The project TEO “Tunnel Emisor Oriente“ in Mexico city

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ABSTRACT: The paper gives firstly a general presentation about the project TEO, currently under excavation in Mexico City. Secondly, the tunnel Section included between the Shafts 5 and 6 is approached more in details. In particular, the TBM excavating such a section includes the extraction of the muck with the use of a solid matter pump. The pump works properly and with acceptable pressures only when high amounts of water are added to the muck. In order to avoid so high consumptions of water (that lead to several problems from economic and social points of view), a solution was found with the injection of a high-lubricating polymer, diluted in water at very low concentration before its use.

1 Introduction

The project TEO (“Tunel Emisorio Oriente”) is currently one of the greatest projects worldwide. The TEO is under construction in Mexico City and deals with the construction of a new underground hydraulic channel (7.00 meter diameter with sheathing) , which will be used to collect the wastewaters in the Mexican megalopolis and to bring them to a treatment plant located out of the town.

Once completed, this tunnel will play an important role in order to solve some of the worst problems of Mexico City: manage of wastewaters, risks of flooding (that periodically hit the town) and soil subsidence. The safety and quality of life of people living in Mexico City and its suburbs (more than 20 millions) will therefore be significantly improved.

CONAGUA (“Comision Nacional del Agua”, the Mexican Commission responsible for the water management) assigned the construction of the project TEO to the Joint Venture COMISSA, consisting of the Mexican contractors: ICA, Carso, Cotrisa, Lombardo and Estrella.

The whole project is divided in several contracts:

- Section 1: originally it was between the Shaft 0, located in the north-east of Mexico City, and the Shaft 5, for a total of approx. 10 km. An inundation hit the working shaft and damaged the TBM seriously, thus stopping it for a rather long period. For this reason, another TBM was launched from the Shaft 5 in order to accelerate the completion of this first Section. It is currently excavating towards the Shaft named 3A.
- Section 2: from the Shaft 5 to the Shaft 10, for a total of 11.5 km.
- Section 3: from the Shaft 10 to the Shaft 13.
- Section 4: from the Shaft 17 to the Shaft 13.
- Section 5: from the Shaft 20 to the Shaft 17.
- Section 6: from the Exit Portal to the Shaft 20.

The Joint Venture COMISSA is excavating the 62km long tunnel with a total of 6 TBM, 3 manufactured by the German Herrenknecht and 3 by American Robbins.

The geology found by the 6 TBM during the 62 km of tunnel is very heterogeneous, as easily predictable for such a long tunnel. For this reason, the TBM have a flexible configuration of the cutter head, that allows to change the excavation tools according to the geological variations of the ground.

The soil conditions include: mainly clay and silts (especially in the first sections), limestone and sandstones, intercalated with basaltic rocks.

Underground water is normally not a significant problem relating to the control of EPB pressures. Up to now, only in the Section 6 very high pressures of water were found due to the high overburdens, up to 6.5-7.0 bars, thus representing an important problem for the TBM advance and the tunnel waterproofing. A TBM could advance extremely slowly for several weeks because of such water pressures. Finally the injection of a super-absorbing polymer was able to solve the problem and to allow the control of the EPB pressures and the extraction of muck through the screw conveyor.

2 Section 1, Shaft 5 – Shaft 6

The Shaft 5 is located in the suburbs of Mexico City and from this position two TBM were assembled and driven by the Mexican Contractor ICA:

- a Herrenknecht EPB, excavating from the Shaft 5 to the Shaft 6
- a Robbins EPB, excavating from the Shaft 5 to the Shaft 3A

In particular, the 1.4km-long section between Shafts 5 and 6 will be considered in the following part of the paper.

Several soil cores were extracted before the TBM launch. Their analysis allowed to draw the geological profile below, that can be summarized as following;

- the first part of the tunnel is mainly includes a high percentage of fine material, in particular clay with intercalation of silt and fine sand
- in the second part the geology switches to a higher percentage of fine and medium-coarse sand

