DRILL PAC

www.drillpac.com

ROCK - SOIL TECHNOLOGY AND EQUIPMENTS

PACCHIOSI DRILL

BOTTOM PLUG

BARCELONA SUBWAY (SPAIN)

BARCELONA SUBWAY (SPAIN)

PROJECT

Jet Grouting treatment with the three-fluid PACCHIOSI MEGA JET PS3 method, for construction of waterproof bottom buffers and consolidations with varying geometry and function, as part of the works for construction of line 9 of the Barcelona Subway below the water table level; minimum resistance to compression 3.5 MPa; column diameter Ø over 5 m; maximum depth over 35 m.

PERIOD OF CONSTRUCTION

2004 - in progress.

CLIENT

UTE L9 HOSPITALET - UTE TUNELADORA METRO.

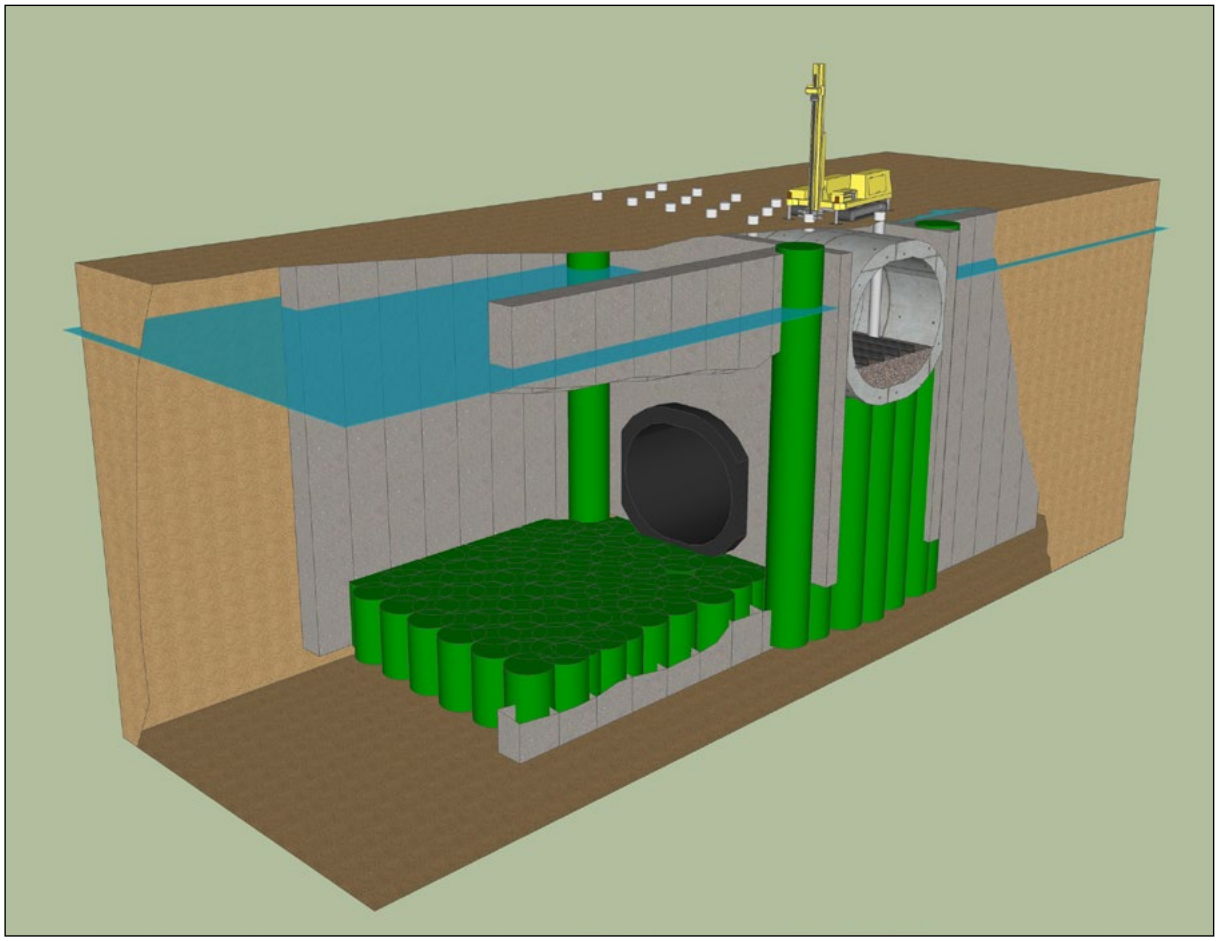

Fig. 1. 3D view of works for crossing of the Ferrocarril.

Introduction.

Works are in progress in the city of Barcelona for expansion of the subway and construction of the new Line 9 which will link the airport to the city center.

The structural details chosen and the depth of the project, associated with the characteristics of the subsoil with the presence of water, led to systematical and extensive recourse to treatment with Jet Grouting, which is particularly effective for the consolidation and waterproofing of "difficult" terrain and highly complex logistic situations due to the presence of other services or existing structure that place significant limitations on the works.

Geology.

The Barcelona plain consists mainly of the deposits in the delta formed by the Besos and Llobregat waterways, and material carried down from the Collserola

by the many brooks and creeks formed during the Quaternary. The Collserola is the part of the mountain chain called the Cordillera Costera Catalana, located in the area north of the city; the paleozoic granite of the Cordillera has been gradually eroded toward the sea and in the coastal area it is covered by fluvial deposits from the tertiary and quaternary ages, i.e. relatively recent.

