



Indian National Committee  
on Large Dams

# INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

## Experience of Flexible Impermeable Geomembrane in DRIP (Dam Rehabilitation and Improvement Program) Project in India

presented by

**carpi**

**Jagadeesan Subramanian**

***Carpi India Waterproofing Specialists, Chennai, Tamil Nadu***

10-12 October 2022 at Jaipur, Rajasthan (India)

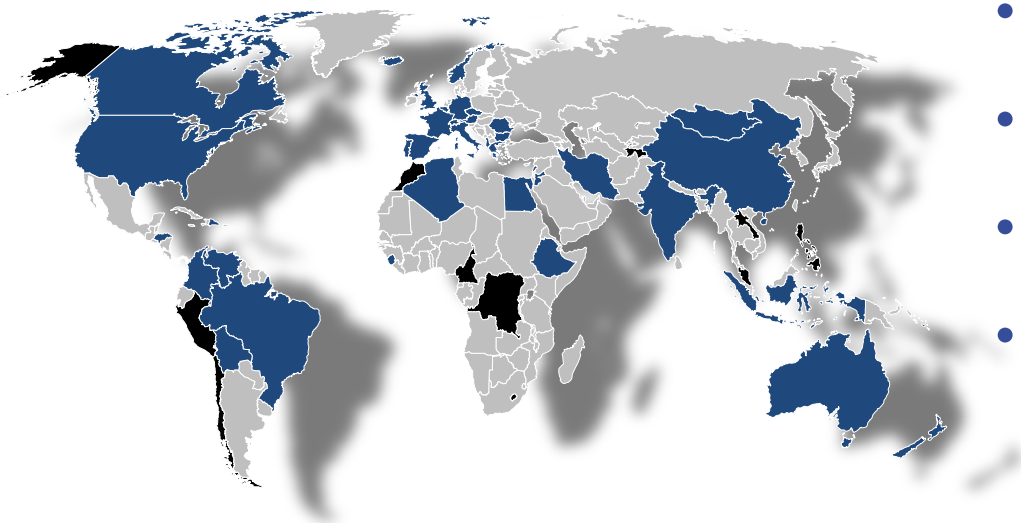


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**Carpi has successfully rehabilitated more Than 350 Successfully Completed Waterproofing Projects Worldwide & Several Investigation Projects Since 1963**



- LARGE DAMS
- RESERVOIRS
- CANALS
- HYDRO TUNNELS AND  
SHAFTS
- TRAFFIC TUNNELS
- SUBWAYS

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**GEOMEMBRANES ARE THIN  
FLEXIBLE MATERIALS WITH VERY  
LOW PERMEABILITY**

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

**Geomembrane  
+ Geotextile  
= GECOMPOSITE**

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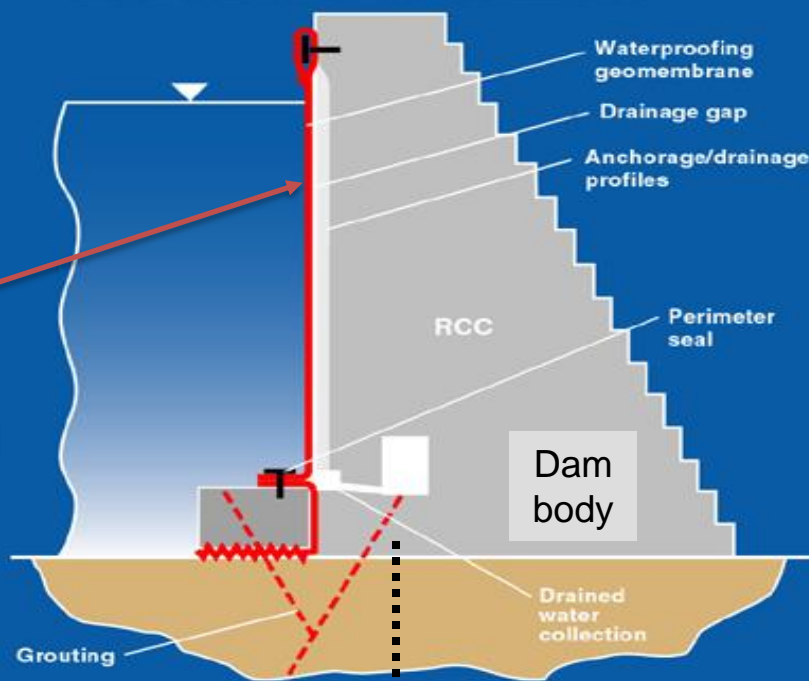
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The CARPI system consists in the installation of a PVC geocomposite, with its own drainage system, on the upstream face of the dam, from crest to foundation.

## THE CONCEPT

The geomembrane is represented by the red line.



