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Geomembrane systems in The Netherlands and abroad
risks and lessons-learned

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Figure 1 - *Slope failure by stability problems after finishing the geomembranes caused by external water pressures versus insufficient backfill levels [Genap]*

Table 1 - Risk assessment based on project phases

Phase	Risk issue
Design	• Geomembrane material selection. • Maximum design water levels during construction and completion stage. • Feasibility of local excavations within the geomembrane. • Presence of environmental pollutions. • Stability of slopes/retaining structures, especially in case of stacking several geotextiles. • Feasibility re-use local excavated material around the geomembrane. • Connection type/detailing to structures.
Construction	• Quality of welding (on site/off site). • Weather conditions (rain, sunlight, UV-radiation, frost, wind conditions, etc.). • Installation damage by handling personnel, equipment or vandalism. • Stability problems caused by external water pressures, loads, etc. • Suitability subsoil (i.e. subgrade) to apply geomembrane. • Backfill method and backfill material quality. • Local excavation within backfill material (drainage pipes, sewage, etc.).
Completion and Maintenance	• Damage by a calamity with fire or aggressive liquids. • Gradual damage by external pollutions from the containment or adjacent sites. • Damage/puncturing geomembrane by human activities (drilling, digging, foundation works, etc.). • Lack of maintenance to drainage and sewage systems.

1 Introduction

The success of realizing a watertight and durable geomembrane construction depends on a lot of factors. In terms of risk analysis we can divide the construction process in three important stages:

1. Design stage
2. Construction stage
3. Maintenance stage

A technical risks assessment based on these project phases is given in table 1. The common denominator in all three stages will be the limited knowledge of geomembrane systems, material properties and procedures. A lack of knowledge means that potential risks are not being recognized at an early stage, resulting in a possible major impact. An example of severe damage by a slope failure is given in figure 1.

2 Risk assessment

Direct or gradual developing damage of the geomembrane can cause leakage and if not controlled total failure of the construction may occur. It shall be evident, severe damage or total failure should be avoided by recognizing the risks at an early stage.

For risk management technical risks are to be classified. Each identified risk can be rated to the occurrence probability and impact effecting costs and time. Also precautionary actions and residual risks are assessed. For obtaining an active risk management during the building

Abstract

This article gives an overview of risks and lessons learned about geomembrane constructions in The Netherlands. The aim of this paper is to emphasize an integral approach during the entire process and importance of acknowledging quality risks to all involved companies. The success of a watertight and durable installation will depend on an integration of design aspects, materials, construction issues and quality assurance. To avoid risks during lifetime attention shall be given to proper restrictions, maintenance issues and monitoring of leakage/durability. The article presents examples, to illustrate risks and lessons learned.

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process, it is important the risk assessment is lively and updated, as risks can change during the construction process. For example the occurrence of new risks or change in classification based on new circumstances.

3 Evaluation of risks

In the paragraphs below 5 issues are described more in detail and illustrated with pictures from engineering, construction and inspection practice.

3.1 Welding quality

Welds and seams can be designated as the weakest points of a geomembrane. According to *Scheirs 2009* seams are regions with high stress concentration due to defects in seaming operations, the heat-affected zone (HAZ) and residual stresses. The welding quality depends on a lot of factors, knowing the presence of contamination on the geomembrane welding surface (soil/moisture), weather conditions, workmanship of the personnel involved, material selection, and proper inspection. In figure 2 to 3 several examples are given of defects designated at welds and seams.

Obtaining a high quality weld will require serious craftsmanship and experience. Factors to take into account to ensure welding quality are weather conditions (humidity, low and high temperature, abrupt changes of temperature, etc.). Wind, rain and pollution by means of mud or sand (blown by the wind into the joint) will also influence the quality of the welding. Also good maintenance of the welding machines is important to insure proper welding. The machine shall be cleaned after usage and it shall be free from any pollution to the heating and pressure rollers.

3.2 Suitability excavated and re-use soil material

A lot of geomembranes are used and installed as underground barrier in the subsoil. This will imply excavations and backfill with soil/stone material, resulting in damage risks to the geomembrane. Based on electrical leak location surveys performed by *Nosko et al. 1996* it was assessed that about 20% of the leaks occur at seams (improper welding), but over 70% (!) of leaks occur when the liner is covered by soil or stone. Based on these values and practical experiences the quality of groundwork's is showing a factor which is under-estimated in a lot of projects. The covering operation has to be seen as a very critical stage for the geomembrane. Related to this issue many examples in projects are known, observing unacceptable circumstances during the excavation or covering stage (see figure 4).

Figure 2 **-** *Example of poor nip roller tracking in a HDPE wedge weld [Scheirs]*

Most desirable material to use around a geomembrane will be clean sand suitable as infrastructure foundation, according values of the standard contract specifications used in the Netherlands (CROW, 2015). Furthermore, the soil material adjacent to the geomembrane

