Multiple Use Applications of Super Water Absorber Polymer

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ABSTRACT: The application of Super Water Absorbents polymers (SWA) as chemical solutions in TBM tunneling is becoming increasingly demanding, due to their extensive multiple use and their relative facility in the application. The use of SWA polymers is extensively employed to enhance the performance of foams, further reduce the permeability of the soil, turn the loose material into a soil paste, modifying its physical and mechanical properties to improve the balance of pressure in the working chamber. The main objective of this paper is the demonstration how SWA polymers have been used in multiple applications, thus proving that the polymers developed for soil conditioning technology have made giant steps to support contractors and the entire TBM tunneling industry.

KEYWORDS: Tunneling, TBM, Polymers, Chemicals, Water Absorption, Anti-Clogging, Anti-Dispersion

1. INTRODUCTION

The industry of EPB TBMs experiences an unprecedent exploit in projects with cohesionless grounds below the groundwater table. High stable foaming agents contribute to stabilize the excavation pressure, increase front face stability and favor the extraction of the spoil outside the tunnel.

In addition, Super Water Absorbents polymers (SWA) are widely used to support the performance of foaming agents, restructuring the soil with low fines content, lubricating inner friction and, most importantly, avoiding costly down times and reducing wear of the mechanical parts of the TBM.

The water-retaining and yield-increasing capacity of super water absorbent polymers make them suitable for acting as a binding agent restructuring soils with poor grading and low fines content, increasing its plasticity and cohesion, leading contractors to better approach the TBM excavation cycle in safety and quality.

In addition to the above, SWA polymers have been successfully used for multiple applications, becoming de facto a standard chemical solution present in several TBM projects around the world.

In this paper, we introduce how one SWA polymer has been used for the following functions:

1. As anti-clogging solution
2. As anti-dispersion agent

1. SWA polymer as anti-clogging solution

In Paris Metro Line 15, Lot T2B the SWA polymer has been used as alternative, innovative and efficient way to prevent clogging of cutting tools during mining through diaphragm walls. Specifically, there are two major risks to manage when the TBM passes through diaphragm walls:

a) Wear of metal parts in the peripherical area of the cutterhead, more specifically on cutting teethes;
b) Clogging due to thins of cement reduced to dust by the passing of the TBM.

The above two situations are riskier when the TBM cutterhead is designed with more cutting teethes rather than peripherical roller disc cutters.

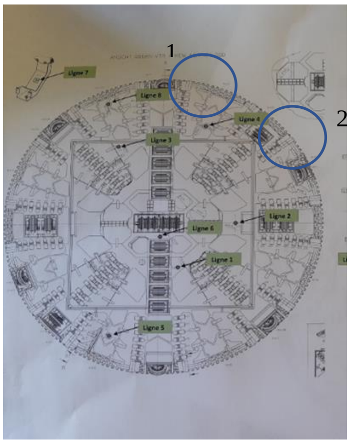

Figure 1 – Identification of cutting teethes[1] and roller disc cutters[2] in Paris Metro TBM cutterhead

1.1 Application

The solution it was decided to implement to overcome the above two risks has been innovative, efficient and quite easy at the same time. A diluted SWA polymer it was applied as protection treatment of cutterhead tools, by spraying it directly on tools before the excavation thought the D-walls, with focus on cutting teethes.

Figure 2 – Picture showing the spraying of SWA polymer from within the cutterhead

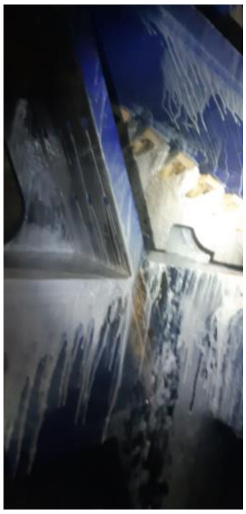

Figure 3 – Picture showing the sprayed SWA polymer into the cutterhead

The TBM has been stopped before the diaphragm wall, the spraying team has physically reached the excavation chamber and, from the inside of the cutterhead, the diluted SWA polymer has been sprayed directly on tools.

1.2 Equipment used

The spraying team has used a standard oil pump that is generally used to fill the foams' IBCs (foam tanks).

