Innovative techniques for the realization of large diameter tunnels in loose land

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ABSTRACT: The report on the works completed to date for constructing the "Venezia" Station of the Milan Railway Link. The Station which, when completed, will have an inside diameter of 22.80 m and only 4 m loose soil overburden, is being excavated by the "Cellular Arch" method. It consists of a special use of the pipejacking method, in the production of a series of microtunnels which are then connected by means of large reinforced concrete arches.

The Milan railway link, built to connect directly the railway network to the urban transport system, has been developed mainly underground with rail and station tunnels built mainly by direct sub surface excavation. The link includes the exchange station of Venezia, on line one of the Milan subway, and is the biggest yet planned. The Consorzio GIEMME (Joint Venture with the Grandi Lavori S.p.a., Mazzi S.p.a., Romagnoli S.p.a., Astaldi S.p.a., Vianini S.p.a.), has been commissioned to execute the work.

The link is developed entirely in the tunnel, and has the greatest dimensions of all such direct sub surface excavation work in the Milan Area:

length	214.50 m
internal diameter	22.80 m
external diameter	28.80 m
internal height	16.25 m.

The station tunnel is located in Regina Giovanna Avenue, a street with particularly intense traffic above the convex part of the tunnel cap (fig. 1).

The earth is made up of recent incoherent river deposit type of rock with variable alternation of loose rock and lime sand.

The exceptional dimensions of the tunnel, the characteristic of the land, the limited covering and the interference with underground services, particularly an electrical duct of 220,000 Volts capacity extremely sensitive to possible land movements, did not allow the use of traditional constructions methods adopted over the last few years for the realization of the Milan subway tunnels. Therefore the design engineer has planned and developed with the cooperation of those in charge of planning the Milan subway and project engineers of GIEMME Joint-Venture and Rocksoil S.r.l., a new construction system named "Cellular Arch". It consists of a special use of the pipe jacking method, in the production of a series of microtunnels which are then connected by means of large reinforced concrete arches.

Fig. 2 shows diagrammatically the principal stages in the execution of the work, which are:

a) grouting of the ground around the perimeter of the side drifts, working from a central service drift;

b) two stage heading-bench excavation of the side drifts, completion of grouting around the station perimeter, followed by the pouring of concrete to form the posts;

c) jacking, from a thrust pit, of 10 microtunnels of 2.10 m diameter, constructed by means of reinforced concrete pipe sections;

d) construction of the connection arches following excavation for the upper section pipe and relative excavation for arch housing;

e) excavation in successive stages of the upper section of the tunnel;

f) excavation and casting in stages of the invert for limited lower sections.

The fixing of the pipes over a length of 214.50 m could have been carried out, with available equipment, in one operation, by constructing an inlet thrust pit at one end of the station and en exit pit at the other end in order to recover the shields.

The need to avoid disruptions to traffic flow both during the execution of the pits and, particularly, during the shifting of equipment and the pipes themselves, obliged the engineers to construct just one pit in correspondence of the access shaft to the station tunnel in Pancaldo Street.

