A NEW CONSTRUCTION METHOD FOR WIDENING HIGHWAY AND RAILWAY TUNNELS

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SUMMARY: The idea of widening highway tunnels while they are in operation was first thought of by Società Autostrade engineers as early as the start of the 1980s when the need first arose to widen highways to three lanes and to add an emergency hard shoulder.
Studies were undertaken in some technical environments with the aim of producing a universal methodology for use in all types of rocks and under all conditions.
For grounds with poor cohesion, however, the diffusion of the pre-cutting technique has so far made it possible to actually implement a widening method, above all by resort to a secondary lining in reinforced concrete, prefabricated segments made active by special jacks fitted in the key segment (active arch method).

1 THE HISTORICAL BASIS

The idea of the method certainly goes back to the beginning of the 1970s, when the company Società Autostrade, which already at that time managed the largest network of highways in the world, started to experience the first phenomena of traffic saturation on some stretches of its network.
Most of the network had in fact been commissioned in the previous decade and had two lanes in each direction and an emergency hard shoulder only on open stretches, designed for traffic that does not normally exceed 25,000 vehicles per day (Average Daily Traffic).
At that time A.D.G. was well over that level on some stretches making it necessary to widen them to three lanes and add an emergency hard shoulder.
This was not very difficult for new stretches, where traffic flows of this size were forecast before construction, and consequently the first three lane highway tunnels were designed

in Italy. Otherwise widening to three lanes was performed almost entirely on the surface in flat regions.
For variale geography, with many tunnels, widening highways seem clearly not only very costly but difficult for environmental reasons since there would be an inevitable waste of land resulting from long new routes and the abandoned old routes.
It was then that engineers started to think of how they might ream out the bores of tunnels. However, another problem had to be solved, the need to keep traffic flowing, even if at reduced speed, while reaming was being performed, similarly to what is done when highways are widened to three lanes on the surface.
The only answer to this problem that occurred to engineers was to pipe traffic through a steel shield with a diameter a little smaller than that of the tunnel, while the work of ground improvement in advance (where necessary), excavation to widen the tunnel and the placing of a new lining was performed outside the shield.
Work performed outside the shield must occur in absolute safety, not just for construction site personnel (as is always the case), but also for the shield itself, which although it must be designed to be of great strength should nevertheless not be overstressed by the sudden release of loads or by fall-ins.
As a result of initiatives taken by experts of different types, studies and experiments were performed on the basis of these considerations aimed at solving all the problems inherent to the complexity of the system. Given the different types of ground and rock concerned, these included theoretical studies of the statics of the cavity in the mediums considered, the geotechnology and the geomechanics, the various technologies for implementing ground improvement and excavation in underground construction sites and finally all types of TBM technology.
Naturally at the beginning, research was oriented towards solutions that could tackle all types of possible situation but, although a universal technology may be hypothesised for the future, it very soon became clear from multidisciplinary analysis of the problems that the first applications could be actually tried out with satisfactory advance rates in grounds with poor cohesion.

2 PRECONFINEMENT TECHNOLOGY THAT MADE THE FIRST MECHANICAL PRECUTTING EXPERIMENTATION POSSIBLE

In 1985 the first tunnels to employ preconfinement by mechanical*pre-cutting*, technology were driven in Italy.
They consisted of four railway tunnels on the Italian State Railways Sibari – Cosenza line. They had a cross-section of 80 sq. m. in ground consisting of clays and silts in which 3,000 m. of 14 cm. thick shotcrete arch was placed with a diameter of 10.50 m to form the arch and the relative sidewalls before the tunnel advance of 3.5 m. took place.
It is important to consider that the method achieved very constant advance rates of around 3 m per day.
Furthermore the metal portal used to perform the precutting was not large in size, but above all it allowed vehicles to reach the face during the excavation and mucking out phases.
An examination of table 1 shows just how successful the precutting method has been in Italy and how fast its use has spread. However the experience that convinced us that practical application of the method sought to widen the bore of existing highway tunnels

to three lanes was possible, was that of the Rome "Baldo degli Ubaldi" Metropolitan Station.

