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INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE

SIDE EVENT BY THE INTERNATIONAL GEOSYNTHETIC SOCIETY (IGS) ON WATER MANAGEMENT AND STORAGE WITH GEOSYNTHETICS

04 November 2023, 9:30-11:00 hours (Session 1) and 11:30-13:00 hours (Session 2)
(Room – SA, Raddison Blu Resort, Vishakhapatnam (Vizag), India)

INTRODUCTION

Geosynthetics have been used in hydraulic structures for over 60 years, i.e., in small to large earth or concrete dams, for water storage, and in water transport structures. However, conventional materials have maintained their dominancy for a variety of reasons, sometimes cultural / well-anchored habits, or because of the lack of knowledge about the availability of alternative solutions. With the global interest in reducing the carbon footprint of human activities, the use of low-carbon technologies has become a priority in several industries. This concern, combined with the limitations of conventional construction materials and techniques, has brought geosynthetics at the forefront of technologies with high growth potential. They can substantially contribute to improving water supply and accessibility for people and farmers, at a relatively low cost, short construction time, and much lighter carbon footprint.

About the International Geosynthetics Society (IGS): The IGS is a learned society dedicated to the scientific and engineering development of geotextiles, geomembranes, related products, and associated technologies. The purpose of the IGS is to provide the understanding of and promote the appropriate use of geosynthetics throughout the world.

SCOPE AND OBJECTIVE

The technical program of this side-event was developed by the Technical Committee on Hydraulics of the International Geosynthetics Society to provide an overview of the applications of geosynthetics in hydraulic structures and irrigation infrastructure. The purpose of this event is to introduce the experience gathered using geosynthetics in hydraulic structures such as dams, levees, water reservoir and canals, with a focus on seepage control and water transport within irrigation schemes, as well as for erosion control and bank stabilization. The various types of products and their applications will be introduced. Basic elements of design with geosynthetics and important aspects of quality control and installation quality assurance will be delivered. The contribution of geosynthetics will be approached considering the development of new infrastructures, as well as for the retrofitting of aging structures. Their contribution to sustainable construction practices will be analysed, considering their reduced carbon footprint, and often reduced costs compared to traditional lining methods. Finally, case studies will be presented to illustrate their applicability, their durability, as well as their economic and technical benefits based on projects executed in various regions of the world.

Coordinator: Eric Blond (Email: eric@ericblond.com)

25TH ICID CONGRESS AND 74TH IEC MEETINGS
1-8 NOVEMBER 2023, VISHAKHAPATNAM (VIZAG), INDIA

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Final Program

Side Event: Water Management and Storage with Geosynthetics

Date : 04 November 2023, 9:30-11:00 hours (Session 1) and 11:30-13:00 hours (Session 2)

Venue : Room – SA, Raddison Blu Resort, Vishakhapatnam (Vizag), India

Time	Session – Particulars	Presenter
9:30-9:50	Welcome and introduction to the Side Event, introduction to geosynthetics	Eric Blond ***Eric Blond Consultant***
9:50-10:10	Geosynthetics as Membrane and Reinforcement in Canals	Vivek Kapadia ***Government of Gujarat***
10:10-10:25	Use of Geosynthetics for Water Conservation – Experience in Asia	Kiran Kumar Rumandla ***Solmax***
10:25-10:40	Use of Geosynthetic Cementitious Composite Mats (GCCMs) for erosion and seepage control in water transport infrastructures	Darren Hugues ***Concrete Canvas***
10:40-10:55	Service life of Geosynthetics in Hydraulic Applications	Eric Blond ***Eric Blond Consultant***
10:55-11:00	Questions / Answers, closure	
11:00-11:30	Health Break	
11:30-11:50	Reflections on canal lining experience from a global perspective	Amal Talbi ***World Bank***
11:50-12:10	Geosynthetics for Design of Energy Dissipation Components in Dams	Vivek Kapadia ***Government of Gujarat***
12:10-12:25	Sustainable solutions for riverbank protection	Rudra Budhbhatti ***Maccaferri***
12:25-12:40	Case study on the use of Concrete Mattress in India, showcasing the Taldanda Main Canal & the Dhakrani Power Channel	Karan Vyas ***Signet Enertech (Huesker)***
12:40-12:55	Flexible polymeric geomembranes to arrest leakages in Dams and Canals enabling effective usage of water for irrigation and human needs	Jagadeesan Subramanian ***Carpi Tech***
12:55-13:00	Questions / Answers, closure	

Coordinator: Eric Blond (Email: eric@ericblond.com)
Chairman, Technical Committee on Hydraulics, International Geosynthetics Society
https://www.geosyntheticssociety.org/

Registration: https://icid25congress.in/registration.html

The Home of Geosynthetics

The International
Geosynthetics Society

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International Geosynthetics Society

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The International Geosynthetics Society (est. 1983)

The IGS is a learned society dedicated to the scientific and engineering development of geotextiles, geomembranes, related products and associated technologies.

Mission (est. 2010)

- The core purpose of the IGS is to provide an understanding and promote the appropriate use of geosynthetic technology throughout the world.

Vision (est. 2018)

- The vision of the IGS is that geosynthetics be recognized to be fundamental to sustainable development by providing technological and engineering solutions to answer societal and environmental challenges.

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Geosynthetics:

- Geotextiles
- Geomembrane
- Geosynthetic Clay Liner
- Geogrid, Geostrap
- Geonet and Geocomposite Drains
- Geocells
- Geobags
- etc…

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2023 IGS Membership

45 Chapters

2,600+ Individuals

500+ Students

177 Corporate

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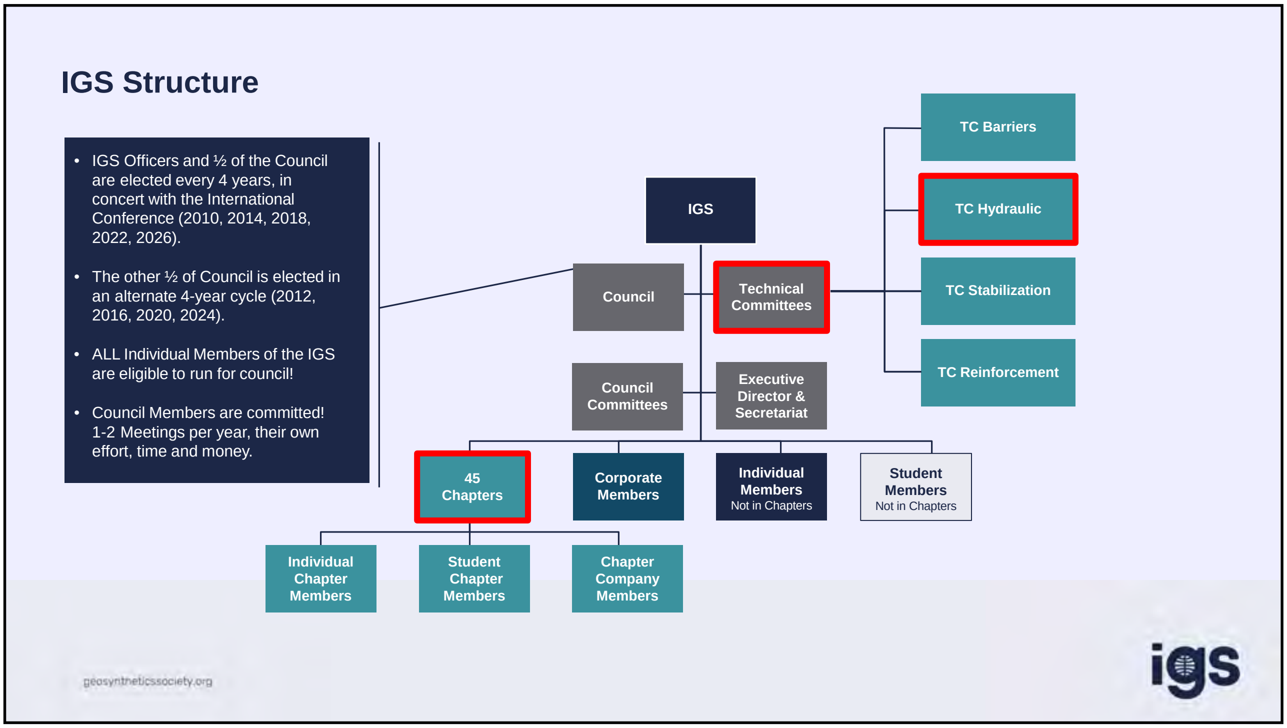

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Corporate Membership

Benefits & Access for Members

› The society brings together individual and corporate members from all parts of the world, who are involved in the design, manufacture, sale, use or testing of geotextiles, geomembranes, related products and associated technologies, or who teach or conduct research about such products.

› The strength of the IGS lies in diversity and strong local leadership. Our society is comprised of 45 hard-working National and Regional Chapters and includes members from over 70 countries! New Chapters are regularly being formed and existing ones continue to grow.

› By becoming a member of the IGS you will help support our aims and become part of a community where designers, manufacturers and users exchange new ideas and develop new contacts.

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Conferences of the IGS

International Conferences

- Once every 4 years
- Hosted and Managed by a Chapter
- Next Conference: **2026 Montreal**

Regional Conferences

- Held every 4 years, alternate years to the International Conference
- Hosted by a different chapter each time
- Chapters bid for the event
- Chapters grow membership, involvement, community and geosynthetics success when they host either a regional or international IGS Conference
- Regional conferences leave the majority of the proceeds with the chapter!

International

2023 Rome, Italy
2018 Seoul, South Korea
2014 Berlin, Germany
2010 Guaruja, Brasil
2006 Yokohama, Japan
2002 Nice, France

European Regional

2025 Lille, France
2022 Warsaw, Poland
2016 Istanbul, Turkey
2012 Valencia, Spain
2008 Edinburgh, Scotland
2004 Munich, Germany
2000 Bologna, Italy

Asian Regional

2025 Brisbane, Australia
2022 Taipei, Taiwan
2016 New Delhi, India
2012 Bangkok, Thailand
2008 Shanghai, China
2004 Seoul, South Korea
2000 Kuala Lumpur, Malaysia

PanAm Regional

2024 Toronto, Canada
2020 Rio de Janeiro, Brazil
2016 Miami, USA
2012 Lima, Peru
2008 Cancun, Mexico

African Regional

2025-2026 Gauteng, South Africa
2022 Cairo, Egypt
2017 Marrakesh, Morocco
2013 Accra, Ghana
2009 Cape Town, South Africa

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Upcoming Conferences of the IGS

- **April 28 – May 1, 2024**
  - GeoAmericas 2024 – 5th PanAmerican Regional Conference on Geosynthetics

  Toronto, Canada
- **June 10-13, 2025**
  - GeoAsia 8 – 8th Asian Regional Conference on Geosynthetics

  Brisbane, Australia
- **September 15 - 17, 2025**
  - EuroGeo 8 – 8th European Regional Conference on Geosynthetics

  Lille, France
- **September 13-17, 2026**
  - 13 ICG – 13th International Conference on Geosynthetics

  Montreal, Canada

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IGS Events and Initiatives – Meeting the Mission

IGS Technical Committee (TC) Initiatives

- 4 TCs: Barriers, Stabilization, Hydraulics & Soil Reinforcement
- Hold workshops in odd years to propel high-level development.
- Development of collateral to support teaching
- Creation of short-courses and technical sessions in activities in sister-societies events
- TCs may be formed by a group of IGS Members with interest in addressing a topic or issue
- Join a TC and work with your peers from around the world and move the technical understanding and use of geosynthetics forward internationally and nationally

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Past collaborations between IGS and ICID

- **2011 – ICID Congress (Teheran) - Signature of MoU**
- **2017 – ICID Congress (Mexico**
- **2018 – ICID Congress (Saskatoon)**
- **2019 – ICID Congress (Bali)**
- ***2021 – Virtual Webinar on Canal lining***
- ***2021 – Hybrid Session at the 5th African Regional Congress (Marrakesh, Morroco)***
- **2022 – ICID Micro-Irrigation Conference (Dakhla, Morroco)**
- **2022 – ICID Congress (Adelaide, Australia)**
- **2023 – IGS GeoAfrica Conference (Cairo, Egypt)**
- **2023 – ICID India (Visakhapatnam, India)**
- **…**

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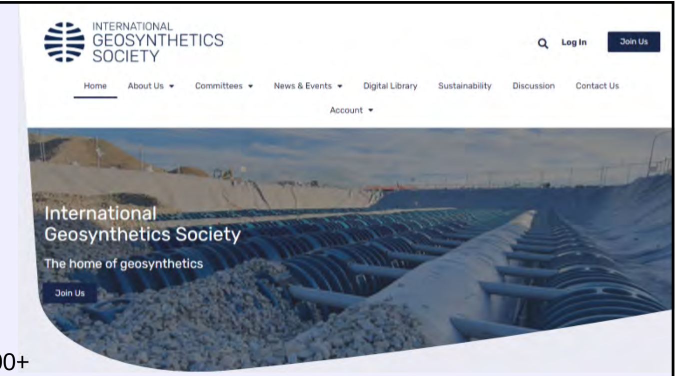
IGS Events and Initiatives – Meeting the Mission

IGS Communications



- Dedicated to developing and disseminating news and information to the IGS membership
- **IGS News**
  - Publish your Chapters' events to the 9,000+ international readers
- **IGS Website**
  - Member Directory – Access to contact information to 1,000s of the worlds geosynthetics experts
  - Proceedings – Access to searchable & indexed proceedings from past IGS events. Valued at thousands of dollars available at no cost to members.
  - Technical Documents, developed by the Education Committee and the various technical committees this segment of the site will see significant growth in the next few years.

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igs Educate the Educators

Training events targeted at providing professors the materials and understanding to easily include geosynthetics in their **UNDERGRAD** Curriculum and some advance courses.

Educate the Educators

- Request through the Regional Activities Committee
- IGS Provides the curriculum and funds speaker travel to teach the EtE
- Typically a 2-day course, taught in local language
- Approximately 40 professors are accepted via an application process
- Chapters raise sponsorship resources and organize the logistics
- On-site attendee expenses are paid through funding of the EtE Program, professors only need to pay their transportation to the event.
- Professors return to their universities with the ability to implement geosynthetic curriculum immediately into their courses.
- Attendees are provided presentations, sample books and collateral materials to use in their classrooms
- Start an Educate the Educators task group in your chapter and help grow the acceptance of geosynthetics for every engineering student in your country!

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Sister Societies of the IGS

The IGS has a very well established and highly productive relationship and a strategic partnership with each of the societies listed below. Through Sister Society Agreements, possible collaboration in the areas of membership, publications, technical meetings, and various joint activities are promoted. If you are aware of sister society relationships that should be considered, or you would like to learn more about developing such a relationship, please contact the IGS Secretariat.

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ASTM INTERNATIONAL Standards Worldwide

SIMSG ISSMGE

EAGM

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Benefits of Joining the IGS

- Online access to the IGS Membership Directory
- Subscription to the IGS News newsletter, published online monthly
- Online access to the IGS Digital Library
- FREE Access to Geosynthetics International and Geotextiles & Geomembranes, valued at over $1,000 US
- Discount rates for any IGS publications and at all international, regional or national conferences organized by the IGS or under its auspices
- Eligible to be granted an IGS Award

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IGS Events and Initiatives – Meeting the Mission

IGS Video on Geosynthetics & Sustainability

- Target Audience: Engineers, regulators, administrators, etc.
- Purpose: To improved the comprehension of the value of geosynthetics among non-experts.
- This video and other translated version can be found on the **IGS YouTube Channel**

https://www.youtube.com/watch?v=LIH-7djSPO0

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25th International Congress on Irrigation and Drainage & 74th International Executive Council meeting

Theme:

Tackling Water Scarcity in Agriculture

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1-8 November 2023, Vizag, Andhra Pradesh State, India

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GEOSYNTHETICS AS MEMBRANE AND REINFORCEMENT IN CANALS: CASE STUDIES OF SARDAR SAROVAR PROJECT, INDIA

Vivek P. Kapadia
vivekpkapadia@gmail.com
vpk@vivekpkapadia.info

4th November 2023

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1-8 November 2023, Vizag, Andhra Pradesh State, India

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CASE STUDY – 1

RESTORATION OF BREACHED SECTION OF NARMADA MAIN CANAL

- Carrying capacity of 1133 cubic meter per second at the off-take point.
- From Ch. 269 km to Ch. 271.5 km - total bank height above the ground level is about 9 m
- Canal bed is 53.70 m wide and the full supply depth (FSD) is 6.5 m
- Designed discharge is 583.57 m^3/ s
- Canal side slopes are 2 (H) : 1 (V)

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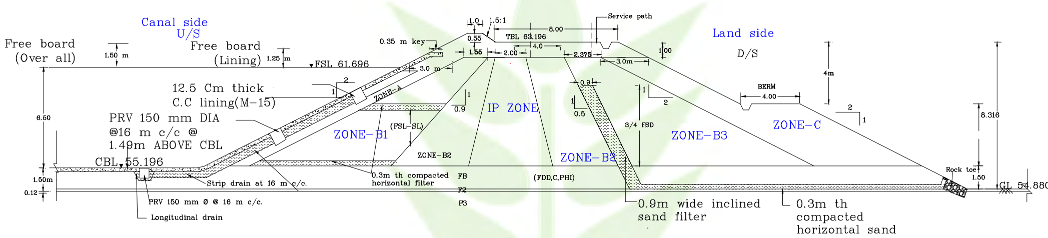
CASE STUDY – 1

DESIGN FEATURES AND PERFORMANCE ISSUES



Zoned embankment designed to suit the codal provisions, design practices and material availability

Date of Occurrence of Failure	Chainage in km	Side of the Bank
30-08-2005	272.500	Left
08-09-2005	271.300	Left
17-09-2005	269.700	Left (Huge Breach)
17-09-2005	270.900	Left (Huge Breach)
13-01-2006	271.180	Left
13-01-2006	271.450	Right
11-03-2006	270.300	Right

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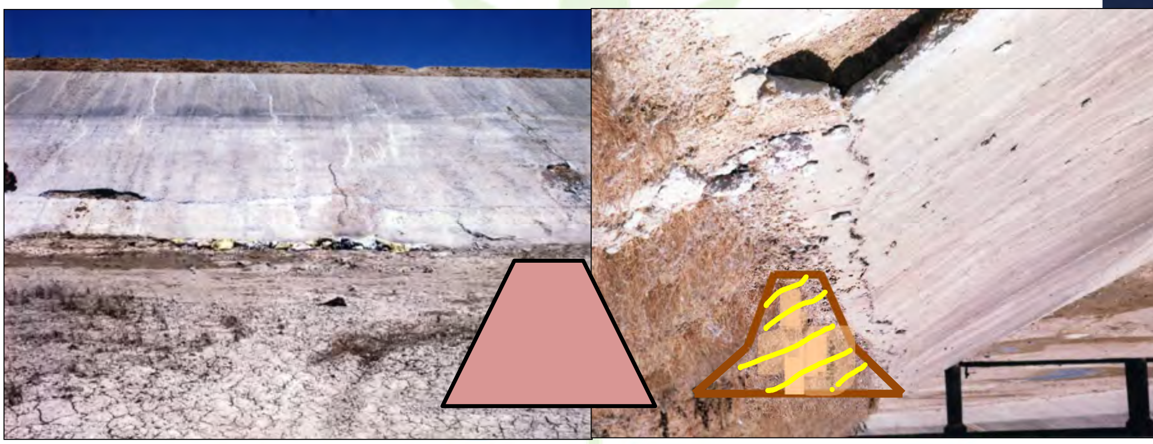
CASE STUDY – 1

DIAGNOSIS OF FAILURE



Shear failure of lining suggests subsidence

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CASE STUDY – 1

DIAGNOSIS OF FAILURE

Piping

Devastation in Vicinity of Canal

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CASE STUDY – 1

DIAGNOSIS OF FAILURE

Embankment Section - Stratified Strata without Zones and Filters

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CASE STUDY – 1

DIAGNOSIS OF FAILURE

- No zones with specific soil properties as per design
- Obligatory technical specifications for laying and compacting the soils totally neglected - numerous locations and bands of loose or inadequately compacted soil zones
- No chimney filter or horizontal filter blankets to protect the soil and prevent migration of particles outside.
- Due to very loose soil bands there was substantial subsidence of the earthwork - lining, as a result, cracked irregularly, even big hollows at some locations
- Canal water entering the embankment with relatively high pressure caused dislodgment of particles in the inadequately compacted soil due to high seepage forces resulting into piping and progressive failure ultimately

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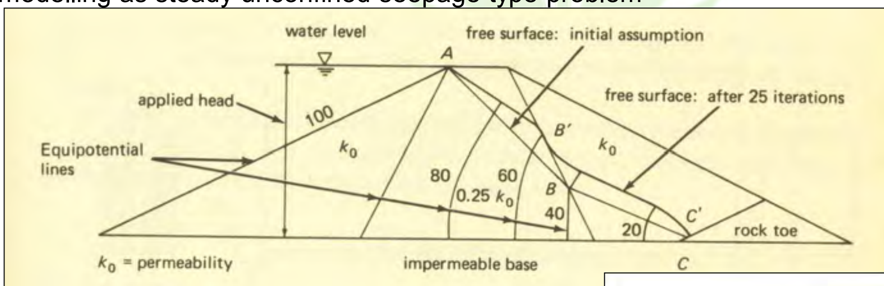
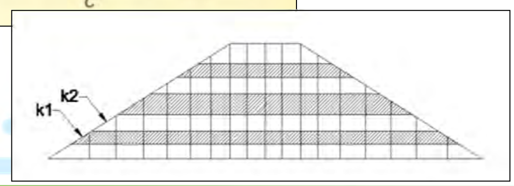
CASE STUDY – 1

DIAGNOSIS OF FAILURE

Slip circle modelling can not be taken as stratification of soil and therefore Finite Element modelling as steady unconfined seepage type problem





Steady Unconfined Seepage Problem

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CASE STUDY – 1

CONSTRAINTS IN RESTORATION

- Time of only 10 days was there - drinking water for many towns and villages depending up on the main canal
- Rainfall had already occurred once, borrow areas were not available and the soil available was predominantly sand with small amount of clay - for zoning and for filters suitable material was not available
- In given time and small length proper compaction was a matter of doubt
- Bonding with the surrounding parts of the canal was difficult
- Other than technical issues like people's wrath, political intervention, movement of media, etc. were adding fuel to fire.

