PVC geomembranes for dams & reservoirs

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Among the large family of geomembranes, PVC geocomposites have a very long record of successful applications in dams, reservoirs, canals, hydraulic tunnels and shafts, both in exposed and covered position.
PVC waterproofing geomembrane

**Key properties**

* Flexibility, with ultimate deformation ≈ 300%
* Durability, long functional life even when exposed in severe environment
  * > 40 years from field experience (in the Alps, at > 2,000 m a.s.l)
  * > 100 years from analytical extrapolations of accelerated aging tests
* Steady performance in cold/hot climates
**Elasticity & Flexibility**

PVC geocomposite is capable to deform, reducing stresses in the material.

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**Puncture and burst resistance**

PVC geomembranes are tested on very aggressive substrates in hydraulic vessel.

Pressure vessels apply water heads up to 250 m.

The rock "pizza"
Very flexible PVC geocomposite conforms to substrate distributing load.

PVC geocomposite (very flexible and resistant) is not punctured at 100 m hydrostatic head.

Key properties – impact resistance

Impact by floating trees, Salt Springs CFRD dam, USA

PVC geomembrane resist impact by covering rocks.
Exposed or covered geomembrane?

- The progress in the chemical and manufacturing fields allows producing high performance geomembranes
- First EXPOSED installations started >40 years ago. Data from the field show that behaviour of exposed geomembranes after >40 years is still good
- Some exposed geomembranes manufactured with modern techniques provide expected durability exceeding 100 years, when FULLY EXPOSED
- Therefore selection of exposed/covered geomembrane is a design choice, not only based on expected durability

Exposed geomembranes

Crucial aspects

- The geomembrane itself must resist the applied loads
- The anchorage system must be adequately dimensioned
Exposed geomembranes: Applied loads

* Wind (uplift)
* Subgrade (puncture, burst, differential settlements)
* Action of floating debris/ice
* Environment (UV, temperatures, etc)
* Impounded water (current, waves, type of water)
* Resistance to back pressure (drainage capacity)

Dams

* PVC geomembranes have been used in rehabilitation of existing dams of all types and in new construction
* They have been used for rehabilitation of dams underwater
* Different anchoring system used
* Some examples
Why a dam needs a waterproofing system?

Infiltration of water through the dam deteriorates the structure and affects the stability.

The waterproofing system must intersect the seepage and drain it out.

Geomembranes in dams is not a new solution

* Used in large dams since >60 years. Installed on >350 large dams worldwide

* ICOLD, International Commission on Large Dams has issued 3 theme Bulletins, the most recent in 2010.
**Waterproofings systems components**

* For Concrete, CFRDs and ACFRDs, the anchoring system consists typically of lines of stainless profiles bolted to the surface.

* On granular substrates the face anchorage system generally relies on embedded strips of geocomposite or point anchors.

* Drainage and its discharge is designed in function of the type of structure.

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**Concrete dams**

* Lago Nero, Italy 1980

* Exposed PVC geocomposite

* After 40 years in operation, fully in service, no maintenance required.
Concrete dams

- 31 years in operation
- Cignana, Italy 1988

Concrete dams, pumped storage

- Exposed PVC geocomposite
  - Grosser Mueldhorfersee, Austria 2013
  - Scais, Italy 1993 to 1995
Concrete dams, multiple arch

Butgenbach, Belgium 2004

Gem dam, USA 2007

Concrete dams affected by AAR

Exposed PVC geocomposite

Chambon, France, 2014
Masonry dams have a very aggressive surface

A geotextile, 2000 g/m², is installed on the upstream face, to protect the geomembrane against puncturing.

Masonry dams

Rehabilitation of Kadamparai dam to cure leakage

Rate of leakage before the waterproofing works was 38,000 lpm
Masonry dams

Leakage in the drainage gallery, left abutment, total leakage 38,000 l pm

rate of leakage reduced from 38,000 to 80 lpm.
RCC new dams, geocomposite part of the design

Exposed PVC geomembrane

Miel 1 RCC dam, Colombia, 188 m, 2003
At that time, the highest RCC dam in the world

RCC dams

Olivenhain RCC dam, the first RCC dam in USA in seismic area
REPAIR OF CFRDs

Exposed PVC geocomposite

Pecineagu, Romania 2012

Before repair

After repair

Exposed PVC geocomposite

Yacambu, Venezuela 2014
160 m
REPAIR OF AFRDs

Installation steps

Exposed PVC geocomposite

Moravka, Czech Republic

REPAIR OF EARTHFILL DAMS

Exposed PVC geocomposite

Deep earth anchors, wind velocity >200 km/h

Vaité, French Polynesia
New rockfill earthfill dams with exposed PVC geocomposite

PVC geomembrane strips anchored to extruded curbs

Geomembrane strips anchored to extruded curbs

Exposed PVC geocomposite

Nam Ou VI, Lao, 88 m
Geomembrane strips anchored to extruded curbs

Exposed PVC geocomposite

Sar Chesmeh, Iran

2007-2008 (1st phase)
2010 (2nd phase)

Geomembrane strips anchored to extruded curbs

Exposed PVC geocomposite

Las Bambas, Peru, 235 m, on going
1. Trenches are excavated at slopes and bottom, PVC geomembrane strip is embedded in the trench, and ballasted with porous concrete or soil.

