Managing Wrinkles, Bridging, and Ballasting During Geomembrane Installation

Ian D. Peggs
I-CORP INTERNATIONAL, Inc., USA (Icorp@geosynthetic.com)

ABSTRACT: There have recently been a number of geomembrane liner installation projects involving ponds and dams where concern has been expressed about the occurrence of bridging, wrinkles, wind uplift, and associated ballasting. For instance most liner installation projects state that there shall be no bridging in corners or at the toes of slopes. In locations where there are wide swings in diurnal temperature and daily temperatures bridging can appear and disappear. Is it important that bridging be removed if it occurs at the lower installation temperatures when pond filling will occur at higher temperatures and service temperatures will be higher when no bridging is observed? Should we require no bridging over a specific temperature range? Is bridging worse than an area of repair extrusion welds? Can bridging be resolved by ballasting the liner until it touches the ground? For all materials? How do we repair wrinkle-type bridging along a seam?

At the high end of installation temperatures wrinkles can occur. At what size/geometry do they become unacceptable? Height more than twice the width? When they can flop over? How do we repair wrinkles? Or how do we prevent them forming in the first place? On steep slopes and walls geomembranes expand and excess material travels downslope, but does not contract back upslope during lower temperatures. How many thermal cycles should we allow before removing the wrinkle and repairing the liner? Can and should we avoid horizontal extrusion seams at the toes of slopes?

A more specific wrinkle problem occurs on dams where the wrinkled liner is to be covered by about 100 mm of concrete. What is the maximum size of wrinkle that can be allowed to prevent stress concentrating notches initiating cracking of the concrete?

Ballasting can clearly be used to prevent/minimize movement of the geomembrane both laterally and vertically. Typically, when ponds are to be empty as a part of their operating cycle ballast unit weights and their distribution are defined by the project engineer. However, this is typically to prevent wind uplift rather than to manage expansion (wrinkles) and contraction (bridging). But who is responsible for ballast placement during liner installation? Certainly the installer is responsible for ballasting to prevent the liner from blowing away altogether, but is the installer, the engineer, or are both of them responsible for ballasting for the management of wrinkles and bridging?

One area where the engineer typically does not assume the responsibility he/she should is in the specification of the amount of compensation to be built into the liner between fixed points subject to contraction, remembering that the geomembrane should function solely as a barrier and not as a load-bearing member of the lining system.

General contractors take note, and hear European liner experts present their opinions on these installation details that can only improve the lifetime of geomembrane lining and containment systems.

Suggested Practice in USA for Geomembrane Wrinkles in Bottom Liners for Waste and Mine Stacks

Richard Thiel
Thiel Engineering, USA (Richard@rthiel.com)

ABSTRACT: When observing bottom liner construction in waste or mine repositories, one question typically facing CQA personnel in the field is "How big, and how many, wrinkles in the geomembrane are allowable at the time of covering?" In the USA, and many other countries and locations around the world, the answer given in the specification is either not clear, or clearly not enforceable. Consider, for example, the following statements from the document: "Waste Containment Facilities Guidance for Construction, Quality Assurance and Quality Control of Liner and Cover Systems (Second Edition)" (2007) by Koerner and Daniel as published by the ASCE Press:

- Underlying geosynthetic materials should have all folds, wrinkles, and other undulations removed before placement of the overlying geomembrane.

- The geomembrane must be flat when it is backfilled.

By virtue of the state-of-the-practice in North America, and more of the rest of the world except perhaps for Germany, these statements are virtually ignored. When such statements are included in the specifications, they in fact disempower the role and authority of the CQA Organization because they are statements that are clearly not followed, which makes enforcing other provisions of the contract more difficult.

Perhaps other vague statements are used, such as "Avoid excessive wrinkles and compensate for stress bridging…Excessive wrinkles and stress bridging will be removed and repaired…" What does that mean?

For the past 15 years the author has been quantifying the "allowable wrinkle height" at which point covering operations over the geomembrane must be stopped. This height is in the range of 50-75 mm. Having a specific non-zero value in the specifications became a practical enforceable measure, and very commonly shut down covering operations between the hours of 9:30 a.m. and 6 p.m., depending on the actual weather conditions. In the end, controlling wrinkles in geomembranes is all about adjusting the work to suit the ambient temperatures for any given time of day.

