

VSE Edmundo Lins – Metrô Linha 4 Amarela

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ABSTRACT: Diaphragm walls are known as underground structural elements commonly used for retention systems and permanent foundation walls or elements. It can be anticipated that, with the increasing trend of utilizing more and more underground space to accommodate environmental considerations and urban/suburban development, there will be an increasing requirement for diaphragm walling in even more difficult conditions. Of course they can also be used as deep groundwater barriers.

This paper is focusing on a project which is part of the line 4 Amarela extension in Sao Paulo, Brasil. It is actually one of the most important investments in public transport of the government in Sao Paulo region. The extension connects the southwest with the center of the city, crossing other important lines and station which are in operation. Due to the geology, especially with the presence of hard rock Granite, for the excavation of the diaphragm wall the use of trench cutter became mandatory. Approx. 2.500 m³ of rock needed to be excavated during the project. The paper describes the construction method and the sequence of activities required for the construction using the trench cutter system. It will describe also the main equipment which was needed to execute these works under this specific circumstances.

KEYWORDS Diaphragm Wall, Trench Cutter

1 Introduction

D-walls are known as underground structural elements commonly used as retention systems for excavation pits and shafts and permanent foundation walls or elements.

It can be anticipated that, with the increasing trend of utilizing more and more underground space to accommodate environmental considerations and urban/suburban development, there will be an increasing requirement for diaphragm wall usage in even more difficult conditions and with increasing depth.

The trench cutter is the most important tool for performing this work as the hydraulic grab, as well known as valuable excavation tool for d-walls is facing limitations in terms of depth and when there is the need to key into rock. Therefore, in the following, the focus will be given to the trench cutter technology.

The trench cutter itself is a reverse circulation excavation tool. It consists of a heavy steel frame with two drive gears attached to its bottom end, which rotates in opposite direction around horizontal axis. Cutter wheels are mounted onto the drive gears. As they rotate, the soil beneath the cutter is continuously being broken up, removed, mixed with the bentonite slurry in the trench and moved towards the opening of the pump suction box. The slurry loaded with soil and rock particles is pumped by a centrifugal pump which is located right above the cutter wheels, up through a hose system up to a desanding plant where the slurry is cleaned and returned into the trench.

The torque of the cutter wheels combined with the weight of the cutter is strong enough to cut into hard soils, crush stones to a certain grade and to overcut into the concrete of adjacent panels.

Depending on the soil type, different types of cutter wheel configurations and teeth can be deployed, ranging from aggressive teeth for cutting fine-grained soil to percussive teeth for crushing boulders. Changing the cutter wheels to suit different types of rock can be readily accomplished as well. Experiences exist for being able to cut rock with strength up to 250 MPa.

2 Equipment and tools

2.1 Working sequence

The typical working sequence for the construction of a diaphragm wall using a trench cutter as shown in figure 1 comprises the following key steps:

- Site preparation,
- Guide wall construction
- Trench pre-excavation
- Panel excavation
- Panel cleaning (desanding)
- Reinforcement installation (for retaining walls)
- Concreting

This general working sequence was slightly modified on the project and will be described detailed in the following.