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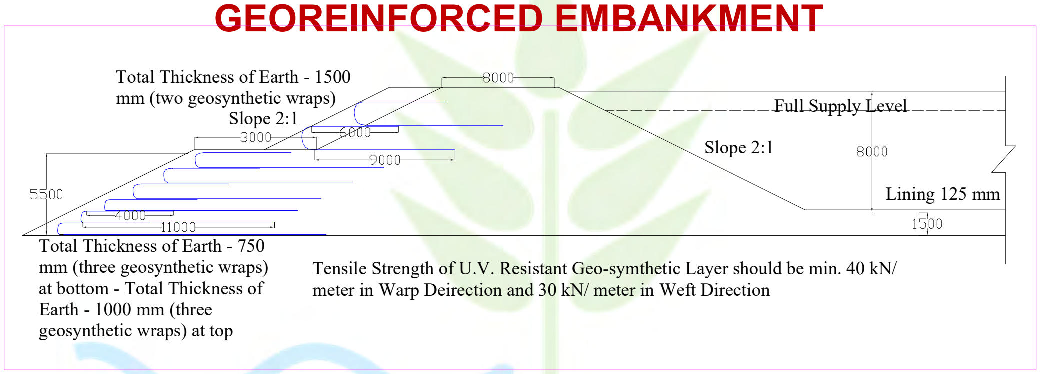
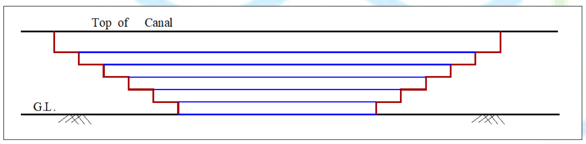
CASE STUDY – 1

GEOREINFORCED EMBANKMENT



Section for Restoration of Main Canal Embankment



Preparation for repairs - Longitudinal view from outer side

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CASE STUDY – 1

GEOREINFORCED EMBANKMENT

Material Properties

Property	Unit	Value
Weight	g/m^2	270
Wide Width Tensile	kN/m^2	50
Wide Width Elongation	%	15
Trapezoidal Tear Strength	kN	0.50
CBR Puncture resistance	kN	6.0
Flow Rate	l/ m^2/min	260
UV Resistance	%/hrs	70 / 500

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CASE STUDY – 1

GEOREINFORCED EMBANKMENT

Restored Main Canal Embankment

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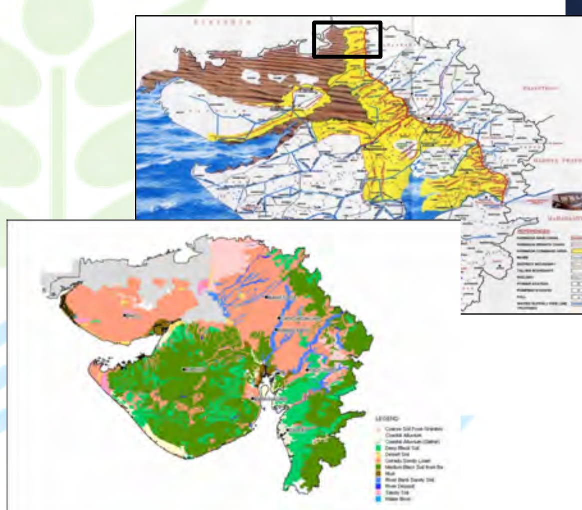
CASE STUDY – 2

CONSTRUCTION OF CANALS IN SANDY SOILS

- Tail Branch Canals of Sardar Sarovar Project passing through sandy soil and their command areas adjoining dessert
- Capacity about 15 cumec and length about 20 Kilometer
- All the canals have cutting, partial banking and banking – banking up to 3.5 meter
- SM soil with almost uniform particles and hence compaction the biggest problem



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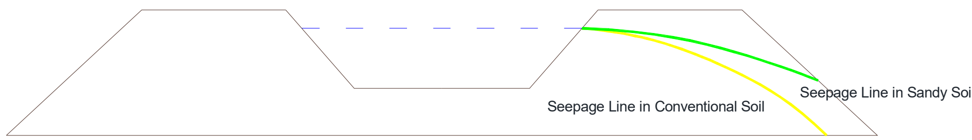
CASE STUDY – 2

ISSUES WITH SANDY SOILS



Difficulty in compaction and high permeability, both required to be addressed – larger section required

High permeability means flatter hydrostatic line requiring much larger width of embankment - economic viability adversely affected

Lower compaction results in susceptibility to disintegration i.e. stability failure especially in earthquake prone zone

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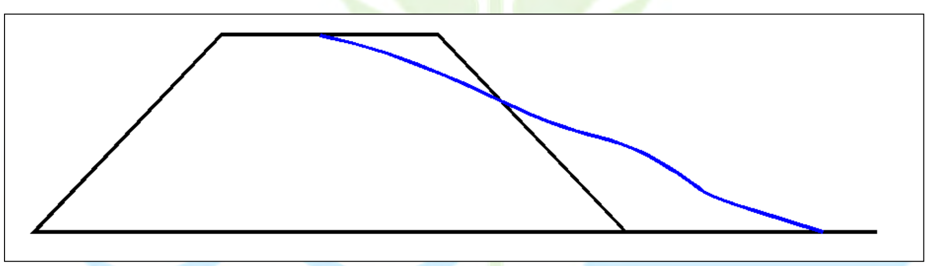
CASE STUDY – 2

ISSUES WITH SANDY SOILS

- Fluctuations in water levels – variations in pore pressure
- Sudden variations in pore pressure may cause spreading or dispersion failure of the embankment



Checking seepage and addressing the issue of dispersal failure was anyhow needed

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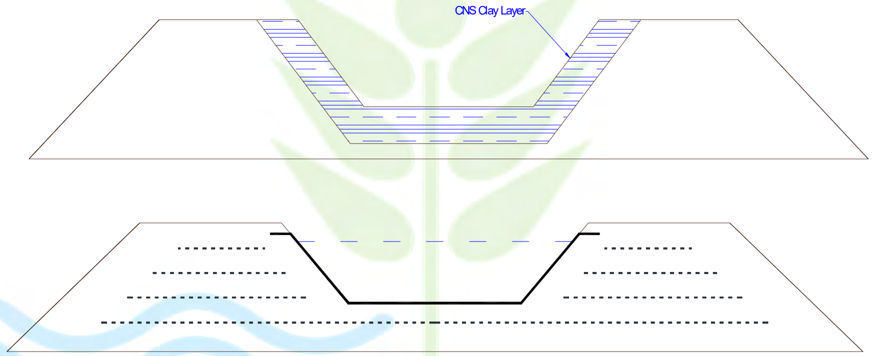
CASE STUDY – 2

SOLUTIONS



GCL checks the seepage path

Geogrid checks the disintegration of sand particles

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CASE STUDY – 2

REINFORCEMENT AND MEMBRANE

Three levels of Geogrid
1st Layer at [CBL – 0.30] m level
2nd Layer at [CBL + 0.40] m level
3rd Layer at [FSL - 0.40] m level

Property		Test Method	Unit	TG U-60
Ultimate Tensile Strength	MD	ASTM D-6637	kN/m	60
	CD			20
Reduction Factor (RF) and Machine Direction Long Term Design Strength (LTDS)				
Creep				1.55
Installation Damage	Sand/ Silt/ Clay			1.05
	<7.5 mm Gravel			1.15
Durability	pH – 4 to 9			1.15
LTDS – 120 Years, 40° C : Sand/ Silt/ Clay ; pH – 4 to 9			kN/m	32
LTDS – 120 Years, 40° C : Gravel < 7.5 mm ; pH – 4 to 9			kN/m	29.3
Aperture (± 2 mm)			mm	30 X 25

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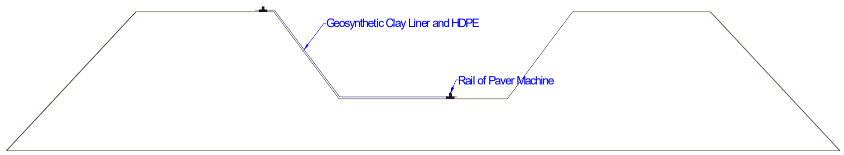
CASE STUDY – 2

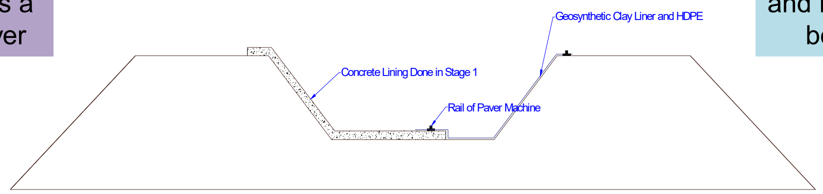
REINFORCEMENT AND MEMBRANE



GCL and o.5 mm thick HDPE as a protective layer

First Stage of Concrete Lining With Paver Machine

Imperviousness and integrability – both added



Second Stage of Lining With Paver Machine

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CASE STUDY – 2

REINFORCEMENT AND MEMBRANE

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Thank You
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74th International Executive Council meeting

Theme:

Tackling Water Scarcity in Agriculture

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Use of Geosynthetics for Water Conservation – Experience in Asia

Kiran Kumar Rumandla
04/11/2023

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Outline

- Introduction
- Geosynthetic Lining Solution
- Our Experiences in Canal Lining & Water Containments
- Summary

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Introduction

- As clean water becomes more expensive to acquire, the need for secure water containment and transport grows.
- Conserving water is important and an effective conveyance of water is through the canal or a channel.
- Canals can be constructed either unlined (earthen structure) or lined (concrete, bricks, geomembranes, combination, etc.)
- Linings are provided on the bed and sides of canal to improve the service life and discharge capacity of canal. Over time, concrete-lined canals may crack, resulting in a significant loss of water and earthen canals are often subjected to erosion and leakage problems.
- Geosynthetics provides an effective and economical solution to control and prevent loss of conveying water in existing canals and construction of new irrigation projects.

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The Challenges

Stability concerns of canal banks.

- Erosion
- Soil stability

Maintenance

- Side vegetation, weed growth & silting
- Time and cost of repairs.

Reduced seepage & loss of water

- Leakage & seepage problem.
- Effectiveness of the hydraulic barrier.

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GEOSYNTHETICS LINING SOLUTION

Product Types

- HDPE Geomembranes
- LLDPE Geomembranes
- Specialty Geomembranes
- Geotextiles as cushion protection

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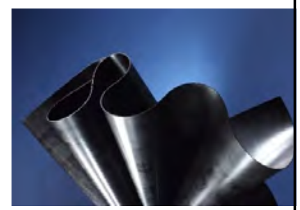
Why Polyethylene Geomembrane?

- Unique material characteristics & performance:
  - Very low permeability ($k_v < 10^{-12}$ cm/sec)
  - Most chemical resistant liner materials
  - Quick install & easily repaired if damaged
  - Established welding technology
  - Strong, High mechanical properties due to polymerization
  - Excellent UV resistance (with CB & stabilizers)
  - Longevity : successfully used since 1970's, last for hundreds of years (buried), and several decades (when exposed).
  - Lower cost, compared to other liners



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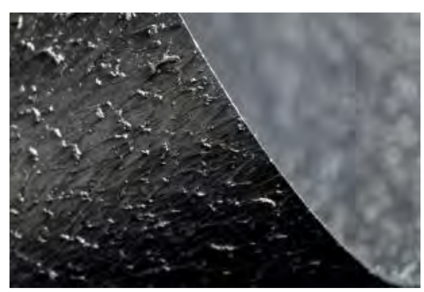
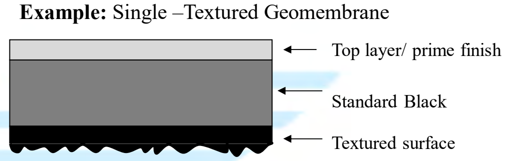
Textured Geomembrane on Slope

Roughened surface geomembrane provides:

- Better Slippery prevention
- Enhanced interface frictional properties and improve liner system stability on side slope applications
- Better grips and stability for concrete cover



Example: Single –Textured Geomembrane



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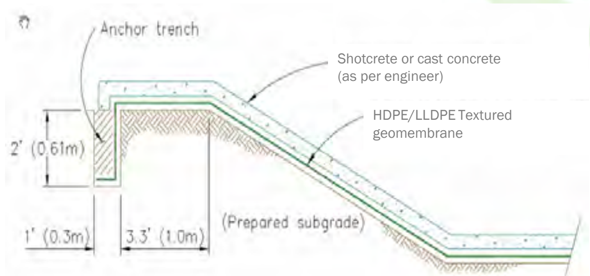
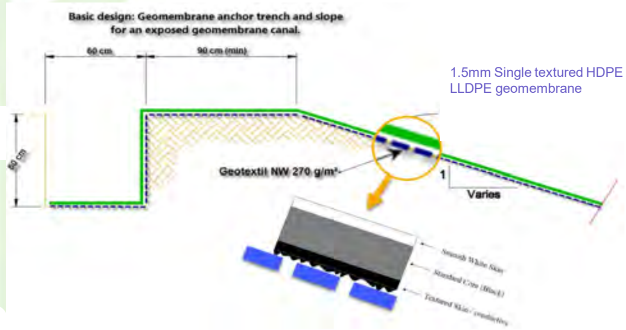
Types of geomembrane lined canals

Canal with geomembrane

Covered



Exposed



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Specialty Geomembranes

- White Surfaced (Smooth or Textured)
- High Performance (Smooth or Textured)
- Leak Location (electrically conductive base) Layer

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White Reflective Surfaced Geomembrane
igs
1. Easier Damage Detection
2. Aesthetic Look
3. Less heat absorp, reduce Thermal Expansion and Contraction
4. Less Wrinkle
Leachate
hole
5. Reduce Leakage Rate
water flow
6. Better Flow
7. Extend Service Life
8. Easy for installation
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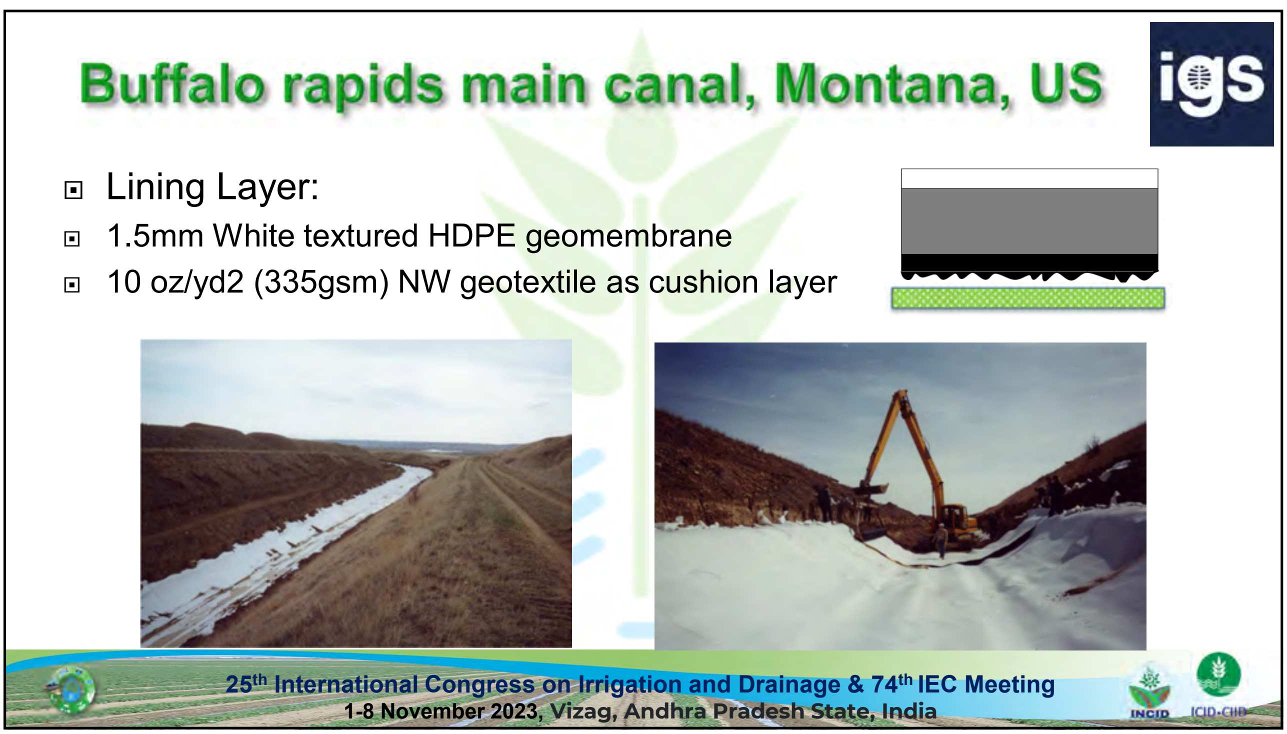
Buffalo rapids main canal, Montana, US
igs
Lining Layer:
1.5mm White textured HDPE geomembrane
10 oz/yd2 (335gsm) NW geotextile as cushion layer
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OUR EXPERIENCES

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Warna Canal, Maharashtra, India

Liner System:

- Leveled soil base layer
- 200 gsm non-woven geotextile
- 1.0mm smooth HDPE geomembrane
- 200gsm non-woven geotextile
- 15cm thick concrete layer

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DoodhGanga Canal in Maharashtra , India

- HDPE Geomembrane sandwiched between two non-woven geotextile layers was used. 1mm HDPE membrane and 250gsm nonwoven geotextiles were used in this project.
- Geomembrane was lined on the bottom side and the side slopes of the canal

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Integrated Shrimp Aquaculture Park, Malaysia

HDPE as primary barrier layer

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Summary

Geomembrane is lined at the base and the side slopes of the canal, it improves the service life and discharge capacity of canal.

Few considerations in geomembrane selection:

- HDPE geomembranes: Outstanding chemical resistance & mechanical strength, endurance to exposed conditions.
- White surfaced geomembrane : UV light reflection, cooler surface, wrinkle reduction, helps to keep a low Manning coefficient, longer lifespan under exposed conditions.
- LLDPE geomembranes: Excellent flexibility; allows the prefabrication of customized panels and easier installation, last long if using highly stabilized formulation with enhanced UV resistance for exposed applications.
- Smooth PE geomembranes offers a low manning coefficient
- Textured geomembrane provides greater Stability on side slope design

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THANK YOU

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Introduction to Geosynthetic Cementitious Composite Mats, a low-carbon approach to lining hydraulic structures.

4th November 2023

Presented By: Darren Hughes
Concrete Canvas Ltd.

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1

Current Challenges with Lining Canals

Conventional concrete solutions are problematic

- In-service
  - Ground-heave / settlement causes cracking
  - Cracking leads to water seepage
  - Seepage can cause
    - Salination of soils
    - Waterlogging
    - Undermining leading to total collapse
- Installation
  - Time consuming
  - On-site quality control
  - Side slope angle limitation (<1:1.5 without formwork)

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2

Current Challenges with Lining Canals

Concrete also has its advantages…

So why is concrete still used?

"concrete linings remain the preferred method of lining canals, because engineers and agencies are familiar with concrete linings"

Giroud & Plusquellec 2017

- Hard-wearing
- Durable
- UV Resistant

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USBR 10yr Research Project

Geomembrane Canal Lining: Benefit / Cost Comparison

In 2002 the US Department of Reclamation completed a 10 year trial on 34 canal lining test sections across 11 irrigation districts. The 34 sections are divided into 4 generic categories.

Type of Lining	Durability	Maintenance Cost	Effectiveness at Seepage Reduction	Benefit/Cost Ratio
	years	$/ft^2-yr	%	B/C
Fluid Applied Membrane	10-15	0.01	90	0.2-1.5
Concrete Alone (Shotcrete)	40-60	0.005	70	3.0-3.5
Exposed Geomembrane	10-25	0.01	90	1.9-3.2
Geomembrane with Concrete Cover	40-60	0.005	95	3.5-3.7

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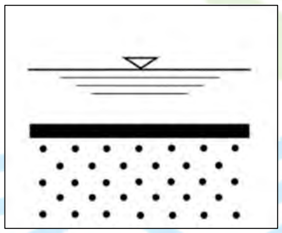
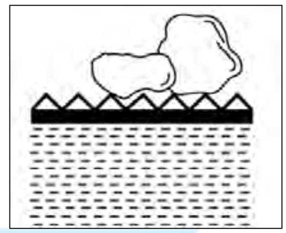
Ideal Canal Lining Solution

Dual Challenges of:

FUNCTION: **Waterproofing** + **Protection / Erosion Control**





PROPERTIES: ***Impermeable*** ***Durable & Hard-wearing***

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Geosynthetic Solutions

New Class of Materials: GCCMs (Geosynthetic Cementitious Composite Mats)

https://www.ccportal.co.uk/s/qfHndkm6K3pdCcB

https://www.ccportal.co.uk/s/x5Mox7t7BQdPsRA

GCCMs change from flexible to rigid on hydration

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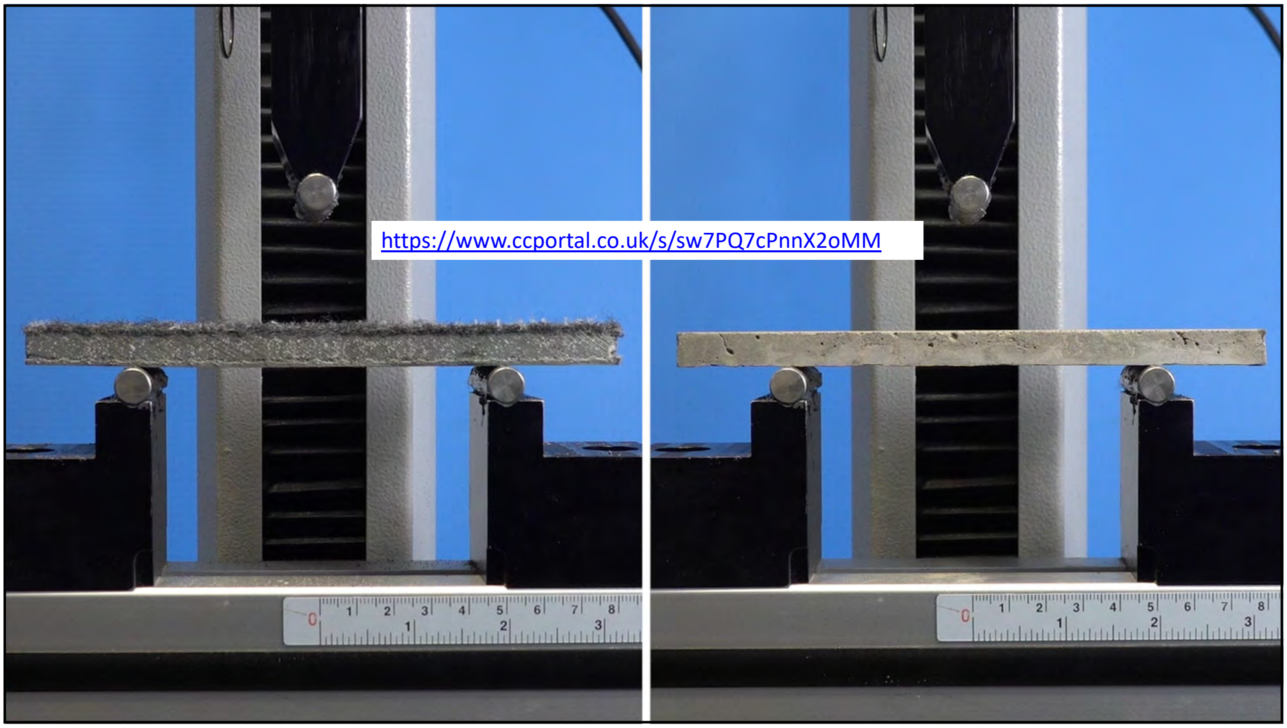

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Low-Carbon Solution

1 GCCM Roll provides the equivalent coverage area of two ready-mix trucks

- Reduced vehicle movements
- Over 60% CO_2 savings
- Full Life-cycle-analysis

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GCCM's Are Already Widely Used in India

- Rail Embankments
- Drainage Channels
- LHS Waterproofing

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DRC Canal Lining Case Study

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DRC Canal Lining Case Study

Case Study Location & Parameters

±50km from Kolwezi in the Southern DR Congo

Underground copper mine requiring continuous pumping of sub-terranean water. Pumped water collects in settling ponds and then canalised 4km to river outlet.