Lithology.

Above the granite, slate and calcareous rock formations at the base, are the fluvial deposits of variable thickness (also on the order of 100 m) consisting of materials with a prevalently fine granulometry, generally layers of silty sand becoming sandy silt, with occasional insertions of gravel and very high permeability values

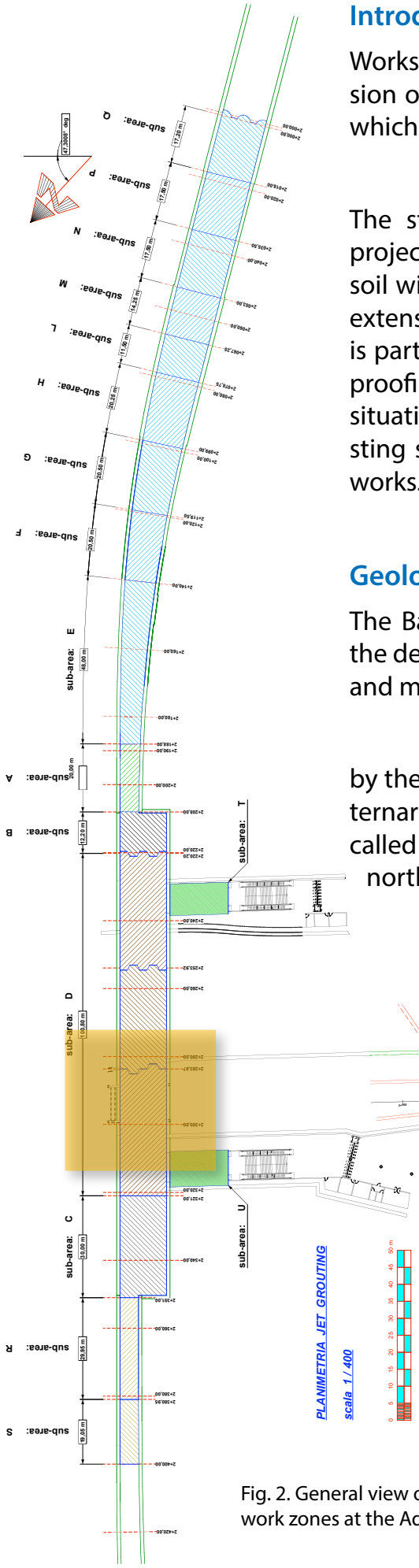

Fig. 2. General view of one of the first work zones at the Adeu Torner station.

Description of works.

The main groups of enterprises assigned to perform the different construction lots appointed PACCHIOSI, starting in 2004 and continuing uninterruptedly to the present, to perform the main treatments with Jet Grouting foreseen during the works, in 15 different locations (characterized each by special particularities such as the stations of AMADEU TORNER, SAN COSME (part), EIXAMPLE NORD and PLAÇA CATALUN IA, shafts 1A, 3A, 3B, 4, 4A, 6, 6B, V1, the section on two levels of PLAZA EUR OPA.

In all cases, Pacchiosi's ability to provide excellent columnar treatments in large diameters (even greater than 5 m) was decisive. The reliable PS3 system was used as this has been used many times with obvious advantages:

- significant reduction of construction time, with drastic reduction of the number of columns necessary to obtain the volumes treated as foreseen by the project,
- absolute safety of the existing structures or any already built, without the danger of causing undesirable sinking or lifting,
- high quality of treatments obtained using the most modern equipment, designed and built specifically for Jet Grouting,
- significant reduction of the "logistic" impact on the areas, with the use of a greatly limited number of perforating machines.

The PACCHIOSI MEGA JET PS3 three-fluid system in any case ensures high quality treatment (demonstrated in special preliminary field tests and systematically during inspections while the works are under way), both as regards uniformity, and in terms of mechanical resistance and waterproofing. In general, the types of work (consolidation and/or waterproofing) most frequently done are:

- mass treatments for construction of bottom buffers between bulkheads, along the line, at the stations and shafts, as a

Fig. 3. Before the works.

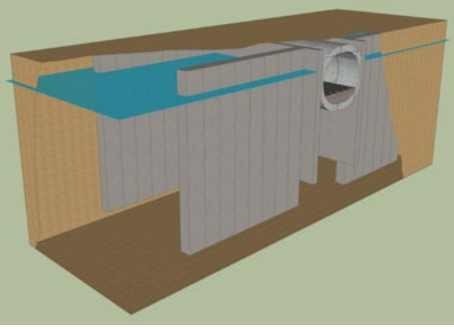

Fig. 4. Preparation of preliminary holes.

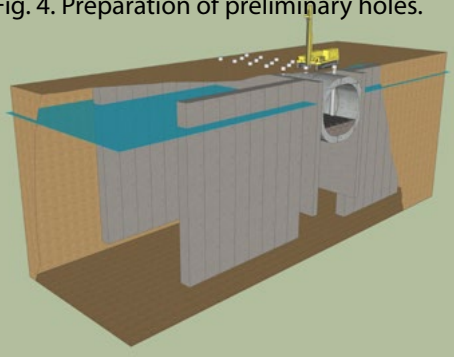

Fig. 5. Construction of bottom buffer.

