Building Climate Resilience: Adaptive Rehabilitation of Aging Dams with Exposed CARPI's Flexible Geomembrane Systems

presented by

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CBIP
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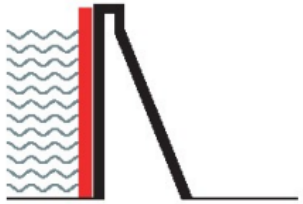
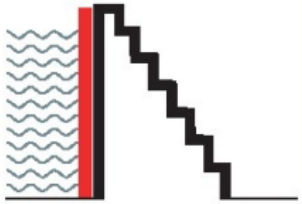
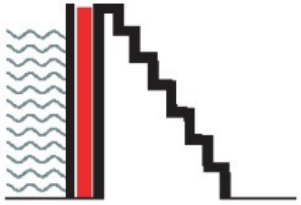
CARPI WATERPROOFING GEOMEMBRANES IN HYDRAULIC AND CIVIL STRUCTURES

RANGE OF APPLICATIONS

CARPI waterproofing systems stop leakage in hydraulic, civil and environmental protection structures


CONCRETE DAMS


RCC DAMS


RCC DAMS

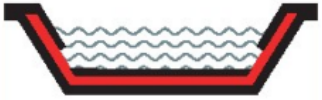

EMBANKMENT DAMS


EMBANKMENT DAMS


EMBANKMENT DAMS


RESERVOIRS


CANALS


CANALS


CANALS UNDERWATER

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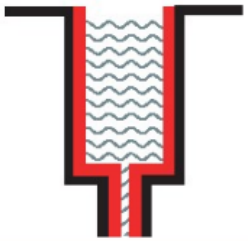
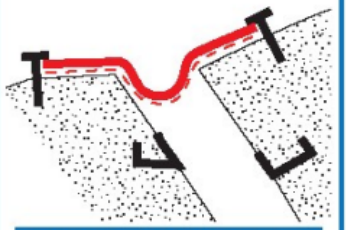
HYDRAULIC TUNNELS

HYDRAULIC TUNNELS



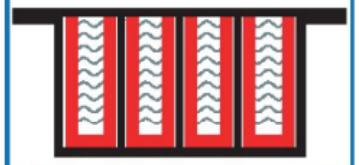
SHAFTS

EXTERNAL WATERSTOPS



EXTERNAL WATERSTOPS

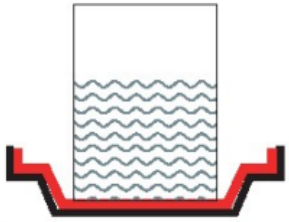
WATER STORAGE



UNDERGROUND WATER STORAGE

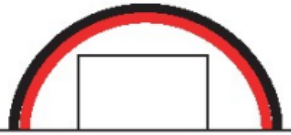
WATER STORAGE

FLOATING COVERS



CONTAINMENT

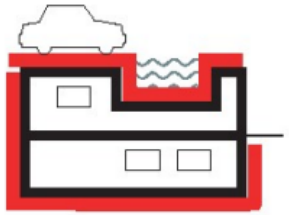
WASTE DISPOSAL



UNDERGROUND STRUCTURES

TRAFFIC TUNNELS

DECK OF BRIDGES



FOUNDATIONS AND ROOFING

ABOUT CARPI: What we do

Carpi was founded in 1963, CARPI provides design, supply and installation of waterproofing and protection geomembrane systems.

Type of Structure	Number of hydro projects as of December 2024	Quantity of geomembrane material as of December 2024 (m^2)
DAMS	204	3,384,717
RESERVOIRS	53	6,469,388
CANALS	50	2,077,757
HYDRO TUNNELS	30	62,499
TRAFFIC TUNNELS	46	1,590,165
Total	**383**	**13,584,526**

Single source guarantee without dilution of responsibilities

CARPI in INDIA SINCE 2004

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ABOUT CARPI: What we do

- Offers turnkey solutions: **engineering + materials + installation**, both **dry and underwater**
- Manufactures high-performance **SIBELON® geomembranes** tailored for high water heads, strong currents, and tough environments
- Develops **patented durable anchorage systems** consisting of tensioned profiles resisting huge wind and flood in old dams
- Develops **patented anchorage systems** embedded in porous concrete curbs, enabling waterproofing on new flexible rockfill and reinforced concrete dams

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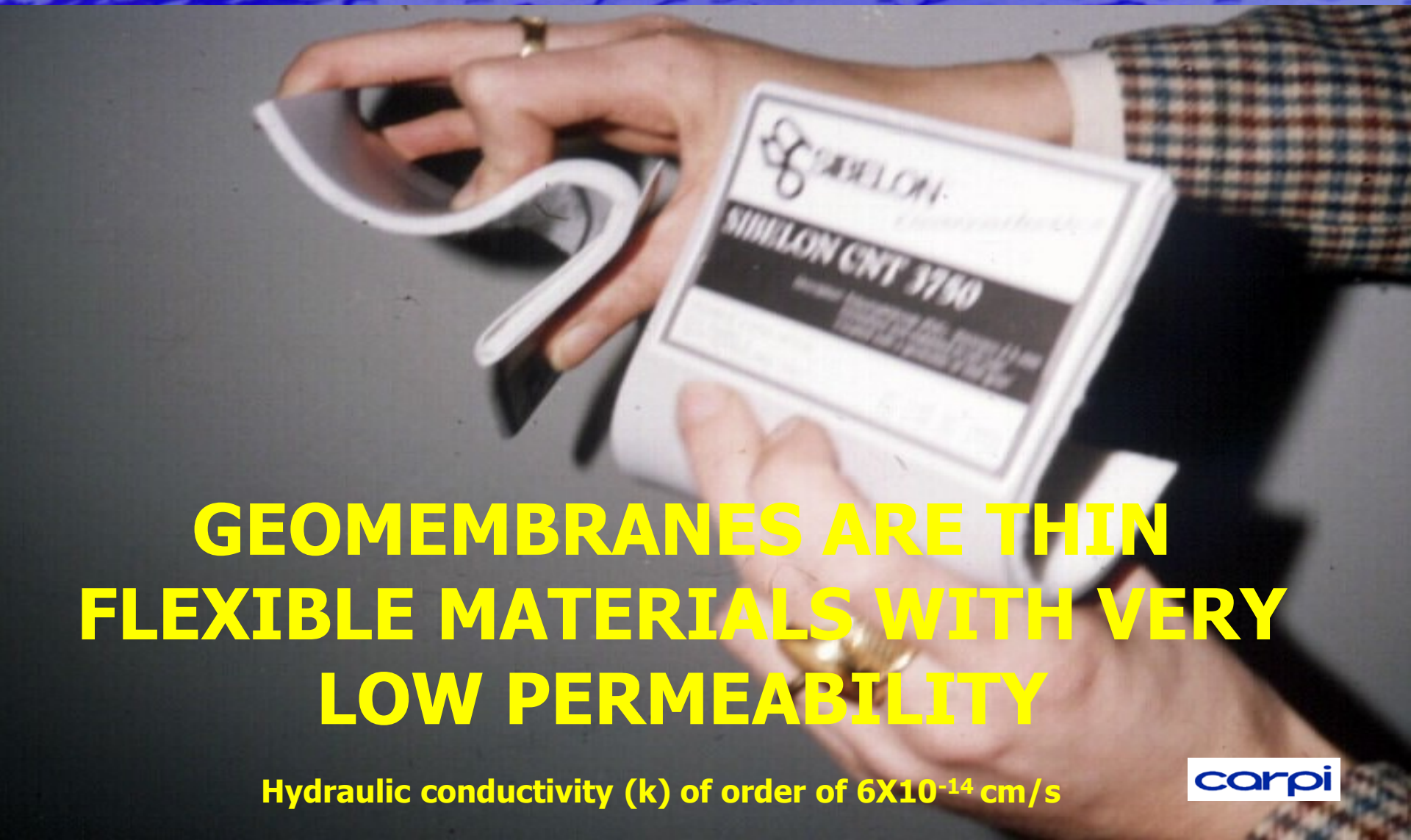
What is a Geomembrane??



