

CONSTRUCTION OF SEWAGE TUNNEL: “ A MALATA – PRIORIÑO CAPE ”. FERROL. SPAIN

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Summary: The Project is located in Galicia, in the Northwest of Spain. It is included in the Sewage disposal scheme from Ferrol. Its total investment is about 170 million euros. The Ministry of Environment, by means of the Confederación Hidrográfica del Norte, is the owner of the project. It is necessary the construction of a tunnel of 7.344 meter long and with 3.7 meters of excavation diameter. The tunnel is being executed at the present time, using an open face T.B.M. Robbins 1215-265. This text provides information related to geological and geotechnical characteristics, modifications of the project and complexities of the tunnel execution.

Résumé: Le projet, situé en Galicie, dans la région Nord-Ouest de l'Espagne, est partie d'arrangement de disposition d'eaux résiduelles de Ferrol. L'investissement total du projet est environ 107 millions €. Le Ministère de l'Environnement à travers de la Confederación Hidrográfica del Norte, est le propriétaire du projet. Il est nécessaire la construction d'un tunnel de 7'344 mètres de longueur et de 3'7 mètres de diamètre d'excavation. Le tunnel, actuellement en marche, est excavé avec une T.B.M. Robbins 1215-265 de visage ouvert. Ce report fournit des informations au sujet des caractéristiques géologiques et géotechniques, des modifications du projet original et des complexités de l'exécution du tunnel.

1. INTRODUCTION.

During decades, wastewaters of Ferrol has been poured directly into the sea and, as consequence, its estuary is resented and in need of a firm regeneration.

After many attempts, the works, which will convert Ferrol in a drained environment, have begun.

In September 2003, the Xunta de Galicia, Aguas de Galicia and the Confederación Hidrográfica del Norte signed an agreement to finance the improvement of the purification and flow of Ferrol.

Thanks to the investment of the Ministerio of Medio Ambiente and the Xunta of Galicia, with the support of the FEDER and Cohesion Funds from the U. E., waters from Ferrol, Narón and Neda will be depurated before being sent to the sea, with the consequent improvement of the environment of the town of Ferrol and its estuary.

The paper pretends to gather the experiences obtained so far in the construction of the Sewage Tunnel, which is actually in execution.

The tunnel is located in the west of La Coruña (Northwest of Spain), in the municipality of Ferrol.

2. DESCRIPTION OF THE PROJECT.

The project consists of the construction of a tunnel of 7.344 meters long, with an excavation diameter of 3,70 meters and an inside diameter of 3 meters long, with a slope of 1,86/1000 which will carry waste waters from the Pumping Station in La Malata towards the water treatment plant in the Prioriño Cape.

The project is part of the "Purification and Flow Improvement of Ferrol", which is divided into four actions:

CROSS AND RISING MAIN OF LA MALATA: (18,645 million €).

This action is made up of:

- Cross of the La Malata Bay.
- Pumping Station.
- Rising main to connect with the Sewage Tunnel.

SEWAGE TUNNEL FROM LA MALATA TO THE PRIORIÑO CAPE WATER TREATMENT PLANT: (37,158 million €).

Hydraulic tunnel of 7.344 meters long and 3 meters of diameter that allows communication between the Pumping Station and the Prioriño Cape water treatment plant.

THE PRIORIÑO CAPE WATER TREATMENT PLANT: (36,000 million €).

Water treatment plant of 6 hectares, which will make possible to treat an average flow of 1.150 l/s. with a system of treatment of active muds of high charge.

UNDERWATER TAP OF PRIORIÑO CAPE: (15,554 million €).

It is made up of:

- Disinfected UV rays in Sewage Tunnel head.
- Underwater tap with over 1.000 meters long.

With a total investment of more than 107 million euros, this ambitious action will provide to Ferrol with a complete purification system at the end of the year 2008.

Figure Nº 1 shows a scheme of the four mentioned projects

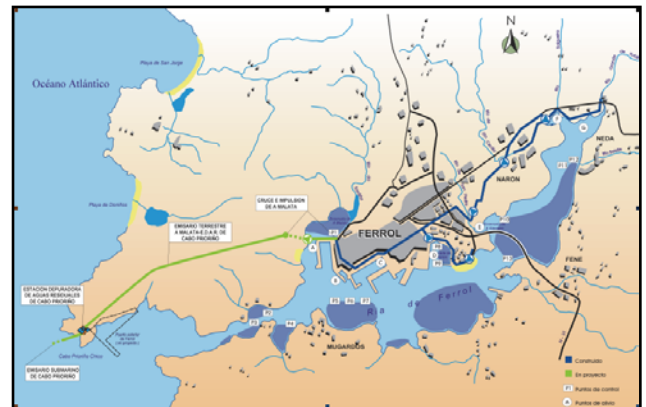


Figure 1. General Layout of Project.