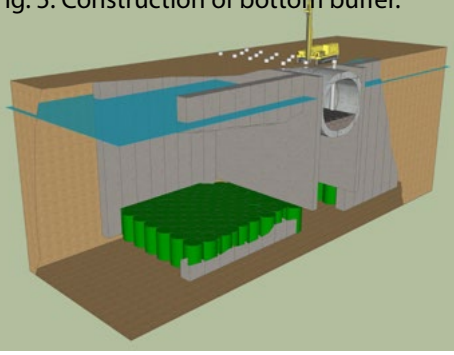

Fig. 6. Construction of closing columns.

Fig. 7. Construction of lower tunnel..

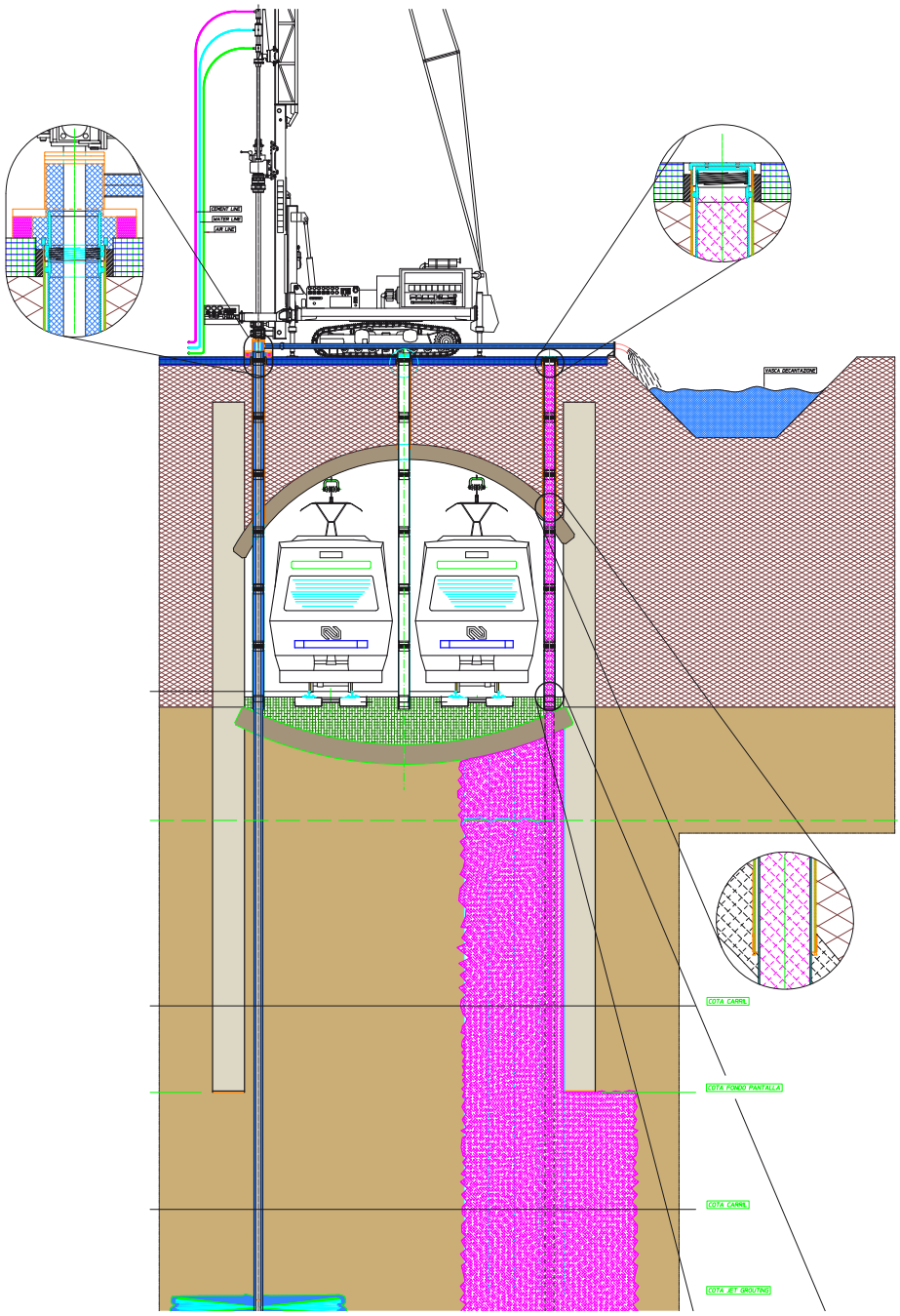

Fig. 8. Treatment below existing tunnel, through special metal pipes prepared and positioned so as not to interfere with traffic; through these pipelines it is also possible to recover the drilling and injection fluids.

structural contrast for the bulkheads and barrier against the ascent of water from the table;

- mass treatments for construction of bottom buffers before construction of the bulkheads,
- mass treatment for the formation of break-ins and break-outs, i.e. uniform masses that permit the arrival or departure of the TBM cutters in the shafts or stations under safe, dry conditions;
- treatments in line for the construction of walls, screens and diaphragms;
- treatments with particular geometry and angle in the vicinity of certain accessory works, to prevent interference with systems or sub-services, or limitations of space or height;

