Mexican Experiences with Geomembranes in Hydraulic Works

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ABSTRACT. The first practical experiences with exposed geomembranes in hydraulic projects were unsuccessful in general terms because of the lack of knowledge and the poor quality of the products. Asphalt membranes are not suitable as barriers or protection against surficial erosion. The availability of geomembranes made of CSPE, PVC and HDPE together with a better knowledge of their performance has made it possible to use them to reduce leakage to a large degree and as protection against erosion in agricultural canals, reservoirs for treatment and recycling of waste waters, ponds for aquaculture, and evaporation reservoirs. The main concern of the users resides in the durability of the products when exposed to the environment since there is no direct relationship between the laboratory test results and the service life of the materials. It has been considered that the polymeric geomembranes will behave satisfactorily provided a quality design and installation is achieved.

1 INTRODUCTION

Since 1978, the present Comisión Nacional del Agua (National Water Commission), the responsible agency for the hydraulic resources, as well as other government institutions of Mexico, have used exposed geomembranes to reduce water leakage at their respective works and to prevent the pollution of the surface waters and underground aquifers. Generally speaking, the first experiences were unsuccessful and as a result in the eighties very few projects were built with such products. At present, the availability of a wide range of geomembrane products in the country and a better knowledge of their properties have induced a wider application for public works. A brief report is presented herein of some of the preliminary experiences and of the major projects executed in the last few years including an evaluation of the efficiency of the solution adopted.

2 GEOMEMBRANES USED

During the decade of the 70s, the supply was mostly represented by asphalt-based products and by low-density polyethylene (LDPE) membranes, but the difficulty in obtaining safe seams restricted their use. In recent years, with the advent in the market of membranes made with other polymers and with safer seaming techniques, their application in major construction projects has expanded. The results obtained from some hydraulic works carried out by public agencies will be presented in what follows. Quality tests of the materials were performed in all cases and the properties of the products became similar to those suggested by the manufacturers. The information presented herein has been derived from evaluations made from 1989 to 1993 (Murillo-Fernández, 1990; 1993).

2.1 Asphaltic geomembranes

Sheets 0.91 x 3.05 m in size and 12.7-mm thick (Rhino Hide) have been mostly used; they are made of 65% asphalt and 35% mineral fillers, reinforced with fiberglass and spliced by overlapping them along a width of 10 to 15-cm with hot-applied oxidized asphalt and asphaltic mastic as binders.

At a dam and a dyke of La Cangrejera, in the State of Veracruz, with a homogeneous embankment of silty sand, a maximum height of 15.5 m, slopes of 3h:1v and lengths of 280 and 80 m respectively, built upon a compressible foundation, this material was used in 1979 for surficial erosion control of the upstream slope. The area exposed to sunlight has been subject to major repairs in 1985, 1989 and 1992 due to the separation of the splices and to holes punched by the grass. The behavior of the asphaltic geomembrane in the course of 13 years has been regarded as satisfactory although aging effects are already evident.

With the same function, this type of product was used in the same zone in 1980 for protecting two small dams with 4:1 slopes (Pemex I and II). Because of improper maintenance the vegetation has punched through the part left in the open.

From 1983 to 1987, 40,000 m^2 of this material were placed at the Zumpango Lagoon, in the State of Mexico, as protection against erosion in part of the wet slope of a CH-clay levee 18-km long, 6-m high and with 2:1, 2.5:1 and 5:1 slopes. In the course of six years, half of the revetment suffered contraction and became ripped thus defaulting as protection material (Fig. 1). Damages of a lesser magnitude are evident in the rest of the revetment.

Fig. 1 Asphaltic revetment shrinkage at Zumpango Lagoon

At the aeration lagoons for the treatment of waste water in the city of Tijuana, State of Baja California, founded upon tuff, basalt and cemented sand, a crack that reopened in 1987 induced important water leakage that triggered earth slides in the vicinity. To prevent further leakage, the crack was filled with concrete and the site was covered with close to 40,000 m^2 of this product. In 1989 and as a result of the wave action, a horizontal ripping took place that favored the erosion of the cemented sand on the 2:1 slope. The damage was repaired and an intensive maintenance program has been implemented to protect the revetment in the area exposed to sunlight. Furthermore, leaks detected at the splices have not been stopped.

To protect against the wave action the slope of a CL-sandy clay levee, 2098-m long, 6.7 m of maximum height and a 2:1 slope, to impound the waste water treated for the city of La Paz, State of Baja Californa Sur, 16,000 m^2 of this asphalt product were placed in 1990. After three years of operation, the material shows evidence of surficial cracking and creep of asphalt.