The drainage canal from settling ponds was previously unlined but water was permeating back into the underground mine.

Original proposed solution: 100mm, mesh reinforced 25 Mpa concrete. Problems: lack of ready-mix & local resource.

CCX-M selected based on:
- Provision of erosion control and improved hydraulics
- Speed and ease of installation
- Reduced permeability of joints
- Turnkey supply solution
- Ability to provide on-site installation training

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DRC Canal Lining Case Study

Drainage Canal

- Distance from settling ponds to river of ±4km
- Canal profile width of ±8m
- Total of 32,000m² GCCM
- Overlaps were thermally bonded and screw fixed.
- Intermediate pegging incorporated for hot weather conditions
- Installation rate of 1000sqm per day

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DRC Canal Lining Case Study

Installation Preparation

Before commencement of installation, the canal profile had to be prepared in accordance with the GCCM specification.

Section 6.2 References:

- De-vegetation
- Removing of oversize, sharp and loose objects
- Uniform Profiling & Compaction
- Anchor trench detailing

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DRC Canal Lining Case Study

GCCM Deployment

50m long 1.90m wide GCCM rolls weighing 1400kg's each were deployed by double width spreader beam attached to a 30 T excavator bucket.

The excavator was selected based on reach of the boom to far side of the canal.

The material is rigged into place by hand to achieve the specified overlap across each length.

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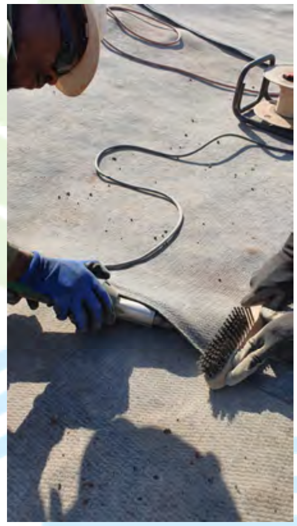
DRC Canal Lining Case Study

Installation Details

Overlaps are thermally bonded with a Leister Triac AT hot air welder at a rate of 1m/min with a 60mm wide perforated nozzle to reduce joint permeability.

Joint mechanical strength was achieved by inserting 30mm long stainless steel collated screws at 100mm spacing, 30-50mm from the material edge.



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DRC Canal Lining Case Study

Installation Details

Intermediate pegs were installed to the underlap of each joint at each transition from floor to side slope.

Overlaps were pegged within each anchor trench. Anchor trenches were a minimum of 150mm deep and 150mm from canal crest.

Galvanised, 250mm long, 12mm Ø ribbed rebar peg with 4mm thick, 50mm Ø round head.

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DRC Canal Lining Case Study

Hydration in Hot, Dry Weather

The temperatures on site are typically between 25 and 30°C with a drying wind. The GCCM was hydrated 3 times at 30 minutes intervals to saturation, in accordance with the warmer weather guidance. To ensure sufficient curing, an additional hydration was provided at the end of each days' installation.

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Canal de provence video
https://www.youtube.com/watch?v=mLOOk9N9C8M

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Expertise
Geosynthetics
Engineered Construction Materials

IGS-TCB / IGS-TCH Webinar

Service life of Geosynthetics in Hydraulic Applications

June 1, 2023 (31 May in North-America)

Eric Blond, Eng., M.Sc.A.
Eric Blond Consultant Inc.
Montréal, Québec, Canada
eric@ericblond.com - Cell +1-514-621-9934

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Eric Blond
www.ericblond.com

Eric Blond is an independent consultant offering technical services to the geosynthetics and engineered construction material industries. His key expertise are soil filtration and drainage with geosynthetics; durability of geosynthetics and construction materials; geosynthetics lining materials and systems, and other applications of Geosynthetics.

Eric Blond is actively involved in several technical committees and Industry associations:

- ASTM D35 on Geosynthetics: Past-Chairman of subcommittee D35.02 on endurance properties of geosynthetics
- ISO TC221 on Geosynthetics: Chairman of the Canadian Mirror Committee, WG6-PG3 on Designing for Filtration
- IGS – International Geosynthetics Society: chairman of the Technical Committee on Hydraulics, council member (2010-2016)
- IGS-NA – North-American Chapter of the IGS: Secretary
- CGS – The Canadian Geotechnical Society: vice-President
- CCCME – Canadian Commission on Construction Material Evaluation: member of the commission
- CSA A123 on Bituminous roofing materials – member of the committee

Eric Blond is committed to education and introduction of geosynthetics technologies. He has authored more than 100 technical papers, conferences and courses. He is lecturer at Ecole Polytechnique de Montreal. He also offers custom trainings to engineering firms, and regularly contributes to pre-conference short courses and other training events.

He is a professional engineer, member of the OIQ (Quebec) and APEGA (Alberta). With more than 25 years of experience and projects conducted in Canada, the USA, South-America, Europe and the Middle-East, Eric Blond holds one of the most comprehensive independent expertise in geosynthetics and polymeric materials used in the construction industry.

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2

Fitness for purpose of concrete as a single lining material

Concrete offers a low permeability with:

- Ideal subgrade conditions, perfect compaction of the subgrade
- Concrete veneer thickness of 150 mm or more
- Perfect installation
- Adequate management of the thermal expansion of the concrete (~10^{-5} mm/mm/°C)
- A water table always lower than the canal
- …

Under these conditions, a concrete veneer may hypothetically not crack and remain watertight for many decades.

HOWEVER…

(photo Hervé Plusquellec)

3

Fitness for purpose of concrete as a single lining material

This concrete liner almost made it to the second year

(photo Hervé Plusquellec)

4

Fitness for purpose of concrete as a single lining material

(photo Hervé Plusquellec)

(photo Hervé Plusquellec)

5

Fitness for purpose of concrete as a single lining material

Using reinforcement may reduce the occurrence of problems

…when the reinforcement is well designed and located in the right place

…when the thermal expansion of concrete can be managed

($$$)

(photo Hervé Plusquellec)

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Fitness for purpose of concrete as a single lining material

Geocells may preserve concrete from excessive cracking / collapsing by creating an articulated mattress, and potentially mitigate problems associated with the thermal expansion of concrete.


Geocells (photo PRS)

Geocells could help make an effective use of concrete:

- Without geomembrane, when seepage control is not a critical concern?
- To cover a geomembrane?

Fitness for purpose of concrete as a single lining material

Concrete is widely used for canal lining. But is it actually 'fit for purpose'?

For concrete to preserve its watertightness:

- It must not crack. Therefore, the concrete layer must be designed to resist reasonable soil settlement: it must be thick and reinforced. A thin layer of concrete will crack and will not preserve its watertightness.
- It must not degrade over time. The formulation must be selected to resist permanent exposition to water.

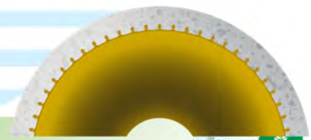
Despite broadly used in hydraulic structures, concrete is not a material that is fit to control seepage!

Fitness for purpose of concrete as a single lining(?) material

A 'synthetic' veneer is often used to protect concrete from premature degradation. The concrete is, then, only used for its structural properties.

Even concrete users acknowledge that synthetic materials are suitable to protect the concrete for many decades (and contain water doing so), especially in hydraulic structures.

Lago Nero Dam, Italy, 1980



Lifetime Prediction of Polymeric Geomembranes Used in New Dam Construction and Dam Rehabilitation, R.M. Koerner and Y.G. Hsuan, 2003

Photos AKS Lining Systems

Concrete panels laid over a geomembrane?

35-years old canal in Ghana

The concrete cover is essentially gone.

But the geomembrane seems to be holding water, still! (surprisingly)

(photo Hervé Plusquellec)

- Synthetic materials can provide a durable sealing function – and are widely used for that purpose across many industries, from electric cable (shielding) to automotives and aircrafts.
- ‘Synthetic materials’ used in construction, or ‘geosynthetics’, must be formulated to meet the service conditions encountered in these applications.
- The structure must then be designed considering the properties – and limitations – of the geosynthetic material.

Using geosynthetics in hydraulic applications

The selection, and formulation of geosynthetics must consider the service conditions of the structure, and in particular its exposition to the sun.

Piggybacking on their experience with other ‘plastic’ materials, a frequent question asked by designers is: “how long do geosynthetics last”

A better way to express this concern is:
Do geosynthetic liners offer a sufficient service-life for hydraulic structures?
- When exposed?
- When covered?

(photo Solmax)

Proceedings of GeoAfrica2023 Conference with open-source access to Giroud’s paper (and others)
https://www.e3s-conferences.org/articles/e3sconf/abs/2023/05/contents/contents.html

The service life of geosynthetics can be estimated

- **Based on field observations, i.e. learning from the performance (and failure mechanisms) of existing structures**

- **Based on laboratory projections, i.e. using available science on aging mechanisms of geosynthetic materials**

Service life of a geomembrane

The criteria defining the 'end of life' of a geomembrane is when it leaks.

This end-of-life can be reached:

- During construction (when detected on time, most leaks can be repaired) — **Survivability**

- When service conditions are beyond what the material can handle (improper design) — **Performance**

- When the material has lost its intrinsic properties and fails under normal service conditions — **Durability**

1- Designing for Survivability

Essentially based on field experience

Assessment of the ability of the geomembrane to survive involves a holistic approach to the construction process:

- Storage and handling
- Construction and installation technique (competency / experience of the stakeholders)
- Mechanical properties of the geomembrane
- Use of cushioning materials, such as geotextiles
- Design of the structure
- Quality assurance? Electrical Leak Location?

1- Designing for Survivability

Improper storage and handling may affect the properties, hence the performance of the product

Survivability heavily depends on onsite storage and handling techni

- Use experienced installers!

1- Designing for Survivability

For canal lining:

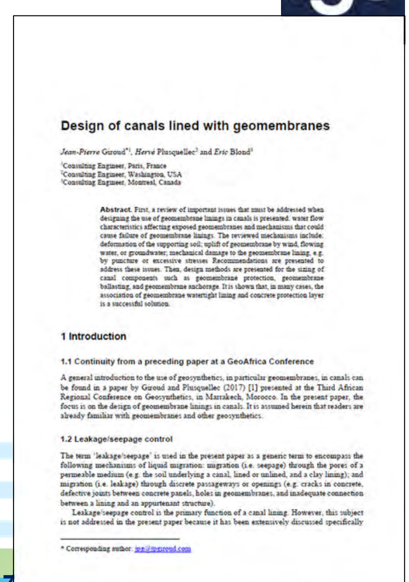
- **Minimum thickness 1.0 mm – may be increased to 1.5 mm under warm climate**
  - Ease / reliability of welding is essential, wh
    products (up to some extent)
- **Minimizing the development of wrinkles cau thermal expansion reduces the risk of accide puncture**
  - White-surfaced geomembranes

2- Designing for Performance

Design guidance focusing on geosynthetics are available:

- **Hydraulic (water flow) considerations**
- **Soil / geosynthetic interaction**
- **Some issues specific to geosynthetic in canals**
  - Flowing water!
  - Varying level of water / of water table
  - Boat traffic?
  - Etc
- **Leakage management**

- **Paper by Giroud et al (GeoAfrica 2023)**
  open access https://doi.org/10.1051/e3sconf/202336801001
- **Complete book to be published in 2024**



Design of canals lined with geomembranes

Jean-Pierre Giroud*[1], Hervé Plusquellec[2] and Eric Blond[3]

[1]Consulting Engineer, Paris, France
[2]Consulting Engineer, Washington, USA
[3]Consulting Engineer, Montreal, Canada

Abstract. First, a review of important issues that must be addressed when designing the use of geomembrane linings in canals is presented: water flow characteristics affecting exposed geomembranes and mechanisms that could cause failure of geomembrane linings. The reviewed mechanisms include: deformation of the supporting soil; uplift of geomembrane by wind, flowing water, or groundwater; mechanical damage to the geomembrane lining, e.g. by puncture or excessive stresses. Recommendations are presented to address these issues. Then, design methods are presented for the sizing of canal components such as geomembrane protection, geomembrane ballasting, and geomembrane anchorage. It is shown that, in many cases, the association of geomembrane watertight lining and concrete protection layer is a successful solution.

1 Introduction

1.1 Continuity from a preceding paper at a GeoAfrica Conference

A general introduction to the use of geosynthetics, in particular geomembranes, in canals can be found in a paper by Giroud and Plusquellec (2017) [1] presented at the Third African Regional Conference on Geosynthetics, in Marrakech, Morocco. In the present paper, the focus is on the design of geomembrane linings in canals. It is assumed herein that readers are already familiar with geomembranes and other geosynthetics.

1.2 Leakage/seepage control

The term 'leakage/seepage' is used in the present paper as a generic term to encompass the following mechanisms of liquid migration: migration (i.e. seepage) through the pores of a permeable medium (e.g. the soil underlying a canal, lined or unlined, and a clay lining); and migration (i.e. leakage) through discrete passageways or openings (e.g. cracks in concrete, defective joints between concrete panels, holes in geomembranes, and inadequate connection between a lining and an appurtenant structure).

Leakage/seepage control is the primary function of a canal lining. However, this subject is not addressed in the present paper because it has been extensively discussed specifically

* Corresponding author: jpg@jpgiroud.com

2- Designing for Performance

- **Longitudinal anchors**

(photo Nortene - Engepol)

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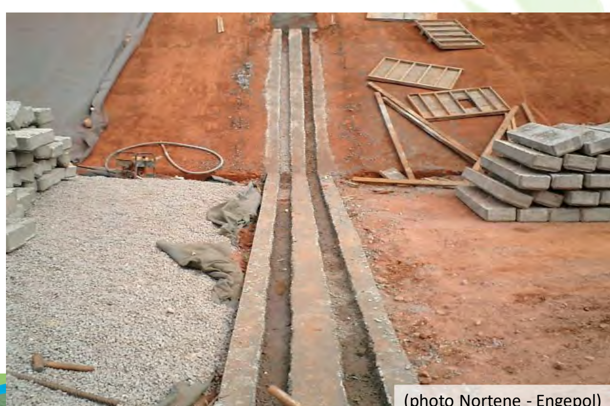
2- Designing for Performance

- **Transversal anchors**



(photo Nortene - Engepol)

(photo Nortene - Engepol)

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2- Designing for Performance

Drainage under the geomembrane

(photo Nortene - Engepol)

(photo Nortene - Engepol)

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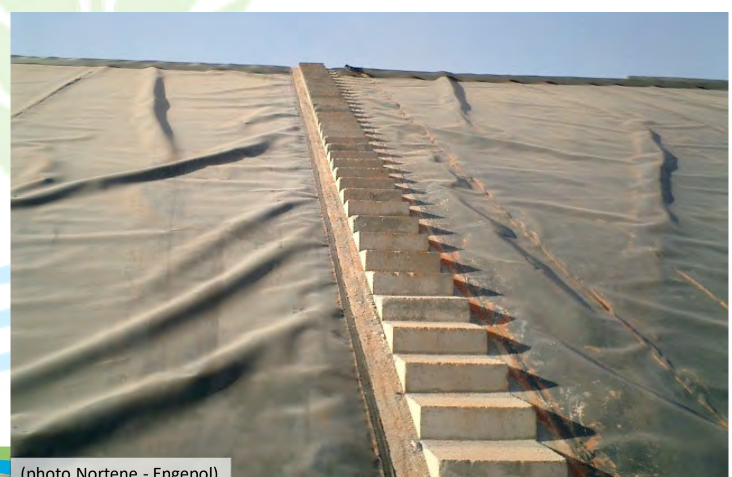
2- Designing for Performance

Canal Safety



(photo Nortene - Engepol)

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2- Designing for Performance

- **Derivation**
- **Connection to other structures**


(photo Solmax)


(photo Solmax)

2- Designing for Performance

Gravel puncture resistance

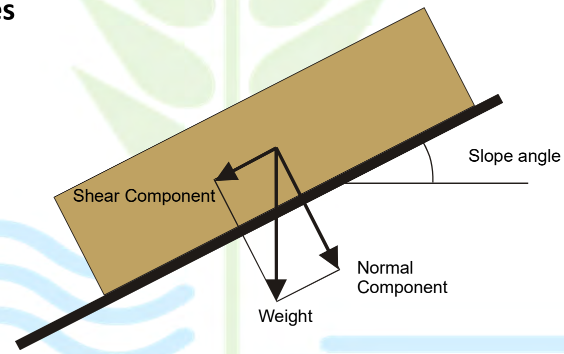
- **ASTM D5514 to observe gravel / geomembrane interaction**

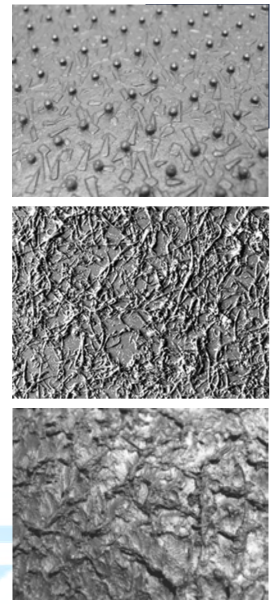
Photos: CTT Group

2- Designing for Performance

Several other design considerations

- **Interface friction properties**
- **Surface erosion**
- **Elongation over crack**
- **...**





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2- Designing for Performance

IGS Video Library

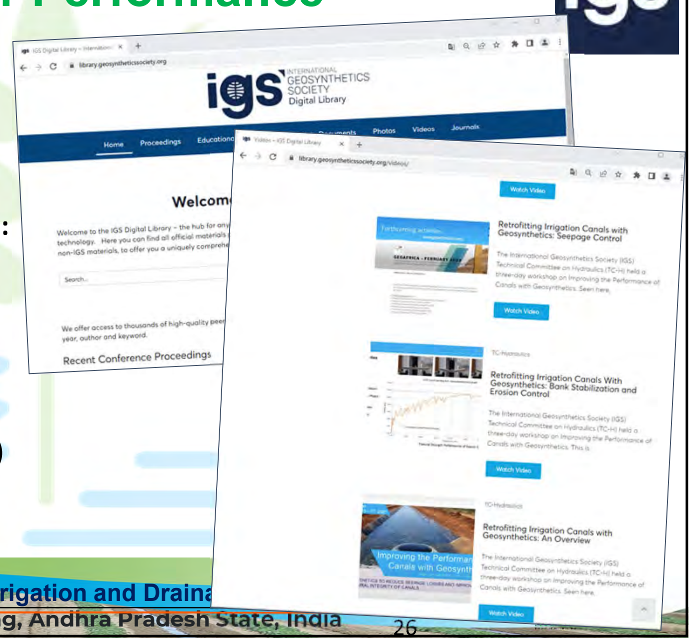
https://library.geosyntheticssociety.org/

Many hours of training – recordings

- **IGS webinar on geosynthetics in canals, 2021:**
  - J.P. Giroud
  - Ragab (ICID)
  - Minister of Water and Irrigation of Egypt
  - H. Plusquellec
  - N. Touze

  \+ Case studies
- **ICID 5th African Conference, 2022 (reservoirs)**
  - J.P. Giroud

  \+ Case studies



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3- Durability

Importance of material properties, service conditions and design choices!

Example of bitumen used as a sealing product

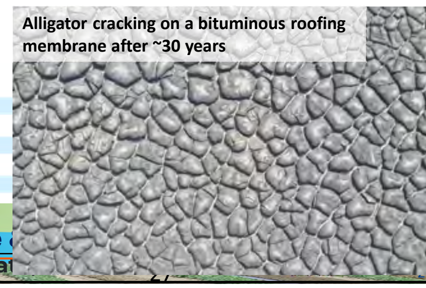
- Bitumen used in Roman aqueducts (protected from sun and heat) lasted for centuries.
- However, bituminous roofing products must be replaced periodically, typically every 15 to 30 years.

This observation applies to essentially every geomembrane:

- Aging of most materials is faster when they are exposed to heat and UV radiation

HOWEVER, the use of exposed geomembranes may be interesting for other reasons: e.g., to facilitate periodic replacement, which is easier if it is not covered by concrete.

