DRAINAGE AND STABILIZATION OF THE SOIL SURROUNDING A TUNNEL OF THE PARIS UNDERGROUND RAILWAY, BY MEANS OF SYSTEMATIC INJECTIONS OF CHEMICAL PRODUCTS UNDER PRESSURE, IN PRESENCE OF SELENITIC GROUND-WATER

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SUMMARY OF THE FRENCH REPORT

The lines No.8 and No.9 of the Paris Metro follow a common superposed itinerary under the Grands Boulevards, from the Carrefour Richelieu-Drouot to the Place de la République. The work on this stretch is a straight run and forms a huge culvert in masonry of pebble-concrete. It comprises 4 one-way tunnels, superposed 2 by 2.

The whole set is based on sand and gravel under which lies marl. The latter is flush with the floor of the culvert. The soil is soaked in ground-water to 2/3 of the height of the structure. The ground-water is saturated with lime sulphate.

Despite precautions taken during building operations (carried out from 1926 to 1931), the concrete of the lower tunnels was eroded in some places by running water and did not remain as compact as the presence of sulphated ground-water would normally require.

Shortly after the opening of the line, there were extensive infiltrations. The concrete attacked by aggressive waters was breaking up. The situation was rapidly deteriorating. As local repairs had not given any lasting results it was decided in 1943 to treat the damaged structures systematically with injections of different products adapted to local conditions and the desired effect.

The problem was twofold :

1. Strengthen the loosened masonry,
2. Stabilize the surrounding soil, weakened through the loss of its fine elements, washed away by infiltrations; render the soil impervious so as to set up around the structures a screen to protect the masonry from contact with the sulphated groundwater.

The successful strengthening of the masonry was of real interest, but does not fall within the scope of the 9th section. The second part of the problem, on the contrary, will be the main subject of our paper.

As stated above, the structure is set in sand and gravel. The floor of the structure is supported mainly by dense marl. Sampling, carried out through the lateral walls made it possible to determine the best products to give the jet a sufficient penetration to set up the impervious screen required. According to local possibilities of boring, sometimes hypersulphated cement was used, but more often specially treated marl, the fineness of which was adapted to the grading of the soil, by stabilizing the suspension through admixture of sodium silicate to obviate dispersion. This method yielded satisfactory results in regard to treatment of the soil along the whole height of the lateral walls.

It has already been said that the invert of the whole structure was laid on dense marl. But in certain places between the invert and the marl, extensive lenses of very fine sand were noted; these lenses were completely impervious to cement and to the finest treated marls.

The consolidation of these lenses was indispensable, for the infiltrations proceeding therefrom were rapidly aggravated by erosion and the washing away of the smaller particles, and, loosening of the ground, might cause failure of the floor through settlement of the structure under the vibrations of the trains.

A chemical treatment was worked out: Silica jelly from soda silicate and soda aluminate solutions, was created inside the body of the sandy patches themselves, which reached a depth of 0.70 m (2'4") along the axis of the structure. The content of the leachings, their proportion in the mixture and the method of injection having been determined by numerous field and laboratory tests.

The result obtained was remarkable. Samples of the soil, taken several months after the completion of the works, showed that sand and silica jelly had formed a practically impervious mass consistent enough to prevent any displacement.

The execution of the work, requiring a great number of borings through the walls of the tunnel, had to be made with a revolving hand-drill. The injections were carried out with a ram-pump, capable of injecting solutions under a pressure of 20 kg/cm2 (140 psi.) and with a continuous control of pressure. The materials were mixed in a rotating double-drum mixer with intermediate sieve. All the mechanical devices were driven by compressed air. The nozzles were made of tubes, fitted with watertight caps and adjutages for discharge pipes and a pressure-gauge.

The whole set of materials was placed on a workshop train. The work was carried out exclusively by night, during normal hours of interruption and without any perceptible hindrance to the working of the whole Metro network.

The choice of the methods and the execution of the works had been adjudicated after submission of competing tenders, to the firm "Fondations et Travaux Hydrauliques" which fully achieved the desired results.

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