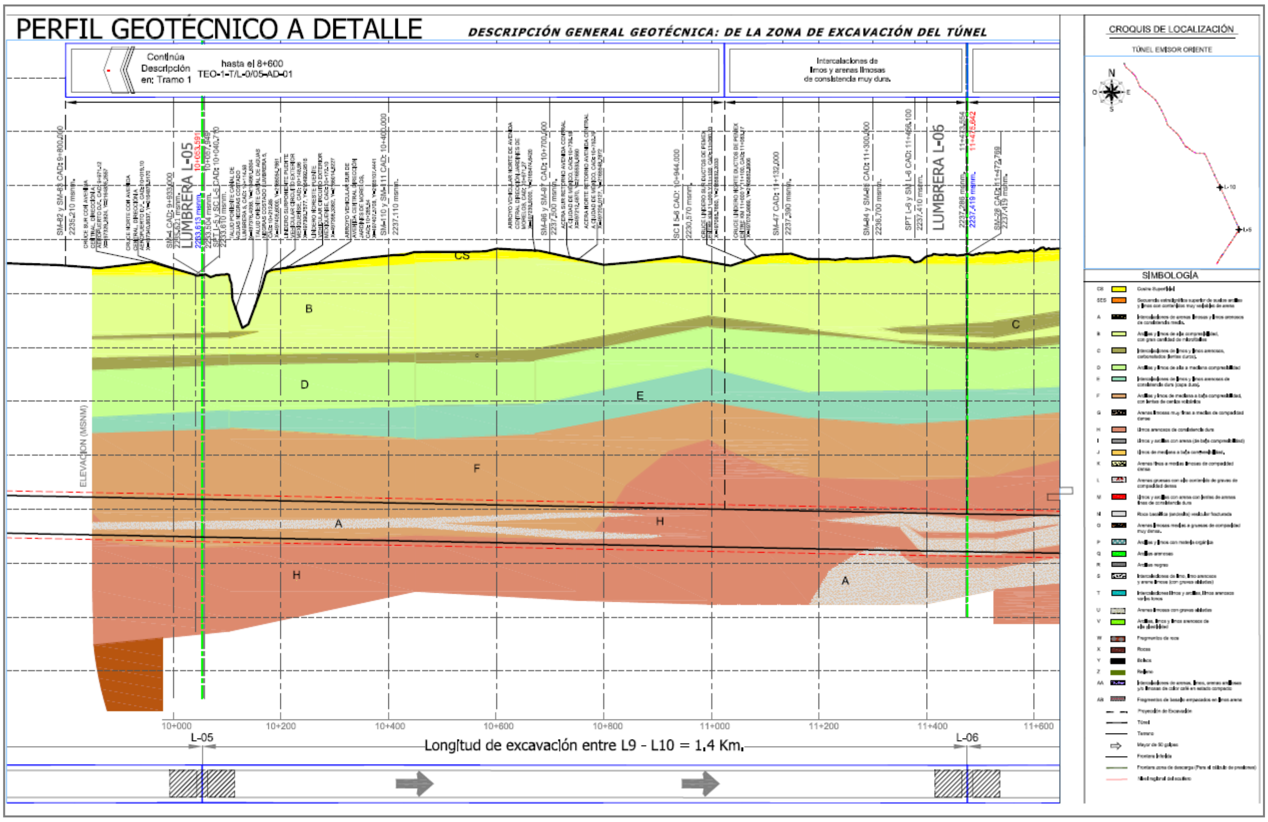

Figure 1. Geological profile of the tunnel between Shafts 5 and 6

2.1 Ground conditioning

As already known, the conditioning of the soil to be excavated with EPB represents one of the most important aspects in order to achieve successful TBM productions. Therefore the proper choice of the products (foaming agents and/or polymers) and their parameters has to be carefully analyzed by the Contractor.

The important steps to be considered for getting good results regarding the soil conditioning are:

- Prior to the TBM launch:

o to accumulate information about the tunnel geology: geological profile, geotechnical characterization, other tunnels excavated nearby, etc.

o to collect a representative sample of soil and to carry out tests in the laboratory.

- During the TBM advance:

o to optimize the whole ground conditioning system according to the local situation: TBM size, distribution of the injection lines, variations of the geological conditions, etc.

Regarding the tunnel section between Shafts 5 and 6, before the TBM launch some samples of soil were collected from the TEO project and sent to the MAPEI Laboratory located at the Technical University of Turin. Such a laboratory is fully dedicated to tests for ground conditioning.

The samples showed quite high characteristics of stickiness, that can represent a problem during the TBM advance. For this reason it is necessary to add a rather high amount of liquid foam.

The tests proved that a foaming agent in combination with a lubricating polymer (POLYFOAMER FP/CC) gives better results than the use of a foaming agent combined with a dispersing agent (sometimes defined as “anti-clay” agent). This because the lubricating polymer is able to “encapsulate” the clay particles and stop their water absorption. This effect is much more immediate than the dispersing effect given by the other type of polymer.