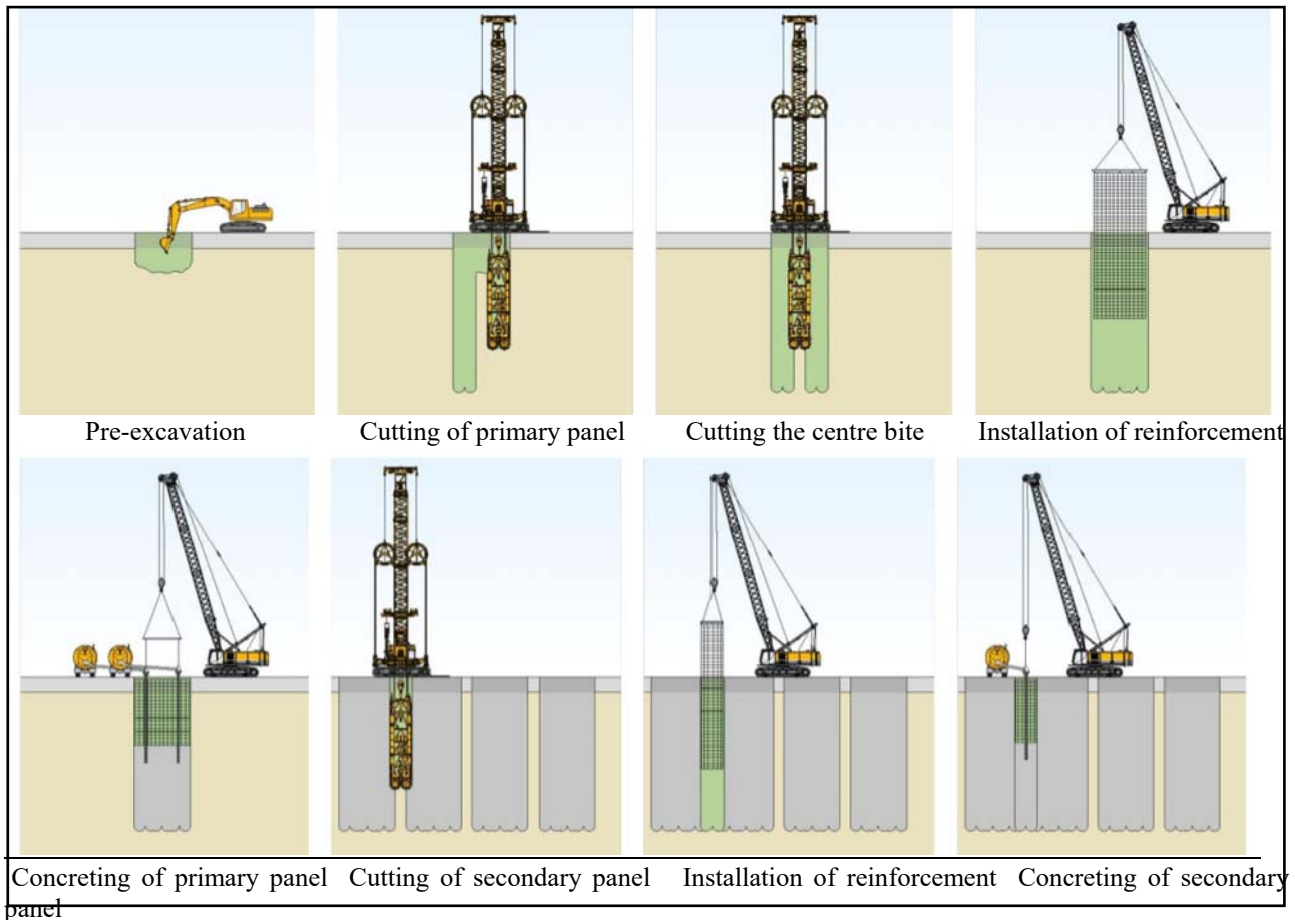


Figure 1. Construction process, exemplary for Diaphragm wall process

2.2 Wheels and teeth

Use of the most appropriate cutting wheels and teeth is one of the main keys to optimized productivity. Trench cutters are typically fitted with one of three types of wheels and teeth. Commonly they differ for the range of rock strength, where they usually are used. Figure 2 shows the three types of wheels.



Figure 2. Standard Cutter Wheel (left), Round shank chisel cutter wheel (centre), Roller bit cutter wheel (right)

The “Standard Cutter Wheels” are usually used in all types of soils with various types of teeth but is also able to cut into weak to moderately strong rock conditions. Obviously, there is no strict borderline but starting with rock strengths approximately in the range of 50 MPa, which means dealing with strong/hard rock, a more aggressive wheel like the “Full Face Cutter Wheel (or Round shank chisel cutter wheel (RSC)

Cutter Wheel)”, equipped with special round shank chisels, will provide a better cutting process. At the upper end of the scale, when dealing with rock strengths exceeding 120 MPa, there may be a need to consider using the “Roller bit cutter wheel”. Usually, when using the Roller bit cutter wheels, a high weight of the cutter is required, as each Roller bit requires a load of at least 4-8 metric tons for a reasonable functionality.

