Lining of Ponds and Reservoirs - Indian Experiences

K. R. Datye
Consulting Geotechnical Engineer, Bombay, India

V. N. Gore
Consultant, Geotextile Application Engg, Bombay, India

ABSTRACT: The paper presents case studies to bring out the experiences of use of relatively thin synthetic membranes for the lining of fresh water ponds, reservoirs and irrigation channels. High cost of synthetic polymers in India, necessiates use of relatively very thin liners as opposed to thick sheet liners used in Europe & U.S.A. The paper brings out the problems faced in the use of these thin liners of low tensile, tear and puncture resistance, when used for the barrier function. For small and medium projects in India, optimising the cost of lining is very crucial and thus choice of a lining system to form a perfect barrier becomes a major challenge. The paper addresses this issue and based on actual field experience, suggests various alternative systems for the future applications.

1. INTRODUCTION

For seepage control of small and medium size ponds, reservoirs and irrigation channels, lining is very crucial. There are areas, where the insitu soils are highly pervious and lining to control seepage becomes obligatory. Cost of lining is a very important consideration. Synthetic polymers in India are expensive and therefore, the choice is restricted to using only very thin synthetic liners. Thin synthetic liners are however, subjected to the hazard of damage by tear and puncture. Strengthening measures to avoid tear and puncture must be cost effective, yet damage to the thin liners during handling and placement continues to be a matter of concern. Alternative approaches are therefore, suggested. Thin synthetic liners would perform only the secondary function of encapsulation, in the areas of insitu impermeable soils, which are subjected to dessication cracking. In such situations minor puncture/tear/pin holes to the liner would be of no consequence. In the areas, where insitu soils are pervions two alternative approaches can be adopted. Either a perfect barrier is formed of an optimised bentomat used in conjunction with a thin synthetic liner with crab/rodent proof septums. Alternatively, imperfect barriers are formed with under-drains to collect seepage. Reinforced soil open up possibility of constructing vertical side walls for the ponds/ channels to optimise the ratio of area of lining to the capacity.

2 SYNTHETIC LINERS IN INDIA

Synthetic liner materials, commonly available in India are 100-200 micron thick LDPE, (extruded), P.V.C, HMHDPE, PP (biaxially oriented) and recently developed composite of LDPE melt coated on HDPE slit tape fabric. Representative physical characteristic of the liners are exhibited in Table 1.

Table 1 Physical characteristics of LDPE, P.V.C, HMHDPE liners.

	P.V.C.	LDPE/PP/ HMHDPE
Tensile Strength, MPa		
Machine direction	14	14
Cross direction	14	12-14
Elongation at break %	250	300-500
Tear resistance, N/mm	60	30

For a thickness of 200 microns the cost of liners range from U.S $ 0.3 - 0.4 /m^2. However, the use of synthetic liners other than LDPE is limited by their narrow widths (1.2 to 1.4 metre),. Seaming methods are yet not routinised, which create uncertainty with regard to integrity of the liner performance. Seaming techniques such as the extrusion welding or hot air are not suitable for thin liners. Quality assurance for the seams using air lance or other methods are yet not in practice.

3. CASE STUDIES

There seems to be a preference to the use of LDPE liner because it is readily available in 7-14 m wide rolls and economical as compared to PVC/HMHDPE. Case studies are therefore, presented to address problems associated with the use of thin LDPE and other liner materials.

Lining of reservoir at Mangaon in distt. Raigad

For the reservoir at Mangaon, a 100 micron thick extruded black LDPE was considered as a liner to control seepage of the reservoir bed and sides. The lining system included a 100 mm thick clay underlay and 200 mm thick clay overlay for the LDPE liner placed with 200 mm wide over lap seams, Fig.1. The lining system failed to perform and the post failure observations brought out clearly the following deficiencies of the system:

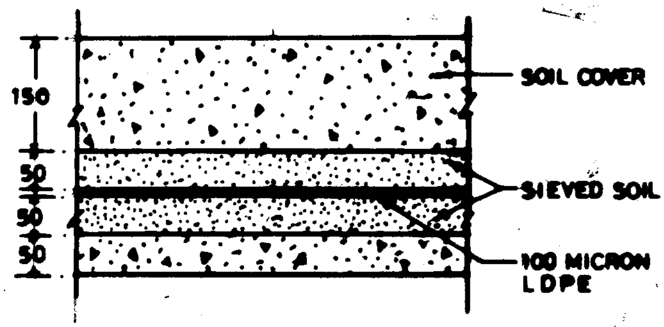

Fig. 1 Lining of reservoir at Mangaon

heavy seepage was noted through the overlap joints. The joints were made by only over lapping the liner at the edges without using any bonding agent. The project was executed way back in 1983 and very little was known about the methods of constructing joints in the synthetic liners.

- the clay underlay of residual soil contained angular coarse fragments, which caused extensive damage to the liner. This is believed to have become more pronounced after the failure of over lap seams. The concentrated seepage flow through the open seams caused erosion of the clay particles leaving the angular fragments at the interface of liner and the underlay,

- damage to the liner caused by the crabs. The damage was so extensive that it rendered the liner beyound repairs. It would be pertinent to note that crabs and most of the burrowing animals during the dry season migrate deep down in to the ground. During the wet season these animals migrate back towards the surface and in the process cut through the liner system,

- tensile failure of the liner placed on the slopes. Thin LDPE liner did not withstand even the minor slippage of the clay cover and failed in tension.

It was concluded that a 100 micron LDPE has poor puncture,tear and tensile resistance and would not perform in the areas, where soils are heterogeneous and contain coarse, angular fragments. There are a few reported cases of successful use of 100 micron LDPE for the lining of channels and ponds in fine grained plastic clays. Authors believe that in such cases, LDPE liner performed only the encapsulation function and prevented cracking of the insitu impermeable plastic clay.

In view of the failure of LDPE liner at Mangaon, other alternatives were explored to improve puncture, tear and tensile resistance of the liner material. It was also recognised that improvement in these properties would have to be achieved without increasing the cost of the liner. A composite of LDPE melt coat applied between two layers of HDPE slit tape fabric was developed. Several semifield tests (Fayoux 1984) were carried out to evaluate the puncture and tear strength of LDPE, PVC, HMHDPE and the recently developed LDPE - HDPE composite liner, of equivalent weight, (Fig.2). At the end of 10 passes of a 6 T truck, it was noted that except for the composite liner all other liners were badly damaged.

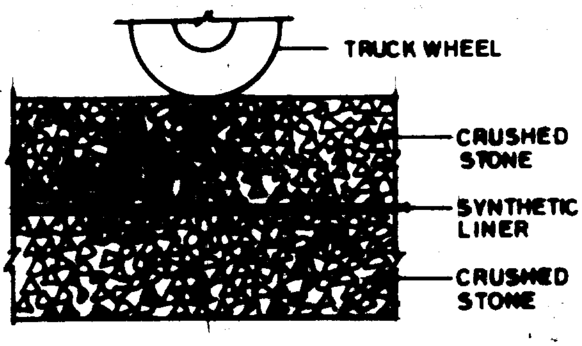

Fig 2. Field test to evaluate puncture/tear resistance of liners.

Farm pond at Bhogaon, Solapur

Based on the results of semi field tests, a composite liner of 120 gms/m^2 was selected for the lining of a 300 m^3 capacity farm pond. The composite liner withstood puncture and tear during placement as opposed to LDPE of equivalent weight used earlier at mangaon and several other small projects. However, composite liner failed to perform the barrier function. It was observed that the LDPE melt coat of 50 micron thickness was subjected to a differential thermal stress due to the restraint offered by the HDPE slit tape geotextile. Van Den Berg (1984), reported a successful case of lining of a manure storage facility. The composite liner (400 gms/m²) used in this case was similar to the one used at Bhogaon, except that a relatively very heavy LDPE melt coat (250 gms/m²) was used, which probably withstood the differential thermal stress. Such a thick composite liner in India, would cost approximately U.S $ 2/m² and for small and medium projects, it would be unaffordable.