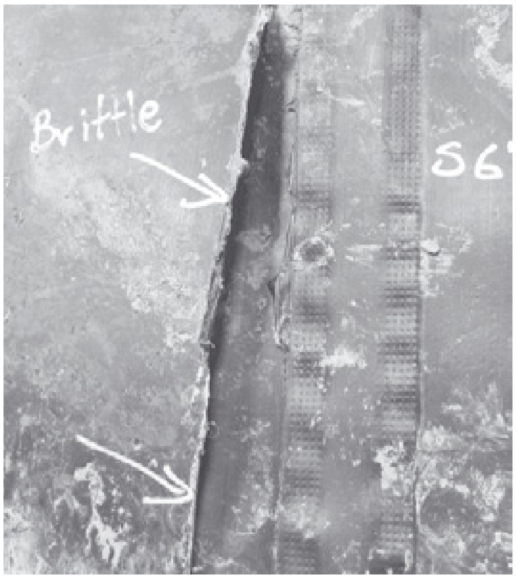

Figure 3 **-** *Example of stress cracking on edge of overheated weld [Scheirs]*

Figure 4 **-** *The presence of sharp/big stones without protective geotextiles will significantly increase the risk on damaging the geomembrane [Gerritsen]*

Figure 5 *- Example of proper installation using a protective non-woven geotextile at the subsoil and topside of the geomembrane, working sequence with excavation works and installing method at large slopes [Gerritsen]*

shall be free of admixtures with sharp stones, desiccated subgrade, boulders, concrete blocks, tree roots, construction waste (wood, beams, steel rebar, nails, piles, drainage or sewage pipes, foundation materials etc.).

The subsoil on which the geomembrane will be installed needs also to be clear from sharp subjects which may puncture through the geomembrane. Measures can be taken for additional protection of the geomembrane. Since 2012 state-of-art geomembrane applications in The Netherlands are provided with protective non-woven geotextiles on both sides (bottom/above), see figure 5. In case of non-woven protective geotextiles attention should be given to the material type (polypropylene / polyester), minimum density, dynamic cone drop resistance and static puncture resistance. Applying a good quality non-woven will reduce the risk of perforations of the geomembrane significantly.

3.3 Stability of slopes, backfill and retaining structures

To ensure a safe situation during the design and building process a lot of attention should be paid to the stability of slopes, backfill and retaining structures. In case stability is not assured, this will have major effects to the project. In case of (geotechnical) slope failure adjacent to geomembrane constructions damage to sealing is almost inevitable. Worst case this can result to a total loss of the geomembrane sealing and major effects to costs, planning, etc.

An important attention point is the presence of groundwater affecting the stability of slopes and retaining structures. Groundwater levels and overpressures used for submerging geomembranes can have a significant effect on the stability of geomembranes and the deformation of retaining structures, used in cases of limiting space by vertical boundaries and fixations of geomembranes *[Gerritsen, et al., 2014]*. The conditions of groundwater are of major importance, and also the proper working of dewatering devices (deep wells, filters, etc.). In case the dewatering devices (pump generators) fail, a quick build up of water pressure can occur, this can cause severe problems to the stability of geomembrane construction. Also excessive rainfall can lead to problems by rapid increasing groundwater levels, exceeding the design water levels or overflow of the working area. Several cases are known of groundwater conditions which damaged the excavated slopes or already installed geomembrane structure during the construction process (see figure 6).

3.4 Installation damage

During the construction stage the geomembrane remains very sensitive for damage, knowing it can be exposed to all influences from transport, handling, weather influences, etc. During transportation and off loading full rolls may be damaged by means of insufficient packaging or due careless handling by drivers of fork lifters or cranes. Another cause is the impact of heavy equipment used on the construction site, causing mechanical damage by cranes, trucks, dozers (see figure 7).

3.5 External influences after completion

After completion of the installation it may seem

Figure 6 **-** *Geomembrane 'whales' due to uplifting water pressure below the geomembrane related to improper backfilling levels [Genap]*

Figure 7 **-** *Mechanical damage to a geomembrane anchoring trench by using wrong backfilling equipment (crane) and less instructed personnel on site [Gerritsen]*

that the geomembrane is save for lifetime. However, during the entire lifecycle all kind of influences can harm a geomembrane. Special influences to be listed are:

1. Damage of geomembrane during lifetime by a calamity with fire or aggressive liquids.
2. Gradual damage by external pollutions from adjacent sites.
3. Damage/puncturing geomembrane by human activities (drilling, planting trees, etc.).
4. Lack of maintenance to drainage and sewage systems.

Damage/puncturing geomembrane by human activities is a likely cause for damage. The existence of a barrier is often 'forgotten'. Examples can be drilling, digging and foundation works.

4 Conclusions

The success of realizing a watertight and durable sealing will depend on a good understanding of design aspects, materials and on quality assurance during the building process. Risk determination shall be in cooperated in the total process. In terms of risk analysis we can divide the construction process in three important stages: the design, construction and maintenance stage. The common denominator in all three stages mentioned above will be the limited knowledge of geomembrane systems, material properties and procedures. A lack of knowledge means that potential risks are not being recognized in an early stage resulting in a possible major impact to final harming the integrity of the geomembrane construction during the building process or even years after completion.

An integral perspective is necessary to obtain a durable geomembrane construction. For the construction stage it can be stated that open and active communication between all involved parties (client, contract manager, supervision staff, engineer, main and subcontractors, QA) is of major importance. Special attention shall be given to the interfaces of different disciplines by main and subcontractors.

The installation of geomembranes as underground barrier in the subsoil will imply excavations and backfill with soil/stone material, causing a strong interface with damage risks to the geomembrane. The covering operation has to be seen as a very critical stage for the geomembrane. Related to the high risks of covering, the best standard should be geomembranes to be embedded by non-woven protective geotextiles at all times. Applying a good quality non-woven will reduce the risk of perforations of the geomembrane significantly by external influences as well during the construction stage as well after completion.

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