2.2 Polyethylene geomembranes

Low-density polyethylene (LDPE) film with a thickness t_{GM} of 0.12 mm has been used without protection against weathering in small works such as irrigation canals in the State of Quintana Roo after placing it on top of clay-type soils that crack upon drying, as well as in small ponds in the central part of the country. Its durability under tropical climates has ranged from six to 12 months.

An LDPE sheet (t_{GM} = 0.25 mm) was installed in 1987 across a recreation lake covering an area of 10,000 m^2 in the eastern part of Mexico City. Due to the presence of gases in the soil, the geomembrane was lifted and floated. The lining was placed with extremely poor seaming techniques. It has been considered that a complete ignorance about the geomembrane function existed in the project because the soils encountered at the site have been classified as clays (CH) that require no further waterproofing.

The high-density polyethylene (HDPE) has only been used in the last few years. The oldest application corresponds to an irrigation canal built through organic clays (OH) susceptible to cracking upon drying, in the State of Quintana Roo, with a length of 167 m, a cross section stretch out of 4.7 m and 2:1 slopes, where a geomembrane of this material (SLT) was applied in 1990 having a value of t_{GM} equal to 1.52 mm, united with field welding techniques with extrusion of the polymer. The product has withstood adequately the tropical climate, the crossing of cattle and the vegetation growth.

With the purpose of protecting the aquifer underlying the town of Villa Juárez in the State of Durango, the Comisión Federal de Electricidad (Federal Power Commission), CFE, waterproofed in 1991 two evaporation reservoirs of brackish water produced by the Victoria thermoelectric power plant, covering an approximate area of 22 ha by means of 8000 m^2 of a HDPE-geomembrane of the same brand and with 14,000 m^2 of other product (Gundline), with a thickness of 1.5 mm and united in the field with hot-wedge techniques and extrusion welding. The subgrade material was sand and compacted sandy clay. This solution has proven successful to date since neither leaks nor pollution of the aquifer have been recorded and the lining shows no evidence of damages.

At the former Texcoco Lake, 2400 m^2 of such material (t_{GM} = 1.52 mm) were applied in 1992 together with 3600 m^2 with a thickness of 1.02 mm (NSC) in order to waterproof five tanks for aquaculture lined with concrete, each one measuring 30 x 40 m with embankments built with permeable debris from demolition works (slopes 1:1). Seaming in the field was performed with extrusion welding and with hot-wedge techniques. Although only a short time has elapsed after first operation of both applications, the results thus obtained have proved satisfactory since no leaks have been recorded.

In 1975, the Instituto Mexicano del Petróleo (Mexican Oil-Research Institute) developed a 0.5-mm thick geomembrane made of LDPE and asphalt (Asfaleno). The difficulty to produce safe seams and the lack of knowledge about the geomembranes restricted its production on a commercial basis.

2.3 Chlorosulphonated polyethylene

This product (CSPE or Hypalon) was available in the country in the decade of the 70s; the pioneering use was in a reservoir for industrial fluids in a plant at Coatzacoalcos, State of Veracruz in 1979. Because a drainage system was not installed under the membrane, the emission of gases from the organic soils made it float and it had to be removed within a few months.

To profit from a differential elevation of 500 m at the Oblatos Gorge in the State of Jalisco, the CFE built a hydroelectric power plant to generate electricity for peak demands by exploiting the waste waters collected from the city of Guadalajara. To control the water flows it has available a 300,000-m^3 concrete settling tank and another reservoir for regulation bounded by concrete walls and an embankment of zoned earth materials with a height of 14 m, 2:1 slopes and a capacity to hold 1,340,000 m^3. Both reservoirs were excavated through fissured fluidal and vitreous tuffs. Although the cracks were treated with concrete, when the plant started operating leaks of about 0.06 m^3/s were recorded in the first tank that caused pollution of natural springs at the cliff of the gorge and it was then decided to waterproof both reservoirs. At the settling tank, 30,000 m^2 of a reinforced membrane (t_{GM} = 1.52 mm) were placed along the concrete walls and along the 1.5:1-slopes, on top of a polyester geotextile with μ = 350 g/m^2 and t_{GTnw} = 3.5 mm (Trevira 11-35) as a draining material and to protect the membrane. The membrane was anchored to the walls by means of stainless steel plates. At the bottom of the tank a sequence of geotextile, reinforced geomembrane (t_{GM} = 0.91 mm), geotextile and 15 cm of concrete was used as protection against mechanical damage during the removal of the silt in the future. At the regulating reservoir, a 30-cm thick layer of compacted sandy clay was placed at the bottom as well as soil-cement on top of the rockfill to smooth the slope of the embankment. Over an area of 111,000 m^2 a geotextile was installed to drain and protect the CSPE membrane (t_{GM} = 0.91 mm). The membrane was anchored to the slope shoulder by means of a trench filled with concrete. The field seams were executed with an integral solvent plus hot air with an overlap of 10 cm. The overlapping between the geotextile sheets was equal to 30 cm. During the installation the membrane ripped off because of thermal effects and of the wind forces at two places. The settling tank has been operating since February 1992 and only a flow rate of 0.001 m^3/s of leakage has been detected, without impairing the springs in the area, whereas the regulating reservoir has been functioning since June 1992 without appreciable leakage and only in one piezometer a raise of the water level of a few centimeters has been recorded (Fig. 2); therefore, the results obtained can be regarded as excellent.