3. PROJECT GEOLOGY.

The area of the project is located in the Galicia "Tras os Montes" area, originated from the Centro-Iberica Paleo-geographic unit, which extends itself from the Precambrian to the Devonian Age. It is a late intrusion of cylindrical shape of the Ordenes series.

The granodiorite is the present rock all over the tunnel. Its grain is of a half-thick size.

In general, it can be considered like a rock of great hardness and with a high level of quality.

These materials have been affected by a poliphasic tectonic of hercynic age. The detected faults present two principal positions:

NO-SE, with dip towards the Northeast, and NO-SE, with a very vertical dip

A campaign of geologic and geotecnic studies, based in three steps, were done in order to achieve a wide knowledge of the geologic means, as well as the geotechnical characteristics of the materials:

1. Geologic mapping based in a photo geologic study of the area and a geologic mapping of field.
2. Electric logs: 15 electric logs were done with a total length of 6.370 meters.
3. Probe holes execution: 10 probe holes were done with a total of 800,35 meters.

The tunnel goes through granite mass that is permeable only for fracturation, in which there is a superficial layer of alteration from about 20 to 25 meters thick. Water underground circulates over that layer of alteration and fills up the fractures of the mass.

The average permeability of the mass is about 10^{-7} and 10^{-8} m/s. The ground water level is very superficial, about 10 meters deep.

The chart below shows a summary of the geotechnical characteristics of the rock that crosses the tunnel, according to previous test:

Type of Rock	Peso Esp. (T/m ³)	Cohesion (Kp/cm ³)	Friction Angle. (°)	Mass Deformation Module (Kp/cm ²)	Poisson Ratio
Granite	2.4	40	43	120.000	0,25
Fractured Granite	2.2	10	40	35.000	0.25
Very weathered granite	2.2	1-2	36	600-2000	0,30

Chart N° 1. Geotechnical characteristic of rock mass.

As additional data, we can emphasize that the strength to the average simple compression is of 73.64 Mpa.

The faults to the tunnel level, their position and dip have been all deduced from the layout of the faults in surface, detected by photo geology, from the drilling surveys, from the observations in the area and from electric logs.

In the geologic plant, it has been considered to represent sandy areas detected in field, which will correspond to faults of certain importance.

The biggest fault observed is the one of Valle de Cariño, in which there are important sandy areas, with caolinitization and areas of oxides associated to water running.

The tunnel will cross this fault between P.K. 3+210 and 3+400.

The overburden in the tunnel varies from 20 to 220 meters; such as it is shown in the geologic profile below:

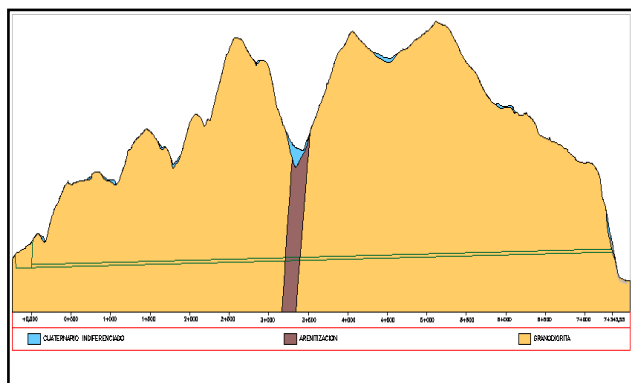


Figure N° 2. Geological profile.

3.1. ADDITIONAL GEOTECNIC AND GEOLOGIC STUDIES.

Due to uncertainty, which represents the excavation of an area of fault using a Tunnel Boring Machine (T.B.M.) for rock, before the beginning of the excavation of the tunnel, different possibilities were analyzed for the construction of the tunnel in the area of the Cariño Fault.

As a result of the study, four alternatives were analyzed:

Alternative N° 1:

Execution of a vertical shaft of access of approximately 110 meters long and 3 meters of free diameter in the fault area, to build a pilot heading parallel to the axis of the tunnel from which would be carried out a previous consolidation treatment of the area, before the T.B.M. arrived.

This option wouldn't modify the term of execution of the tunnel, since it could be begun together with the excavation of the tunnel.

Alternative N° 2:

To build a gallery in by-pass for the treatment of consolidation of the fault area, from the Sewage Tunnel, leaving from the end of the back up, approximately to 170 meters of the front, once the cutter head of the tunnel reaches the beginning of the fault.

This option would represent the possibility of having to stop the excavation works with the T.B.M.; during the time the process of consolidation process of the fault area lasts.

Alternative N° 3:

Execution of a vertical shaft of approximately 110 meters long and 5 meters of free diameter in the adjacent area to the end of the fault, in order to proceed to excavate the plot of the Sewage Tunnel for conventional methods, with a section which allows the passage of the T.B.M. later on, to continue the excavation of the tunnel with mechanical means.

This option wouldn't modify either the term of execution of the tunnel, since it could be carried out at the same time that the excavation of the tunnel.

