International Conference on Dam Safety, 2023

Efficient Design and Usage of Synthetic Geomembranes for Wateproofing in Dams to restore Watertightness and increase service life of the structure

by

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PVC Geomembranes in Dams

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

Video SIBELON CNT

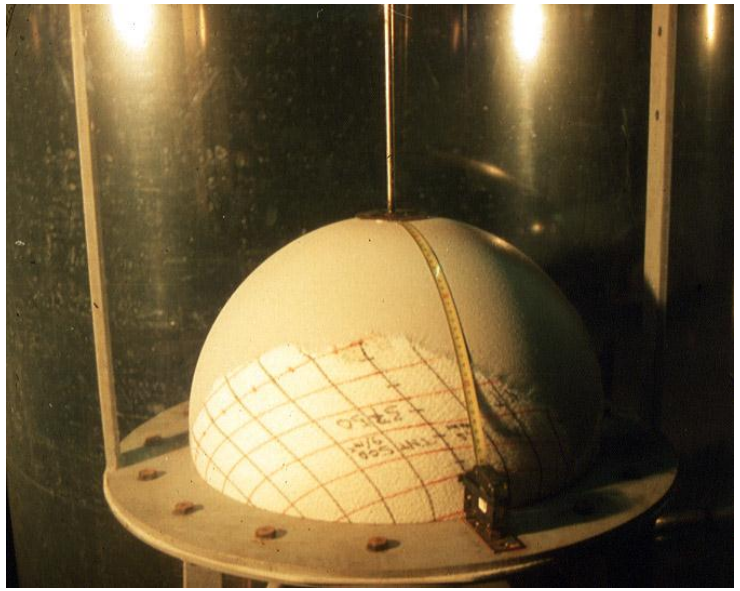
Key Properties

- 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

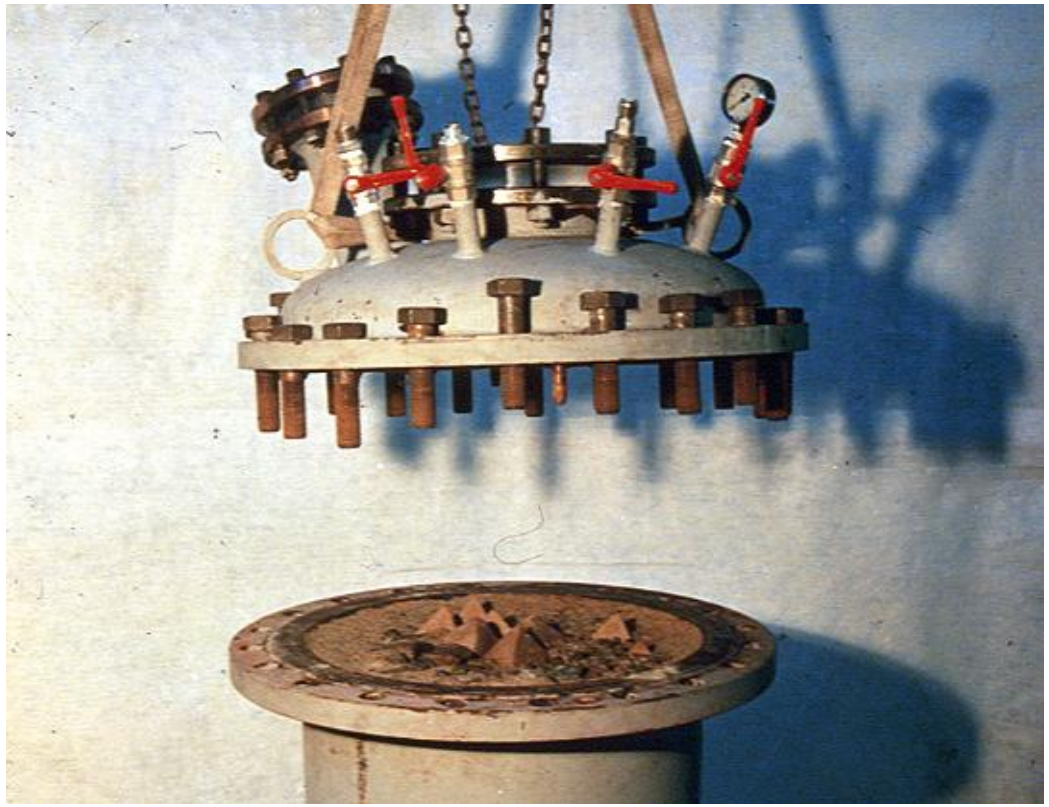


Highly Elastic and Flexibility PVC geocomposite is capable to deform, reducing stresses in the material

Key Properties

Puncture and burst resistance

PVC geomembranes are tested on very aggressive substrates in hydraulic vessel



Pressure vessels apply water heads up to 250 m

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

Crucial aspects

- The geomembrane itself must resist the applied loads
- The anchorage system must be adequately dimensioned
- Geomembrane is a design choice, not only based on expected durability

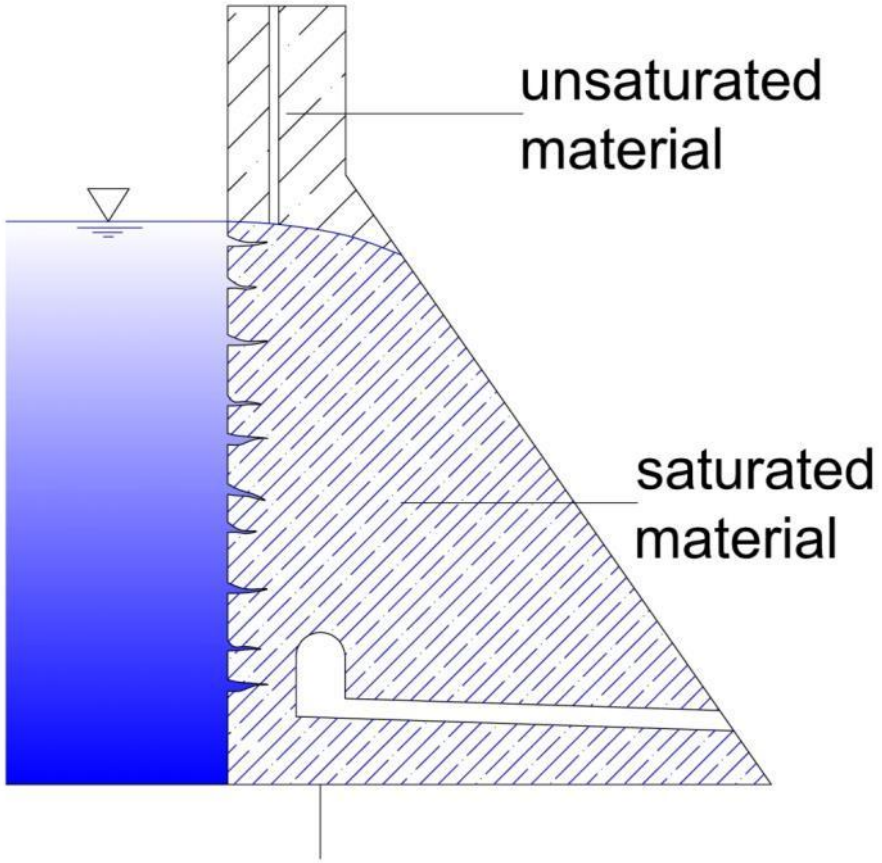
Exposed geomembranes: Applied loads

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

PVC Geomembrane in Dams

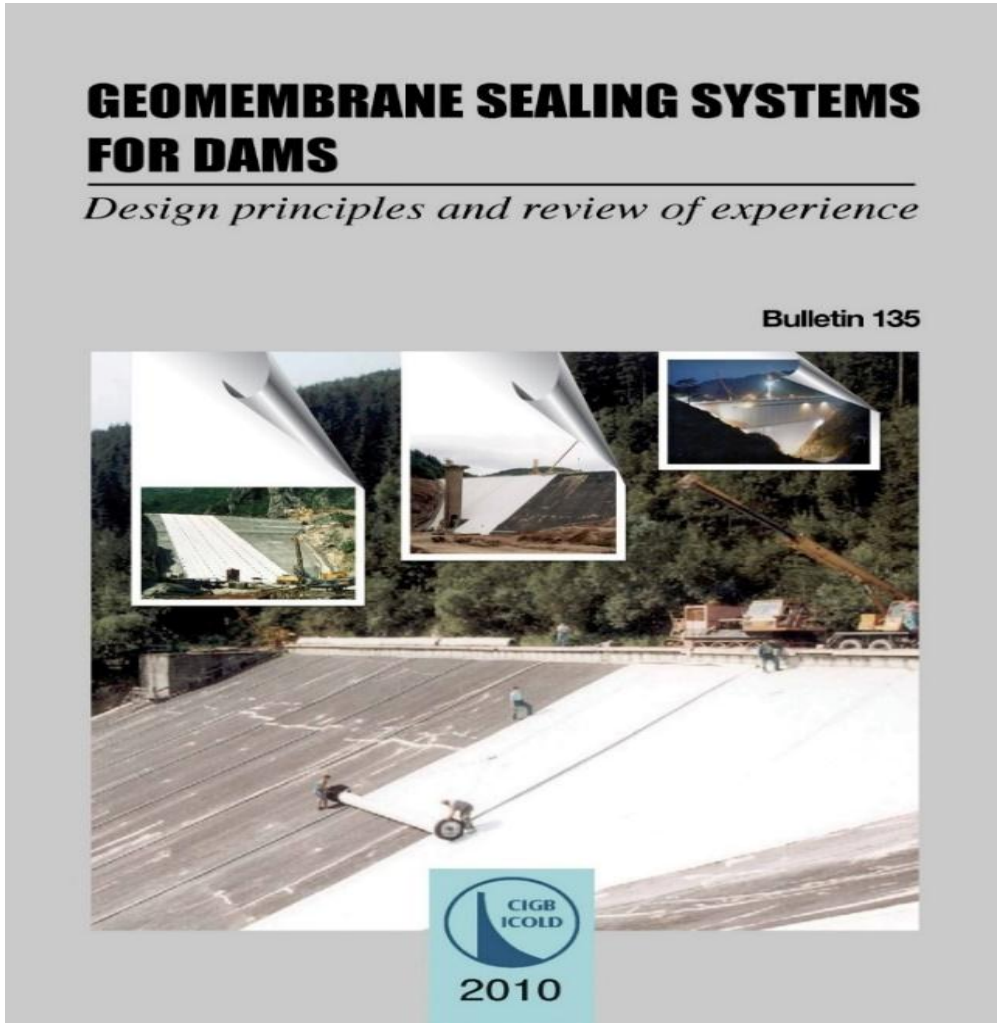
- PVC geomembranes have been used in rehabilitation of existing dams of all types and in new construction
- They have been used for rehabilitation of dams underwater
- Different anchoring system used
- Some examples

Drainage System in Geomembrane



- **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



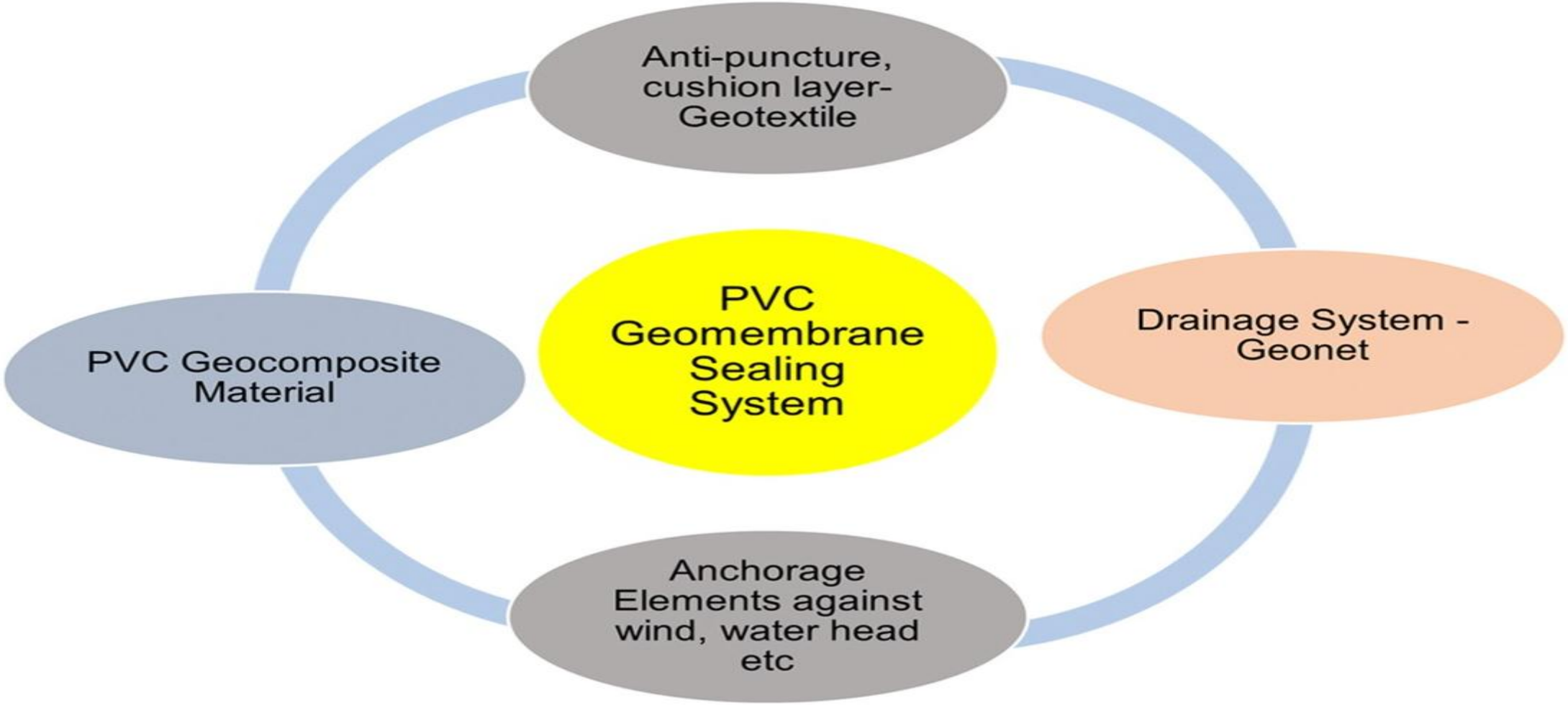
- Used in large dams since >60 years. Installed on >350 large dams worldwide
- ICOLD, International Commission on Large Dams has issued 3 theme Bulletins, the most recent in 2010