Fig. 2 Regulating reservoir lined with CSPE geomembrane at Agua Prieta

2.4 Polyvynil chloride

The PVC products have been available in the market since the decade of the 80s although its first application in Mexico at a large scale was at the wet slope (2.25:1) of the Zumpango Lagoon embankment referred to before, upon which 17,700 m^2 of a membrane with t_{GM} = 1.5 mm (Vinimanta) were placed in 1990 with the function of protection against wave action. As of to date, the material shows no evidence of weathering, but the seams carried out in the field with the use of solvent can be easily split apart and the material has been vandalized.

For protecting slopes against erosion, such product was used at the slopes of treatment lagoons for waste water in Santa Ana Pacueco (9000 m^2, t_{GM} = 0.8 mm, slope 2:1, 1991, Fig. 3), in Irapuato (39,000 m^2, t_{GM} = 1.0 mm, slope 1.5:1, 1992) and in Abasolo (17,500 m^2, t_{GM} = 1.0 mm, slope 1.5:1, 1992), all in the central part of the country. A PVC geomembrane was used in 1992 along a

Fig. 3 Treatment lagoons lined with PVC geomembrane at Santa Ana Pacueco

canal with erosion problems and water leakage near the town of Guasave, State of Sinaloa (1600 m^2, t_{GM} = 1.0 mm, slope 1.5:1) and in 1993 at the "Coria" canal, State of Guanajuato (24,000 m^2, t_{GM} = 1.2 mm, slope 1.5:1), where a crack induced by regional subsidence frequently fractures the embankments and produces major leakage losses. In these cases, the solution adopted has proved satisfactory without any evidence of weathering, although in some cases the membrane was gnawed by rodents and at the canals it has been vandalized. Because of the short time elapsed, its efficiency cannot yet be fully evaluated.

2.5 Other geomembranes

In 1978 full-scale tests were carried out in irrigation canals excavated through fissured clays (CH) lined with elastized polyolefin (ELPO) with seams united with dielectric welding. The results became satisfactory but the product was discontinued because of its low demand. A 0.63-mm thick membrane of butyl rubber (IIR) was placed along a canal in Xochimilco, close to Mexico City, where a crack associated to regional subsidence induced water leaks of 0.4 m^3/s in 1986. During emergency situations, the same product was used (t_{GM} = 0.51 mm) to prevent leakage along canals lined with concrete in Río Verde, State of San Luis Potosí, where the dissolution of gypsum in the soil induced cracking of the rigid lining in 1987. The splices were cross-linked and the procedure was quickly implemented without closing the operation of the canals.

3 CONCLUSIONS

The results determined from the the first projects in which geomembranes were used became a total disaster due to the insufficient knowledge, deficient designs and in some case a poor quality of the materials and as a result of this they were used only in a few projects during the decade of the 80s. Technical personnel is nowadays available with a good knowledge of these materials as well as a large variety of commercial products and consequently their use is now common in public works. The exposed asphalt sheets fall short of complying with the functions of impervious lining or protection against erosion. It has been considered that the geomembranes made of HDPE, PVC and CSPE represent suitable options to be used for water reservoirs for irrigation and for storage of waste water, as well as to line agricultural canals, although in this last application the risk of vandalism increases.

The main concern of the public agencies is the durability of the geomembranes exposed to tropical or semiarid climates because in temperate or cold weather a service life of 10 to 25 years can be expected from HDPE and of less than six years for the PVC, whereas the CSPE has shown a durability of more than 20 years. Although accelerated weathering tests are available for these products, there is no reliable relationship between such results and the actual service life of the materials and this information can only be obtained from their application in actual projects and from the continuous monitoring of their performance. The ideal geomembrane to fulfill the expectations of a customer should be a product that in addition of being impervious to water is easy to unite and to repair, resistant to environmental effects and has a cost comparable with the conventional solutions.

The geomembranes are not either suitable or unsuitable for the hydraulic works; it suffices to say that the results depend upon the quality of the design and of the installation.

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4 REFERENCES

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