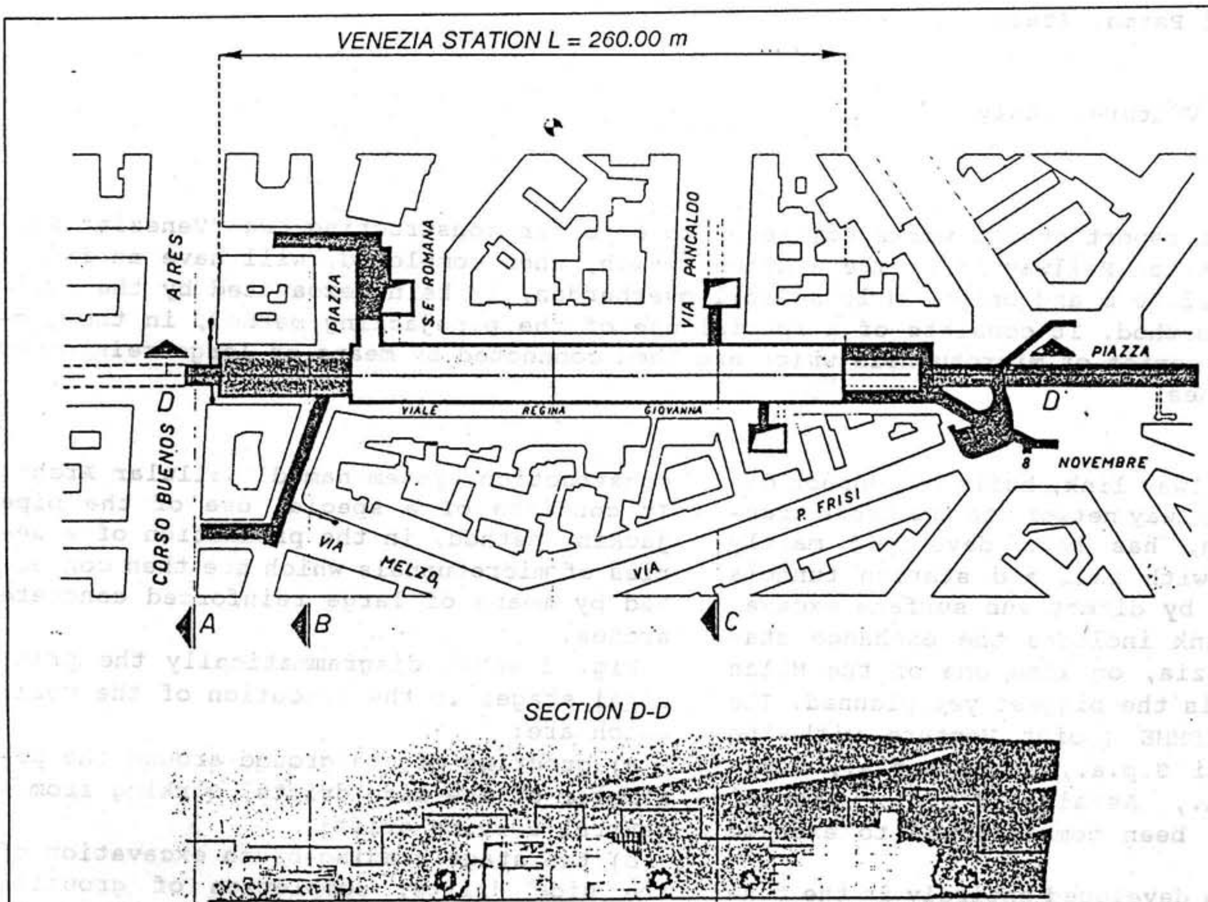

VENEZIA STATION L = 260.00 m
AIRES
CORSO BUENOS
PIAZZA
S.E ROMANA
VIA PANCALDO
PIAZZA
VIALE
REGINA
GIOVANNA
8 NOVEMBRE
P. FRISI
VIA
MELZO
VIA
D
D
A
B
C
SECTION D-D
A
B
C
SECTION A
SECTION B
SECTION C
Design stratum
Stratum
10.10
20.80
28.80