Alternative N° 4:

This alternative is similar to n° 2, but beginning the execution of the by-pass in the area immediately later to the Grippers of the T.B.M. and before the beginning of the back up.

This option would make possible the saving of the execution of the 170 gallery meters, even when, it would be also necessary to come to a standstill of the excavation of the T.M.B. and to take the necessary measures to guarantee the machine is not damaged with the excavation process with drill and blast method of the by-pass.

Parallel to the study of alternatives, an electric log was done in the area of the fault, whose results confirmed that the area was made up with materials with alteration grades of III, IV and V, but the tunnel length seriously affected by the fault it could be of the order of the 100 meters, half of that foreseen in the original project.

With these new elements, four probe holes with extraction and core drilling in the area of the fault were carried out to know the geology of the area with more accuracy.

As a result of these probe holes, it has been observed that the condition of the rock at the town level is much better than the one indicated in the electric log, and that the weathered area may be in the order of 30 meters.

According to the facts already exposed, it has been decided to reject the four studied alternatives and to do the excavation of the tunnel with the T.B.M., with a continuous pursuit of the geology of the excavation front.

It is possible to use a steel liner in the area, which has already been used in other tunnels carried out by the contracting firm with good results.

4. DESIGN CRITERIA OF THE TUNNEL.

The design of the Sewage Tunnel's type section required a study of alternatives in what different sections and constructive systems were managed, taking account aspects such as economic cost,

execution term, environmental damages, functional aspects and constructive viability.

Two options can be extracted from the study of alternatives:

- No visit section: water would flow free through out the circular tunnel and executed by a T.B.M. with precast concrete segments.
- Service gallery: it was a visit section in which purification conductors would be hosted and water would flow free or by gravity through them.

Five alternatives were studied:

Section	Type	Shape	Internal Diameter (m)	Excavation Method
1	No Visit	Circular	3,00	T.B.M.
2	Visit	Circular	5,00	T.B.M.
3	Visit	Circular	6,00	T.B.M.
4	Visit	Horseshoe	5,00	Conventional.
5	Visit	Horseshoe	6,00	Conventional.

Chart N° 2. Tunnel section alternatives.

After analyzing the five mentioned sections, Section n° 1 was selected as the most suitable, with a modification to the method of support/lining of the tunnel.

According to the suitable geologic conditions in the nearby whole of the tunnel layout, it was decided the placement of an invert precast concrete like against stable roof for the T.B. M. advance.

This option would also allow that, don't being necessary to make the lining jointly with the excavation of the tunnel, having a bigger room for the ventilation system and the transport of mucks.

Definitely, the tunnel was projected with an inside diameter of 3 meters, excavated with an open front T.B.M., advancing by means of the use of Grippers.

The lining will be made with invert precast reinforced concrete on which the back up of the T.B.M. will lean and reinforced concrete of 35 cm thick, once the excavation of the tunnel is finished.

To stabilize the excavation until the lining is executed, three types of initial support have been projected based on rock bolts, steel ribs and wet mix shotcrete.

In the following chart the projected support types are shown

Rock Type	% Use	Initial support
I	65	Occasional resin anchor bolts in rock wedges. L= 3 meters.
Ila	35	3 systematic resin anchor bolts of L=3 in roof, separated a meter in longitudinal sense. Shotcrete with steel fiber of 8 cm thick.
Ilb		TH-21 steel rib @ 1 meter. Shotcrete with steel fiber of 8 cm. thick.
III	5	HEB-120 Type steel rib @ 1 meter. Shotcrete with steel fiber of 12 cm. thick.

Chart N° 3. Projected support types.

In relation to the in-plant layout, this was designed taking in consideration the following criteria:

- Implantation of the portals in favorable areas, both from the geotechnical point of view and from their placement in the city-planning framework, especially in La Malata.
- Implantation of the tunnel in the most favorable geologic areas.
- Smaller possible length.
- Acceptable minimum radius to be able to carry out the excavation with a T.B.M.

4.1. T.B.M. CHARACTERISTICS.

According to the characteristics of the rocky mass to be crossed for the Sewage Tunnel, the project recommended the use of an open front T.B.M., without shield, with a power of 1.500 KW, a thrust around 900 ton and 28 cutters of 17", with a noun diameter of 3,70 meters.

The machine should dispose of windows on the cutterhead to be able to perforate the probe holes of recognition in advance, as well as those of injection and treatment of the land.

In relation to the guidance, the machine should dispose of guidance and positioning system that make possible to know at any time its position and direction.

For the execution of the tunnel, the contractor proposed the use of a Robbins T.B.M.

The main characteristics of the T.B.M. are:

Year of manufacture: 1.991

Model: 1215-265

Diameter of excavation: 3,70 meters.

Number of motors: 4

Power: 1.800 HP.

Speed cutterhead: 11.9 rpm.

Thrust: 875 ton.

Number of cutters: 26

Diameter of cutters: 19"

The main body of the machine has drilling hammers of rock bolts to both sides and a steel rib setting device.

