Third International Conference on Geotextiles, 1986, Vienna, Austria

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RIVER SILLS AND WATER DIVERTERS MADE OF CONCRETE INJECTED OR REINFORCED CLOTH
WASSERLAUFSCHWELLEN UND -ABWEISER AUS BETONVERFÜLLTEM ODER VERSTÄRKTEM GEWEBE
SEUILS ET DEVIATEURS EN RIVIERE EN TISSUS INJECTES OU ARMES

. As part of EDF development for the site of Ferrières sur Ariège, a large embankment was designed to widely penetrate into the bed of the Ariège River (mean water 40 m^3/s; hundred year flood experienced in 1982: approximately 800 m^3/s). Because it was necessary to slow down the flow rate of the water as it came into contact with the embankment, two sills were constructed, each creating a waterfall of over 1.50 m. These sills were constructed without diverting the river, using riprap covered with concrete injected cloth. In other instances, concrete injected cloths were used to protect certain installations (such as a concrete batching plant on the riverbanks) or to construct sills for measuring stations or fish ladders.

. A reinforced cloth (80 tons per linear meter) was used to form a preliminary cofferdam during water filling of the Garrabet dam. The purpose of this cloth was to raise the banks and restrain waters to a height of 4 m and over a length of 16 m between supports. Other water diverters of a simpler design were provided in underground galleries (6 m diameter).

1 - INTRODUCTION

When, in 1980, the EDF (1) needed to protect the cofferdam bank upstream the temporary diversion of the Ariège River (2), they used geotextile layers as forms, and injected them with motar. These layers were set in place empty on the bank slopes or directly in the water.

The difficulties of controlling the filling procedure under water naturally lead to the use of a more robust geotextile, and the suspended panels were filled with concrete, and then set in place using a crane while the concrete was still wet.

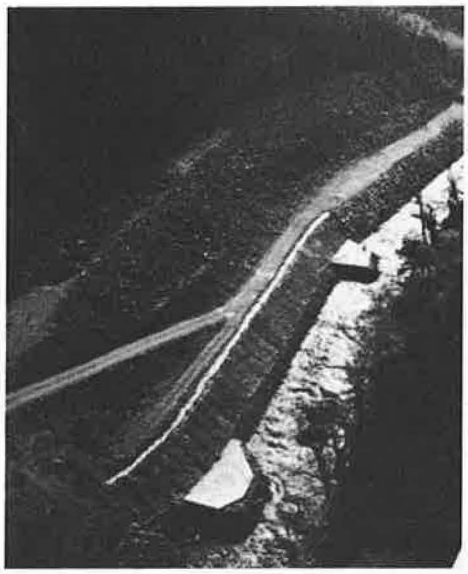
Several other projects were subsequently completed on this same site. The "COFRABETEX" process was perfected during this period and was implemented at a regular industrial pace. It was necessary to improve the quality of the concrete injected, as well as the method used to fill in the pockets created by the seams joining the two geotextile layers (thus it was necessary to improve the quality of the sewing thread to meet with the high resistance of the geotextile layers).

2 - PROJECTS COMPLETED USING CONCRETE INJECTED CLOTHS

The Ariège River is in fact a torrent:
Mean water Qm = 40 m^3/s
Hundred year flood water Q_{100} = 800 m^3/s
(observed in 1982)

(1) EDF, Electricité de France, (French National Electricity Co.)
(2) Ariège, tributary of the Garonne river in the southwest of France

The valley is narrow and any modification of the flow rate would have been incompatible with the stability of the banks (the 1982 flood eroded between 30 and 40,000 m^3 of a slope installed to stabilize a weak bank; the flood swept away the slope, along with a large part of the underlying land).