Pont du Gard aqueduc, France
2000 years old, active for ~6 centuries



Alligator cracking on a bituminous roofing membrane after ~30 years

Noticeable (old) projects with geosynthetics

Field experience with geosynthetics shows their ability to perform for >50 years in dams

Table 1 - Oldest Geomembrane Installations by Type of Geomembrane (after Scuero, 2005)

Type	Basic material	Abbreviation	Total exposed	Total covered	Oldest exposed	Oldest covered
Polymeric	Polyvinyl chloride	PVC-P	73	70	1974	1960 (Terzaghi Dam, Canada)
Polymeric	Polyolefin	LLDPE	0	28	-	1970 (Atbashinsk, Kirgizistan)
Polymeric	Polyolefin	HDPE	2	11	Not known	1978 (Bitburg, Germany)
Polymeric	Elastomeric	Polysobutylene IIR	5	4	1982	1959 (Contrada Sabetta, Italy)
Polymeric	Chlorosuflonated Polyethylene	CSPE	3	5	Not known	1981 (Kolnbrein Austria)
Polymeric	Polyolefin	PP	1	2	Not known	Not known
Polymeric	Chlorinated Polyethylene	CPE	0	3	-	1970 (Odiel-Perejil, Spain)
Bituminous	Oxidized bitumen	Prefabricated GM	7	10	1973 (Banegon, France)	1978
Bituminous	Polymer bitumen	SBS	0	1	-	1996

Oldest project: 63 years

Field observations

Literature relating the actual performance of geomembranes after:

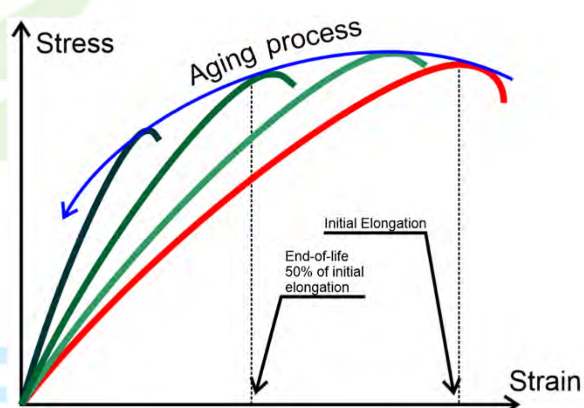
- **Bituminous: ~30 years**
- **EPDM: 30-40 years? Based on Butyl Rubber**
- **PVC: 40-50 years**
- **HDPE (including in environments harsher than water): ~40-50 years**

There are many positive experiences demonstrating ~50-years of service life is a realistic (verified) assumption

Laboratory predictions

A lifetime can be predicted based on the degradation mechanisms of the geomembrane, which depends on the type of polymer and the environment of service:

- **Temperature**
- **Chemical environment**
- **Exposure to UV**
- **Stress**
- **…**



Typical end-of-life criteria: 50% property-loss on a property related to performance

e.g., elongation at break for a waterproofing membrane

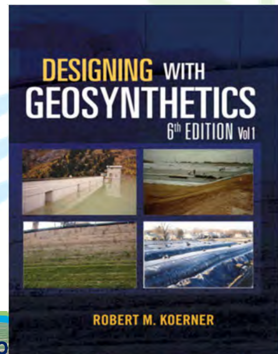
Laboratory predictions

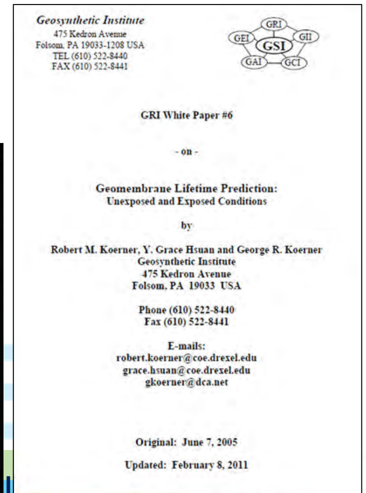
A lot of literature is available documenting the performance and durability of geosynthetics.

Many research has focused on geomembranes.

Standards are available:

- **ASTM D35**
- **ISO TC221**
- **CEN TC189**





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FAX (610) 522-8441

GRI White Paper #6

- on -

Geomembrane Lifetime Prediction:
Unexposed and Exposed Conditions

by

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Folsom, PA 19033 USA

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grace.hsuan@coe.drexel.edu
gkoerner@dca.net

Original: June 7, 2005
Updated: February 8, 2011

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Projected lifetime of geomembranes in EXPOSED applications

HDPE, EPDM, and high-performing grades of fPP and PVC geomembranes have predicted lifetimes in excess of 30 years – with tests still ongoing

These results are supported with the performance observed on actual projects:

- **PVC (1974)**
- **Butyl (1982)**
- **Bituminous (1973)**

Table 6 – Exposed lifetime prediction results of selected geomembranes to date (2011)

Type	Specification	Prediction Lifetime in a Dry and Arid Climate
HDPE	GRI-GM13	> 36 years (ongoing)
LLDPE	GRI-GM17	≃ 36 years (halflife)
EPDM	GRI-GM21	> 27 years (ongoing)
fPP-2	GRI-GM18	≃ 30 years (halflife)
fPP-3	GRI-GM18	> 27 years (ongoing)
PVC-N.A.	(see FGI)	≃ 18 years (halflife)
PVC-Eur.	proprietary	> 32 years (ongoing)

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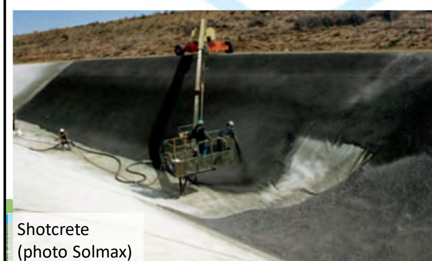
Covering geomembranes

Several solutions are available to cover a geomembrane.

A critical component of the design is to select the adequate solution considering size, available materials, workmanship, subgrade, cost, etc.


Rehabilitation of irrigation canal, west of Fayoum (photo from MWRI (Egypt) Facebook page)


Shotcrete (photo Solmax)


Concrete-filled Geocells (photo PRS)


Concrete paver (photo Solmax)

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Covering geomembranes

Exposed geomembranes are also exposed to UV and the weather, drag stress from water flowing, wind uplift, etc.

Exposed geomembranes may also be exposed to unexpected stresses, vandalism and wildlife.

Temperature of exposed geomembranes will be close to, or higher than (in the case of black geomembranes) the air temperature, therefore, it will age faster.

It is often better to cover a geomembrane:

- **To increase its service life**
- **To minimize its exposure to accidental damages**


(photo Solmax)

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Service life of HDPE geomembranes in covered applications

Lifetime prediction for typical HDPE geomembrane

The lifetime prediction depends on the temperature

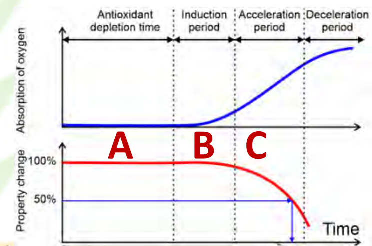

Table 2 - Lifetime prediction of HDPE (nonexposed) at various field temperatures

In Service Temperature (°C)	Stage "A" (years) Standard OIT	High Press. OIT	Average OIT	Stage "B" (years)	Stage "C" (years)	Total Prediction* (years)
20	200	215	208	30	208	446
25	135	144	140	25	100	265
30	95	98	97	20	49	166
35	65	67	66	15	25	106
40	45	47	46	10	13	69

*Total = Stage A (average) + Stage B + Stage C

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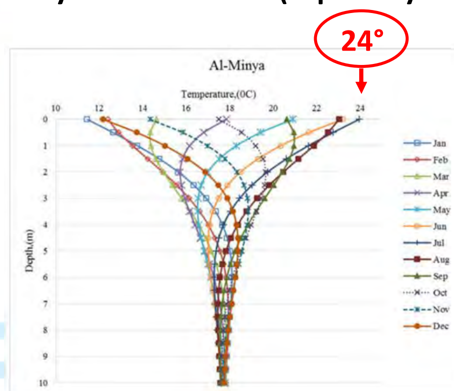
Service life of HDPE geomembranes in covered applications

The temperature of the geomembrane can often be estimated considering the temperature of the soil. For canals, this temperature is typically lower than 30° (especially if the geomembrane is covered).

Therefore, the predicted lifetime for a HDPE geomembrane can be considered to be in exceed of ~160 years for most hydraulic applications.

In Service Temperature (°C)	Total Prediction* (years)
20	446
25	265
30	166
35	106
40	69



Temperature data from A.A. Serageldin et Al: Soil Temperature Profile for some New Cities in Egypt: Experimental Results and Mathematical Model

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Final remarks (1/2)

Geomembranes are more suitable than concrete to act as a sealing material.

Geomembranes are, in fact, the most suitable materials for sealing canals.

To maximize their service lives, geomembranes should be protected against accidental degradation, vandalism, exposition to UV and excessive heat. Poured concrete, concrete pavers, or other protection materials can be used for that purpose.

Final remarks (2/2)

Some EXPOSED geomembranes can offer a service life in excess of 50 years

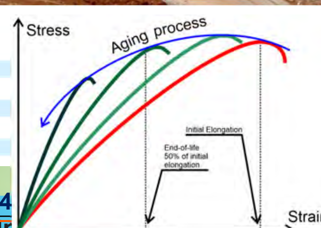
Most PROTECTED geomembranes can offer a service life in excess of 100 years

To offer such a performance, the geomembrane must be adequately sized and formulated

To offer such a performance, the structure must be adequately designed

To offer such a performance, the geomembrane must be adequately installed

Questions?



Expertise
Geosynthetics
Engineered Construction Materials

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Service life of Geosynthetics in Hydraulic Structures

Case studies

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'Heritage' geomembranes: impregnated geotextile, Butyl Rubber

Giroud (2014)

- **Pont-de-Claix, French Alps, 1974**
- **First double liner system**
  - Secondary liner: spray-in-place bitumen, on a geotextile
  - Primary (exposed) liner: Butyl Rubber

  (none of these products still exist)
- **2 holes observed in ~49 years**
  - 2004 (after 30 years): 5 meters underwater in a high stress region, repaired by gluing a different membrane under water.
  - 2011: on the permanently exposed portion of the pond.
- **Closest modern product**
  - Butyl Rubber: EPDM
  - Impregnated GX: Bituminous geomembrane

Giroud (2014): The first double geomembrane liner 40 years later, ICG Berlin

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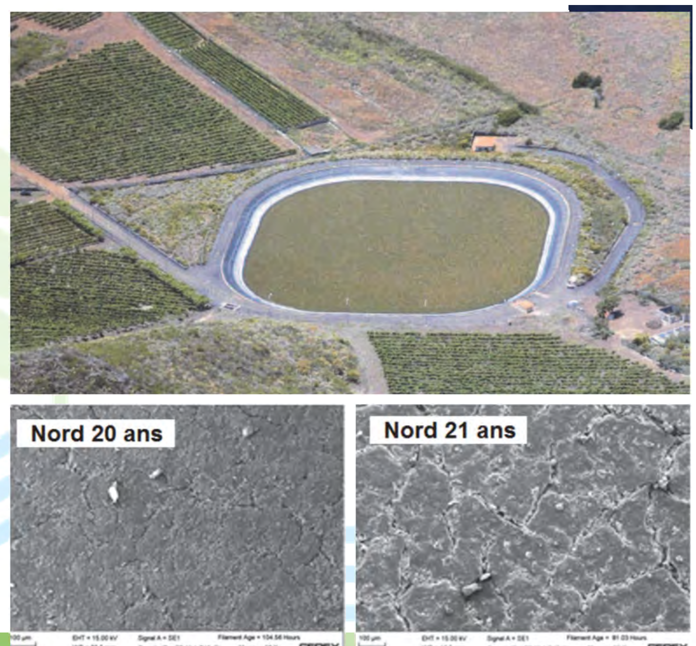
EPDM

Noval (2015)

- **1.5 mm EPDM Geomembrane**
- **Reservoir, Canary Islands, 21 years old**
- **Key Performance indicators, to monitor post-vulcanization and oxidation**
  - Hardness
  - Mechanical properties
  - Additives / plasticizers

Exposed geomembrane facing the sun >>>

No loss of functionality at the time the paper was published



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Noval at Al (2015): Study of the Durability of the EPDM Geomembrane at the "El Boquerón" Reservoir

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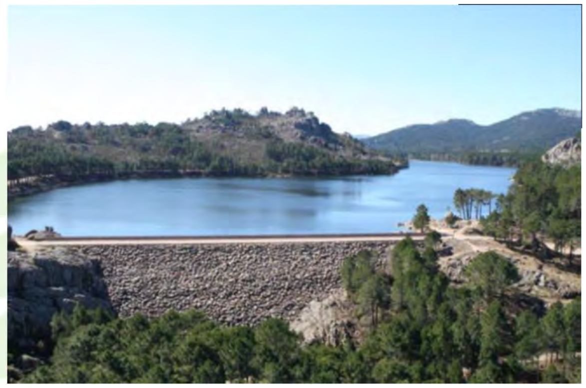
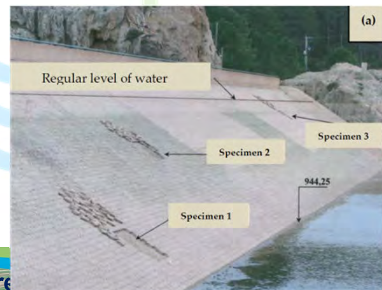
BGM – Oxidized Bitumen

Gourc (2017)

- **Rockfill dam upstream geomembrane sealing system, covered by concrete blocks**
- **4.8 mm oxidized bitumen installed in 1979 (44 years), between 2 layers of NW-GX (400 g/m²)**
- **Key performance indicators:**
  - Bitumen softening point increased
  - Asphaltene content increased
  - Tensile properties unchanged
  - Permeability maintained



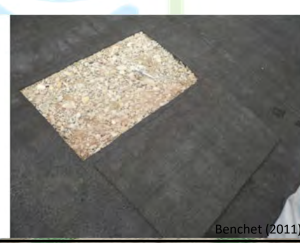


Gourc et al. (2017): Back to the first large rockfill dam with an upstream Geomembrane Sealing System (Ospedale,1979)

BGM – Elastomeric Bitumen

Benchet et al. (2011)

- **Pond, east of France (-13°C to +39°C)**
- **Elastomeric bituminous geomembrane, ~4.1 mm**
- **Monitoring after 6, 10, 15 and 30 years**
- **Performance indicators**
  - Alligator cracking
  - SBS Content, molecular weight
  - No loss of strength
  - Remains watertight



Benchet (2011): Durability of Elastomeric Bituminous Geomembrane Exposed on Site Since 6 to 30 Years

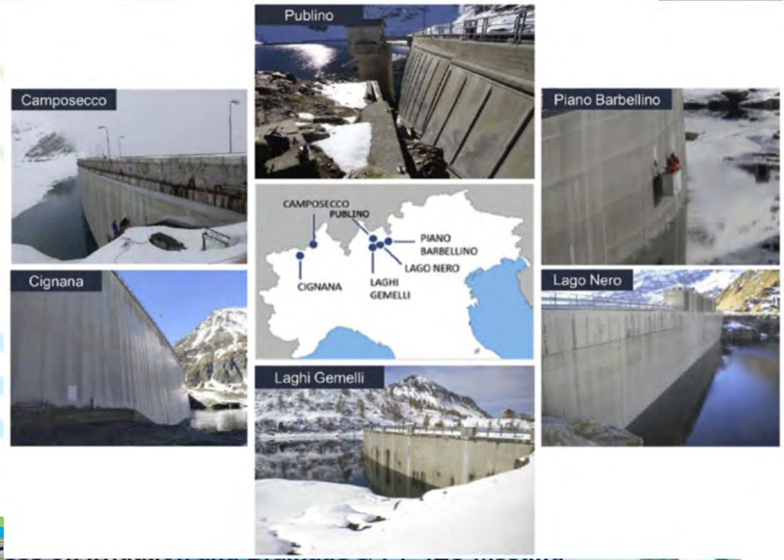
PVC-P

Cazzuffi (2020)

- **2.0 to 2.5 mm PVC geocomposite with non-woven geotextile backing**
- **Several dams, Northern Italy, monitored over up to 25 years**
- **High altitude = high UV irradiance**
- **Key performance indicator:**
  - Loss of plasticizers
  - Tensile properties

Projected service lives: 35 to 45 years

Modern formulations are even better, with plasticizers less prone to be leached out



Cazzuffi et al.: Lifetime assessment of exposed PVC-P geomembranes installed on Italian dams, 2021

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PVC-P

Blanco (2022)

- **1.5 mm PVC**
- **Reservoir, Tenerife (Canary Islands), installed 1986, observed 30 years after (2016)**
- **Key performance indicators:**
  - Low temperature flexibility
  - Loss of plasticizers – observation of the performance of different plasticizers, validation of >400 g/mol criteria, definition of a 15% minimum plasticizer content as an end-of-life criterion

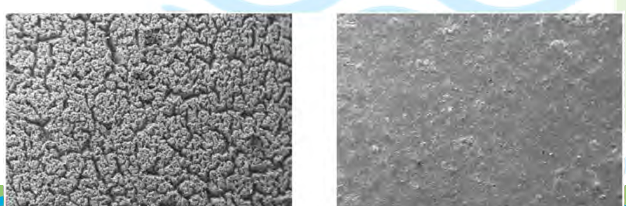

Figure 7. Microphotographs SEM (x90) of the external surface (left) and internal surface (right) of PVC-P samples taken 30 years after installation of the geomembrane

Blanco et al (2022): Long-term performance of PVC-P geomembrane installed in "Los Llanos de Mesa" reservoir, EuroGeo 7, Warsaw

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PVC-P

Lago Nero's dam (Carpi Case study)

- Degraded, then repaired concrete substrate
- Installed 1980 (43 years)
- No maintenance since then.

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HDPE

Tarnowski, Baldauf (2014)

- **2.5 mm HDPE (linear PE with α-olefin- C8 copolymer)**
- **Reservoir installed in 1975**
- **Iran, altitude 3000 meters**
  - -26 to +38°C
  - 290 kLy annual solar energy
- **Performance indicators:**
  - OIT
  - SP-NCTL
- **Tests performed after 25 years exhibit excellent retention of properties**

Table 3. SP-NCTL (ASTM D 5397) and OIT (DIN EN 728, 190°C) after outdoor weathering/initial properties (in brackets)

Levante	Above water level		Intermittent water level	
SP-NCTL [h]	581 ->1000*	(>1000)*	785- >1000*	(>1000)*
OIT [min]	56 – 67	(145)	107 - 110	(145)

* tests were terminated after 1000 h

Tarnowski (2014): Ageing resistance of HDPE-geomembranes – Evaluation of long-term behavior under consideration of project experiences

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HDPE

Putah Canal (Solmax Case study)

- **80 mils (~2.0 mm) textured HDPE, installed 1989 (34 years) and 1993, Vacaville, California (USA)**
- **Covered by 2'' (50mm) of shotcrete with reinforcing fibers**

Maskal (2014): Long-term Integrity of Canals Lined with Geosynthetics, IGS TCH Webinar on Improving the Performance of Canals with Geosynthetics (IGS Video Library)

HDPE

Putah Canal

- **Condition in 2021 (32 years):**
  - Expansion joints perform as planned
  - No leak detected

Good design!

HDPE

Buffalo Rapid Irrigation

- **White Textured HDPE, 2001 (22 years)**
- **Terry, Montana, USA**
- **No testing done so far**

The canal performs as planned

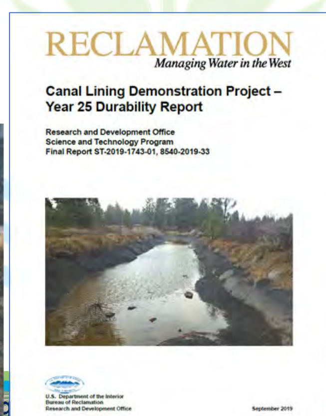
Maskal (2014): Long-term Integrity of Canals Lined with Geosynthetics, IGS TCH Webinar on Improving the Performance of Canals with Geosynthetics (IGS Video Library)

USBR Report, 2019

- **25 years in central Oregon**
- **HDPE, LLDPE, EPDM, CSPE, PVC, RCC, Shotcrete**
- **Small channels**

Exposed HDPE

Geotextile impregnated with bitumen



RECLAMATION
Managing Water in the West

Canal Lining Demonstration Project – Year 25 Durability Report

Research and Development Office
Science and Technology Program
Final Report ST-2019-1743-01, 8540-2019-33

U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

September 2019

Exposed LLDPE

HDPE Geomembranes

USBR Report, 2019

Several failures (caused by poor design?), with 7 out of 24 test sections removed from the study

- Anchorage
- Tear
- Wrong product used (SPUF, exposed GCL)

Most successful solutions (excellent condition + 95% seepage reduction):

- Bitumen-impregnated geotextile + 3’’ shotcrete
- VLDPE + GX + 3’’ shotcrete
- HDPE 80 mils, exposed
- PVC + 3’’ grout-filled mattress
- 3’’ grout-filled mattress
- (12 other solutions not described)

The method used to project the durability is not clear in the report, it appears to focus on the structure more than the product

Table ES-1. Benefit/Cost Summary for the Three Major Lining Types

Liner Type	Advantages / Disadvantages	Durability (years)	Effective-ness (%)	Maintenance ($/ft²-yr)	B/C Ratio
Concrete	Excellent durability, low initial maintenance costs, prevents soil migration, and maintains canal capacity; provides lowest effectiveness	50	70	0.005	3.0-3.3
Concrete over Geomembrane	Favorable durability, effectiveness, and maintenance costs, prevents soil migration and liner uplift, maintains canal capacity; most expensive lining type	50	95	0.005	3.5-3.7
Exposed Geomembrane	Low initial construction costs, high effectiveness and in certain cases can deliver long service lives; performance highly dependent on service conditions, subject to soil migration, liner whales, liner uplift, damage from ice, and capacity reductions, maintenance can be difficult and expensive for field crews	15-30	90	0.010	2.2-3.8

Agricultural water management changes to feed people on a livable planet

Amal Talbi-Jordan
Global Lead for Climate Resilient Irrigation

November 4, 2023

WORLD BANK GROUP Water

GWSP GLOBAL WATER SECURITY & SANITATION PARTNERSHIP

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Reflections on canal lining experience from a global perspective

