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ROCK - SOIL TECHNOLOGY AND EQUIPMENTS

PACCHIOSI DRILL

CLOUJET

FROSINONE (ITALY)

FROSINONE (ITALY)

PROJECT:

construction of the third lane of the Milan – Naples motorway.

PERIOD OF EXECUTION:

April – June 1991

CLIENT:

Società Autostrade

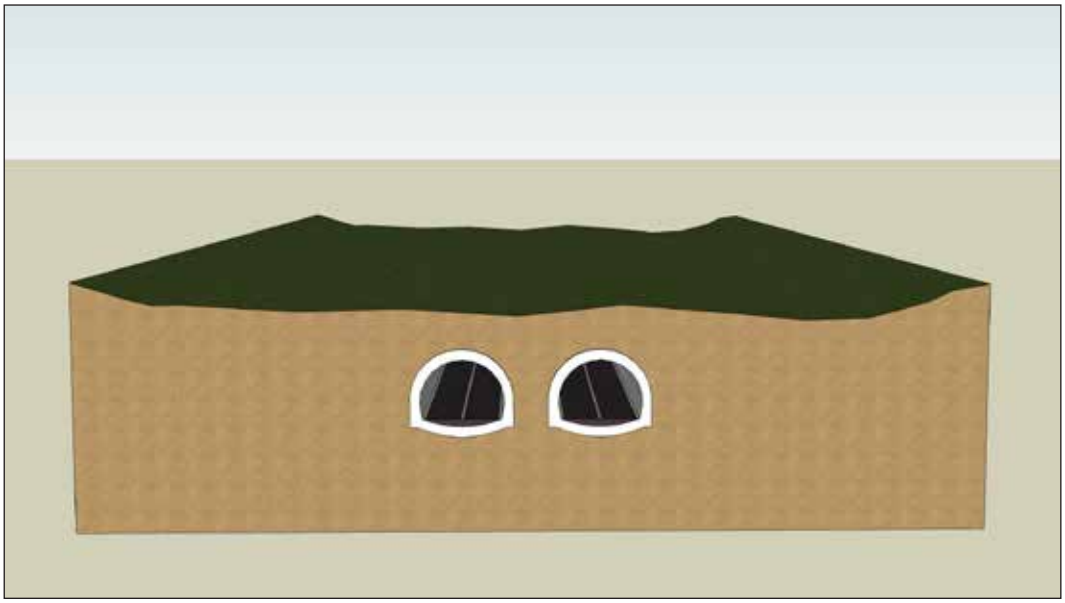

Fig. 1. Situation prior the starting of project.

Introduction.

The first application in Italy of the CLOUJET technique was made by Pacchiosi Drill S.p.A. along the section between Frosinone-Ceprano of the A1 motorway at the Casette tunnel (T.E.R. lot) and the tunnels of Cervona and Cimenzano (Costanzo Lot) during works for the construction of the third lane.

Lithology.

The terrain consists of a dense stratification of alternating layers of clay marl and sandstone, more or less altered, with variable thickness between a few dozen centimeters and about ten meters, belonging to the Miocene formation.

The water table is located at a depth of 15 meters from ground level.

A geological-structural study revealed the presences of two surface fault lines at right angles to the direction of the layer, and a rather high level of cracking and fracturing of the rocky mass. The high interstitial pressure due to the presence of water also reduces the resistance to shearing and facilitates separation and sliding of the soil. From the geotechnical viewpoint, the values of resistance to compression in one direction reside in a rather wide range, that goes from minimum values of about 20 MPa (clay marl) to about 85 MPa (sandstone). The parameters of cohesion and internal friction angle determined in the laboratory on the basis of the approximate relation between R.Q.D. and empirical constants are: $c = 1\ t/m^2$ e $\varphi = 33°$.

From the tests made to determine the cohesion and friction angle of resistance to shearing along the stratification joints, the following values were obtained: c=0 and φ=4O°.

