermediate support during the excavation works.

QDVC, the main contractor for Red Line South, designed and tendered pipe arches as an intermediate step for excavating and constructing these pedestrian tunnels. The length varied between 49 m and 88 m (see Table 1).

In the first stage of design, the outside diameter of the pipes was intended to be 559 mm with a distance of 50 mm between each pipe. Consequently, the deviation of

each drill couldn't be more than 25 mm in either direction. At the stage of subcontracting the pipe arch drilling works, the outside diameter was reduced to 508 mm and the accepted deviation was raised to 90 mm. So the tolerated deviation was  $\pm 45$  mm in either direction.

After some problems with the first subcontractor, who wasn't able to get through the ground while keeping the desired accuracy, the main contractor contacted several more experienced contractors who were willing and able to get the drills through the difficult ground conditions.

One of these companies was Bauer Spezialtiefbau Schrobenhausen and its local branch, Bauer International Qatar LLC, together with Seeliger Drilling Services (S.D.S.).

Bauer and S.D.S., having had experience with HDD-like drillings in the Qatar limestone, knew the limits of their existing HDD-like equipment. Therefore, they decided to invest in new equipment with capabilities proven in Hong Kong granite, far above the limits of the small HDD pilots.

As a consequence, Bauer contacted Bohrtec at the Bauma Trade Fair 2016 and ordered two systems: one Front Steer FS609 that was already designed, produced and immediately available with a flat head cutter disk, and one BM600LS in combination with a Front Steer FS508 with flat head cutter disk and a DTH hammer that was custom made for this project.

Although Bohrtec recommended a retractable drilling head in case of excessive wear of the cutting tools during the drills, the FS609 was ordered with a flat drilling head (see image D). According to the customer's plan, the FS609 should be pushed using 508 mm steel with U-channel pieces to centralise the 508 mm pipe within the hole drilled by the FS609.

The equipment was delivered in June 2016 and a first drive started at the beginning of June. After facing problems with the excessive





**F:** The FS508 with DHT hammer.  
**G:** The BM600LS with the FS508 and the pipe arch.  
**H:** The pipe arch tunnel 3. Starting shaft.  
**I:** The pipe arch tunnel 3. Receiving shaft.  
**J:** The metro access tunnel after all construction works have been completed.

wear of the drilling head, it was decided that the equipment would be moved over to another shaft in favour of using the retractable head (see image E), as recommended by Bohrtec.

At the other shaft there were 21 drills remaining because 2 drills had been completed in February by another company. At the time, the Bohrtec FS508 with the DTH hammer hadn't arrived in Qatar yet.

Once the FS609 arrived at the other shaft, it was equipped with the retractable head and drilling started. The ground was as hard as the first location, but performance was constant and not the worst.

Finally this drive was completed, taking a total of six days. Line and grade could be kept perfectly, it was only the wear on the teeth that was significant after only the half-length of the drive.

While doing the next drives, the choice of the head and cutting tools was optimised step-by-step based on the experience of the crews of Bauer and Bohrtec. As a result of the improvements, the next drill was completed within four to five days, once again perfectly on line and grade at a length of roughly 70 m.

In mid-August the BM600LS and the FS508 with DTH hammer arrived in Qatar. Equipped with the hammer, the BM600LS and the Front Steer FS508 could archive a penetration rate of up to 12 m/h.

Nevertheless, it took five days to complete



this 74 m drill due to site constraints, such as lifting devices for the coupling work and inexperience with the new equipment. Despite all these constraints, an average of 14 m per day was achieved. From one drill to the next, the crew gained more and more experience with the equipment. After engaging in a two-shift work plan the majority of the drills were finished within two days.

By mid-November all remaining 21 drills, – 1.554 m of total drilling length – had been completed. All with perfect and impressive alignment, and all within the tolerances accepted by the general contractor. This can be seen in image F and G, which show the starting and receiving shafts. While finishing

the first tunnel, the crew moved equipment to the next tunnel with 23 drills, each 71 m long. For the first drill and every second drill after that, the crew used the FS609, while the gaps between these drills were systematically drilled by using the FS508.

During the first drill the crew realised that the ground wasn't dry throughout the complete drive length as it was on the first tunnel. There were sections that were wet and sticky, especially in the lower area of the tunnel.

In order to manage this, the crew applied high pressurised water in front of the Front Steer to avoid enclosing the drilling head within the sticky sections.

The first drill took two days, but the crew





J

was still learning more and more.

During all 23 drills, a majority of the drills could be finished in less than 30 hours; the fastest one was done within 18.5 hours.

This extraordinary performance includes the time taken for drilling, welding and moving the machine from one hole to the next one, for a total length of 1,065 drilling metres to be achieved. By the beginning of January, all 23 drills were finished with impressive accuracy.

On 4 January, the equipment was moved to the third tunnel where the next 23 drills are currently in progress (Image A).


Despite the harder ground conditions on this third tunnel, due to the experience of the crew a new drill can be commenced every 48 hours. This means that setup, adjusting, drilling, welding and cleaning is completed within these 48 hours.

The condition for achieving this remarkable performance is that everything on site is well maintained, kept clean and tidy, and is well organised.

By the end of February 2017 the drilling works for the three pipe arches were finished, as seen in image H and I. Within one and a half months all 23 drillings, with a total length of 1,426 m, were successfully completed.

Meanwhile, the excavation works for the tunnels have been started, and the accuracy of all drills throughout the complete drive length can be admired while doing the excavating works.

Within this project, Bohrtec has once again been able to show the outstanding abilities of the Front Steer system, especially when working with difficult ground conditions. With the experience and efforts of the Bauer and the S.D.S. crew, the Front Steer system has the potential to be further optimised.

At the moment, the Bohrtec Front Steer method is the fastest and most accurate solution for drilling canopy pipes or pipes for pipe roofs in difficult ground conditions by using a one-step method, without the need of any reaming process. 








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