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ROCK - SOIL TECHNOLOGY AND EQUIPMENTS

TUNNEL

MACERATA (ITALY)

FONTESCODELLA TUNNEL (MACERATA - ITALY)

PROJECT:

Construction of the new Fontescodella tunnel that crosses the town from north to south, with works of completion and accessories, including technological and safety systems.

PERIOD OF CONSTRUCTION:

January 2004 – September 2008

CLIENT:

Comune di Macerata

Fig. 1.General view of the northern entrance to the Fontescodella tunnel during the works.

Purpose of the work and main difficulties encountered.

Construction of the new Fontescodella tunnel (about 830 m long) which crosses the central part of the city of Macerata from north to south, with relatively reduced covering; excavation in full section with provisional support of the front using VTR anchorages; preliminary covering with metal cambers and sprayed concrete; final covering in concrete poured at the site. The contract also includes all the works of completion and accessories inside and outside, as well as the technological and security systems.

In addition to absolute control of possible collapse (which is intolerable in the historical urban context), particular difficulties were encountered in crossing the Civitanova-Albacina railroad line underground, with scanty covering of only about 8 meters.

Fig. 2. Morphology of the area in the zone of the northern entrance.

Lithology.

The tunnel was built in Plio-Pleistocene rock overhung, at the roof level, by the Quaternary series and alluvial agglomerations from recent floods, as well as surface buildup. The Plio-Pleistocene formation of marine origin consists of alternating layers of hard clay marl with thin layers of sandy soil and molasse, in other words, compact sand with sandstone levels, while the Quaternary sequence contains silt, silty clay and fine sand in a pseudo-stratified deposit. With the exception of a single point which is described more in detail below, the tunnel was always inside the Plio-Pleistocene formation.

Structural choices and methods.

Along the entire length of the tunnel a closed structure was built, consisting of a preliminary covering with cambers and spritz-beton, low walls, a reverse arch and cap in reinforced concrete poured at the site. It was also necessary to perform systematic consolidation of the front using VTR nails (from 55 to 103 elements per front depending on the state of the excavation) injected with a mixture containing cement. At the entrances and at the point where the tunnel intersects the Civitanova-Albacina railroad line, special crowns of steel insertions were injected into the cap.

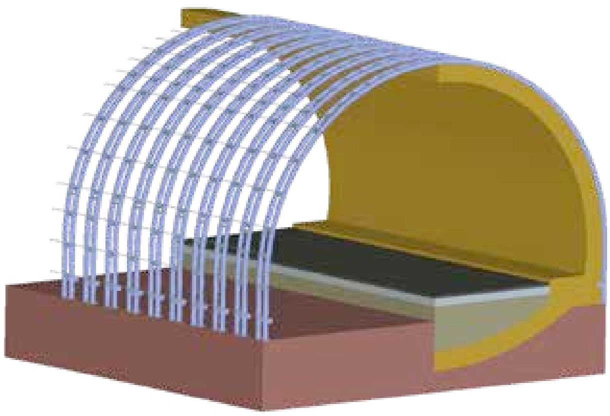


Fig. 3. Axonometric view of the tunnel structure

The excavation continued in full section with a systematical sequence of seven well-defined stages that, with the necessary adjustments necessary during the works, made it possible to complete the works without causing any surface breakdowns which would have been extremely harmful to the buildings in the historical old center of the town.

Constant monitoring (measurement of convergence) on the inside and outside (precision leveling) kept the progress of the works under control as they proceeded; the control system was then kept in function for a congruous period after completion of the tunnel, before it was opened for traffic.

The following graph illustrates the seven main operating stages of the "typical" work sequence, with the distances from the front of the various structural elements.