Waterproofings system 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

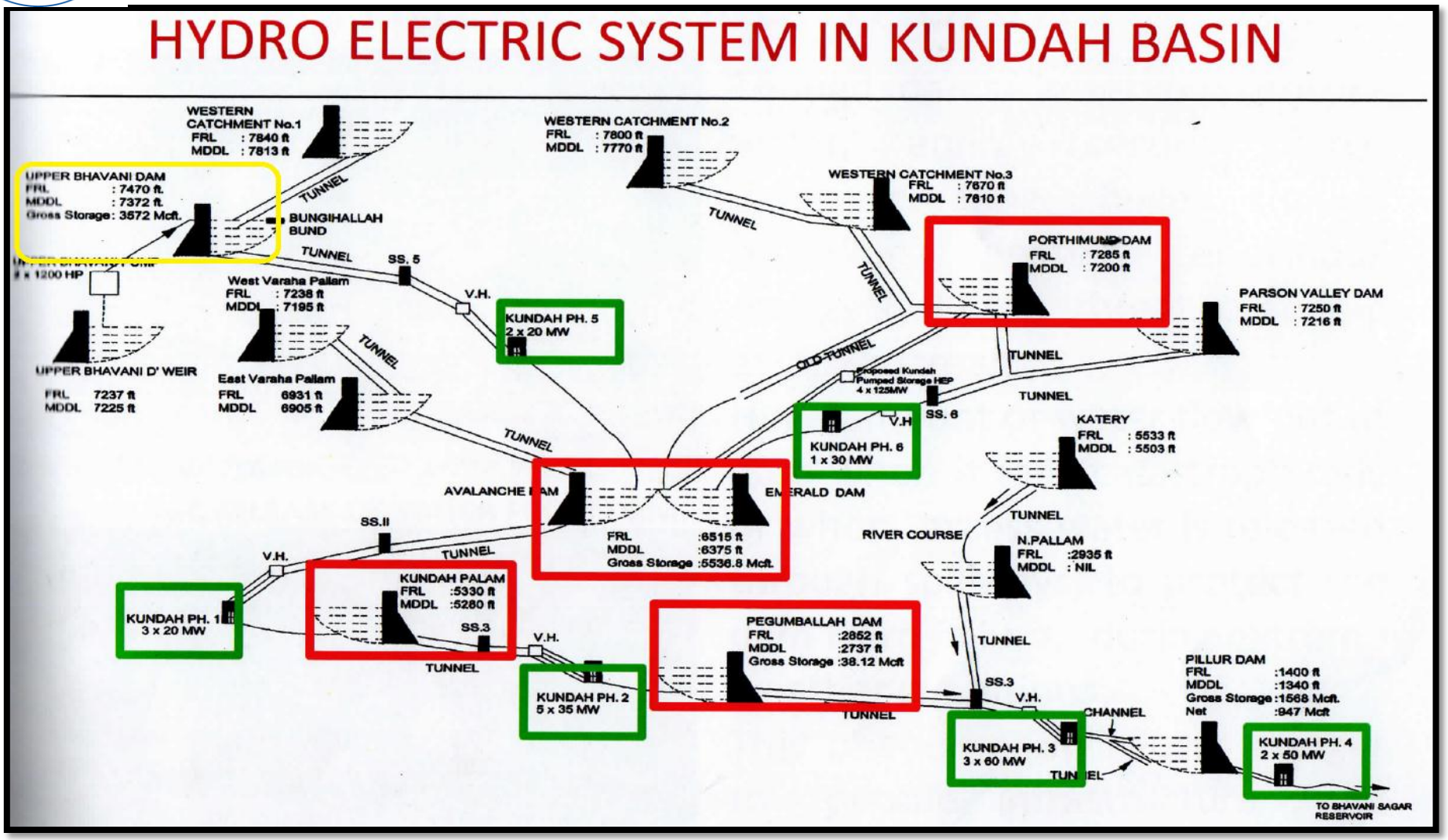
Waterproofings system components

MAJOR FUNCTIONAL ELEMENTS IN GEOMEMBRANE COMPONENTS



UPPER BHAVANI DAM

Importance of this Dam



First Source of water for a series of power houses downstream side (> 600 MW)

Coveted name of being Asia's first cascade Hydro Electric scheme at the time of construction in 1960's

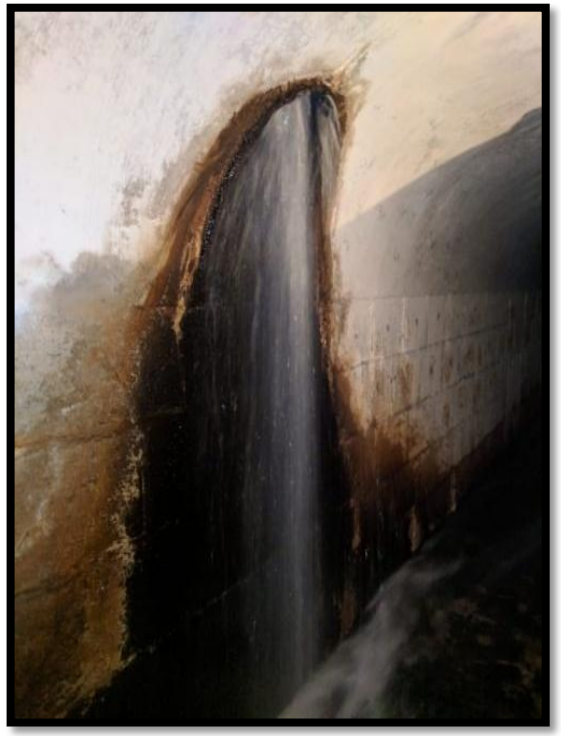
Condition of Dam before Rehabilitation

DECLARED AS
DISTRESSED DAM IN
2005 BY THE DAM SAFETY PANEL
OF CWC/CLIENT

Leakage

- **9000 Lpm (at 9 M Below FRL)**

> 15,000 Lpm (At FRL)



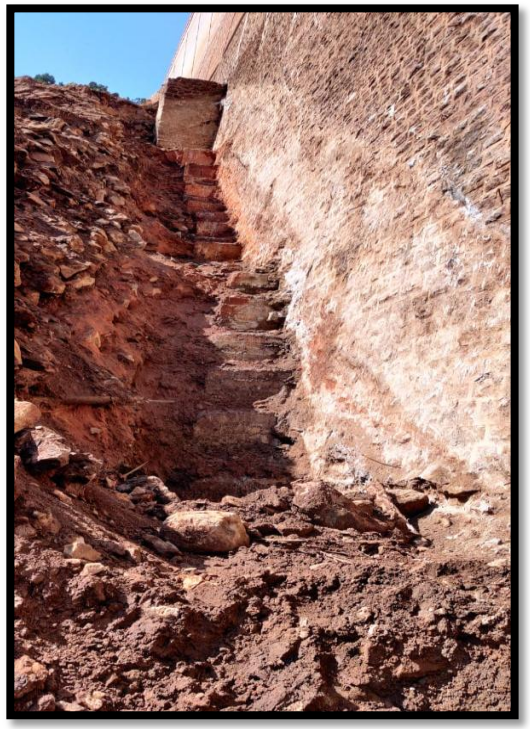
Performance of previous repairs

- Problems in Dam : Severe Leakage in shafts surrounding the spillway and leakage recored at 8200 LPM at 9.14 m below FRL level
- Previous Repair : Grouting, Epoxy Pointing, Guniting/Shot creting

Desilting

Desilting was carried out to expose the toe end of the masonry dam.

Complicated Steep Left Flank. Fairly Safer and levelled Right Flank. Desilting in some places were as deep as 15 meter

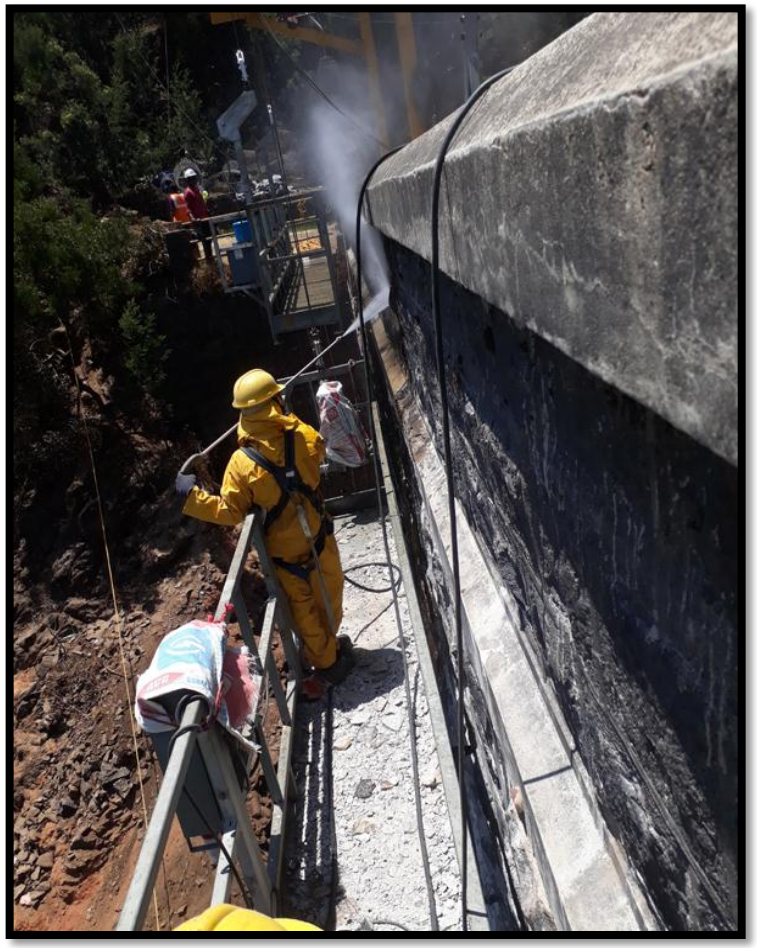


Coffer Dam & Dewatering Arrangements

Coffer Dam and Dewatering using 100 HP pump to expose the the upstream face below the sill level of the gates

