Geosynthetics Asia'97, 26–29 November, Bangalore, India

BITUMEN GEOMEMBRANES IN IRRIGATION

B. Breul[1] *and R. Herment*[2]

[1] Société COLAS S.A., 7, Place René Clair, 92653 Boulogne-Billancourt Cedex, France
[2] Société des Pétroles SHELL, 89 Boulevard Franklin-Roosevelt, 92500 Rueil Malmaison Cedex, France

ABSTRACT: Bitumen was in use 5000 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. 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 geomembranes available in 4m widths in France.

INTRODUCTION

Four thousand years before the birth of Christ, the bank of the Tigris were lined with a layer of impervious bitumen, natural sand, gravel and clay, protected above and below by bitumen-jointed brick. The linings are still in good condition.

Waterproofing with bitumen has changed since that time. Asphalt and bituminous geomembranes have adapted in line with the larger areas covered. Lightweight bituminous geomembranes are ideal for lining frequently inaccessible irrigation channels. They may be made in situ by spraying the bitumen onto a geotextile (ISBGs) or prepared in the factory and delivered to site in rolls (PBGs).

1. BITUMINOUS GEOMEMBRANE LINERS

Both in situ and prefabricated bituminous geomembranes must be laid on a suitable base course and, in some cases (see below), must be protected by a covering of some sort.

1.1. Base Course

The base course must be free from topsoil and grass and properly drained if the underlying foundation is pervious of the lining is placed in a cut or excavation (figure 1). Air vents are needed if the underlying ground if fermentable. The surface is graded and rolled to a density of 90% Proctor optimum. Sharp stones are stones removed. Cut and embankments slopes must be stable, for the geomembrane must not be expected to provide any structural support.

1.2. Bituminous Lining

The bitumen for in situ linings (Table 1) must be compatible with the reinforcing material. The bitumen is applied by spray bar at the rear or side of the vehicle by hand, through a long hose. Normal applications are 3-5 kg/m^2 per coat and two coats are applied. The reinforcing material

