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PACCHIOSI DRILL

ROCK - SOIL TECHNOLOGY AND EQUIPMENTS

FREEZING

ROME (ITALY)

CONSOLIDATION AND WATERPROOFING OF SOIL WITH FREEZING TECHNOLOGY

PROJECT:

Demolition and reconstruction of the reverse arch in reinforced concrete of the Cassia – Monte Mario railroad tunnel, after consolidating and waterproofing the underlying terrain by freezing.

PERIOD OF CONSTRUCTION:

February 2004 – 2013

CLIENT:

RFI - ITALFERR

Fig. 1. Wide-angle view of the Cassia - Monte Mario (Rome) tunnel; freezing in the reverse arch and piers.

During works for the restructuring and reshaping of the Cassia- Monte Mario railroad tunnel, during demolition and reconstruction of the reverse arch foreseen for a part of the tunnel, it was necessary to waterproof and stabilize the underlying terrain after the events that had occurred in the tunnel in November 2004. At that time, the presence of fine-grain soil, fine sand and clay from plio-pleistocene formations of marine origin, with high hydraulic levels, had caused dangerous infiltrations of water bearing fine material into the tunnel and triggering damage in the form of a breakthrough with the consequent surface effects.

Fig. 2. Perforation for installation of the freezing (and thermometric) probes) in the piers and reverse arch; PACCHIOSI PRP 150 drilling machine.

Fig. 3. Perforation in the piers for installation of the freezing (and thermometric) probes)

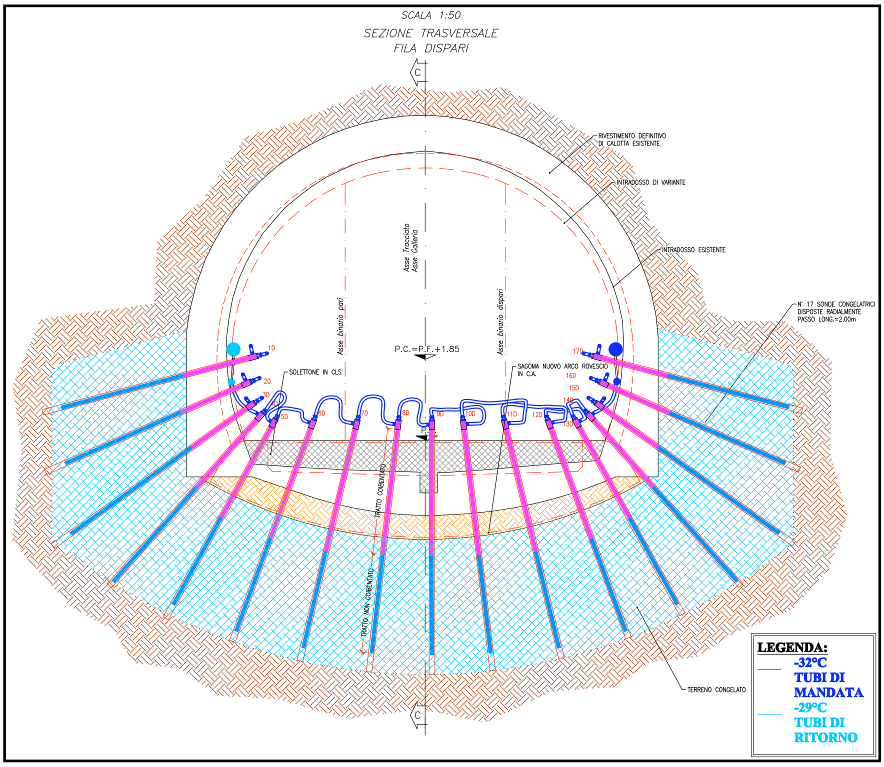

Fig. 4. Typical spoke diagram of freezing (and thermometric) probes.

After examining the various possible ways to obtain a strip of suitably consolidated and sufficiently waterproof terrain to withstand the hydraulic pressure generated by the high water level under the reverse arch to be rebuilt, and testing the different technologies available, indirect freezing was found to be the optimum method. This method consists of freezing the water in the pores of the soil and is often satisfactory in geotechnical contexts such as the one described above, as it can provide a fully impermeable screen that is statically efficient once the optimum working temperature is reached,

Fig. 5. Storage tanks for unchilled brine.