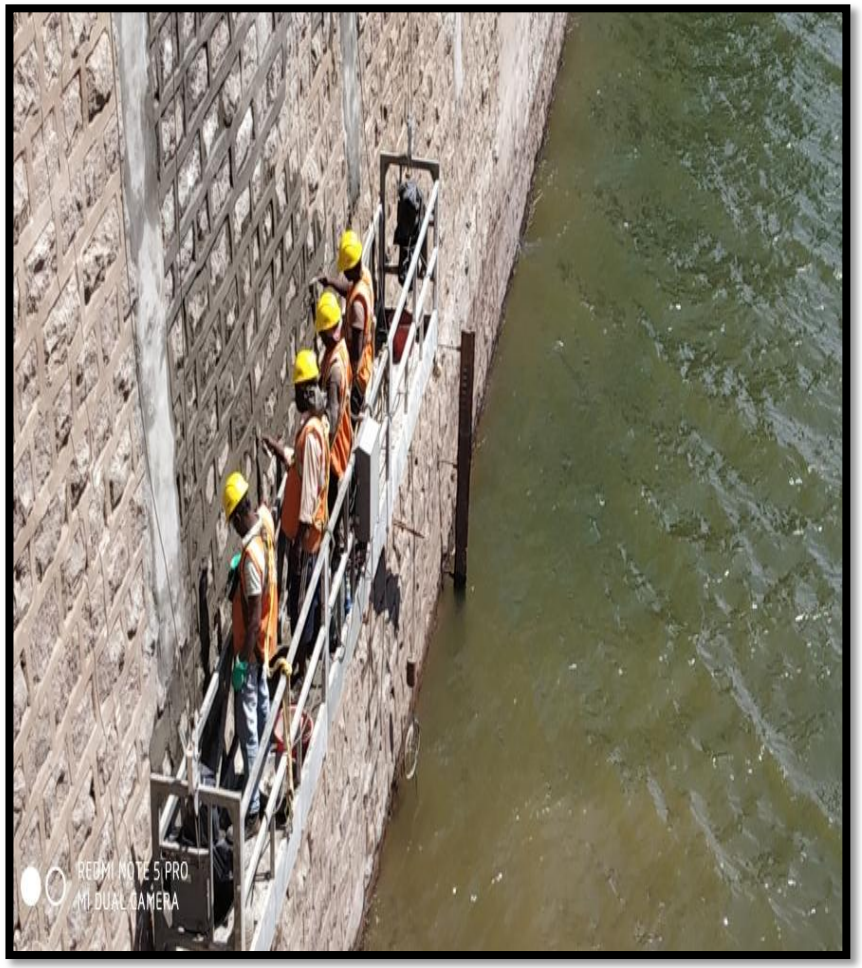
Surface Preparation –

Hydrojet Washing & Pointing

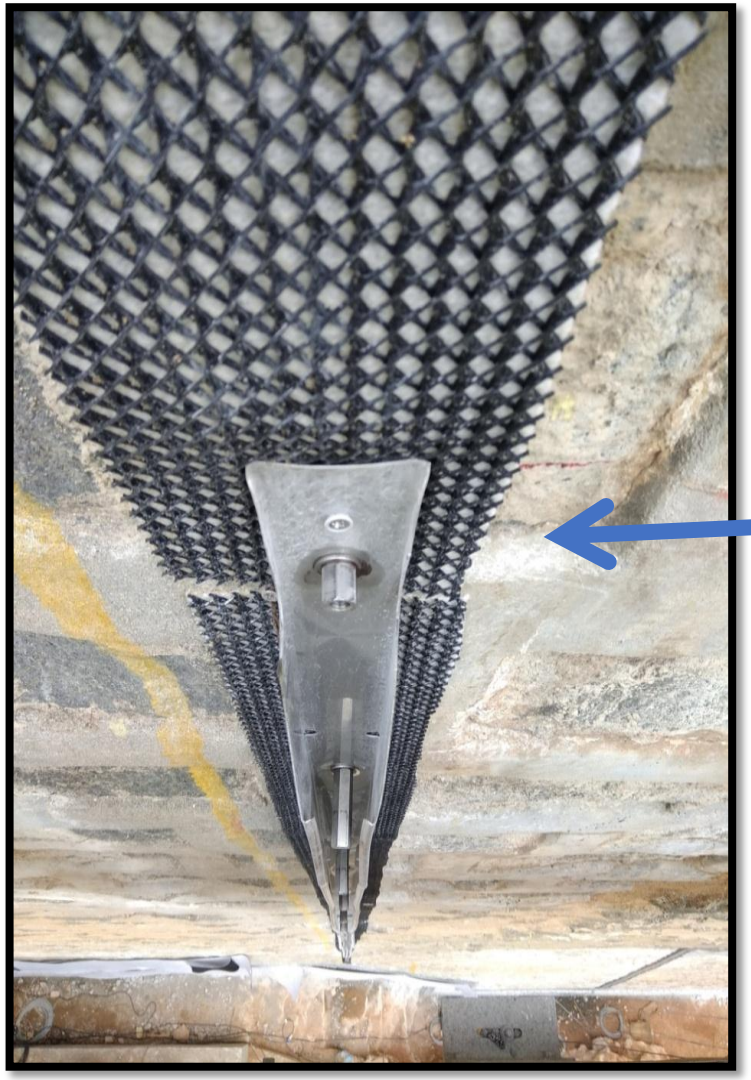


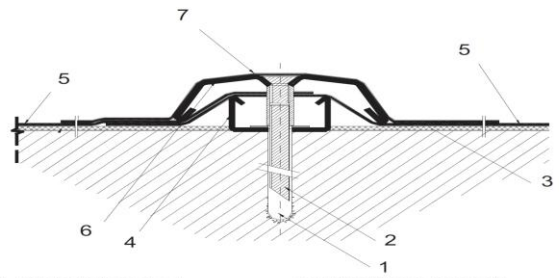
Loose and weak zones were identified using hydrojetting method whereby water applied at high pressure around 150 bar is used to clear and clean the loose particles in the mortar joints.

The withered mortar joints are re-pointed with cement mortar



Fixing of Lower Tensioning Profiles



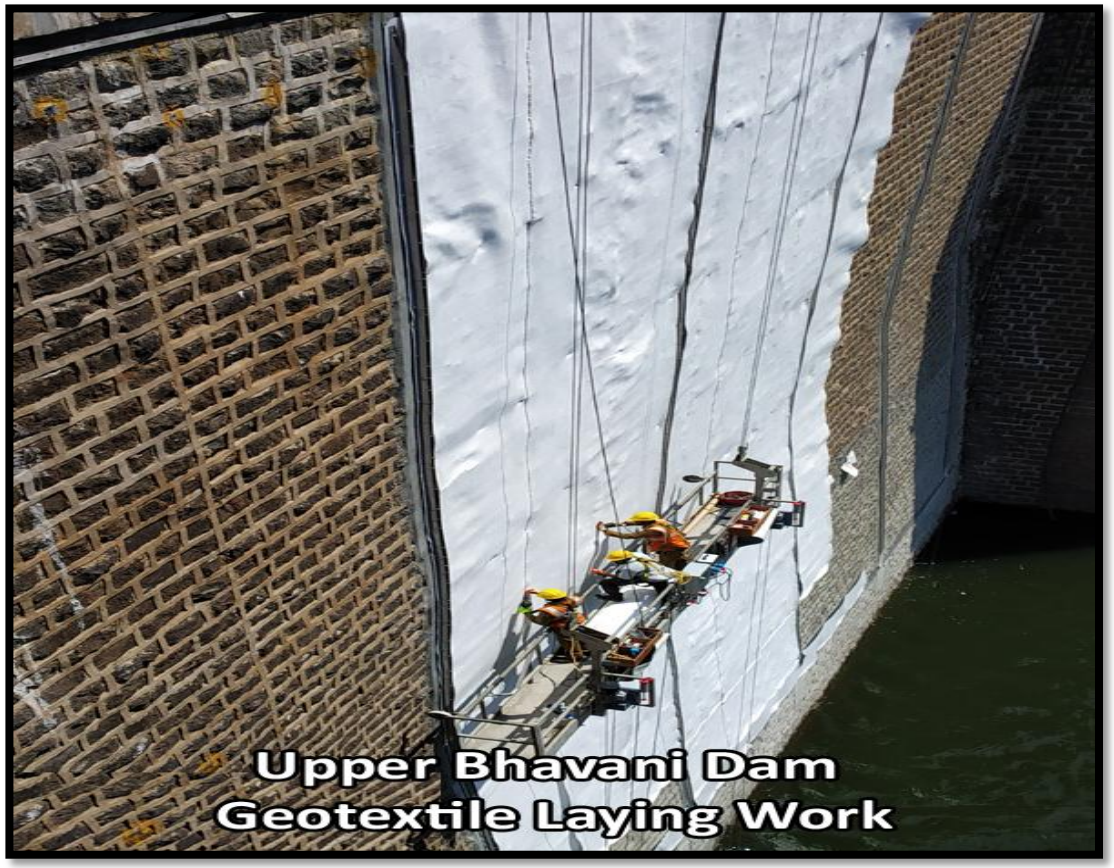


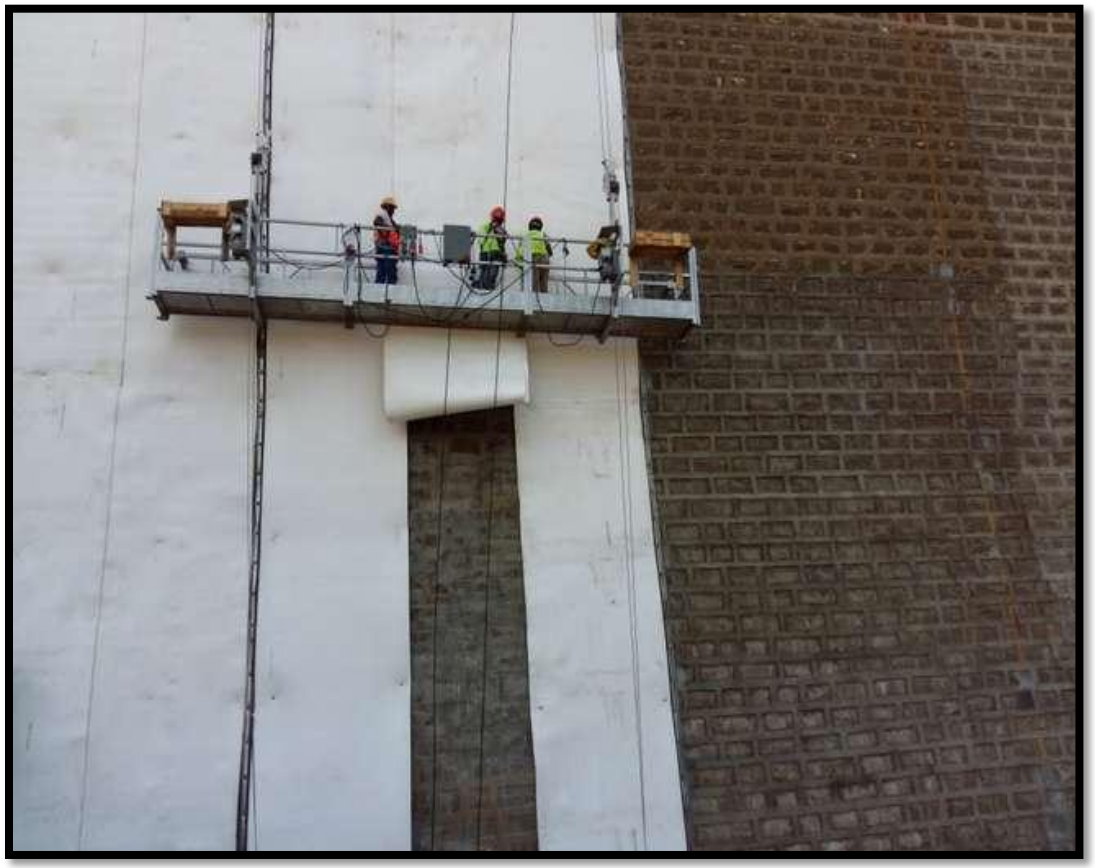
1. Chemical anchor
2. Stainless steel anchor rod
3. Geonet
4. SS internal "U" profile
5. PVC Geocomposite
6. SS external "Ω" profile
7. PVC cover strip

The Lower Tensioning Profiles are fixed at designed intervals @5.7m c/c . Holes are drilled to a depth of 4 to 6 inches and using chemical anchors the bottom tensioning profiles are put in place