General view of the development project

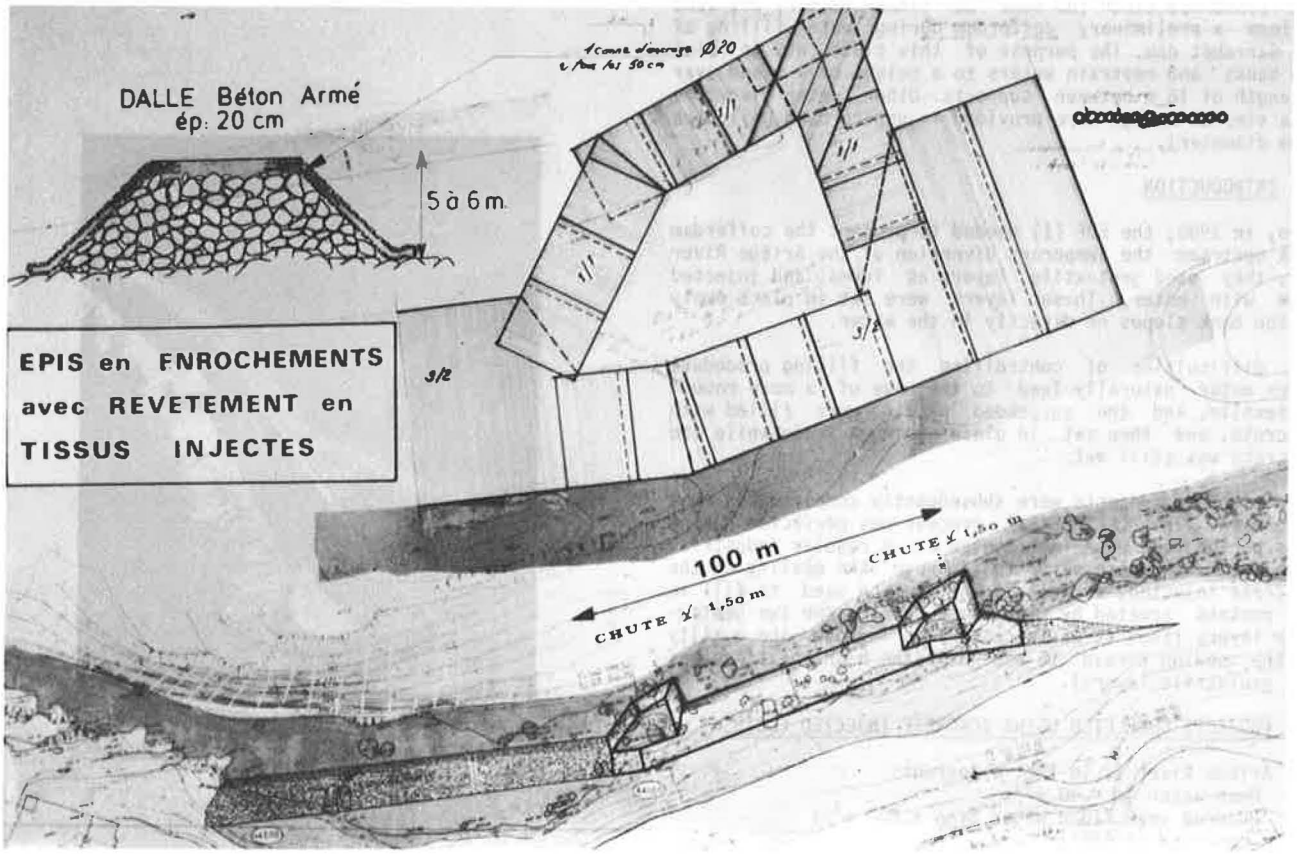
2.1 - Studies showed that it was necessary to stabilize the foot of a morainic cliff. The necessary filling which narrowed the valley had to be protected at the foot against erosion due to increases in the water flow rate, especially during flood periods. In order to control the flow rate, two sills were constructed directly in the river, without water diversion.