Amal Talbi-Jordan
Global Lead for Climate Resilient Irrigation

November 4, 2023

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World Bank's mission
End extreme poverty and boost shared prosperity on a livable planet
Water Group Vision: A water secure world for all
Sustain Water Resources
Deliver Services
Build Resilience
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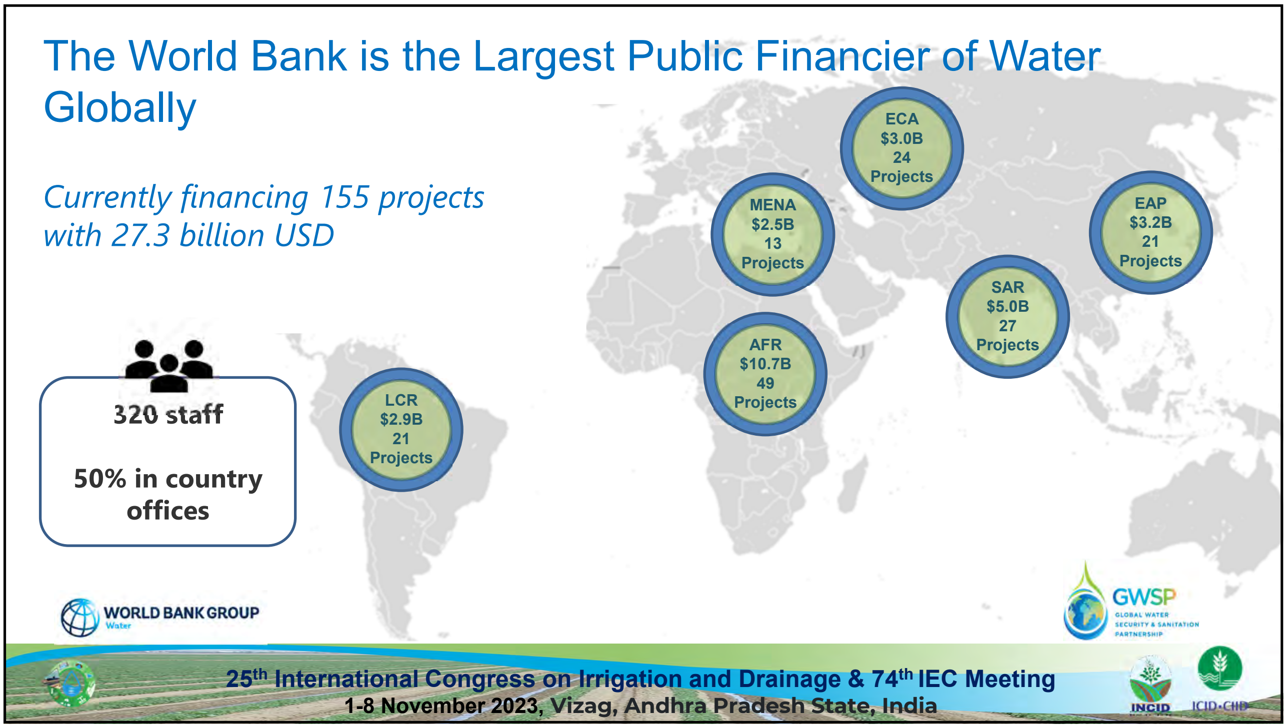
The World Bank is the Largest Public Financier of Water Globally
Currently financing 155 projects with 27.3 billion USD
320 staff
50% in country offices
ECA $3.0B 24 Projects
MENA $2.5B 13 Projects
EAP $3.2B 21 Projects
SAR $5.0B 27 Projects
AFR $10.7B 49 Projects
LCR $2.9B 21 Projects
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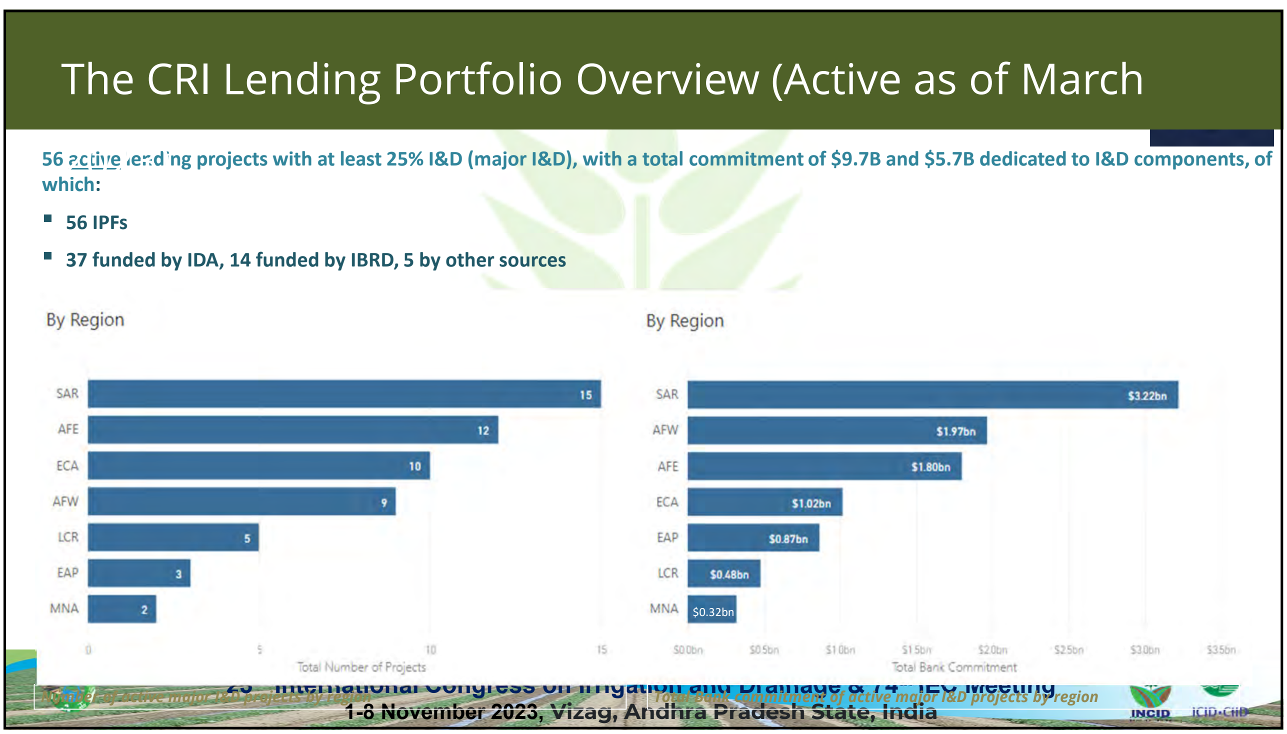
The CRI Lending Portfolio Overview (Active as of March
56 active lending projects with at least 25% I&D (major I&D), with a total commitment of $9.7B and $5.7B dedicated to I&D components, of which:
56 IPFs
37 funded by IDA, 14 funded by IBRD, 5 by other sources
By Region
SAR 15
AFE 12
ECA 10
AFW 9
LCR 5
EAP 3
MNA 2
0 5 10 15
Total Number of Projects
By Region
SAR $3.22bn
AFW $1.97bn
AFE $1.80bn
ECA $1.02bn
EAP $0.87bn
LCR $0.48bn
MNA $0.32bn
$0.0bn $0.5bn $1.0bn $1.5bn $2.0bn $2.5bn $3.0bn $3.5bn
Total Bank Commitment
1-8 November 2023, Vizag, Andhra Pradesh State, India

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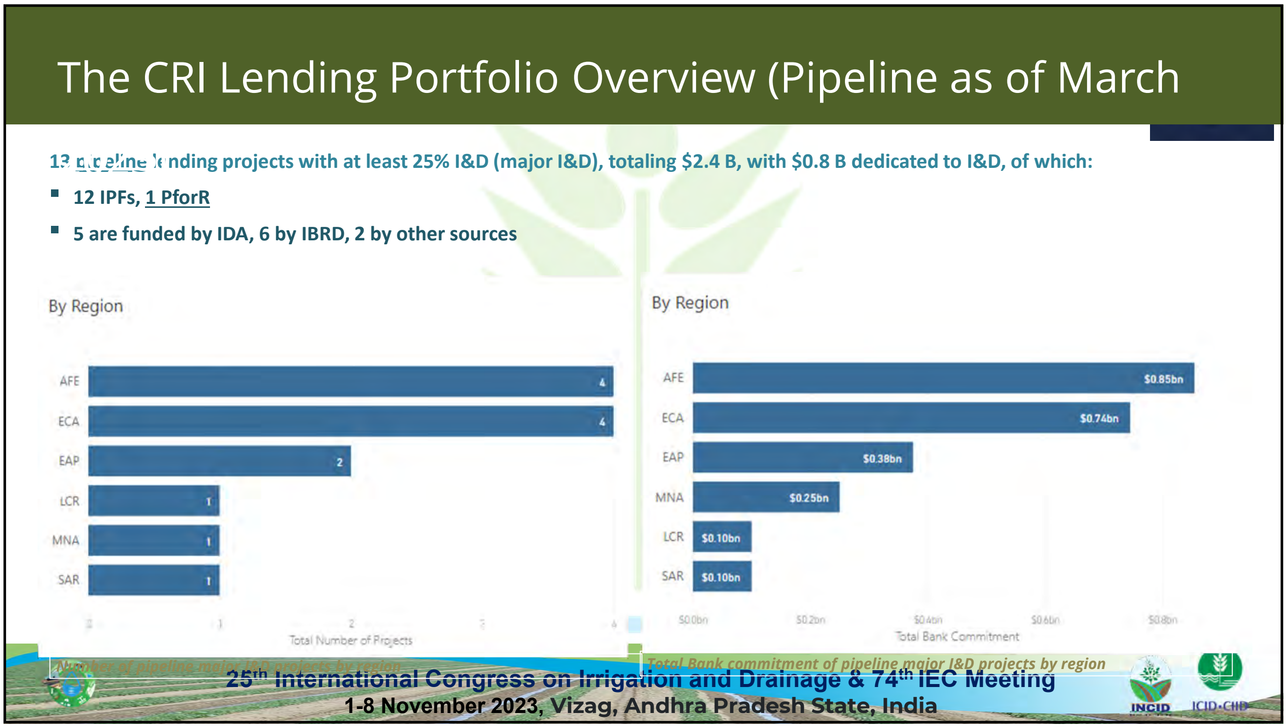
The CRI Lending Portfolio Overview (Pipeline as of March
13 pipeline lending projects with at least 25% I&D (major I&D), totaling $2.4 B, with $0.8 B dedicated to I&D, of which:
12 IPFs, 1 PforR
5 are funded by IDA, 6 by IBRD, 2 by other sources
By Region
AFE 4
ECA 4
EAP 2
LCR 1
MNA 1
SAR 1
Total Number of Projects
Number of pipeline major I&D projects by region
By Region
AFE $0.85bn
ECA $0.74bn
EAP $0.38bn
MNA $0.25bn
LCR $0.10bn
SAR $0.10bn
$0.0bn $0.2bn $0.4bn $0.6bn $0.8bn
Total Bank Commitment
Total Bank commitment of pipeline major I&D projects by region
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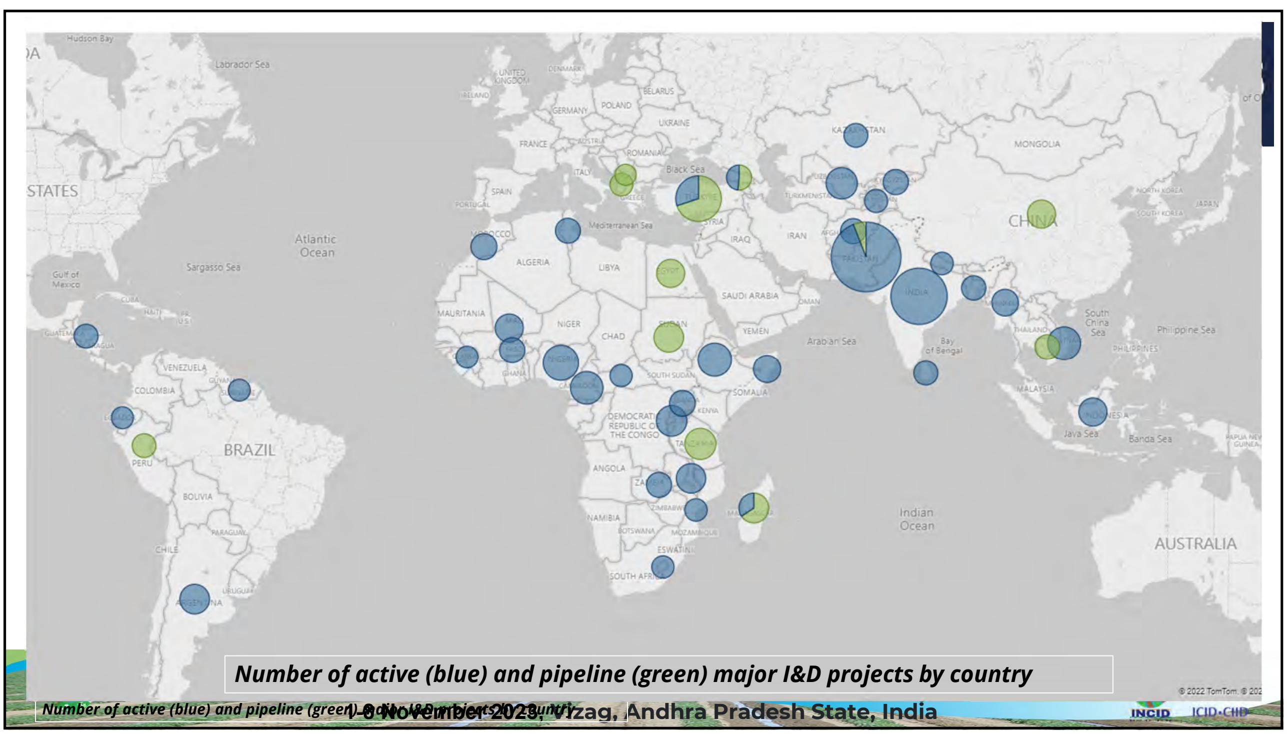
Atlantic Ocean
BRAZIL
CHINA
Indian Ocean
AUSTRALIA
Number of active (blue) and pipeline (green) major I&D projects by country
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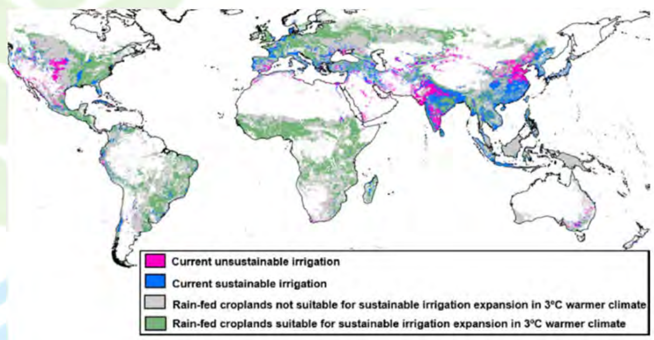
Developing sustainable irrigation can feed an additional people on a livable planet.

- Countries need to proactively implement policies and investments for sustainable irrigation and increasing yields in rainfed agriculture.
- Many studies have shown the potential of developing sustainable irrigation to feed additional people up to 1.4 billion people depending on assumptions.

Rain-fed croplands suitable for sustainable irrigation expansion in 3°C warmer climate



Source: *Rosa, L et al. Adapting agriculture to climate change via sustainable irrigation: biophysical potentials and feedbacks. Environmental Research Letters (17) 063008, 2022.*

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The process of deterioration of rigid concrete canal lining : from cracking to collapsing ..

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PHYSICAL FAILURE: FREEZING/THAWING

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successful canal lining with rigid concrete

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FIBER-REINFORCED CONCRETE

MOROCCO: 50-YEAR OLD LINING- PRE-STRESSED CONCRETE OF SEMI-CIRCULAR SECTION IN KARSTIC AREA

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Example of use of geomembranes example dam

The rehabilitation of the Studena dam was carried out while the dam remained fully operational, and reduction in water level for rehabilitation was not permitted, requiring development of innovative approaches.

For example, the geomembrane was put in place by divers and the supervising engineers had to develop special technology so that they could supervise installation of the geomembrane underwater.

Rehabilitating the structure while it remained in operation increased the overall implementation timeline, however it allowed the municipality to retain the benefit of flow regulation and dry-season water supply during the Project period, which has both economic and societal benefits.

Bulgaria Municipal Infrastructure Development, Studena Dam

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Some reflections

- Use of geomembranes in irrigation in the canal lining, and also increasingly in the regulation reservoirs (increasingly) to help stabilize flow and provide pressure.
- Not a high demand of canal lining to the World Bank with projects increasing in regions such as the Africa region and capacity evolved in countries that have been working for a long time with partners.
- A development of farmer led irrigation, groundwater irrigation, modernization of irrigation requiring pressure, and improving operations/governance and increased private sector participation.
- Use of geomembranes in dams not a major part of the demand from clients to the World Bank for example increasing demand on dam safety with safety concerns related to aging dams.

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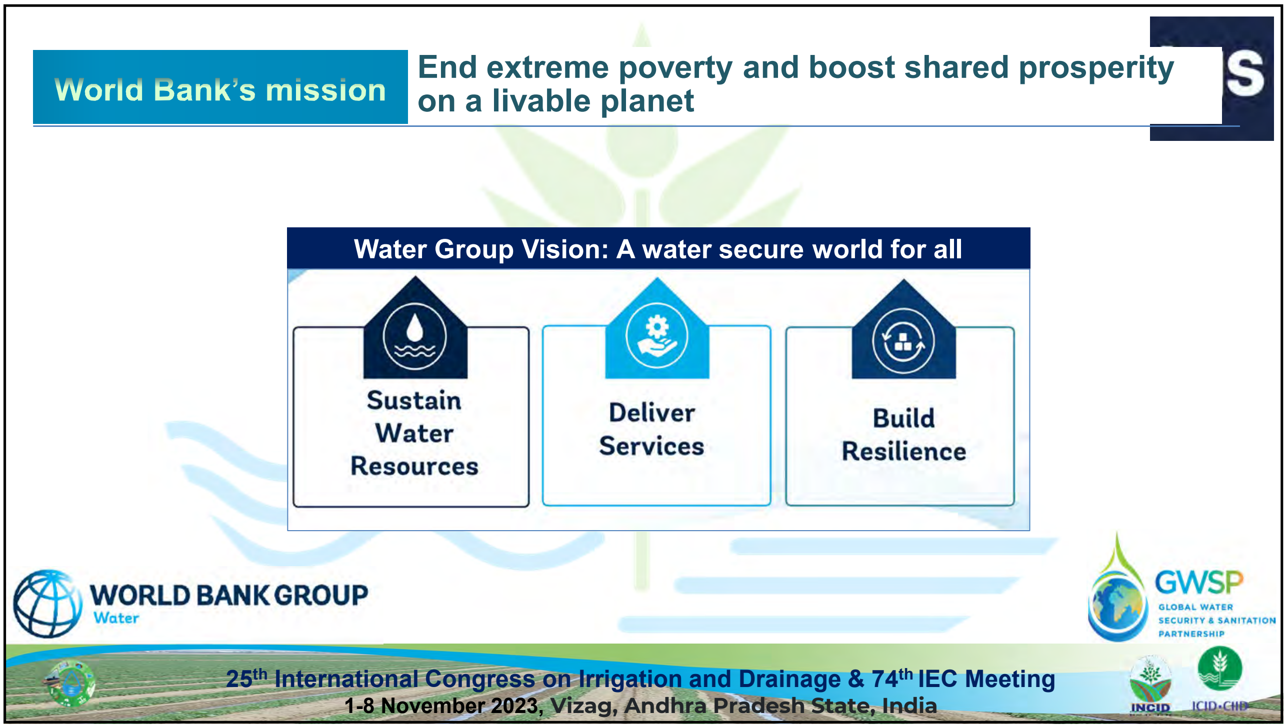
World Bank's mission
End extreme poverty and boost shared prosperity on a livable planet
Water Group Vision: A water secure world for all
Sustain Water Resources
Deliver Services
Build Resilience
WORLD BANK GROUP
Water
GWSP
GLOBAL WATER SECURITY & SANITATION PARTNERSHIP
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Water
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GLOBAL WATER SECURITY & SANITATION PARTNERSHIP
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25th ICID International Congress
74th IEC Meeting

Theme:

Tackling Water Scarcity in Agriculture

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GEOSYNTHETICS FOR DESIGN OF ENERGY DISSIPATION IN DAMS

Vivek P. Kapadia
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vpk@vivekpkapadia.info

4th November 2023

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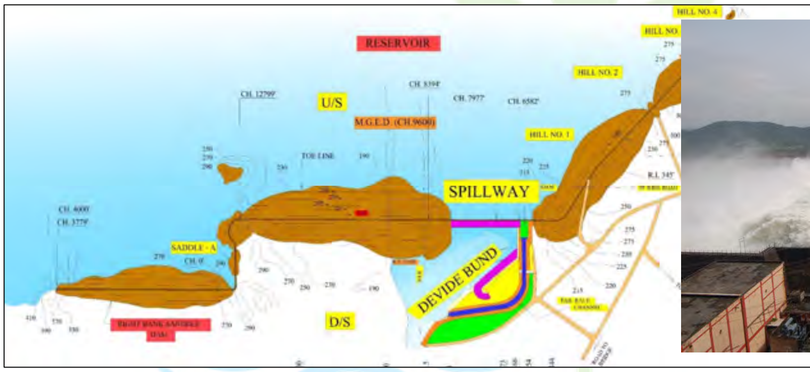
2

Divide Bund between Tail Race Channel and Spillway Gorge



Ukai Dam, Tapi River, Gujarat, India

Gross Storage - 7414.29 Mm3
Gates - Radial, 22, 15.55 m X 14.783 m
Maximum Discharge - 46269 m3/s

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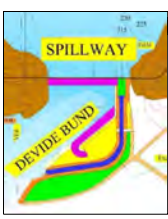
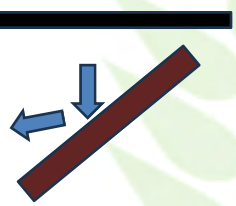
Divide Bund between Tail Race Channel and Spillway Gorge



Plan



Perspective

Toe erosion due to eddies at bottom

Embankment having no support at toes is unstable

Cyclical dynamic loads and wave rebounding and refraction – disintegration of pitching, rubble and earthen bank

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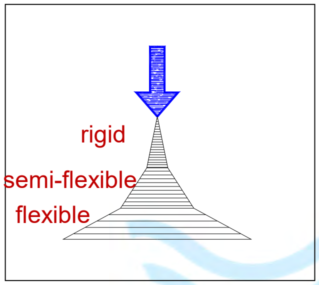
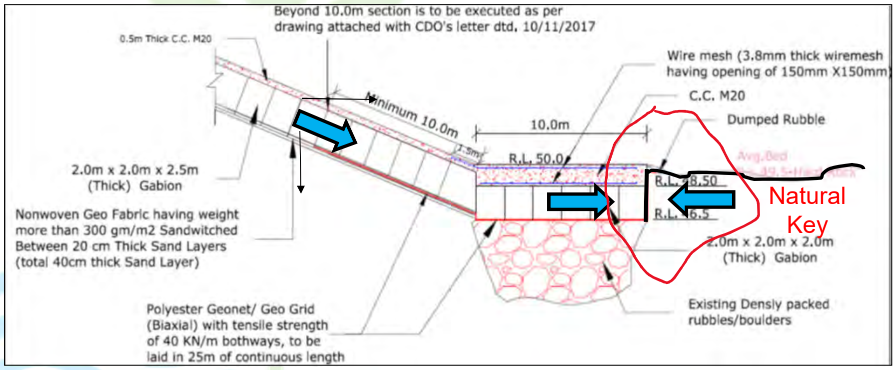
Divide Bund between Tail Race Channel and Spillway Gorge



Dispersion of Impact using Different Materials and Multilayer Mechanism



Force Resolution and Stability Aspects

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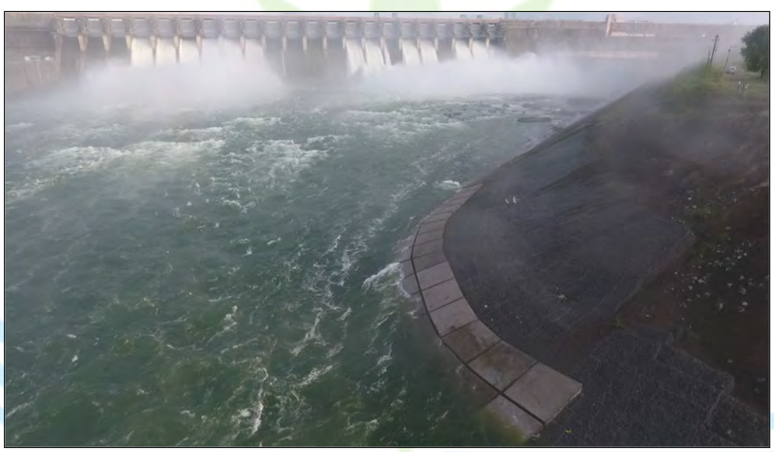
Divide Bund between Tail Race Channel and Spillway Gorge