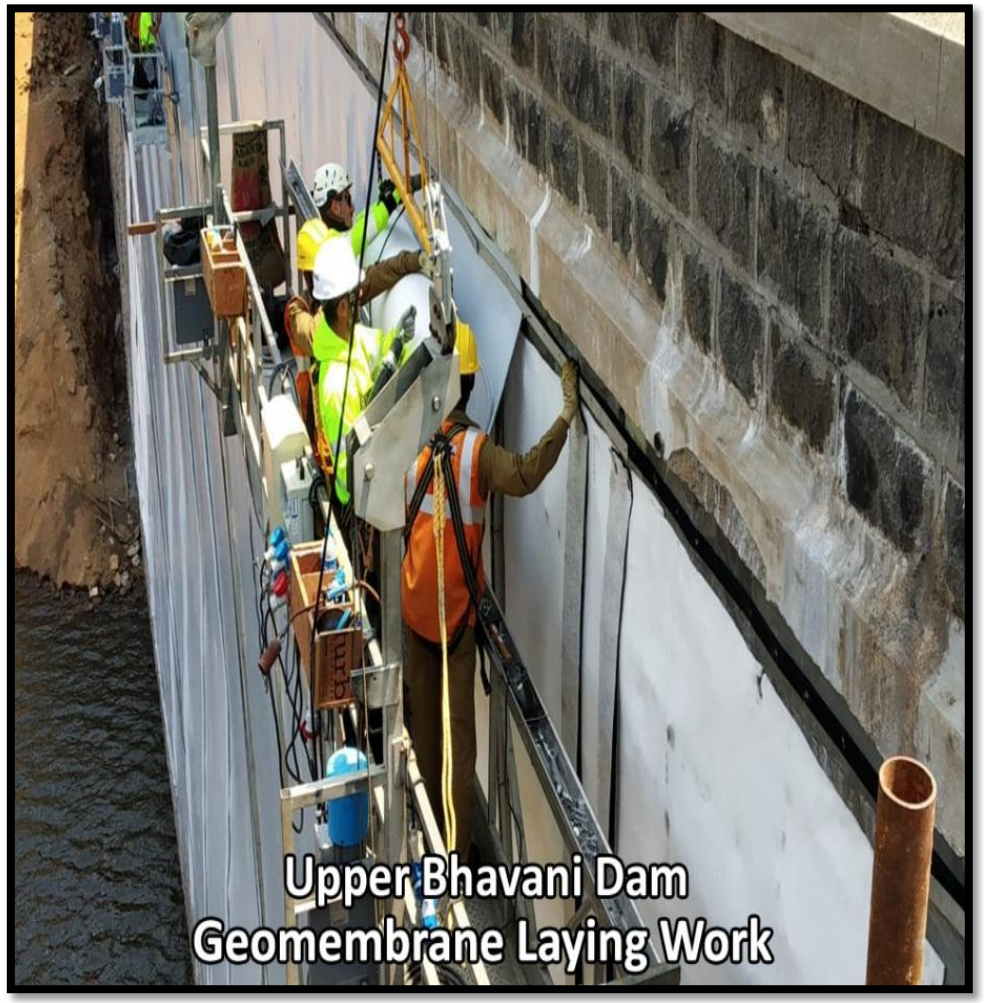
Fixing of Anti puncture geotextile

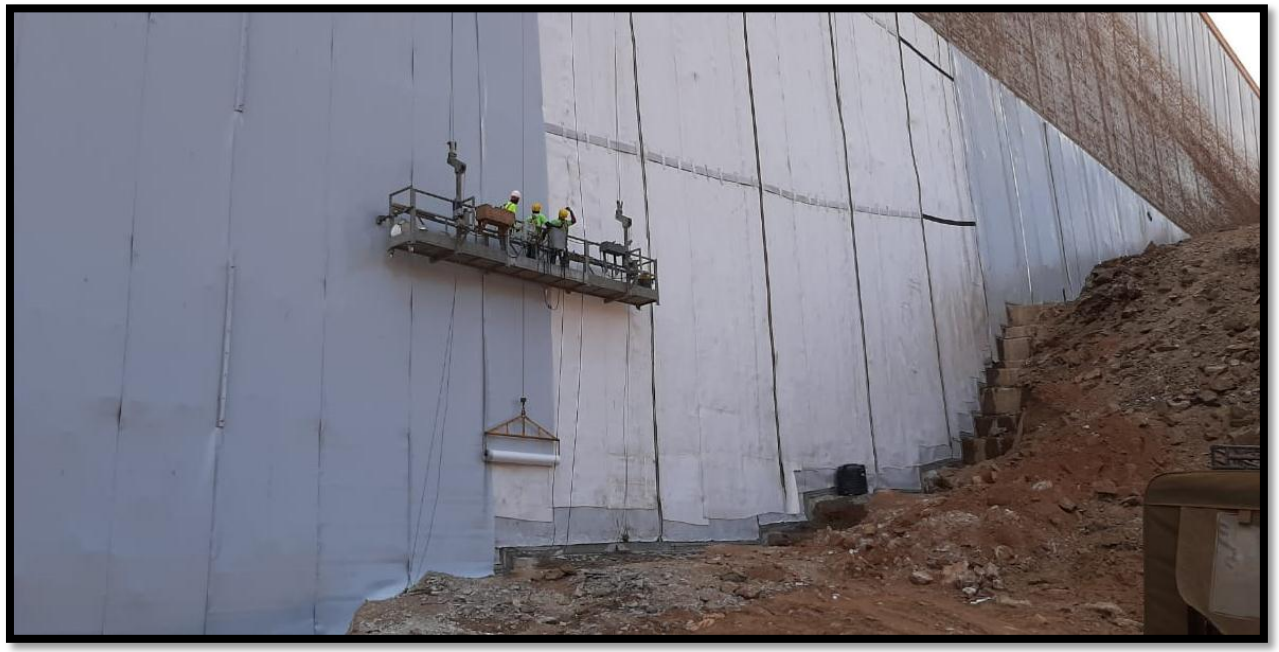
A thick anti puncture geotextile of 2000gsm is installed from the top of the dam till the bottom and fixed by Impact anchors





Unrolling of Geocomposite

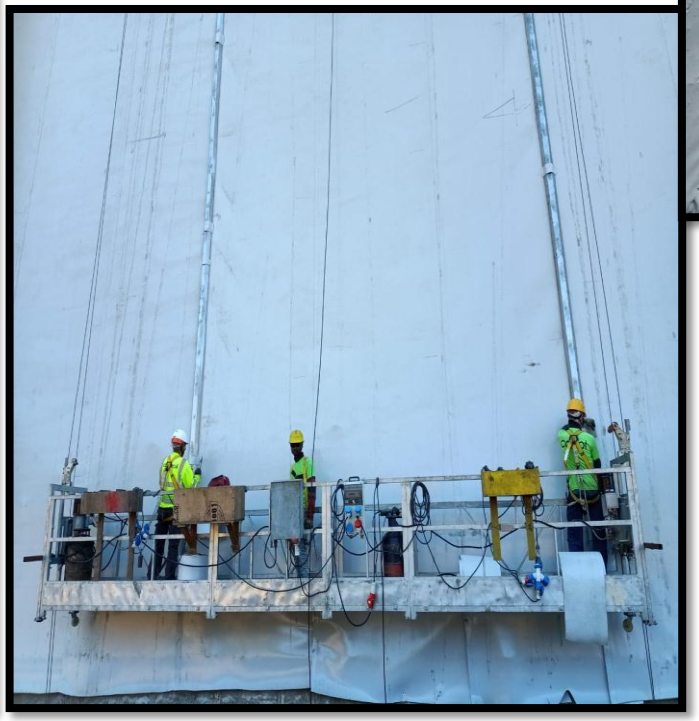




A 3 mm thick geocomposite (3 mm PVC +500 gsm geotextile) rolled over the bottom profile is used as the main waterproofing element

Geocomposite Welding & Upper tensioning profile fixation

Multiple Rolls of Geocomposite are welded by Hot Air Welding. The Upper Tensioning profile is fixed over the lower tensioning profile and adequate torque is provided to tighten and no formation of wrinkles between rolls



No wrinkles to be observed during tightening of Upper Profile

Fixation of Cover Strip

Geomembrane sheets laid over the Upper tensioning profile and welded by hot air seaming

Fiber Optic Cable Leakage Detection System

It works by Heat Pulse method. Cable sandwiched behind the geomembrane and the geonet, detects water entry with velocity

Performance of the Geomembrane waterproofing system to be monitored using special Optical Fiber Cable using Heat Pulse method (HPM)

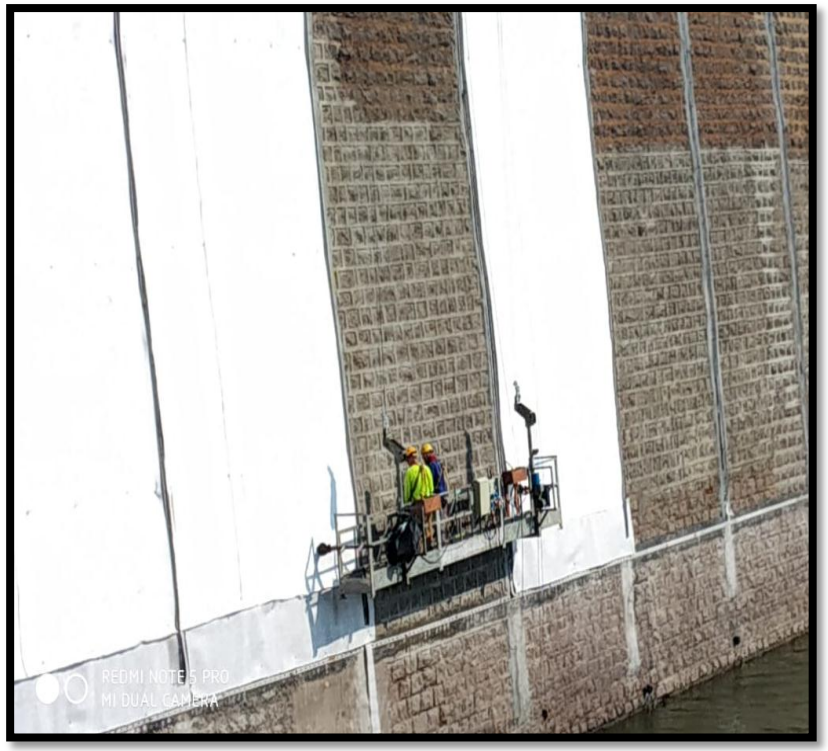
The region of water saturation behind the geomembrane can be easily monitored using this technology advancement

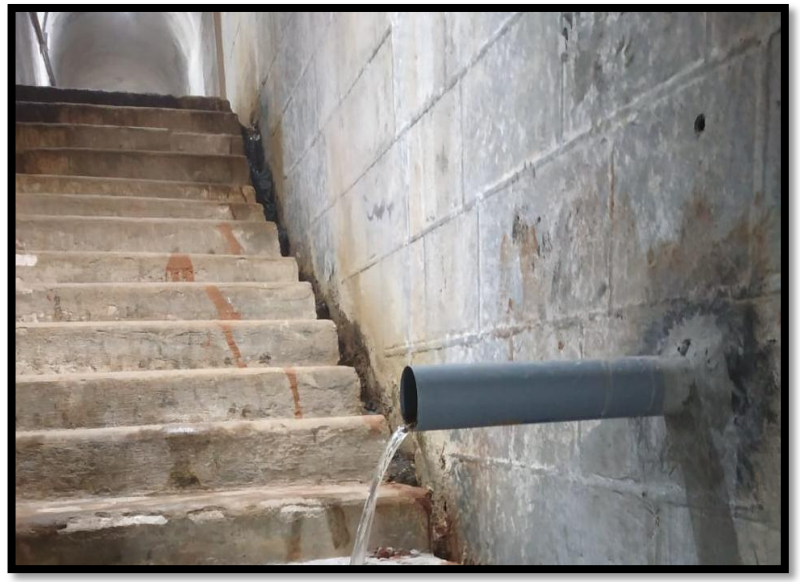
Fixation of Bottom Perimeter Seal

The geomembrane rolls are terminated to the dam face by using special watertight seal made of thick Stainless Steel (80x8mm) material. The geocomposite sheets from the top is connected to the perimeter seal at the bottom and high bonding resin is used with rubber gaskets and seals to prevent entry of water from the bottom.

