BITUMEN GEOMEMBRANES IN IRRIGATION - CASE HISTORIES FROM A RANGE OF CLIMATES

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ABSTRACT: Bitumen was in use 5000 years ago for irrigation works that are still in good condition. Today, bituminous geomembranes are providing efficient, durable waterproof linings to irrigation canals, ponds and reservoirs throughout the world. They are either fluid-applied or delivered in rolls 4 metres wide. A survey of twenty irrigation dams around 10m high built between 1973 and 1983 in France with unprotected geomembrane facings found them performing well after 10-20 years service. Linings to a reservoir at Goudel in Niger and canals cut in laterite near Niamey have demonstrated their suitability in tropical climates. In North Africa, the Gulf States, Singapore, India and New Zealand, 5m-wide bituminous geomembranes have been in use on irrigation canals for some ten years and are still performing satisfactorily. In the USA, leaky areas on a large concrete-lined canal were stopped with an SBS bitumen-based geomembrane available in 4m widths in France.

KEYWORDS: Aging, Canal Liners, Case Study, Dams, Embankment, Geomembranes, Bitumen

1 INTRODUCTION

Five thousand years ago, crude petroleum was only accessible where it emerged from deep fissures in the ground. The heavy residue contained a high percentage of bitumen, which the ancients, especially in the Middle East, used for its waterproofing properties. Since those early times, it has been used to build and repair wells, reservoirs, canals and baths and consolidate irrigation canal embankments. Many of these constructions are still in good condition.

Bitumen emerged as a standard 20th century waterproofing material in civil and water engineering in the form of bituminous concrete, asphalt and bituminous geomembranes. The last-mentioned are lightweight materials that are easy to lay and repair, with waterproofing properties that make them ideal for irrigation works. They may take one of three forms:

- Bitumen can be sprayed onto a geotextile in situ (ISBGs)
- They may be prepared (prefabricated) in the factory and delivered to site in rolls (PBGs)
- An impervious asphalt may be laid on the canal or reservoir floor with the membrane confined to the sloping sides.

2 BITUMINOUS GEOMEMBRANE FOR IRRIGATION WORKS

The material underlying the lining must be free from grass an other organic matter, and well drained if it is not naturally impervious. Gas collection wells are also needed if there is a risk of fermentation. It must be stable, smooth, with no sharp stones, and compacted to at least 90% Proctor optimum.

Although not always necessary, a protective covering should be added if the geomembrane is exposed to uplift pressures, wind suction, severe sunlight, impact, ice, debris, animals or wilful damage. It usually consists of unprocessed natural material although stabilisation with cement or bitumen reduces the thickness required.

Bituminous geomembranes, 3.3mm to 5.6mm thick with a density of 1.15, are three times heavier than polymer geomembranes, and therefore less affected by wind action.

3 EXAMPLES OF IN SITU BITUMINOUS GEOMEMBRANES

3.1. France

In situ bituminous geomembranes (ISBGs) were used in France in the early sixties under railway track and for renovating old roads; the ballast and top foundation courses respectively were removed to a depth of up to 800mm and the bituminous membrane was sprayed in two 3-5mm coats with a glass fleece or non-woven polyester geotextile in between, before covering with new material. The membrane isolates the overlying material from contaminated groundwater and shields the foundation from percolating surface runoff.

This approach was used again on the Huningue (1962) and Nord (1966) ship canals. It usefully reduces leakage through the canal floor. It must be protected on the banks against erosion and wave action.

When water reservoirs began to be lined in the seventies, it was found necessary to design special reinforcing arrangements to control root damage.

The choice of bitumen grade is governed by air temperatures at the site, altitude and exposure to sunlight. The bitumen is sprayed from a tanker through a spraybar at the rear or extending out to one side, horizontally or at an angle when spraying slopes. The geotextile is normally unrolled after the first coat has been sprayed.