GEOMEMBRANES ARE THIN FLEXIBLE MATERIALS WITH VERY LOW PERMEABILITY

Hydraulic conductivity (k) of order of $6X10^{-14}$ cm/s

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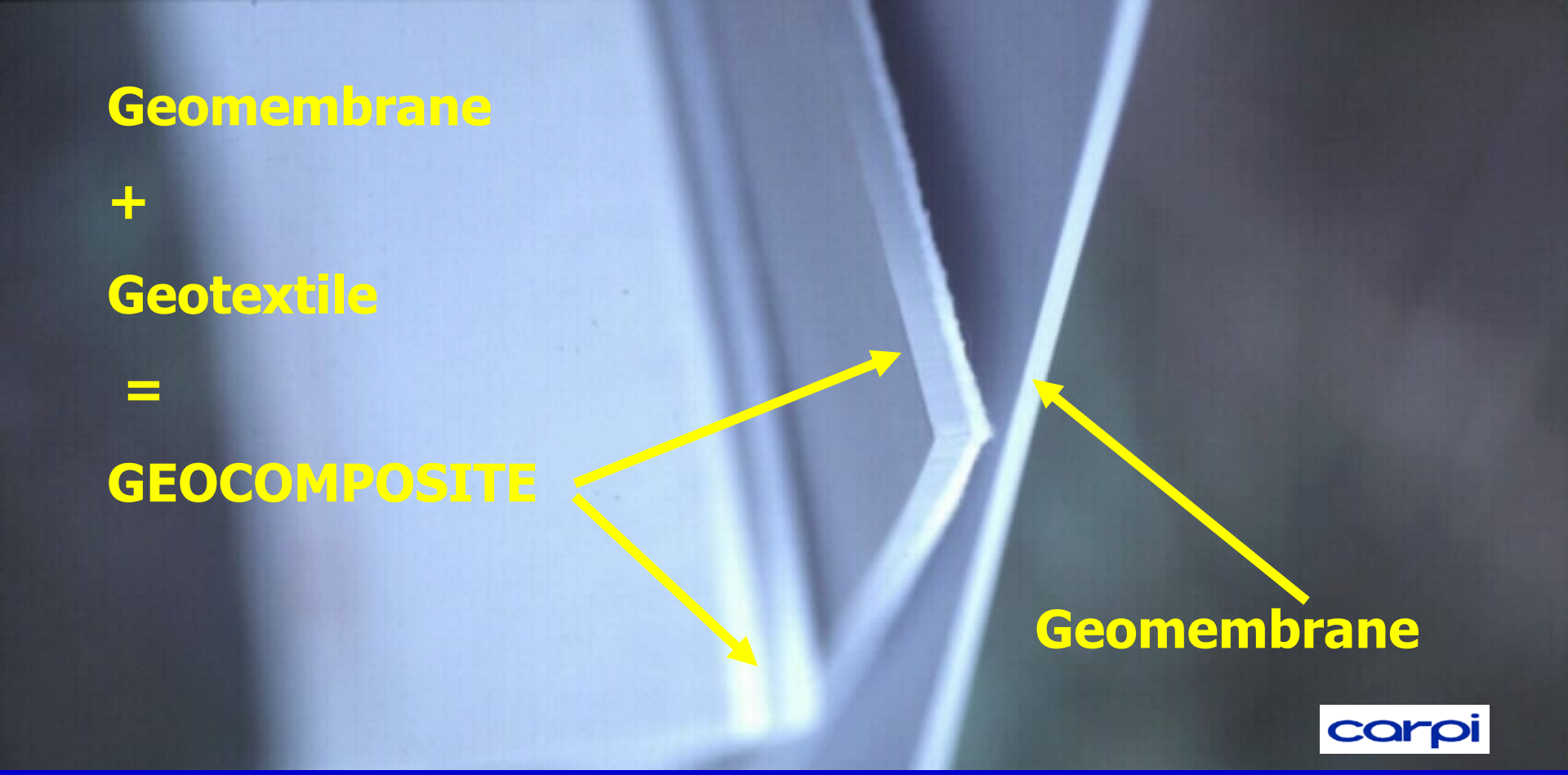

TERMINOLOGY

When a geomembrane is associated with a geotextile, laminated during the production process, it is called GECOMPOSITE

Geotextile provides: dimensional stability, antipuncturing protection, drainage capability

Properties of Carpi's Geomembrane

- Very Low Permeability (<10^{-6} m^3/m^2/day EN 14150)
- Elastic Behaviour under uni-axial and multi axial tensile strain
- Large ultimate elongation (>230% to EN ISO 527/4 Standards)
- High resistance to puncturing, bursting and impact
- Excellent performance to harsh climate (proven in extreme temperature, hot and cold)
- High resistance to UV Radiation (>100 years based on lab testing and live project >40 years still in service)

Carpi geomembranes are

- Impermeable and flexible
- Resistant to settlements
- Resistant to earthquakes
- Durable
- Installed quickly, also underwater
- Applicable to all types of structures
- Respectful of environment
- Efficiently monitored

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ICOLD defines as “large dam” a dam with a height of 15 metres or greater from lowest foundation to crest, or a dam between 5 metres and 15 metres impounding more than 3 million cubic metres of water

Recent statistics mention that more than 70% of dams accidents and incidents are directly due to, or related to leakages

(GeoAfrica 2017 Congress Proceedings)

Sometimes with catastrophic consequences

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ICOLD defines 'Geomembranes are one of the most efficient solutions to mitigate or even eliminate leakages'

Geomembranes are: durable, resistant and cost effective

Geomembrane Sealing System (GSS) can stop leakage, but choosing the wrong geomembrane, or an inadequate design for the anchorage system, can have (very expensive) consequences

Inadequate anchorage, failure of weld

Inadequate anchorage, uplift

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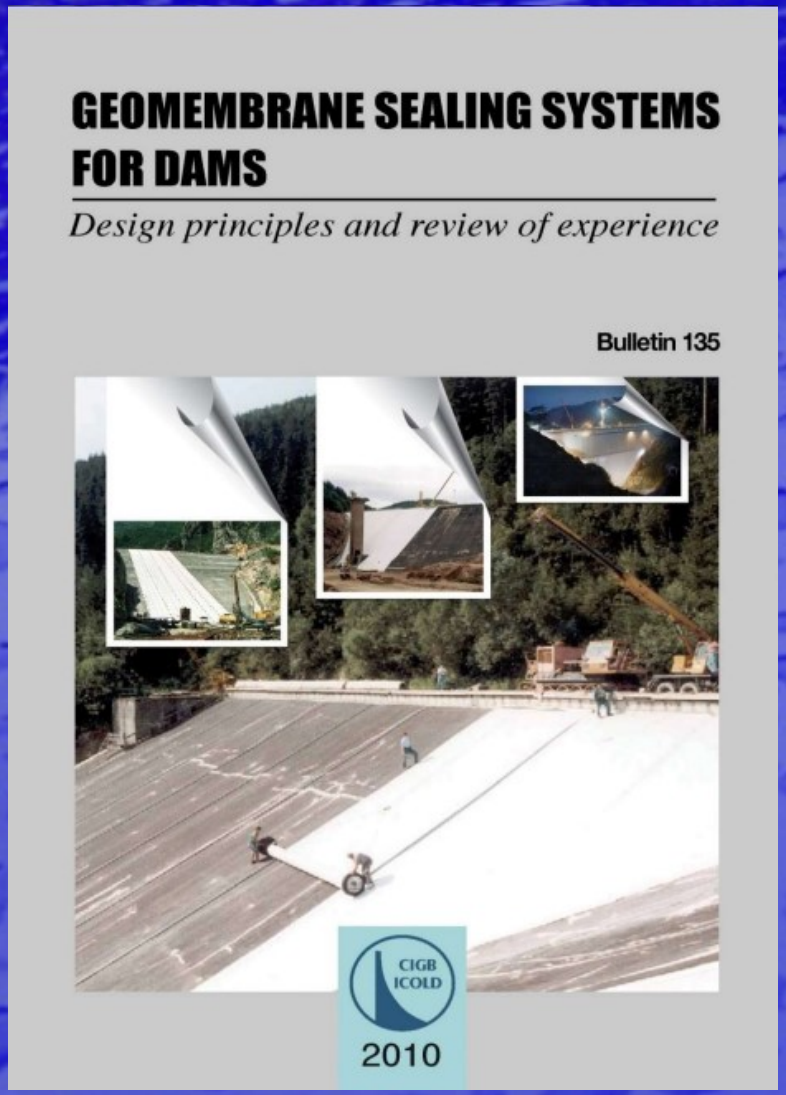

ICOLD Bulletin 135

The group who prepared the bulletin was formed by owners, government agencies, universities, designers of 11 countries (Austria, Colombia, Czech Republic, France, Germany, Italy, Portugal, Spain, Switzerland, UK, USA) that have extensive experience of geomembranes in dams

Which geomembrane?

GEOMEMBRANES HAVE DIFFERENT MODULUS OF ELASTICTY THEREFORE DEGREE OF FLEXIBILITY IS DIFFERENT

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ICOLD Bulletin 135

- In Section 5.4 (Table 30 on page 118), the Bulletin lists suggested conservative minimum default thicknesses for PVC-P geocomposite liners used in exposed applications on concrete/masonry dams:

Dam Height	ICOLD Default Thickness	Geotextile Backing
< 40 m	2.0 mm	200 g/m²
> 40 m	2.5 mm	500 g/m²

- These values are not mandatory standards, but are conservative safe defaults when specific design details are missing.
- It offers 2.5 mm as a recommended default (with 500 g/m² geotextile backing) for larger dams (> 40 m high) when no tailored design guidance is available.
- Final thickness selection should still follow project-specific engineering design, considering factors like surface roughness, expected loading, wind, UV exposure, and anchorage details.