Figure 2. Same sample of soil before and after the addition of foam

The use of such a foaming agent in the TBM confirmed its compatibility with the types of soil excavated.
The average parameters for ground conditioning were as follows:

Table 1. Average parameters for ground conditioning

Parameter / average value	Concentration	FER	FIR
	1.5 – 2.0%	2 – 3	40-50%

The aspects considered by the Contractor to check the suitability of ground conditioning were:

1. Acceptable value of the cutter head torque (generally less than 70% of the alarm value depending on the cutter head rotation speed)
2. Acceptable value of the screw conveyor torque
3. Advance speed (the average values has been between 30 and 35 mm/min)
4. Absence of big lumps of clay or other materials dry and not conditioned

2.2 The solid matter pump

The TBM are configured with a particular design that allows the extraction of the excavated soil in two ways:

- with a belt conveyor discharging in a train wagon
- with a solid matter pump

The two systems are exchangeable, thus making the TBM more flexible depending on the punctual geological conditions, but the pump is the system generally used by the Contractor to extract the soil from the tunnel.

The ground conditioning parameters found with the laboratory tests had to be controlled and optimized during the TBM advance. In particular, the extraction of muck made with the solid matter pump influenced significantly the ground conditioning system and represents a factor which could not be simulated with the traditional laboratory tests.

Figure 3. Schwing pumps TAP-140 used in the Herrenknecht TBM

The solid matter pump is placed immediately after the screw conveyor and is especially designed for pumping cohesive soil with a high water content. It is therefore needed to add a significant amount of liquid in the soil in order to facilitate its pumping operations until the tunnel exit. In several rings, the amount of water added was almost 100% of the volume of soil excavated.

This important addition of pure water leads to two problems:

- The excavated soil stocked at site has to be transported away by trucks. The number of trucks needed increase significantly if so many liters of water are injected per advance, thus making the total costs for the Contractor higher.

- In the area of Mexico City, water is a precious resource and cannot be constantly used in so huge amounts for tunnel constructions.

For these reasons, it was necessary to find another way how to facilitate the soil pumping.

The solution found is to combine the use of a foaming agent with the injection of the lubricating polymer MAPEDRILL M1. This polymer is diluted in water at very low concentration before use and then injected into the excavation chamber and at the end of the screw conveyor trough a dedicated line.

Its use allows to lubricate the clay superficially: clay and silt are therefore facilitated to “slide” onto the metallic pipes between the pump and the tunnel exit. In this way, the pumping pressures are reduced and at the same time it can be decreased the total amount of water added for pumping the soil.

The polymer MAPEDRILL M1 was used with continuity in approx. 450 rings during the drilling in clay. The average amount of polymer injected per ring was around 10 kg. The injection of fluid decreased significantly down to 5000 – 10000 liters per ring, that means in average half than before without the addition of the lubricating polymer.

The amount of polymer and fluid used per ring was varying according to:

- The geological variations
- The pumping distance

The soil was pumped from the TBM to the Shaft 5 for the first 450 rings, that means 675 m. After this progressive, an exit for the pumping lines was created from the tunnel crown to the surface.

3 Conclusions

The TEO represents one of the most challenging underground projects in the world, with its more than 60 km length and the extremely varying geological conditions.

In particular, the section between the Shafts 5 and 6 was excavated with an EPB shield and used an innovative way to extract the soil out of the tunnel, that means with a solid matter pump.

In order to allow the pumping of different types of soil for long distances (up to 675 m) and without achieving too high and dangerous pumping pressures, firstly huge amounts of water were injected per advance. This was creating problems in the muck remocal from the job-site (several trucks had to be used, with consequent increases of costs and logistic problems) and in water supplying to the job-site.

A solution was found by creating a lubricating solution injected into the excavation chamber and the screw conveyor. Such a solution was generated by adding a polymer to the pure water, able to lubricate the clay particles superficially and to help their flow inside the pumping line. This solution helped solve the two main problems that arise from the use of the solid matter pump, that means to decrease significantly the amount of water needed per advance and to avoid too high pumping pressure.

The solid matter pump certainly represents a solution alternative to the more classic belt conveyor, useful for example where the lack of space in the TBM starting station or shaft avoids the installation of a belt conveyor. In such a case, the pump is able to ensure higher production than the use of muck removal cars and crains, because it is a faster and more constant system.

The use of a pump represents an important factor which has to be considered while evaluating the most suitable products and parameters for ground conditioning. Specific site tests need to be carried out in order to find the optimal solution.

As the TEO project in Mexico City proves, the choice of the right product helps significantly solve some of the problems which can be related to the use of such a technology for the muck removal.