The first application of an ISBG to a mountain reservoir 1800m asl in the French Alps was followed by several coastal reservoirs near Toulon with capacities ranging from 3000 m^3 to 40,000 m^3, where the membrane was laid on pervious material and protected with 8cm of lean concrete.

Surface protection is not always necessary. Two small rockfill dams, 4-13m high, were built in 1973 and 1975 in southern France, each faced with an ISBG exposed to direct sunlight. The agricultural ministry's research institute CEMAGREF monitored the performance of the facings and reported the appearance of only one tear at the crest after eight years, which remained unchanged over the following seven years. A strip of geotextile that had not been impregnated with bitumen and had aged was easily repaired. The other dam showed no flaws after more than 20 years.

Use of ISBGs was slowed in France because the country's dense road network accessible to heavy trucks favoured prefabricated bituminous geomembranes, but they are an excellent answer for narrow inaccessible sites and for covering large flat areas.

3.2 USA

There has been a special ISBG working group within ASTM committee D35-10 since 1996.

3.2.1. Irrigation Canals

The United States has a very extensive irrigation canal system and the US Bureau of Reclamation has issued tables correlating canal size and capacity, slopes, fill material and thickness.

3.2.2. Reservoirs

American engineers use ISBGs to line large reservoirs with capacities in excess of 1 Mm^3.

At Oakland, the ISBG is covered with 100mm of concrete and lies on a foundation of 10cm of dense and porous asphalt.

Engineers and scientists at the Department of Energy's Hanford site in Washington have developed a maintenance-free waste-site surface barrier made from natural materials that will last for 1000 years. They monitor a 5-acre prototype constructed in 1993 over a decommissioned wastewater disposal facility. There is a multi-layer barrier of various natural materials (sand, gravel, clay, etc.) 4.50 metres thick. In addition, an ISBG was laid on 150mm of asphalt.

4 PREFABRICATED BITUMINOUS GEO-MEMBRANE RESERVOIR LININGS

A few interesting examples are described in the following.

4.1. France: Embankments Less than 18m High

Seventeen water reservoirs impounded by rockfill embankments have been monitored by CEMAGREF over the last twenty years. Only four linings had protective coverings and all the underlying rockfill was free-draining. Reported damage was minor, consisting of a single case of a PBG being punctured by sharp stones underneath, one tear by vandals, and one section of seam that separated. The three spots were quickly repaired in a durable manner.

The only reported damage on the other embankments was minor damage to seams from plant roots, which was easily repaired. Mud curling was observed on the PBG without surface protection although it had no effect on watertightness and the process always stopped at the geotextile.

There are many other geomembrane linings ranging from 1500 m^2 to 10,000 m^2 in area all over France that have been giving complete satisfaction for the last twenty years.

4.2 France: Large Irrigation Works

Ospedal dam, 26m high, with a 5000 m^2 PBG facing laid on porous asphalt and a geotextile and protected with interlocking pavings, was built in Corsica in 1978 and remains in excellent condition, as evidenced by 19 years of periodic inspection.

In 1976, an irrigation reservoir was built at Gap in southern France with a 25,000 m^2 PBG facing, and Ortolo rockfill dam in Corsica was completed with a similar 6800 m^2 facing. Problems were experienced with the poorly compacted soil when first filling the Gap reservoir. A tear in the geomembrane where it joined a concrete pipe allowed leakage to wash away material from the embankment, but it was easily repaired.

The Ortolo facing was laid on a elaborate base (25-30mm ballast impregnated with 3 kg/m^2 bitumen emulsion and 100mm cold laid asphalt) plus a geotextile. The protective covering was geotextile plus 140mm in situ fibre reinforced concrete (polypropylene fibre, length 30mm, weight 1kg/m^3). All seams were 100% tested with an automatic ultrasound tester. The quality of construction enabled the structure to withstand exceptional floods successfully.

4.3. Reservoirs in Hot Climates

From 1981 to 1983, large jobs ranging in size from 50,000 m^2 to 80,000 m^2 were completed in Saudi Arabia at Hail, Riyadh, Taif and Dorman at the Royal Palace. They included many ornamental ponds.