Fig. 1

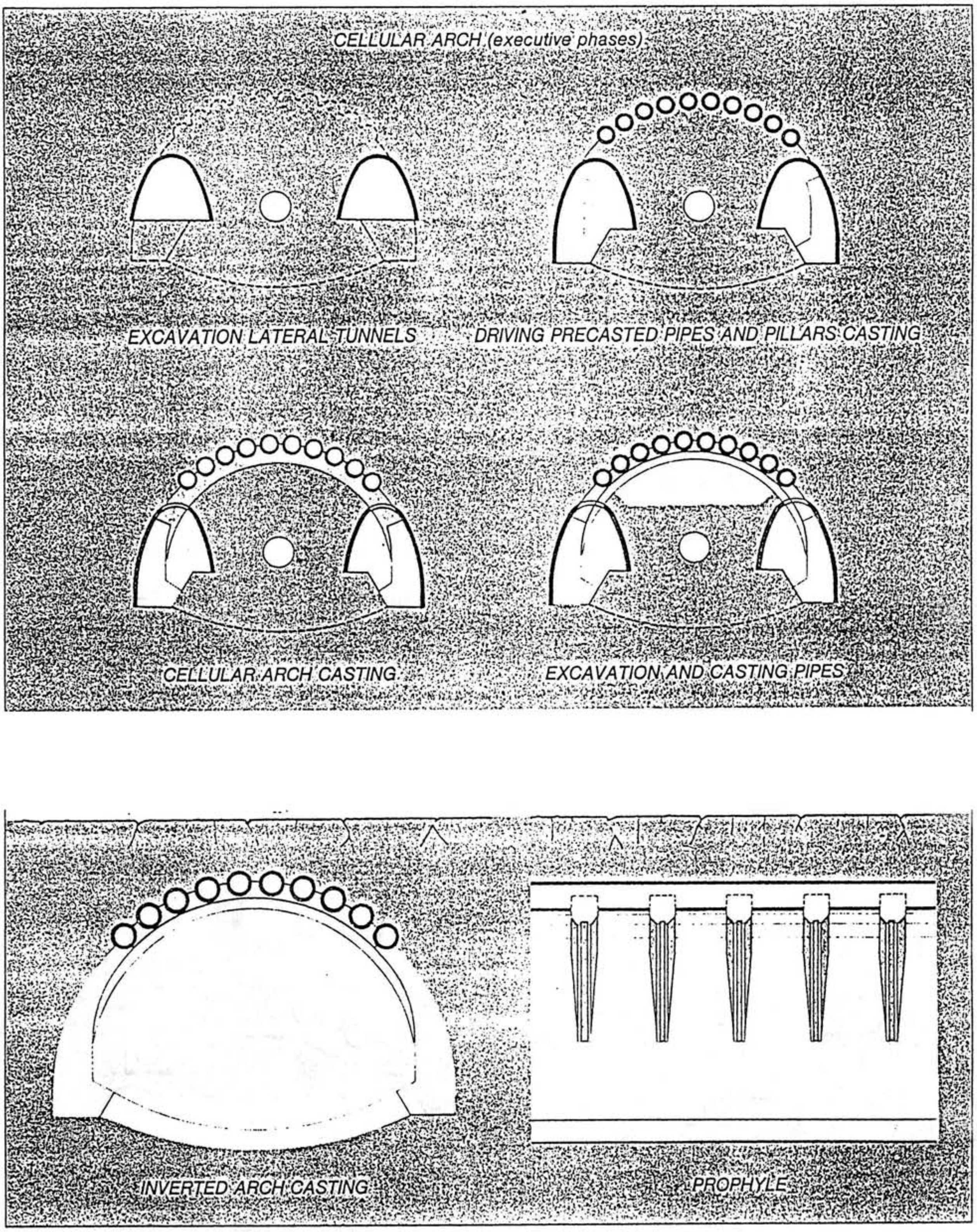

CELLULAR ARCH (executive phases)
EXCAVATION LATERAL TUNNELS
DRIVING PRECASTED PIPES AND PILLARS CASTING
CELLULAR ARCH CASTING
EXCAVATION AND CASTING PIPES
INVERTED ARCH CASTING
PROPHYLE

Fig. 2

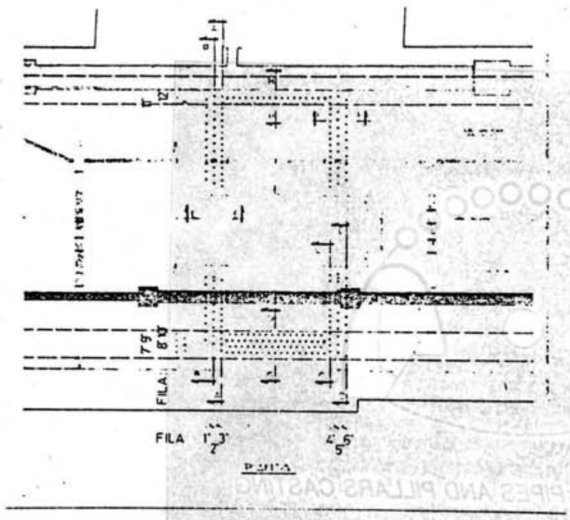


Fig. 3

In this way pipe fixture takes place in two stages. In the first the pipes are driven along a tract of about 50 m in direction of 8th November Square; in the second, inverting the thrust equipment, towards Buenos Aires Avenue along a distance of 160 m.

The adoption of a unique thrust pit implies the significant loss of twenty valuable metal shields relinquished "in situ" at the end of the thrust operation, only the accessory and internal equipment of the drilling head being recovered.