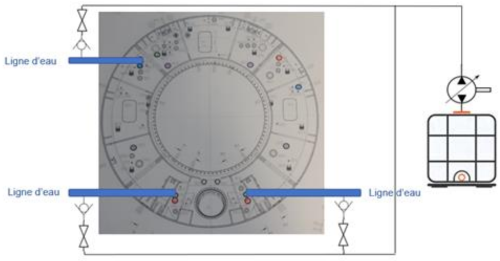

Figure 4 – Schematic P&I diagram used for the SWA spray

1.3 Our approach

The approach of SWA application for anti-clogging has been the following. Before excavation:

a) Spraying of gel on tools in the center of the cutter head;
b) Used an oil pump normally used to fill IBC;
c) Polymer lines were filled with a biodegradable oil before injection.

During excavation:

a) Constant injection during excavation on one line directly inside the chamber;
b) Used an oil pump normally used to fill IBC.

Overall consumption was approximately 500Kg/intervention. No clogging was detected during mining through diaphragm walls.

2. SWA polymer as anti-dispersion solution

In the Ahmed Hamdy2 tunnel in Egypt, total length 3km, the slurry TBM has bored in rock conditions consisting of hard clay/shale, having the unlucky property of dissolving very quickly in water; mixed face conditions along the tunnel alignment with rock class II to IV; rock strata as a combination of breccia and basalt with shale.

Figure 5 – Clay dissolved
when placed in water for one minute

With this challenging geology, the following was forecasted during tunneling production:

a) Regular cutterhead interventions and high specific gravity of the slurry affecting the TBM operations and the overall tunneling progress;
b) High variations of the specific gravity of the mixed slurry in the mixing chamber, due to fine particles of crushed rock dissolving in water;

In agreement with the contractor it was decided to carry out trial laboratory tests to understand what polymers to recommend avoiding dispersion.

2.1 Testing Phase – The Rotary Sieve test - Slake Durability apparatus

It has been decided to test the clay/shale by using the Rotary Sieve Test machine for slake durability. The rotation test is a testing procedure modified from ASTM D4644-87, a standard test method for slake durability of shales and similar weak rocks.

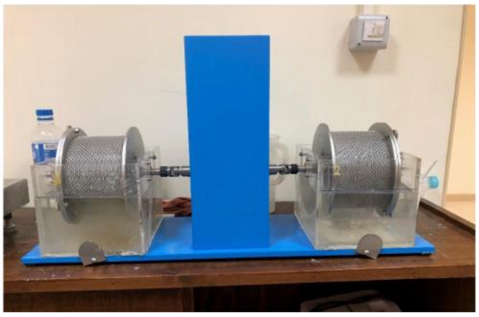

Figure 6 – Testing device for clogging tests (Ref. BabEng)

The equipment consists of two screen rollers with a diameter of 14cm and a width of 9cm, which simultaneously rotate at a speed of approx. 20 rpm inside a water basin, being these under the same rotating axis.

Figure 7 – Steel mesh drum (Ref. BabEng)

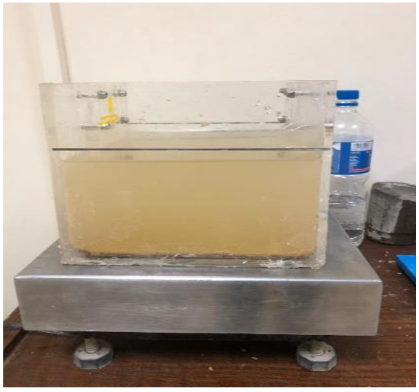

Figure 8 – Deposit of clay on the bottom of glass basin

The goal of the test was to find a way to reduce dispersion of clay/shale as much as possible, by applying several types of polymers. The test was conducted by the contractor's consultant.

2.2 Testing Phase – Soil sample and equipment preparation

The first step has been the calibration of the Rotary Sieve testing device by measuring the tare of the apparatus, as per table 1 here below:

Table 1 Preliminary Measurements
(Applicable to all rounds)

Item	Screen Roller 1	Screen Roller 2
a-Drum	2293 gr	2320 gr
b-Basin	993 gr	988 gr

Soil samples have been prepared for six different rounds of test, where six different polymers have been used, including the ones from other producers.

To run the tests, soil samples have been cut into small cubes of approximately 100gr each and then inserted within both drums for test execution.