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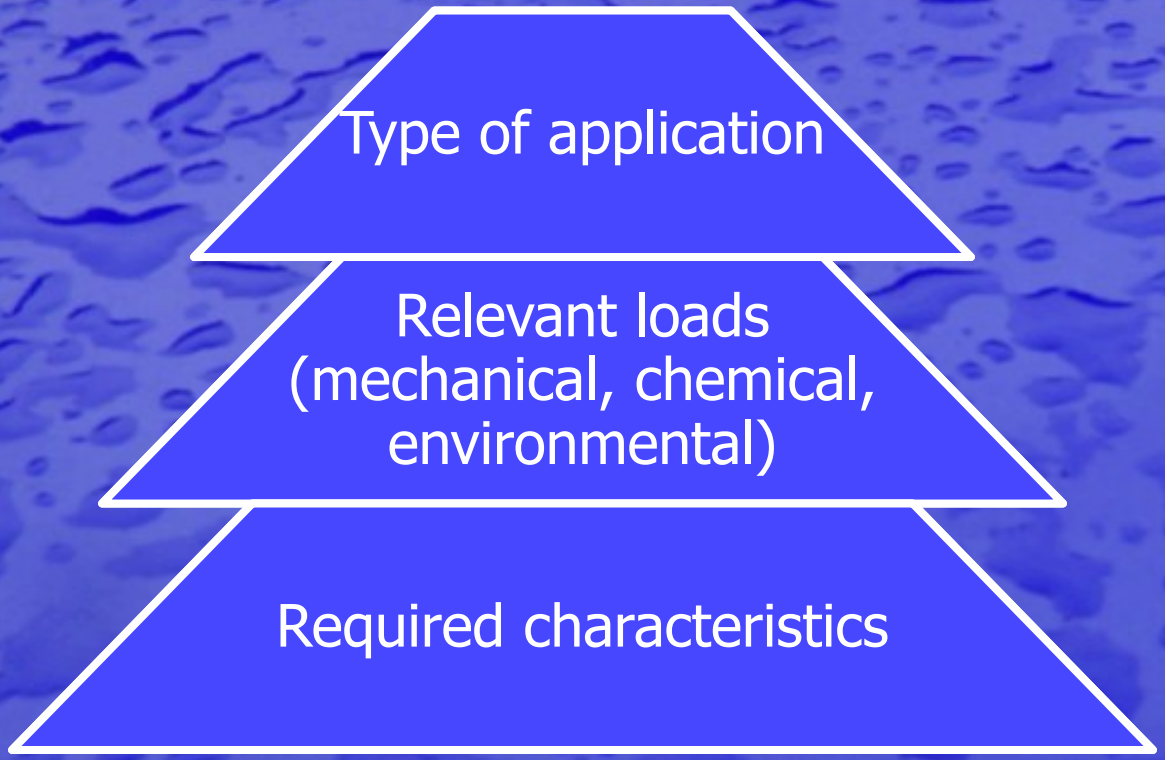
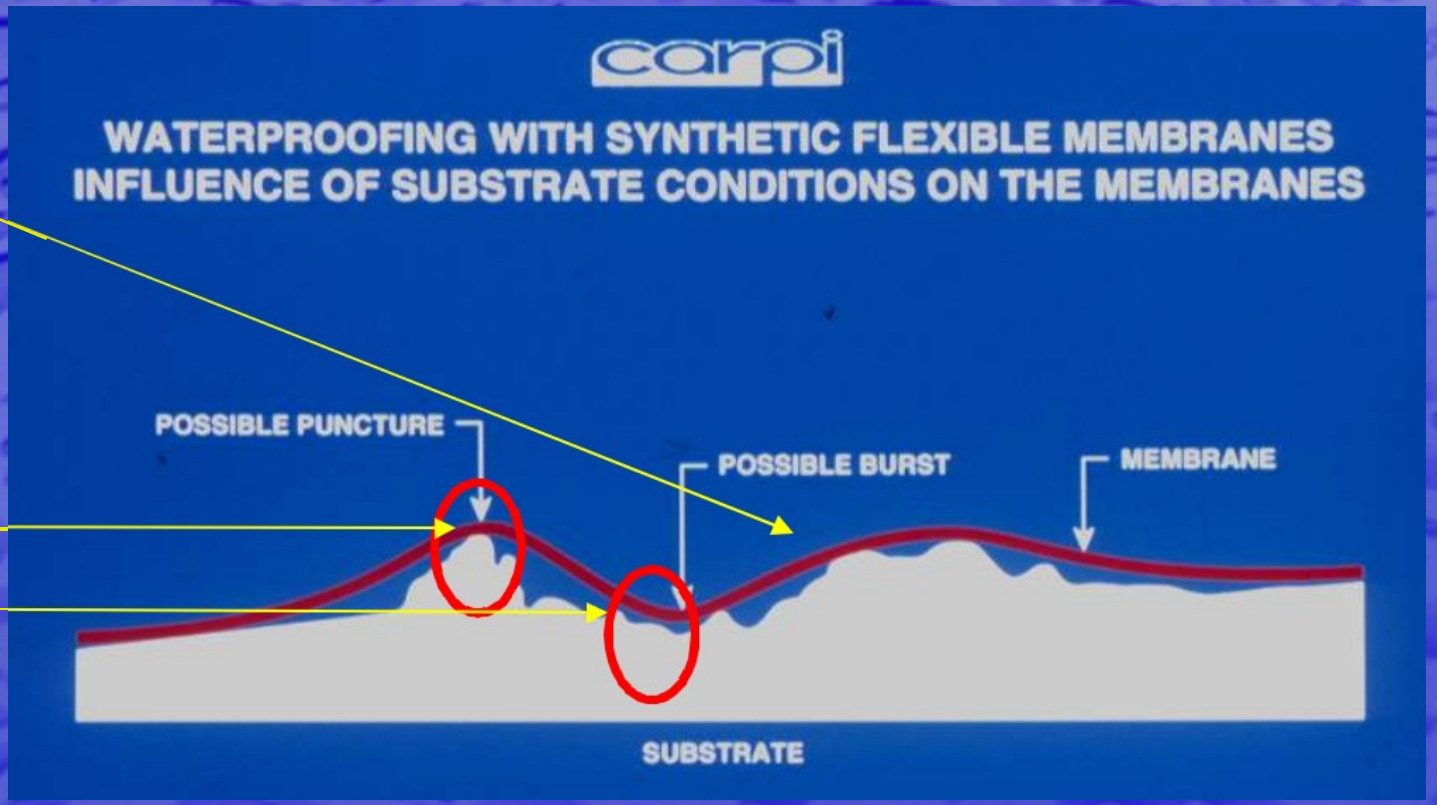
GEOMEMBRANE SELECTION



Geomembranes must be

Flexible: adapting to the subgrade distributes load

Resistant to puncture and burst



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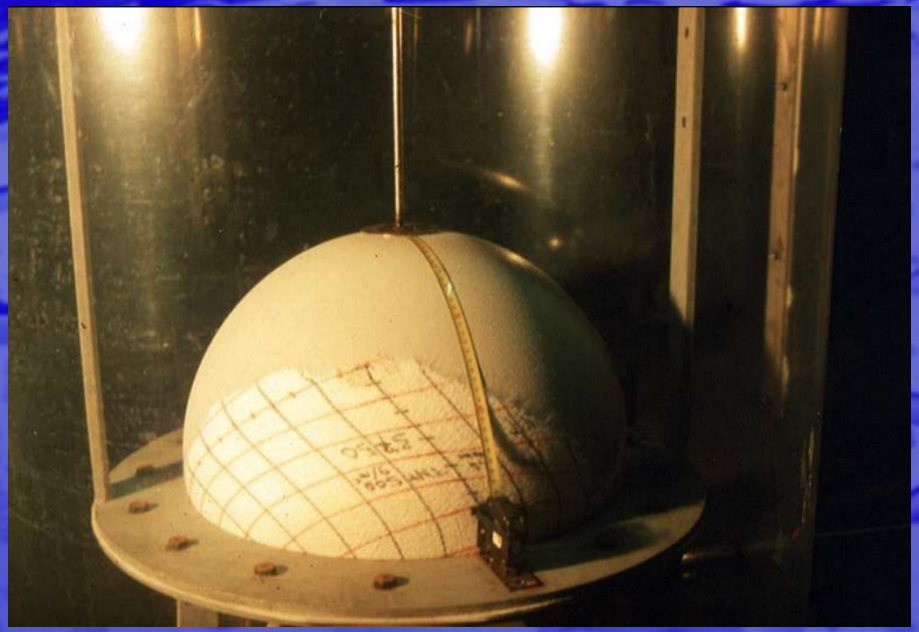

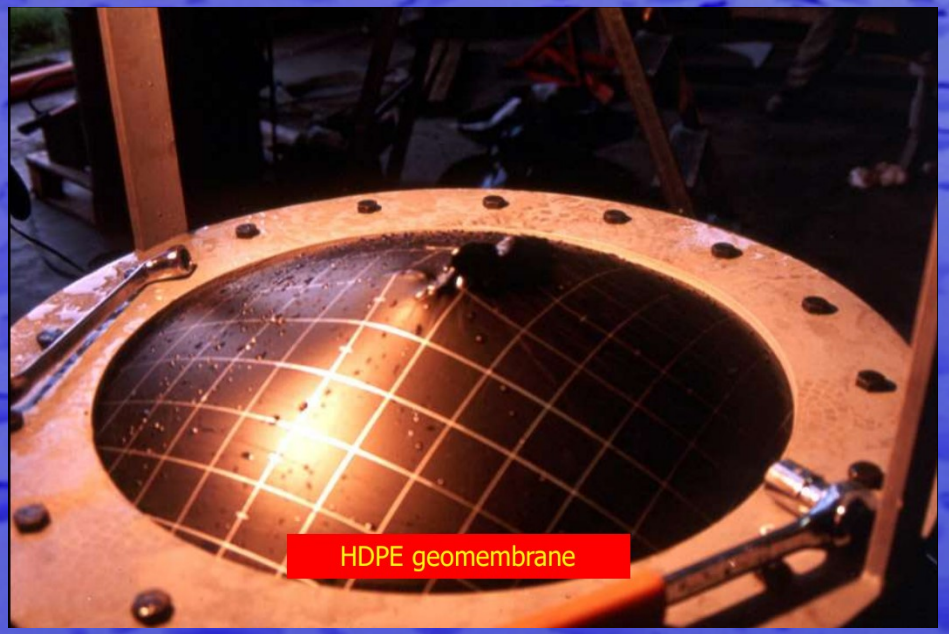

SIBELON® geocomposite is capable to deform, reducing stresses in the material

HDPE geomembrane deforms less, stress is higher

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Exposed or covered geomembrane?