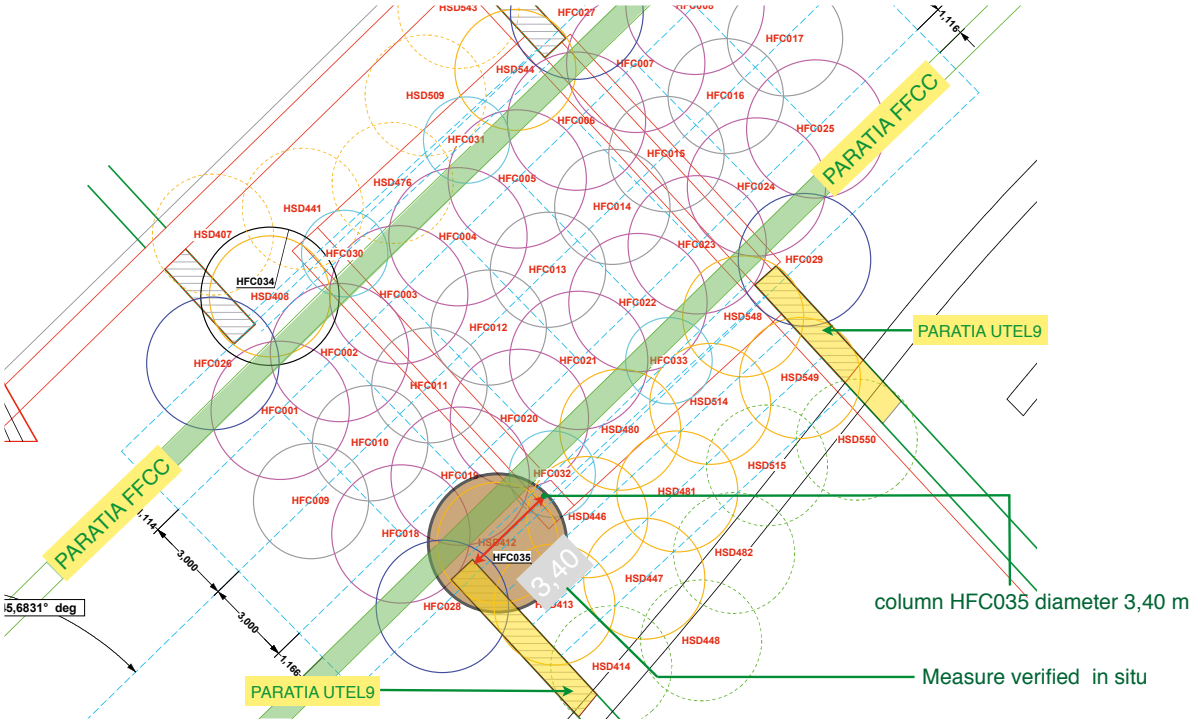

Fig. 9. Detail of a closing column between right angle diaphragms; layout drawing.

Fig. 10-11-12. Measurement of a closing column between right angle diaphragms.

Fig. 13-14. Excavation of the consolidated soil mass with the MEGA JET GROUTING PS3 method.

- profound treatments through tunnels (using special equipment) when already built, without interrupting traffic;
- prompt or concentrated treatment for the repair or reinforcement of existing structures.

Fig. 15-16. Reinforced concrete slab with preparation of preliminary holes for performance of treatments.

All works were completed from the outside, normally from the street level, sometimes slightly below street level.

Slabs in reinforced concrete were installed, ready for the holes in the positions foreseen for drilling; the spacing of the columns was defined, case by case, taking account of the

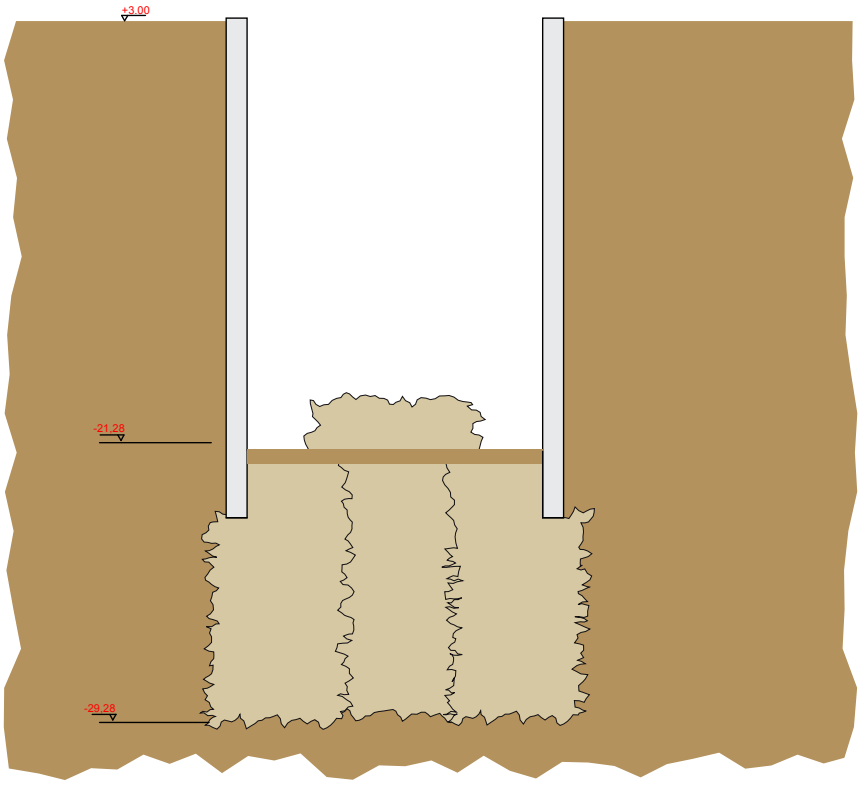

Fig. 17. Diagram of a bottom buffer with a prolonged column over the excavation to permit direct observation and dimensional control; diameter measured: over 4 m

Fig. 18. Summit of an uncovered column measured directly: Ø over 4 m.

optimum diameter, the depth to be reached and the deviation in perforation to compensate systematically (usually 1%).