Drainage Discharge Pipes & Drainage Layer

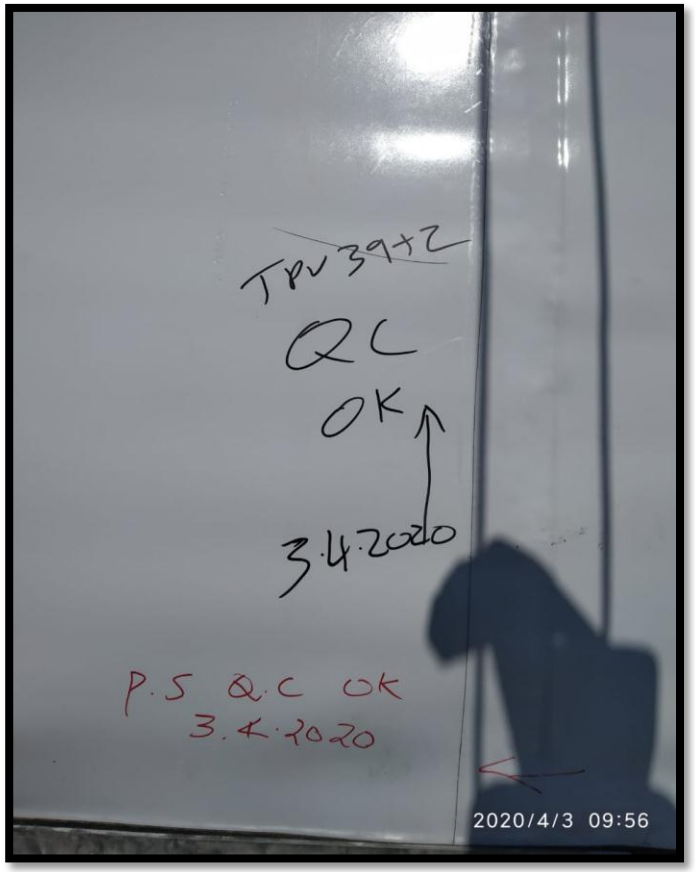
- Drainage discharge is the key element in the geomembrane waterproofing system
- Water entering behind the geomembrane needs to be conveyed through a sophisticated drainage layer consisting of transmissive Geonet layer installed in a band of 0.5 meter above the perimeter seal
- Drain holes are drilled into the gallery from the upstream face

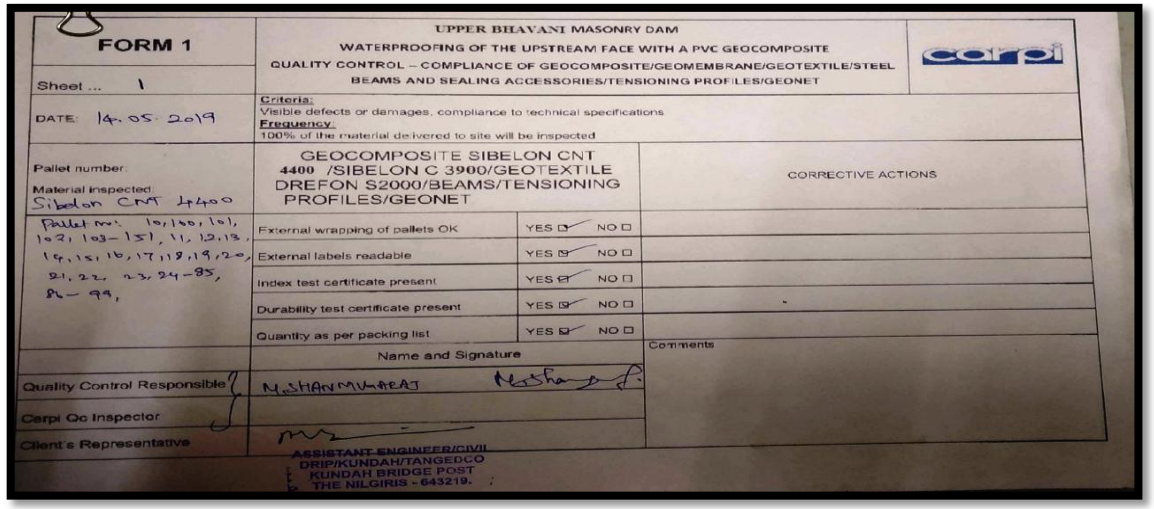




Quality Control and Quality Check

Quality Control Plan -> Quality Check (Carpi) > Quality Check (Client) > Quality Control Form





FORM 1

UPPER BHAVANI MASONRY DAM
WATERPROOFING OF THE UPSTREAM FACE WITH A PVC GEOCOMPOSITE
QUALITY CONTROL – COMPLIANCE OF GEOCOMPOSITE/GEOMEMBRANE/GEOTEXTILE/STEEL BEAMS AND SEALING ACCESSORIES/TENSIONING PROFILES/GEONET

carpi

Sheet ... 1

DATE: 14.05.2019

Criteria:
Visible defects or damages, compliance to technical specifications
Frequency:
100% of the material delivered to site will be inspected

Pallet number:
Material inspected:
Sibelon CMT 4400

GEOCOMPOSITE SIBELON CNT 4400 /SIBELON C 3900/GEOTEXTILE DREFON S2000/BEAMS/TENSIONING PROFILES/GEONET

CORRECTIVE ACTIONS

Pallet nos: 1a, 100, 101, 102, 103–151, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24–85, 86–99,

External wrapping of pallets OK	YES ☑	NO ☐
External labels readable	YES ☑	NO ☐
Index test certificate present	YES ☑	NO ☐
Durability test certificate present	YES ☑	NO ☐
Quantity as per packing list	YES ☑	NO ☐

Comments

Name and Signature

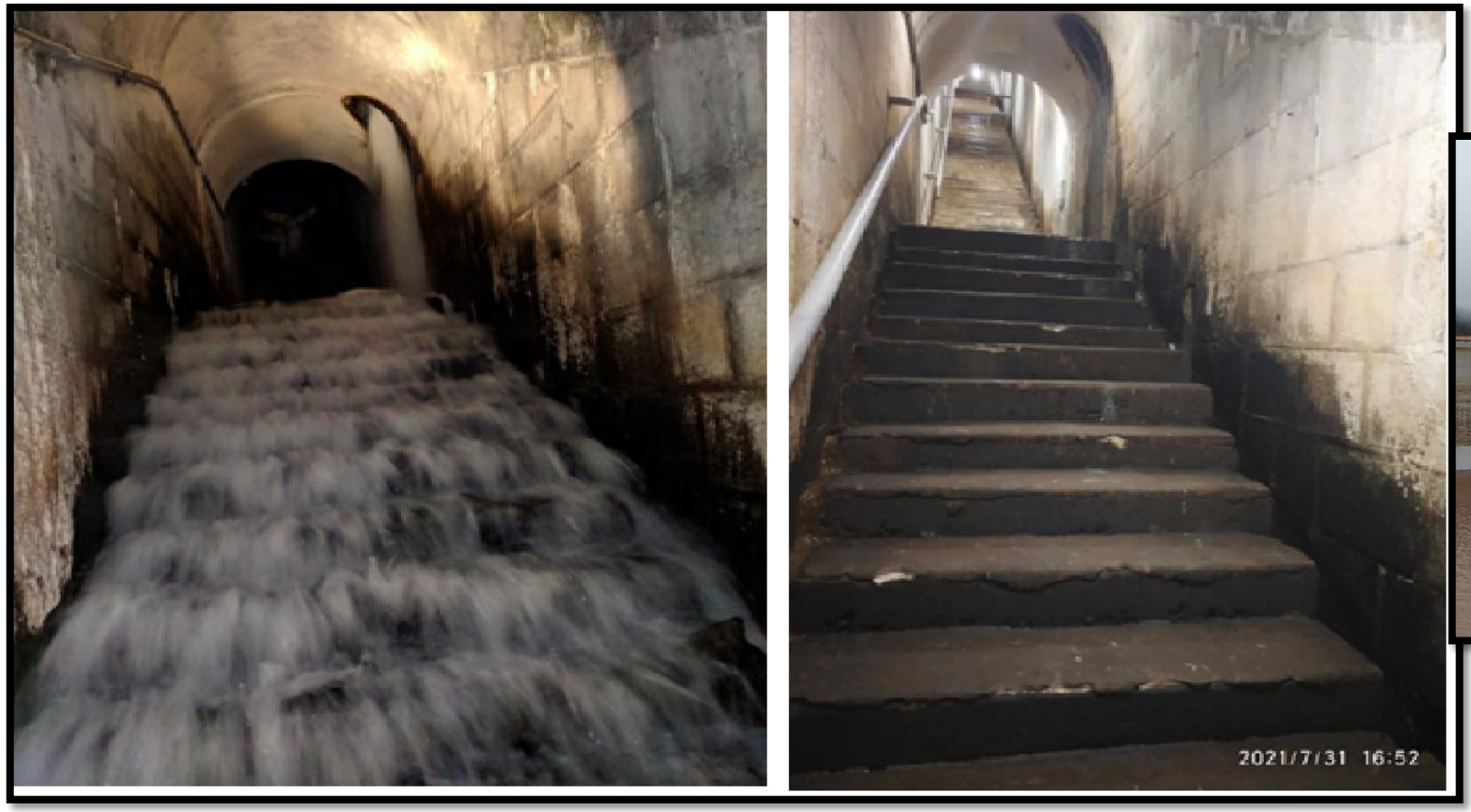
Quality Control Responsible / Carpi Qc Inspector: MOHANMURAT

Client's Representative:

ASSISTANT ENGINEER/CIVIL
DRIP/KUNDAH/TANGEDCO
KUNDAH BRIDGE POST
THE NILGIRIS - 643219.

Results Of Waterproofing

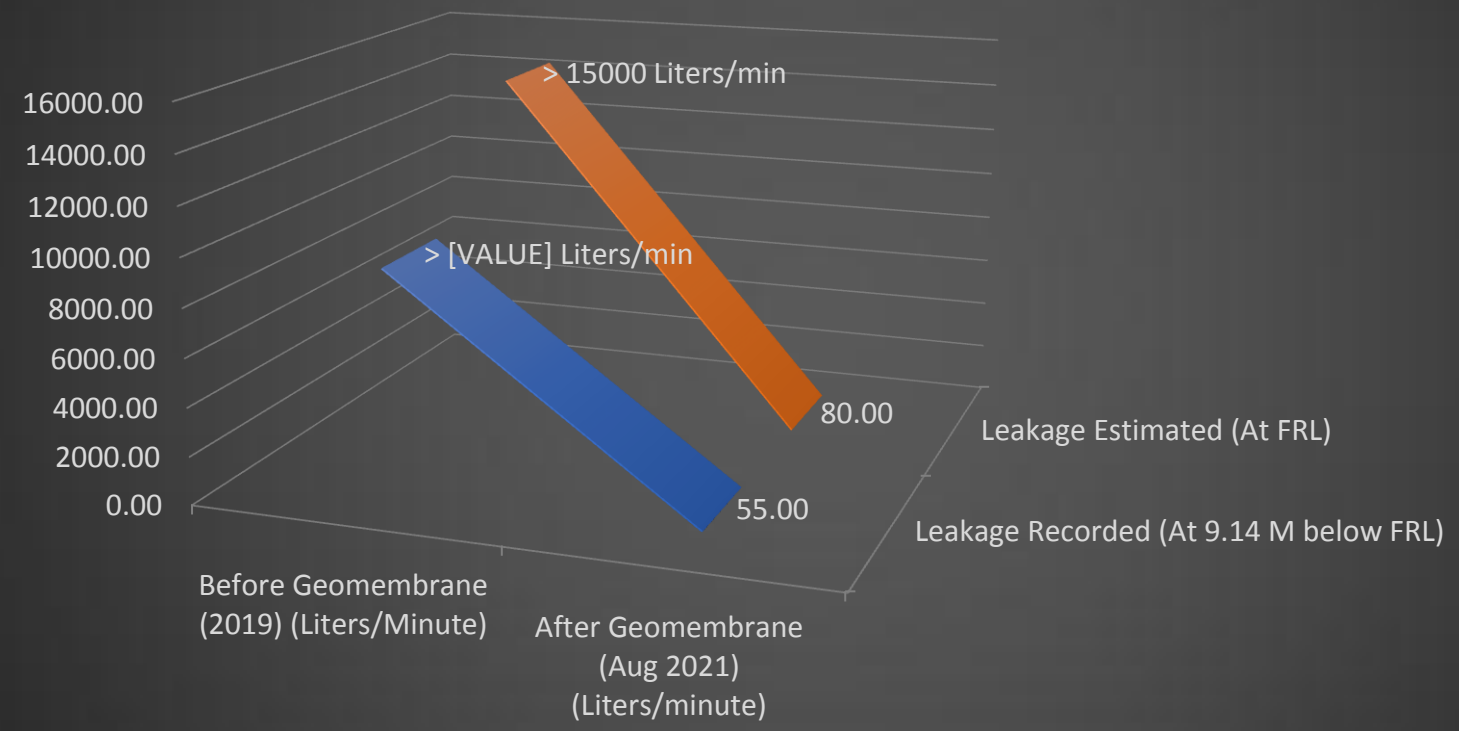
Vertical Drain Shaft (Right Spillway)Before and After GM Installation