TABLE 1 - TUNNELS DRIVEN IN ITALY USING PRECUTTING

Tunnel	Outer Φ (m)	Thicknes s (cm)	Lengyh (m)	years
1. Tunnels, 1,2,3,4 F.S. Sibari-Cosenza	10.50	14	3000	1985-1988
2. Talleto and Caprenne F.S. Rome – Flor.	7.70	14	1800	1987-1989
3. Tasso and Terranuova F.S. RM-FI	12.20	18	1600	1988-1991
4. Siracusa F.S. Bicocca-Siracusa	12.20	18	300	1989-1992
5. S. Giovanni ANAS Tangenz. CZ	14.10	20	350	1989-1991
6. Staz. Baldo d. Ubaldi Rome Metro	21.64	20	120	1996-1998

As can be seen from table 1 not only was a considerable preconfinement diameter of 21.64 m achieved with the precutting method on that Station but a final lining system that became rapidly effective was developed. It consisted of prefabricated segments in reinforced concrete placed by erectors on runners, set into the same portal of the machine on which the precutting saw was mounted, and placed under pressure by the key segment fitted with jacks (*active arch*).

Basically, while any ground improvement or preconfinement method (where necessary) normally adopted in any type of tunnel can be employed for widening road or highway tunnels without interrupting traffic, one indispensable condition typical of all these types of tunnels is that it must be possible to place a final lining in a restricted space (the absence of shuttering *in situ*). It must therefore be prefabricated and placed rapidly in the space around the inside of the tunnel (erectors on the arch portal) and made active statically immediately after erection (grout injection behind the lining and key segment fitted with jacks).

3 THE METHOD AND DESIGN DEVELOPED FOR THE FIRST APPLICATION OF TUNNEL WIDENING

At the end of the 1990s, the company Società Autostrade felt, on the basis of the conditions discussed in the previous paragraphs, that the time had come to put the ideas collected over 20 years of study together and awarded contracts for the first project involving tunnel widening in its highway network.

With the intention of proceeding step by step, this first application is designed for ground that is not loose but has poor cohesion.

This is in fact the best possible situation since preconfinement by means of pre-cutting can easily be adopted in it. Precutting is easy because of the poor consistency of the ground which, however, is sufficiently stable to allow an arch of cement grout to be formed the inside the cut.

And that is not all, excavation to remove the ground around the crown of the existing tunnel can be easily done with a point cutterfitted on runners on the same arch portal on which the precutter saw is runner mounted.

The final lining, or the second phase, will be in prefabricated reinforced concrete segments, placed by erectors on runners again fitted on the same machine. They are then placed under pressure against the arch created before excavation by means of further injections of cement grout the behind the segments and by activating the jack fitted in the key segment (*active arch*).