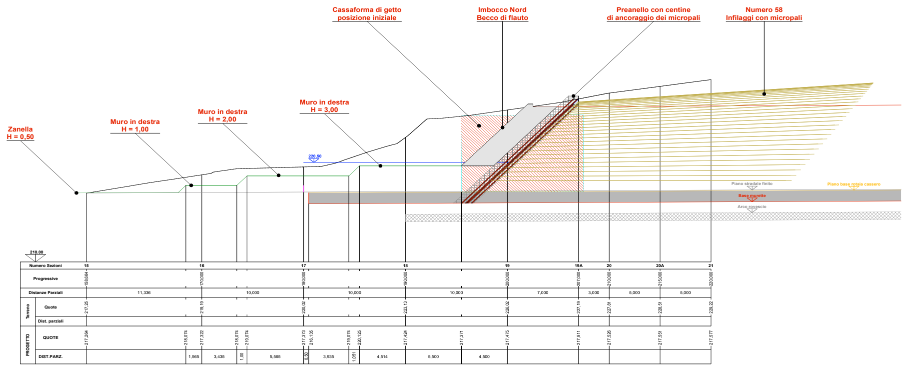


Fig. 4. Longitudinal cross section view of northern entrance

Description of works.

Entrances.

Sub-horizontal VTR nails were placed at the entrances of the front and crowns of steel insertions were injected into the cap.

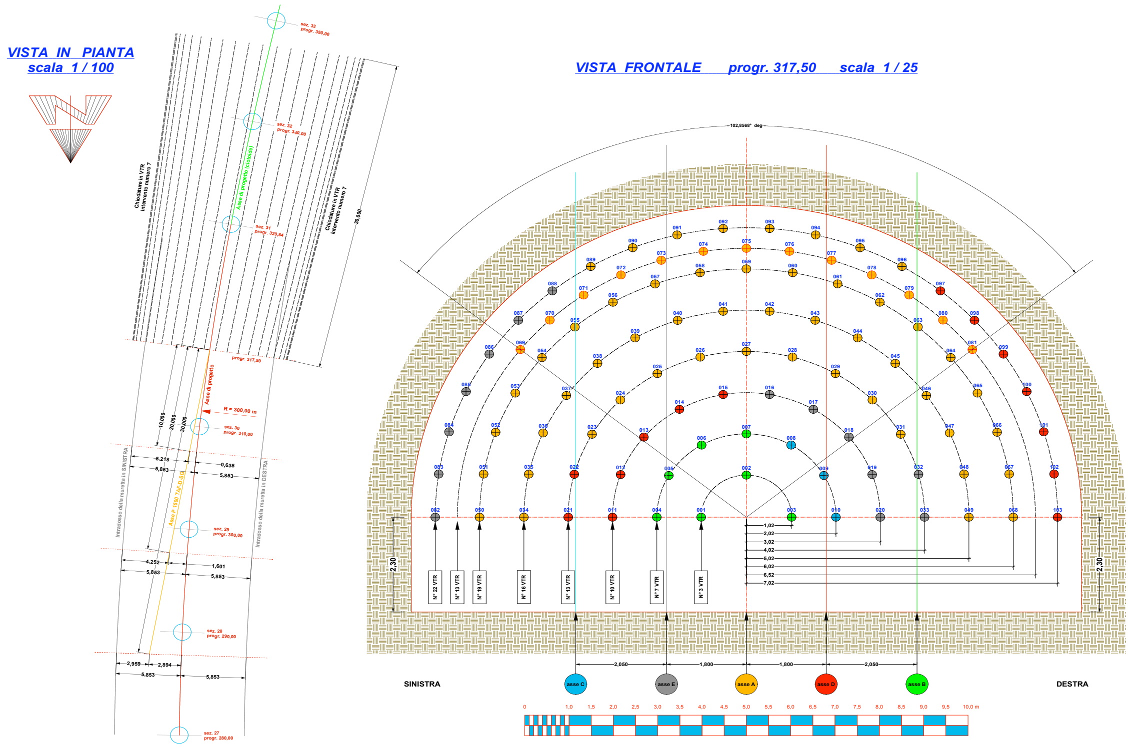


Fig. 5. Typical nailing pattern on front.