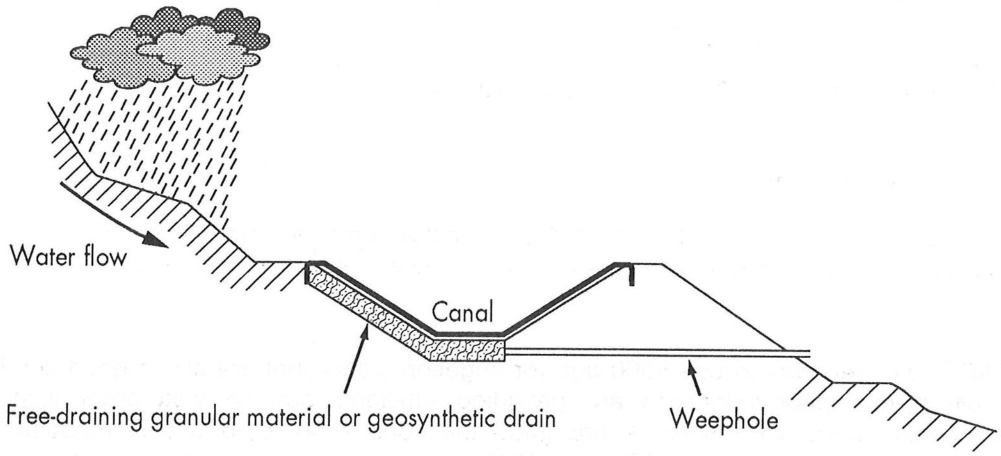

Figure 1 : Geomembrane Underdrainage System for Canal in Cut

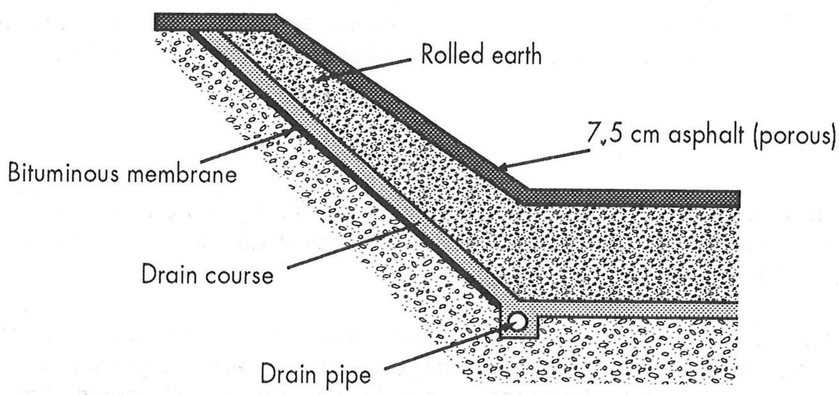

Figure 2 : BALDWIN HILLS RESERVOIRS (LOS ANGELES)
Membrane stops soil migrating into embankments and regulates seepage flow into drain pipes

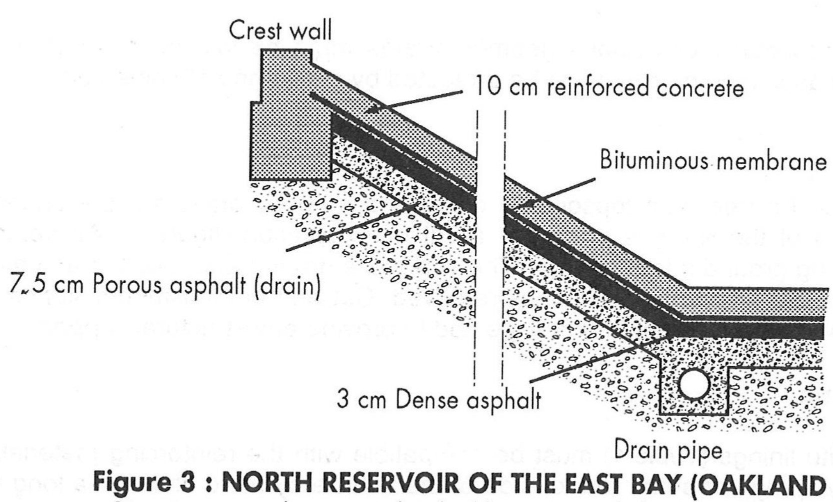

Figure 3 : NORTH RESERVOIR OF THE EAST BAY (OAKLAND - U.S.A.)
Bituminous membrane sandwiched between asphalt and reinforced concrete.

impregnated with bitumen had aged in 1990 and was easily repaired. No incidents were reported at the Vallon les Bimes dam.

In situ bituminous geomembranes are used in the USA to line irrigation reservoirs of more than 1 Mm^3 capacity. The embankment lining at Baldwin Hills reservoir near Los Angeles is laid on an underdrain and covered with 7.5cm gap graded asphalt topped with soil.

The lining at Oakland North overlies two layers of asphalt (7.5cm thick porous and 2.5cm dense) and protected with 10cm of reinforced concrete. For canal linings, the US Bureau of Reclamation has issued a design checklist based on flow rate and velocity, etc.

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 1000 years. They are monitoring a five-acre prototype constructed in 1993 over a decommissioned wastewater disposal facility. The cap will consists of 4.50m of sand, gravel, clay and other natural materials; an in situ bituminous geomembrane was laid over 15cm of asphalt as part of the barrier.

The ASTM committee D35-10 working group was formed in 1996 to deal with in situ bituminous geomembranes.

3. PREFABRICATED BITUMINOUS GEOMEMBRANE LININGS

Two examples are described.

3.1. Moderate-Depth Reservoirs in France

For the last twenty years, CEMAGREF has been monitoring performance of seventeen reservoirs impounded by PBG-faced rockfill embankments up to 18m high with water-face slopes of 2.5 horizontal to 1 vertical. They all have gravel protection.

The following points have been noted. Three single incidents - puncturing by sharp stone, wilful tear damage and seam failure - were easily repaired and the repairs were still intact ten years on. Of ten reservoirs in the Landes area near Bordeaux, nine have performed well over the last 12 years, and one was made unserviceable through having no gas venting system when fermentation occurred under the membrane. Only minor damage from easily repaired root growth and insignificant mud curling that had no effect on watertightness was reported at the other reservoirs.

At the 300,00 m^3 Guazza irrigation reservoir in Corsica, similar damage was reported with 1-5mm dia. cracks on a 6 hectare unprotected Colétanche® prefabricated membrane after only a few weeks but it stabilised, and nine years afterwards, the lining was still in good condition both where it was permanently under water and where it was periodically exposed to the weather.

