



## PVC geomembranes for dams & reservoirs

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1

1



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

2

2



3


**PVC waterproofing geomembrane**

**Key properties**

- \* Flexibility, with ultimate deformation  $\approx 300\%$
- \* 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

4

## Elasticity & Flexibility



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



5

5

## 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"

6

6

Very flexible PVC geocomposite conforms to substrate distributing load

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



7

7

## Key properties – impact resistance

Impact by floating trees , Salt Springs CFRD dam, USA



PVC geomembrane resist impact by covering rocks




8

8

## 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

9

## Exposed geomembranes

### Crucial aspects

- \* The geomembrane itself must resist the applied loads
- \* The anchorage system must be adequately dimensioned

10

## 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)

11

11

## Dams

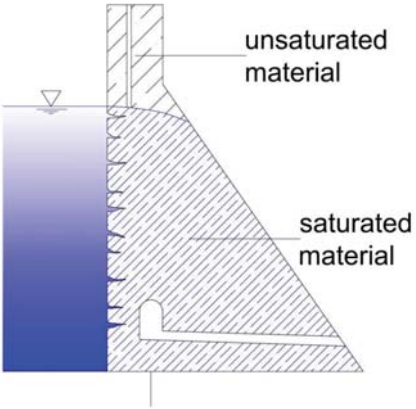


- \* PVC geomembranes have been used in rehabilitation of existing dams of all types and in new construction
- \* They have been used for rehabilitation of dams underwater
- \* Different anchoring system used
- \* Some examples

12



## Why a dam needs a waterproofing system?



unsaturated material

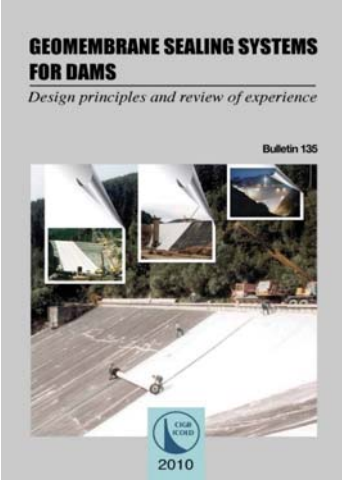
saturated material

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

The waterproofing system must intersect the seepage and drain it out

13

## Geomembranes in dams is not a new solution



**GEOMEMBRANE SEALING SYSTEMS FOR DAMS**  
*Design principles and review of experience*  
Bulletin 135  
2010

- \* 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

14

## Waterproofings systems components

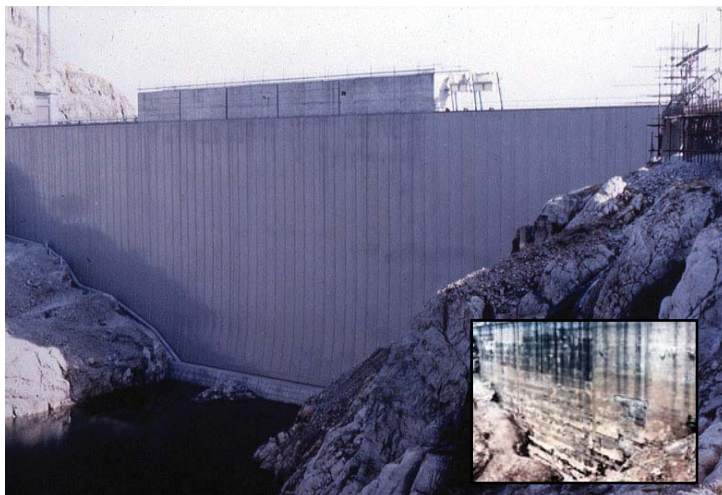


- \* For Concrete, CFRDs and ACFRDs, the anchoring system consists typically of lines of stainless profiles bolted to the surface
- \* On granular substrates the face anchorage system generally relies on embedded strips of geocomposite or point anchors
- \* Drainage and its discharge is designed in function of the type of structure

15

15

## Concrete dams




- \* Lago Nero, Italy 1980
- \* Exposed PVC geocomposite
- \* After 40 years in operation, fully in service, no maintenance required