Before Geomembrane in 2019

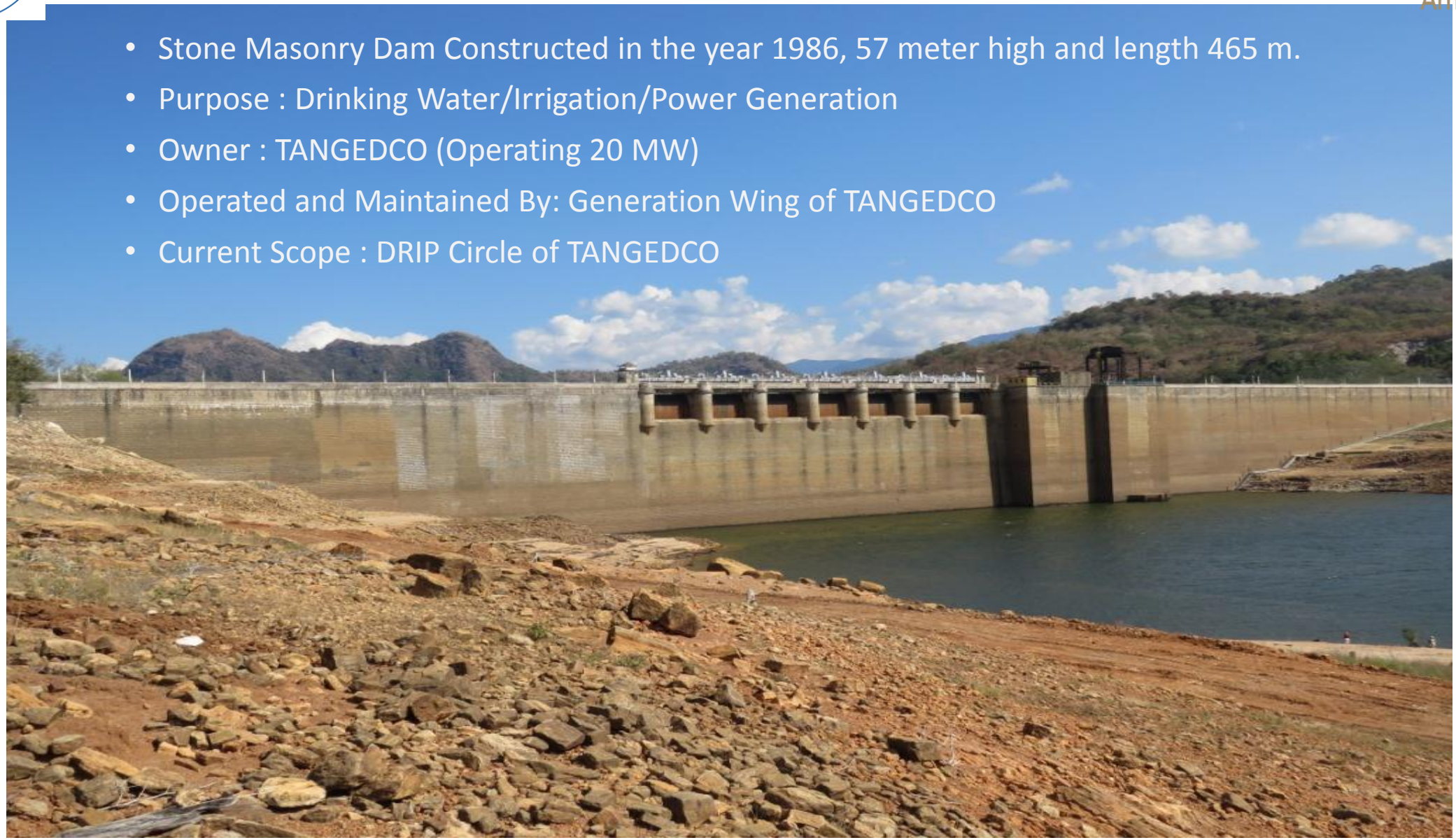

After Geomembrane in 2021

Upper Bhavani Dam Leakage (Before & After Geomembrane)

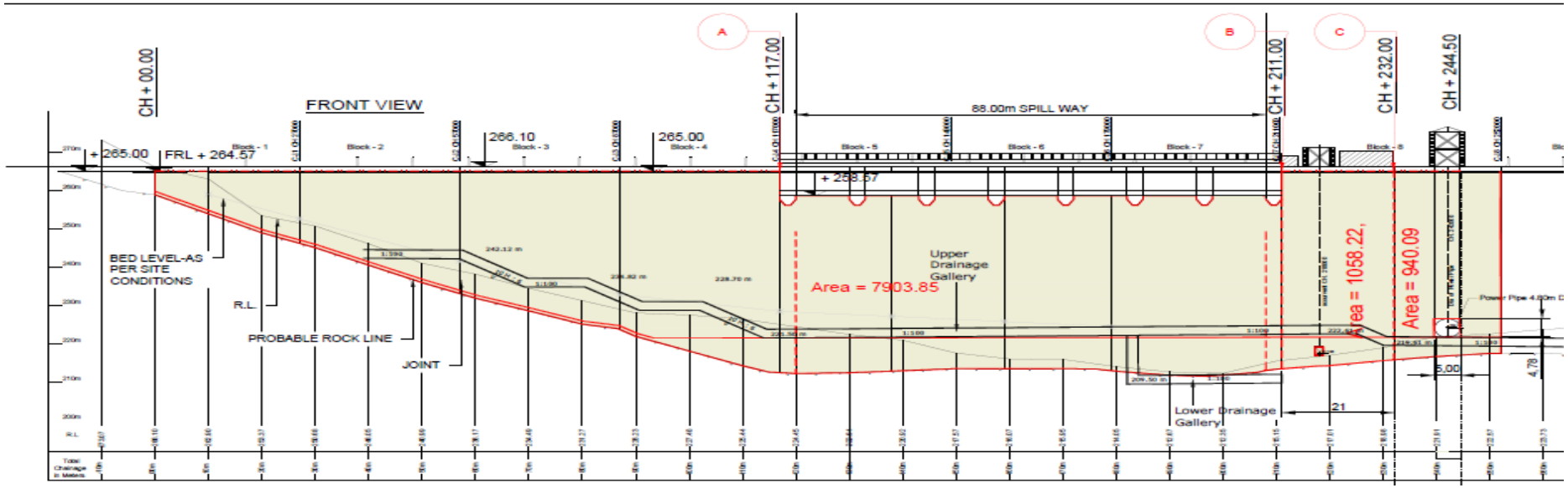


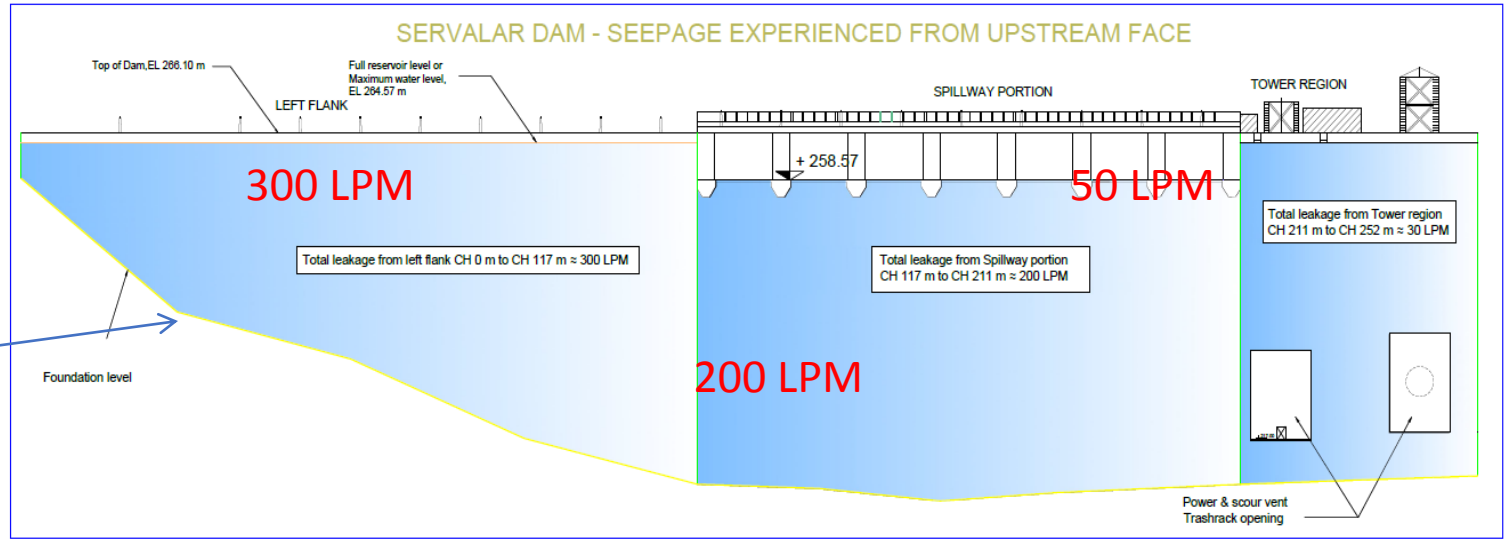
SERVALAR DAM

- 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
- Current Scope : DRIP Circle of TANGEDCO



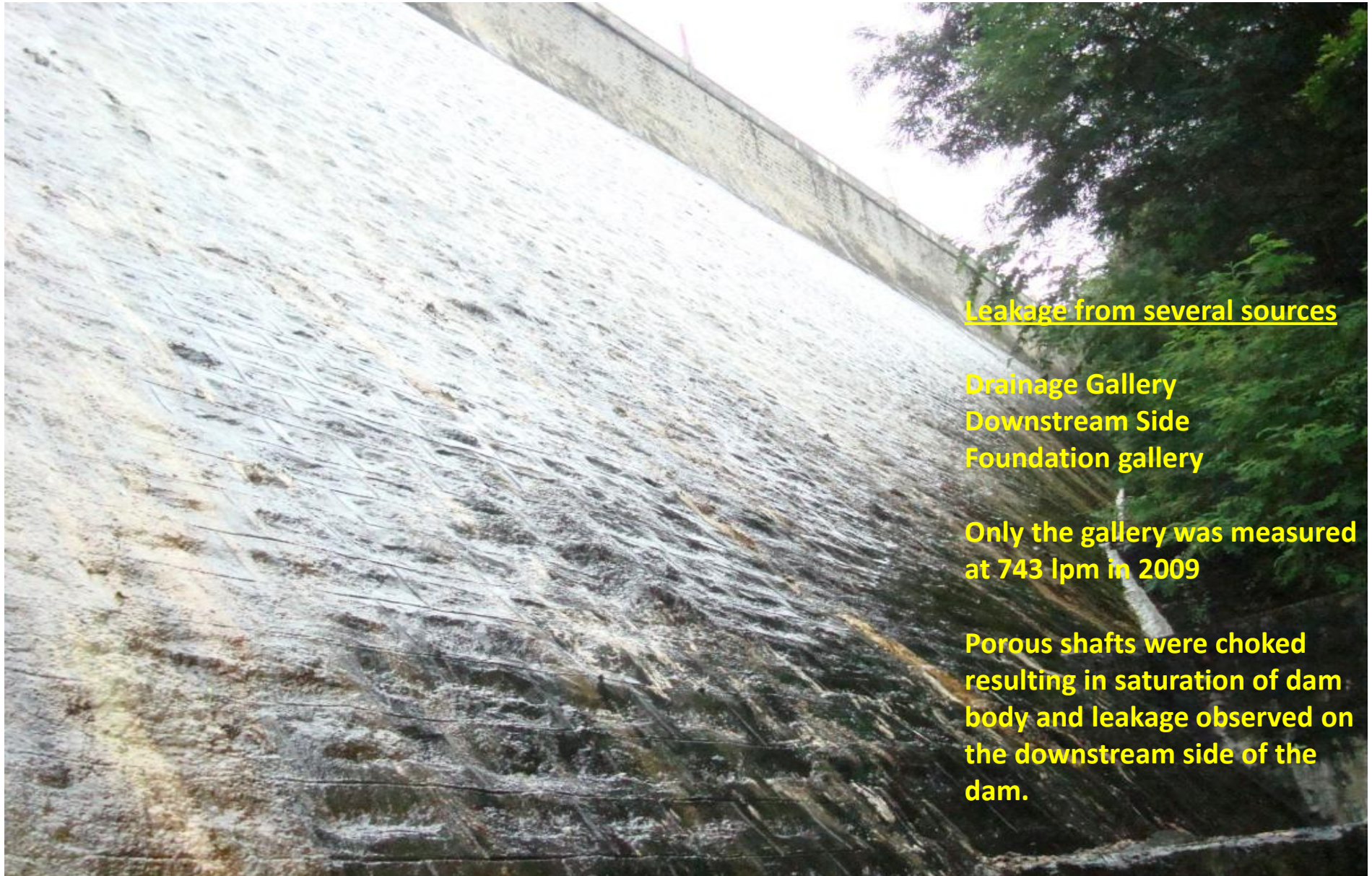
Part of the Dam – Left Flank and Spillway





> 550 Lpm @ 80% FRL

Heavy Seepage in the dam



Leakage from several sources

Drainage Gallery
Downstream Side
Foundation gallery

Only the gallery was measured at 743 lpm in 2009

Porous shafts were choked resulting in saturation of dam body and leakage observed on the downstream side of the dam.

Placing of Anti puncture Geotextile

Once the Top seal is fixed, the geotextile is rolled from the top till the bottom and fixed by Impact Anchors.