There is a need to evaluate the capability of LDPE melt as barrier, since there is a reason to believe that at equivalent weight, extruded LDPE would be functionally far superior. A project is in an advanced stage of construction, where for the lining of a 3000 m³ capacity reservoir, an extruded LDPE liner has been placed between two layers of HDPE slit tape geotextile. HDPE geotextile layers are designed to perform the reinforcement function while extruded LDPE is designed to perform, the principal barrier function. Depending on the performance of the composite construction described above, there is a good prospect of replacing HDPE geotextile by preservative treated and locally fabricated mats of bamboo or palm.

4. SUGGESTED LINING SYSTEMS

After extensive field trials, two alternative approaches emerged. In the first alternative, the lining system is aimed at creating only an imperfect barrier to bring down the seepage by an order of magnitude and the balance seepage is lead in to a sump through a network of trench drains, (Datye 1994). Seepage water collected in the sump is pumped back by small capacity pumps.

There is a good potential of using natural nonwoven geotextile for the construction of imperfect barrier as well as under-drains. A few ponds have been built, where trench under-drains were formed by wrapping the local stone/gravel in the natural nonwoven fabric strengthened by a scrim of HDPE slit tape fabric. The imperfect barrier consisted of a layer of natural nonwoven geotextile with an overlay of cement and fibre admixed in soil and an under-lay of local sand as filter.

In the second alternative, a perfect barrier is formed by employing a composite construction combining judiciously the clay liner i.e. bentomat and a thin synthetic liner. Commercially available bentomat weigh as much as 5-8 Kg/m² priced approximately at US $ 8/m². For the optimised bentomat system developed recently, the assembly of bentomat is made at site. Bentonite powder or slurry is evenly spread on a natural nonwoven strengthened by a synthetic slit tape fabric. Natural nonwoven coated with a slurry of cement-stonedust-flyash performs dual functions that of a filter as well as of a crab barrier. Coated natural nonwovens are in service over the last two years, when used as a cover for the LDPE. Coated natural nonwoven is adequately tough and has not shown signs of degradation inspite of severe sustained thermal and U.V. exposure. Local sand placed under the bentomat forms a permanent filter, Fig. 3.

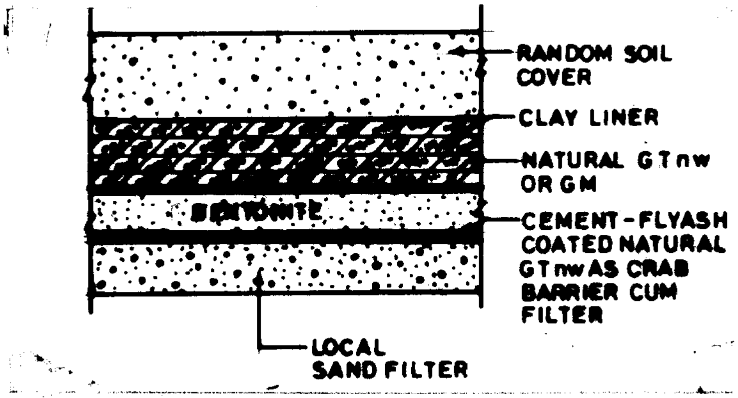

Fig 3 Optimised bentomat system

At a few pond constructions, optimised bentomat have been effective in controlling the seepage and have been found superior to thin synthetic liners.

Trial Constructions of the multiple anchored walls (Fukuoka 1986) for vertical sided water storage ponds are in an advanced stage of design and planning, (Fig 4.) Here, a cement coated nonwoven geotextile laminated with light weight synthetic slit tape fabric strengthened by preservative treated bamboo strips would be used for the facing, while timber ties anchored in to the soil mass would constitute the reinforcement.