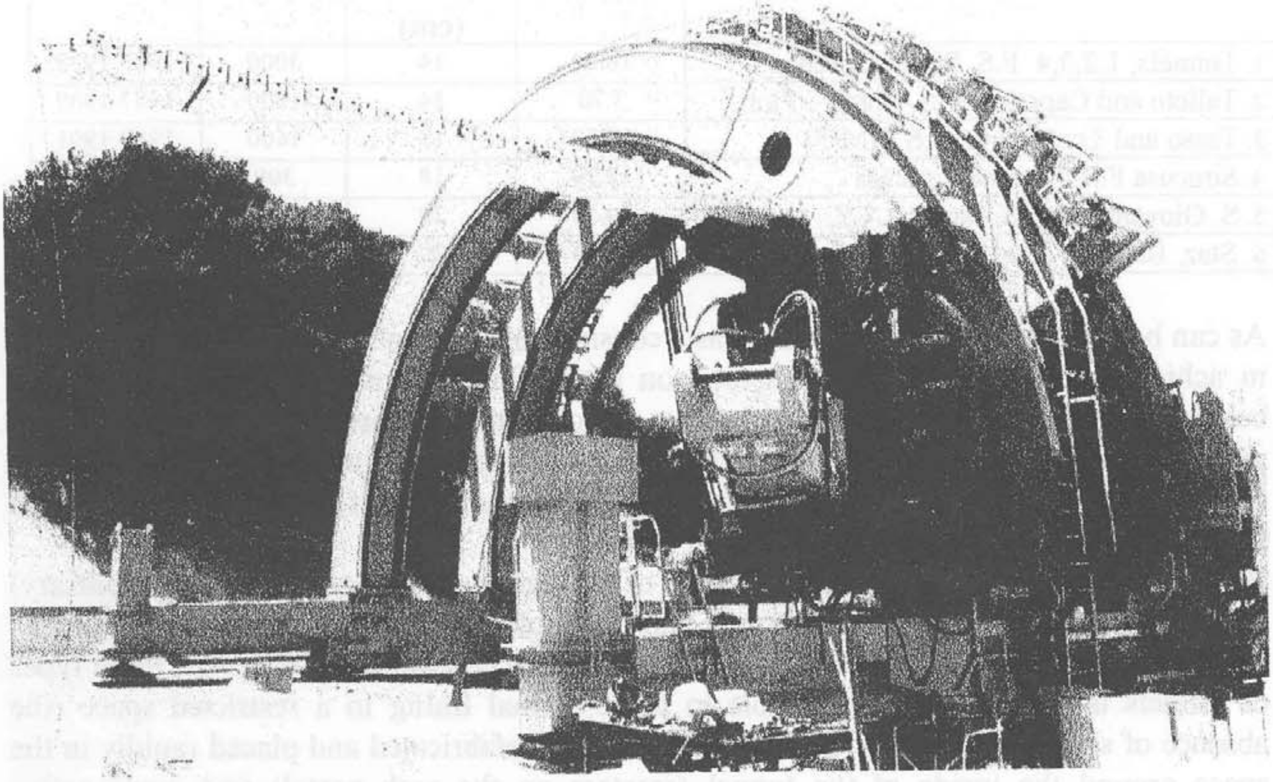


Photo No 1 -- The multi-purpose machine

Finally, as already hypothesised at the beginning of the 1980s, traffic will be protected by a tubular steel shield that will advance in step with tunnel widening advance, and which will always be inserted in the stretch of the old tunnel that remains to be widened.

The prototype of the machine, that certainly deserves its multipurpose definition, has already been constructed and tested (photo No 1 and 2).

As concerns the shield, which was kept separate from the machine, this was also tested for the first time when it was inserted in a tunnel to protect traffic as can be seen in photo No 3.