Installation of a cover layer must be justified by specific constraints due to particular service conditions as it is more risky (damages at installation, unaccessibility for control) and more expensive.

RESISTANCE TO DIFFERENTIAL MOVEMENTS

In all hydraulic structure there are locations of potential higher stresses on the geomembrane:

- Subsidence in embankments
- Displacements between deformable embankments and concrete structures
- Movements of active joints and cracks

Geomembrane must be tested for capability to resist all these movements

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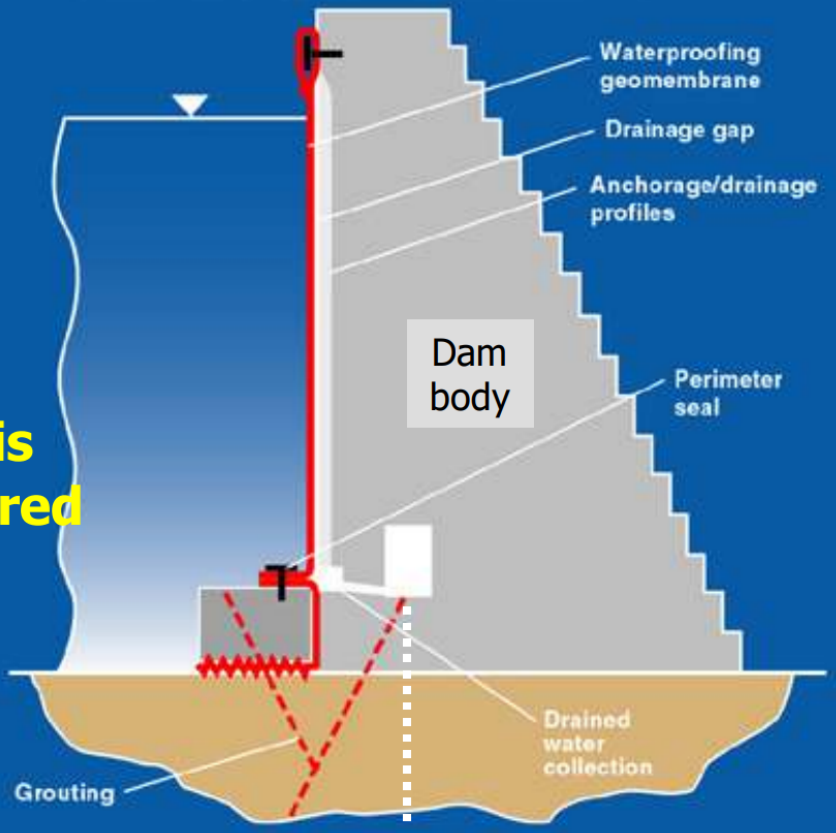
THE CONCEPT

The CARPI system consists in the installation of a PVC geocomposite, with its own drainage system, on the upstream face of the dam, from crest to foundation.

The geomembrane is represented by the red line.



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Geomembrane in Hydraulic Structures

REHABILITATION

Since 1960s

NEW CONSTRUCTION

Since 1990s

PVC geomembranes have been used in rehabilitation and new construction, fully exposed and covered, installed in the dry and underwater.

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Geomembrane Sealing System - How different is it from other System?

Rehabilitation of Dams	Improving Structural Strength	Grouting Re-Pointing
Protective Sealing System Prevent Water Infiltration/ Chemical or Aggression Attack	Protective Sealing System	GM u/s Face Steel Face New Concrete Face

U/S GM barrier formed prevents any further deterioration in the strength of the dam thereby eliminates:

- Need for repeated grouting
- Need for repeated re-pointing works

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India has witnessed three outstanding applications of waterproofing geomembrane systems in Dams

- Kadamparai Dam – 67 Meter high Dam (2004-2005)
- Servalar Dam – 52 Meter High Dam (2016-2018)
- Upper Bhavani Dam – 80 Meter High Dam (2019-2021)

Thanks to

WORLD BANK, DRIP AND TANGEDCO

Years of Experience (Indian Case Studies)

Name of the Dam	Year of Installation	Area of Installation	Leakage Before Geomembrane	Leakage After Geomembrane	Present Service Life
Kadamparai Dam	2005	17,303 Sqm	38,000 Lpm	< 120 Lpm (99.8% Savings)	20 years
Servalar Dam	2018	9,854 Sqm	5,000-6,000 Lpm	< 30 Lpm (99.6% Savings)	6 Years
Upper Bhavani Dam	2021	17,904 Sqm	9,000-15,000 Lpm	< 40 Lpm (99.5% Savings)	4 Years

