LIQUID BOOT FOR BROWNFIELD CONTAMINATED SITES

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INTRODUCTION:

Development of contaminated sites often requires the use of geomembrane to stop volatile organic contaminants, existing in the soils, from penetrating into the newly constructed buildings, very possibly impacting building’s air quality.

The Resource Management Act defines contaminated land as land with hazardous substances in or on the land that are reasonably likely to have significant adverse effects on the environment (including human health).

Contaminated sites in New Zealand can be created as a result of industrial, domestic, or agricultural activities. Manufacture, storage and use of pesticides, fertilizers, coal and gas production, mining, timber treatment and sheep dipping, service stations and mechanical workshops - only short list of traditional New Zealand activities, often leading to significant contamination of land not only in immediate proximity to source of contamination, but with ability of contaminants to migrate sometimes quite a long distance, surrounding areas as well.

Brownfields are abandoned or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contaminants.

In city planning, brownfield land (or simply a brownfield) is land previously used for industrial purposes or certain commercial uses that may be contaminated by low concentrations of hazardous waste or pollution and has the potential to be reused once it is cleaned up. Land that is more severely contaminated and has high concentrations of hazardous waste or pollution, such as a Superfund or hazardous waste site, does not fall under the brownfield classification.

There is a range of geomembranes used to protect new developments from intrusion of harmful gases into buildings and structures. Complex considerations have to be undertaken with application of each type of geomembranes, including nature and concentration of contamination, purpose and structural design of the buildings, soil properties, as well as nature and physical characteristics of the proposed geomembrane itself.

Most commonly HDPE, or High Density Polyethylene, very well known for its excellent resistance to wide range of contaminant chemicals, it is used as a gas proofing geomembrane. HDPE has a relatively low cost and, in combination with its chemical resistance, and mechanical characteristics, makes it the simplest choice for specifiers and property owners. However, the process of installation can be lengthy, intensive, and difficult, and sometimes it makes it impossible to guarantee structure’s protection because it is simply impossible to make secure joint between geomembrane and structural elements. Generally speaking, HDPE is cheaper for large, flat installations, as in the case of industrial built-ups. Our goal is to show that other system, Liquid Boot can be applied in situations, where traditional
geomembranes are not performing well, and often Liquid Boot is less expensive where the complex building structure needs to be built, with number of footings, penetrations, stairs, etc.

Lack of attention to construction details or specific details in construction documentation can lead to huge variations from the geomembranes quoted costs, big increases in installation time, and sometimes resulting in stressful disputes.

Liquid Boot is the industry standard in gas vapour membrane technology and is designed to eliminate vapour intrusion into structures built on Brownfields or any other contaminated sites, i.e. former landfills and manufacturing facilities, former dry cleaners and gas station sites, etc. Liquid Boot is chemically resistant and seals all vapour intrusion pathways, preventing contaminated soil vapours from penetrating the slab. Liquid Boot Gas Vapour Barrier and the Liquid Boot GeoVent ventilation system is the most widely known and used vapour intrusion mitigation system used today. Around 5 million square meters of Liquid Boot has been installed under Hospitals, Schools, Libraries, High-rise Commercial and Residential Buildings, Single Family Housing Developments, and Major Public Works Projects throughout the United States, Canada, Australia, New Zealand and Asia. Liquid Boot truly is the global leader in cold-spray applied gas vapour membrane and venting technology. No other membrane technology has been tested as extensively as Liquid Boot or has the long standing success history. Liquid Boot’s introduction in to the market made it possible to speed up the process of installation, but as well made the process of project’s costing more accurate and predictable, as well as reduced chances of membranes failure, due to absence of any joints and welds and existence of unique and comprehensive testing procedure. Other geomembranes of similar nature, while may be looking more attractive price wise, however cannot guarantee geomembrane’s integrity with the same level of confidence, as Liquid Boot.

Not every sprayable membrane can be used for gas and vapour proofing. Not every waterproofing membrane can be used for gas proofing. The purpose of this exercise is to show why Liquid Boot should be a first choice for protection of buildings and structures against intrusion of harmful gases.