The thrust pit measuring 10 m by 12 m is located in Regina Giovanna Avenue, inter-

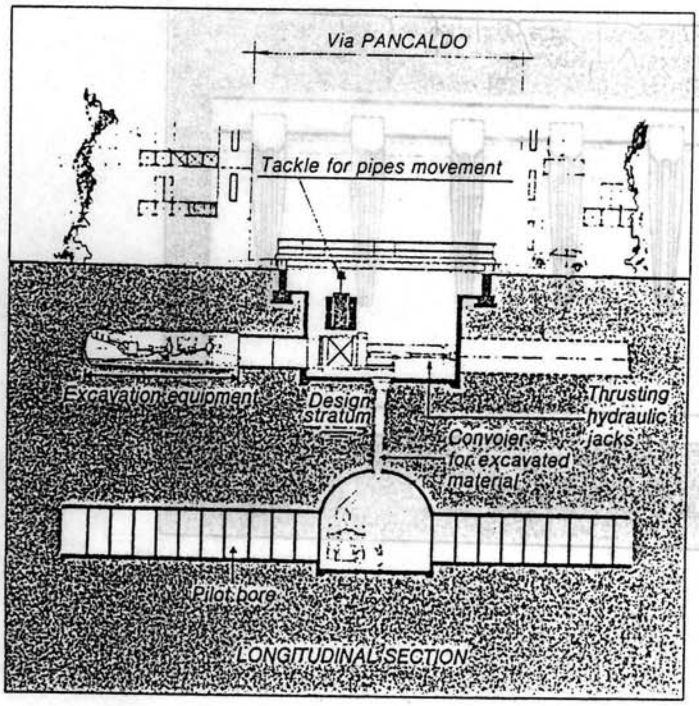


Fig. 5

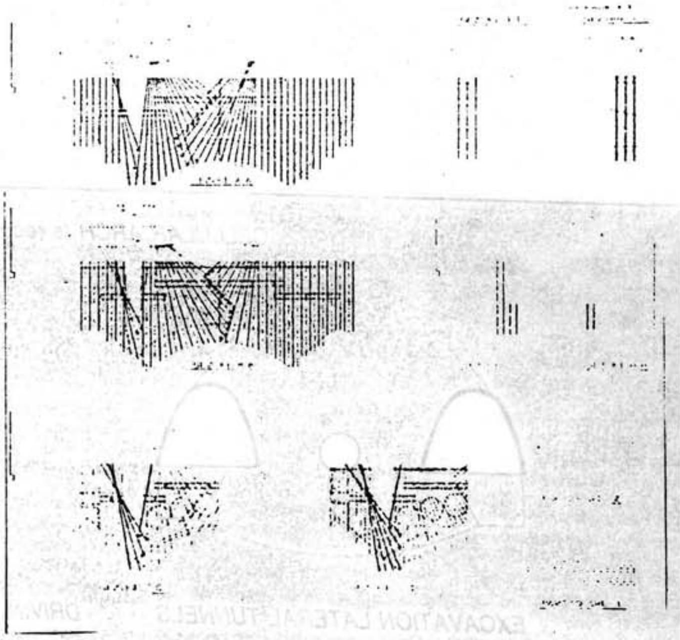


Fig. 4

cutting the flow of traffic.

In order to avoid any interruption during construction of the pit, its wall construction was accomplished by means of divisions (diaphragm-like) of grouted earth executed by jet-grouting method (figures 3 and 4).

The "diaphragms" were then fixed in position by means of tendons.

Before proceeding with the pit excavation, a tram bridge and two road bridges made of prefabricated steel components we-

