Water Seepage Control Through a New Class of Geomembrane

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ABSTRACT
A new class of Geomembranes with their superior water barrier capabilities and puncture resistance properties have proved useful for water seepage control in ponds and channels. Generally, HDPE sheets with thickness of around 1.5-2 mm are used for lining purposes. However, as these are thick sheets, there is significant cost of installation. Further, these sheets are limited by stress cracking phenomenon and low yield strain. Geomembranes developed at IIT Delhi are of around 0.6 mm thickness, excellent stress crack resistance and are not affected by loss of plasticizers. These sheets are typically used in buried versions and support all type of protective layers. These sheets have been used to line a channel at WTC IARI, a pond at IIT Delhi and ponds at CARI, Port Blair. Results over several years show that the seepage is significantly controlled with these sheets. These may prove most effective in expansive soils conditions.

1. INTRODUCTION

1.1 HDPE Geomembrane

HDPE is well researched geomembranes in terms of applications (Gross et al. 1990; Lawrence at al. 2002) and life time predictions (Popelar et al. 1993; Li 2005; Koerner et al. 1998). Due to its susceptibility to stress cracking, it requires well compacted smooth sub grade and with minimal differential settlement. It may not be easy to meet these requirements in a large number of cases as this could lead to significant cost escalations. In many cases, and particularly in expansive soils, it may not be easy to predict the differential settlement. HDPE are typically used in the thickness range of 1.5 to 2mm to achieve suitable puncture resistance. To be able to conform to the sub grade, these sheets need to be ductile and this property in turn depends on square of the thickness. For example, bending rigidity of a two mm thickness sheet will be 1.78 times to that of 1.5mm thick sheet. Thus the conformability of these sheets is very limited and this in turn require very smooth sub grade. The high bending rigidity of these sheets also requires elaborate arrangements for transportation and installation. This all adds to the cost of the project.

HDPE and similar polyethylene based geomembranes are available in limited widths and thus requires extensive field sealing. This adds on the time for implementation of the project. These materials are sensitive to temperature of weld and thus trained manpower is needed for the field sealing. All these limitations lead to substantial costs and lead to the fact that a large number of lining projects are not taken up at all. Large elongation for the geomembranes is a very useful property as this allows deformations during settlement underneath these sheets. Typical stress-strain curves for several types of these sheet materials have been reported in literature (Young 1981).

The deformation of HDPE beyond yield point is through yielding as shown in Figure 1. This phenomenon is used for fibres for drawing purposes known as necking and lead to increase in strength and decrease in elongation. In this case, there is sudden reduction in the diameter. In case of films similar situation is observed and result into a decrease in the width. In case of uncontrolled deformation in actual field conditions, the thinning may not be uniform across the width of the sheet and may have areas of stress concentration leading to failure. Another factor of relevance is the effect of tangential stress combined with in planer stresses. For tangential stress, if the material deforms beyond yield then it continues to reduce in thickness till failure. This is a typical deformation in a puncture test. The useful deformation is, thus, limited to the yield point i.e. around 5%, although the elongation at break may be 500%. This is a significant limitation of these sheets. The yield point for other polyethylene based sheets like LLDPE extends to around10%.

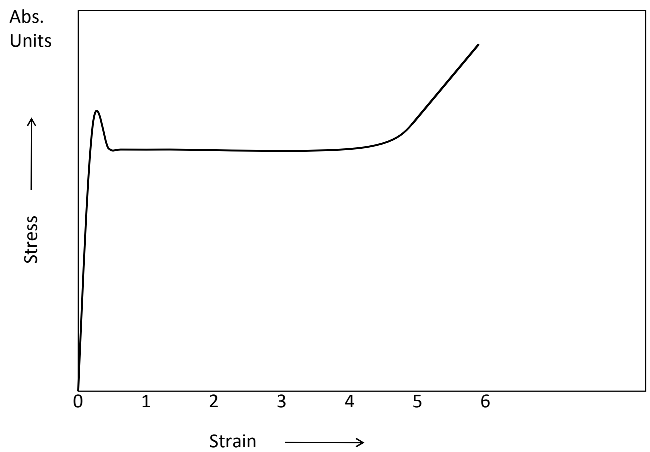

Figure 1. Typical Stress-strain curve of HDPE

1.2 PVC Geomembrane

These PVC samples were field tested by placing them in a pond at Port Blair for around eight months as shown in Figure 2. A very significant level of algae is generated in a pond with these sheets only, which could be related to leaching out of plasticizer. The question of release of plasticizers is vital for PVC as it containments water and also changes the property of the PVC.