In calculating the stability analysis, $c = 0$ and p $\varphi = 33°$ were taken into consideration, in view of the high degree of fracturing of the terrain.

Description of works.

The specialized activities performed with machinery and equipment designed and built by Pacchiosi Drill, consist of stabilization of the walls of the trench dug for construction of the third motorway lane. (Fig. 1).

The Cloujet technique, as applied at the Casette, Cervona and Cimenzano worksites, requires an initial stage of insertion of the cloujet nails along the beam, after excavation of the slope. The next stage was the installation of the reinforcement (consisting of a double layer of electrically welded metal screen) and pouring of the adjoining wall (Fig. 2).

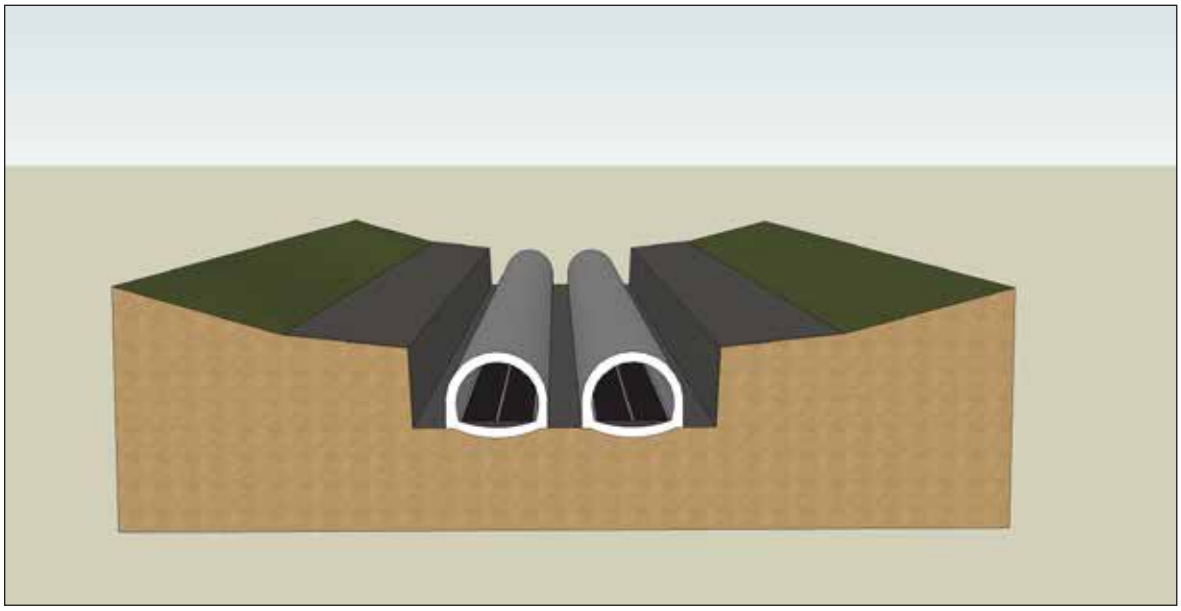

Fig. 2. Sketch of worksite after stabilization of the walls and before demolition of the tunnels.

After completing and stabilizing the excavations, the three artificial tunnels were demolished as they were old structures built as retaining walls to support the trench walls (Fig. 3). These artificial tunnels located along the motorway southbound from Frosinone were built about thirty years ago to adapt the road to the morphological layout of the