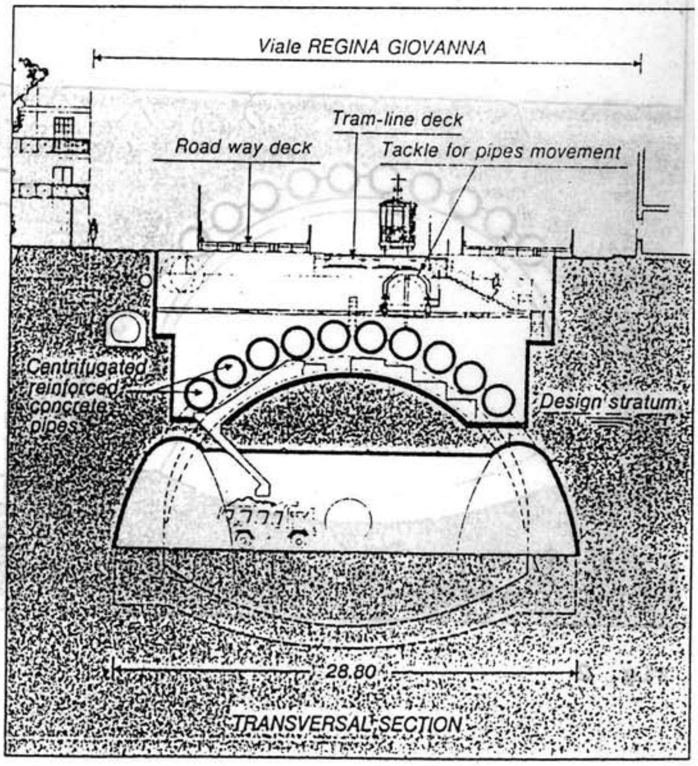


Fig. 6

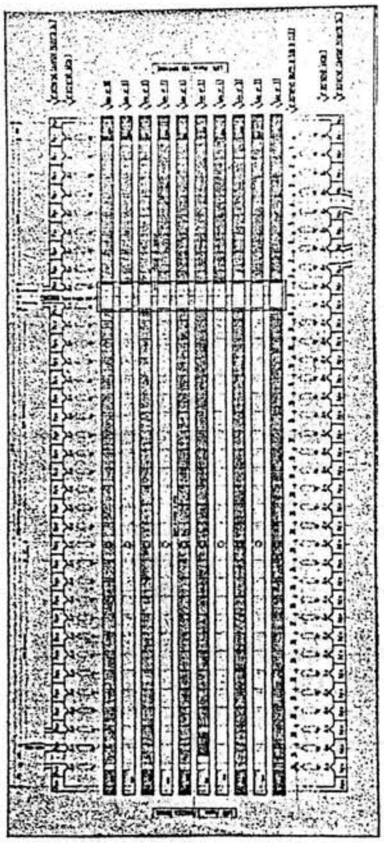


Fig. 7

re set up in just 12 hours, mainly overnight.

Particular attention was paid to the

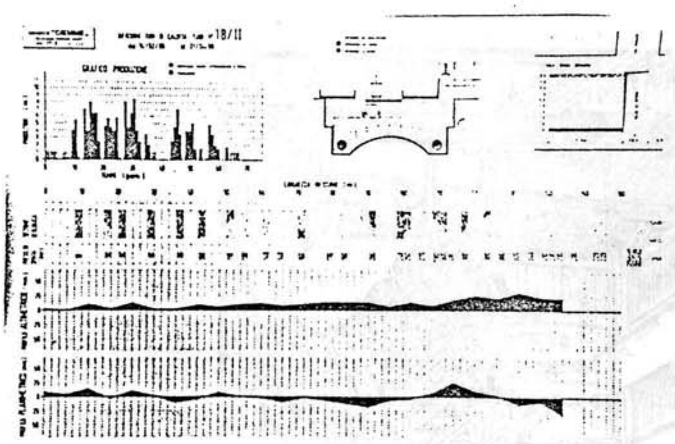


Fig. 8

equipment for moving the pipes and shields. This includes external frames and lifting/pulling machines to convey pipes to the pit and two carriers for pipe movement within the pit, as shown in figg. 5 and 6.

Pipe fixing is executed by means of equipment consisting of a metal shield 8 m long, subdivided into three parts of which the first, 1.3 m in length, movable and having a cutting edge, allows the operator to control vertical and horizontal plane movement.

The shield has a computer controlled front drilling head, of circular section about 3