The machine has got a back up of approximately 192 meters long, of which 82 meters correspond to the California switch rail.

The back up is a mobile structure that moves itself pushed by the own T.B.M. and disposes of all the necessary equipment to construct the tunnel.

Among these equipments, we can emphasize the following ones

- Operator's cab of the machine.
- Cabin of operation and filling control of muck cars.
- Close circuit television and remote control operation placed in strategic parts of the T.B.M. with monitor in the operator's cab.
- Grease pump and oil tanks for lubrication of the cutterhead.
- Refrigeration tanks for the lubrication oil.
- A warehouse.
- Transformers of 660 V. a 220 V. to feed auxiliary systems.
- Electric boards to feed the cutterhead.
- Generator for auxiliary systems of 20 KVA.
- Fans in stiff pipes of 400 mm. of diameter.
- Dust collector of the ventilation.
- Water pumps to feed refrigeration circuits.
- Coil of energy cable of 15.000 V with capacity for 300 meters.
- Compressor for rock bolts.
- Water tank for recirculation with 6 m³. of capacity.
- Dining room.
- Secondary conveyor belt to load the muck cars.
- Unloading system of invert precast ashlars by a tackle of 3 ton.
- Bag line cassette of 100 meters long.
- Gas detection system.
- Lighting system.
- Phone system among the operator's cab, filling cab of the muck cars and the electromechanical factory located on the plain.
- Handrail.
- Operation system for the movement of muck cars by means of chains, without intervention of locomotives.
- System of traffic-lights to check the traffic of locomotives in the neighborhoods of the Californian switch rail.

The guidance of the machine is based on the PPS system (Poltinger Precision System).

This system allows determine automatically the exact position and the direction to follow, as well as the correction of the deviations with respect to the axis of the project, which has been previously introduced in the computer system.

The system has a motorized theodolite that makes continuous readings to two motor prisms, located in the main body of the T.B.M. and to a remote prism placed at the back that serves like direction element.

All this information is presented in a monitor in the operator's cab, where the operator knows the exact position of the T.B.M. at any moment.

This system has been used in different projects worldwide in this kind of machines, as well as in roadheaders, EPB, microtunnels, etc.

4.1.1. WORKS EXECUTED PREVIOUSLY BY THIS MACHINE.

This model of T.B.M. was designed by Robbins in 1991 for the project of Meeraker in Norway.

One of the main achievements obtained in the design of this machine is that for the first time in history, it was possible to excavate with a maintained load of 32 ton by cutter.

In this project, it got an average advance of 253 meters a week, in a tunnel with 3, 5 meters of diameter.

Once the excavation of the tunnel was finished, the machine was prepared to perforate with an excavation diameter of 4,23 meters.

Later on, this machine was used to construct a tunnel of approximately 13 Km. in the Middle-East, Pipeline tunnel Medina Site 7 to Yanbu Oil Refinery (Saudi Arabia) which was ended at the end of 1997.

Before the excavation of the Sewage Tunnel, this machine had been used in Tunnel C of the project named "Hong-Kong Strategic Sewage. Stage 1". In that work, it obtained average advanced of 98 meters a week.

4.2. MODIFICATIONS DURING CONSTRUCTION.

Usually, before the beginning of the excavation works of a tunnel, different alternatives are analyzed in relation to the use of equipment, what it is translated in modifications of technical character related to the constructive aspect of the work.

Among the main necessary modifications and changes to initiate the construction tunnel, we have:

Invert precast concrete:

The invert precast concrete of the project had 1,85 meters in cross-sectional section to the tunnel and 3 meters in longitudinal sense to the advance.

With these dimensions, it was necessary the use of a tackle of great proportions in the area near to the back up of the T.B.M., to be able to transport the invert precast concrete, which are placed immediately after the Grippers area.

In addition to this, the projected dimensions originally disposed of little clearance due to the limited space of the back-up area.

This situation was solved with the design of a new invert precast concrete of smaller dimensions.

The adopted invert precast concrete is of 1,613 meters of cross-sectional section and it has 1,20 meters in the sense of the advance.

This modification increased the number of joints among invert precast concrete and the increase of the volume of the lining concrete.

An advantage to emphasize of this change is that the new design of invert precast concrete has made possible a great versatility in the inside transport of the tunnel and has increased the placement yield of it.

Another important aspect to enhance, it is the design of a "reduced" invert precast concrete, which is used in the areas where it is necessary to place steel ribs.

This reduced invert precast concrete is similar to the normal one, but with a diminution in its inferior part that allows to place the complete ring of steel ribs.

This situation guarantees a better execution of the support in comparison with the original project, in which the steel rib was discontinuous, that is to say, it leaned laterally in the invert precast concrete.

The space between the invert precast concrete and the ground, once the steel rib is placed, is filled up with fluid concrete.

In the following picture, it can be appreciated a cross-sectional section of the new invert precast concrete that is being used in the works.