3 The Project: VSE Edmundo Lins – Metro Line 4 Yellow

3.1 About the project

The Line 4 Yellow extension in São Paulo, Brazil, is currently the most important public transport investment by the São Paulo state government. It will connect the southwest part to the center of the city, crossing other major lines and subway stations; all currently in operation. The VSE Edmundo Lins (ventilation and emergency exit) is part of this expansion along with the Morumbi Station, Vila Sônia and the new phase of Vila Sônia Maneuvering Yard. The solution of using the trench cutter in the execution of the VSE containment allowed the diaphragm wall to set in the rock allowing with an excavation of the subway tracks at approximately 22m depth. The construction of the stations and wells is currently carried out by the TC Line 4 Consortium, formed by Tiisa and Comsa. Owner and client is the Metrô - Companhia do Metropolitano de São Paulo.

Given the need to speed up the progress of the work, since the tunnels in NATM are running towards the VSE, it was defined by the designer, a design that would add a circular well and an open pit for the well be executed together with the diaphragm wall of the open pit in order to impact as little as possible within the time frame of the work. The success of this project and optimization of the design were only possible due to the dialogue between the client, designer, builder and foundation executor. Figure 3 show the general layout of the wall. Parts of the wall were already executed earlier in a separate sequence.

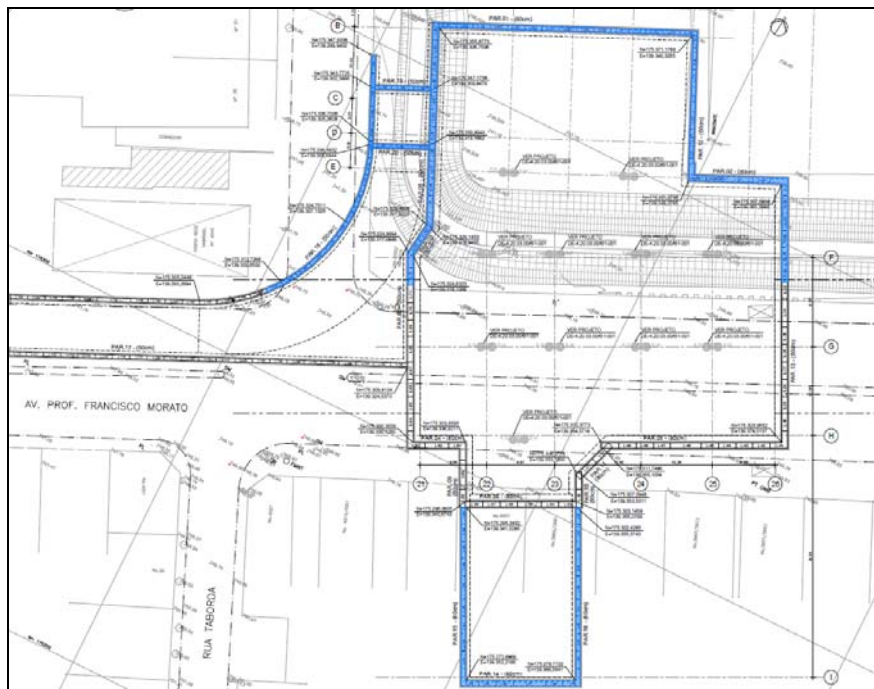


Figure 3. General layout

The diaphragm wall was composed by 19 primary panels and 17 secondary panels, 0.8m thick, standard width of 2.8m, existing some primary panels of 6.5m width, created in order to adequate the perimeter in project. For the execution of the secondary panels the concrete overcut was 20 cm on each side of the

primary. The depth varied between 15 and 30m. This layout, as well as the excavation sequence adopted, helped to reduce the execution time, which was 137 days. Being a total excavated of 2500m³ of soil and rock.