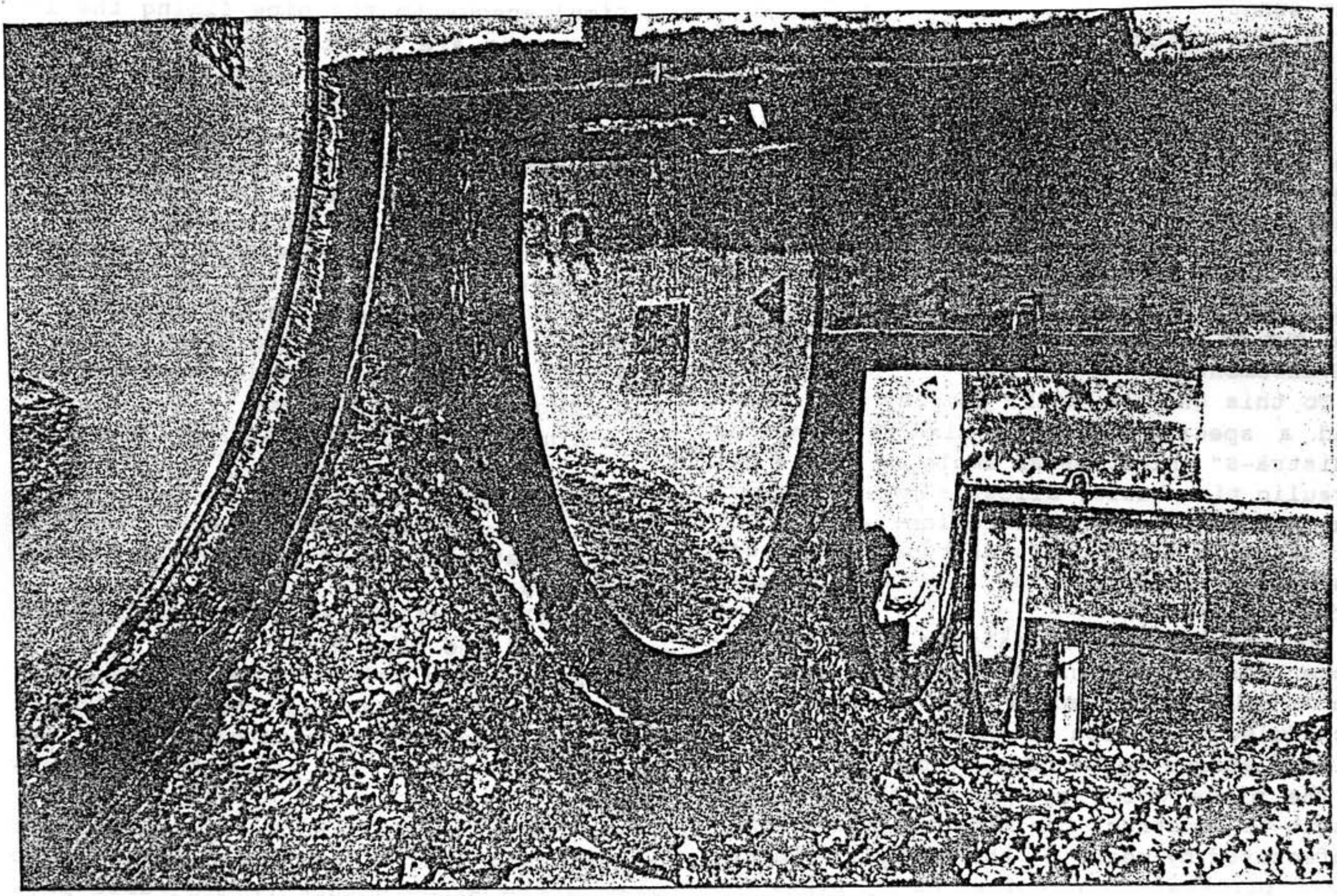


Fig. 9

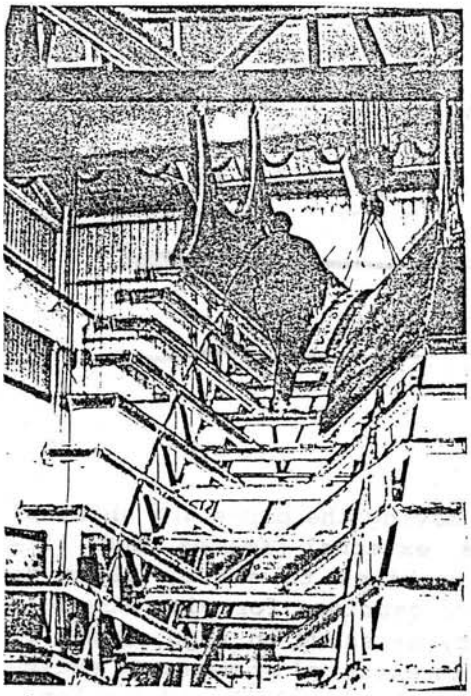


Fig. 10

cm smaller than the external shield section in order to limit the formation of cavities outside the pipes when drilling.

Excavated material is loaded by means of a conveyor belt onto rail cars and is taken to the pit where it is unloaded into the lower tunnel.

Thrust equipment consists of two hydraulic jacks, thrust distributing structures and a 60 Mpa hydraulic pump.

In order to ensure that no road subsidence whatsoever occurs pre-grouting of the concerned parts of the earth was carried out.

It was necessary to obtain a layer of earth which had been uniformly treated so as to gain sufficient cohesion to avoid subsidence, but at the same time allow ease of shield advancement.