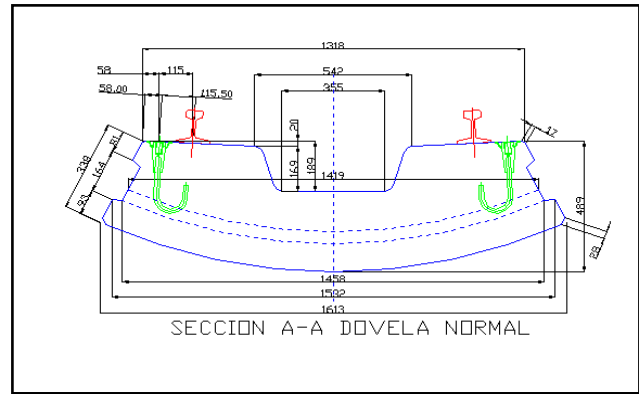


Figure N° 3. Cross Section of invert precast concrete.

Rock Bolts:

The T.B.M. has in the area immediately rear to the shield two lateral roof drills which make possible the placement of rock bolts.

These roof drills have a limitation with respect to the placement of the rock bolts. It is only possible to perforate at roof level (between 10 and 2, according to the hour positions of a clock).

Another disadvantage it is the little existing room in the area, what took to the decision of placing bolt rocks of L= 1,30 meters instead the foreseen bolt rocks of 3 meters long.

Nevertheless, there are manual drillers in the work that allow to place rock bolts of the necessary length and in the required hour position, once the back-up of the machine has been passed.

Steel ribs:

The projected steel ribs were overlapped of the TH-21 and HEB-120 types, with the use of UPN-80 bracings, spaced one meter approximately.

Finally, it was decided to place TH-16.5 steel ribs, joined by means of the use of plates.

The separation of the steel rib was reduced to 0.75 meters because of two main reasons: the first one is that the steel rib is less strong, so the space between them has been reduced and the second one because of operative reasons of support to the gripper.

It has been chosen to place steel ribs of four sectors.

The join among steel ribs is guaranteed with angular placed in the surroundings of the steel rib, which allow to place rod bracings of 25 mm diameter.

This decision was taken with the purpose of placing a steel rib lighter, that would allow a better ease of construction and, at the same time, would reduce free jib between the placed steel rib and the T.B.M. back up.

Outlet Area:

Originally, it was foreseen the execution of two outlet galleries of 25 meters long, in the area of both main doors, in horseshoe tunnel, and excavation by means of drill and blast method. Finally, it was decided to do the outlet with the same T.B.M.

In order to do that, during the excavation of the plain, there were two rock walls left, covered with shotcrete, which were a support to the Grippers of the T.B.M. to initiate the excavation of the tunnel.

5. DEAD WORKS.

Previously to the beginning of the excavation of the tunnel, it was necessary to make a plain with an area of about 14.000 m², zone from which would part the T.B.M. and where there would be the necessary installations to carry out the works.

Once the excavation of the tunnel is finished, this same area will be part of the water treatment plant.

It was necessary the excavation of approximately 325.000 m³ of rock material, by means of the use of blasting.

This fact forced to that the T.B.M. was joint in a workshop and later on, once concluded the excavation of the plain, it was transported to the work for the beginning of the tunnel construction.

The transport of the T.B.M. to the work was made by road, being a distance of 15 Km. of which, the four first were on motorway. The remaining kilometers run by narrow highways, with strong slopes, pronounced inclines and with close bends within a semi-urban space.

It was required the support of the local police to coordinate traffic.

By virtue of the weight of the T.B.M., it was necessary to have two tractor heads at the back and at the front of the T.B.M.

Additionally, there were two cranes in both ends of the convoy to be able to help the transport in the areas of high slopes, where the motor strength of the tractor heads was not enough to continue the way.

In total, the transport process to the work lasted approximately six hours.

The following picture shows the arrival of the T.B.M. to the plain.



Figure N° 4. T.B.M. Transport

5.1. TUNNEL INSTALLATIONS.

All the fittings of the tunnel are located in the excavated plane. Basically, they consist of:

Electric Power:

For the electric feeding, there are in the work 5 generators from 810 KVA to 380 V. There are also 6 transformers from 380 V/15.000V. The electric control can be carried out from the T.B.M. operator's cab or from the synchronization and joint cab placed in the plain.

Ventilation:

There are two fans in series with a power of 30 KW each one at the entrance of the tunnel. It is foreseen the placement of relief fans inside the tunnel once they are necessary.

The ventilation duct is a flexible pipe of 700 mm of diameter.

Air compressed:

There is a portable compressor in the work that provides the required air.

Water supply:

It is required basically for the refrigeration of the T.B.M., for the cutterhead diffusers, for the rock bolts and for the cleaning of the back up. To this business, there are two tanks of 150 m³ each in the work.

It is pumped to the tunnel by means of groups of pressure through a metallic pipe of 3 inches of diameter.

There is a caudal meter for to register of the water pumped inside the tunnel.