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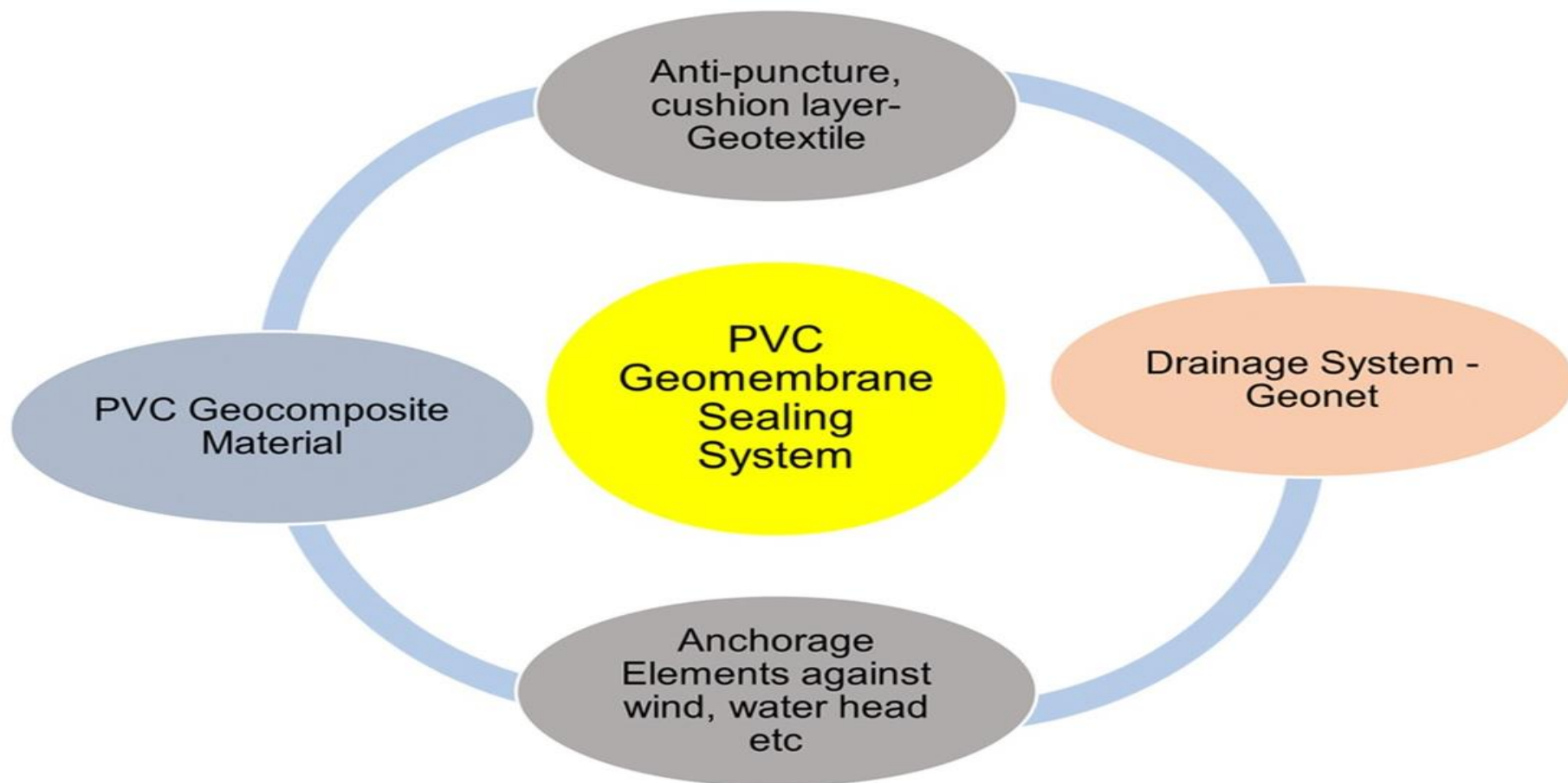


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## MAJOR FUNCTIONAL ELEMENTS IN GEOMEMBRANE COMPONENTS



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

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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)**



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Dam Rehabilitation & Improvement Project



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## UPPER BHAVANI DAM Second Dam Rehabilitated Under DRIP in 3 Stages between 2019 and 2021

80 m high stone masonry dam  
425 m length

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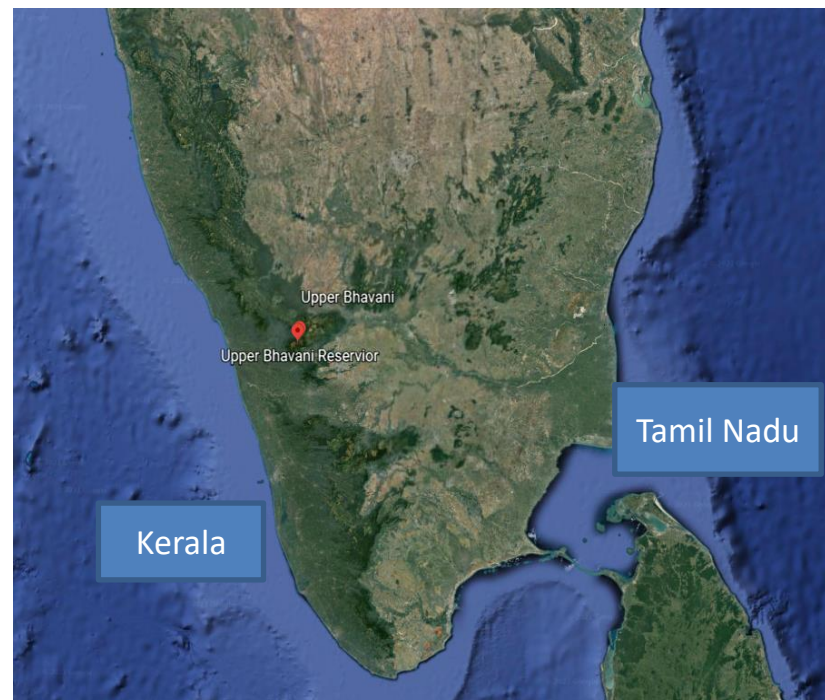
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## Geographical Location

LOCATED IN THE BORDER BETWEEN STATE OF TAMIL NADU AND KERALA



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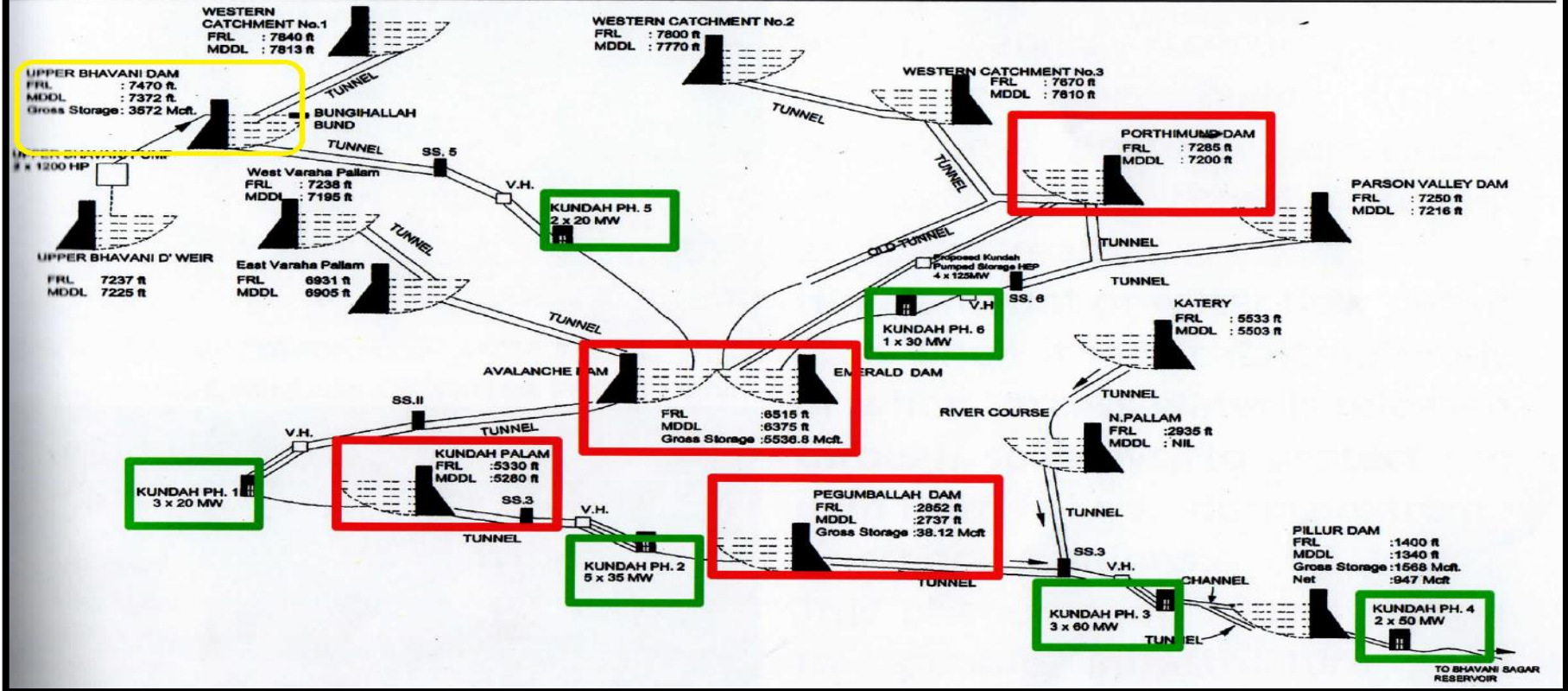
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## HYDRO ELECTRIC SYSTEM IN KUNDAH BASIN



