IX c 14

DISADVANTAGES PRESENTED BY INJECTIONS OF CLAY SUSPENSIONS

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Les Travaux Souterrains, Paris

SUMMARY OF THE FRENCH REPORT

Contrary to cement suspensions used in injections - which fix chemically when curing a considerable quantity of water serving for crystallization of silicates, aluminates and silico-aluminates - common clay suspensions usually absorb by means of simple physical linking a relatively reduced proportion of water. Consolidation of a porous medium through elutriation of clay, will therefore be defective.

Whereas a suspension of cement is easy to prepare by simple mixing, a clay suspension, stable enough to permit injection without the risk of premature sedimentation, requires special attention.

The problem we have set ourselves is to :

1e Prepare a stable suspension of clay;
2e Produce in the soil a floculation after injection;
3e Obtain a sedimentation containing a maximum of absorbed water.

Moreover, we purposedly confined ourselves to the use of common clay. We endeavoured to prepare therewith suspensions presenting in a lesser degree the characteristics of special and expensive clays such as Bentonites, Water-jellies, Stearic Clays.

Preparation of the Suspensions :

1e Clay suspension is stabilized by addition of a solution of potassium soda, sodium carbonate or sodium silicate. The concentration of alkali or alkaline salt depends on the density of the suspension, on the nature of the clay and that of the delution water.

2e Floculation of the above stable suspension is obtained by adding a certain quantity of strong electrolyte, i.e. sulfate of alumina; one remarks that the floculated sediment has a variable volume according to the amount of electrolyte which has been added. This volume reaches a maximum value for a determined amount of floculent. The mix corresponding to this maximum value of sediment, is used for the injection. Thus, the greatest possible quantity of water is retained in the sediment in the shape of water physically linked with the clay, and the efficiency of the injection is considerably increased.

3e The suspension thus prepared produces a flaky sediment of very considerable volume which may amount to 80 or 90% of the total volume of the suspension. Besides, the suspension presents such a degree of viscosity and density, that it is possible to add thereto a high proportion of coarse clay or loam. By this procedure loose soils with a high ratio of voids may be treated more economically.

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IX c 15

THE LAC NOIR DAM
CONSOLIDATION AND WATER-PROOFING

ENTREPRISE DE FONDATIONS ET TRAVAUX HYDRAULIQUES, Paris

SUMMARY OF THE FRENCH REPORT

GENERAL

Above Colmar, in the Vosges, there are two lakes, called LAC NOIR and LAC BLANC and as far back as 1850 hydraulic works were undertaken with the object of regulation the flow of streams coming out of the lake and watering the Orbey valley in the Haut-Rhin Department.

These lakes are of glacial origin and belong to the type known as 'periglacial dolina'. They are bounded on one side by the natural dam formed by the glacial moraine composed of a mass of sandy clay containing granite blocks of all sizes.

The natural level of the Lac Noir is 945 metres (3100 feet).

Works composed successively of a plain wall, a dam built of all in morainic material with a central core, and then a dam with a wall at the foot and a facing on the water side were built between 1850 and 1905.

In 1932 a hydro-electric scheme for the harnessing of the Lac Noir and the Lac Blanc, was carried out by the Société Hydroéléctrique des Vosges.

A deeper foot wall was built in front of the Lac Noir dam. Lac Noir, hitherto a seasonal reservoir with a slow variation of level, became a daily reservoir with an extremely rapid variation of level, up to 18 metres (60 feet) per day.

The main characteristics of the job are as follows:

Length along the crown of the Dam.	76 metres	250 feet
Height	15 -	50 -
Height above sea level of the crown	954.5 -	3130 -

Height above sea level of the maximum rise	951.5	-	3118	-
Height above sea level of the minimum water level	930	-	3051	-
Height above sea level of the Thalweg beneath the construction (circa)	942	-	3092	-
Height above sea level of the watertight base of the moraine	925	-	3036	-
Height above sea level of the lake bottom	900	-	2950	-

As soon as the plant was in operation extremely serious erosion became apparent within and beneath the Dam, provoking settlement and failure of the rigid structures.

When the lake was full an upsurge took place on the water side of the Dam and when the water level went down rapidly, large fissures with sand washing through them appeared on all the banks in front of the Dam.

Different observations were made and among the most significant were:

Loss of water measured below the Dam in 1933,40 to 50 litres per sec.

Loss of water measured below the Dam in 1939, 80 litres per sec.

Sand scour below the dam, estimated at 220 litres per day.

Sand scour above the Dam, varied from a few dozen litres to several hundred litres per day according to the rapidity of the fall of the lake's water level.

WATERPROOFING AND CONSOLODATION SURVEY

Faced with these alarming conditions, the Société Hydroéléctrique des Vosges made a systematic study of the undertaking and of the subsoil. It then became apparent:

-That the Dam was built on a Moraine of which the upper part had suffered some degree of water erosion and wherein there was a considerable amount of water circulating.

-That the lake side facing and the foot wall of the Dam were no longer acting as a wa ter tight panel since the water level inside the Dam varied synchronously with that of the Lake. There was nothing left to assure the water tightness of the structure except the old central wall whereof the foundation was very precarious.

-That the considerable leaks and fissures observed on the lake side of the Dam at low water were caused by water accumulated in the body of the Dam and in the subsoil when the lake rose and flowed back to the Lake during sharp falls in the water level.