Invert Precast Concrete storing:

Invert precast concrete are manufactured in a plant outside of the work; in the plain there is an area of about 500 m² for their storage.

Excavation material storing:

Room of approximately 4.000 m² for the provisional storing of the muck material from the excavation of the tunnel.

Several storing:

Space reserved for the storing of rock bolts, steel ribs, wire mesh, Bernold type sheet, tracks, wind pipes, etc., with an approximate surface of 500 m².

Gas oil tank:

For the gas oil supply to the generators it has got a capacity of 20.000 litres.

Muck ditch:

Due to the fact that muck cars unload at the back, it was necessary the excavation of a ditch to empty out the muck coming from the tunnel. The material is gathered provisionally in the plain and later on, it is retired in trucks to the authorized dump.

Decanting basin:

In this basin, waters coming from the tunnel and from the muck ditch are collected for their decantation. It has an approximate surface of 70 m² and a storage capacity of 120 m³.

Electro mechanic workshop:

It is where it takes place the maintenance and repair of T.B.M. pieces, system of cars, locomotives, mixer, etc.

Work offices:

Offices of the contractor, owner and inspection staff.

Dining room, changing rooms and toilets:

Rooms to be used by workers.

The following picture shows a view of the existent installations in the plain, as well as the entrance of the tunnel, at the bottom.



Figure N° 5. Tunnel Installations.

5.2. OUTLET TUNNEL.

Parallel to the auxiliary installation in the plain, it was carried out the execution of the outlet works in the plain of the Prioriño Cape.

The first stage of the outlet was the protection of the slope where the tunnel excavation would be initiated. There, works were to place injection bolts of 8 meters long and 25 mm of diameter in the outlet slope placed into squares of 2 m. H x 3 m. V and to place wire mesh made of corrugated round of 150 x150x6 mm.

It was also placed a shotcrete layer of 10 cm thick.

The second stage of the outlet was the execution of crown bars protection of bolts of 15 x 12 m long and 150 mm of diameter, with a distance among bolts axis of 30 cm.

All the bolts made were joined through execution of a shotcrete beam of 4,5 meters long and 600 x 600 mm of section.

6. TUNNEL CONSTRUCTION.

By virtue of the work, it is being executed at the present moment, to the effects of the treatment of this chapter, we will show the advances and experiences obtained until the 28th February, dead top fixed by the organizers of the event for the reception of the works.

6.1. WORKS SCHEMES

Excavation works of the tunnel began at the end of August 2004.

In a first stage, there was only a work shift, between 8 and 10 hours a day, which made possible the outlet of the T. B.M. and the entrance of the back up inside the tunnel.

At the end of November, once the back-up was inside the tunnel, a double shift was established of about 12 hours by shift, five days a week.

At the end of December 2004, the Californian switch rail was installed.

It is being considered the possibility to incorporate a third shift, with the purpose of working the 7 days of the week.

In the following graph, it can be appreciated in the changes of slope, the impact produced by the advance of the excavation, as consequence of the implemented measures before mentioned.

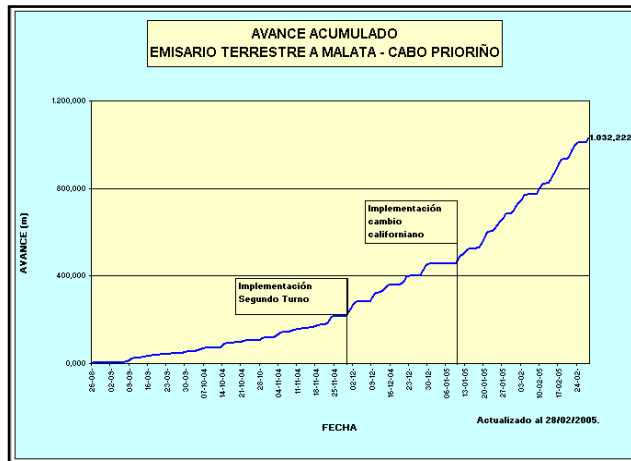


Figure N° 6. Advance impact as consequence the implementation of double shift and Californian switch.

6.2 EQUIPMENT USED FOR THE TRANSPORT.

All the transport of materials, mucks, invert precast concrete and personnel is done by trains.

There is the following equipment in the work at present:

- Two diesel locomotives of 15 Ton.
- 14 muck cars of 10 m³.
- 2 platforms for the transport of invert concrete precast.
- 3 personnel cars of approximately 12 seats.
- 1 mixer for shotcrete.
- 1 concrete gun.

The manoeuvre is practically carried out at present with a single locomotive, and the other one remains outside of the tunnel in reserve. Because of the proximity of the excavation front, it has been possible to manage the excavation works with a single locomotive to date.

Each train is composed of one segment bogie, seven muck cars, and one personnel car.

The locomotive parks the two trains in the Californian switch rail and, by means of a change feed for the movement of the cars, one of it is taken to the back up for the removal muck of the excavation material.