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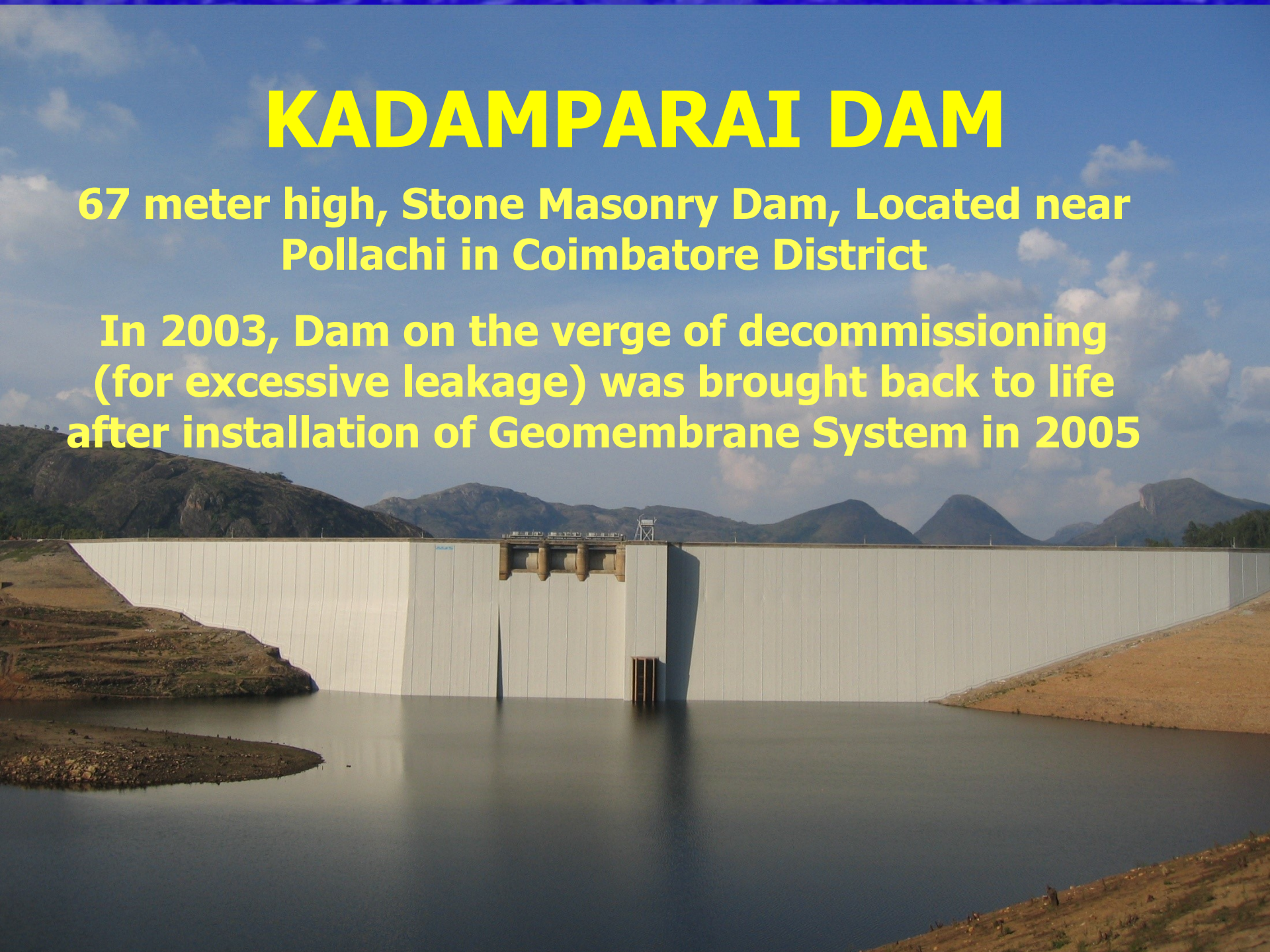
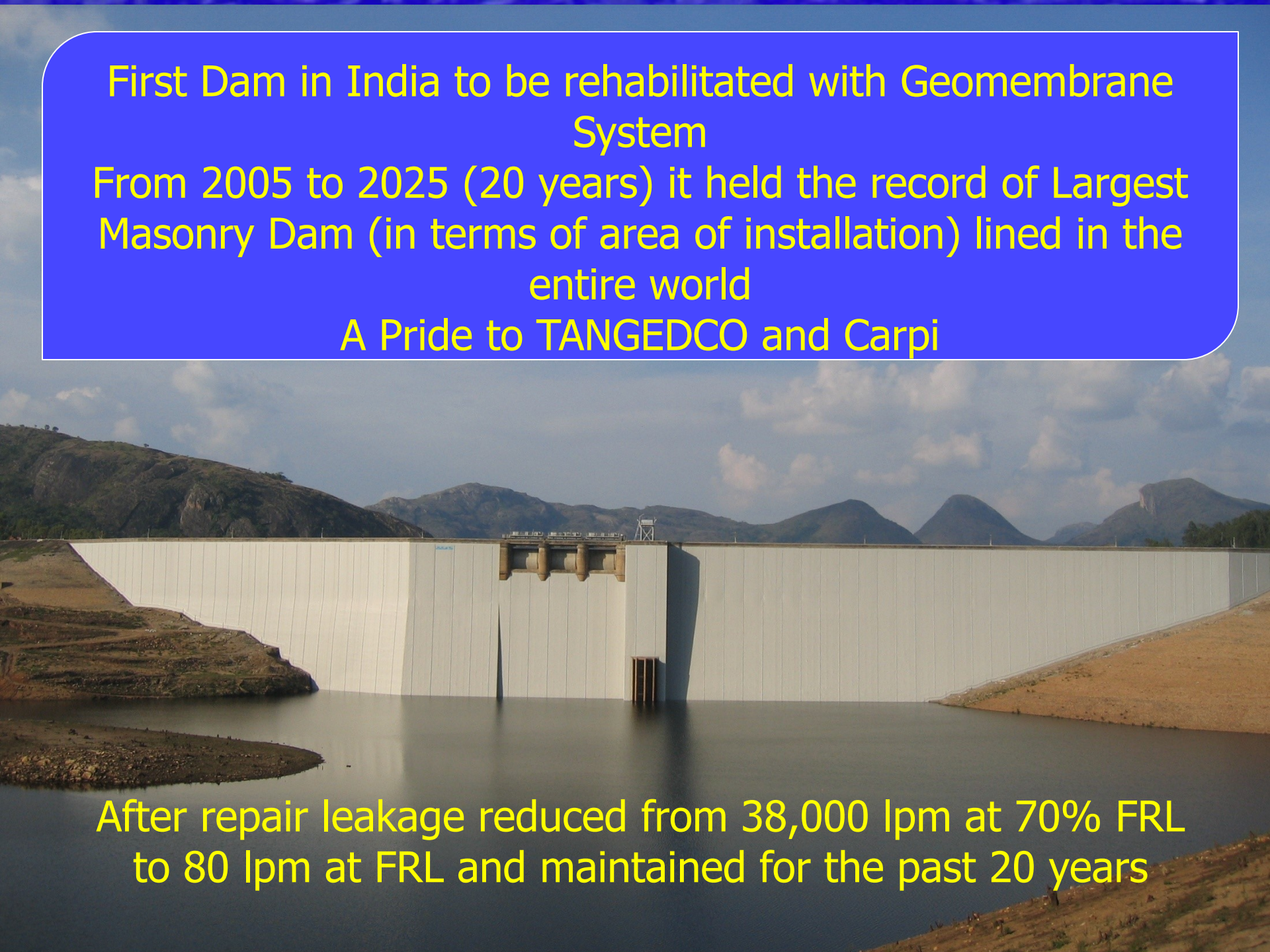

KADAMPARAI DAM
67 meter high, Stone Masonry Dam, Located near Pollachi in Coimbatore District
In 2003, Dam on the verge of decommissioning (for excessive leakage) was brought back to life after installation of Geomembrane System in 2005

Leakage in the drainage gallery, left abutment

First Dam in India to be rehabilitated with Geomembrane System

From 2005 to 2025 (20 years) it held the record of Largest Masonry Dam (in terms of area of installation) lined in the entire world

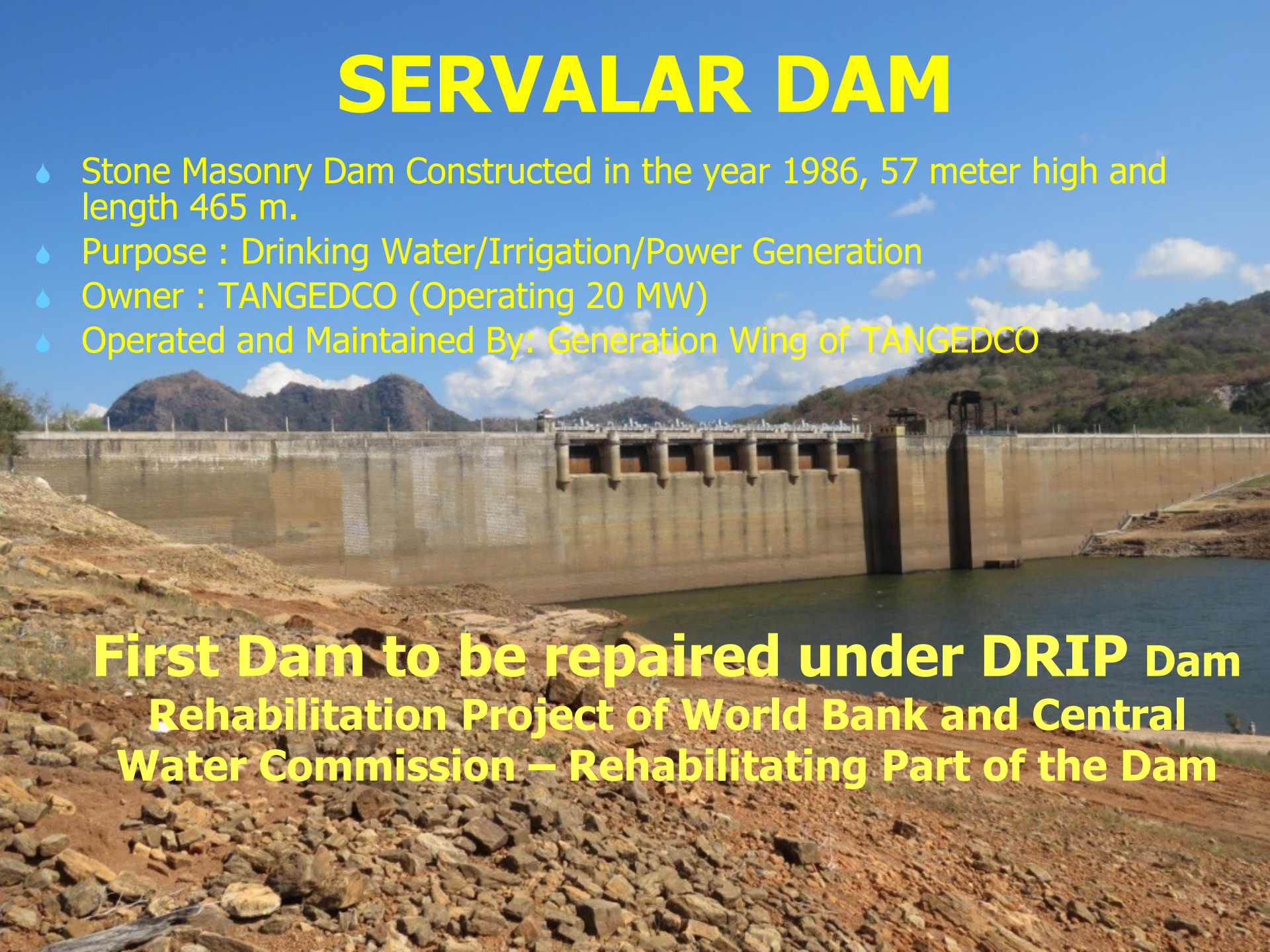
A Pride to TANGEDCO and Carpi



After repair leakage reduced from 38,000 lpm at 70% FRL to 80 lpm at FRL and maintained for the past 20 years

SERVALAR DAM

- Stone Masonry Dam Constructed in the year 1986, 57 meter high and length 465 m.
- Purpose : Drinking Water/Irrigation/Power Generation
- Owner : TANGEDCO (Operating 20 MW)
- Operated and Maintained By: Generation Wing of TANGEDCO



First Dam to be repaired under DRIP Dam Rehabilitation Project of World Bank and Central Water Commission – Rehabilitating Part of the Dam

Servalar dam

Leakage Before Geomembrane> 5000 Lpm,
After Geomembrane < 30 Lpm

After 4 Years of Service

UPPER BHAVANI DAM

Second dam rehabilitated under DRIP in 2 stages between 2019 and 2021

80 m high stone masonry dam
425 m length

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High rate of leakage before the installation of the geomembarne