3.2. Large Structures in France

Ospedale rockfill dam was commissioned in Corsica in 1978 and impounds a 3 Mm^3 reservoir. It is 26m high and faced with a 5000 m^2 Colétanche prefabricated bituminous geomembrane with porous asphalt and a geotextile underneath and a covering of another geotextile and 8cm-thick interlocking pavings. The whole system is in excellent condition 18 years on.

The Gap water supply reservoir at an altitude of 1700m asl in the French Alps was built in 1995. It is 10m deep with a capacity of 150,000 m^3, and lined with 25,000 m^2 of Colétanche PBG without a base course. It is laid on a geotextile drain placed directly on the graded and is laid with overlaps of at least 20cm unless the strips are sewn together into panels (Photos 1, 2, 3, 4).

Table 1. Shell Bitumens for Buried Bituminous Membranes

	Mexphalte SM1	Mexphalte SM2	Mexphalte SM3
Penetration at 25°C (ASTM D5)	35-45	20-30	40-50
Ring & ball softening point (IP 58)	85-95	80-90	60-70
Penetration index	+5	+3.5	+2
Density at 25°C	1.01-1.06	1.01-1.06	1.01-1.06
flash point (Cleveland open cup)	250	250	250
Average spraying temperature (°C)	180-210	170-200	160-190
Uses	Very hot climates Areas exposed to sunlight	Temperature climates	High altitudes, low temperatures with prolonged frost

Prefabricated geomembrane is delivered to site in rolls, 4m or 5m wide, and 3.3mm to 5.6mm thick. It consists basically of a layer of elastomeric or oxidised bitumen reinforced with a polyester geotextile, protected on the underside by a polyester film and with a sanded top surface. It is dispensed from a frame suspended from a crane jib.

1.3. Protective Covering

Although a protective covering is not always needed, it has the advantage of helping the geomembrane resist uplift pressures and wind suction by weighting it down, shielding it from the weather, and protecting it against impacts, ice, debris, animals and wilful damage. It may consists of unprocessed soil, sand or random stone in a 20-50cm layer or cement- or bitumen-stabilised material in a 4-10cm layer.

1.4. Concrete Interface

The junction between the geomembrane and concrete is frequently a source of tears. Modern practice, especially careful compaction of the supporting soil, overcomes this problem.

2. EXAMPLES OF IN SITU BITUMINOUS GEOMEMBRANES

In the seventies, in situ bituminous geomembranes were used in the French Alps, such as at Avoriaz (1974) to line a water reservoir for the mountain resort 2000m asl. It is still operating satisfactorily today.

At Castalet (1984), a number of fire-fighting ponds for 3000-40,000 m^3 capacity were lined with in situ bituminous geomembrane laid on a stone and sand base course and protected with 8cm of lean concrete. The soil in the immediate catchment areas was impregnated with 3 litres of bitumen emulsion per square metre to help channel runoff into the ponds.

Two rockfill dams with upstream face slopes of 1/2 near the French Riviera at Vallon les Bimes and Campaux, 9m and 13m high, were faced with unprotected in situ bituminous geomembrane linings in 1973 and 1975. Performance was monitored by the French agricultural ministry's body CEMAGREF. In 1983, a tear was found at the crest interface at Campaux dam, but no growth was reported up to 1990. A strip of geotextile whose anchorage was not