2. Waterproofing PVC liner is welded unto the PVC geomembrane strip.

Geomembrane strips embedded in the embankment

Exposed PVC geocomposite

Bulga, Australia
**PVC geocomposite as a central core, zig-zag configuration**

Ethiopia

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**Waterproofing underwater, rockfill dam**

Exposed PVC geocomposite

Turimiquire CFRD, 113 m, 2009
Waterproofing underwater

Installation of anchoring stainless steel profiles

Installation of geogrid, geotextile, PVC geocomposite

2008
Before repair

2009
After repair
Waterproofing underwater, buttress dam

Exposed PVC geocomposite

Studena buttress dam
Bulgaria, 51 m, 2018
Waterproofing underwater, buttress dam

6/3/2018 8:14:50 AM
GeoTexte installation on left side TP 25

H: 249.4 m
D: 2.68 m
Temp: 20.3 °C

5/28/2018 11:33:56 AM
Concave corner Flat Profile on right side TP 26

H: 290.4 m
D: 19.06 m
Temp: 9.8 °C

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Waterproofing underwater, cracks and joints

Platanovyssi RCC dam, Greece

Before repair

Exposed PVC geocomposite

After repair

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RESERVOIRS

* PVC geomembranes have been used in rehabilitation and new construction

* All types of use

* Mainly exposed applications

* Different anchoring system used

* Some examples

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PVC Geocomposite experience in reservoirs

PVC geocomposite fully covered

Tampa Bay, Florida, USA
drinking water reservoir
PVC Geocomposite experience in reservoirs

PVC geocomposite fully covered

Herbes Blanches, Reunion
Irrigation, hydropower reservoir

Dumanoir, Guadeloupe
irrigation, hydropower
PVC Geocomposite experience in reservoirs

PVC geocomposite fully exposed

Aleko, Bulgaria, hydropower

PVC Geocomposite experience in reservoirs

PVC geocomposite fully exposed

Saint Martin Vesubie, France, EDF hydropower
PVC Geocomposite experience in reservoirs

PVC geocomposite fully exposed

Pico da Urze
Portugal, pumped storage

Panama canal extension
650,000 m² exposed PVC geocomposite
Expected durability >100 years
Selection of anchoring systems for exposed geomembranes

Exposed PVC geocomposite

Anchoring in trenches

Kohrang, Iran

Selection of anchoring systems for exposed geomembranes

Exposed PVC geocomposite

Anchoring in trenches and pretensioning

Panama canal
Selection of anchoring systems for exposed geomembranes

Tensioning profile in rock with deep grouted anchors

Punctual deep anchor in soil with deep grouted anchors
Thank you for your attention

Another time I will speak about use of PVC geomembranes in canals, hydro tunnels, shafts!!

PVC geocomposites in canals

Geocomposite fully covered reinforced concrete cover on slopes and bottom

Ala Bussolengo, Italy 1973
PVC geocomposites in canals

Geocomposite covered only on invert

Concrete ballast

Pointis, France 1989

PVC Geocomposite partially exposed

PVC geocomposite covered in the upper part of the slope for aesthetical reasons

Pernegg, Austria
PVC geocomposites in canals

Exposed geocomposite

Poschiavino, Italy, 1979

Canals

Exposed geocomposite

Tanakpur, India

40+ years in operation, no maintenance required
Exposed PVC geocomposites are smooth and allow increase of water flow.

For installation of geomembranes in canals in flowing water, to reduce costs by avoiding underwater installation of stainless-steel profiles, Carpi developed a revolutionary solution:

An innovative impermeable heavy-duty zip.
Concept of SIBELONMAT®

The invention of the heavy duty zip allowed to develop the SIBELONMAT geomattress

It consists of:

2 PVC geomembranes connected by PVC flexible strips

10 m wide

Custom made length

Connecting zips
Concept of SIBELONMAT®

Double SIBELON C perforated strips as interlayer connection

The mattress is deployed underwater by a specially designed unrolling machine

Adjacent rolls are automatically connected by means of the watertight zip

Cement grout is injected in the mattress to provide ballast against the dragging force of the flow.
Concept of SIBELONMAT®

Deployment of SIBELONMAT

The finished product

Hydraulic tunnels and shafts

Exposed PVC geocomposite, Colombia

Exposed PVC geocomposite, USA

Exposed geocomposite
Thank you for your attention