Rate of leakage before works 9,000 lpm

Rate of leakage after works 80 lpm

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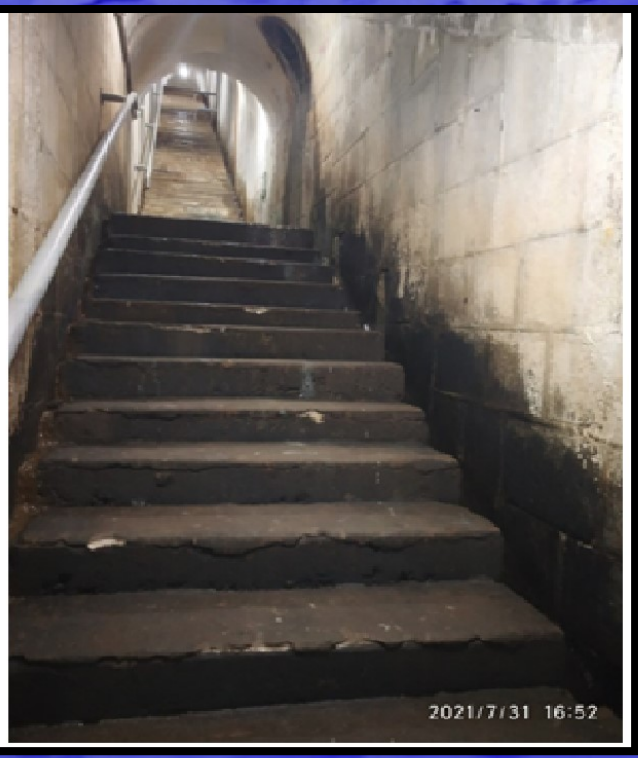
Results of Waterproofing Vertical Drain Shaft (Right Spillway) Before and After GM Installation



TANAKPUR CANAL, India 2008

The PVC geocomposite sheets are placed on the slopes perpendicular to the water flow

TANAKPUR CANAL, India 2008

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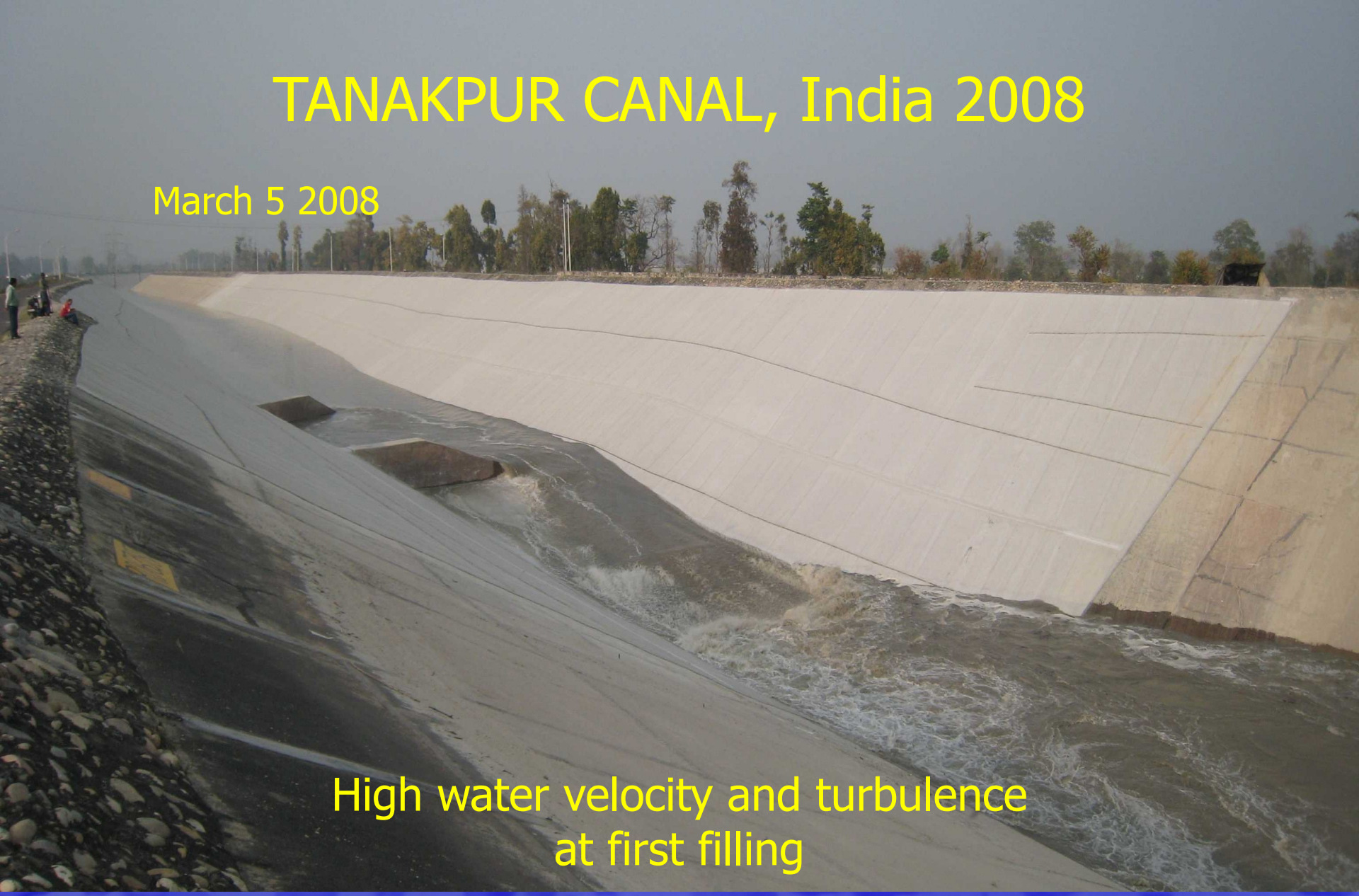
TANAKPUR CANAL, India 2008

March 5 2008



High water velocity and turbulence
at first filling

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Condition of Headrace Tunnel Before Rehabilitation

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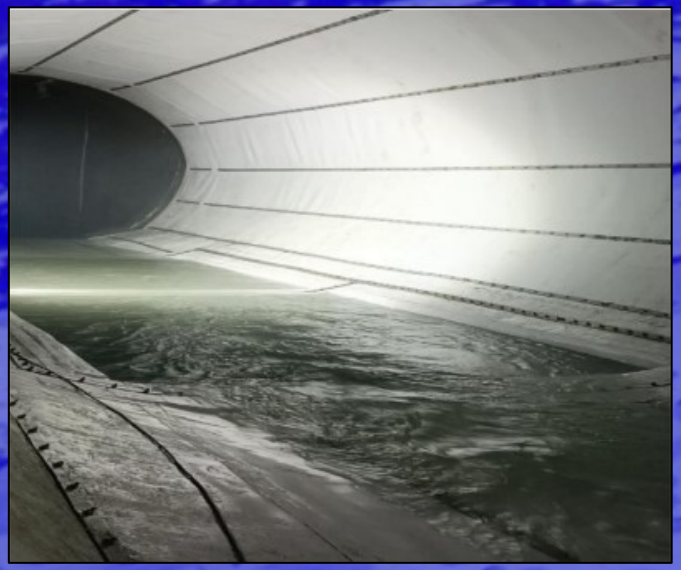
Bajoli Holi HRT – GMR Hydro - 2023