At Goudel near Niamey, a river water storage reservoir was lined with 4500 m^2 of PBG in 1981 and remains in good condition apart from some tears at junctions with concrete structures.

In 1989 at Palma, Majorca, 22,500 m^2 of PBG was used to line an aeration lagoon.

In 1991, reservoirs in the gulf of Marrakech had 90,000 m^2 of elastomeric bitumen PBG laid directly on the sand, without any protective covering.

In the same period, large reservoirs were lined with 30,000 m^2 PBG in Abu Dhabi.

In 1996, 110,000 m^2 of PBG was used at a settling pond in Nigeria.

All these prefabricated bituminous geomembranes performed well with respect to sunlight and temperatures in these hot climates.

5. CANALS

5.1. France

PBGs are used extensively for lining irrigation ditches and canals. Tests performed after fifteen years service near Le Mans revealed that PBGs covered with soil and grassed, were ageing well. They performed valuable service in controlling leakage from critical canal sections in the Freyssinet system. The largest job was the 260,000 m^2 of elastomeric bitumen PBG lining to the Nieffer canal near Mulhouse.

5.2. Very Hot Climates in Africa and Asia

Prefabricated bituminous geomembranes were effective in the construction of Ishagi canal, Iraq, in 1981 and the Mines d'Or canal at Poula in Burkina Faso. They also successfully repaired the 64,000 m^2 of leaking concrete lining to the Tanorga irrigation canal in 1985, and controlled leakage over 22,000 m^2 of Tungabhadia canal in India in 1987. A geotextile underlay and slate gravel protective covering were provided for the Mines d'Or canal PBG.

5.3. North America

Two of three leaking sections of the Caspa District canal in Wyoming, USA, were repaired with 9000 m^2 and 60,000 m^2 elastomeric bitumen PBG in 1992 and 1994 respectively. The third, slightly larger (80,000 m^2) section was repaired in 1995 by the canal operator's own employees.

When the West canal in Oklahoma was leaking in 152 places, PBG repairs to an 800m section restored irrigation supplies to 120 ha of farmland.

California has the densest canal system in the USA, and PBG has been used extensively to repair earth and concrete-lined canals.

Two water treatment ponds covering 75,000 m^2 and 6.50m deep, lined with elastomeric bitumen PBG, lost only 1 litre per square metre per day as against the design criterion of not more than 20 litres.

5.4. Special Problems in Livestock Farming Areas in Developing countries

Near Niamey in Niger, canals cut into the laterite were lined with 20,000 m^2 of PBG in 1991, and six years later, it was observed that:

- ◆ Canals in vegetable-growing areas were in good condition.
- ◆ Canals in livestock farming areas had been damaged at cattle crossings.
- ◆ Local residents had purposely torn the geomembrane in places to take water. It is also said that bituminous geomembrane material is popular for re-soling shoes.

This means that special measures are needed to combat damage of animal and human origin, such as fencing, thorn hedges, concrete cattle crossings and more water offtakes.

In Niger as in many other places, special care is needed when joining geomembrane to concrete, and should include firm cold jointing, double membrane thickness and clamp bars.

6. CONCLUSION

Laying bituminous geomembranes, with or without surface protection, is such a simple job that it can be successfully performed in many countries with standard tools and trained local labour, to build and repair irrigation canals and reservoirs. The examples described also illustrate that bituminous geomembranes are easy to repair, retain their waterproofing properties over time and age well.

The choice between in situ and prefabricated alternatives or combining bituminous geomembranes with asphalt is governed by local cost factors, since all three approaches have proved their worth.

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Colétanche bituminous geomembrane being laid at Ortolo dam

Reservoir lined with Colétanche at Goudel, Niger

Canal lined with Colétanche near Niamey, Niger

Caspa Alcova, Wyoming (USA)

Caspa Alcova, Wyoming (USA)

Irrigation Canal, California (USA)

Altus, Oklahoma (USA)