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





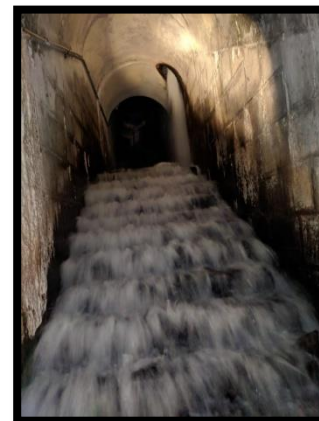
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## Condition of Dam before Rehabilitation



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

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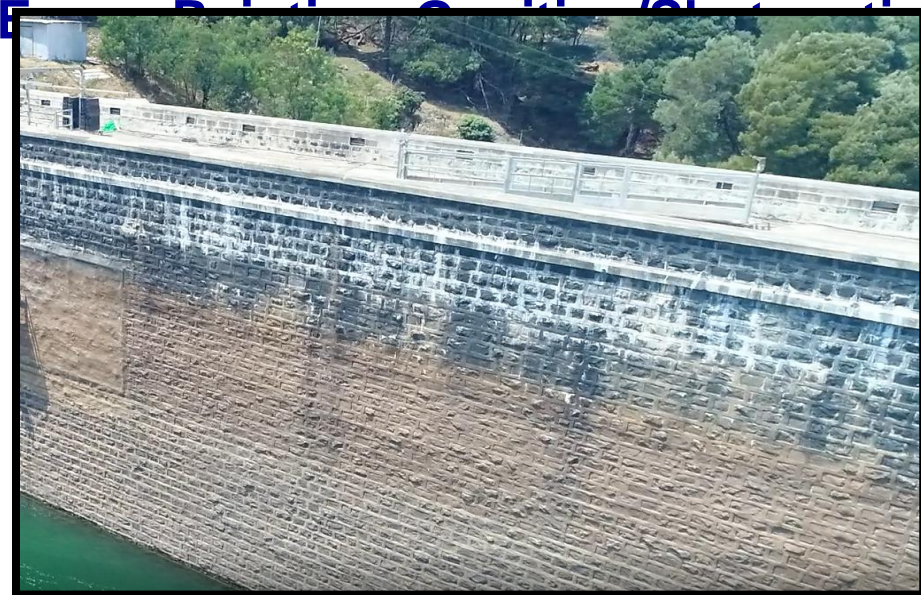
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## Performance of previous repairs

- **Problems in Dam : Severe Leakage in shafts surrounding the spillway and leakage recored at 8200 LPM at 9.14 m below FRL level**



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## Contract Awarded to Carpi in 2019 February

Earth Excavation  
Raised Re-Pointing  
Drilling & Grouting  
Coffer Dam  
Dewatering

Upstream Geomembrane Installation  
Optical Fiber Cable Monitoring  
System



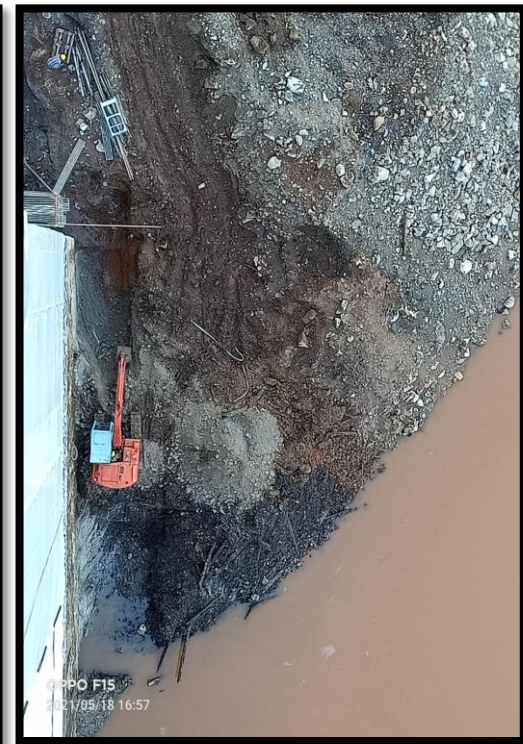
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## Earth Removal

- Earth Removal and excavation was carried out to expose the toe end of the masonry dam.
- Desilting in some places were as deep as 15 meter



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## Coffer Dam & Dewatering Arrangements

- To waterproof region below dead storage, a coffer Dam and Dewatering using 100 HP pump to expose the upstream face below the sill level of the gates