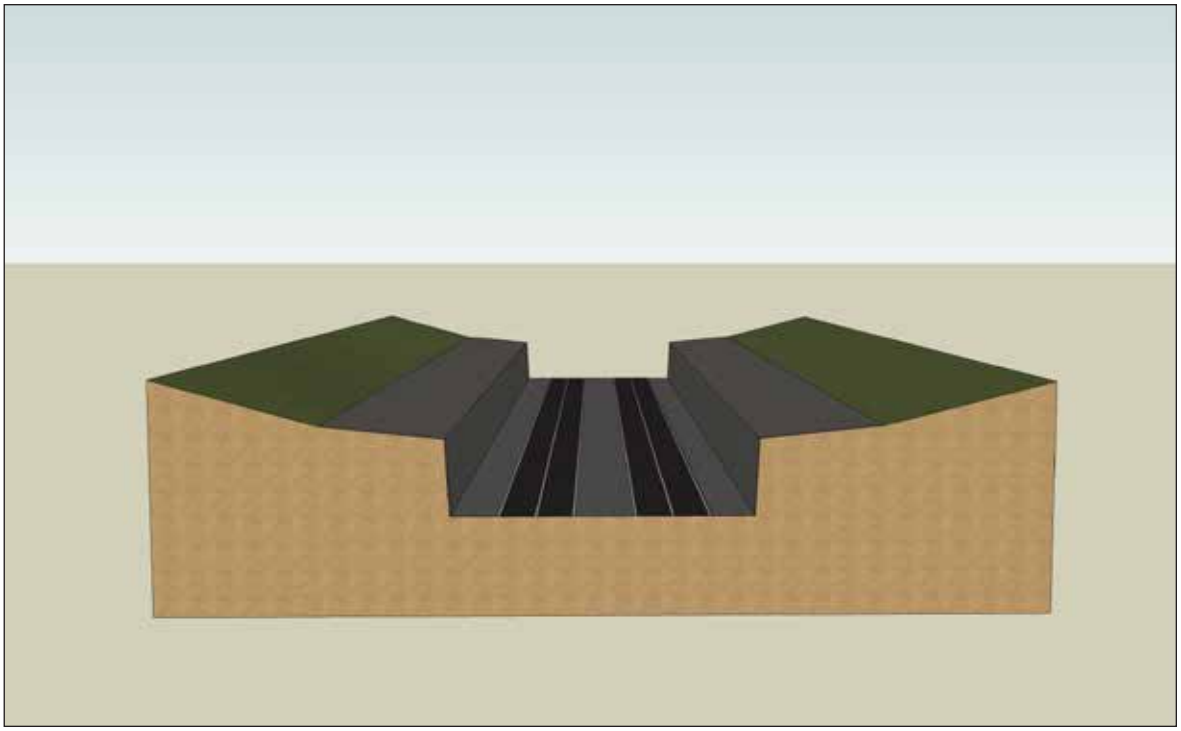

Fig. 3. View of the work zone after demolition of the tunnels.

soil that tends to rise due to the presence of structural outcroppings of loam rock and sandstone.

For example, the following data were reported relative to the work of stabilization performed at the three sites:

Casette (northbound and southbound lanes):

- wall height = 12-16 m
- wall length = 400 m
- Cloujet nails = 18,500 m
- spritz beton = 4,400 m^2
- vertical drains = 700 m^2
- horizontal drains = 1,300 m

Cimenzano (northbound and southbound lanes):

- wall height = 16 m
- wall length = 520 m
- Cloujet nails = 21,500 m
- spritz beton = 9,400 m^2
- vertical drains = 1,600 m^2
- horizontal drains = 5,500 m

Cervona (northbound lane):

- wall height = 16 m
- wall length = 250 m
- Cloujet nails = 8,000 m
- spritz beton = 4,00 m^2
- vertical drains = 600 m^2
- horizontal drains = 1,200 m

Test Field.

To optimize performance and the results of the CLOUJET works, a preliminary field test was carried out, during which the machinery, equipment and construction parameters were tested and fine tuned. The choice of the most suitable methods and construction parameters is naturally of crucial importance. For this purposes tests were carried out on six experimental nails produced with the Cloujet technology; different construction parameters were applied so as to obtain anchorage bulbs of variable length from 1.5 a 3.0 meters. The 6 trial nails, identical to those used for stabilization of the walls at Casette, Cervona and Cimenzano, consisted of a Dywidag steel bar 12 m long, with a cross section of 551 mm^2, protected on the outside by an aluminum pipe (Ø= 38 - 48 mm).