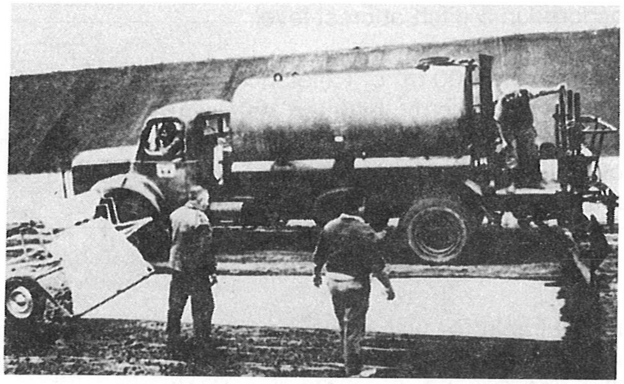

Photo 1. Bitumen spreader with side spraybar

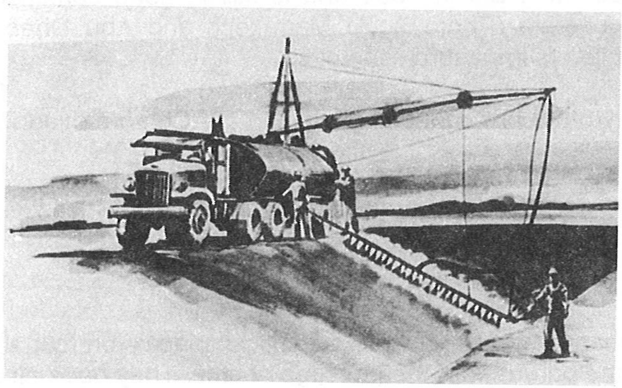

Photo 2. Spraying bitumen on slope

Photo 3. Spraying bitumen by hand

Photo 4. In situ application of bituminous geomembrane reservoir lining

rolled fill material, from which sharp stones had been removed. It has no protective covering. The geomembrane on the side slopes is anchored in a ditch at crest level.

The 38m-high Ortolo dam in Corsica was faced with 6800 m^2 of Colétanche PBG in 1996. The base course is 25-50mm ballast impregnated with 3 kg/m^2 bitumen emulsion overlain by a 10cm layer of cold-laid asphalt and a geotextile. The protective covering is a 450 g/m^2 geotextile and 1'cm of in situ concrete (Photo 5). All geomembrane seams were tested with the CAC 94 full-width ultrasound machine, at a rate of 500m of seam per day.

3.3. Work in Hot Climates

Prefabricated bituminous geomembranes are suitable for waterproofing large structures in hot climates. At Palma, Majorca, a 22,500 m^2 lining was applied to an aeration lagoon for wastewater destined for re-use for irrigation. At Goudel, near Niamey in Niger, a storage reservoir for river water was lined with 4500 m^2 PBG in 1981 and is still in good condition except for some tears at junctions with concrete (Photo 6). At Marrakech and Abu Dhabi, 70,000 m^2 and 50,000 m^2 of PBG were applied to irrigation reservoirs.

These linings have also been used in many other hot countries including the Comoro Islands, Nigeria and New Zealand.

4. PREFABRICATED BITUMINOUS GEOMEMBRANE CANAL LININGS

4.1. France

PBGs have been used in France to enhance watertightness at critical places on canals originally lined with concrete that had become porous with the passage of time. They have also been applied for widening the Nieffer canal joining the Rhine to Mulhouse in eastern France to modern European standards; 260,000 m^2 of elastomeric bitumen PBG as used to cover the area where the water level fluctuates between the watertight asphalt lining and the bank. It was protected with a rockfill covering.

4.2. India

PBG was used in India in 1987 to restore watertightness to 22,000 m^2 of a section of the Tungabhadra irrigation canal.

4.3. North America

An irrigation canal in Oklahoma, USA, was leaking badly in some places. An 800m section was repaired in 1994 with elastomer bitumen PBG laid on the stripped soil, restoring irrigation supplies to 120 hectares. When three section of a Wyoming canal were leaking, a 9000 m^2 in 1992 eventually led to further PBG applications of 60,000 m^2 and 80,000 m^2 in 1994 and 1995 respectively. California also uses PBGs.

Water losses from PBG-lined reservoirs in Canada were twenty times less than predicted.

4.4. Africa

When replacing the concrete panel lining to the Tauorga irrigation in North Africa in 1985, a geotextile was placed under the PBG, and it was protected with a covering of slate gravel. The 64,000 m^2 lining was completed in six weeks. In 1991, 19,000 m^2 of irrigation canal slopes were lined with PBG in the Lata irrigation area near Niamey. The dry climate and environment yielded interesting and picturesque information (Photo 7): the canals inside the rice-growing irrigated area not crossed by animals remain in good condition, but the geomembrane has