For each round of test, one drum has been filled with polymer (i.e. Screen Roller 2), meanwhile the other drum remained without polymer (i.e. Screen Roller 1). The test has been repeated six times, for each polymer. Measurements have been recorded as per table 2 here below:

Table 2 Fill the drums with 400gr of soil
and fill the basin with 2,5 litres of water
(Test round for polymer E)

Item	Screen Roller 1	Screen Roller 2
c-Drum with soil	2742 gr	2772 gr
d-Basin with water / bentonite	3599 gr	3600 gr
e-Polymer	0 gr	25 gr

The next step has seen the execution of the test, in six different rounds, by rotating the screen rollers for ten minutes. Measurements have been recorded as per table here 3 below:

Table 3 Rotate for ten minutes/round
(Test round for polymer E)

Item	Screen Roller 1	Screen Roller 2
f-Drum with dried soil	2645 gr	2635 gr
g-Drum with clogged soil	2300 gr	2345 gr
h-Basin with water and soil	3683 gr	3710 gr
i-Soil cubes clogged?	NO	YES

The same type of test has been carried out on all six candidate polymers, including the ones supplied from other producers. The results have been recorded as per table 4 here below:

Table 4 Final test results
(All six polymers)

Polymer Code	Product	Degree of dispersion	% of soil clogged in the mesh
A	Competition Anti-dispersion Polymer	16.90%	8.80%
B	Competition Anti-dispersion Polymer	< 0%	8.50%
C	Competition Anti-dispersion Polymer	16.50 %	1.20%
D	Competition Anti-dispersion Polymer	< 0%	16.50%
E	Our SWA Anti-dispersion Polymer	< 0%	4.00%
F	Competition Anti-dispersion Polymer	20.80%	3.50%

2.3 Interpretation of Test Results

Sample E was found to be the one with less degree of dispersion (<0%) and the lower percentage of soil clogged in the mesh (4.00%) combined. Our SWA polymer has been used with success every time the TBM was mining through clayey geology. Though, normal bentonite slurry was used to mine through other rock formations.

2.4 TBM Application Overview

The use of SWA polymer has been done by establishing a liquid tank at the TBM and filling it with 1% solution with water (or as per the sample trials done at lab). A dosing pump like a standard Single Screw Progressive Cavity Pump has been utilized for pumping the solution directly at the cutterhead nozzles and in the mixing chamber.

A quantity between 20 to 30 liters of polymer has been pumped at the beginning of mining while continuous monitoring of the cutter head torque and the slurry properties, also when the slurry was pumped back to the STP form the outlet line.

If required, more SWA polymer has been added from time to time during mining to adjust the slurry properties to overcome the variation of the specific gravity of the slurry, so the agglomeration of the clayey strata can be avoided to optimum levels. In this way also filtrate loss has been minimized. The flow meter readings were constantly recorded to monitor the consumption levels. It started with 3 to 5 liters/min flow and injecting through the center water flushing of the cutterhead. The PLC programing at the operator cabin has ensured control of the parameters. Other application methods from the slurry feeding tanks can be considered in the future but, in such case, the SWA polymer consumption may increase drastically.

Depending on the mixing inside the chamber, whether with water or in some cases with bentonite, the consumption parameters are set only after several trials done during excavation, to reach the best and optimum situation to avoid clogging at the TBM cutterhead.

CONCLUSION

The Super Water Absorber (SWA) presented in this paper is a liquid polymer specifically designed for its use in difficult grounds and slurry conditioning. The main peculiarity of this polymer is to be adaptable for multi-use applications:

a) EPB and Slurry TBMs;
b) Grounds with high water pressures;
c) Poorly graded soils;

d) Grounds containing low number of fine particles;
e) As bentonite slurry modification in case of high soil porosity or saline water conditions;
f) To improve the yield and filter cake properties of bentonite and filler slurries;
g) As anti-clogging agent;
h) As anti-dispersion agent;
i) As lubricant agent.

The advantages are multiple:

i. Structuring the soil, particularly effective in, coarse, clean sands and gravels below groundwater;
ii. Reducing soil permeability;
iii. Creating plastic deformation properties in the soil providing an even and controlled support pressure and increased face stability;
iv. Lowering the inner friction and abrasiveness of the soil;
v. Increasing cohesion of coarse sands and gravels;
vi. Ready to use - no mixing equipment required before use.

REFERENCES

Raynaud, S. and Montalban Vicente, D. (2021) “How-to pass-through Diaphragm Wall with TBM”. Paris, France.

Tharwat, P. (2021) “Polymer for Slurry TBMs in Clayey Soil“. Cairo, Egypt.

Babendererde, T. “The Rotary Sieve test - Slake Durability apparatus“ (2021). Cairo, Egypt.

Reviewer feedback:

- Fig. 1 the circles are not on the correct location, please check.
  Author: The circles in Fig. 1 are in correct position.

- If you take pictures from someone else please refers, this time: Fig. 5 is from BabEng
  Author: Done.