Geotextile acts like an anti puncture layer (also assists in drainage layer)

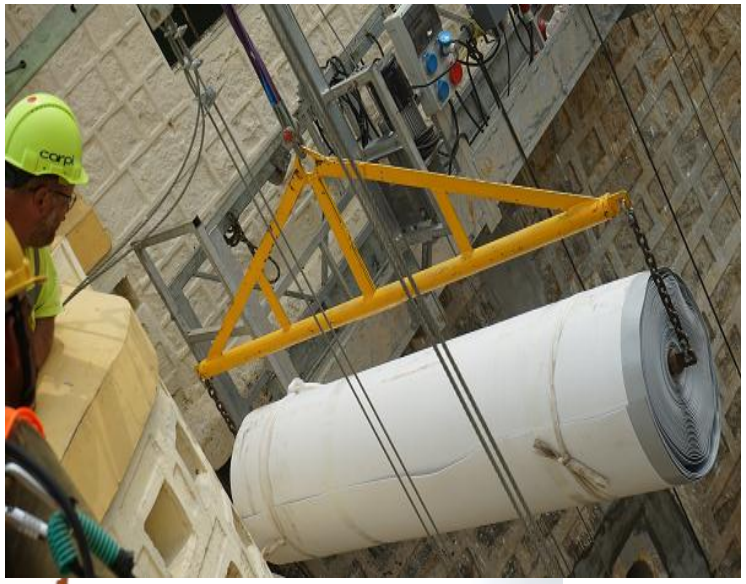
Drainage Geonet

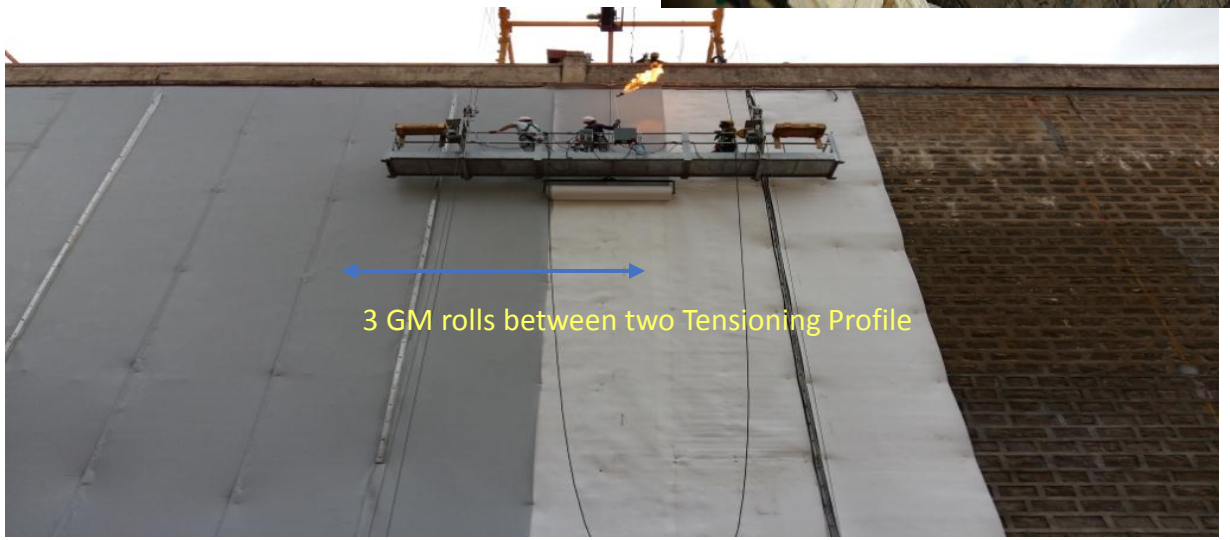
High Transmissive geonet is fixed just above the first perimeter seal and also between the first and second perimeter seal. Another innovation and advancement is the usage of new geonet which has filter material on both the sides or on one side, depending on the application.

The purpose is to filter the water and convey the water at ease thereby preventing congestion of the water path

Rolling and Installation of Geocomposite

Geocomposite rolls are unrolled using the lifting mechanism inbuilt in the suspended platforms. The lowered rolls are put in place by the installers in the platforms

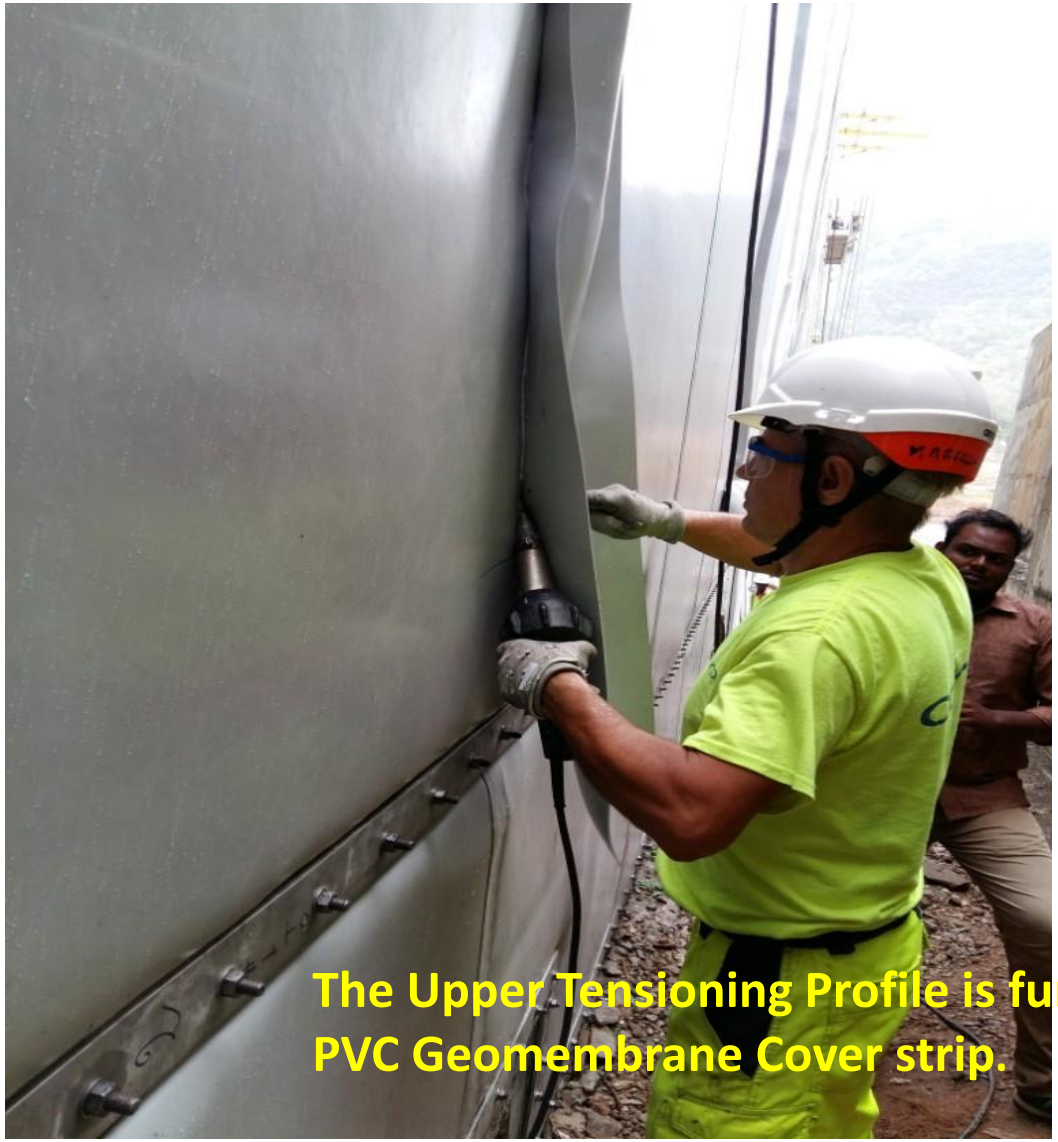




Geocomposite Welding

Multiple Rolls of Geocomposite are welded by Hot Air Welding.

Fixation of Cover Strips



The Upper Tensioning Profile is further covered with PVC Geomembrane Cover strip.