Among the different Jet Grouting technologies developed by PACCHIOSI, the three-fluid PS3 MEGA was chosen for the treatment, as it is particularly suited to the types of soil encountered, and extremely effective when it is necessary to obtain large diameters while reducing the risks of overpressure or claquages to a minimum; the system first requires separation of the soil by high speed jets of water made more accurate and effective by a perimetral crown of water at relatively low pressure, then the formation of the columnar treatment by injection (with rotation in ascent) at high speed of a cement-based binder. In particular, the mixture consists of water and cement, stabilized with bentonite, that serves to prevent separation of the cement, which is used in very high dosages.

Special field tests were performed, generally with a set of three intersecting columns in accordance with the project spacing with deviation (to be compensated for in the project) diverging position, controlling, by core sampling with the drawing of samples the diameter obtained, continuity, uniformity, resistance to compression and permeability in the critical position, i.e. near the central intersection and areas of contact between the paired columns.

The works were systematically monitored by computerized instruments specifically designed and developed by PACCHIOSI, the RPS3 data acquisition and registration system. This system, making use of a series of real time detection devices installed on the mixing and pumping equipment and on the perforating machine, can record all the main working parameters such as fluid pressures and capacities, torque applied to the tools, speed and depth of perforation and injection, rotation speed, etc.; the operator can read all the working parameters on the monitor, and at the end two graphs are produced relative to perforation and injection, respectively, that certify the success of the work performed.

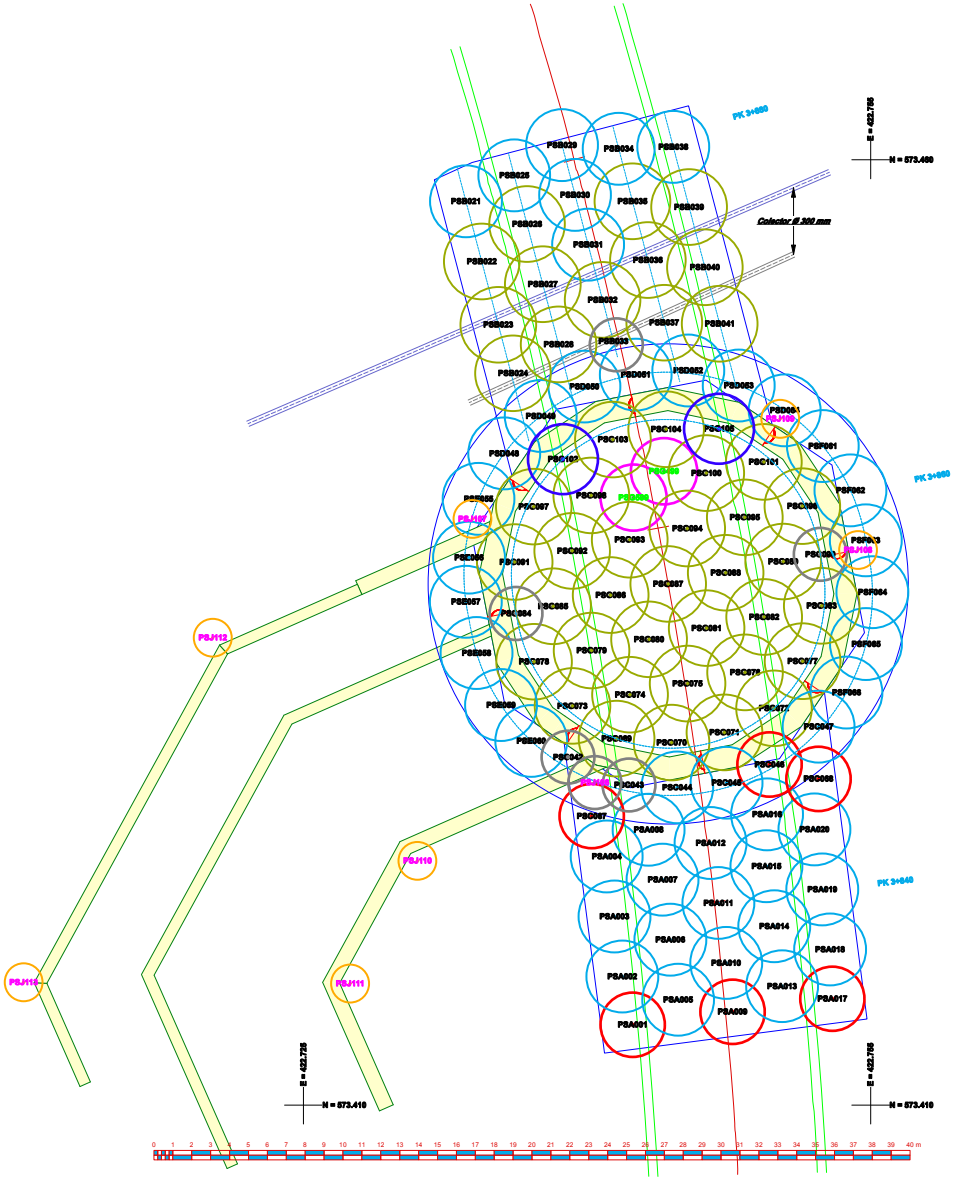

Fig. 19. Drawing of treatments (bottom buffer, break-ins and break-outs) at shaft 6.

