CANAL LINING with use of Geosynthetics

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Herve PLUSQUELLEC graduated from the Hydraulics Engineering School of Grenoble, France. He has 60 years experience in irrigation sector and water resources in about 35 countries from different perspectives: An irrigation agency in Morocco, an international consulting firm from Italy and a donor agency, the World Bank. After formal retirement, he has worked as a free consultant for the World Bank and other organizations for about 25 years.

He has mainly devoted his work to the adoption and promotion of advanced canal technologies to reduce seepage and operational losses. He has published a number of papers and books on these two subjects:

* Application of Geosynthetics in Irrigation and Drainage Projects (ICID)
* How Design, Management and Policy affect the performance of irrigation systems (FAO)
* Audio-visual production on improving operation of canal systems

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CONTENT

- **Use of geosynthetics in irrigation sector is lagging behind other civil engineering applications (Case of Egypt)**
- The benefits of canal lining and the debate on "to line or not to line"
- The preference for concrete lining by irrigation agencies and their consultants
- Lining canals with geosynthetics: The World bank experience

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APPLICATIONS OF GEOSYNTHETICS IN CIVIL ENGINEERING

SOLID WASTE STORAGE

MINING

* TRANSPORTATION (roads, airports, tunneling..)

* LARGE AND MEDIUM DAMS: 280 up to 200 m high
  - Earth dams
  - Concrete arch/gravity dams
  - RCC dams

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Use of geomembranes for waterproofing large dams (up to 200 meters)

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USE OF GEOSYNTHETICS IN ROAD CONTRUCTION

* Reinforced with geotextile

* Unpaved road over peat

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USE OF GEOMEMBRANES FOR WATERPROOFING NAVIGATION CANALS

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USE OF GEOMEMBRANES FOR WASTE STORAGE LANDFILL

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USE OF GEOMEMBRANES FOR WATERPROOFING RESERVOIRS

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EGYPT IRRIGATION CANAL SYSTEM

* Total Irrigated area: 3.45 million Hectare
* Area irrigated through surface water: 2. 843 million ha

- Total length of government-controlled canals (primary (13 000 km) and secondary canals (19 000 km)) : 32 000 km
- Length of farmer-controlled canals; 80 000 km (meska and below)

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RESEARCH PROGRAM ON CANAL LINING TECHNIQUES

USAID funded : EGYPT Water Utilization Project (EWUP)_ (1984)

Project Technical report #56 (1984)

* PILOT APPLICATION TESTS
* El Nasr canal (km 31-55) : Failures of concrete-lined side slopes
* Several short sections in 1977-78 using LDPE and other materials such as bentonite, butyl rubber (Beni Magdul canal ; Nubariya governate..)

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Egypt: Bank Failures in Concrete Lined Canals

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RECOMMENDATIONS FOR CANAL LINING (1984 EWUP REPORT)

- MOST VIABLE TECHNIQUES:
- Small canals: 10 mil PVC protected with soil cement
- Large canals: 10 or 20 mil (0.2- 0.5 mm) PVC protected with concrete

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Use of 0,2 mm thin plastic films before the 1980s : PVC (USA) and LDPE (USSR)

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TOSHKA CANALS (20 million m2)

Courtesy of POLY-FLEX and J.P. Giroud

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EGYPT CANAL REHABILITATION PROJECT (2020)
First phase: 9000 KM

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Canal-Irrigated Areas Worldwide (million ha)
About 1 million km of main and branch canals

	Irrigated area	Groundwater irrigated areas	Canal-irrigated areas
WORLD	**325**	**124.7**	**200**
AFRICA	15.6	3.0	12.6
AMERICA	52.2	23.7	28.8
ASIA	232.7	90.0	142.7
EUROPE	21.4	7.2	14.2

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Expected Canal Lining Benefits

- Reduces seepage losses
- Improves canal hydraulics
- Reduces water logging and salinization
- Reduces weed growth
- Reduces maintenance costs
- In pumping schemes: Reduces pumping costs
- Improves equity and reliability of water distribution

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Seepage Losses From Unlined Canals

- Daily seepage losses per square meter water from unlined canals range from 5 liters for clayey soils up to 500 liters and more for sandy soils
- Typical loss in the silty soils of the Indo-Gangetic plain is : 0.25 m3/day/m2
- Estimates of average losses up in conveyance system: 20 to 25 % of inflows at head of main canals. About 30 % is lost in field channels; farm losses are 35 %, leaving about 30-40 % of diverted water available to meet irrigation crop requirements.