The equipment used for the stretching tests consisted of a hydraulic annular jack.

The purpose of the test was to check the calculation hypotheses formulated for analysis of the stability, on the basis of which an admissible service traction of 7 T/m was established and, considering the safety limits required, a final traction of 14 T/m (Tab.1).

The results of the tests were reported in terms of the curves representing "force - deformation", illustrated in fig.4; every curve, referring to one test nail, indicates the amount of elongation depending on the load applied. The increase of the load is not constant in time; where the tensions correspond to 10 T, 15 T, 20 T, 25 T, 30 T, 35 T and 40 T, the load is maintained constant for 15 minutes and the elongation value is read before and after this time.

In Tab. 1, the maximum tensions supported by each test nail are reported at the service tension and at the final tension, the latter determined by analysis of the stability.

On the whole, the results of the tests are more than satisfactory as, in spite of the high load values applied and the shortness of the mortar bulbs, it was not possible to load any Cloujet nail to the breaking point. Moreover, during application of the loads, no significant sliding or "fluage" phenomena were observed.

The basic engineering theories are therefore reassuring.

Before starting the works, a monitoring system was installed to determine the reactions of the terrain to the progress of the work. This system includes inclinometers and extensometers, to reveal any fractures or dislocations, as well as instruments for measuring the tensional states of the terrain as the depth of the excavation increases. The latter are read by dynamometers applied to the nails and capable of recording the forces mobilized in themi.

Dimensions of the supporting works

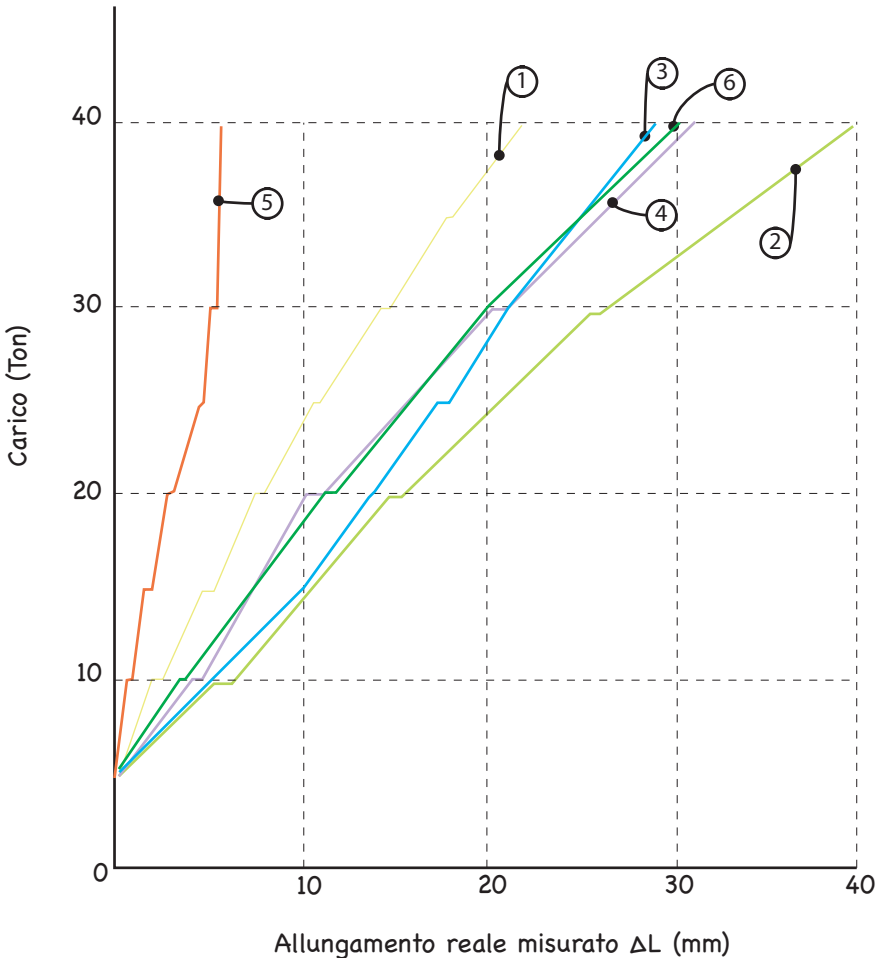

Fig. 4. Grafico dell'allungamento dei chiodi in funzione del carico.