Fig. 20. Example of core sampling; note the perfectly cemented inclusions

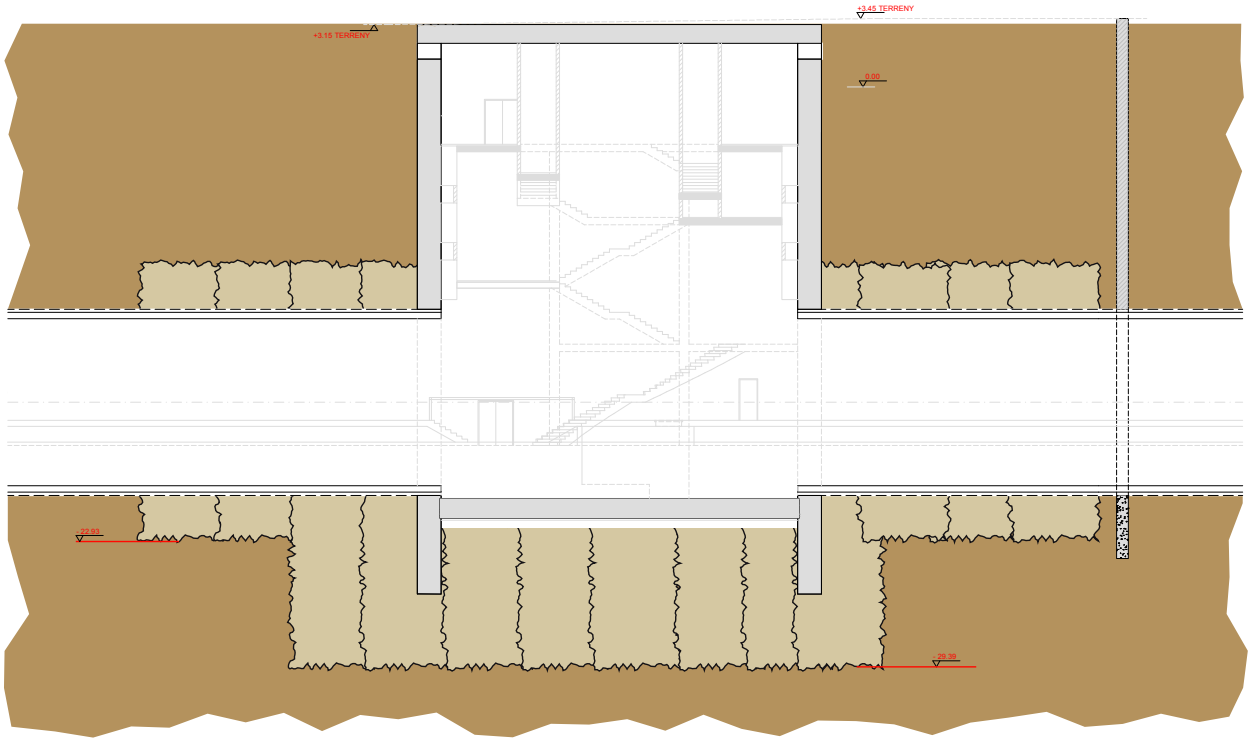

Fig. 21. Typical cross section of a shaft with central bottom buffer, break-ins and break-outs.

A recent development of the system makes it possible to perform injection in a fully automatic way (after completing drilling) starting from the project data loaded in the electronic management system.

The works are carried out with the systematic recovery of the fluids, during

perforation and injection, then conveying them to special decanting tanks where the excess water is separated, allowing the fine portion “displaced” from the soil treated

Fig. 22. Example of core sampling; note the perfectly cemented inclusions

Fig. 23-24.
Detail of uncovered column, diameter Ø over 5 m.

Fig. 25. Example of core sampling; note the perfect uniformity and continuity of the treatments performed