Different projects for waterproofing and consolidation were contemplated, some of the proposed solutions were of a civil engineering type whereas others called for special waterproofing processes and soil consolidation.

It was laid down that the project was to preserve the appearance of the Dam and this condition would have been difficult to observe had a civil engineering solution been adopted.

The consolidation project finally adopted x) called for,

1. Filling of the Dam between the water side and central panels.
2. Embedded injection in depth and in width in the Moraine to make it watertight where it faces the foot wall.
3. Regeneration of the panel facing the lake and of the foot wall and binding of these structures to the subsoil and encompassing earthworks by injection.
4. Filling of erosion fissures in the soil.
5. Treatment of the soil encompassing the drainage channels.

CHARACTERISTICS OF THE SUBSOIL

From the numerous grading analyses of the moraine, carried out by the Soil mechanics Laboratories of Paris and Zurich, it appears that the fine elements of diameter 0.1 mm. had been washed out of certain layers of the moraine.

This had been made possible by the fact that it is a peculiarity of moraines, unless they are corrected, that their coarser elements do not act as self filters for the finer elements assuring its watertightness. Eventually therefore the infiltrations carried away the fine elements of certain layers transforming the whole of this watertight moraine into relatively permeable alluvium by the forming of privileged circulation channels and fissures.

In particular the structure of the Dam itself, which was made up of morainic elements borrowed nearby was completely washed out in its upper part and no longer contained anything but very coarse elements (big stones). On the other hand, however, the fine, clean and very permeable sand had accumulated in the lower part of the Dam.

TREATMENT BY INJECTION

The injection treatment consisted therefore of filling up zones composed almost entirely of very coarse elements (big stones) as well as waterproofing the layers of very fine sand which had to be reached through material of every degree of permeability and grain size. One had therefore to resort to a means of progressive obturation, starting with the major voids to end up with the smallest and for this it was necessary to use four different processes of injection:

- -Sand-cement-clay mix for filling the major voids.
- -Pure cement with possible addition of clay for normal voids.
- -Waterproofed clay for impermeabilisation of coarse sand into which the cement could not penetrate.
- -and, finally, treatment of the finest sands with silicate gel.

According to circumstances the injection was effected downwards by the injecting of borings by degrees and then re-perforating the injected sections downwards or upwards, as the case may be, be means of collar tubes (patented system) wedged into the material by means of a special cement-clay grout.

RESULTS OF TREATMENT - OBSERVATION AND CHECKING.

The different phases of treatment of the Dam and of the ground were systematically controlled as the work progressed:

-By means of piezometers (distributed all over the interested zone) whose variations, in terms of lake level fluctuations, were consistently followed.

-And by means of measuring the losses by infiltration below the Dam and through fiss-

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x) This project was submitted by the Société Sondages-Etanchements-Consolidations-Procédés Rodio.

The work was commenced by this Company and continued by the Entreprise de Fondations et Travaux Hydrauliques, who took over the first mentioned Company.

ures above.

Final control of waterproofing is obtained by filter wells installed below the watertight panel for measuring the total flow of residual losses passing through the panel.

When the work accepted the results were as follows:

- 99.5 % reduction of infiltration through the Dam.
- Total suppression of sand washaway.
- Suppression of fissures above the Dam.

These results were obtained by injecting:

1600	metric tons of	cement.
650	" " "	clay.
585	" " "	fine sand.
416	" " "	chemicals.

The work was carried out without stopping or hindering the work of the plant.

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IX c 16

CLAY-CEMENT MIXTURES IN SOIL INJECTION

SOCIÉTÉ DE SONDAGES, INJECTIONS, FORAGES

SUMMARY OF THE FRENCH REPORT

1. If increasing quantities of clay of suitable qualities are admixed to a given cement, it appears that the mechanical properties of the various samples at first deteriorate but slowly; it is only after an important proportion of clay has been reached (40% to 50% of the mixture, by weight) that these properties deteriorate rapidly.

The observed effects are caused at the same time by two phenomena: one physical, the other chemical. The results obtained are all the better as the clay is finer, and richer in alumina and silica. For example, in the case of clay of medium fineness containing 15% of alumina and 40% of silica, the strength is still about one half of that of pure cement when the proportion of clay reaches 45%, by weight, of the mixture. Beyond that proportion resistance decreases rapidly and shrinkage becomes too important.

The interest of clay-cement mixtures for soil improvement through injection appears clearly. As a matter of fact they generally utilize but a very small fraction of mechanical resistance of the binder. They rarely suffer the addition of inert materials of superior grade than that of the binder. In addition to the economy the following advantages have been established

-Curing time practically unchanged;
-Mixture of finer grade than that of pure cement;
-Greater resistance to corrosion;
-Improved imperviousness and resistance to physical action of water.

2. If a small proportion of clay with marked colloidal properties (for instance bentonite) is added to a mortar or a pure cement paste, and if these newly prepared mixtures are exposed to the action of running water, an important decrease of the usual washaway becomes apparent.

It should be noted that a good fine clay can also be used, provided it is treated specially, with a view to developing its thixotropical properties.

This procedure is very useful, if injections of cement or mortar are to be made in a moving acquiferous medium, liable to washing away the injected materials.

Conclusion. The importance which the admixture of clay to cement presents in many cases can be realized (through the application of either of the two phenomena described above or even of both combined) at a time when extensive works of reconstruction are to be carried out in the best possible economic conditions and particularly in reducing to the greatest possible extent the consumption of scarce and expensive products.

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