The surface of the riprap sills was protected by concrete injected geotextile panels. On the surface, the tops of the panels were joined by a reinforced concrete slab set in place by sinking anchoring rods into the wet concrete. These sills are incomplete, allowing completion in the water without much difficulty, but are as effective as completed sills in flood water periods.

2.2 - In front of the dam (sill elevation 432.80) is the cofferdam at an elevation of 438. According to plans, concrete batching installations will be constructed on this cofferdam. Protection for the concrete batching installation situated in front of the water intake was built inside the soil-constructed cofferdam using concrete injected panels. This protection, which provides against destruction of the cofferdam by flooding (as in 1982), would anchor the concrete batching station in place, and would subsequently be removed to serve as a bank of the funelling channel. The cofferdam has also been protected against light flooding by placing cloths on the downstream side.

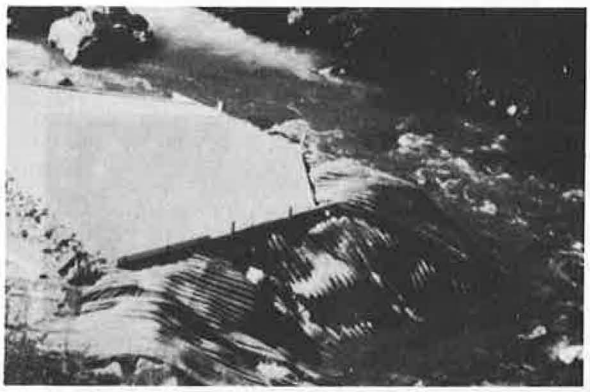
2.3 - At the end of the reservoir, the construction of a measuring station made it necessary to regulate and stabilize the bottom of the river bed. Once again without water diversion, the injected cloths, placed directly on the ripraps, were used to form a sill. Later, the riprap sill was injected with cement mortar, in order to bind the riprap into a more permanent structure. In this example, the injected cloth can be considered as lost formwork.

2.4 - Finally, normal to the plant, a river sill was constructed using the same method. On the right bank a passage, the size of which can be regulated using large blocks, creates an attractive access for migrating fish. Preferably, they should choose this smaller seperate water passageway that has a high flow rate, rather than the larger outflow canal that has a low flow rate and is thus a dead end for the fish.



Plan view of a sill

Anchoring the tops of the "COFRABETEX" layers using the rods of a reinforced concrete slab



View of first completed sill

Partial view of the canal located upstream the first sill

3 - DESCRIPTION OF PROCEDURE

The geotextile chosen was a woven polypropylene with high traction and tear resistance. These properties keep the material from distorting while loaded, and favour precise installation (providing precise coverage, with a full or empty tube).

3.1 - The cloth used, "ROBUSTA 500", was tested at the Toulouse Regional Bridges and Roads Laboratory:

- Mean surface mass	: 504 g/m^2
- Mean thickness	: 1.574 mm
- Mesh aperture	: O_{95} = 250 µm
- Mean traction resistance	:
. Working direction	: 90.4 KN/m
. Crosswise direction	: 86.7 KN/m
- Elongation	
. Working direction	: 8.3%
. Crosswise direction	: 6.5%
- Slow tear resistance	
. Working direction	: 1.25 KN
. Crosswise direction	: 1.65 KN

3.2 - Delft Laboratory tested the sensitivity of the geotextile to corrosive agents:

- Excellent chemical resistance to pH levels of higher than 2.

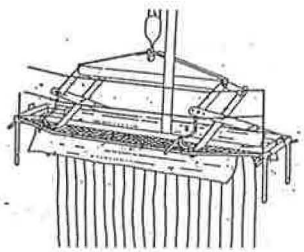
- Excellent resistance to micro-organisms (fungus, bacteria, micro-algae, etc.).

- The polypropylene fibres were treated against sensitivity to U.V. rays (experiments in a salt-water environment for over 4 years, with hygrometric variations and maximum solar irradiation, confirm high resistance at the salt works in the south-west of France).