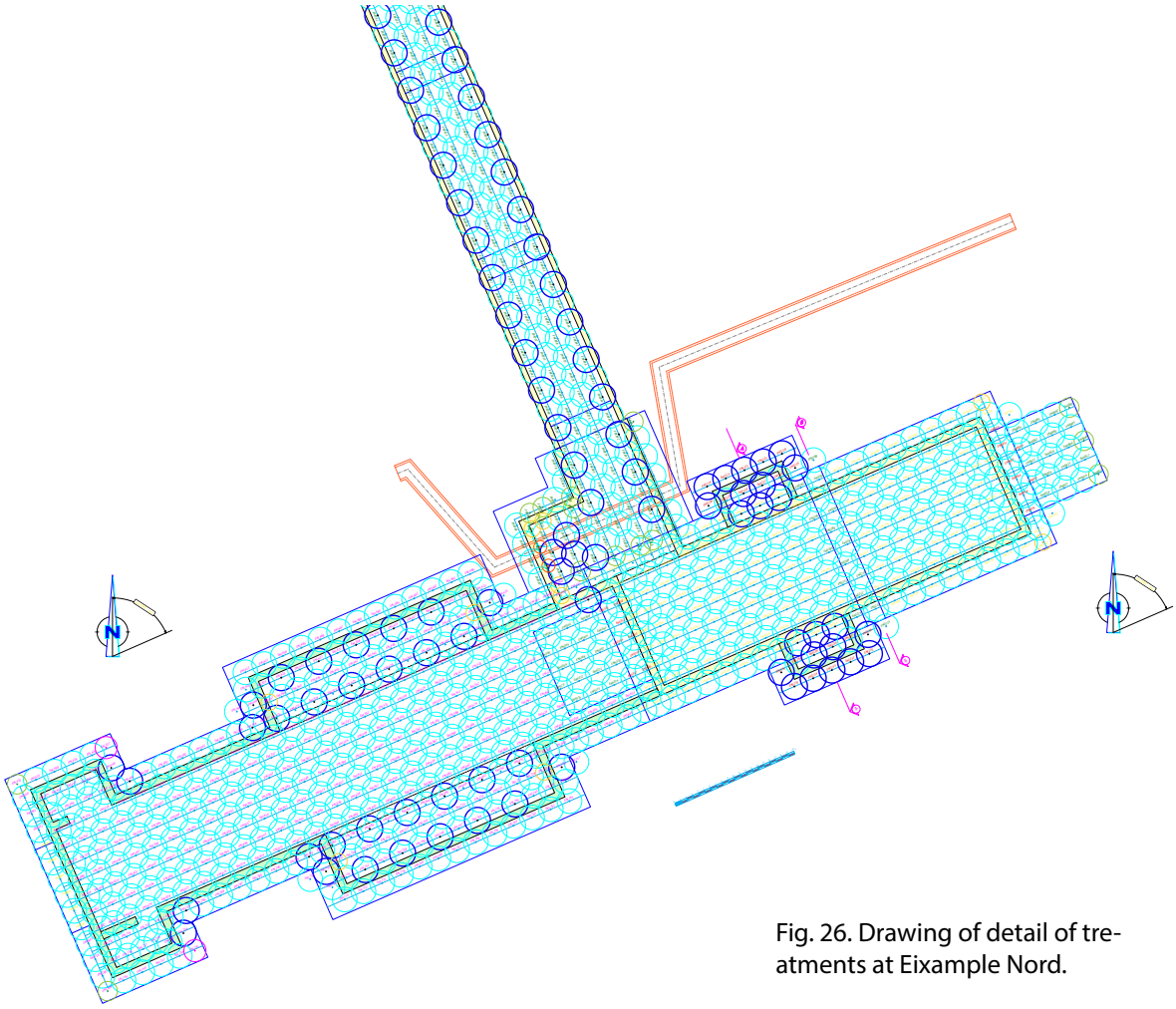

Fig. 26. Drawing of detail of tre-atments at Eixample Nord.

during Jet Grouting; the solid deposit, which has a relatively reduced volume, can then be handled easily and at low cost. The special head that serves for complete recovery of the waste fluids from the hole without interfering with the Jet Grouting treatment, was designed and built by PACCHIOSI, and can easily be adapted to the different situations encountered at the worksite.

Fig. 27. Computer installed on the perforating machine; view on the monitor of characteristic parameters.

During the works, meticulous quality control inspections were carried out (at predefined times) in all stages, and particularly:

- control of the viscosity of the mixture with the MARSH cone;
- control of the density of the mixture with the BAROID scale;
- tests of decanting the mixture with graduated cylinders;
- visual control on the monitor, during the executive stages, of the perforation and injection parameters;
- control of the density of the waste fluid with the BAROID scale;
- control of the records (graphs) of perforation and injection parameters;
- core sampling with control of RQD and visual inspection of treatments;
- sampling, from the core samples drawn, of material for laboratory tests, particularly determination of the resistance to compression;
- determination of the permeability by water testing inside the core samples drawn.

The resistance to compression (after 28 days) obtained for the samples treated with JetGrouting drawn by core sampling have been found to be better than 3.5 Mpa. With the exclusion

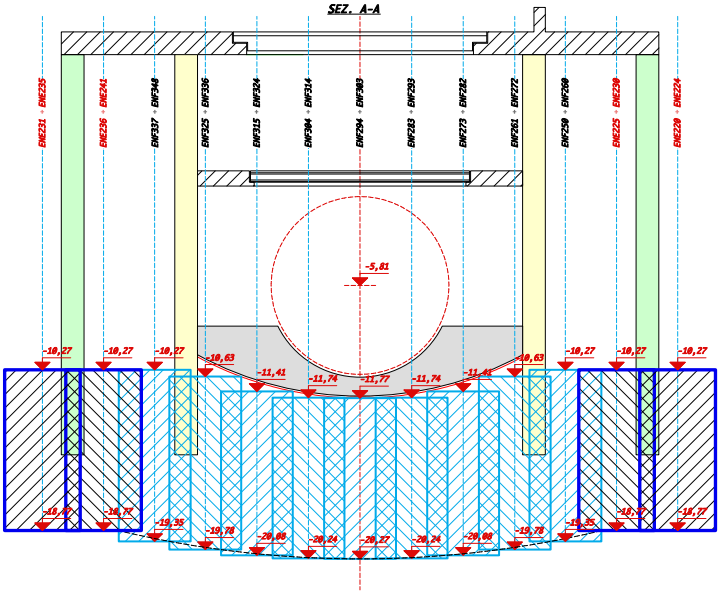

Fig. 28. Type A section of treatments at Eixample Nord.