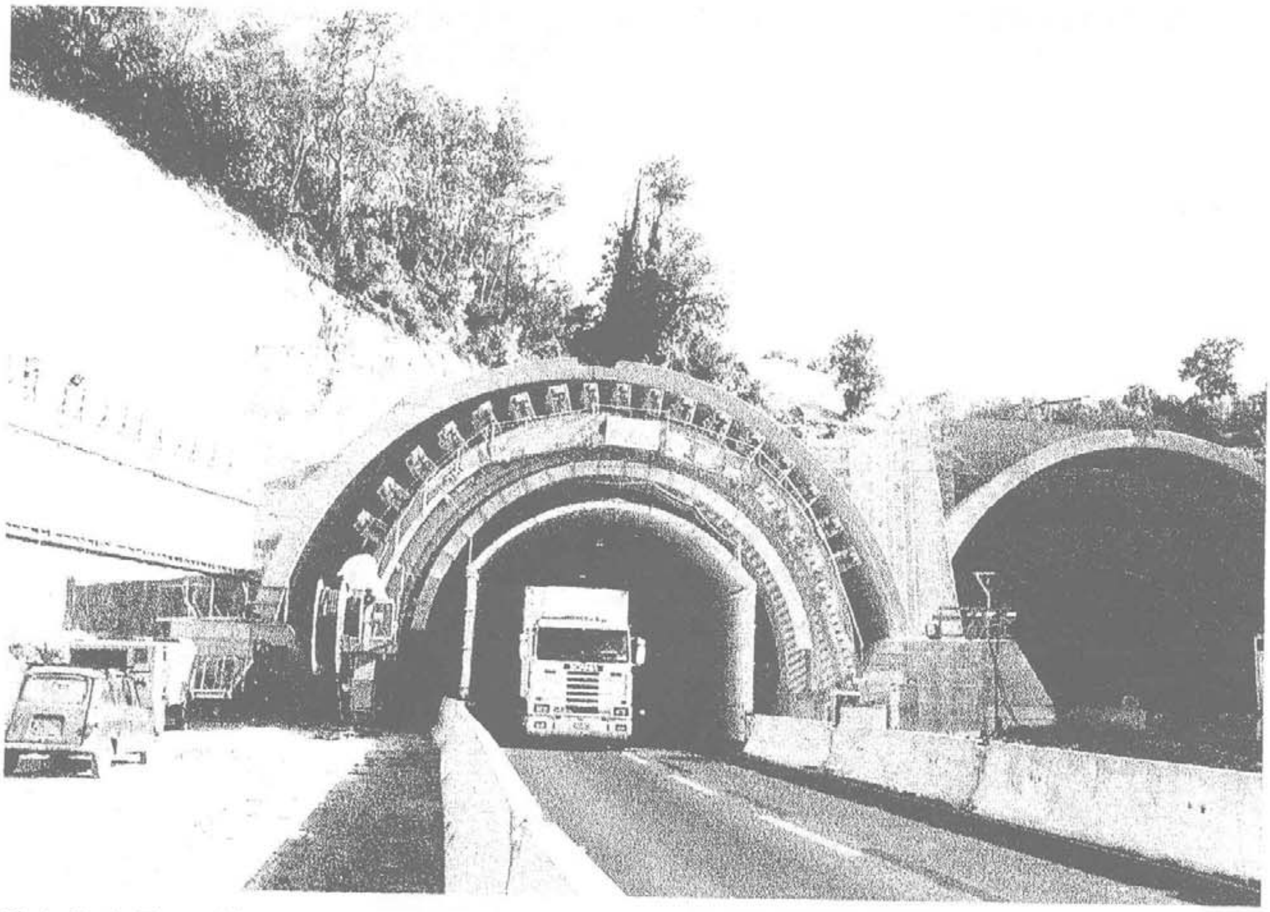


Photo No 2 The multipurpose machine in a construction site on the Nazzano tunnel

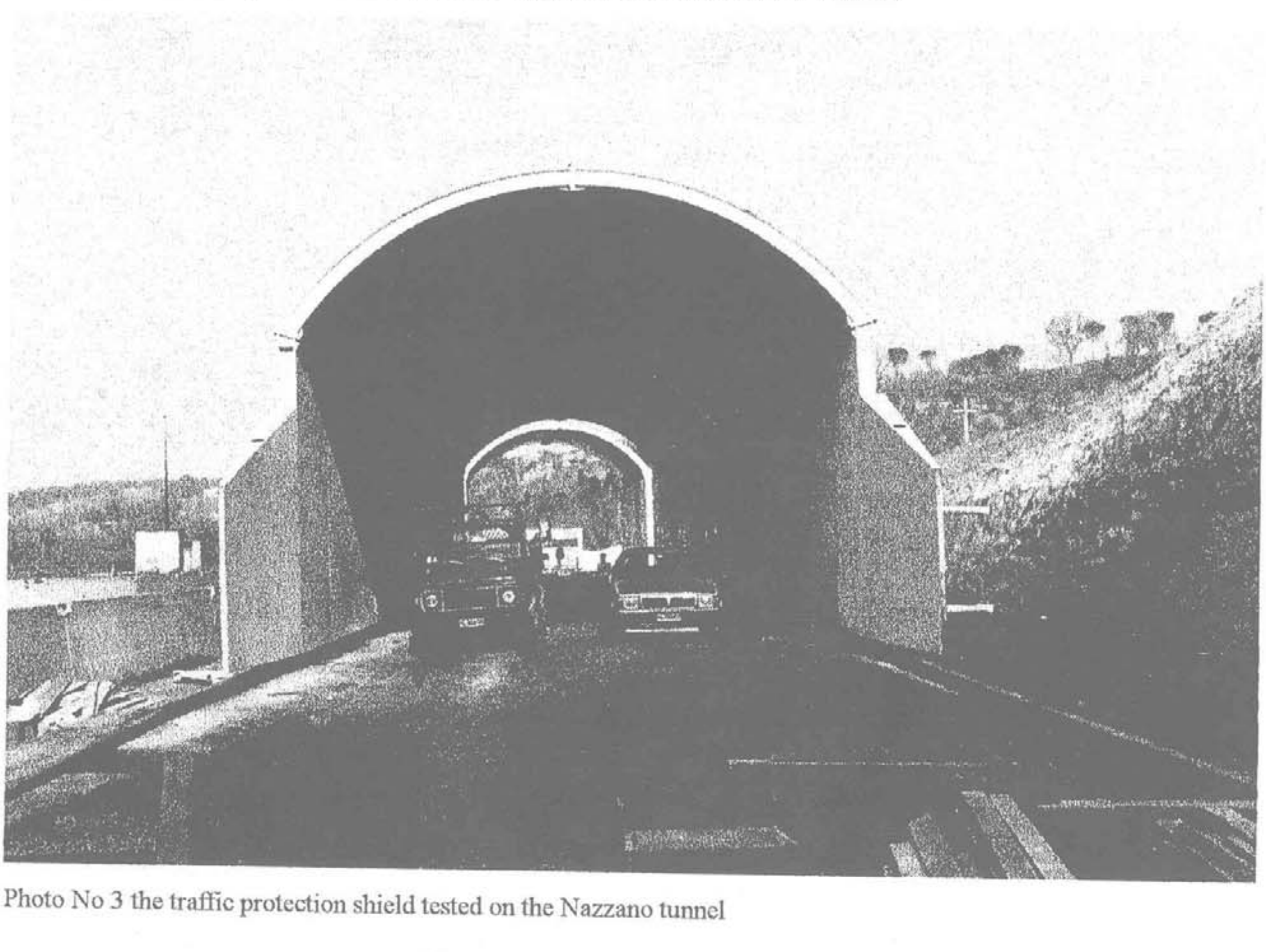
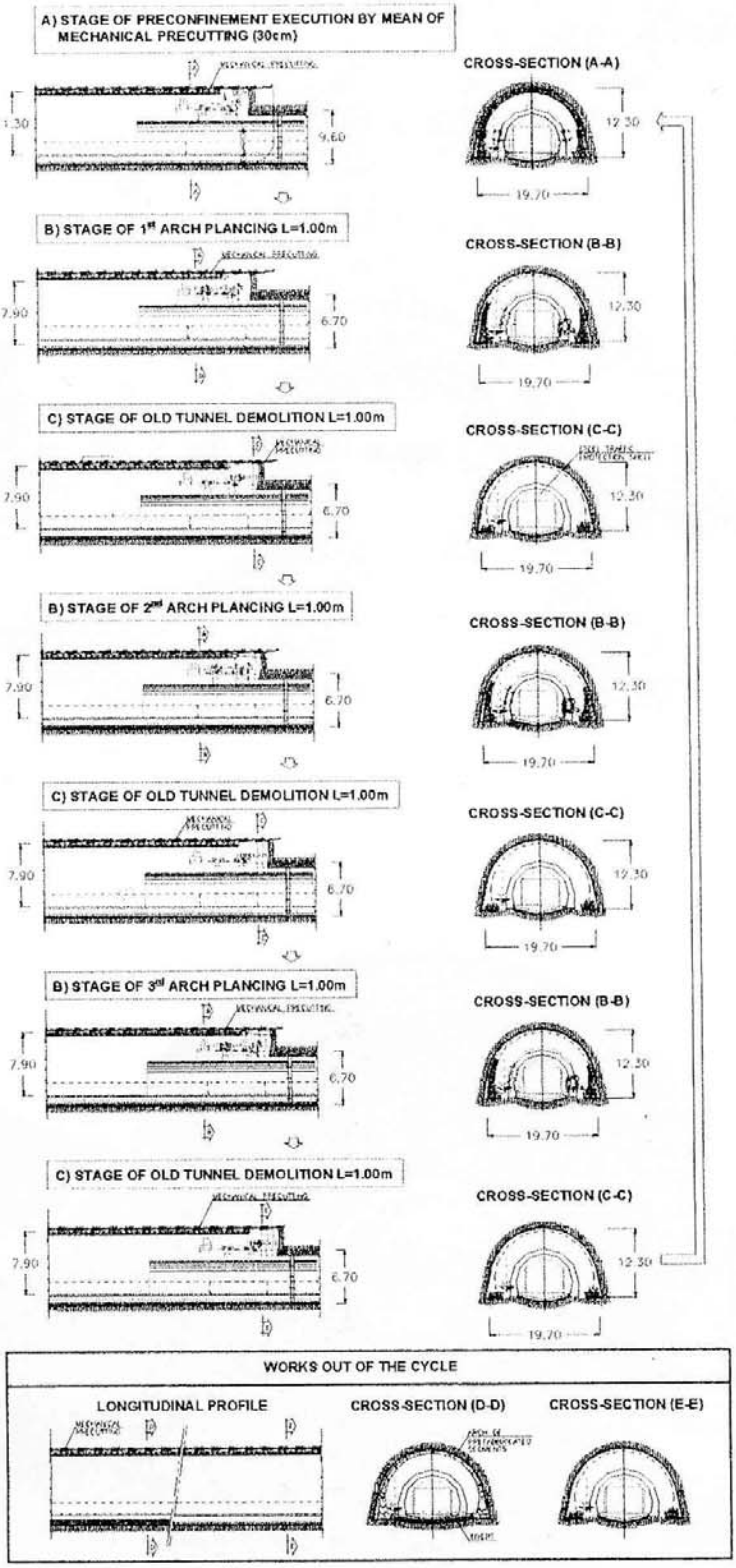


Photo No 3 the traffic protection shield tested on the Nazzano tunnel

THE DIFFERENT PHASES OF THE WIDENING OF A HIGHWAY TUNNEL EMPLOYING THE COMBINED MECHANICAL PRE-CUTTING AND ACTIVE ARCH METHODS



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