3.2 The Geology

The local geology is composed of a superficial landfill, basically of average organic clays, sands and gravels. From 10 m up to 23 m deep, the geology is composed of a compact tertiary soil, composed of a sandy clay, little altered to much altered (Saprolito). Then rock starts at a depth of 23 m depth. Starting fractured with increased strength for the competent granite. The excavation of the rock embedment was only possible with the use of trench cutter using round shank chisel cutter wheels.

3.3 Diaphragm Wall Execution

Brasfond was contracted to construct the diaphragm wall using trench cutter technology for two specific reasons. The first reason was to provide accurate control of verticality in the execution of the diaphragm wall panels. The second, more decisive reason was the need for the diaphragm wall to key into sound rock, since the designer considered that a minimum rock plug for the wall to withstand the stresses along the open pit trench.

The sequence of panel construction for this project was slightly modified, involved the following steps:

- 1) Guide Wall Construction.
- 2) Excavation of primary panels using hydraulic grab until the minimum depth of 4.0m (required to introduce the trench cutter in the excavation) or up to the excavation limit of the equipment.



Figure 4. Partial excavation with hydraulic grab

Panels located above the tunnel were only excavated with the grab since they were shallower. Increased depth control of the panel depth was required to avoid any damages of the tunnel.

For the grab excavation, Brasfond used the Bauer GB46 together with a hydraulic clamshell measuring 2.80 m by 0.80 m, equipped with flaps to control in real time the verticality during excavation. The average penetration speed for the use of the grab was in a range of approx. 5 m/h.

3) Completion of the excavation with the trench cutter in order to reach the embedment in the rock background determined on the project.



Figure 5. Excavation with hydromill

The Bauer BC40 trench cutter, mounted on a Bauer MC96 hydraulic crane, was used for the excavation of the rock embedment and has the dimensions of 2.80 m by 0.80 m. Depth performance in rock obviously decreased with increasing granite strength and was seen in a range of 1,2 m/h in the fractured rock decreasing to 0,10 m/h for the hard granite.

Throughout the excavation with hydromill, all the excavated material was pumped to the batching plant and recycled, where it passed through sieves separating the bentonite from the rock material, sand and clay. All the rock material, predominantly granite, was reused by the for landfill of temporary roads in other service fronts, contributing to decrease costs and reuse of excavated material.



Figure 6. Desanding unit with excavated material

4) Laying of the reinforcement, with the use of a supportcrane with capacity of 80 tons.



Figure 7. Placing the cage on the panel (left), using concrete spacers (right)

Concrete spacers (Figure 7 on the right) were adopted ensuring a proper installation and positioning of the reinforcement cage (Figure 7 on the left) in order to avoid that during the the installation of the secondary panel the cutter could hit the cage.

Each reinforcement cage weighed 10 tons and, when necessary, was divided into 2 to 3 sections.

5) Concrete pouring



Figure 8. Concreting an initial panel with a length of 6.50m using multiple tremie pipes

- 6) Repeating the previous methodology for the next primary panel.
- 7) Secondary panel drilling overlapping both primary with the use of trench cutter

Penetration of the secondary panels were done with an overcut of 20 cm into each adjacent primary panel. The concret spacers used ensured successfully the positioning of the reinforcement cage without any incident in cutting into reinforcement. Therefore, an average penetration speed of approx. 2.5 m/h could be achieved.

- 8) Repeating the operations of items 4 and 5.

Due to limited footprint of the site, a detailed executive sequence had to be planned a agreed wo reduce the standby times to a minimum.

Another challenge was the rock elevation. In average, the rock started 3 m above the expected depth. Obviously, this lead to an increased amount of rock to cut including the related consequences, increased wear and tear, increased excavation time and consequently increase costs.