The original basis of the 50-75 mm allowable wrinkle height was based on observation and judgement, but little else. Recent field and laboratory studies performed under the leadership of Dr. Kerry Rowe of Queen's University in Canada have now corroborated the author's initial judgment by providing quantifiable benefits for allowing the onset of a maximum wrinkle height of 50-75 mm at the time of covering. The studies cover two specific areas: maximum interconnected wrinkle length and GCL overlaps. The criteria addressed by these two issues is controlling advective leakage rates.

Wrinkles, Bridging, and Ballasting Geomembrane During Installation

Garcia Girones, Mario
Atarfil, Spain (mgirones@atarfil.com)

Ozdemir, Adnan Berkay
Atarfil, Turkey (bozdemir@atarfil.com)

ABSTRACT: This article seeks to establish a series of reflections on what may be the best treatment of the effects linked to changes in temperature and wind during the installation of a geomembrane.

It is conceivable that a manufacturer of geomembranes has little to teach to an installation company on many aspects related to the installation. Of course, it is the case.

However a manufacturer can have a very deep understanding of the behavior of manufactured materials which together with the permanent contact maintained with hundreds of installation companies and in very different environments, with Project Designers and Project Managers from very different backgrounds and experience, allow us to store a lot of information that is which gladly want to share.

1 INTRODUCTION

A polymeric geomembrane provides a behavior to temperature changes, basically linked to their crystallinity.

Perhaps the most used of all, the high density polyethylene HDPE, is precisely the one with the highest percentage of crystallinity (> 50%) and this fact is responsible for all the problems that arise during installation caused by temperature changes and the expansions and contractions that appear as a result of them. Crystallinity provides to HDPE relevant chemical resistance and UV durability, which in turn are justifying its widespread use in waste safe containment applications and large water storage.

In contrast, it offers a high coefficient of linear expansion, what it forces the installer, among other concerns, to have temperature parameters under control.

As an introduction we will reflect on two ideas.

• Changes in temperature generate expansion and contraction. Consider a piece of material 100 lm length experiencing a temperature increase from 20°C, that is the ambient temperature within the factory, to 40°C for example.

Expansion $\mathbf{\Delta = 100 \;.\; 2{,}15.10^{-4}.(40-20) = 0{,}43\ m = 43\ cm}$

• Exposure of the geomembrane to UV radiation increases more or less the temperature depending on the color, black being the maximum absorption, over thermal gap on the ambient temperature. This affection sometimes justifies that temperature of the geomembrane surface is 70°C or even higher. With the example of the previous case, there would be an extra UV expansion which should be added to the previous one.

Extra UV expansion: **Δ=100 . 2,15.10^{-4}.(70-40)= 0,645 m = 64,5 cm**

The sum of both gives an idea of the problem of expansions and contractions which logically has to face the Installer. They cause wrinkles, raisings and terrain bridging from support, effects that are the subject of this document.

2 DESCRIPTION, DEVELOPMENT AND CONSEQUENCES OF THE WRINKLE AND SEPARATIONS

It is logical to think that a wrinkle by expansion or a separation from ground support, will recover as soon as the temperature drops to the initial state. But this is not entirely true for two reasons:

• Because the geomembrane has its own weight and angle of friction at the interface support with its bearing and therefore, is capable of storing captive tensions. By this fact we know that it will not be the same a geomembrane lying directly on the ground to one that rests through geotextile.

• Nor is it the same, a slope geomembrane where the wrinkle of expansion by own weight shifts to the bottom and then must recover against gravity, to another geomembrane located in flat bottom where wrinkle recovery is immediate.

Based on the above two effects, the installer should be aware of the degree of expansion within the geomembrane panels throughout the day and thus try not to accumulate too many captive tensions at the end of the day, which will prevent to the geomembrane entirely recover wrinkles and risings.

If both remain, we must conclude that temperature control has not been adequate and we will have to study the influence of these in the implementation of the geomembrane to take the necessary corrective measures.

To finish raise the problem is to remember one last very useful concept to my judgment.

Anywhere in particular, room temperature evolves throughout the year. The end customer is who usually choose the time of installation of the liner, so that in fact this decision is conditioning the temperature range in which it will play out the Installer. Consequently we could have a temperature of "closing" of the Installation of the geomembrane which may be different from the average temperature of the place.