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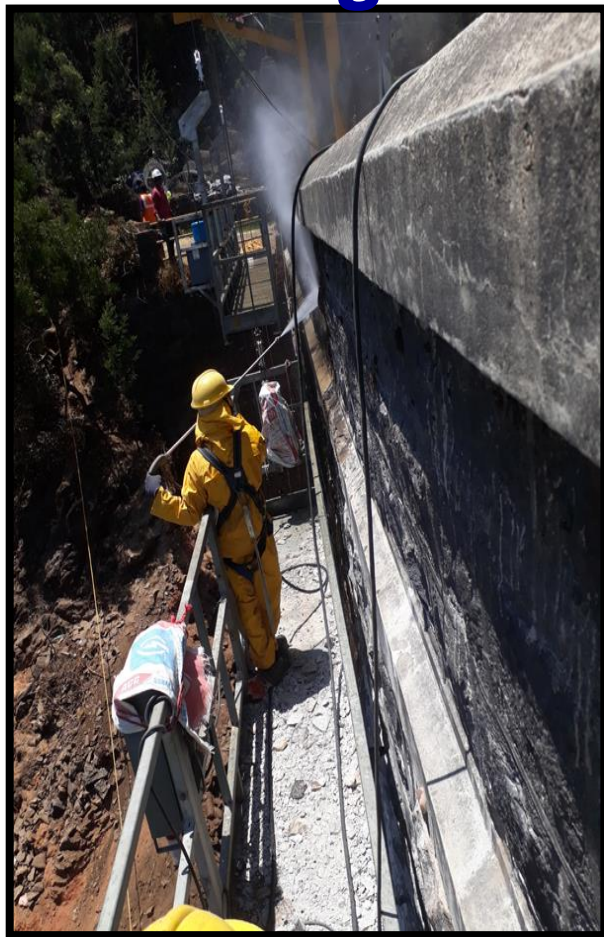
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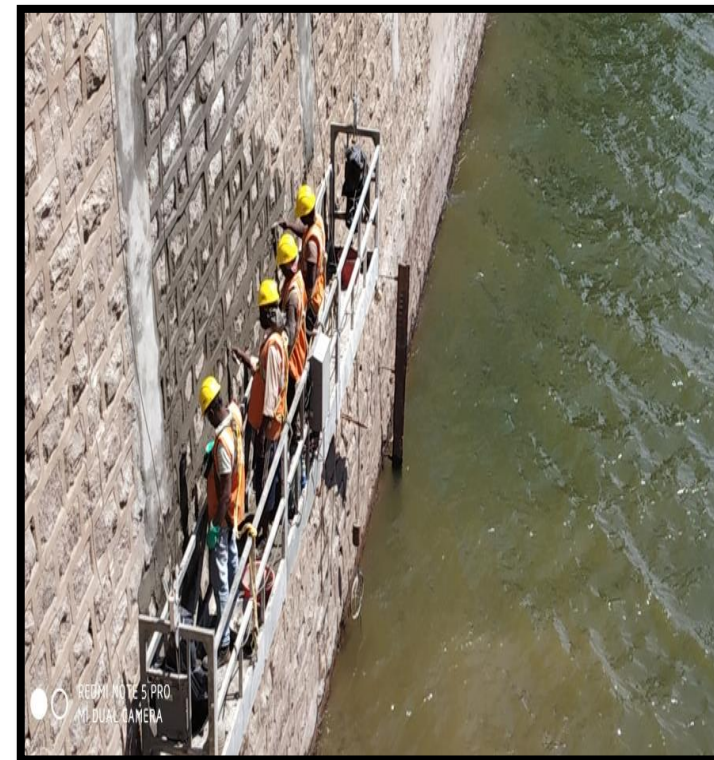


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## Surface Preparation – Hydrojet Washing & Pointing



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

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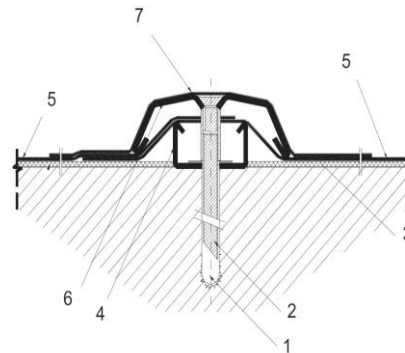
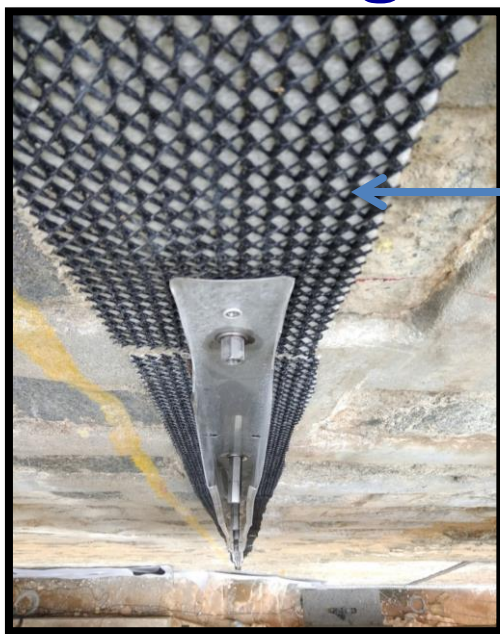
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## Fixation Profile (2 component System) Fixing of Lower Tensioning Profiles



- 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

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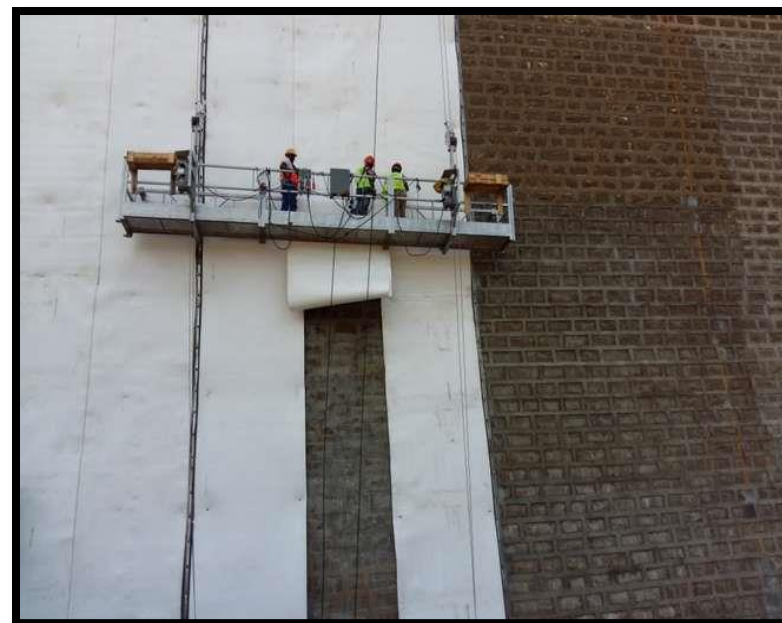
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## Fixing of Anti puncture geotextile