Figure 2. Silpaulin PVC Geomembrane tested in a pond at CARI Port Blair

2. SUPERIOUR GEOMEMBRANE: A MATERIAL APPROACH

Thus, it is important to look for alternate materials for geomembranes with superior properties. Let us first consider the general requirements of a geomembrane sheets. The most critical of these is the puncture resistance. This is for the fact that with lower puncture resistance, undulation in the sub grade may lead to catastrophic failure. Typically minimum values of Puncture resistance (ASTM D4833) are in the range of 250 N (~ 60 lbf.) and the preferred value should be above around 500N to account for safety factors. Similarly, the minimum value of trapezoid tear test values (ASTM D4533) are in the range of 220 N (~ 50 lbf.). This should be combined with large elongation of these sheets before yield to account for settlement. These values range from ~5% for HDPE to 15% for fpp. Additional elongation beyond yield is preferable to account for symmetrical settlement beyond yield. Materials like EPDM and PU which are rubbery in nature and thus do not show typical yield behaviour and have superior conformability with rough sub grade as compared to HDPE.

To be able to find a superior solution for these sheet materials, let us reconsider HDPE sheets. From a material point of view, these sheets are homogeneous or isotropic in character. Crystallisable polymeric materials in sheet form could be made anisotropic by stretching in planer directions i.e. machine direction and transverse direction. These are referred as biaxial sheets and such sheets of PET, PP and HDPE are commercially available. These are capable of taking high stresses in the planer directions, while these are highly deformable in the tangential or out of plane directions. This is an advantage, as we do require easy deformability for conformity to the sub grade and requirement of smooth sub grade may be reduced. For these oriented systems like biaxial films the values of thermal expansion coefficient (α) could be made small. This is because during heating, there is a combination of contraction due to orientation and expansion due increased segmental motions, and the net result could be a low value of 'α'.

3. A NEW CLASS OF GEOMEMBRANE

There are a number of alternate methods of producing anisotropic sheets. PET scrimped reinforced PP sheet is an example of planer anisotropic sheets. We report development of a range of such anisotropic sheets. These are poly olefin based sheets and are typically stabilised for UV radiations. These sheets have thickness in range of 0.5-0.7 mm and have puncture resistance in the range of around 500-600N. The extension to break is in the range of 40-80%. The yield strains are approximately 12%. A typical stress-strain curve of these sheets is shown in Figure 3.

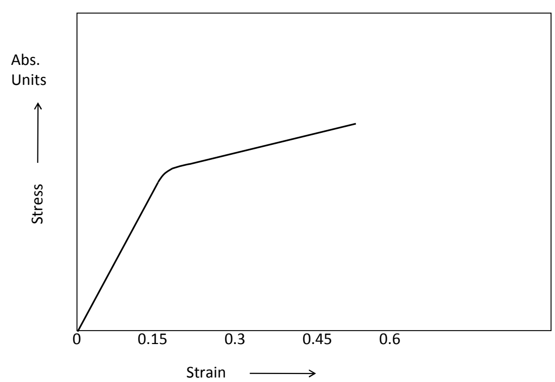

Figure 3. Typical Stress-strain curve of IITD sheets

It has excellent stress crack resistance due to the intrinsic nature of the resin. As the thickness of these sheets is low, it is very ductile and has good conformability. A comparison of bending rigidity of sheets of thickness of 1.5 mm (say HDPE) to 0.6 mm will give a very high multiplier factor of approximately 6. This value may actually be around 4 due to differences in the tensile moduli of these sheets in the planer direction. Thus the conformability of the thinner sheet will still be significantly superior to the thicker one. Being very low thickness, these sheets could be suitably folded for transportation. Further, these sheets could be folded during the placement to take care of the contours in the sub grade. Further these sheets could be maintained in the fold shape indefinitely, without resulting in stress crack. This permits contours on the sub grade and thus reducing the requirements of its preparation.