Cloujet	Teste tension T/m	Ts T/m	Tu T/m
1	27	7	14
2	13,3	7	14
3	27	7	14
4	13,3	7	14
5	27	7	14
6	13,3	7	14

Tab. 1

From a geometrical viewpoint, the walls have variable heights from 13 to 16 meters. The height and length of the excavation pitch depend on the lithological and mechanical features of the terrain to be stabilized.

In deciding the dimensions of the supporting works it was necessary, first of all, to differentiate between the northbound and southbound lanes due to the different types of soil layers with respect to the surface of the embankment. The angle imposed on the supporting embankment, where there is no risk of landslides due to simple sliding along the planes of the layer or along the breakage surfaces, is 30° with respect to a safety coefficient of 1.62; an angle of 25° is imposed on the landslide barrier embankment, considering a safety coefficient F = 1.3.

Control of stability

Using procedures of automatic calculation on the basis of the geotechnical parameters described above, the analysis of stability was performed relative to three sections of the northbound lane, at heights of 14.1, 10.8 and 5.4 m. respectively, and two sections of the southbound land, at heights of 10.8 and 5.40 m. The tests were made during the intermediate and final stages of construction, obtaining in both cases a safety index of better than 1.3 in seismic terms.

During calculation, only the possibility of stress on the nails due to traction is considered, and not shearing stress, in favor of safety.

Description of works.

The Cloujet technique consists of the following sequence of steps. This sequence was used also during the works at the site described here.

Stage 1: excavation of a step-morphology having sufficient height to ensure its stability;

Stage 2: insertion and injection of Cloujet nails with variable geometry depending on the characteristics of the terrain and slope (Fig. 5);

Fig. 5. Insertion of Cloujet nails after excavation.

Stage 3: installation of the reinforcement in the walls, consisting of a double layer of electrically welded metal screen (Fig. 6);

Stage 4: casting of the enclosing walls by spritz-beton spray (Fig. 7);

Fig. 6. Installation of electrically welded screen.

Parallel to excavated face, between it and the enclosing wall, a draining system of geo-textiles is installed.

These activities are repeated cyclically, until the entire wall has been completed (Fig. 8).

After completing the stabilization of the slope (Fig. 9) and excavation of the third lane, the now useless tunnels were demolished (Fig. 10).

Conclusions

The Cloujet technique made it possible to construct the embankment of the motorway trench at the Casette, Cervona and Cimenzano tunnels in a short time and at highly competitive costs with respect to other methods of stabilization. The main reasons can be indicated as follows:

a) riduzione della formazione di stati tensionali pericolosi dovuta alle modalità esereduction of the formation of dangerous states of tension due to the mode of performance of the technique, in which "nailing" and excavation proceed simultaneously

b) possibilità delle diverse squadre di lavoro (di scavo, di infissione dei chiodi, possibility of having different construction teams (for excavation, insertion of nails, installation of covering) at work independently and with machinery of reduced size and weight, so as to decrease down time as much as possible

c) great adaptability to the worksite conditions and ease of performance in extremely heterogeneous soil types

d) great versatility of the technique which, on the basis of a careful geognostic study, rather sophisticated systems of calculation, and solid experience, can determine the size of the

Fig. 7. Pouring of the enclosing walls after installing the reinforcement.

"stabilizing" elements such as nails, covering and drainages depending on the specific features of the work and project demands.

Fig. 8. Subsequent stage of insertion of cloujet nails.

Fig. 9. View of the finished wall.

Fig. 10. Demolition of the tunnels.

Fig. 11. View of the zone after completion of the works.

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