Once completed the load of the first train, the locomotive takes the mucks outside the tunnel, whereas, parallels, the excavation goes on with the second equipment of trains parked in the back up.

The main contracting-firm has planned the incorporation of more powerful locomotives of 25 Ton in the short term.

6.3 T.B.M. PERFORMANCE

The company in charge of the construction of the tunnel is NECSO Entrecanales y Cubiertas, company with a large experience in the construction of similar works.

To date of 28/02/2005, there are 1.032,222 meters excavated, which represents the 14,06 % of the total of the tunnel.



Figure N° 7. Excavation tunnel section.

The advance of the excavation has been less that it was expected, however, the output has increased progressively according to the changes disposed on the work schedule, that is to say, with the incorporation of a second shift and the implementation of the Californian Switch rail.

It is important to emphasize that one of the factors to take into account in what concerns to the output, has been the denominated learning curve.

In spite of having in the work experienced personnel, there is always a process of adaptation to the excavation and support system and to the methodology, until it doesn't get to fit the work equipments efficiently.

Nowadays, this process has been accomplished and the obtained output in the last month was of 336 meters in 19 days of excavation. In picture n°3, it can be appreciated one of the built sections of the tunnel.

The obtained excavation records to date are shown in the following chart:

	Advance (m)	Period
Best shift	15,033	Nocturne Shift 17/02/05
Best Day	28,948	17/02/2005
Best Week	108,644	From 14 to 20/02/05
Best Month	336,112	February 2005

Chart N° 4. Best obtained advances.

The obtained cycle of works shows the distribution of obtained times during the execution of the work, which is shown in the Figure N° 8.

We can take out the following thing from the analysis of the cycle of work:

It is considered that many of the presented values are within the acceptable parameters according to analyzed experiences in the execution of similar projects with TBM.

A special mention to point up is the percentage of breakdowns and shutdowns. We consider that the percentage is high, however, it has reduced as the excavation advanced.

Among the main breakdowns and shutdowns, which have taken place, we can to point up:

Breakdowns or shutdowns more frequent:

- Conveyor belt of the TBM, as well as the conveyor belt of the back up. There were problems with the decentred of the belt in the rollers, with breakings of the belt and problems associated to the main roller, which has had to be replaced three times.

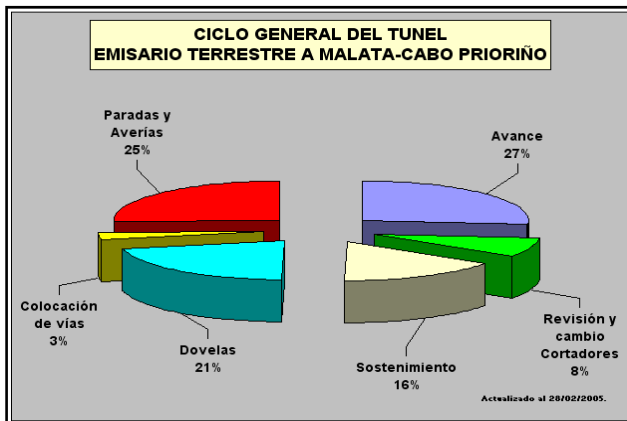


Figure N° 8. Typical Cycle of tunnel.

- Derailment of muck cars in the Californian switch rail.
- Continuous breakdowns of the hoist, which have impeded to continue the excavation due to the impossibility of placing ashlar, on which the back-up of the machine is leaned.

Breakdowns or shutdowns less frequent

- Cleaning of the buckets of the cutterhead.
- Failures in the operation of the PPS system.
- Electric failure in the motors of the cutterhead.

In the following scheme, it can be observed graphically the advance in the excavation of the tunnel.

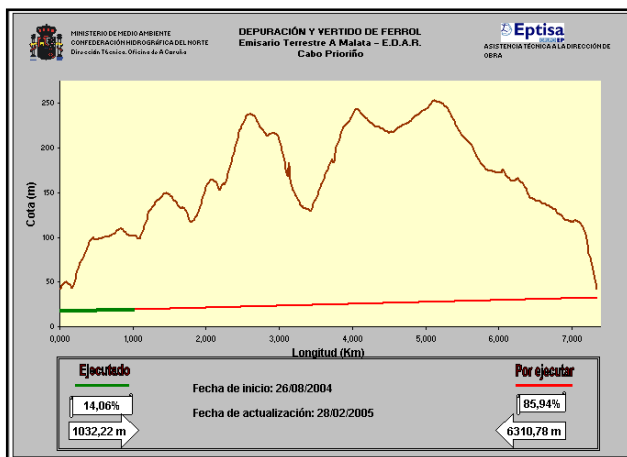


Figure N° 9. Tunnel advance.

7. MONITORING.

7.1 PROJECT MONITORING.

The project regarding to monitoring, contemplates the installation of instruments and monitoring systems that guarantee to control the movements of the tunnel, as well as the surroundings rock, water pressures, support and lining reactions.