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Variables influencing Seepage Losses

- **Characteristics of the soils: permeability, chemistry**
- **Geometry of canals and depth of water**
- **Position of water table**
- Quality of construction
- Age of canals
- Chemistry and temperature of water
- Cycles of filing and draining
- Maintenance

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Reduction of Maintenance Costs

- Studies of operation and maintenance costs in the USA showed a 75 percent reduction when hard surface linings were used

- Some records from the former USSR indicated that maintenance costs savings for concrete-lined canals were as much as two thirds of the cost of maintaining earth canals of similar capacity

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Relative capacity of lined versus unlined canals

* To supply a given discharge the wetted section of a canal can be reduced since the roughness coefficient decreases from about 0.03 to 0.015-0.020.
* For a given section, lining an existing earth canal nearly doubles its capacity. For example: the capacity of a 0.9 m deep earth canal, with a bottom width of 1.5 m, was increased from 2.25 to 4 m^3/s after lining.
* Lining canals several years after their initial construction (without a liner) is a costly decision as the total section (wetted perimeter and freeboard) is nearly double.

Reduction of Waterlogging and Salinization

* Worldwide, as much as 10 % of irrigated lands are soil-saturated (waterlogging)
* 70 million ha of cultivated lands are salt affected

In spite of above benefits from canal lining, and the risks related to climate change, there is a debate between water resources experts and designers, managers of irrigation systems on:

TO LINE OR NOT TO LINE IRRIGATION CANALS

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CONSIDERATIONS OVER THE DEBATE TO LINE OR NOT IRRIGATION CANALS

RIVER BASIN WATER RESOURCES

1. Seepage water from canals recharging groundwater aquifer is not lost – but its quality may decline through leaching of soils or reaching a salty aquifer with impact on health.
2. Pumping: Excessive demand in energy for pumping groundwater may disrupt the energy sector. Example of India: About 245 billion m3 are pumped annually for irrigation and other uses.
3. Seepage water from canals may end up in swampy areas where water is definitively lost by evaporation.
4. Losses from one canal system may cause waterlogging in adjacent areas (Old lands in Egypt from New lands) .

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CONSIDERATIONS OVER THE DEBATE TO LINE OR NOT TO LINE IRRIGATION CANALS

TECHNICAL AND FINANCIAL CONSIDERATIONS

Given the increasing scarcity of water for irrigation, domestic and industrial uses and its deteriorating quality, preservation of water through lining of canals should be considered in new and rehabilitation projects.

However there are in average about 25-30 percent of diverted water is lost in distribution system. However very low seepage in heavy clay soils may not justify the investment in canal lining, but erosion control may be needed.

Irrigation systems managed by financially responsible authorities may have limited financial resources.

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Rigid Canal Lining: Concrete ….and Brick

Alternate Concrete Panels

Canal Lining Machinery

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Seepage losses from concrete lined canals

* Seepage losses for canals RECENTLY lined with concrete are typically about 7-10 % of losses prevailing before lining, but could increased to about 50% or more after a few years of operation (Nebraska)

Reference: Effectiveness of lining for seepage control lasted from 3-5 years only (WAPDA Pakistan 1993)

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Rigid Concrete and Brick Liners Deteriorate Over Time

Severe climatic conditions: Freezing and thawing (Northern China, Central Asia, Caucase, Canada..)