16

16



## Concrete dams



31 years in operation


\* Cignana, Italy 1988

carpi

17

17

## Concrete dams, pumped storage



Exposed PVC geocomposite

Exposed PVC geocomposite


Grosser Mueldhorfersee, Austria 2013

Scais, Italy 1993 to 1995

18

18

### Concrete dams, multiple arch




**Butgenbach, Belgium 2004**                      **Gem dam, USA 2007**

19

### Concrete dams affected by AAR

**Exposed PVC geocomposite**

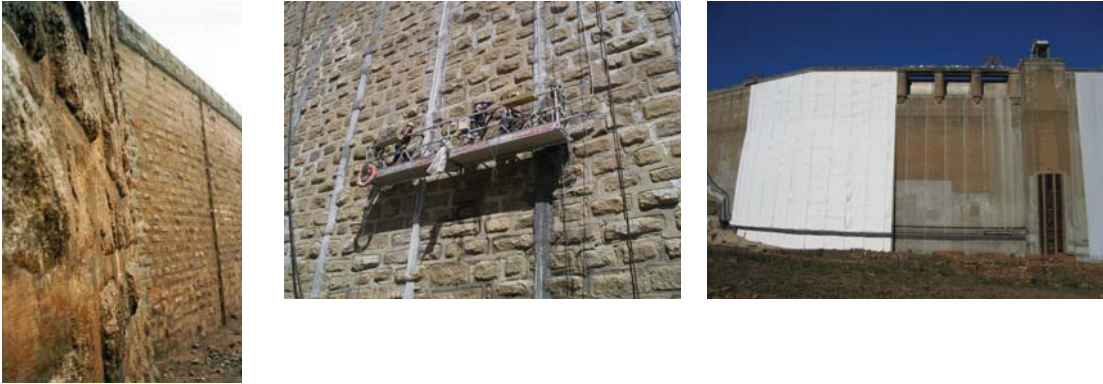


**Chambon, France, 2014**

20

## Masonry dams have a very aggressive surface


A geotextile, 2000 g/m<sup>2</sup>, is installed on the upstream face, to protect the geomembrane against puncturing



21

21

## Masonry dams



Rehabilitation of Kadamparai dam to cure leakage


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

22

22



## Masonry dams



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

23

The slide features a blue header with the text 'Masonry dams' and the IGS logo. Below the header are two side-by-side photographs. The left photograph shows a man in a white shirt and blue shorts standing in a dark, arched tunnel. The right photograph is a close-up of water dripping from the concrete walls of the tunnel. Below the photographs is a caption: 'Leakage in the drainage gallery, left abutment, total leakage 38,000 l pm'. A small number '23' is visible at the bottom center of the slide.

23

## Masonry dams

rate of leakage reduced from 38,000 to 80 lpm.




24

The slide features a blue header with the text 'Masonry dams' and the IGS logo. Below the header is the text 'rate of leakage reduced from 38,000 to 80 lpm.' followed by two side-by-side photographs of a large, multi-bay masonry dam. The left photograph shows the dam from a distance, and the right photograph shows a closer view of the dam's structure. Below the photographs is a small number '24' at the bottom right corner of the slide.

24

## 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

25

25

## RCC dams




Olivenhain RCC dam, the first RCC  
dam in USA in seismic area

26

26

## REPAIR OF CFRDs



Exposed PVC geocomposite

Pecineagu, Romania 2012

carpi

IGS

27

Detailed description: This slide shows a wide-angle view of a dam with a large section of its slope covered in a dark, textured PVC geocomposite. The dam is situated in a valley with forested hills in the background. A 'carpi' logo is visible in the bottom left corner of the image. The text 'Exposed PVC geocomposite' and 'Pecineagu, Romania 2012' is positioned to the right of the image. The IGS logo is in the top right corner, and the number '27' is in the bottom right corner.

27

## REPAIR OF CFRDs



Exposed PVC geocomposite

Yacambu, Venezuela 2014  
160 m

IGS

Detailed description: This slide compares a dam slope before and after repair. The left image, labeled 'Before repair', shows a concrete dam slope with visible vertical joints and some vegetation. The right image, labeled 'After repair', shows the same slope covered with a white PVC geocomposite. The text 'Exposed PVC geocomposite' and 'Yacambu, Venezuela 2014 160 m' is positioned to the right of the images. The IGS logo is in the top right corner.

28



## REPAIR OF AFRDs

Installation steps





Exposed PVC geocomposite

Moravka, Czech Republic

29

29

## REPAIR OF EARTHFILL DAMS



Exposed PVC geocomposite

Deep earth anchors,  
wind velocity >200 km/h

Vaité, French Polynesia

30

30

## New rockfill earthfill dams with exposed PVC geocomposite

### PVC geomembrane strips anchored to extruded curbs

The slide contains three technical diagrams illustrating the construction of rockfill dams with exposed PVC geocomposites. The leftmost diagram shows a cross-section of a dam with 'Curbs' and 'Dam fill'. A note indicates: '"Keys" dug out at suitable intervals to mitigate possible sliding problem'. The middle diagram is a detailed view of the 'concrete surface extruded curbs' and 'SIBELON CNT geocomposite anchoring wings'. The rightmost diagram, titled 'ROCKFILL DAMS EXPOSED WATERPROOFING GEOCOMPOSITE', shows 'EXTRUDED CURBS - CONSTRUCTION STEPS'. It details the 'SIBELON CNT prefabricated geocomposite panel under placement', 'SIBELON CNT prefabricated geocomposite panels welded to anchoring wings', 'waterproofing welds between adjoining panels', and 'waterproof perimeter seal'. The diagram is labeled 'STARTING SECTION - PLACEMENT OF PANELS FRONT VIEW'.