In general, the application of measures will help to know deformations, operating strengths and land decompressions.

In relation to deformations, convergence measurements will be done in the tunnel.

Measurement sections will be installed at distances of approximately 40 meters and will be measured with a tap extensometer.

With relationship to the forces and pressures, vibrating wire extensometers pairs will be installed in order to measure flexion efforts in the lining.

Total pressure cells will be also placed to obtain a better knowledge of the behaviour from the surrounding rock to the tunnel, to guarantee a bigger security in the excavation and lining works, to detect possible expansion trends of certain materials and to try to carry out a more exact determination of the pressure on the lining.

Additionally, vibrating wire piezometers and manometers will be placed to detect the existent pressure against the lining. On the other hand, horizontal vibrating wire piezometers will be placed to check hydrostatic pressures in the mountain.

To know the decompressions of the rock, rod extensometers will be installed, that will make possible to control the way the decompression area around the built tunnel progresses.

7.2. MONITORING REALLY EXECUTE TO DATE.

As a result of diverse meetings with the contracting firm, the Work Management and other specialists in the matter, it has been consider that the monitoring defined in the project was very intensive, for what it was decided to do an evaluation of it and to implant in the work different criteria.

- Placement of convergence measurements stations each 50 meters approximately, the convergence measurements pins, will be placed immediately behind the Grippers of the T.B.M. (about 15 meters of the excavation front), area where it is possible to make a measurement of the springline.
- Placement of rod extensometers pairs each 50 meters, immediately after the shield of the cutterhead, in the area where the roof drills are placed (about 6 meters of the excavation front).
- Placement of invert vibrating wire vertical piezometers, once it has passed the back up of the T.B.M., that is to say, to approximately 230 meters of the excavation face.

The implementation of a monitoring program in a tunnel is a relatively complex task because, in some cases, it is thought that this setting in motion goes against the production works.

Nevertheless, we consider that a good monitoring plan correctly developed allows know with more accuracy the behaviors of the tunnel and so, to be able to confront preventively whatever anomaly is presented.

In the Sewage Tunnel, the monitoring process has been delayed for different reasons and so far, seven convergence measurements stations have been placed, where the accumulated convergence measures are in the order of a tenth of millimeter.

A vertical piezometer has been placed in the P.K. 0+502,00.

Preparations works have being done to carry out the first station of a rod extensometers pair.

8. CONTROL AND SURVEILLANCE.

The Work Managing is in charge of the Confederación Hidrográfica del Norte, whose team is formed by the Work Director and a Technician.

The control and surveillance is carried out by the team of the Technical Attendance to the Work Managing in charge of the Eptisa Company.

Carried out works to date, are the normal ones in this kind of labour, such as: surveillance in the construction of the tunnel, the topographical control, measurements, the supervision of the project, as well as the surveillance of the monitoring process and the geology of the excavated tunnel.

It is also carried out a pursuit to the quality plan and the production process of the invert precast concrete in the manufacture plant.

9. ENVIROMENTAL ACTIONS.

The project of construction of the Sewage Tunnel is within a set of works approved by a Law of the State and according to Evaluation of Environmental Impact Royal Legislative Decree 1302/1986, it is not necessary to do an Evaluation of Environmental Impact of the project.

Nevertheless, since the works affect to the "Place of Communitarian Importance" named "Costa Artabra", it was considered necessary to carry out a study of specific damages on the habitats of the area.

The Costa Artabra is within the Galician Community, a Natural Space in regime of general protection declared by Order.

With this Order, the areas proposed by the Galician Community to include in the European Network Natura 2000 are provisionally declared as Natural Spaces in regime of general protection.

The carried out study has had like aim:

- Identification of damages or environmental effects.
- Description of damages and evaluation/valuation of the repercussions.
- Implementation of correct and protective measures against noise, dust, gas or scents discharges, against the erosion, about water, vegetation, fauna, landscape and archaeological heritage, which should be carried out during the execution of the work.

To guarantee the fulfilment of all these activities, specialist technicians pay a visit every fortnight to the work to evaluate different aspects and do a report aimed to control proposed preventive, protective, corrector and compensating measures. The report is sent to the contracting-firm for the implementation of the pertinent measures that guarantee the fulfilment of the plan.

Another important aspect to emphasize is the accomplishment of a technical study about water filtrations and the hydro geologic impact produced by the construction of the tunnel. This study is being done by means of a contract for technological support activities signed with the Santiago the Compostela University.

The fundamental bases of the study are:

- Hydroclimatical study of the area: it consists of the update and data processing from the climatic station owned by CIS Ferrol.
- Analysis of the obtained results of the hydro geologic works of the project.
- Hidrogeologic and physicochemical data collected in the sampling points: data such as: volume, electrical conductivity, water temperature and pH.
- Analysis of the pursuit of the monitoring process of the tunnel and measurement of infiltration volumes.

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