These sheets could be factory welled to fairly large dimensions thus reducing the field welding and thus superior performance. Additional requirements of field welding of these sheets could be met by standard heat wedge method. Further, this reduces the time for implantation of the project. Reduced thickness may permit the possibility of live installations. One interesting observation relate to the recovery on deformation of these sheets beyond yield point. Samples are loaded to say 60% of the breaking load as a tensile piece and then the load is removed. The sample recovers almost 80% to its initial length. A stress relaxation experiment on these samples was carried out at 20% of the breaking load as shown in Figure 4. There is an initial decay of load to around 30% in a few minutes and there after further decay slows down in the range of 50% of the initial load.

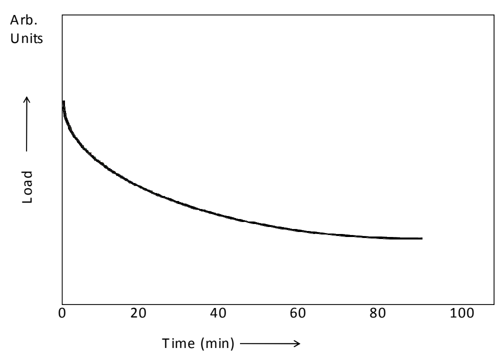

Figure 4. Typical stress relaxation curves of the sheet material

This is quite remarkable observation as on tensile loading, after initial stress decay the sample continue to hold the stress for quite a long time. For a wide width sample in actual field with multi axial stresses, the stress could get distributed across the area of the sheet. Thus, the chance of thinning a sample from select places is reduced even beyond the yield point. In contrast, for HDPE sheet, beyond yield point, there will be thinning of the sample at select places having stress concentration. These samples were installed at several locations including at IIT Delhi are shown in Figure 5.

These tests are going on for last several years. The samples are tested regularly from the pond for testing. A set of samples tested after three years showed no change in the strength and elongation percentage at break. A part of the sample was left exposed to the environment i.e. without soil cover, also showed no change in properties. A flat sample was used for placing in the pond and sample was folded at the corners to take the shape of the pond and sample remained in the folded state. This did not adversely affect the performance of the material with regard stress cracking, mechanical properties and the resultant water seepage control. Another observation of these samples relate to thermal expansion coefficient, which is less than 10^{-4}/ºC in the temperature range from 20º to 80ºC, and these low values improves the performance during variation of environmental temperature.

4 SUMMARY:

HDPE sheets are subject to stress crack and this intern requires a smooth sub grade. The thickness requirement of HDPE is around 1.5mm for adequate puncture resistance and but these do not conform to the sub grade except with smooth sub grade. Further, these sheets require elaborate mode of transportation and installation. These sheets being available in defined width, requires large field sealing. All this adds to a significant project cost. PVC use is increasingly being denied due to its known harmful effects. We have developed geomembranes with thickness of around 0.6mm. Being low thickness, these

Karjat Maharashtra

IARI, New Delhi

IIT Delhi before filling

IIT Delhi after filling

CARI, Port Blair, with tile cover

CARI, Port Blair, without cover

Figure 5. Photographs from different locations for evaluation of the sheet material

conform to the sub grade easily, requirement of the sub grade is not as stringent, could be folded during transportation and installation. Tests carried out at several locations confirm observations on seepage control and ductility. The samples tested after three years shows no change in mechanical properties. The stress-strain curves do not show the typical HDPE behaviour. In typical stress relaxation behaviour, significant level of stress is present even after initial decay. This helps in even stress distribution and thus the chance of thinning on yielding is reduced.

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