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



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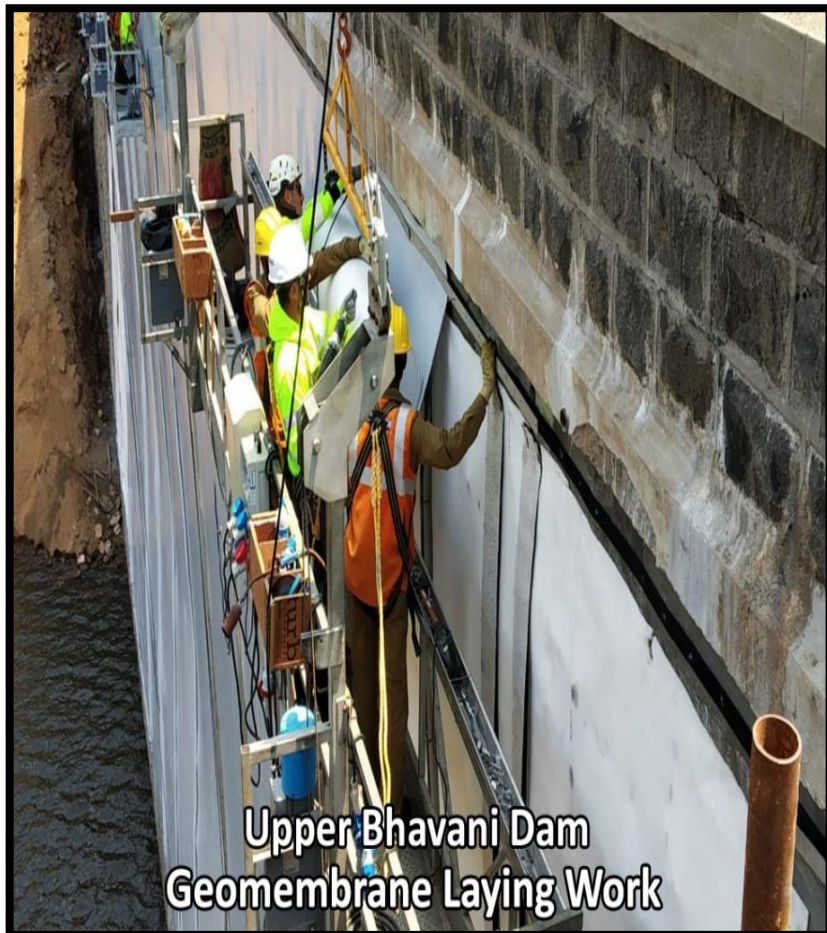
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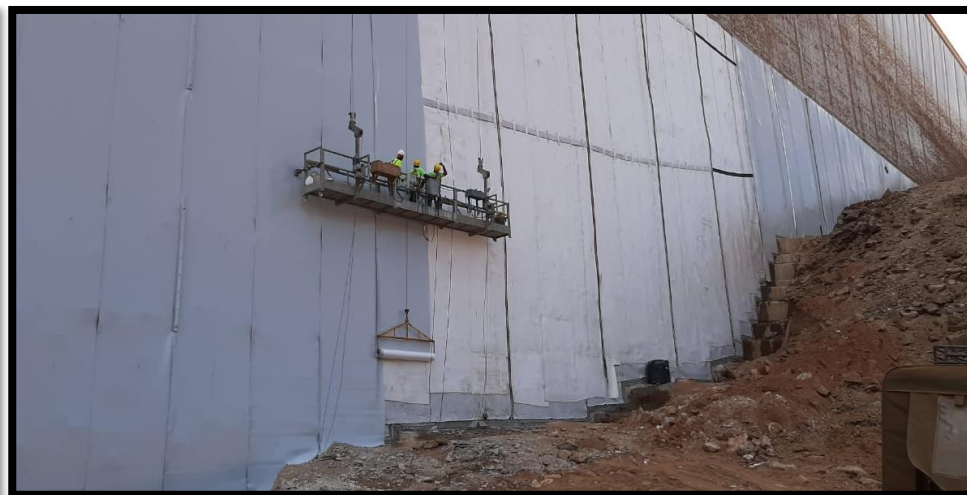


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## Unrolling of Geocomposite



Upper Bhavani Dam  
Geomembrane Laying Work



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

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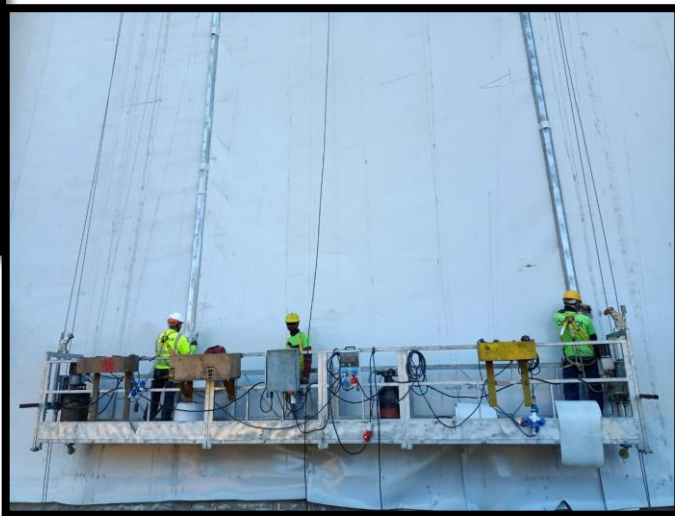
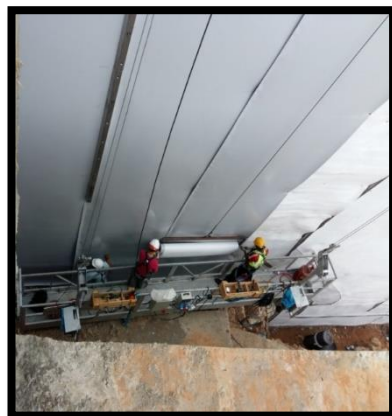
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## Geocomposite Welding & Upper tensioning profile fixation