3.3 - The seams, which were originally sewn using a polypropylene thread, are now sewn with a Kevlar thread (resistance = 100 N/mm^2), and no longer pose the problem of bursting during filling of the tubes.

The 25 cm spacing between seams forms an injected tube of 16 cm in diameter and leaves a porous horizon between the tubes that seems sufficient to allow seepage flow of trapped water.

3.4 - The filling of the panels requires the use of a lifting beam developed specifically to both maintain the opening at the top of the tubes and to support the entire weight of the filled cloth. A worker is present on the lifting beam and directs the filling of the tubes, alternately on the right then on the left, in order to maintain proper balance.



View of lifting beam and the "COFRABETEX" layer during filling

Guidage de la nappe

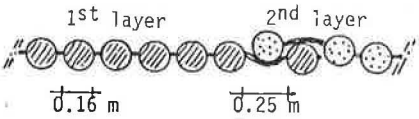
Mise en place du béton

3.5 - The concrete used had a maximum grain of 20 mm, a dosage of 300 kg, with a plasticizer additive (acrylic type in an aqueous phase). The use of a thinning agent would further improve the working characteristics and quality of the finished product (less water, with better plasticity for approximately 3 hours).

3.6 - The work procedure requires specific worksite material, including:

- a concrete truck mixer
- a low-power concrete pump
- a 360° swivel crane with a lifting power of 200 KN/m.

The injected panels represent a weight of 1 ton per linear meter for a width of 3.40 m, when the tubes are filled with concrete.



4 - OTHER USES OF REINFORCED OR NON-REINFORCED DIVERTERS

4.1 - During the start-up of the dam, it was necessary to seal off the temporary diversion of the water flow, and a preliminary cofferdam was designed to facilitate this operation. The use of reinforced cloths (traction resistance 800 KN/m) was considered in designing this cofferdam.

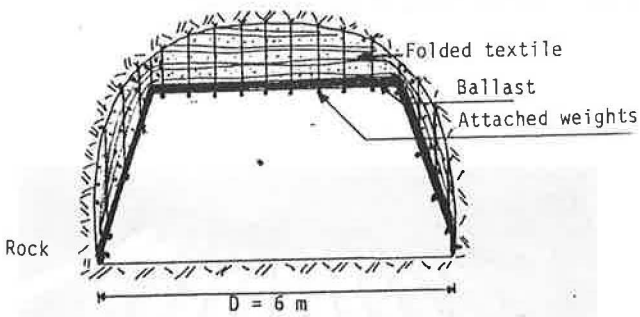
4.1.1 - The "ROBUSTA JUMBOMAT" cloth is a polypropylene geotextile (2000 g/m^2), woven with a metal weft of non-oxidizing wires, 1.2 mm in diameter.

4.1.2 - The chosen design had to allow a pocket to be formed in order to limit load stress (4 m of water) to 700 KN, the opening to be sealed off being 12 m, with a return of 4 m.

4.1.3 - A surface impermeability treatment, using a polymerizable bituminous emulsion, was added at the last moment, in order to ensure the impermeability, which was largely sufficient in our case.

4.1.4 - Unfortunately it was impossible to complete the installation operation, in spite of having the necessary equipment available (i.e. cranes), due to a lengthwise shortage of material. It seems that the most likely hypothesis regarding this shortage is attributable to a shrinkage of a few centimeters that occurred during the surface impermeability treatment described in par. 4.1.3. For its part, EDF does not feel that this setback rules out the use of such a procedure.

4.2 - In the underground galleries, non-reinforced polypropylene curtains were suspended from the ceiling to drop down in case of heavy water flows and would serve as safety water diverters for the worksite and plant, situated downstream. Water flow in the underground galleries could thus be controlled, with the curtains attached to the ceiling and ready to drop into place instantly (with the help of attached weights).