BACKGROUND

Landfill gas, originating from the anaerobic biodegradation of the organic content of waste, consists mainly of methane and carbon dioxide, with traces of volatile organic compounds. Pressure, concentration and temperature gradients that develop within the landfill result in gas emissions to the atmosphere and in lateral migration through the surrounding soils. Environmental and safety issues associated with the landfill gases require control of off-site gas migration.

Landfills are the second-largest single human source of methane emissions in the United States, accounting for nearly 23 percent of all methane sources. Uncontrolled landfills also emit nonmethane organic compounds, which includes volatile organic compounds (VOC) that contribute to ozone formation and hazardous air pollutants that can affect human health when exposed.

“Landfill gas is generated during the natural process of bacterial decomposition of organic material contained in landfills. A number of factors will influence the quantity of gas that landfill generates and the components of that gas. These factors include, but not limited to the types and age of the waste buried in the landfill, the quantity and types of organic compounds...
in the waste, and the moisture content and temperature of the waste. Temperature and moisture levels are influenced by the local environment." Therefore, as we can see, New Zealand climate provides landfills with sufficient amount of heat and moisture to produce volume of landfill gas, worth of addressing as a significant issue, when considering building on close proximity to closed or operational landfills and other brownfields. Even when immediate readings of the gas in the soils do not record harmful concentrations at the design stage, the risk still exists due to ability of landfill gases to migrate far beyond immediate boundaries of landfills.

Most subsurface migration of landfill gas from landfills to other areas within the landfill property or outside the landfill property occurs at older, unlined landfills and landfills with ineffective clay liners, because there is minimal barrier for lateral migration.

Brownfields are not limited only by the landfills. Brownfields can be created on a place of former manufacturing facilities, service stations, former landfills, former dry cleaners, former MGP sites, former tank farm etc. Brownfield even can be created, if, for example, contaminated deposits from sea or lake bottom have been taken on the shore and left here for some time. If soil hasn’t been contained in an appropriate way, contaminants can migrate to lower levels and in lateral direction, extending brownfield’s boundaries. Brownfields can be created in places like former timber treatment plants, agricultural chemicals storage facilities, military ammunition storage facilities, etc.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>AT WHAT CONTAMINATION LEVELS DO VARIOUS AGENCIES REQUIRE A MEMBRANE?</th>
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<tbody>
<tr>
<td></td>
<td>Midwest Region Michigan DEQ</td>
</tr>
<tr>
<td>Benzene</td>
<td>13,000 ppb</td>
</tr>
<tr>
<td>TCE</td>
<td>11,000 ppb</td>
</tr>
<tr>
<td>PCE</td>
<td>N/A</td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>28 ppb</td>
</tr>
<tr>
<td>Methane*</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*50,000 ppm is considered explosive  
** outside methane zone

Some may think “Why would I need to build on a contaminated land?” However, brownfields are often found in central parts of town, where in the past they used to be a place of a local service station or an engineering shop. Redevelopment of these sites can be beneficial for local communities by providing them with affordable housing, or helping in the way of adopting local services to ever-changing economical and sociological situation in the area. Very often redevelopment of brownfields can help communities in preserving historic or locally significant structures. Many are old factories, train stations, schools and hospitals that could be adaptively reused. Preserving such historic structures helps maintain a community’s identity and unique architecture, and converting factories and warehouses into loft apartments is a trend that has proven to be profitable.  

Another good reason for redevelopment of certain brownfield sites is to improve local community morale and provide optimism that the neighbourhood is turning around, and even
may stop people from leaving the area. Abandoned buildings and vacant lands contribute to
the perception that a neighbourhood is deteriorating. Redevelopments can even attract
neighbourhood investment.³

Brownfield sites development often requires the use of contaminant vapour barrier, or gas
proofing geomembrane, to inhibit volatile organic contaminants remaining on-site from
migrating into newly constructed buildings, potentially impacting indoor air quality.