Thus, if we conclude the work in full winter season it is evident we could expect large wrinkles in summer and, conversely, if we close a work in summer, separations could be expected in winter.

Clearly the above hypothesis is set to geomembrane exposed. Otherwise if it is covered by the liquid or solid to store this temperature is determinative of the actual situation.

With these premises, the installer can choose to work at night in summer to lower the temperature of closing or search the hottest hours of the day in midwinter to raise it, but nevertheless can not work miracles.

3 POSSIBILITIES OF TREATMENT

There are different possibilities to face wrinkles and risings that considered not acceptable need treatment.

A wrinkle under the pressure of the liquid or solid to be stored is definitely an air bubble under the geomembrane and will not be detrimental to it when it could disappear in the process of loading and ground deformation support underneath. The factors are therefore:

• supporting soil deformability

• Soil support porosity, either naturally or by the inclusion of a drainage geocomposite. Even a drainage network at the bottom is a way for air to escape.

As a rule, the criteria for a wrinkle is not to be higher than 60% of its width, starting from where obviously it separates from its support. The idea of this approach is that the wrinkle never has available excess material so that when the liner is put into service can not form a loop of material that could be pinched and so that plasticized for the weight of the content.

There are methods to decrease the size of the wrinkle by using special geomembranes:

• With coextruded light-colored geomembranes, usually white or ochre, we are reducing by up to 70% the section of expansion by UV radiation, but nothing of the first section of thermal gap, and therefore the range of 40-50% the average size of wrinkle.

• Sometimes the use of textured geomembranes by the bearing face, significantly increases the friction angle on this interface reducing wrinkles by introducing captive tensions which is not always good measure.

The raisings have different treatment. Initially a bridging from ground support will involve more stress in the geomembrane when this is put into service.

However, just a slight calculation to show that the bridging should be very large for significant deformations in the geomembrane and also that these would be very far from the elongation at yield of it.

But it is clear that a separation is a captive stress and also is not very costly to repair.

4 WIND. PROVISIONAL AND PERMANENT BALLASTING

The wind is by far the biggest enemy Installer.

Geosynthetics are usually lightweight products and wind generate suctions passing through inclined planes or elevations when it has the opportunity to enter under a geosynthetic.

So, we talk about ballast against wind and within them, the provisional with bags during installation or the permanent one, with many other alternatives for the commissioning of the work. (See photos)

In my view it is very important to differentiate between ballast and anchorage, they are not the same.

A geomembrane anchor is the end finishing on the edge of it. A ballast is an extra weight that is placed along its route to avoid raisings. For this last reason a ballast must never entail the loss of continuity of a geomembrane.

A ballast is also a measure against wind and it will never serve to combat a wrinkle or a bridging.

Geomembrane bridging issues in lagoon based anaerobic digesters

Michael Flynn
FLI Group, Ireland (mflynn@fli-group.com)

ABSTRACT: The geosynthetic installation challenges created by such designs are many. The interface between a vertical wall, a steep embankment with either sharp or curved corners and a flat floor create both bridging and wrinkling problems which have to be solved. Concrete structures in and pipe penetrations through the embankment sides add to the complexity in terms of ensuring a high quality installation. A further added challenge is created when the installation is going on in winter as opposed to the summer months as the thermal coefficient of the selected geomembrane comes into play and can lead to welding challenges.

The key to delivering such projects successfully is in the detailed planning and scheduling of the various elements of the works and having a clear understanding of the sequential steps that must be adhered to in order to enable the geomembrane to find its own level so to speak, before it is firmly fixed in place. Managing temporary ballasting during geomembrane installation is a critical element of delivering such projects.

Bearing in mind that there may be several layers of geosynthetics involved in such applications, the temporary anchoring of such materials is complicated. With such smooth surfaces interfacing with the geomembrane during the entire installation period, there is a high risk of the geomembrane slipping as the permanent mechanical fixing at the top of the concrete wall is one of the last elements of the works to be completed in such installations, otherwise the bridging and wrinkling cannot be managed.

A detailed but not an exclusive list of considerations that a project manager and the installation supervisor on such a project have to consider and plan for and around each day include: weather including wind, access to the working face, sequencing of the installation of the geosynthetic layers, preparation and placing of the individual geomembrane and geosynthetic panels, temporary ballasting including water and permanent ballasting, risk of bridging of the geomembrane at the interface of the concrete wall and the embankment and between the embankment toe and the floor, concrete structures and pipe penetrations and fixing to both, geomembrane slippage risks, ensuring that there is sufficient surplus material at the wall level to manage both bridging and wrinkling while ensuring that there remains in place sufficient material to be anchored permanently on the outside of the concrete wall cap.