Performance of divide bund during monsoon of 2019 – no progressive deterioration

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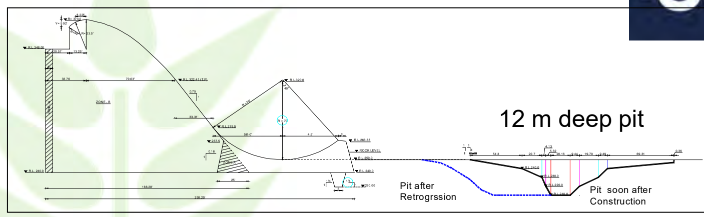
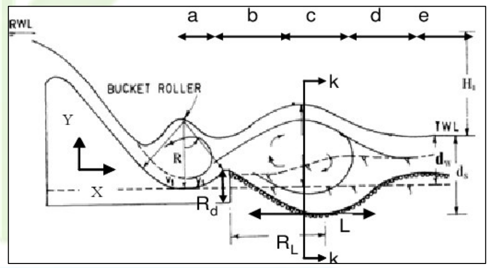
Energy Dissipation: Secondary Apron

- Kadana dam - constructed in 1978 on Mahi River in Gujarat state of India
- Storage capacity - 1542 million m^3
- Main spillway - 406 m long, rubble masonry with reinforced concrete lamination
- Design flood - 31,063 m^3/s
- Ogee fall height from the crest of the dam - 37 m
- *Energy dissipation - solid roller bucket type with exposed basalt floor in the downstream*

Transport of bed material is a typical problem – rocky bed is preferred



Progressive retrogression of pit in downstream of roller bucket



Surface roller and Ground roller

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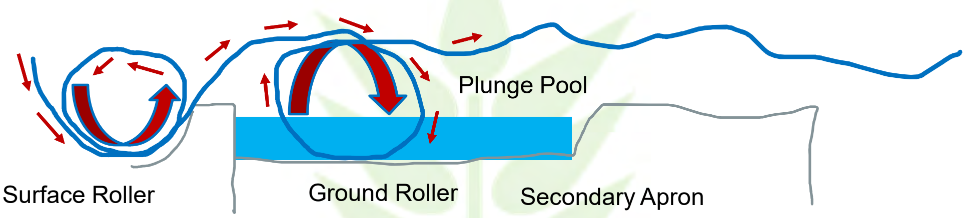
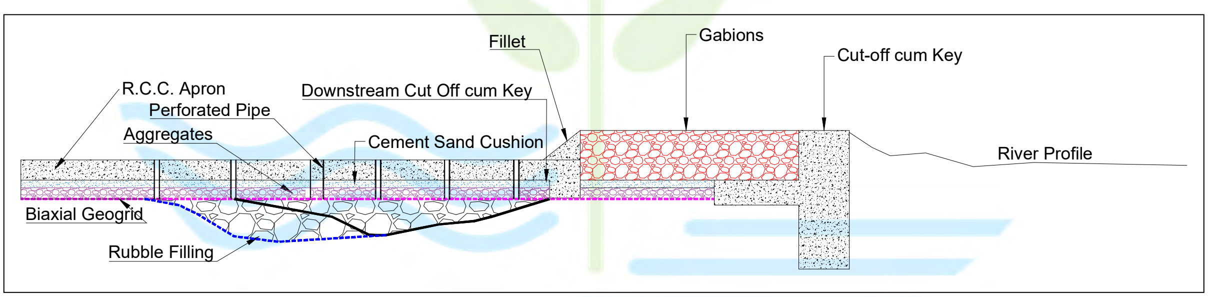
Energy Dissipation: Secondary Apron





Schematic details of secondary apron as an impact resistant mechanism

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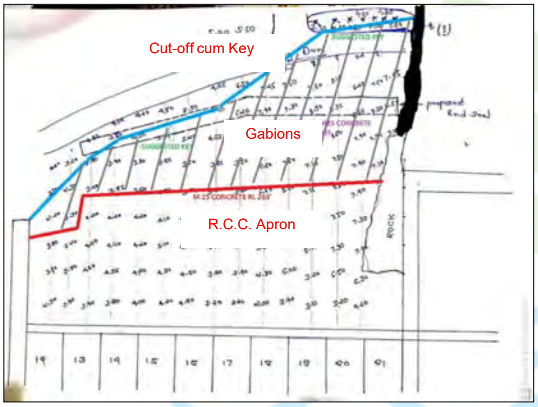
Energy Dissipation: Secondary Apron



Plan of secondary apron, Gabions and Key

Froude number being in range of 2.5 to 4.5, energy dissipation may occur between 20 and 40%

$$F = \frac{v}{\sqrt{gy}}$$

Energy before and after hydraulic jump

$$E_2 = y_2 + \frac{v_2^2}{2g} \qquad E_1 = y_1 + \frac{v_1^2}{2g}$$

Location of surface roller and its velocity depends on discharge released

Plunge pool may not be there during initial discharge

Hydraulic jump formation on gabions disallows bed erosion

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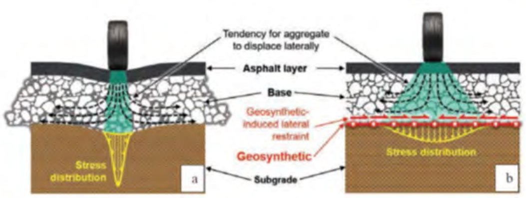
Energy Dissipation: Secondary Apron

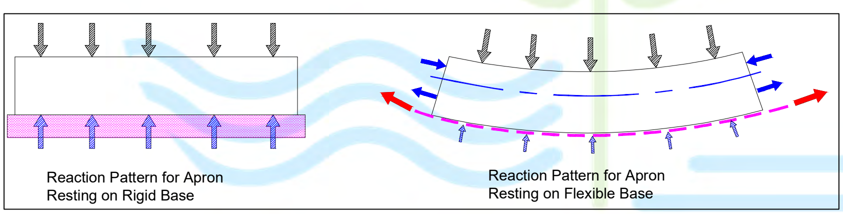


Stress Dispersion with and without Geosynthetics in Road

Bending stresses are shared by biaxial geogrid and apron which reduces the thickness of apron

Surface hardener chemicals used for avoiding pitting on surface

Thick concrete apron is designed for impact-compression



Comparison of Reaction Patterns for Aprons on Rigid and Flexible Bases

Pit filled up with rubble and sand cushion permit some displacement and hence relatively thin apron designed for bending

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Energy Dissipation: Secondary Apron

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- During construction flood required to be released and some damage occurred

Execution of multistage secondary apron

Conclusion

Several dam components subjected to dynamic loads may be designed using flexible or semi-flexible systems instead of conventional rigid heavy blocks; not only to save the cost, but also to make them longevous and maintenance-free

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Sustainable Solutions for Riverbank Protection

Rudra Budhbhatti

(Technical Head – India & Nepal)

4th November 2023

MACCAFERRI

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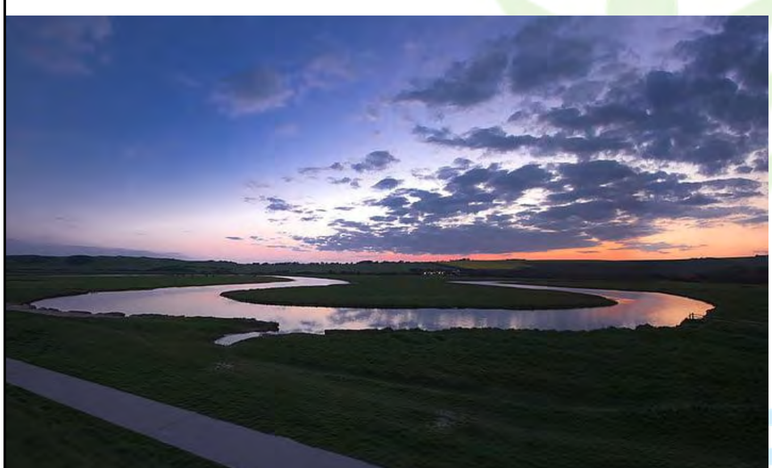
INTRODUCTION



Watercourse management is one of the biggest challenge of the 21st century.

Water hazards are consistently identified as among the highest global risks in terms of impact.

Hydraulic engineers are called to design new solutions that help to manage **water resources**, enhance people **safety** while defending the **ecosystems.**

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INTRODUCTION

A green thought has driven our engineering mindset.

For over 140 years, we have developed solutions that enhance river ecosystem resilience including the social ability to recover quickly from catastrophic events (flood, natural disasters)

Origins: Bank protection along the River Reno at Casalecchio (Bologna, Italy)

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INTRODUCTION

Case study on riverbank protection on Gandak river at Valmikinagar, Bihar

Client: WRD Bihar
Contractor: NNT Developers
Technology provider: Maccaferri

Protection zone:
Left and right bank on upstream Of Gandak barrage
(Total scope on right bank – 3.3km)

Construction period: 2018-19/ 2019-21 (2 phases)
for completed portion

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PROJECT FEATURES

- Heavy water flow during monsoon
- Severe erosion on left bank resulted in slope failure with near vertical cuts
- Excessive erosion leads to increase in bed load and resulting in damage to barrage gates and increase in maintainence requirements for the gates and canal operations
- Deposition of material further downstream can change the river flow pattern and meandering

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PROJECT FEATURES

- Being located upstream of Gandak barrage, water level always present. Limited construction window (6 months) - LWL condition.
- Located in seismic zone V
- Stones/boulders are scarce and expensive
- Eco-sensitive zone – Tiger reserve area
- Department initially was planning for boulder pitching of 1.8m thickness for slope protection
- Requirement of public promanade development

Max Discharge Q = 24100 cumecs

Width of the River = 520m to 800m

BL - 102.74m HFL - 113m LWL - 104m

Flow velocity = 3m/s

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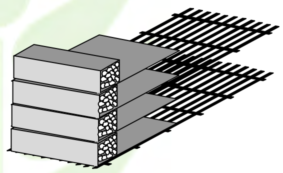
PROPOSED SOLUTION

- Reinforced soil wall (Paramesh) of upto 12m height
- Gabion mattress as launching apron for scour protection
- 3D reinforced erosion control mat (Macmat R) + Hydromulching (MacFlex and Macganics) for erosion protection of embankment slope



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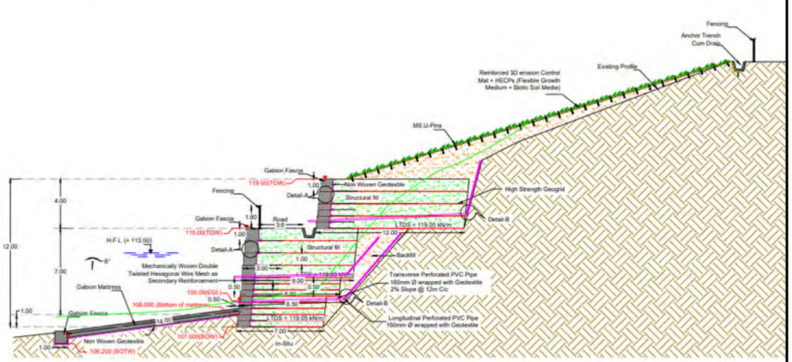
PROPOSED SOLUTION

- Flexible solution suitable for high seismic zone and water front structure
- Permeable structure - minimize pore water pressure development
- Durable & eco-friendly
- Use of locally available fill material
- Minimized requirement of stones/boulders
- Optimized overall project costing
- Requirement of retention/problem of slope instability addressed



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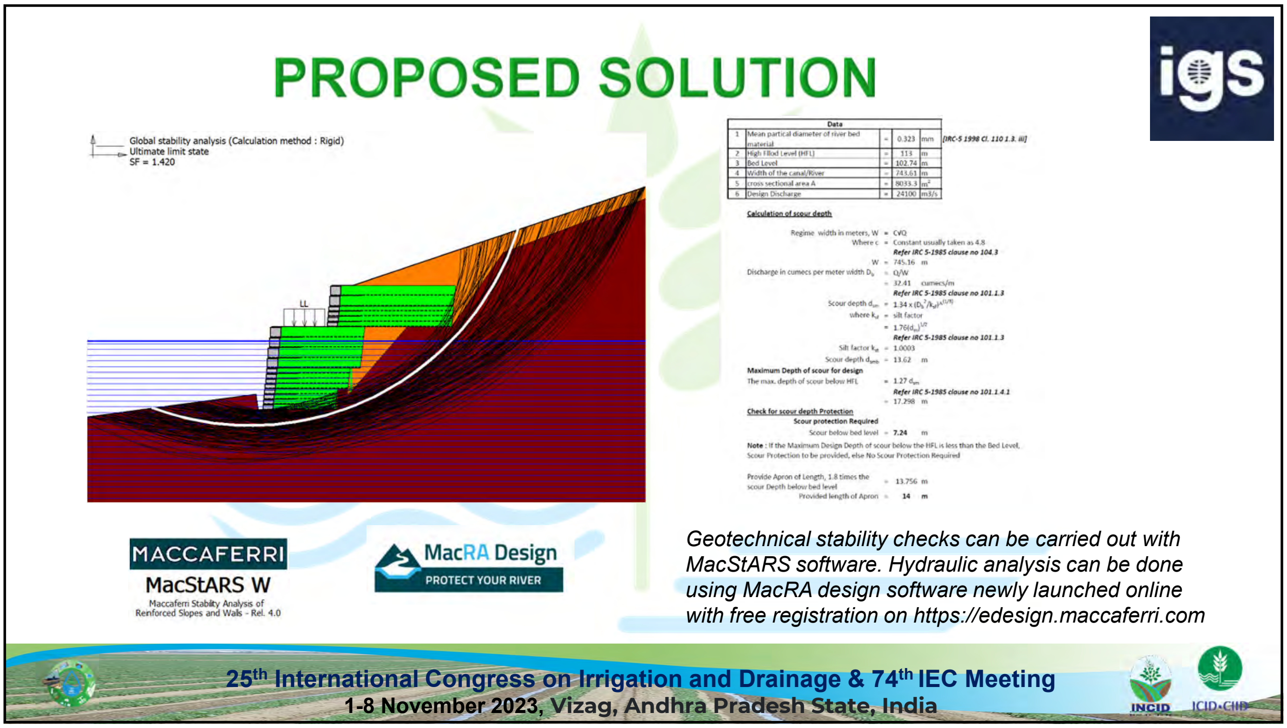
PROPOSED SOLUTION
Global stability analysis (Calculation method : Rigid)
Ultimate limit state
SF = 1.420
MACCAFERRI
MacStARS W
Maccaferri Stability Analysis of Reinforced Slopes and Walls - Rel. 4.0
MacRA Design
PROTECT YOUR RIVER
Geotechnical stability checks can be carried out with MacStARS software. Hydraulic analysis can be done using MacRA design software newly launched online with free registration on https://edesign.maccaferri.com
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CONSTRUCTION PHASE
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CONSTRUCTION PHASE

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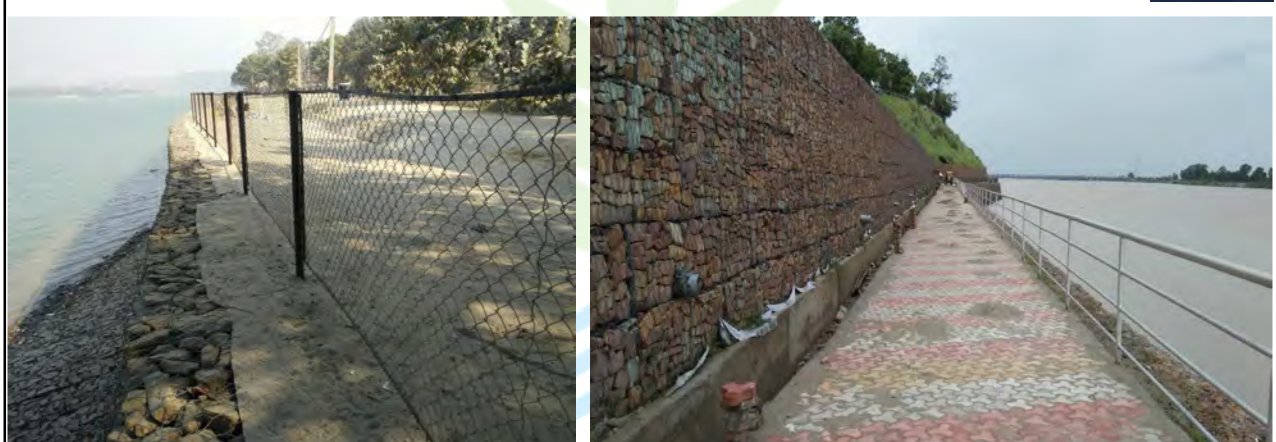
COMPLETED PHOTOS



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COMPLETED PHOTOS

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COMPLETED PHOTOS

Performing well through several monsoon seasons…

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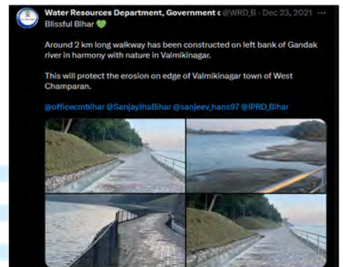
PROJECT COVERAGE & SOCIAL IMPACT

Courtesy: @with.param (online)

https://youtu.be/W2en6OS12As?si=W1CpgvaZxVCsJKDi

Ecopark also developed along the banks



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What we can offer:

- Product supplies
- Technical solution formulation
- Site assistance
- Installation services

*INNOVATIVE * SUSTAINABLE * ENVIRONMENTALLY FRIENDLY*

b.rudra@maccaferri.com

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Theme:

Tackling Water Scarcity in Agriculture

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CASE STUDY ON THE USE OF CONCRETE MATTRESS IN INDIA- SHOWCASING TALADANDA MAIN CANAL AND DHAKRANI POWER CHANNEL

Amruth Chand B

Presentation Date: 04th November 2023

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Introduction

- Signet- Indian Geosynthetics Company
- Offers expertise in Geotechnical, Hydraulics and Environmental issues
- Experts in solving complex issues using creativity and tenacity.
- Sustainable and Ecofriendly Solution- making a difference to our Clients, Country and Planet.
- Develop simple and effective concepts to serve people
- Aim on Conserving Energy and Environment at same time
- Focus on R&D, new products with innovative ideas for better future

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Key Geosynthetic Solutions

- CCGM: **Cementitious Composite Geo-synthetic Mattress-** for quick, uniform, perfect lining for canal including lining underwater
- CCGC: **Cementitious Composite Geo-synthetic Carpet-** for slope protection and landslide mitigation- Faster installation with minimum equipment and manpower with ZERO compromises on quality, loss of time

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Key Geosynthetic Solutions

- **No Flood Barrier:** Synthetic tube, filled with flood water to protect from all types of flood
- **Rubber Dams:** Air Filled Rubber Dam as Weirs for irrigation, water supply, power generation, flood control, Tourism and recreation
- **Geotextile Tubes:** Coastal Protection, revetments, dykes, etc. Uses the locally available sand to fill and doesn't make any damage to the environment

What is CCGM? (Cementitious Composite Geosynthetic Mattress)

igs

- CCGM is a geotextile and concrete combination
- Spacing binders internally connect two layers of synthetic fabrics
- By varying length of these spacing elements, thickness of mattress is controlled
- Internal space created is filled with concrete by pumping method

Features of CCGM:

- Combined lining and erosion control
- Vertical ties arrangement maximizes filling height
- Constant thickness, also on uneven base
- Low hydraulic roughness compared to other concrete mattresses

Case study on Taladanda Main Canal

- **Taladanda Main Canal-** one of the oldest canals in Odisha
- Constructed more than 150 years back during British era
- Off taking from River Mahanadi at Jobra and running upto Paradeep in Odisha
- Passes through millennium city of Cuttack.