Fig. 6. Cold brine tanks and pump units.

Fig. 7. Containerizable compressors (8 units).

taking advantage of the intrinsic weakness of the mass of soil involved, which is the presence of water. Naturally, the best hydraulic efficiency is static and has a cost in terms of technological complexity, with works that must be carefully planned in time and performance, considering that the costs, as well as the potential of the equipment installed, are proportional to the temperature to be reached and duration of the actual freezing

Fig. 8. Command and control unit.

Fig. 9. Evaporation towers installed outside the tunnel.

stages and holding time during the works of demolition and reconstruction of the reverse arch for slabs.

As regards the choice of the freezing method, the indirect solution was chosen, using a brine (solution of calcium chloride) both because the program of works in the tunnel was compatible with the greater time required by the indirect method, and to reduce the costs of the work with respect to the direct solution with liquid nitrogen; this also eliminates the risks connected with the use of liquid nitrogen, which must be handled with greater care.

The indirect method is defined as such because the soil is chilled by means of a double heat exchange: the first exchange occurs inside the refrigerating unit, in which the brine (solution of calcium chloride) is chilled by the evaporator of the cooling fluid, while the

Fig. 10. Overview of the section of tunnel with micropoles ready to receive the probes.

second exchange occurs in the soil around the freezing probes, so as to chill the soil by means of the brine.

The typical refrigeration unit consists of four main elements: the evaporator, the compressor, the condenser and a laminator. Inside this cycle, the cooling fluid circulates in a closed cycle. In the case described, as many as 8 compressor units with two evaporation towers were used, with a total power of 500 kW. All systems were installed in the tunnel, near the work zone; only the evaporation towers were positioned outside, at the

Fig. 11. Detail of the heads of the micropoles in the reverse arch.

distance of over one kilometer from the area to freeze. After preparation of the complex equipment necessary and preparation of all the relative accessories, the freezing system was applied to freeze the first four sections of 12 meters, monitoring the temperature with thermometric probes. The reverse arch was then reconstructed in the first section (for samples of 4 m maximum), detaching the freezing system from the first field to apply it to the fifth, and so on. As a further safety measure, the freezing probes installed in the piers were left active until after demolition and reconstruction, in a position where they did not interfere with the works of demolition.

The data acquired were processed in special daily reports of the characteristic temperature curves in the area, depending on the distance of the thermometric probes from the freezing probes. Analysis and management of all the data acquired were handled by special software that made it possible to generate graphs in the most pertinent way.

Fig. 12. Overview of the fields equipped but not frozen.

Fig. 13. Overview of the fields at the start of freezing

Fig. 14. Overview of the freezing fields.

For validation of the technical choices the characteristics of the terrain were checked before and after freezing by core samplings, readings of the convergence in the tunnel during and after the works, measurement of the tensions on the new covering, monitoring during and after the works of the soil on the surface and in depth over the freezing zone.

The working temperatures were as follows:

- temperature of the brine about -30°C,

Fig. 15. Detail of the heads with the connecting sleeves

Fig. 16. Detail of the heads with the connecting sleeves; freezing field.

- thermal gradient between outgoing brine and the brine returning to the refrigeration unit, of 3÷4°C,
- 0°C positioned on the theoretical profile of the excavation to be made,
- average temperature of -10°C in the soil mass, with the following main working stages:
- installation of stand-pipes in the existing reverse arch and subsequent positioning of pipes on standby (micropoles with valves). This was done with the aid of preventers in the holes to prevent the influx of water,
- performance, through the micropole valves, of the required recompression injections,
- preparation in each field of 12 m with 210 radiating probes housed in the standby micropoles, arranged in a quincunx pattern with a spacing of 1x1 m, and suitably insulated to obtain a thickness of about 3 m of frozen terrain,
- similar preparation of the necessary thermometric probes, equipped with suitable control thermocouples,
- freezing for a time variable from 21 to 28 days per field,
- detachment of freezing system and demolition by slabs of 4 m,
- installation of reinforcement and pouring of the new slab,
- repetition of the cycle so as to ensure sufficient hardening of the concrete in the reconstructed slabs.