4 Quality control

During the construction, Brasfond had strict quality control in relation to the excavation of the panels and the quality of the concrete. In order to guarantee the verticality of the excavation, the operators had in real time information of inclinometers and accelerometers located in the body of the trench cutter and the grab. The devices provided information on deviations along the X and Y axes for an onboard computer (B Tronic), allowing the operator to continuously correct the verticality during excavation with the flaps of the equipment. Verticality reports were provided to the customer (Figure 9).

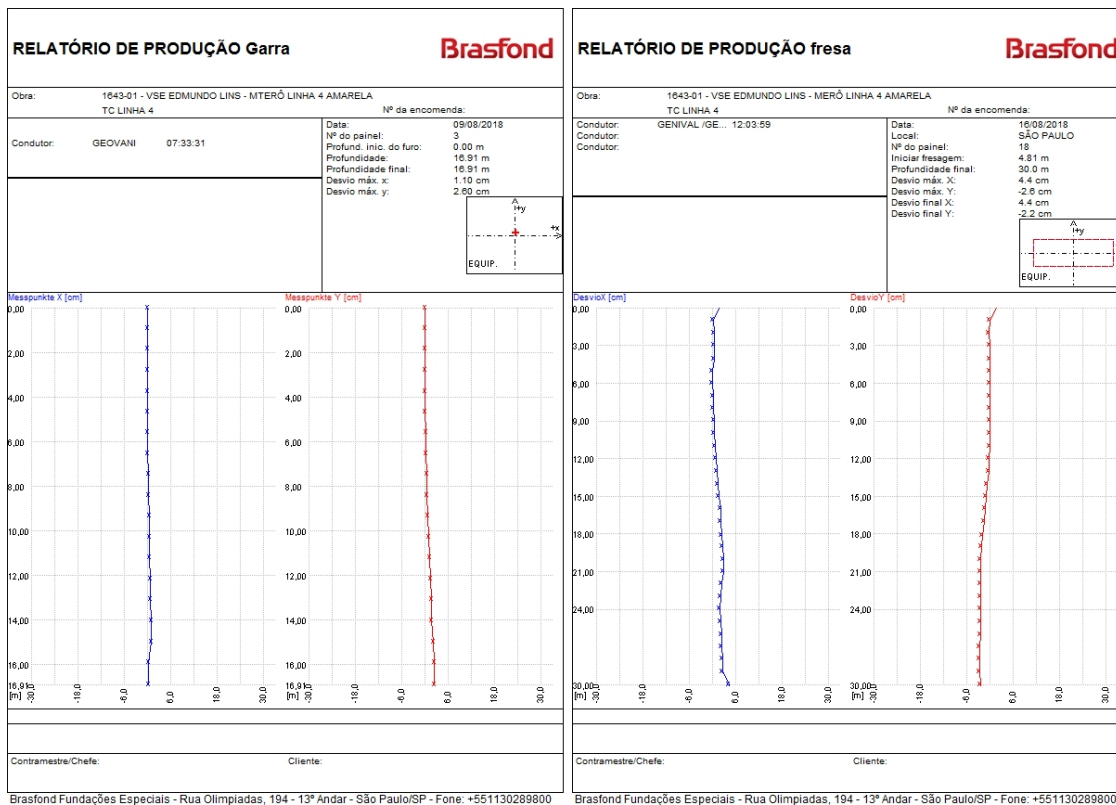


Figure 9. Exemplary verticality reports, Grab (left), Cutter (right)

For each panel that was completed, a quality control report was issued, providing the respective theoretical and actual dimensions of concrete volume. Raising the volume inside the panel during concreting, as well as depth, time and immersion of tremie pipe.

5 Conclusion

The success of this project was based on the interaction between the Metrô - Companhia do Metropolitan de São Paulo, Consórcio Consórcio TC Linha 4, the designer and the founder of Brasfond foundations. This made possible the best solution to reduce construction time and meet the delivery deadline. The use of trench cutter technology was fundamental. This innovative solution, coupled with the use of the latest available technology with robust quality controls during execution, enabled the team to successfully overcome geological challenges. The solution also mitigated the risks of building.

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