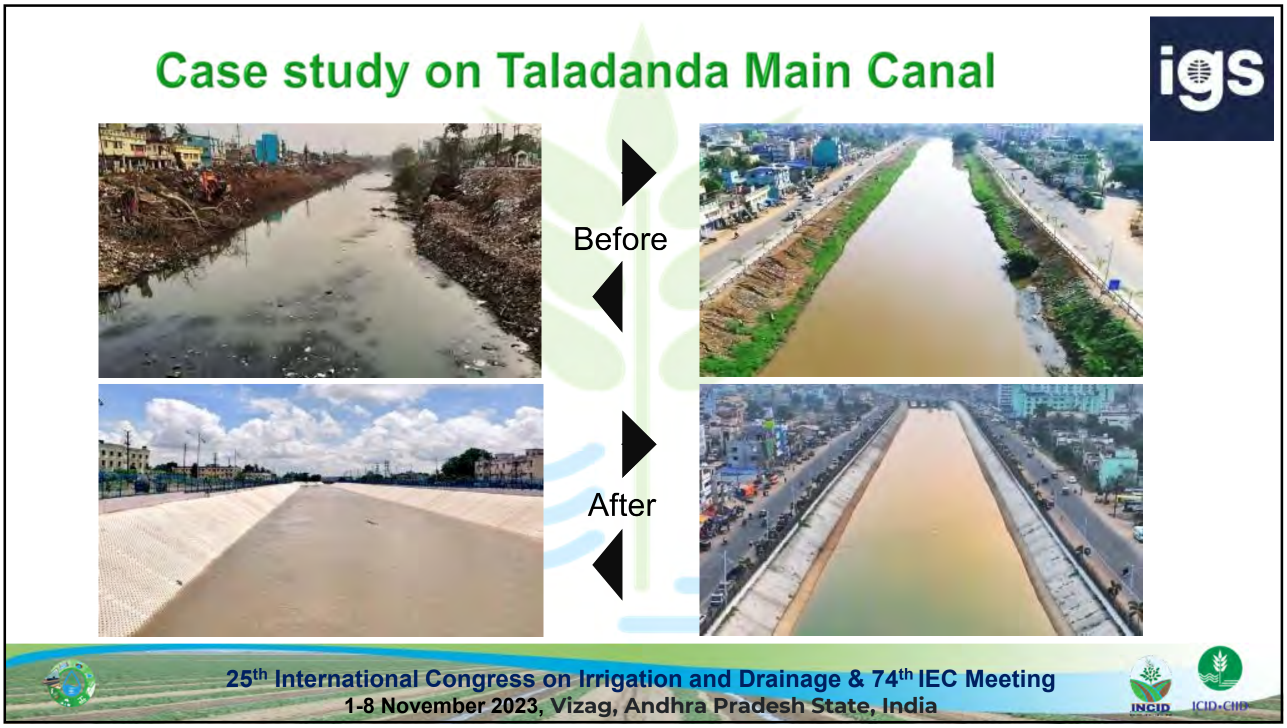
Challenge:

- Canal bed is silted due to lack of adequate maintenance
- Silt and waste debris in Canal bed by locals obstructing flow of water
- Technical issues like seepage on canal slopes, sliding of earth due to higher water table in the river etc.
- Slope and Bed of canal filled with garbage
- Various drainage outlets of hospital and municipality fall into the Taladanda Canal

Case study on Taladanda Main Canal

Solution:

- Signet recommended Cementitious Composite Geosynthetic Mattress (CCGM)
- CCGM has no effect of UV rays and is used across the world for canal sealing, lining & remediation work
- Quality and cost effective and requiring less time
- Lining in Taladanda Main Canal:
  - Slope up to Top Bank Level with a suitable key wall on top
  - Extending maximum up to 3 metres in canal bed in either side
  - Leaving central portion of bed unlined for sub-soil drainage and pressure release


Case study on Taladanda Main Canal
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Before
After
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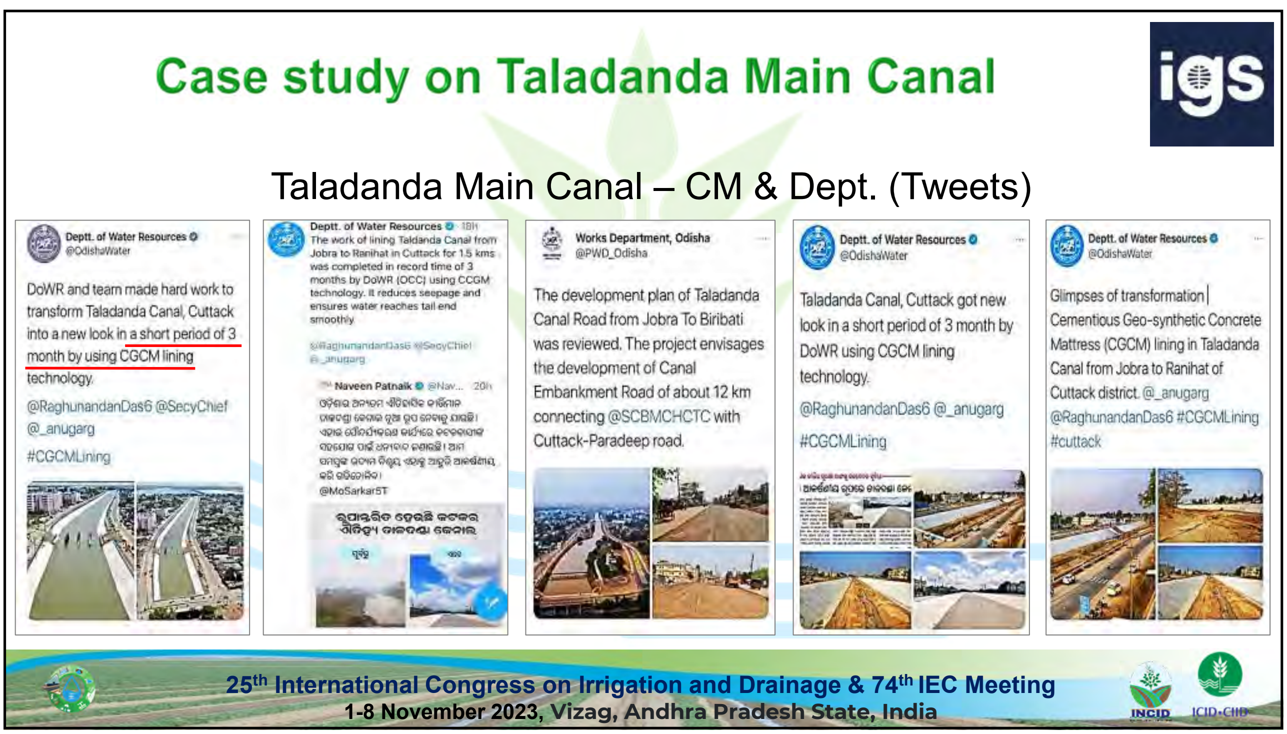
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Taladanda Main Canal – CM & Dept. (Tweets)
Deptt. of Water Resources @OdishaWater
DoWR and team made hard work to transform Taladanda Canal, Cuttack into a new look in a short period of 3 month by using CGCM lining technology.
@RaghunandanDas6 @SecyChief @_anugarg
#CGCMLining
Deptt. of Water Resources 18h
The work of lining Taldanda Canal from Jobra to Ranihat in Cuttack for 1.5 kms was completed in record time of 3 months by DoWR (OCC) using CCGM technology. It reduces seepage and ensures water reaches tail end smoothly
Naveen Patnaik @Nav... 20h
@MoSarkar5T
Works Department, Odisha @PWD_Odisha
The development plan of Taladanda Canal Road from Jobra To Biribati was reviewed. The project envisages the development of Canal Embankment Road of about 12 km connecting @SCBMCHCTC with Cuttack-Paradeep road.
Deptt. of Water Resources @OdishaWater
Taladanda Canal, Cuttack got new look in a short period of 3 month by DoWR using CGCM lining technology.
@RaghunandanDas6 @_anugarg
#CGCMLining
Deptt. of Water Resources @OdishaWater
Glimpses of transformation | Cementious Geo-synthetic Concrete Mattress (CGCM) lining in Taladanda Canal from Jobra to Ranihat of Cuttack district. @_anugarg @RaghunandanDas6 #CGCMLining #cuttack
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Case study on Damaged Power Channel at Dhakrani

- **Dhakrani Power House-** erected in the Yamuna and Tons rivers, Dhakrani town, Dehradun, Uttarakhand, India
- Weir on a Canal, which is a part of the Yamuna Hydel Scheme and one dam powerhouse

Challenge:

- Canal closure is costly in terms of loss of power generation.
- Untimely continuous rain for five days and dewatering
- Canal in a deep cutting, the slope is eroded/failed over the period, and heavy back water pressure

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Case study on Damaged Power Channel at Dhakrani

Solution:

- Signet recommended Cementitious Composite Geosynthetic Mattress (CCGM)
- Quality, Speed and cost-effective
- CCGM needed just 10% of the time compared to conventional method
- Zero leakage and loss- more important for power channels

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Appreciation letter from UJVNL for the successful completion of the project

Project was completed in a record time of 25 days, which was challenging due to untimely continuous rain for five days and dewatering.

UJVN LIMITED

संदीप सिंघल
प्रबन्ध निदेशक

No. 3426 /UJVNL/01/MD/ Date: July 13th, 2023

Dear Sanjeev,

I wanted to take a moment to appreciate your exceptional work in completing the canal lining project ahead of schedule using the Signet Cementitious Composite Geosynthetic Mattress.

Often, such work would need an extension as the actual condition discovered after the closure. In the case of Dhalipur work, you have completed it five days in advance, despite new challenges like untimely rains and total damaged slopes. The CCGM's efficiency and your team's professionalism and expertise have been outstanding. By finishing the project early, you have not only exceeded our expectations but have also made a significant contribution to its success.

Thank you for your dedication and the exceptional service you have provided us. Your company's performance deserves trust and respect.

I am sure the CCGM technology will benefit all the power channels of the country.

Thank you & good luck.

13.7.23
(Sandeep Singhal)
Managing Director

To,
Mr. Sanjeev Vyas,
Signet EnerTech Pvt. Ltd,
Mumbai – 400104.

Before

After

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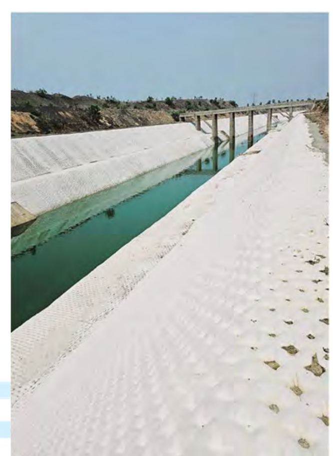
Advantages of CCGM

- Can resist very high flow velocities >7 m/s
- Can be installed even underwater
- Minimum closure time required for canals
- Flexible system-adapts to the ground profile
- High hydraulic resistance.
- Installation on steep slopes possible.
- Long term durability- life of CCGM is > 50 years



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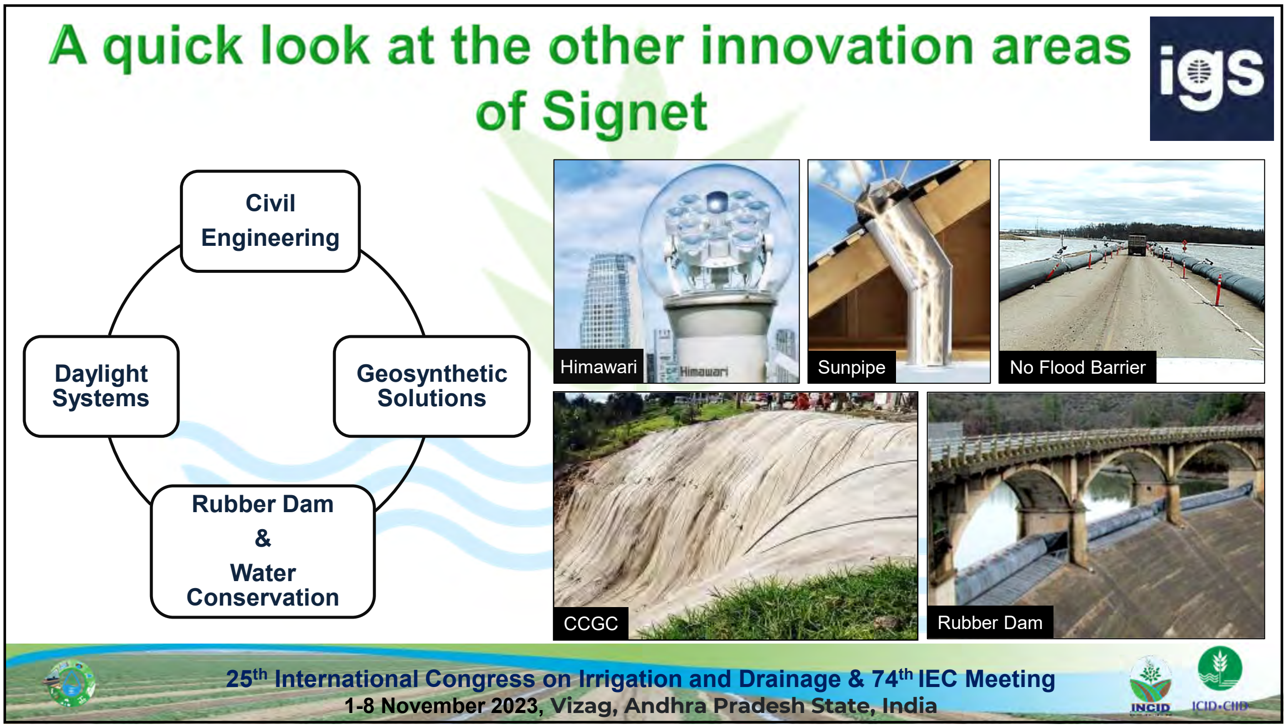
A quick look at the other innovation areas of Signet
igs
Civil Engineering
Daylight Systems
Geosynthetic Solutions
Rubber Dam & Water Conservation
Himawari
Sunpipe
No Flood Barrier
CCGC
Rubber Dam
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Thank You
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74th International Executive Council meeting

Theme:

Tackling Water Scarcity in Agriculture

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1

Flexible polymeric geomembranes to arrest leakages in Dams and Canals enabling effective usage of water for irrigation and human needs

S.JAGADEESAN

BU Manager, Carpi India

4TH November 2023

carpi

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ABOUT CARPI: What we do

Type of structure	Number of projects	Geomembrane installed [m^2]
DAMS	194	2,314,534
RESERVOIRS	51	2,868,756
CANALS	45	1,778,066
HYDRO TUNNELS	24	92,316
TRAFFIC TUNNELS	45	1,589,948
TOTAL	359	8,643,620

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4

Carpi Geomembranes have been used in

- Dams
- Reservoirs
- Hydraulic Pressure Tunnels
- Canals and aqueducts
- Floating covers
- Traffic tunnels

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Key Properties

Flexibility, with ultimate deformation ≈300%

Durability, long functional life even when exposed in severe environment

- **>45 years** from field experience (in the Alps, at > 2,000 m a.s.l)
- **>100 years** from analytical extrapolations of accelerated ageing tests
- Same durability in India projects with high temperature zones

Steady performance in cold/hot climates

Highly Elastic and Flexibility

PVC geocomposite is capable of deforming, reducing stresses in the material

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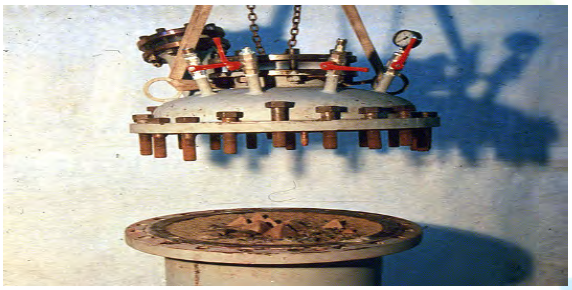
Key Properties – Puncture and Burst Resistance

PVC geomembranes are tested on very aggressive substrates in hydraulic vessel



Pressure vessels apply water heads up to 250 m

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Key Properties – Impact Resistance

Impact by floating trees, Salt Springs CFRD dam, USA

PVC geomembrane resists impact by covering rocks

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Carpi Geomembrane in Dams and Canals

- Carpi is in India since 2004 and 3 Large dams have been rehabilitated by Carpi resulting in saving of nearly 99% of the water in all these hydraulic structures
- In India – Servalar Dam – Multipurpose Dam (Feeding water for nearly 5 M people and over 40,000 Acres)

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Quick Insight into Dams and Canals

- Dams in India - Greater than 25,000 Dams of varying dimensions
  - > 60% of them have crossed 40 years
  - Ageing in Dams phenomenon increases the leakage and seepage thereby effective utilization of water reduces
  - Continued siltation in Dams also reduces the utilization of water from the dam
- Canals in India – Over 2,50,000 km length of canals in India (both lined and unlined canals) and several kms under construction
  - Over 40% of water is lost due to seepage in the canal path

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SERVALAR DAM

57m high Stone masonry dam and length 465 m.

Purpose :
Drinking Water/Irrigation/Power Generation
Owner : TANGEDCO

Generation is dependent on the water needs.

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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.

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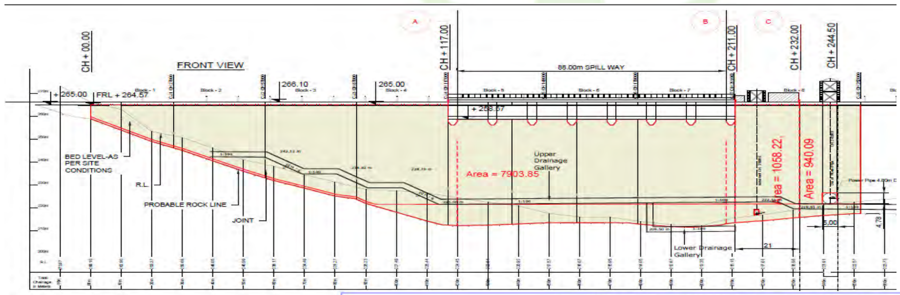
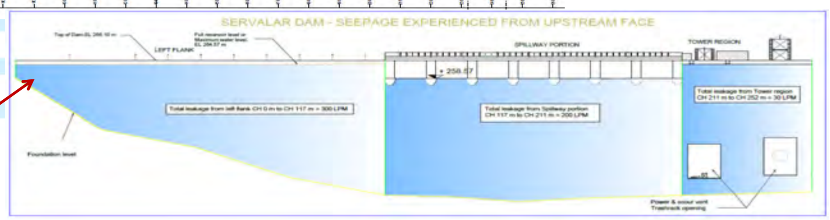
Part of the Dam – Left Flank and Spillway





Leakage Contributing Zones

13

Problems at Servalar Dam

Choked Vertical Drains

Flooded Foundation Gallery

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Desilting Works + Waterproofing Works

Carpi's Solution consisted in removal of removal of silt and debris to expose the deepest portion of the upstream stone face.

Volumes of > 50,000 cum of silt was removed

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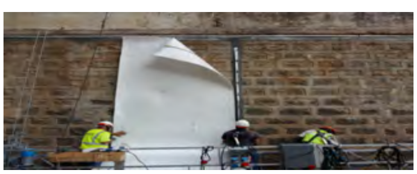
Placing of Anti puncture Geotextile

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)



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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

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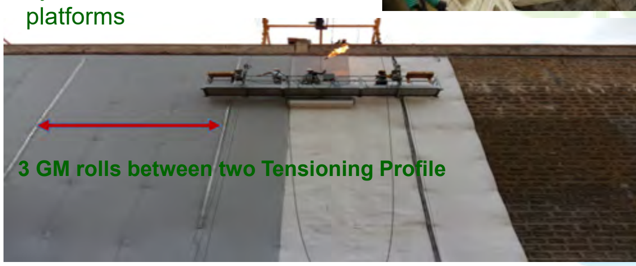
Rolling and Installation of Geocomposite

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



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Geocomposite Welding

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Multiple Rolls of Geocomposite are welded by Hot Air Welding.

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Fixation of Cover Strips

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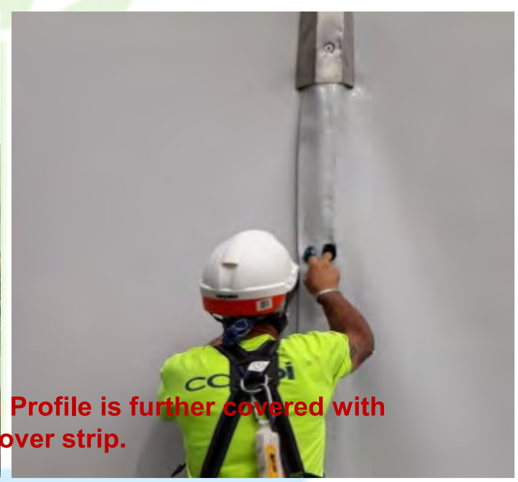

The Upper Tensioning Profile is further covered with PVC Geomembrane Cover strip.

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Fixation of Bottom Perimeter Seal

The Bottom Perimeter Seal is 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 adhesive resin is used with rubber gaskets and seals to prevent entry of water from the bottom.

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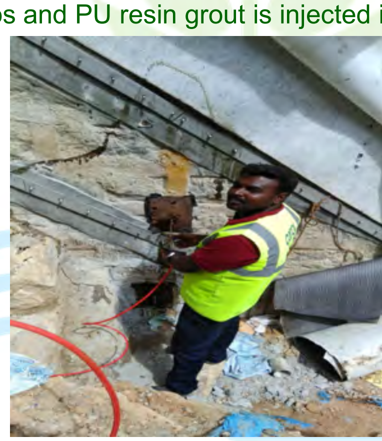
Grouting at Joints

To prevent seepage from below the Contraction joints, Grout holes of 50 mm are drilled till the construction joint copper stops and PU resin grout is injected into the holes



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Drainage Holes

6 No of Drainage holes were drilled from the upstream face of the dam up to the gallery. The drain holes convey the water collected behind the membrane and discharge it into the gallery

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Final Phase of Installation

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Results of Geomembrane Waterproofing System

igs

Before Geomembrane Installation – In 2014

After Geomembrane Installation – In Aug 2018

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Gallery View

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Before Geomembrane

After Geomembrane

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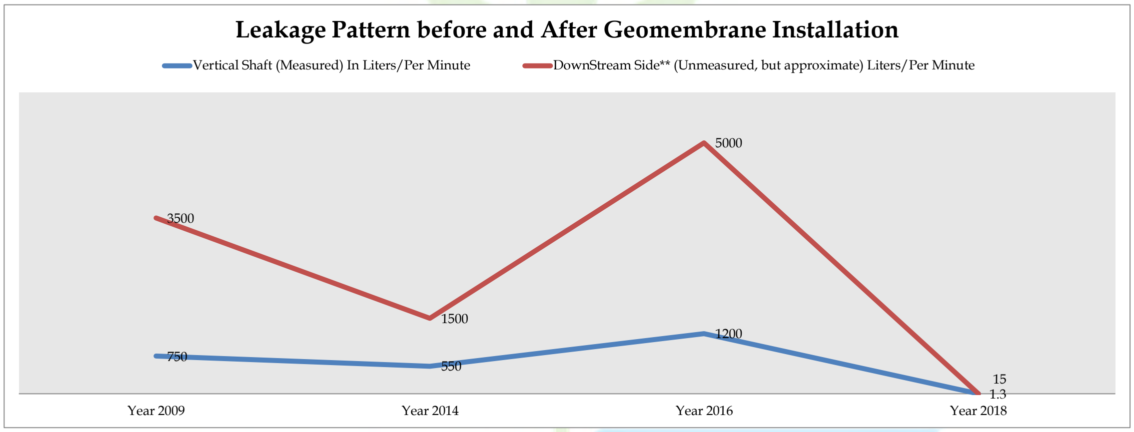
Leakage Results



THIS IS THE ONLY PRODUCT THAT CARPI SELLS

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After nearly 4.5 Years of Service

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Durability of Carpi's Geomembrane System

Kadamparai Dam

Geomembrane installed in 2005 is still in good condition (After 2 decades)

Stone Masonry Dam of height 67 meter

A Dam on the verge of decommissioning (for excessive leakage) was brought back to life after installation of Geomembrane System in 2005