To this end the Rodio Company has invented a special concrete mixture known as "Mistrà-S" which, as an emulsion with a hydraulic tier basis, allows a more homogeneous and extensive penetration, at a lower pressure in mixed granular type earth (sand and loose rock) and has a greater volumetric efficiency.

The results were satisfying in that a homogeneous and extensive treatment was effectively obtained which allowed the scheduled execution of excavation and pipe fixing stages to be completed.

The pipes which are to be fixed to the earth to construct the microtunnels are manufactured by means of the "radial compression" process which confers to the pipes the desired mechanical properties: high compactness and well finished inside surface.

The dimensions of the pipes are:
length 2,000 mm
diameter 1,800 mm
thickness 150 mm.

They are reinforced by a double electro-welded cage with 24 longitudinal bars of 6 mm diameter and spiral of 8 mm diameter with 90 mm lead positioned onto a ring that allows female matching, the whole apparatus being inserted inside a perfectly circular mould.

The concrete mix, in the ratio of 410 Kgf/m^3 of 425 furnace cement, is poured into the mould, compressed and rolled mechanically by the mould piston.

Electronic control of the velocity and advancement of the spindle ensures a perfect and uniform compactness of the concrete mix.

The advancement of the pipe fixing operation is represented in fig. 7.

The 50 m stretch is complete, while for the longer 160 m tract 6 out of the 10 pipes have been laid.

In fig. 8 there is a summary of average recordings taken during pipe fixing, and it is evident that both in the short and long tract the vertical deviations do not exceed 3.0 cm and the horizontal deviations do not exceed 2.5 cm. No road subsidence was recorded.

Simultaneous to the pipe fixing the lateral posts are constructed on which the cellular arches will be supported.

At the moment the most difficult stage of the whole cellular arch technique is in act: the construction of the arches.

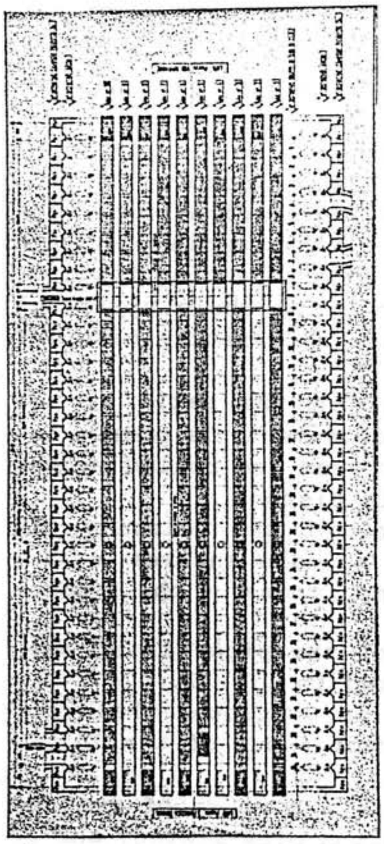
The stages involved in the construction of the arches are the following:

- the lower half of the pipe is cut with a special cutting disk (fig. 9). The pipe is cut into sections which are removed with the excavated earth during the forming of the arch housing. During this phase the double ring placed at the end of the pipe in question support the remaining half pipe;

- excavation starts from the lower outer pipes and proceeds towards the top, the excavated material being dumped into the side drifts;
- levelling of the arch housing base and casting of the base mix;
- insertion of reinforced arch armatures, accomplished by means of the lower tunnel for base components and panels, and by means of the tunnel and pipes for the supports.

For the arch armature it was necessary to manufacture special equipment in order to obtain the architecturally desirable profile (fig. 10).

This particularly complex equipment could



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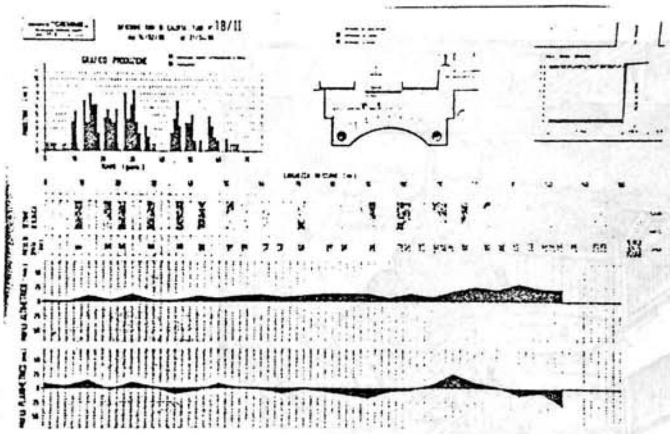