Results of Waterproofing
Before and After GM Installation



Before Membrane Lining

After Membrane Lining

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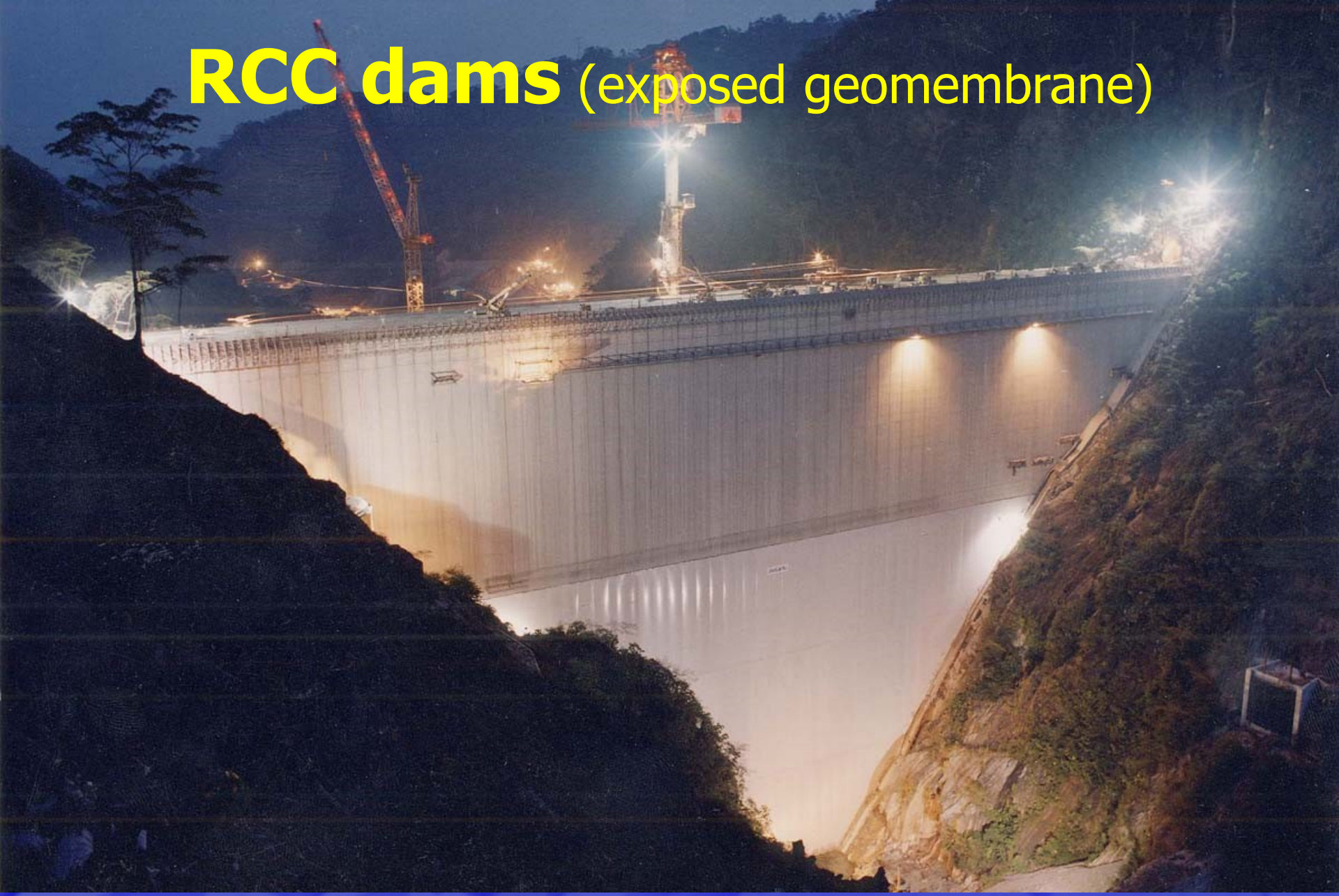
Project History of Carpi India

New construction

RCC dams

RCC dams (exposed geomembrane)



Miel 1, Colombia, 2002

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RCC dams (exposed geomembrane)

Olivenhain, USA, 2003

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RCC dams (exposed geomembrane)

Boussiaba, Algeria, 2009

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RCC dams (exposed geomembrane)

Susu, Malaysia

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RCC dams, raising

San Vicente, USA

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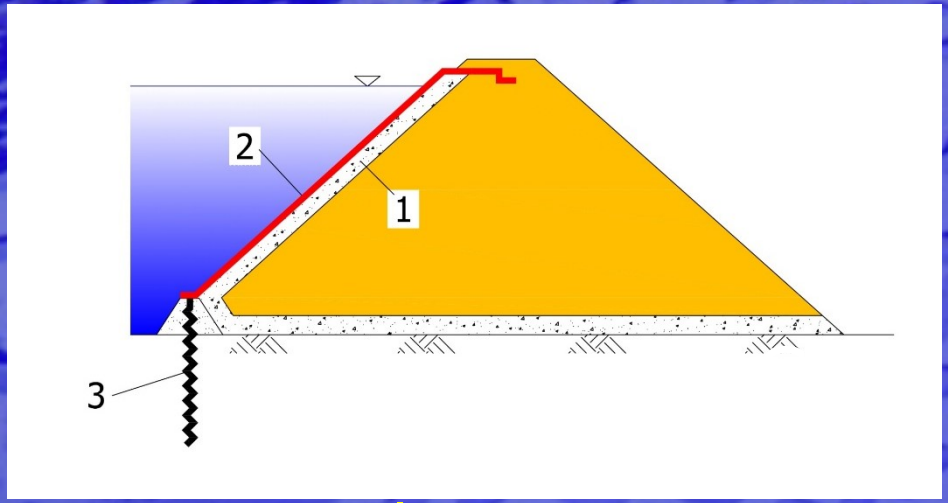
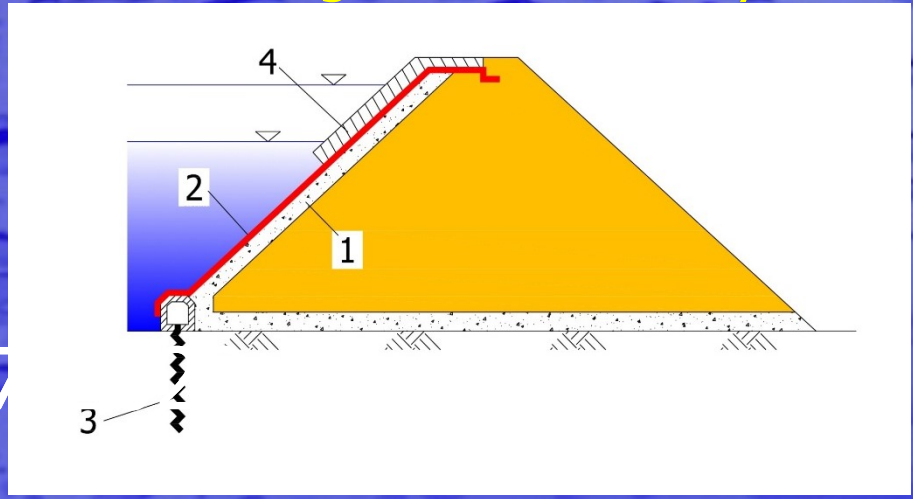
RCC dams (exposed geomembrane)