31

31

## Geomembrane strips anchored to extruded curbs

### Exposed PVC geocomposite

The slide features two photographs showing the installation of PVC geocomposite on a dam slope. The left photograph shows a wide view of the slope with multiple parallel strips of grey geocomposite material laid out. The right photograph shows workers on the slope, actively installing and securing the geocomposite strips. The caption below the photographs reads: 'Nam Ou VI, Lao, 88 m'.


Nam Ou VI, Lao, 88 m

32

32

## Geomembrane strips anchored to extruded curbs

Exposed PVC geocomposite



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

Sar Chesmeh, Iran

33

33

## Geomembrane strips anchored to extruded curbs

Exposed PVC geocomposite



Las Bambas, Peru,  
235 m, on going

34

34

### Geomembrane strips embedded in the embankment

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

35

### Geomembrane strips embedded in the embankment

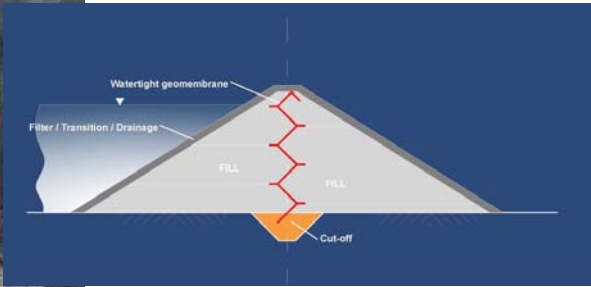
**Exposed PVC geocomposite**

**Bulga, Australia**

36



### PVC geocomposite as a central core, zig-zag configuration



**Ethiopia**

37

37

### Waterproofing underwater, rockfill dam

#### Exposed PVC geocomposite



**Turimiquire CFRD, 113 m, 2009**

38

38

## Waterproofing underwater



Installation of anchoring stainless steel profiles



Installation of geogrid, geotextile, PVC geocomposite

39

39

## Waterproofing underwater



2008



2009



40

40



## Waterproofing underwater, buttress dam

Exposed PVC geocomposite




Studena buttress dam  
Bulgaria, 51 m, 2018

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41

## Waterproofing underwater, buttress dam




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42


## Waterproofing underwater, buttress dam

6/3/2018 8:14:58 AM  
GeoTextile installation on left side TP25



H: 240.4 °  
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: 250.4 °  
D: 19.06 m  
Temp: 9.9 °C

43

43

## Waterproofing underwater, cracks and joints

Platanovrissy RCC dam,  
Greece



Before repair





After repair

Exposed PVC geocomposite

44

44

## RESERVOIRS

- \* PVC geomembranes have been used in rehabilitation and new construction
- \* All types of use
- \* Mainly exposed applications
- \* Different anchoring system used
- \* Some examples

45

## PVC Geocomposite experience in reservoirs

PVC geocomposite fully covered



Tampa Bay, Florida, USA  
drinking water reservoir

46



## PVC Geocomposite experience in reservoirs

PVC geocomposite fully covered



Herbes Blanches, Reunion

Irrigation, hydropower reservoir

47

47

## PVC Geocomposite experience in reservoirs

PVC geocomposite fully covered



Dumanoir, Guadeloupe

irrigation, hydropower

48

48

## PVC Geocomposite experience in reservoirs

PVC geocomposite fully exposed



Aleko, Bulgaria, hydropower

49

49

## PVC Geocomposite experience in reservoirs

PVC geocomposite fully exposed



Saint Martin  
Vesubie, France,  
EDF hydropower

50

50

## PVC Geocomposite experience in reservoirs

PVC geocomposite fully exposed



Pico da Urze  
Portugal,  
pumped storage

51

51

## PVC Geocomposite experience in reservoirs

PVC geocomposite fully exposed



Panama canal extension  
650,000 m<sup>2</sup> exposed PVC  
geocomposite  
Expected durability >100 years