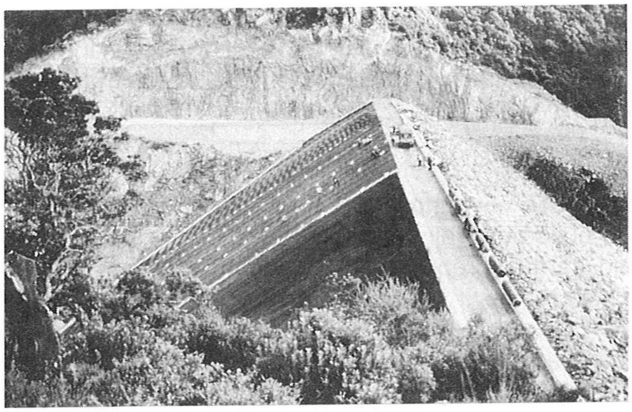

Photo 5. Bituminous geomembrane being laid at Ortolo dam

Photo 6. Reservoir lined with Bituminous geomembrane at Goudel, Niger

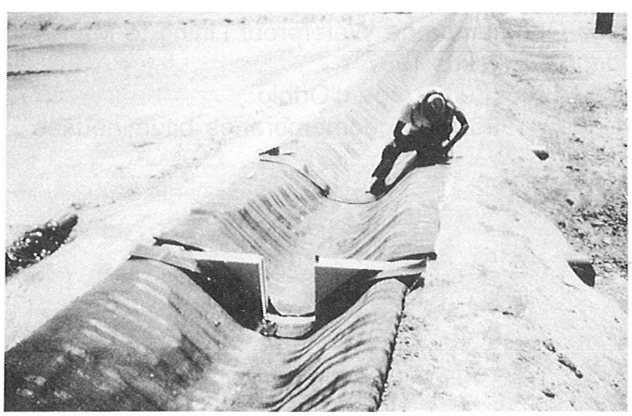

Photo 7. Canal lined with Bituminous geomembrane near Niamey, Niger

been damaged elsewhere by hooves and the locals have pierced the lining in places to steal water. A remedy would be to border the canals with thorn hedges, with gaps for concrete-lined cattle crossings. Canal slopes could be flatter, which would make it easier to install the lining.

5. CONCLUSION

Bituminous geomembranes, with or without protective coverings, are simple to install and in many countries, local labour can be employed to build or repair irrigation canals and reservoirs. Only simple precautions are required, including careful preparation of the job and judicious design of the underdrainage and junctions with concrete.

The examples described show that rarely-needed repairs are quite simple and that structures faced or lined with bituminous geomembrane remain watertight, even with surface protection, for more than twenty years without an appreciable maintenance.

6. ACKNOWLEDGEMENTS

The authors would like to thank Messrs. Siplast and Hypofors for permission to quote their jobs.

REFERENCES

1. Van Asbeck, W.F. (1962). *Bitumen in Hydraulic Engineering*, Vol 1, pp1-3
2. Sheel France brochure. La membrane bitume enterré, Nov 1974
3. Dunglas, J., Lelu, V. and Chaigne, P. Revêtement de canaux di'irrigation par béton bitumineux étanche ou membrane bitume enterré. *Revue Eau et aménagement de la région provençale*. No.14, July 1977
4. Alonso, Degoutte and Girard (1990). Result of Seventeen Years of Using Geomembranes in Dams and Basins. *Proc. 4th Int. Conf. On Geotextiless, Geomembranes and Related Products*. The Hague
5. Wing, N.R. and Gee, G.W. (1994). Quest for the Perfect Cap. *Civil Engineering*. Nov. 1994
6. Tisserand, C (1983). Un grand bassin à membrane non protégée. *Colloque Etanchéité superficiel*. Paris (CEMAGREF issue)
7. ICOLD. Bulletin No. 38 Use of Thin Membranes on Fill Dams
8. Bianchi, C., Rocca Serra, C. and Girollet, J (1979). Utilisation d'un revêtement mince pour l'étanchéité d'un barrage de plus de 20 mètres de hauteur. Communication C11. *Proc. 13th ICOLD Congress*. New Delhi 1979
9. Breul, B. and Herment, R (1997). Bituminous Geomembrane Waterproof Lining to Manes Storage Reservoir. *Proc. Rencontres 97 Congress,* Reims 1997
10. Shell Bitumes newsletter *Le Liant* No. 14, May 1996. Le barrage d'Ortolo
11. Shell Bitumes newsletter *Le Liant* No. 14, May 1996. Les géomembranes bitumineuses conquièrent l'Amérique