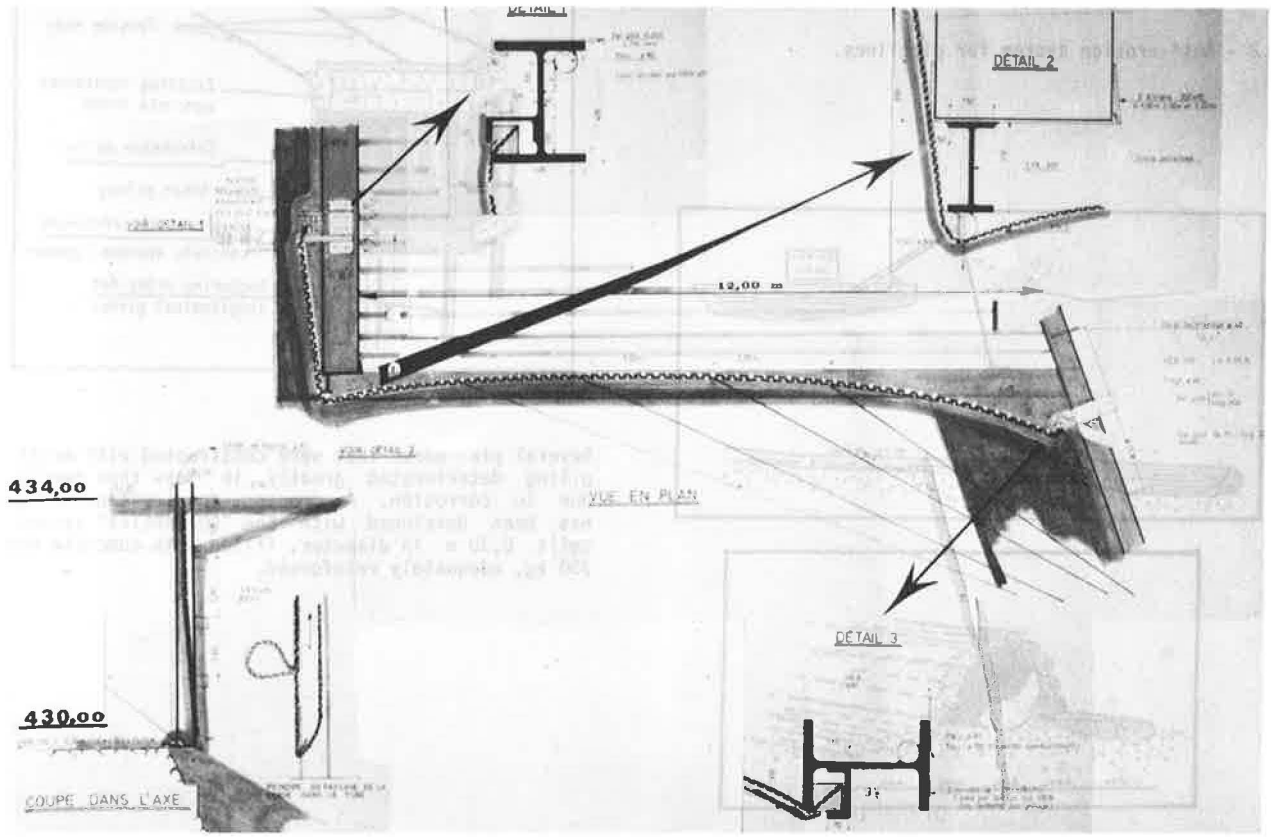


Diagram of the preliminary cofferdam layer at the temporary deviation

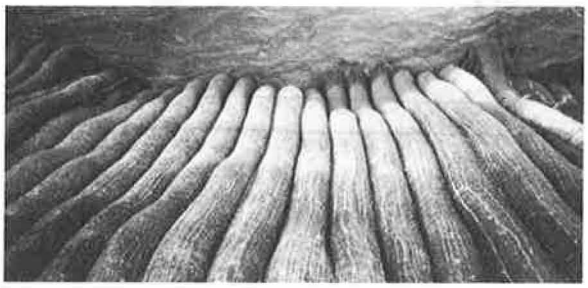
5 - CONCLUSION

5.1 - After these various tests, the described injected cloth procedure seems perfected, has an acceptable cost, and solves problems which were difficult to treat using traditional methods.