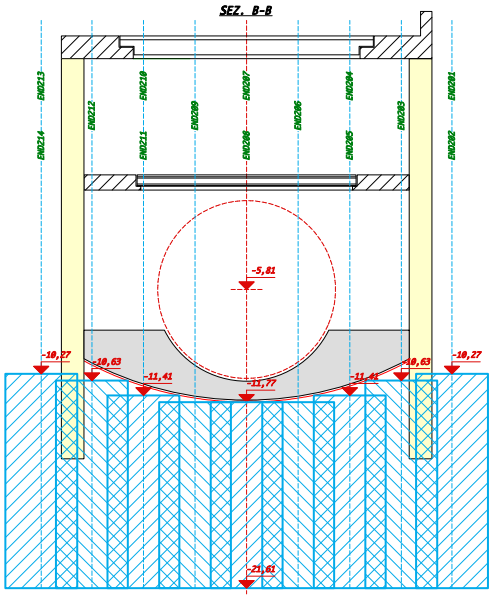

Fig. 29. Type B section of treatments at Eixample Nord.

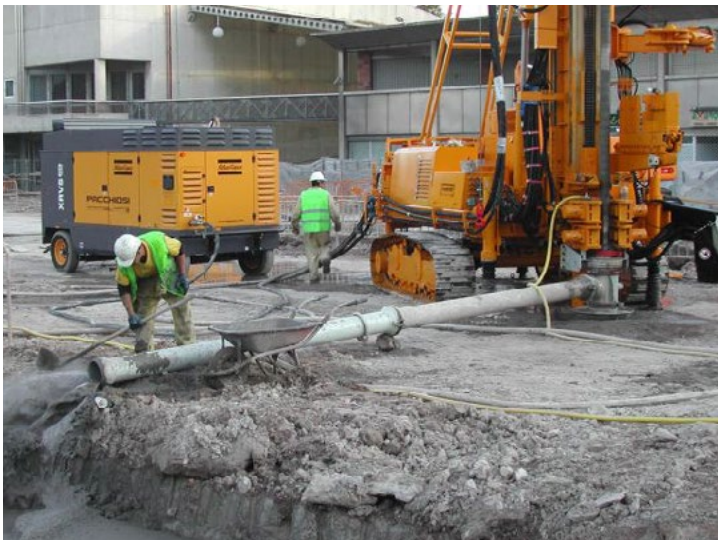

Fig. 30. Recovery of drilling/injection waste fluids.

Fig. 31. Recovery of drilling/injection fluids and conveyance to decanting tank.

Fig. 32. PACCHIOSI P1500 hydraulic drill rig model ES with extention; work on the surface; the silos for storage, dispensing, mxing and pumping the cement mixtures are visible in the background.

Fig. 33 Details of the PACCHIOSI P1500 ES hydraulic drill rig.

of a few particular situations where relatively reduced diameters are sufficient (2-3 m for "geometrical" type needs), the diameter of the columns was found to be on the order of at least 4 m with the maximum, also proven and documented, over 5 m.

The treatment thickness (length of Jet Grouting columns) varies from 2 to 22 m depending on the type of structure to build, with perforation depths up to 35÷40 m; Over 350,000 cu.m. have been treated so far with Jet Grouting.

The special equipment used, designed and built by PACCHIOSI, consists mainly (for a single typical worksite) of the following items:

- PACCHIOSI P1500 hydraulic probe; in the versions ES, ECR and EC depending on the specific needs;
- material storage station, with 2 silos for cement, 1 silo for bentonite and 1 container for water;
- workshop and warehouse (normally in standard containers to facilitate transport);

fig. 39. Fixed worksite installations; silos for storage of cement (2) and bentonite (1), dosing and mixing unit (PACCHIOSI MA 2000 mixer) and PACCHIOSI LASER pump mod.2800 for water and cement mixture; containers for workshop and warehouse.

- dispensing, mixing and storage unit (with continuous agitator to prevent separation of the elements) of the cement mixtures; TURBO MIXER PACCHIOSI MA 2000 C, containerized and fully automatic;
- pumping unit for water and binders for three-fluid system PS3; POMPA PACCHIOSI LASER 2800 C containerized;
- Batteries of PS3 rods, monitors, triple cutters, triple blades, down-the-hole hammers, core sampling devices, various drilling equipment;
- complete set of technological lines for air, water, cement mixture and inter-communication;
- system for registration of drilling and injection parameters with automatic management of the injection stage with PACCHIOSI PRS3;
- accessories (mud pumps, compressor, etc. ...).

Sono stati allestiti ed impiegati, nelle varie fasi di lavoro ed in localizzazioni diverse, anche 3 cantieri in contemporanea.

BOTTOM PLUG

ROCK - SOIL TECHNOLOGY AND EQUIPMENTS

DRILL PAC

COMPANY WITH
QUALITY SYSTEM
CERTIFIED BY DNV GL
= ISO 9001:2015 =

Branches

AMERIQUE DU NORD PACCHIOSI INC, Canada

PACCHIOSI DRILL USA INC, USA

Drill Pac S.r.l. – Società soggetta a direzione e coordinamento di Ghella S.p.A
Sede Legale: Via Pietro Borsieri, 2/a - 00195 Roma (RM)
Tel. +39 06 45603.1 – Fax +39 06 45603040 – e-mail: info@drillpac.com
Sede Operativa: Frazione Borgonovo, 22 – 43018 Sissa Trecasali (PR)
Tel. +39 0521 379003 – Fax +39 0521 879922 **- Sito web:** www.drillpac.com