Final Phase of Installation

Results of Geomembrane Waterproofing System

Before Geomembrane Installation – In 2014

Saturated Downstream

After Geomembrane Installation – In Aug 2018

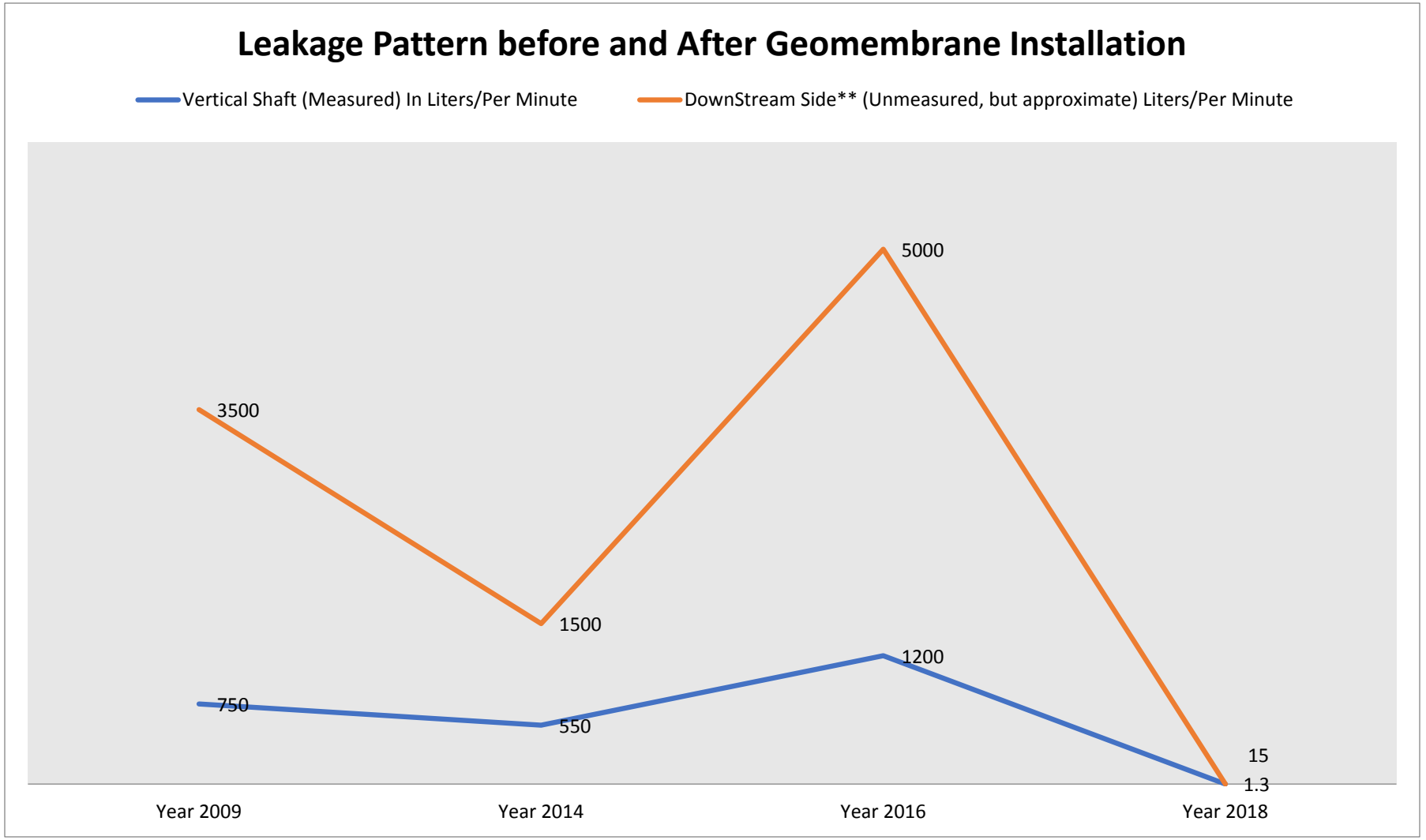
Dry Downstream

Gallery View

Before Geomembrane

After Geomembrane

Leakage Results



THIS IS THE ONLY PRODUCT THAT CARPI SELLS

After nearly 4.5 Years of Service

Faced 5 Floods in the four years

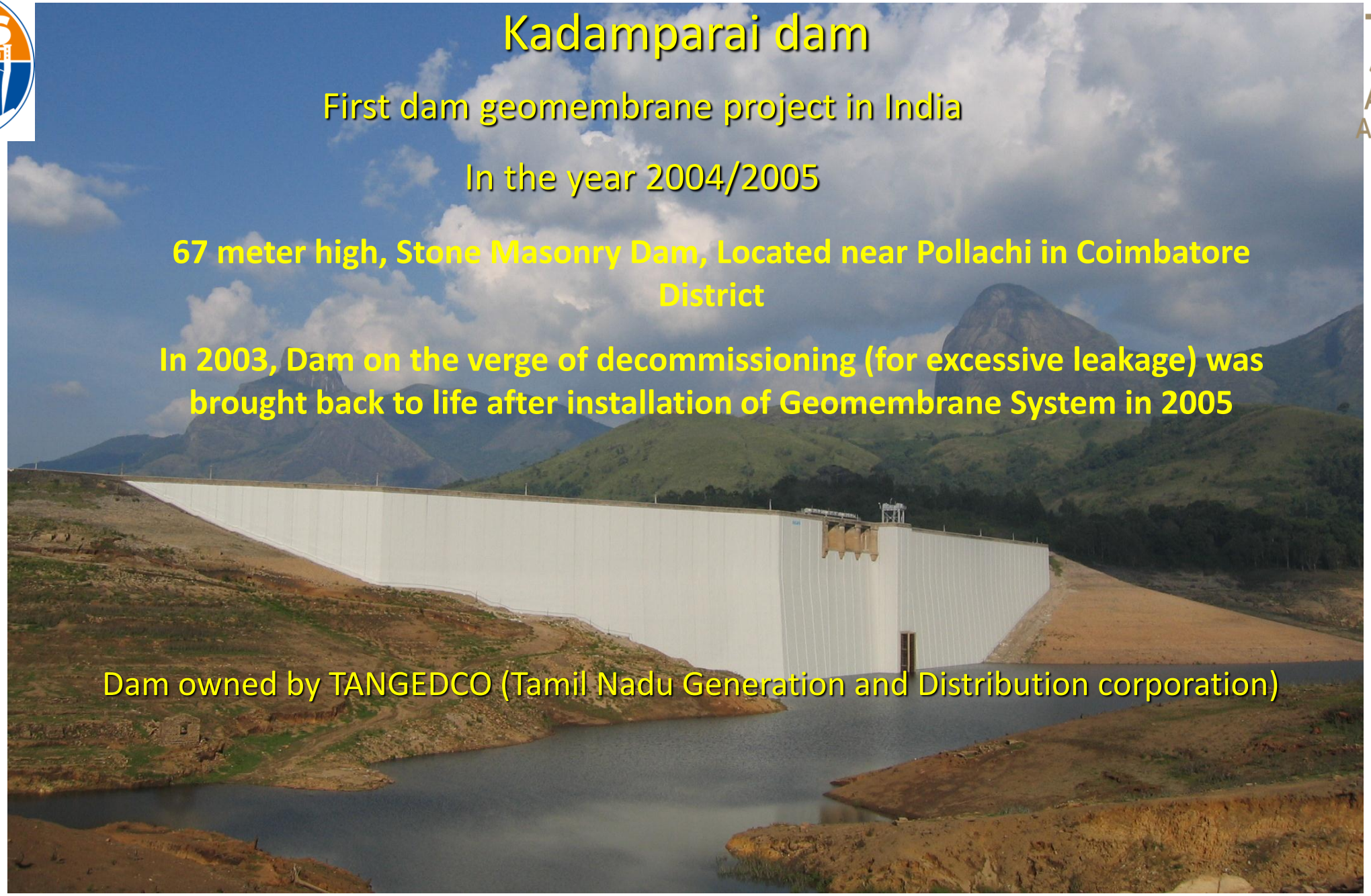
Kadamparai dam

First dam geomembrane project in India

In the year 2004/2005

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



Dam owned by TANGEDCO (Tamil Nadu Generation and Distribution corporation)

Leakage in the drainage gallery, left abutment

KADAMPARAI DAM

Conclusions

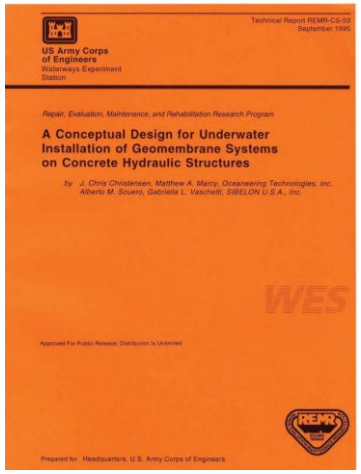

Kadamparai Dam In July 2022 – System still in tact after 17 years
Leakage still around 100 lpm

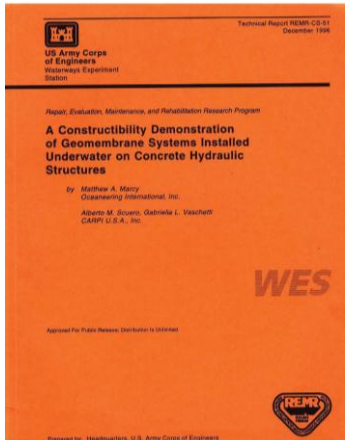
Conclusions (Indian Case Studies)

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	< 80 Lpm (99.8% Savings)	18 years
Servalar Dam	2018	9854 Sqm	5,000-6,000 Lpm	< 30 Lpm (99.6% Savings)	5 Years
Upper Bhavani Dam	2021	17,904 Sqm	8,000-12,000 Lpm	< 80 Lpm (99.5% Savings)	2 Year

UNDERWATER INSTALLATION

CARPI started the first study and tests under a contract for the US Army Corps of Engineers in 1995/1996





UNDERWATER INSTALLATION

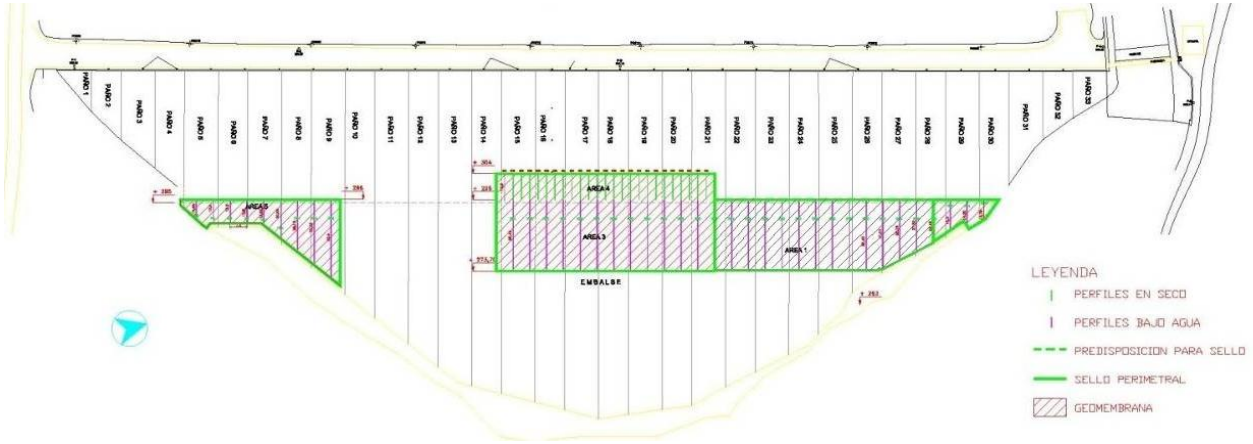
First project in USA 1997, rehabilitation for the full face of Lost Creek arch dam.

Total leakage < 0.0126 l/s

UNDERWATER INSTALLATION

First large project in Venezuela, 2010/2011 for the rehabilitation of some 20% of Turimiquire upstream face. Maximum diving depth 65 m

Leakage reduced from 9,800 l/s to 2,400 l/s



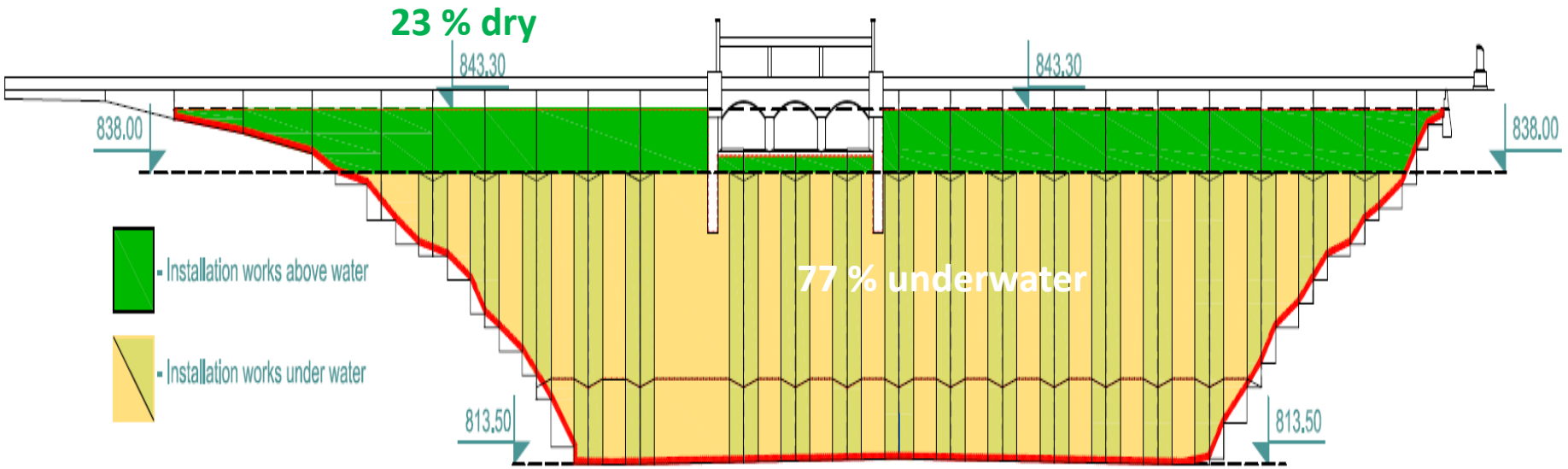
UNDERWATER INSTALLATION

Platanovryssi 95 m high RCC dam Greece, 2001

Waterproofing of cracks in new concrete

Studena buttress dam-Underwater installation

- Owned by the Ministry of Regional Development and Public Works, Bulgaria
- Funds by The World Bank
- Total surface 5,200 m2
- Contract amount: 16,309,000 Euros,
- Only geomembrane works: 39 %



UNDERWATER INSTALLATION

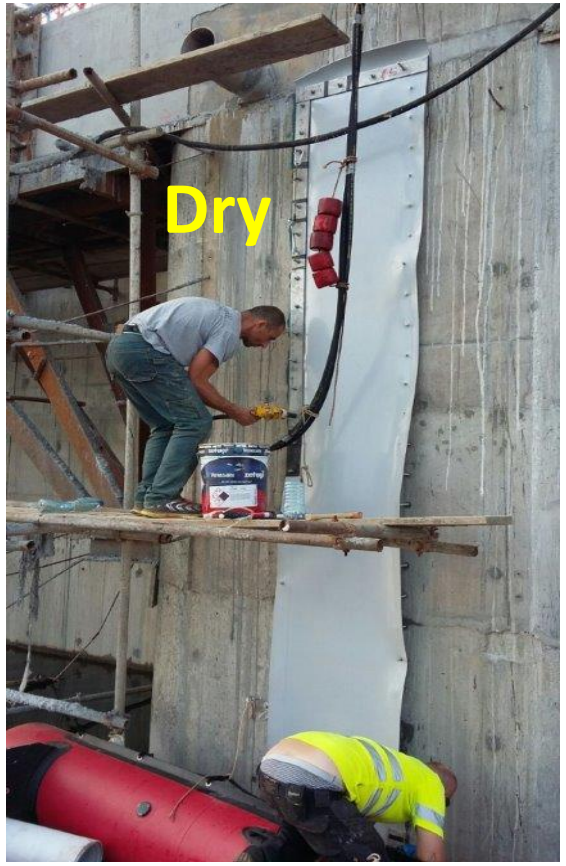
Nakai RCC dam, Laos 2016

Waterproofing of joints, holes, cracks

UNDERWATER INSTALLATION

Lom Pangar embankment + RCC dam Cameroon, 2016

Waterproofing of joint

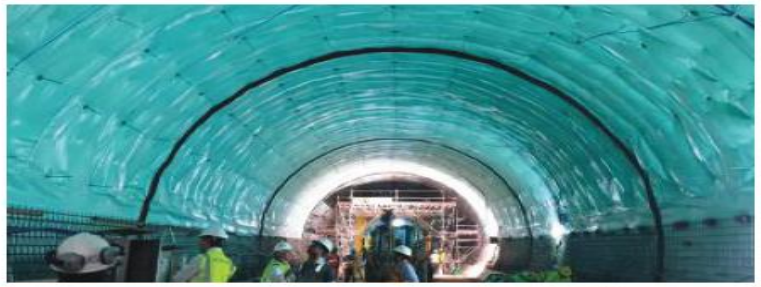


UNDERWATER INSTALLATION

Olai gravity dam, Italy, 2013

Waterproofing of joints







THANK YOU