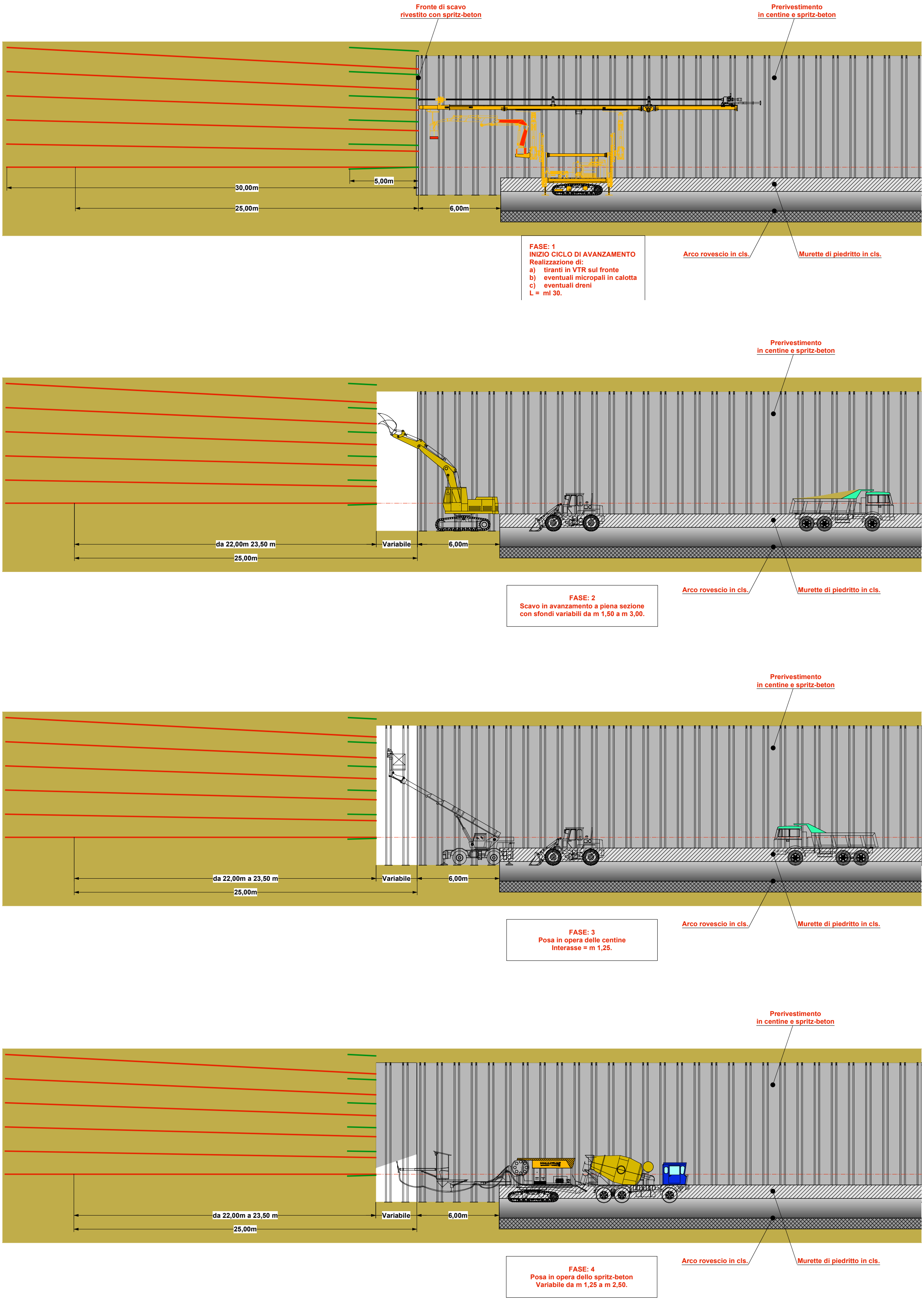
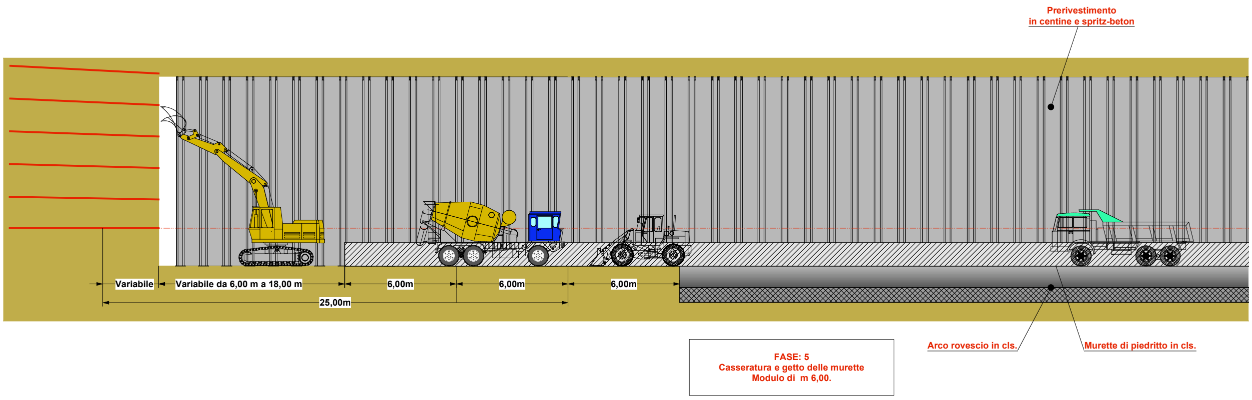