Soil conditions:

* Gypsum (Spain, Middle East countries: Iran, Syria)
* Sinkholes in Karstic areas
* Swelling clay (India)
* Loess and residual soils (China, Brazil)

Poor quality of construction and frequent non-compliance with technical specifications: compaction of embankments and placement of concrete (thickness specs and vibration)

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Cracks Develop following Settlement of the Subgrade: FUNCTIONAL FAILURE

Peru (San Lorenzo canal)

Kosovo (Iber canal)

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Typical Freeze / Thaw Failure: Kyrghistan STRUCTURAL FAILURE

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UZBEKISTAN, Yambash Canal lined with 0.2 mm LDPE with overlap unwelded

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Example of Concrete-Lined Canal built in 1965 failure is not ineluctable…

No cracks after 50 years, BUT 15 cm thick (versus typical 10 cm) and excellent construction quality

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60 years of Experience of the World Bank with Geomembranes

Projects funded by the World Bank and completed:

- 1976-1985 Syria Balikh Irrigation (Butyl)
- 1990-1997 China Tarim I (0,2 mm LDPE, 485km)
- 1990-1997 India Punjab Irrigation
- 1992-1997 Pakistan Fordwah Sadiqia (0. 75 PPE)
- 1997-2003 China Tarim II (0.5 mm PE; 5.5 Mm2; 780 km

Projects under implementation:

- Uzbekistan: Bustan canal (1 mm HDPE 2.9 Mm2)
- Kazakstan : 95 km

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Production of geomembrane Xinjiang province, China

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Canal lining near Kashgar-China

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Geomembrane Protected by pre-fabricated panels Vietnam

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Bituminous geomembranes: Maaktaraal branch, Kazakhstan

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Once the decision is taken to line a canal, the next step in the decision process is the selection of lining materials and their method of installation. The selected option should have a long durability with no risk of functional and ultimately structural failure

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Large Choice of Geosynthetics and Application Techniques

- GEOMEMBRANES:
  - Polymeric: PVC-HDPE-LLDPE, Polypropylene, Hypalon, EPDM
    - smooth or structured
    - Thickness
  - Bituminous
  - Clay liner
  - Composite geosynthetics
  - Others

- INSTALLATION:
  - Exposed
  - Protected

  - DRY OR UNDER WATER

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Bituminous geomembrane India : Pench canal

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Other types:

* GEOCELL

Figure : Geomembranes protected with geocells filled with concrete

* GEOMATTRESS (Indonesia)

Figure: Lining with geomattress, Indonesia

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Bituminous Geomembrane (BGM)

* Installation on a soil base

* Installation on 50 years-old concrete-lined canal during low-flow operations

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Composite materials

* Geosynthetics Cementitious Composite Mat (Chile – bellevista canal)

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Selection Criteria

- Operating life
- Level of control of seepage losses (in gypsum areas: zero seepages)
- Site conditions
  - Subgrade
  - temperatures: major consideration for seaming
  - winds: high winds can stress and permanently deform thin PE and PVC
  - vegetation: some plants can easily penetrate thin PVC and PE
  - Duration of canal closures
- Risk of damage by animals, vandalism, and stealing

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MESSAGE

Interest in Geosynthetics is growing because of an increasing competition for water and poor performance of rigid concrete lining.

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More details
on the uses of geomembranes in canals
can be found in the book

Geomembranes for Lining Canals

by J.P. Giroud & H. Plusquellec

To be published in 2022
Taylor and Francis, Publishers

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THE DREAM OF A MANAGER: no operational and seepage losses through geomembranes lining and automation of canal control

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Questions?

THANK YOU FOR YOUR ATTENTION

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Procurement for Canal Lining with Geomembranes

- Prescriptive specification
  - A particular chemical / type of geomembrane is imposed by the designer
- Performance-based specification
  - The technical specification sets out performance requirements which are the basis for acceptance tests, before signing the contract.
  - Example: BUSTAN in Uzbekistan

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Procurement for Canal Lining with Geomembranes

* Supply and installation of geosynthetics through a separate contract, or included in a civil works contract ??