

Piazza Garibaldi Metro Station Project

Using Micro-Width Paratrack II Guidewires To Complete Close Proximity Underground Boreholes.

1. Project Overview

- Location, overall project, expected completion date.
- Description of Trevi.

Specific Project description:

- Use of freeze-drilling methods for under water-table excavation.
- Desire for long, accurate boreholes to save time/expense.
- Predicted steering Problems due to depth and location (city centre).

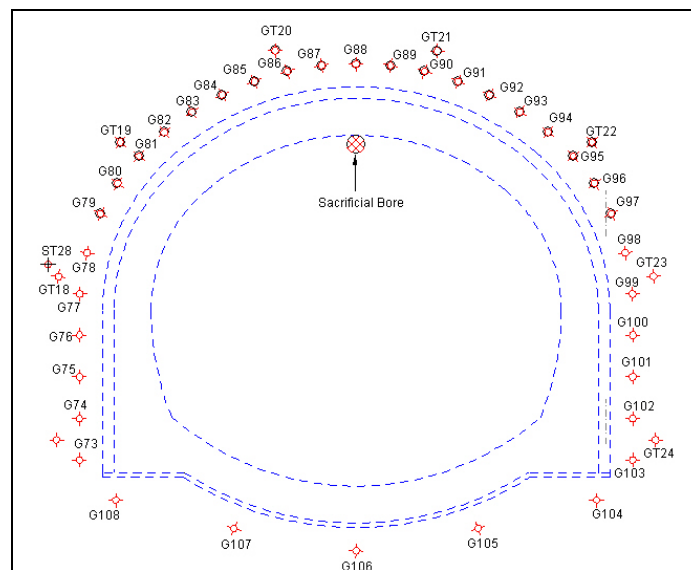


Fig 1

CAD drawing showing the position of all boreholes around the outside of the gallery to be excavated. Those bore holes marked with "GT" are those to be used as temperature gauges (see below).

2. Initial attempts

- Attempted use of surface coil to steer.
- Initial contact made with Prime Horizontal.
- Controlled experiments, revealing the feasibility of small-width guidance wires.
- Possible problems which could be encountered and methods discussed to circumvent these problems. (Lack of signal strength, use of several cables, accurate deployment of guidewire, use of rigid pipe)

3. Onsite Methodology

- Initial drilling of sacrificial borehole.
- Surveying borehole with Maxibore and PII probe for comparison.
- Creation of guide wire and problems encountered.
- Progress made (3-5 hours per borehole depending on interference, which was directly related to distance from the borehole).

4. Summation

- Successful deployment.
- New method of short borehole guidance with limited access.
- Low cost and high productivity.

1.

Project Overview



This project is being carried out as part of the creation of the underground metro system, in Naples city centre, by Pizzarotti & C S.p.A. This particular part of the project was to aid the construction of the Metro Station in Piazza Garibaldi, which is opposite the main train station of Naples. Work began here in January 2002 and is expected to be completed in March 2007.

Initially the external underground walls of the station were excavated and then filled with reinforced concrete. Once this was completed, the excavation of the internal area began, putting in place large supporting beams as the excavation became deeper (Fig 2). Once deep enough, the excavations will be met by the train line tunnels being created by a large TBM (Tunnel Boring Machine). This machine has a wide enough gauge to accommodate the trains, which will eventually pass through the Metro line, but not to create the space necessary for the passenger platforms, which will extend beyond the station walls and underneath the Piazza. This project is concerned with the creation of these passenger galleries. As there will be two lines passing through the station, there will be four such "Galleries", two on each side of the station. It was decided to use freeze drilling to allow the excavation of these much wider tunnels.



Freeze drilling is used as a method of tunnel excavation when there is a large area to be excavated which is well below the water table. It is achieved by creating many close proximity horizontal boreholes around the perimeter of the area to be excavated. The water around these boreholes is then frozen by circulating concentrated brine (a saline solution) through the boreholes, at a temperature of approximately -35°C . The ground temperature is measured during this process by eight temperature gauges inserted through boreholes around the perimeter of the gallery (Fig 1). Once the surrounding area is frozen, the interior of the gallery can be excavated



safely, with the surrounding ground pressure supported by the ice. Obviously a project such as this requires that the original boreholes be drilled to a very high accuracy, as any gaps in this wall of ice could cause a collapse, which would be catastrophic.



Fig 2: Overview of the location. Here you can see the large steel beams supporting the inner walls.



Fig 3: Top half of one of the galleries before excavation. All boreholes in this section have been drilled except for five on the far left hand side, which are marked by square steel plates. The location of the sacrificial bore can just be seen in the centre of the gallery, about 1.5m beneath the highest borehole.

Trevi SA is a large Italian group who specialize in foundations for large civil engineering projects. They were awarded the contract to construct these galleries using the freeze drilling method. The galleries were designed to have a length of 50m. The radius of ice produced by the concentrated brine around the boreholes is only 0.6m, thus the boreholes must be completed to a high degree of accuracy as any separation larger than 1.2m could potentially cause a collapse. The traditional method of completing a project like this would be to complete each gallery in two sections, one 30m long and the other 20m, using unguided boreholes. This would have necessitated a large amount of setup time, as the pipes connecting to the freezing equipment would have to be set up, the ground frozen, excavated and then the rig set up again. Also, it would be impossible to drill the boreholes for the second section in exactly the same direction as those of the first. This is because the drilling of this second section would be taking place within the confines of the first section, creating a problem in setting up the rig so close to the outside wall. Ideally, a method had to be found which would enable close proximity drilling over the full distance of 50m.