Configuration of Carpi GSS in Embankment Dam

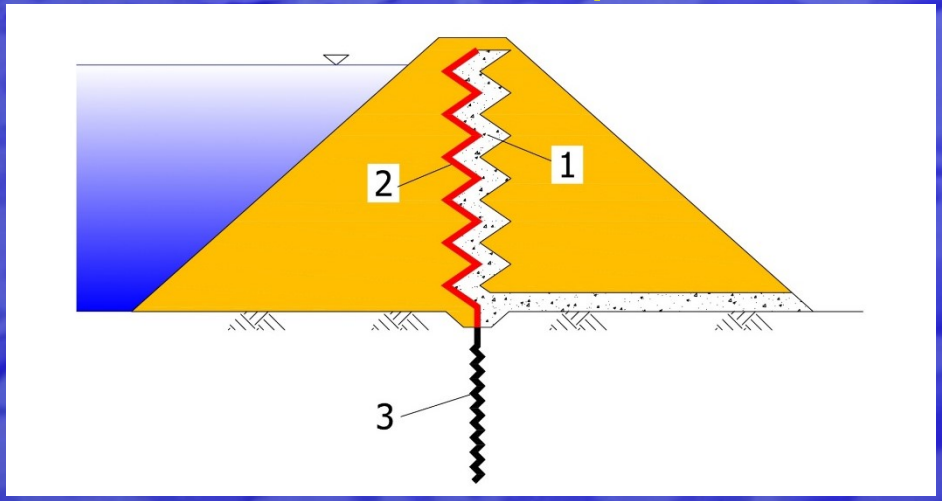
Fully Exposed System



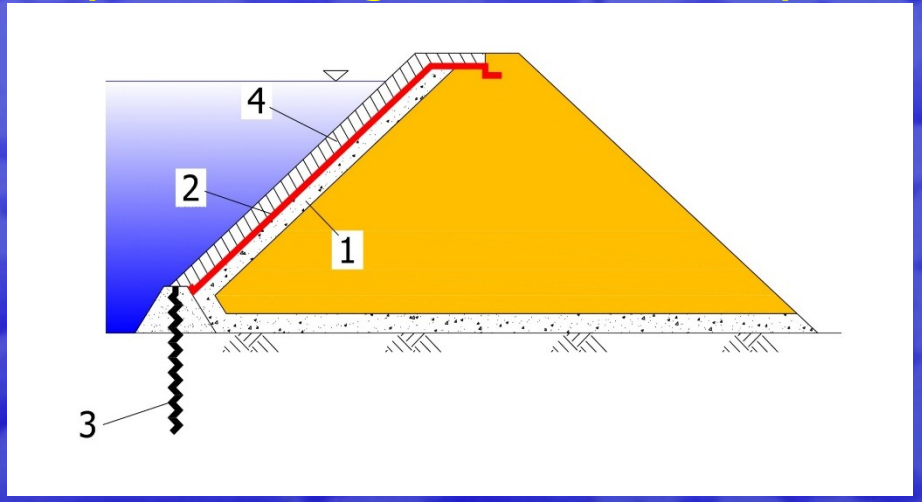
Partial cover geomembrane system



Central Core System



Fully Covered geomembrane system



Geomembrane Face Rockfill Dam

Exposed geomembrane

Nam Ou VI, Laos, 2016

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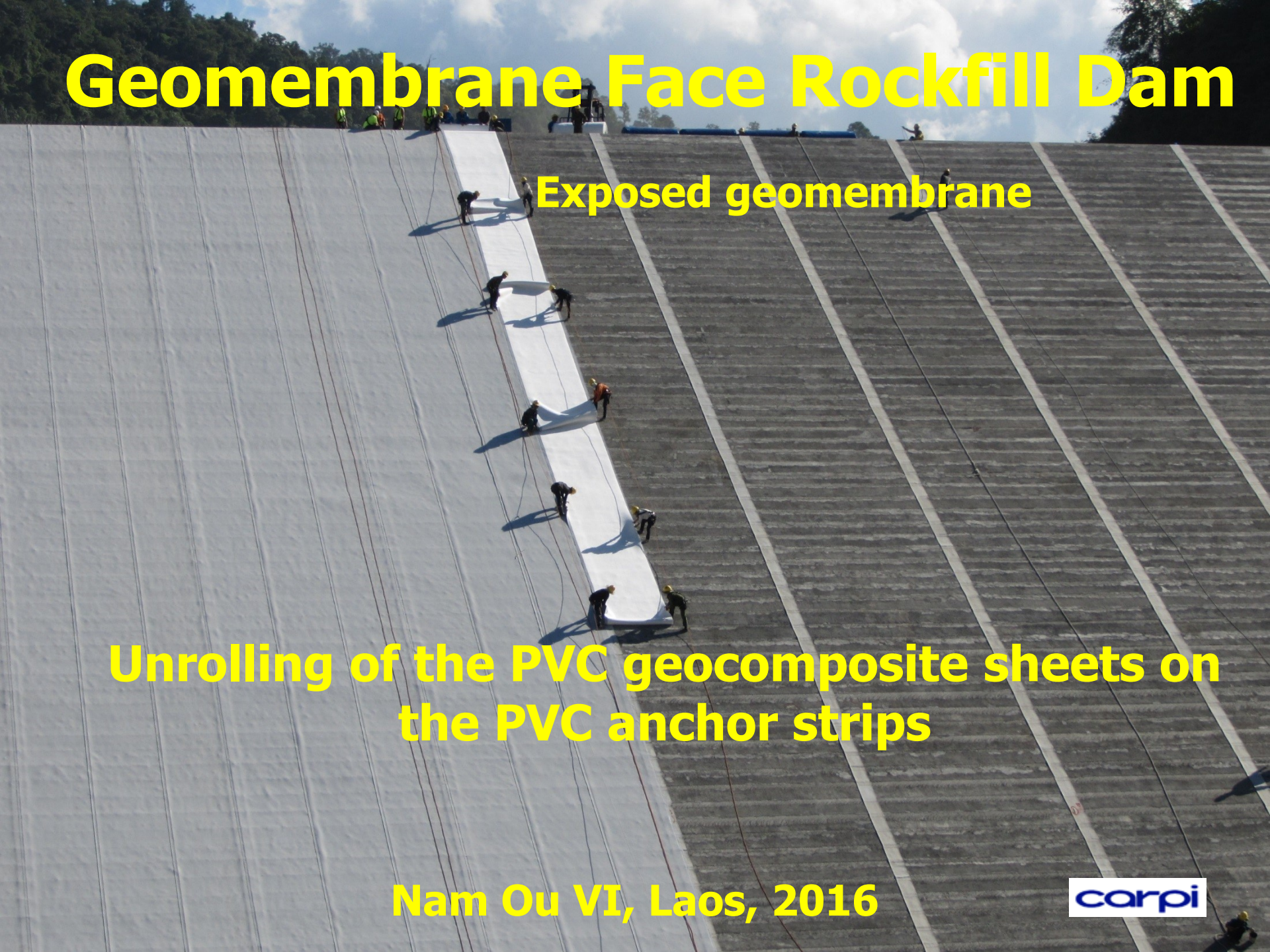
Geomembrane Face Rockfill Dam



Exposed geomembrane

Unrolling of the PVC geocomposite sheets on the PVC anchor strips

Nam Ou VI, Laos, 2016

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NAM OU VI
THE PVC GEOCOMPOSITE IS SEAMED TO THE PVC ANCHOR STRIP
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GEOMEMBRANES IN HIGH ROCKFILL DAMS


NAM OU VI
WATERTIGHT MECHANICAL DOUBLE
PERIMETER SEAL AT PLINTH
carpi

NAM OU VI UPSTREAM FACE SUBGRADE ITA SYSTEM

- Porous concrete extruded curb was selected as subgrade method of construction

Porous concrete extruded curb with cement ratio of < 70-80 kg/cum

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NAM OU VI – JULY 23, 2014
CONSTRUCTION OF DAM FACING STARTS

THE PVC ANCHOR STRIPS ARE TEMPORARILY FASTENED TO THE CURBS AND THEN EMBEDDED IN THE FILL

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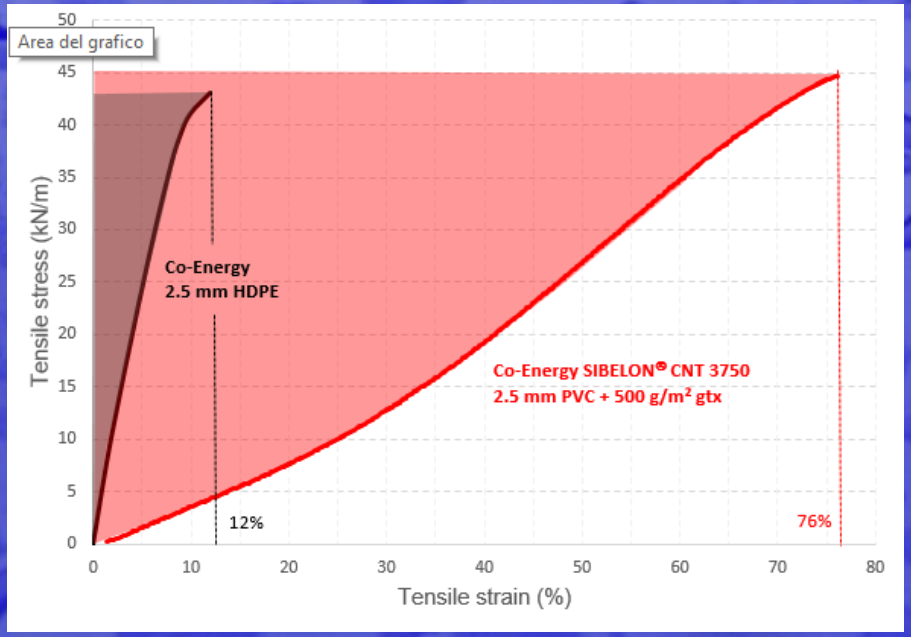
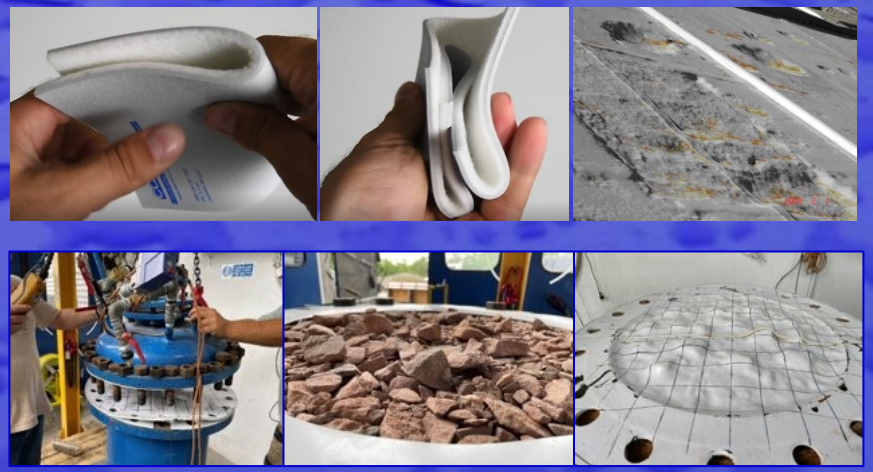
Flexible Carpi PVC Geomembrane Liners

- Resistance to deformations in the subgrade & to cyclic loading
- Accept differential displacements & seismicity
- Durability & maintenance
- Cost effectiveness & lower carbon footprint

PVC-P (Plasticised PVC) geomembranes

- Flexibility, high elongation & no yield, high co-energy
- Precedents in hydraulic structures





PVC-P geomembranes

- Flexibility & elongation
- High co-energy
- Resistance to cyclic loading/unloading
- **Durability: site feedback, testing, analytics**

Lago Nero, Italy 1980

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PVC-P geomembranes in new reservoirs

- Their performance in respect to settlements, differential displacements, seismic events, ensures watertightness, avoiding potential embankment stability issues
- Allow steeper embankment faces, maximizing water volume
- Sustainable: light equipment, simple site organization, shorter construction time, low carbon footprint
- Cost-effective: increased storage volume, lower construction costs, earlier power generation, no routine maintenance, repair possible underwater

GANDHI SAGAR

CHITRAVATI

Key Takeaways

- Carpi's **SIBELON® geomembranes** offer robust waterproofing flexibility—from retrofits to turnkey new systems.
- The solutions are **quick to deploy**, **sustainable**, and **adaptable** to challenging environments—from remote mountainous dams to large renewable energy projects.
- These projects reinforce Carpi's global leadership in hydraulic geomembrane applications, combining technical strength with environmental and operational efficiency.

Waterproof. Durable. Trusted.

carpi