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



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## Fixation of Cover Strip

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



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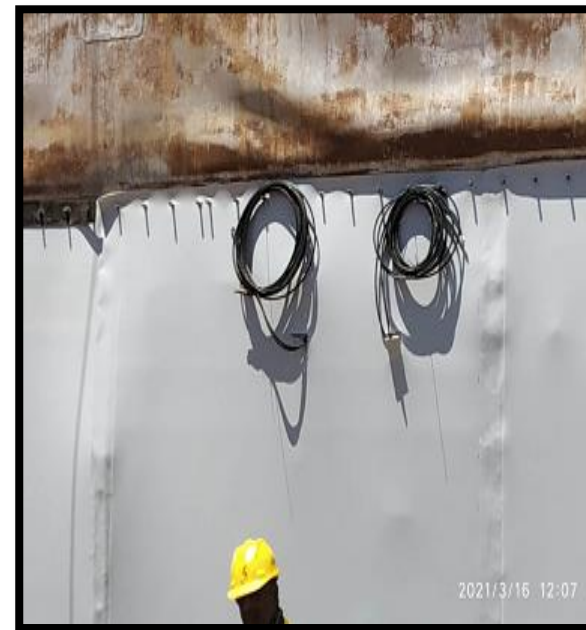
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## Fiber Optic Cable Leakage Detection System

It works by Heat Pulse method. **System** is 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

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## 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.



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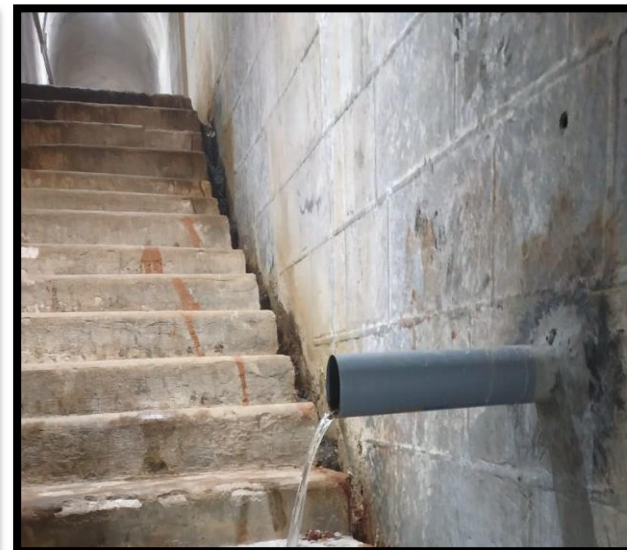
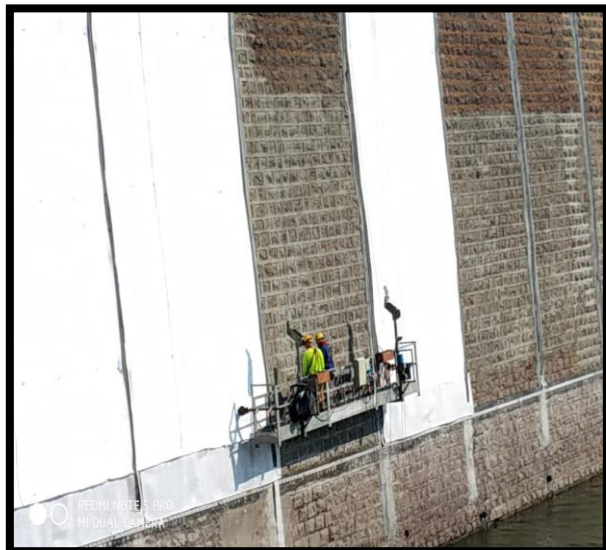
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## Drainage Discharge Pipes & Drainage Layer

- 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



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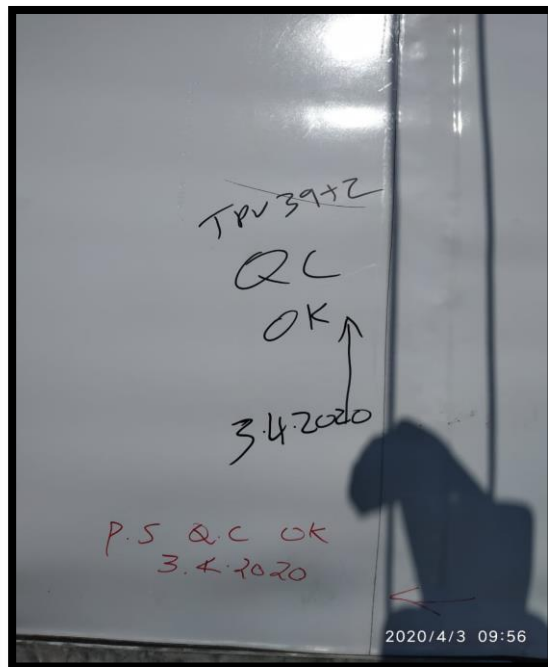
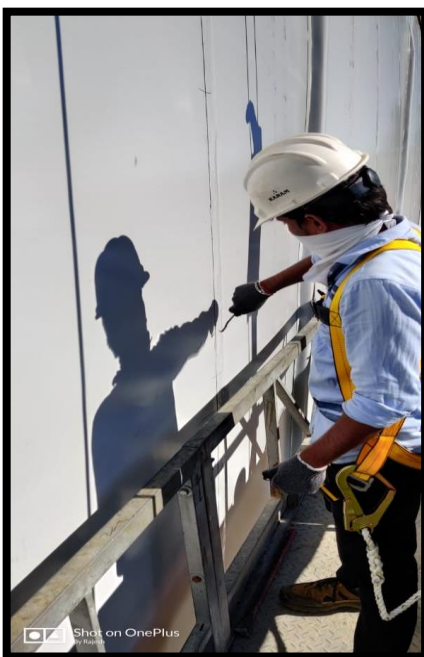