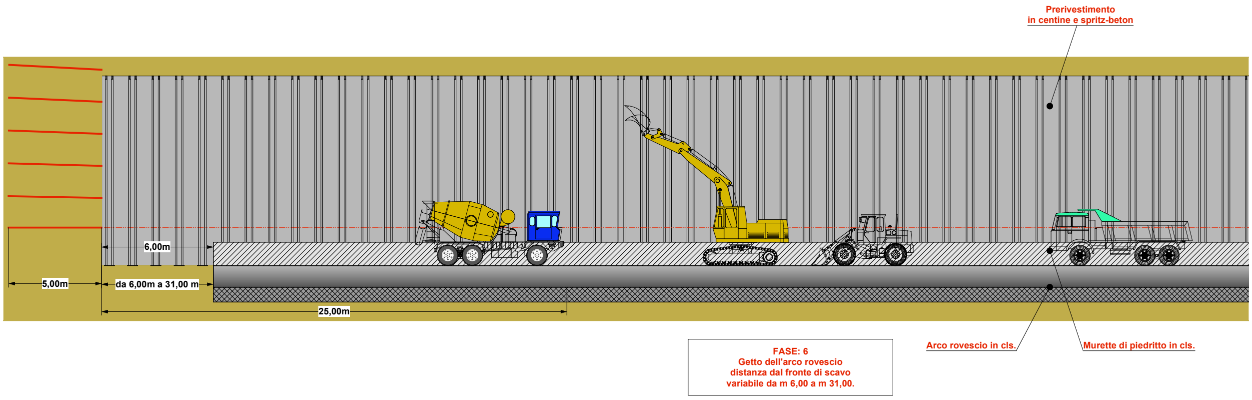
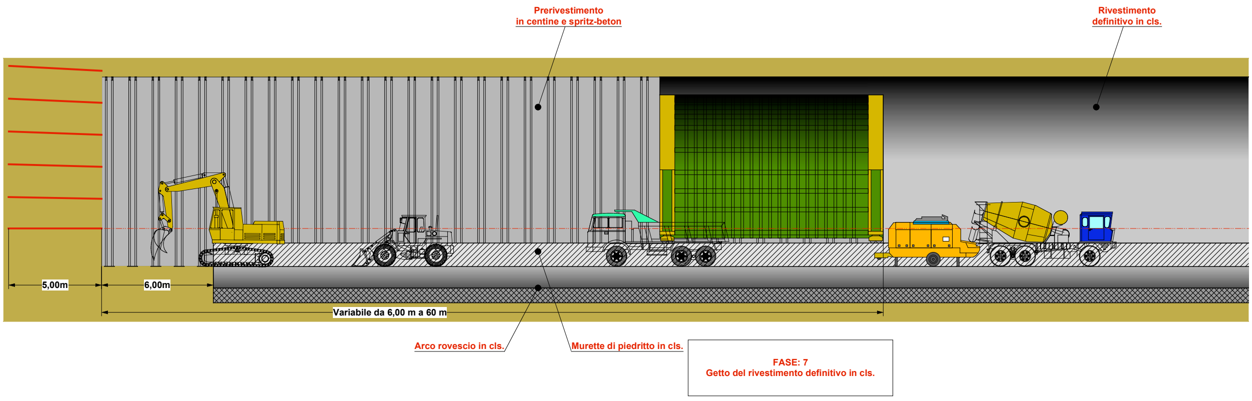