The demolition and reconstruction cycle typically resulted in completion of a 12 m field in one week.

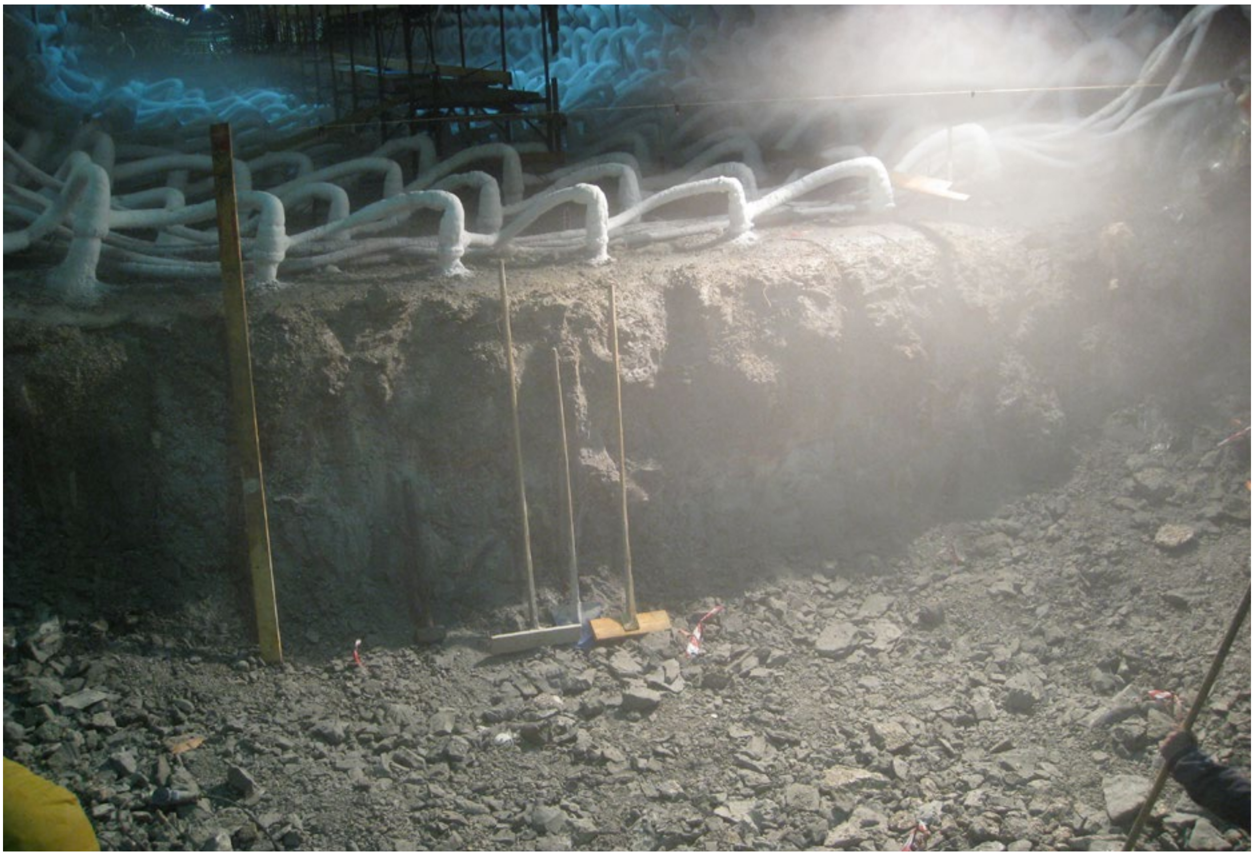

Fig. 17. Demolished slab of reverse arch with adjacent slab held in place.

Fig. 18. Slab under reconstruction; assembly of reinforcement cage for final pouring.

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