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Fig. 9

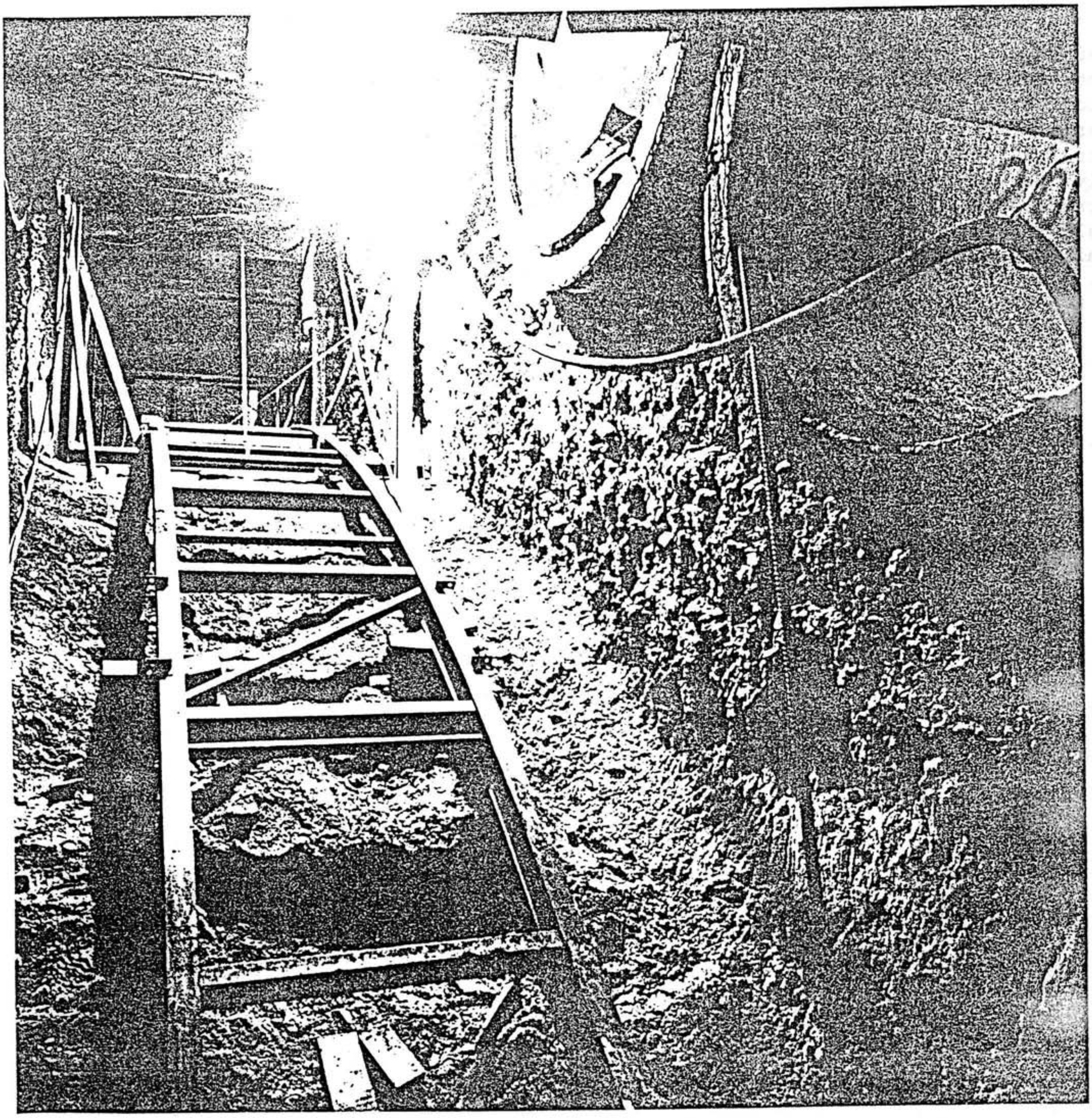

Fig. 11

be eliminated in the case of rectangular profile and direct casting into the ground (fig. 11).

So far about 50 % of the work has been accomplished and is proceeding according to plan, in total safety, considering that the operational system allows control over the static conditions of the work and hence any possible deformation phenomena.

This report follows previous reports, presented at the congresses of Madrid (June 1988) and Paris (February 1989) and the authors assure that they will have updated the information according to work progress for the next ITA-AITES congress.

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