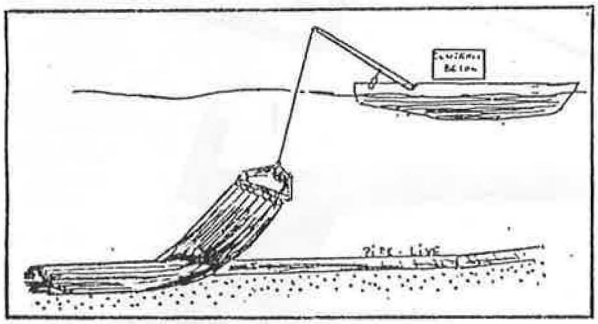
5.2 - The rate of installation can reach 800 to 1000 m^2 per day per work station.

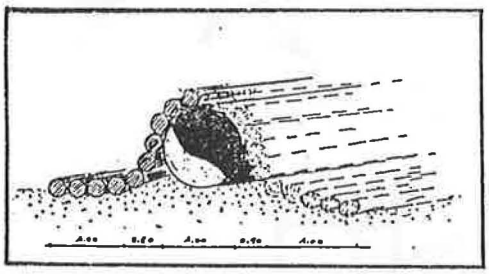
5.3 - There exist various other uses, which have also undergone these tests, such as:

5.3.1 - Various forms of bank protection.

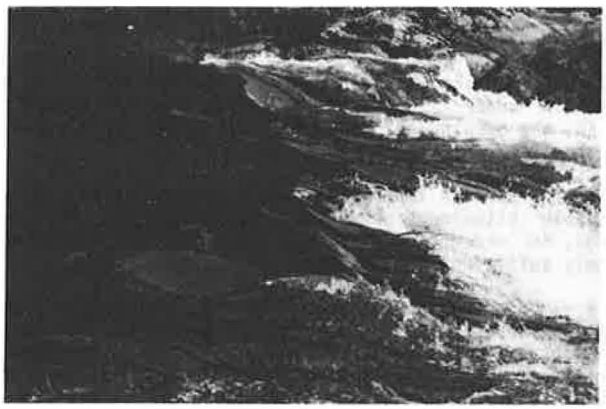


5.3.2 - Anti-erosion system for pipelines.

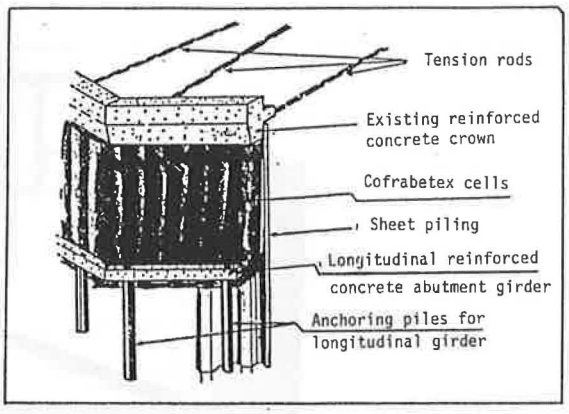




5.3.3 - Fish ladders: It was discovered, during construction of the sills at Ferrières, that the tubular shape of the cells facilitates the passage of the fish. These sills thus become preferred passageways.



5.3.4 - Pier restoration.



Several pier works that were constructed with metal sheet piling deteriorated greatly in less than twenty years due to corrosion. A process for restructuring piers has been developed with the "COFRABETEX" system using cells 0,30 m in diameter, filled with concrete dosed at 350 kg, adequately reinforced.