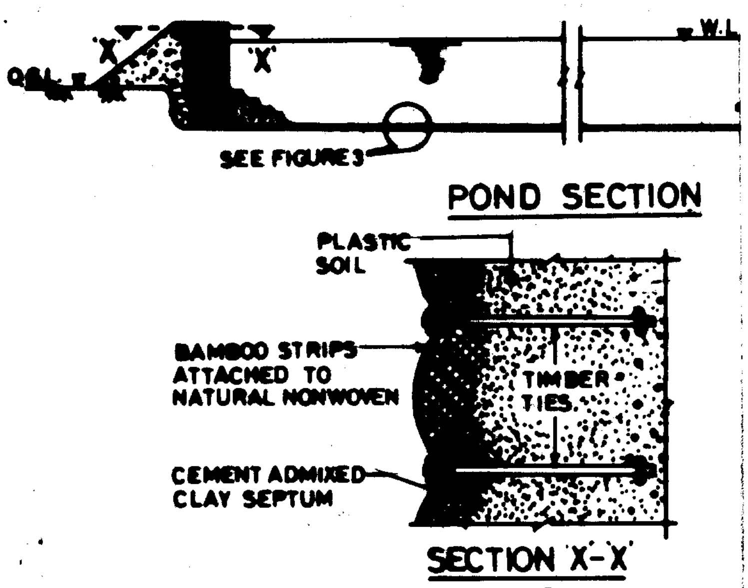

Fig 4 Reinforced soil wall for vertical sided ponds

5 FURTHER WORK

Seams and joints

In the absence of any standardised seaming and jointing methods for thin synthetic liners, a folded overlap joint is commonly used. In this method, a 300 mm wide overlap is provided. A 100 mm wide portion along the edge of the liner is bonded with either hot bitumen or a modified cold bitumen. The overlap portion is then folded such that bonded edges get fully concealed. A systematic evaluation of the efficacy of overlap joints is required to be made. Non-destructive testing methods similar to airlance or vacuum chamber would have to be developed. As a matter of further precaution a 300 mm wide strip of bentomat can be placed on the overlap joint. This has been used on an on-going project and it would be evaluated by opening the joints after testing.

Crab and rodent barriers

There are no reported cases addressing the issue of hazard of damage caused to the liners by the burrowing animals. Relatively very thick liners used in the developed countries probably are not subjected to this damage. Evaluation of cement coated natural nonwovens as crab or rodent barriers would have to be made by a constructing test sections in heavily infested areas. In this case, durability of coated natural nonwovens is a matter concern. It should be possible to attach galvanised steel wire mesh to the natural nonwoven geotextile or steel wires can be encorporated by weaving to minimise concern regarding the degradation of natural geotextile. It is believed that even after the natural geotextile is degraded, the integrity of the barrier would remain unaltered since galvanised steel wires embedded in cement mortar are expected to provide a long service life.

Melt coated geotextiles as liners

Efficacy of synthetic melt coats to perform barrier function needs a critical evaluation. Particularly when it is not possible to use heavy melts.

Bentomat/Clay Liners

Bentomat formed by spreading bentonite slurry or dry powder on natural nonwoven geotextile has performed satisfactorily on a few projects. Synthetic nonwoven geotextiles in India, are prohibitively costly, and therefore, use of natural nonwoven geotextile is obligatory . Here again, it should be possible to provide a coat of cement flyash to minimise degradation of natural geotextile. There is a reason to believe that the coated natural geotextile would be subjected cracking. It would also be worth while to consider use of galvanised steel wires, which would control the cracking and in conjunction with a natural sand filter, the filter performance would be fully satisfied.

REFERENCES

Datye, K.R. and Gore, V. N. (1994). Application and manufacturing developments for jute and related natural materials, *National workshop on promotion and use of jute geotextile,* New Delhi.

.Fayoux, D and Loudiere, D. (1984) The behaviour of geomembranes in relation to the soil, *International Conference on Geomembranes,* Vol-1, Denver, Colorado, pp.175-80

Fukuoka. M., Imamura, Y., (1986) Fabric faced retaining wall with multiple anchors, Journal of Geotextiles and Geomembranes. Vol.4 Nos. 3 and 4. *Special Issue on Geotextiles in Japan. Elsevier Applied Science Publishers Ltd. pp.* 207-221

Van Den Berg, C. (1984) The use of geomembranes for manure storage, *International Conference on Geomembrans,* Vol. 1, Denver, Colorado, pp. 257-262