2. Initial Attempts

Initially Trevi SA contracted another HDD guidance company with the intention of deploying HDD guidance technology. This technology has been developed over the past few years for use in the directional drilling industry. It is one of the most accurate and reliable methods of location and steering available for completing horizontal directional drilling projects. It uses an electronic probe mounted behind the drilling assembly, which relays information back to the surface using a wireline placed inside the drill pipe. The probe gives Inclination and Azimuth readings (The Azimuth is read by a very sensitive and accurate onboard compass), and also readings giving the strength of the magnetic field surrounding the probe and the angle of the earth's magnetic field at that point (known as the Mag and Dip respectively). It is used in conjunction with a surface wire of known dimensions, through which is passed a current. Using the known position of the wire, the probe is able to use the magnitude of the detected magnetic field, and the field's angle in relation to the probe to calculate the probe's position very accurately.

Usually the wire is deployed in a rectangular configuration, with one side of the rectangle passing over, or very close to, the line which is to be drilled (the "centerline"). The other side (the "return path") is kept at a distance large enough not to affect the readings measured from the centerline by the probe.



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It was using this configuration that the initial guidance company attempted to deploy Paratrack II. Unfortunately, the method was attempted in circumstances where the sheer volume of moving traffic on the Piazza compounded by a high volume of reinforced concrete on the construction site created sufficient magnetic noise to result in lost signal and inaccuracies. The guidance company, not sufficiently skilled in trouble-shooting the system, failed to recognize or identify the problems.

Even if data had been obtained within a downtown, major city environment, the distance of the borehole from the surface (approx. 30m) would not have yielded high enough accuracy to solve the problem. Ideally, the error should have been no greater than 0.2m.

It naturally seemed to them the only remaining option would be to position the wire underground in similar ways to guiding parallel boreholes in the HDD industry. Unfortunately it would be impossible to place a wire close enough, and following the drill path without excavating the gallery or drilling a borehole from entry to exit within the Piazza perimeter! Clearly, this was not an option and the initial guidance contractor having no further solutions departed. It was at this point Trevi contacted Prime Horizontal Ltd.

Prime Horizontal, is a five-year co-developer of the Paratrack II system with Vector Magnetics, the owner of the technology. (ParaTrack was initially developed for close approach drilling in oil and gas fields and adapted for use in the HDD market). As a result, Prime Horizontal is considered the foremost authority on the deployment of this system in all horizontal directional drilling applications.

Through extensive controlled testing in the Prime Horizontal workshops in the Netherlands it was discovered that it is possible to get accurate results from a very narrow coil when the probe is in relatively close proximity. This gave rise to an interesting solution to the problem posed by this project. A sacrificial bore hole could be drilled through the middle of the galley and a narrow, 50m long coil placed inside. It could then be used to track all the surrounding bore holes of that gallery.

There were still several obstacles to overcome. One of these was the signal strength. The EM (electro magnetic) field created by two wires alongside each other carrying an equal current is cancelled. Therefore in a situation such as this, with the two paths of the coil being so close to each other, the majority of the EM field created by the closest wire is cancelled by the wire on the other side. Also, the signal strength to distance ratio follows an "inverse square law", if the distance from the source is doubled, the reduction of the field strength is the equivalent of dividing it by the square of this distance.

Another problem was the down-hole position of the coil. With such a narrow coil, any slight deviation from a horizontal alignment would cause a relatively large error. Thus a method for accurate placement of the coil down-hole was devised by using a rigid plastic pipe with markings to help attach and align the coil (Fig 4).



Fig 4: The pipe used to mount the coil. You can see clearly the indents down both sides, which were used to align the cable accurately along the coil's entire length.

3. Onsite Methodology

It was decided that for optimum results a sacrificial bore would be drilled through the centre of each galley to be constructed (Fig 1). This was to be drilled without any guidance tools and surveyed afterwards using a post drilling survey tool called a Maxibore. This is an optical down-hole surveying probe (Approximately 5m in length) which measures the flex along it's length at predefined points in time to calculate the path traveled. To obtain greater accuracy, the sacrificial bores were also surveyed using the inclinometer on the PII probe for an accurate elevation calculation.

Following this, the coil was very carefully inserted into the sacrificial bore. As mentioned above, any slight rotation of the coil down-hole would give relatively large errors, and so was to be avoided at all costs.

Once drilling began, it became apparent that this was indeed an effective solution to the problem. As expected, there was a sharp drop-off in signal strength as the distance to the sacrificial bore increased. This was apparent in the increase of electro-magnetic interference witnessed, which increased the time taken to make an accurate positional survey. The drilling time for those boreholes close to the sacrificial hole was approximately 3hrs, whilst for those furthest away (a distance of 6m from the sacrificial hole) the drilling time increased to approximately 5hrs.



Figs 6 + 7: Drilling in progress on one of the galleries using the 10 ton EGT rig with 2m drill pipes pre-built into 9m lengths to save time in making connections to the probe.

4. Summation

Overall, this new method of deployment of the Paratrack II system, the ParaTrack Micro-Carrier, was considered an immediate success, saving both time and expense for the freezing contractor. The ease of setting up and using the equipment meant that after a few weeks of instruction, the contractor, who had no previous experience in using such a system, was able to operate the



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Paratrack II system entirely unaided. Trevi Spa has since purchased their own ParaTrack equipment.

Once again, Prime Horizontal, when consulted about a specific application, was able to adapt a novel solution to a difficult guidance problem. ParaTrack once again, gives the drilling contractor the confidence to expand the market in technical directions previously thought too difficult.