## Quality Control and Quality Check

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		carpi	
QUALITY CONTROL - COMPLIANCE OF GEOCOMPOSITE/GEOMEMBRANE/GEOTEXTILE/STEEL BEAMS AND SEALING ACCESSORIES/TENSIONING PROFILES/GEONET			
Sheet ... 1	Criteria: Visible defects or damages, compliance to technical specifications	CORRECTIVE ACTIONS	
DATE 14.05.2019	Frequency: 100% of the material delivered to site will be inspected		
Pallet number: Material inspected: Sibelon CNT 2400	GEOCOMPOSITE SIBELON CNT 4400 /SIBELON C 3900/GEOTEXTILE DREFON S2000/BEAMS/TENSIONING PROFILES/GEONET		
Pallet nos. 10,100,101, 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 <input checked="" type="checkbox"/>	NO <input type="checkbox"/>
	External labels readable	YES <input checked="" type="checkbox"/>	NO <input type="checkbox"/>
	Index test certificate present	YES <input checked="" type="checkbox"/>	NO <input type="checkbox"/>
	Durability test certificate present	YES <input checked="" type="checkbox"/>	NO <input type="checkbox"/>
	Quantity as per packing list	YES <input checked="" type="checkbox"/>	NO <input type="checkbox"/>
Name and Signature		Comments	
Quality Control Responsible	N. SHANMUGARAJ	N. Shanmugaraaj	
Carpi Qc Inspector			
Client's Representative			
ASSISTANT ENGINEER/CIVIL DRIP/KUNDAN/TANGEDCO KUNDAN BRIDGE POST THE NILGIRIS - 643219.			



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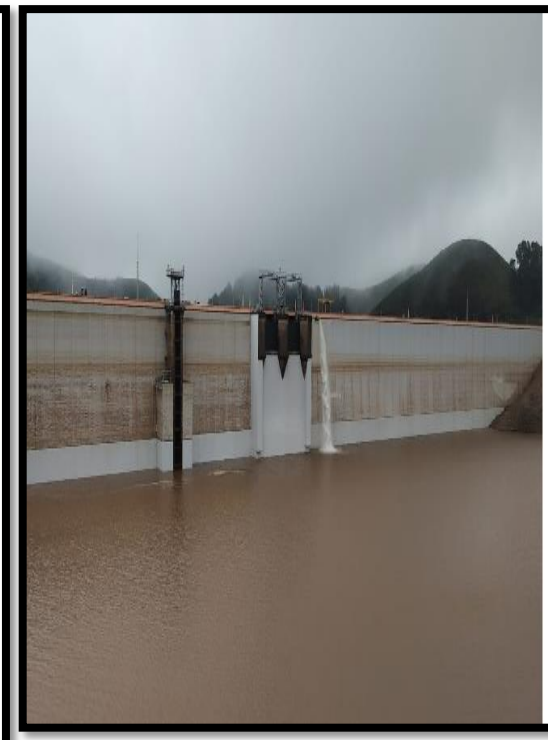
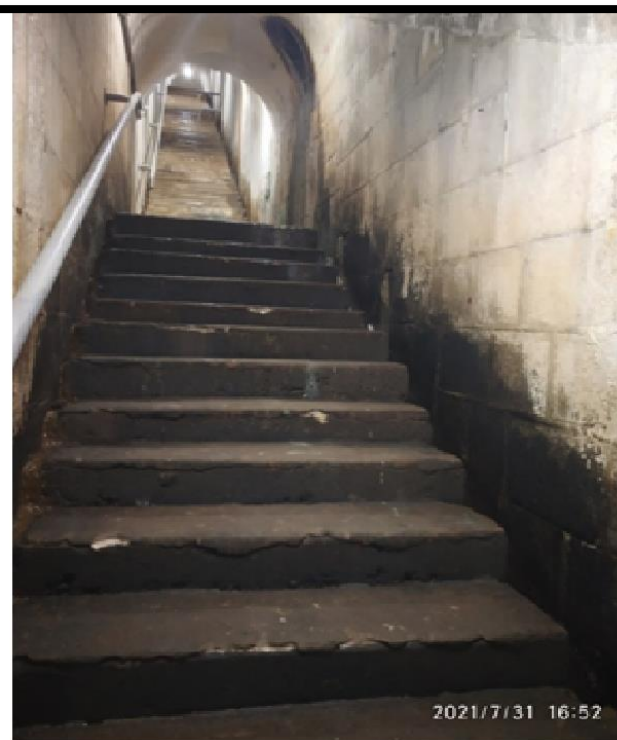
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## Results of Waterproofing Vertical Drain Shaft (Right Spillway) Before and After GM Installation



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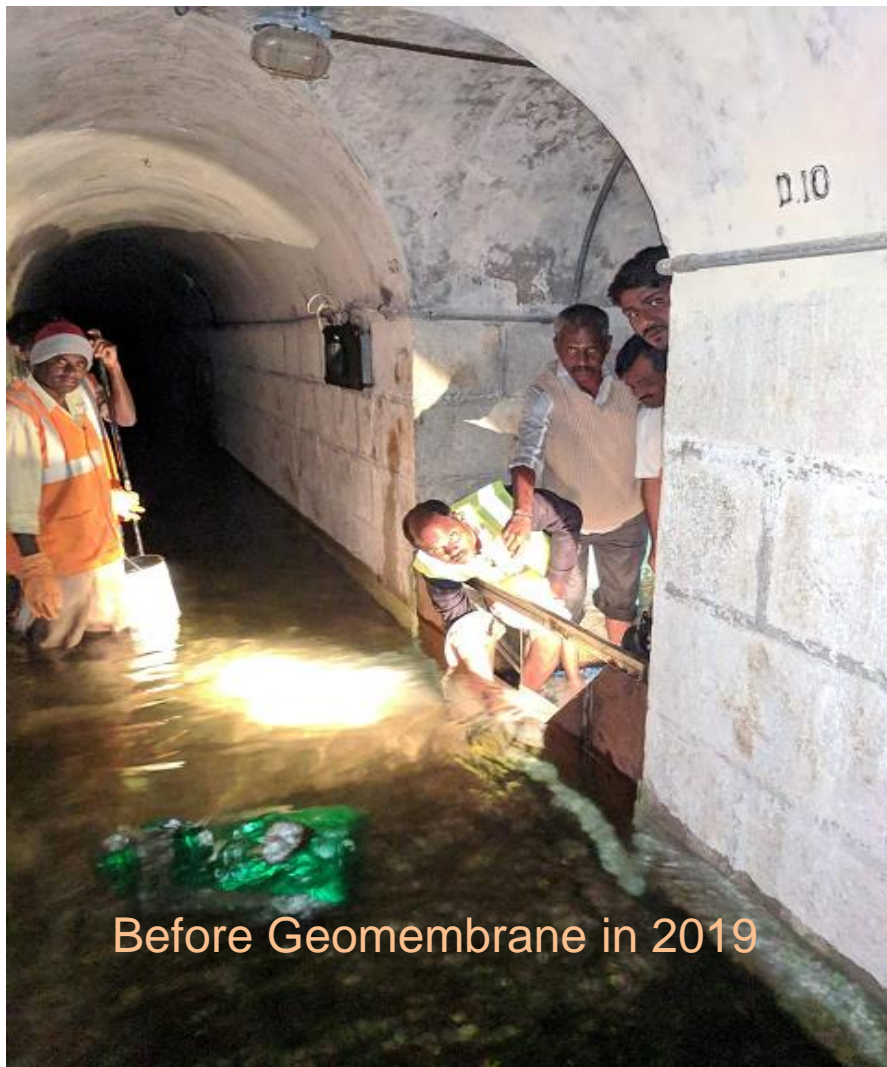