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

Leakage still around 100 lpm

NO MAINTENANCE IN THE LAST 19 years

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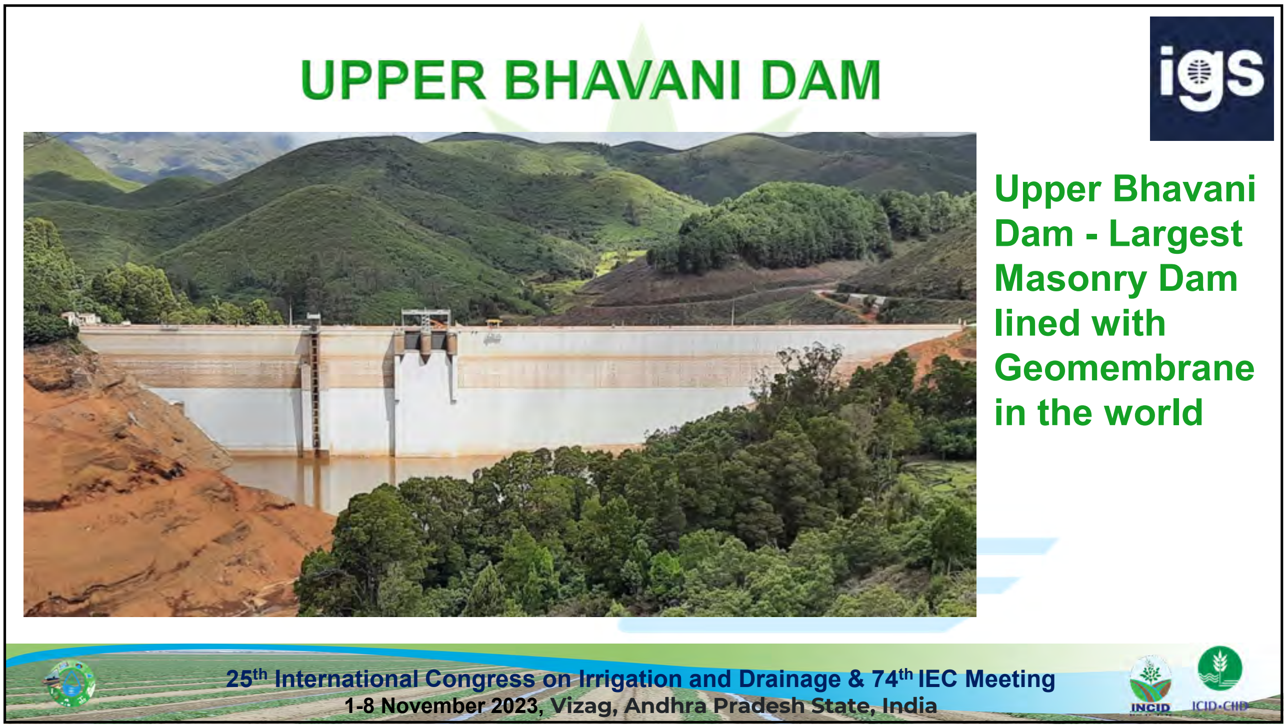
UPPER BHAVANI DAM
igs
Upper Bhavani Dam - Largest Masonry Dam lined with Geomembrane in the world
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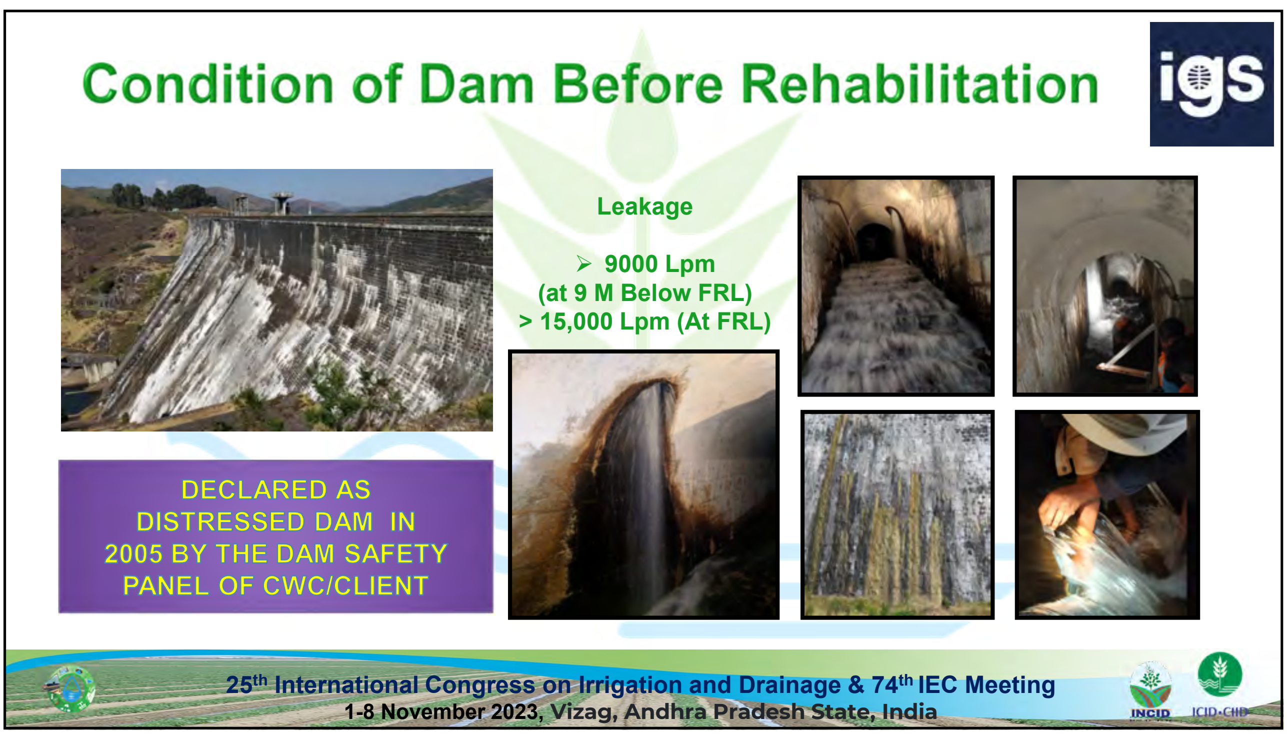
Condition of Dam Before Rehabilitation
igs
Leakage
➢ 9000 Lpm
(at 9 M Below FRL)
> 15,000 Lpm (At FRL)
DECLARED AS DISTRESSED DAM IN 2005 BY THE DAM SAFETY PANEL OF CWC/CLIENT
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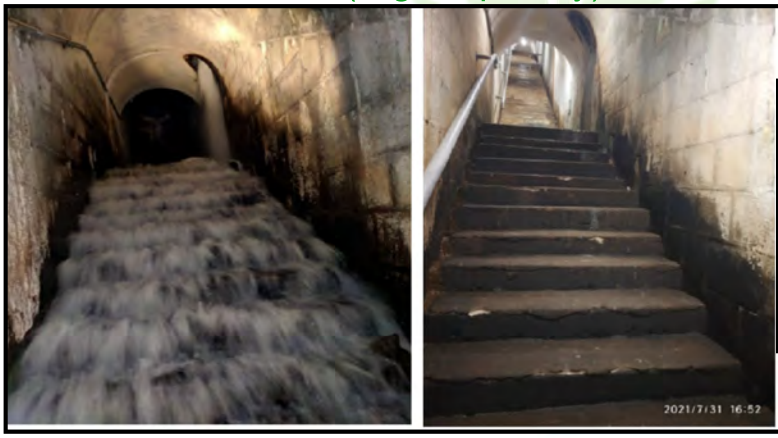
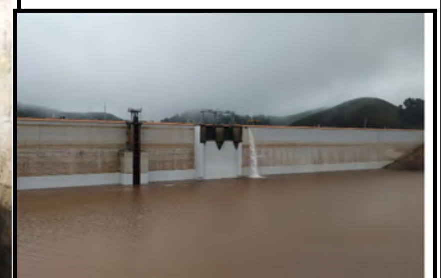
Results Of Waterproofing

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





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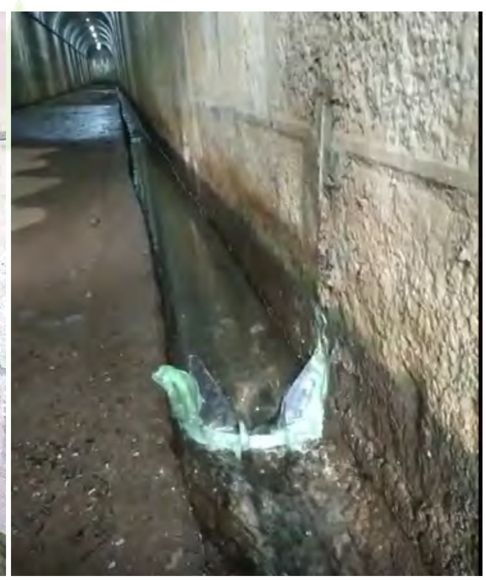
Before Geomembrane in 2019



After Geomembrane in 2021

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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
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

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UNDERWATER INSTALLATION

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




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UNDERWATER INSTALLATION

The first project in the USA in 1997, was a rehabilitation of the full face of Lost Creek arch dam.





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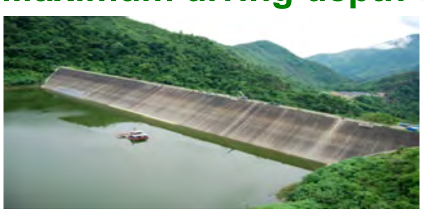
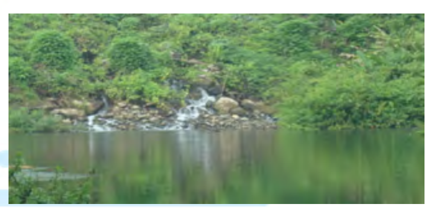
First large project in Venezuela, 2010/2011 for the rehabilitation of some 20% of Turimiquire upstream face. Maximum diving depth 65 m



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





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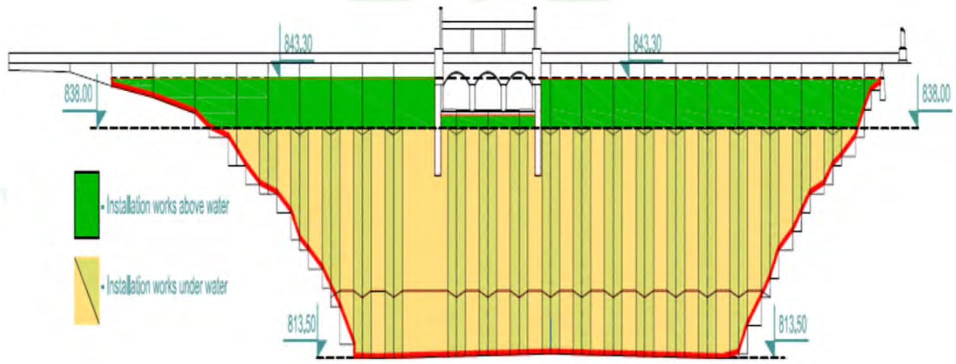
Studena buttress dam-Underwater installation

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 %



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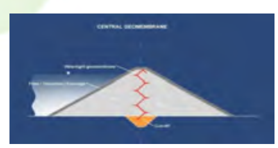
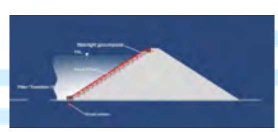
IN FILL DAMS, THERE ARE 3 MAIN POSSIBLE DESIGNS WITH PVC GEOMEMBRANES

Upstream covered PVC geomembrane

Central PVC geomembrane



Upstream exposed PVC geomembrane



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TANAKPUR – INDIA – 2008
igs
National Hydroelectric Power Corporation –NHPC
Tanakpur, India 2008
Water velocity 2.2 m/s
Problem: loss through deteriorated concrete lining
Design of anchors following pull-out tests
Carpi patented tensioning system
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The Dynamic loads of flowing water can severely deteriorate canals
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The main benefits of PVC geocomposite systems in canals are:

- They are completely watertight over the entire surface, including joints
- They withstand action of UV, ice, debris
- They withstand differential settlements
- Because of their smoothness, they allow increase of water flow
- They allow for monitoring of the performance

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Exposed PVC geocomposites are smooth and allow increase of water flow

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Concepts for anchoring PVC Geocomposites in canals

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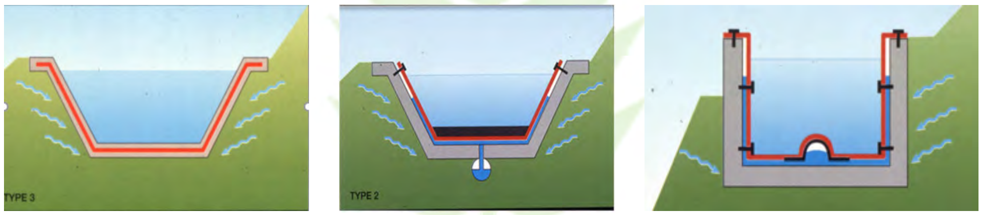
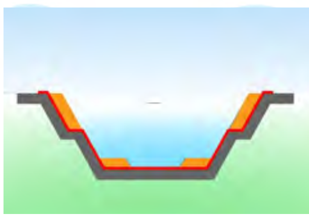
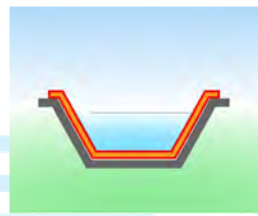


examples





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PVC Geocomposite fully exposed

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Mittlere Isar Strogenbauwerk, Germany 2000

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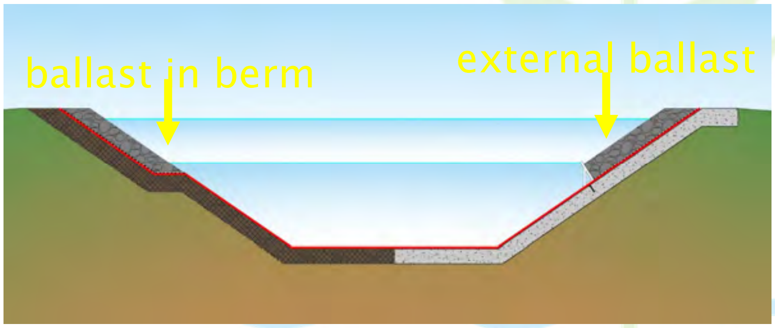
PVC Geocomposite Partially Exposed

In earthen canals, for various type of subgrade, different anchoring and ballasting solutions are available



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Tekapo canal remediation, New Zealand, 470,000 m2 Installation in 12 weeks

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

An innovative impermeable heavy-duty zip

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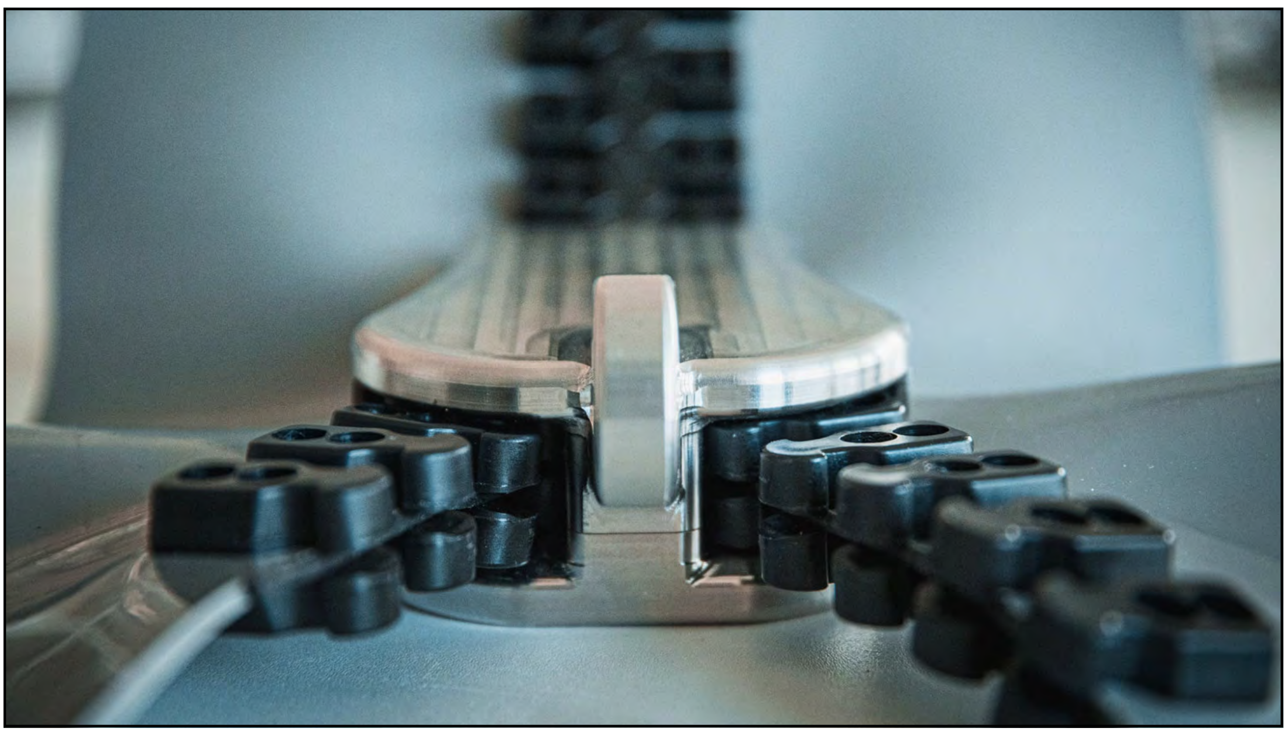

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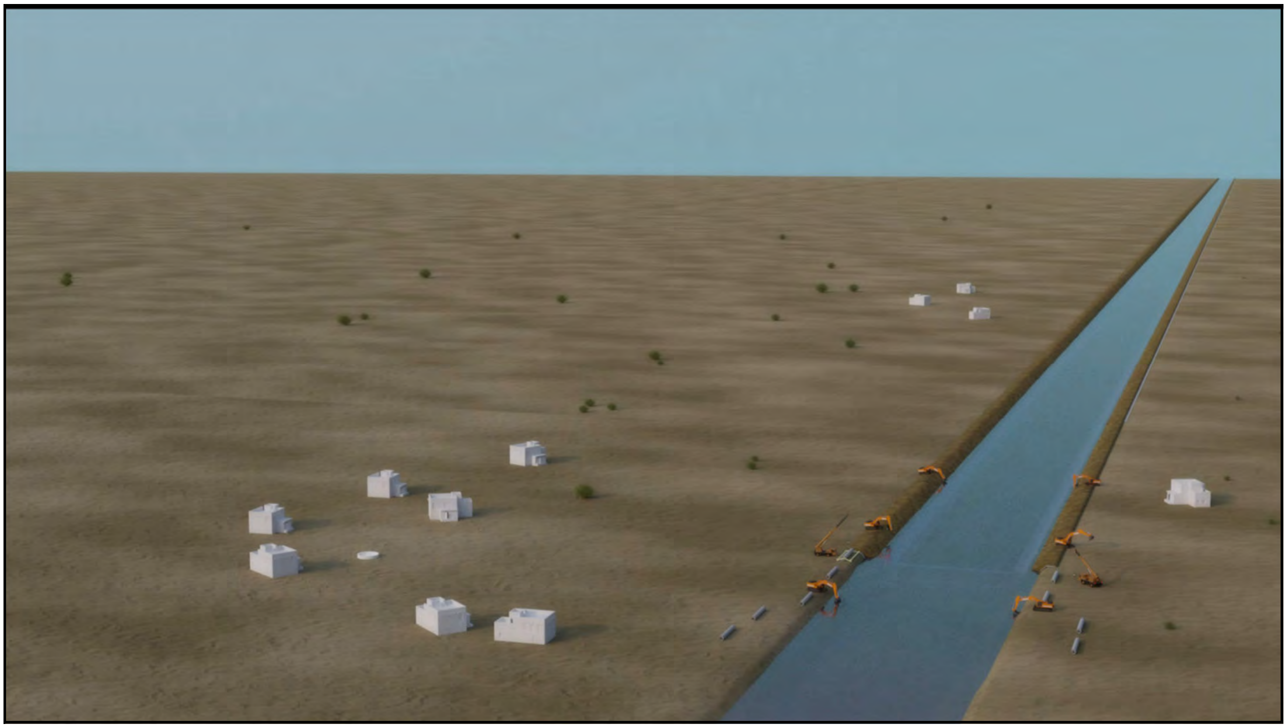

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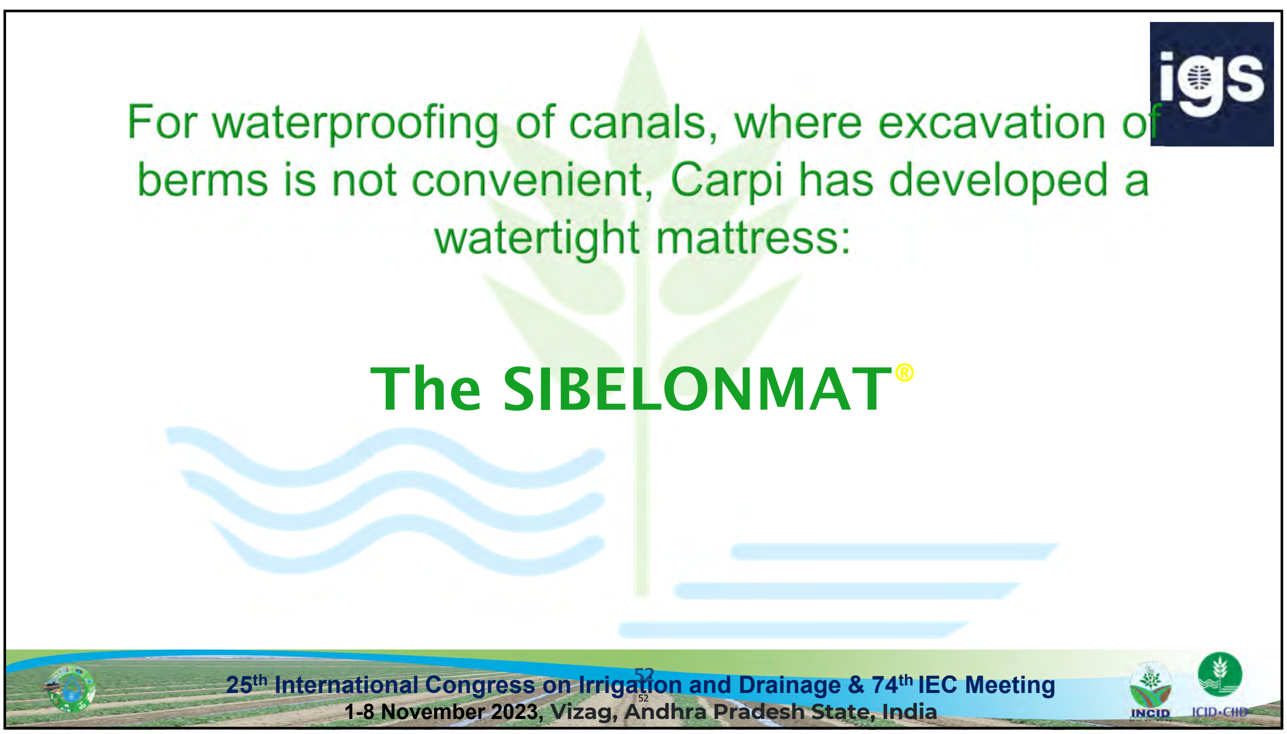
For waterproofing of canals, where excavation of berms is not convenient, Carpi has developed a watertight mattress:
The SIBELONMAT®
igs
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Conclusions

- Installation of PVC geomembrane systems can be performed totally underwater
- At any depth, at water velocity up to 1 m/s, on the full section of the canal
- No impact on canal operation
- Effective long-lasting solution to stop leakage
- Can be installed to repair canals and embankment dams, or as upstream blanket
- Can be used in new construction of embankment dams and canals

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Lower Maintenance Costs for Carpi geocomposites

- No scheduled or preventative maintenance for geocomposite system
- No moving components that can fail
- Monitoring system to locate any damaged area within less than 1 square meter.
- After more than 1,800,000 square meters of installations with more than 500 years of cumulated service history, Customers have experienced $0 maintenance costs

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Thank You

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