Fig. 6. Stages of advancement in the tunnel: complete cycle (1-7)







This system made it possible to excavate the terminal sections safely, where the excavation involved alluvial lithological formations or buildup with poor mechanical characteristics, and facilitated connection of the tunnel and finished entrance without requiring additional supporting works (props, diaphragms or other).

Fig. 7. View of the northern entrance prior to works of consolidation.

Progress through the tunnel.

The tunnel was excavated using an excavator (occasionally with the aid of a jackhammer) in the full section, proceeding from a single direction – north – after consolidation with

Fig. 8-9. Detail of construction and view of subhorizontal steel insertions preliminary to first attachment on the front.

subhorizontal VTR nail insertion and sprayed concrete; the muck was hauled away by trucks, loaded with a shovel and/or excavator. A preliminary covering was systematically applied using metal cambers, electrically welded mesh and sprayed concrete.

Fig. 10. Approach of excavation face at North entrance.

After pouring the low walls and reverse arch, the final covering in concrete was poured at the site using special metal formworks (CIFA) for blocks 12 m long; with the exception of the openings and other particular position, it is not reinforced. For special works of consolidation, equipment designed and built by PACCHIOSI was used (in particular, the TAF hydraulic probe).

Fig. 11. PACCHIOSI P1500TAF drill rig executing the nailing of excavation face

Fig. 12. Nailing of the front with PACCHIOSI P1500TAF.

Geological incident on January 24, 2006.

The night between January 23 and 24, 2006, at position 727.75, a sinkhole opened in the cap on the righthand side of the front. The breakthrough occurred in a landslide cone that went up to the surface at the side of a baseball field.

Fig. 13. Front of the excavation; the soil stratigraphy is visible.

Fig. 14. Preliminary covering with reverse arch immediately after the front.

Fig. 15-16-17. Formworks for pouring of the vault; preparation in the open, carria-ge into the tunnel, works in progress.

Fig. 18. "Damper" at the end built at the site for perfect adaptation to the profile of the preliminary covering already applied

The event was caused by the unexpected and unforeseeable sudden reduction in the thickness of the Plio-Pleistocene covering in favor of a quaternary series lithotype with a high content of water and poor mechanical characteristics.

A targeted series of new geognostic studies made it possible, after stopping the works with the tunnel in safe conditions, to find a solution that would permit rapid, safe resumption of the works underground.

Repair of the break and completion of the tunnel.

In consideration of the high degree of specialization of PACCHIOSI in works of consolidation in general, and its vast experience in the repair of breaks in tunnels, the works management assigned PACCHIOSI the task of finding and implementing the appropriate Jet Grouting consolidation treatment for the case. The treatment was performed from the surface with special equipment, designed and built by PACCHIOSI, that made it possible to produce interlocking columns of consolidated soil with a diameter of more than 3 m each, using the PACCHIOSI MEGA JET PS3 system, to form around the future setting of the tunnel a sort of sturdy "dome", for the entire area containing the damaged soil.

Excavation of the tunnel could be resumed shortly thereafter, and quickly returned to the previous rate of progress, with renewed safety.

Another difficult point to overcome was the interference of the Civitanova-Albacina rail line, just past the southern entrance. In this case, in addition to the usual VTR nails inserted in the front, special subhorizontal steel insertions were made in the cap to cooperate with those already installed from the outside on the side of the railbed embankment. The underground crossing was made with the railroad line in regular operation, under the special control of railroad company inspectors.