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Before Geomembrane in 2019



After Geomembrane in 2021

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## Videos



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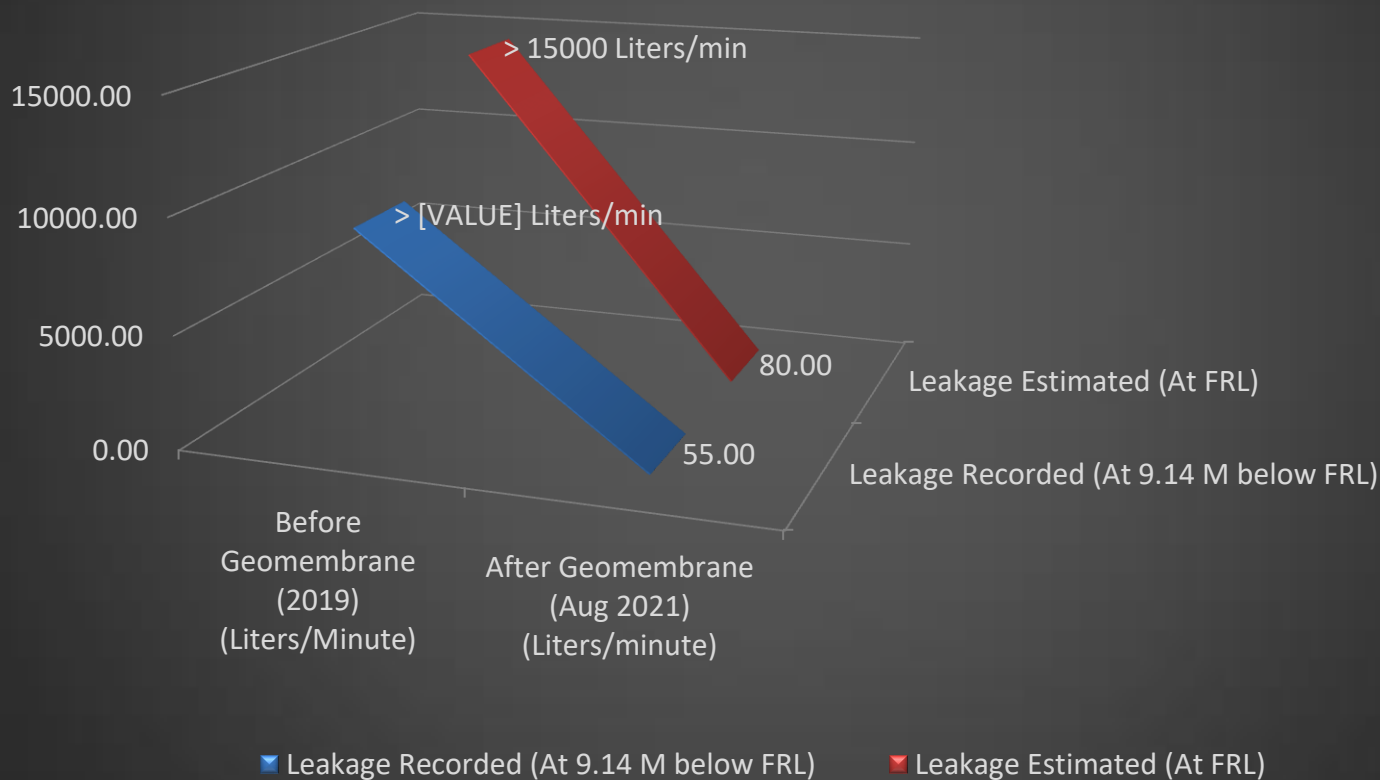


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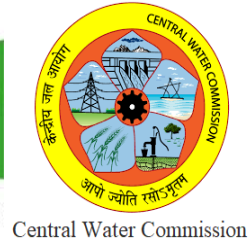
## Upper Bhavani Dam Leakage (Before & After Geomembrane )





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## 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**

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Servalar dam

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

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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.

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**After Installation**

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## Results of Geomembrane Waterproofing System



Saturated Downstream

After Geomembrane Installation – In Aug  
2018



Dry Downstream

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**After 4 Years of  
Service**

**Faced 5 Floods in the four years**



REDMI NOTE 5 PRO  
MI DUAL CAMERA

2021/10/20 15:21

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## Kadamparai dam

First dam geomembrane project in India

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)

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Before repair  
38,000Lpm @70% of  
FRL



Before repair:

Leakage in the  
drainage gallery, left  
abutment, 38,000  
lpm at 70% of FRL

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First Dam in India to be rehabilitated with Geomembrane System  
From 2005 to 2021 (16 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 17 years

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The whole system installation covering more than 17,000 m<sup>2</sup> including the monitoring system has been completed in 3 months, 6 weeks ahead of schedule.





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Kadamparai Dam In July 2022 – System still in  
tact after 17 years

Leakage on the installed area is still  
around 140 lpm



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## Conclusions (Indian Case Studies)

Name of the Dam	Year of Installation	Area of Installation	Leakage Before Geomembrane	Leakage After Geomembrane	Present Service Life
<b>Kadamparai Dam</b>	2005	17,303 Sqm	38,000 Lpm	< 80 Lpm (99.8% Savings )	17 years
<b>Servalar Dam</b>	2018	9854 Sqm	5,000-6,000 Lpm	< 30 Lpm (99.6% Savings)	4 Years
<b>Upper Bhavani</b>	2021	17,904 Sqm	8,000-12,000 Lpm	< 80 Lpm (99.5% Savings)	1.5 Year

**CARPI DOES NOT SELL PRODUCTS IT SELLS SOLUTIONS**



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