GEOMEMBRANE WATERPROOFING FOR REHABILITATION OF CONCRETE AND MASONRY DAMS LAGO NERO DAM, ITALY

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Italian experience of using geomembranes for the rehabilitation works on concrete or masonry dams and spillways is very significant. In 1979 a complete waterproofing of the upstream face of the Lago Nero dam was engineered using a geocomposite formed by a PVC geomembrane thermocoupled to a polyester geotextile. The geotextile was prestressed and fastened to the main structure of the dam with specially designed steel ribs.

THE DAM

The dam, built in 1929/1934 and owned by ENEL (the Italian Electricity Company), is located in the high valley of Serio River, Italian Alps, at an El. 2,000 m asl. It is a massive concrete gravity structure with a maximum height of about 40 m. Its length at crest level is 146 m. The upstream face surface is 3,500 m^2. The capacity of the reservoir approximates 3,350,000 m^3.

REHABILITATION DESIGN

As a consequence of the lack of preliminary testing of the concrete and poor construction procedures, the dam had seepage problems through its foundation and its body. Degradation of the structure increased despite various repairs (Photo 1). In 1979 major remedial works, including reinforcement of the foundation, restoration of the downstream face, loading the central portion of the wall etc., were completed. The most interesting part of this work was the installation of a waterproofing geomembrane on the upstream face (Photo 2).

ENEL discarded other alternatives such as reinforced gunite or steel plate membrane and chose the installation of a synthetic geomembrane. This was selected because of simplicity of installation, especially in regards to the covering of structural joints, rapidity of construction, low costs, and ease of future maintenance and repairs.

The problems to be dealt with were:

- choice of the geomembrane's synthetic material,
- installation procedures for a sub-vertical face, and
- drainage of condensation water behind the geomembrane.

GEOMEMBRANE SELECTION

ENEL's CRIS laboratories tested the different geomembranes provided by manufacturers in order to verify their main characteristics and suitability.

Sibelon CNT 2800, a particular brand of extruded PVC flexibilized and stabilized (now manufactured by Sibelon, Novara, Italy) was finally chosen. Test results are given in Table 1. The choice of this geomembrane was made not only because of its good properties in resistance, deformability and welding potential, but also because of previous successful experiences on the part of ENEL and others in the installation of the same type of geomembrane in similar environment (like Lago Miller dam).

Table 1. General properties of the geomembrane from tests at ENEL-CRIS laboratory.

General Properties	Test Method	Sibelon
Thickness (mm)	ASTM D374-79	1.93
Tensile strength (MPa)	ASTM D638M-81	18.0
Strain at failure (%)	ASTM D638M-81	285
Moisture vapour perm. (g/m^2 in 24h)	ASTM D1653-72	3.2
Abrasion test (mm^3/1000 turns)	ASTM D1044-78	60

The geomembrane was manufactured in a width of 2.05 m and a length, depending on the structure to be covered, so as to avoid horizontal seams. The colour was a light grey shade. A polyester needle punched nonwoven polyester geotextile was heat coupled during manufacturing. The geotextile is 1.95 m in width and has a mass per unit area of 200 g/m^2.

GEOSYNTHETIC INSTALLATION

The PVC geocomposite was installed with an original system, now patented by the installer C.A.R.P.I., Oleggio, Italy. This system is based on the use of metallic ribs. It allows continuous fastening along vertical lines, horizontal prestressing which eliminates sagging due to self weight, and acts as the main drainage system by means of small holes along the side of the ribs themselves.

The geotextile provides protection against puncturing resulting from the existing coarse surface on the upstream facing. It is also designed to provide local drainage so as to eliminate the water between the concrete body of the dam and the geomembrane.

Particular attention was devoted to the waterproofing of the base of the upstream face. An additional concrete wall was poured along the interior borders of the dam.