The excavation was then completed with the southern entrance and, after that, the final covering and construction of the artificial southern tunnel entrance.

Later, the secondary accessory works were completed and the road was built, after which the installations were made.

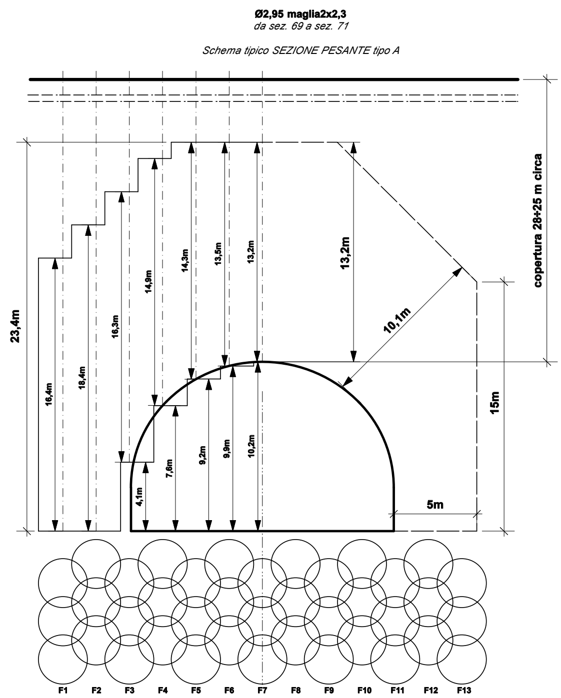


Fig. 19. Drawing of the consolidation from the outside with JET GROUTING to eliminate the breakthrough.

Fig. 20-21. Entrance; view of the inside of the tunnel in the direction from north to south, and inspection from the outside, from the embankment on the southern front.

Installatosi.

The installations include:

- permanent lighting system with reinforcement at the entrances and emergency lighting controlled by a luminous flow regulator subject to probes of the external luminance,
- system of longitudinal ventilation with two pairs of fans, served by special anemometers with continuous speed regulation, possibility of reversal of the flow direction and direct control by the fire department from panels located at the entrance,
- system of traffic lights and variable message panels on the outside, near the entrances,
- fire detection system, consisting of a single heat sensitive wire, located in the upper part of the tunnel and equipped with a continuous sensor that detects any unusual temperature increases and identifies the exact point in which a fire may have developed,
- SOS installation, interphone system and emergency call system,
- signal lights,
- closed-circuit TV monitoring system with 12 TV cameras for constant control of the situation and traffic in the tunnel, connected to a control center,
- system for air monitoring and control with CO readings and smog detectors,
- cabinets with extinguishers for the SOS columns,

Fig. 23. Inside of the finished tunnel complete with all its installations.

- system of supervision and control (instrumental and audio/visual system) in a cabinet with remote control in the municipal offices
- continuity unit with battery to ensure 60 min duration,
- power generator with diesel engine and extra 3000 liter tank,
- fire fighting installation with hydrants and a cabinet with 20 m fire hoses located on both sides of the tunnel with a maximum spacing of 50m; the water supply is guaranteed by connection to the municipal water system at both ends.

Main features of the work.

Roadway tunnel with two-way traffic

Total length of the road section:	1,174 m
Altitude of northern entrance:	217 m asl
Altitude of southern entrance:	221 m asl
Tunnel length:	850 m
Tunnel slope:	0,05 %
Maximum coverage:	63 m
Coverage under railroad line:	8 m
Excavation section:	170 sq.m.
Usable section:	130 sq.m.
Road width:	10.5 m plus two sidewalks measuring 1.6 m

Fig. 24. Southern entrance of the new tunnel in operation.

Volume of soil excavated:	about 125,000 cu.m.
Concrete used:	about 30,000 cu.m.
Steel used:	about 1,100 tons
VTR nails for support of the front:	about 113,000 ml
Jet Grouting consolidation to resolve the geological incident:	about 25,000 cu.m.

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