52

52



**Selection of anchoring systems for exposed geomembranes**

**Exposed PVC geocomposite**




**Anchoring in trenches**

**Kohrang, Iran**

53

**Selection of anchoring systems for exposed geomembranes**

**Exposed PVC geocomposite**



**Anchoring in trenches and pretensioning**

**Panama canal**

54

### Selection of anchoring systems for exposed geomembranes

3 TENSIONING PROFILE @ 5.70m

Tensioning profile in rock with deep grouted anchors

55

55

### Selection of anchoring systems for exposed geomembranes

Punctual deep anchor in soil with deep grouted anchors

56

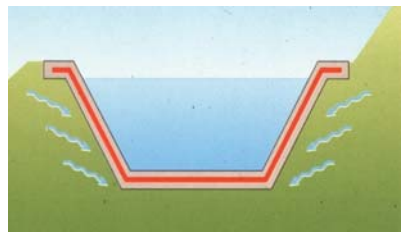

56



57

## PVC geocomposites in canals

Geocomposite fully covered reinforced concrete cover on slopes and bottom



Ala Bussolengo, Italy 1973

58

## PVC geocomposites in canals


Geocomposite covered only on invert



Pointis, France 1989

59

## PVC Geocomposite partially exposed



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

Pernegg, Austria

60



## PVC geocomposites in canals



40+ years in operation, no maintenance required



Exposed geocomposite

Poschiavino, Italy, 1979

61

61

## Canals




Exposed geocomposite

Tanakpur, India

62

62

## Canals



**Exposed PVC geocomposites are smooth and allow increase of water flow**

63

63

## Canals, underwater installation

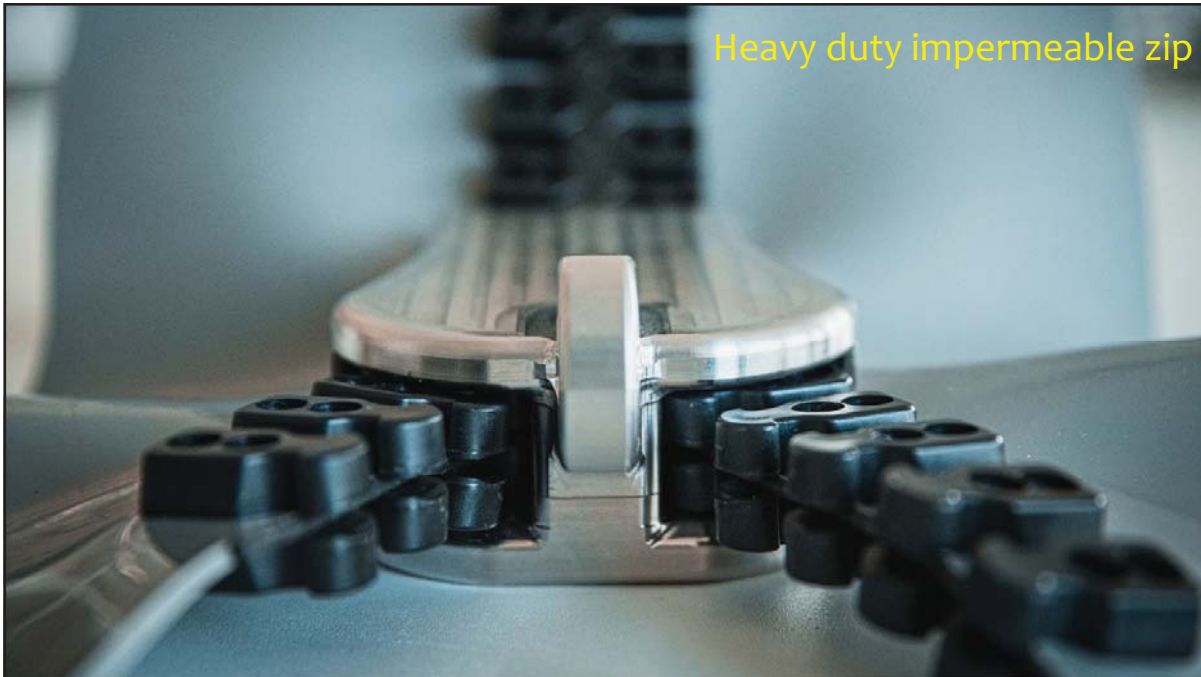
For installation of geomembranes in canals in flowing water, to reduce costs by avoiding underwater installation of stainless-steel profiles, Carpi developed a revolutionary solution:

**An innovative impermeable heavy-duty zip**

64

64





65

**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

A photograph showing a long, continuous roll of SIBELONMAT geomattress in a factory setting. The material is blue and white, with the blue PVC geomembranes connected by white PVC flexible strips. The roll is laid out on a wooden floor, and the background shows a large industrial building with windows.

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66

## Concept of SIBELONMAT®

Double SIBELON C perforated strips as interlayer connection



67

67

## Concept of SIBELONMAT®

### Unrolling machine for SIBELONMAT



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.

68

68

## Concept of SIBELONMAT®

**Deployment of SIBELONMAT**



**The finished product**




69


69

## Hydraulic tunnels and shafts

**Exposed PVCgeocomposite, Colombia**



**Exposed PVCgeocomposite, USA**



Exposed geocomposite

70

70



71