The importance of the choice of the products

Paul Guinard
SOPREMA, France (pguinard@soprema.fr)

ABSTRACT: The design of any new project shall include parameters such as, of course, the nature of the product to contain but also the role of the lining system, the features of the site (including the climatic conditions and sun exposure), the geometry, the way installation will be performed and the conditions in use, to adequately select the geosynthetics. It is only by adequately addressing all these points that one is able to choose the appropriate products (geomembranes, geotextiles or geocomposites, ballasting materials, etc).

Based on this analysis, the choice of the most adapted geomembrane will limit the risk of damages due to thermic variations. In fact, the level of expansion/contraction under variation of temperature depends of the nature of the geomembrane, its surface structure, its color and, of course, is the inclusion of a reinforcement or not. The selected geomembrane will impact by these features the potential apparition of wrinkles or bridging or not . As an example, where a black homogenous HDPE may exhibit a significant number of wrinkles, a white reinforced PVC will not exhibit dimensional variations. The choice of the appropriate geomembrane is thus of the primary importance.

When it is mandatory, for example in relation with chemical resistance to use a geomembrane which nature will lead to important thermic variations, it is necessary to find solutions to limit the apparition of disturbances during installation as during the in use period. These solutions can be found with the use of surface treatment (structure or clear colors), by thermic protection or by specific methods of backfilling taking into account the risk of daily temperature variations.

Once the geomembrane has been selected, it is important for each project to estimate the risk of damages that may result from thermic variation. For most projects, this is of no importance if there is no mechanical stressing of the geomembrane.

As an example, if the site presents high risks of climatic variations or wind, it can be proposed by the installer to realize anchorages or to ballast partially or totally the geomembrane. These measures have to be done during the installation in order to avoid any tension on the product which may create disturbances.

In conclusion, it is necessary to choose the right geomembrane for each project. In case the geomembrane will experience problems due to thermic variation and damages appear, various solutions can be found to limit the impacts.

Wrinkling and Bridging – Can it be kept to a minimum? Best practices

Catrin Tarnowski
GSE Lining Technology , Germany (ctarnowski@gseworld.com)

ABSTACT: Wrinkling does occur - but can it be minimized? There are a lot of good cases with laying flat liners all around the world. Therefore, some most do better than others. Thus can we not accomplish the same on more projects and learn from each case?

Not only wrinkling but bridging also has to be addressed. Is it the correct approach to cut the liner in case of bridging and to install an additional patch in such an area? When is bridging really an issue? It is an issue specifically in cold climates and with inferior liner quality. In many cases the liner has the ability to relax and to overcome the bridging.

Some good practices to overcome the problems are summarized below:

The liner property:
The thermal elongation is a reversible effect and can be controlled. Thus the question is to design with additional slack or to design with anchoring and ballasting. Waviness and dimensional stability belong together. The more "frozen" tension is into the product, the higher the variance in dimensional stability - developing to waves when temperature changes do occur. If the dimensional stability is controlled liners keep flat or waves which occur can again disappear.

Color:
In case of hot climates a light surface color does help to reduce wrinkling caused by thermal elongation.

Design:
Large liner areas are sometimes built with insufficient anchor design. If those areas are left uncovered, bridging and wrinkling will occur due to wind uplift possibilities, temperature changes and thus movement of the liner. Opposite to this there are also projects where utmost care is taken – for example large dam applications or pumped storage ponds - designs with intermediate anchoring keeping the whole liner flat. Are there enhancement possibilities for other projects as well?

Installation:
It needs to be considered that liner panels welded to each other shall have the same temperature to avoid wrinkling. Thus the panel just unrolled shall not be welded to that installed the prior day or one which has heated up for a while already. Diagonal waves and waves just in the weld area can be avoided by this.

Ballasting:

Shall ballasting be left to the liner installer only - or are there appropriate methods which can already be specified to keep the liner flat? The “Riegelbauweise “ = anchor bar method = is an installation procedure keeping the geomembrane completely flat.

There are a variety of measures to keep liners flat and some of them would not even influence installation progress. Why not better utilize them?