Mechanical fastening of the geocomposite to the wall was made by means of metal plates and anchors which were then tested at 2 MPa pressure. The testing

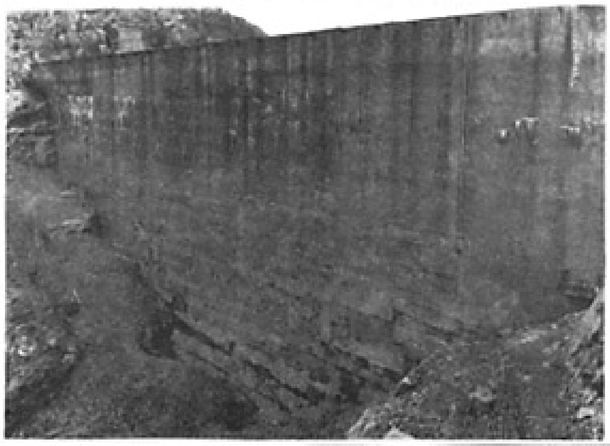

Photo 1. Lago Nero Dam before rehabilitation.

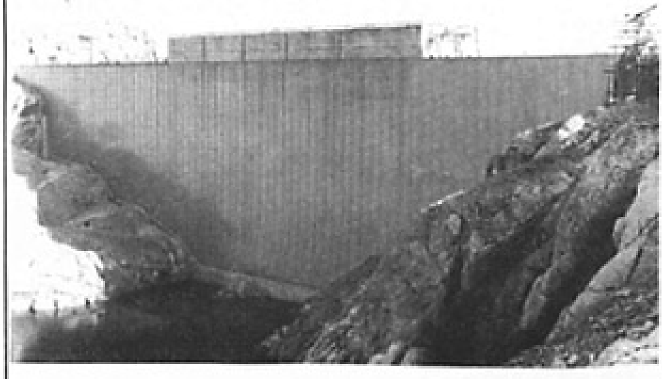

Photo 2. Lago Nero Dam after installation of geomembrane.

confirmed the water tightness of the system. The installation of the geomembrane was performed employing self-hoisting platforms secured to the dam's crest. The installation took 90 days for completion.

PERFORMANCE

Daily measurements of water losses showed a maximum total loss of 2.7 l/s. Only 14% of the total losses were attributable to the PVC geomembrane.

Because of the importance of this application, regular inspections are carried out on site, whenever the reservoir is drained. These inspections have ensured that no yielding or loosening of the geocomposite nor any other detectable alteration has taken place. The general behaviour has been satisfactory.

DURABILITY

In 1976 a previous application of a PVC geomembrane made by Sibelon was carried out on the upstream face of a masonry dam, the 11 m high Lago Miller dam, built between 1925 and 1926 and owned by ENEL. Table 2 summarizes mechanical characteristics of samples taken in 1985. The geomembrane is exposed to the action of ice and of UV as Lago Miller dam is at El. 2,170 m asl.

The results show that permanence of the dead load causes an increase in the longitudinal tensile strength, while longitudinal strain at failure tends to decrease. The strain decrease makes the material more rigid. The results are encouraging, due to the long period of exposure.

CONCLUSIONS

The main benefits involved in the geocomposite solution are:

Table 2. Results of tensile tests conducted at ENEL-CRIS on Sibelon PVC geomembrane after 9 years in operation at Lago Miller Dam (El. 2,170 m).

Tensile test (UNI 8202/8)	Longitudinal (Vertical)	Transversal (Horizontal)
Tensile strength (MPa)	21	15.4
Strain at failure (%)	258	284

- total waterproofing of construction joints,
- new and efficient upstream face drainage system, created by the geotextile and the metallic vertical ribs,
- prefabrication off the site,
- low cost of civil works for preparation of the face,
- reduced time of installation,
- easy and practically cost-free maintenance,
- long durability,
- competitive price of first installation.

The described patented method is suitable for most types of dams, as proved by the following list, including name, country of the dam and year of geomembrane installation:

- masonry gravity dams (Italy: Lago Miller/1976, Camposecco/1992)
- concrete gravity dams (Italy: Lago Nero/1980, Lago Barbellino/1987, Lago Cignana/1989; France: Migoelou/1989, Chambon/1991; Portugal: Pracana/1992)
- multiple arches concrete dams (Italy: Lago Molato/1985, Pian Sapejo/1990, Ceresole/1992)
- concrete arch dam (Italy: Publino/1989)
- roller compacted concrete dams (France: Riou/1990; Honduras: Concepcion/1991)
- embankment dams (Italy: Gorghiglio/1979, Valle Cornuta/1990, Saforada/1992; France: Crueize/1988)
- cofferdam (Italy: Alento/1988)

On the basis of the results obtained so far, this system has proved to be highly suitable both for maintenance and new construction purposes, provided that adequate attention is given to all installation details.

REFERENCES

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