Table 2 IMPORTANT PHYSICAL PROPERTIES OF A MEMBRANE

<table>
<thead>
<tr>
<th>Chemical Resistance Testing</th>
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</thead>
<tbody>
<tr>
<td>Permeability</td>
<td></td>
</tr>
<tr>
<td>- Methane Gas</td>
<td>ASTM 1434-82</td>
</tr>
<tr>
<td>- Hydrogen Sulphide gas permeability</td>
<td>ASTM D1434</td>
</tr>
<tr>
<td>- Benzene, Toulene, Ethylene, Xylene</td>
<td>ASTM D543, D412, D1434</td>
</tr>
<tr>
<td>- Gasoline, Hexane, Perchloroethylene</td>
<td>ASTM D543, D412, D1434</td>
</tr>
<tr>
<td>- Sodium Sulphate (2% water solution)</td>
<td>ASTM D543, D412, D143</td>
</tr>
<tr>
<td>- Acid exposure (10% H₂SO₄ for 90 days)</td>
<td>ASTM D543</td>
</tr>
<tr>
<td>Weight Change</td>
<td>ASTM D6392</td>
</tr>
<tr>
<td>Diffusion</td>
<td>City of Los Angeles</td>
</tr>
</tbody>
</table>

| Strength Tests:            | ASTM D4068-88        |
| Bonded Seam Strength Test  |                      |
| Dead Load Seam Strength Test|                       |

| Aging Tests:               | ASTM E154-88         |
| Heat Aging                 |                      |
| Soil Burial                |                      |

| Coefficient of Friction Test: | ASTM D5321          |
| - Coefficient of Friction (geotextile both sided) |                      |

| Adhesion Tests:            | ASTM D413            |
| Tensile Bond Strength to Concrete |                      |

| Temperature Considerations: | ASTM D146, A742      |
| - Cold Bend Test            |                      |
| - Freeze Thaw Resistance    |                      |

Traditionally plastic sheet geomembrane materials, such as High Density Polyethylene (or
HDPE), as well as Flexible Polypropylene (known as FPP, or Permaliner), and other
materials were used as lining vapour barriers. The use of these types of materials, known for
their chemical resistance and durability, require labour intensive installation procedures
including cutting, seaming, bending and battening to the constructed building walls, and
testing. This installation process can be intensive, difficult, and costly when applied to
construction foundations with multiple penetrations (such as for piping and electrical
conduits). Very often a whole structural design of the constructed building needs to be
adapted to include vapour and gas proofing geomembranes. It makes sense if the building
foundations are designed to make it possible for the gas-proofing geomembrane installation
crew to operate plastic welding equipment and securely install sheet material. Multiple cuts and extra seams with considerable testing, plus the less than ideal attachment of the geomembrane to the foundation walls add significant cost to the overall geomembrane installation while it still can not guarantee a totally leak free membrane.

Seaming

In big installations like landfills and ponds, the number of seams can be reduced by seaming standard wide width rolls (such as 8 m wide). For brownfield liners this can lead to even more problems, as wide rolls can be hard to move around the construction site, especially when other contractors are working. Typically a construction site has limited manoeuvrability and heavy, bulky rolls of geomembrane usually do create problems. The main problems include weather and material damage due to the often extended length of time it must be exposed while protrusions and panels are sealed. A Liquid Boot installation takes a fraction of the time of traditional methods. In terms of costs not only is construction delayed by these problems but also in terms of materials consumed as small sections of foundations usually lead to excessive amounts of material waste.

The fastening of plastic materials around corners, under footings and around penetrations results in an increased number of cuts and welds. This in turn increases the chances of error (faulty workmanship) due in part to pressure from the client to complete the job.

Mechanical Attachment

One of the major problems associated with installation of vapour barrier liner includes the attachment of sheet plastic geomembranes to foundation walls. This is done generally in two ways – physical battening of geomembrane, and by using cast-in profile made from the same type of plastic.

Both methods are labour intensive and while use of cast-in profile, for example, allows seam testing, battening cannot provide the same level of assurance. Due to limited contact between geomembrane and the building’s wall, any future building foundation settlements can compromise the seal, resulting in leakage of harmful gases in the building and placing building air quality under risk. Temperature also plays a part as the expansion and contraction of the material secured to the foundation can also result in leaks. Both methods (battens and profiles) require a skilled crew to install, a strict testing regime and professional engineering control. Anyone without experience in this type of installation can miss significant elements and potentially create serious consequences. This is why verification and approval for every stage of gas proofing geomembrane, regardless of material type, is done by appropriately trained and experienced geotechnical or environmental engineers. This is critically important for every construction where installation of a gas proofing geomembrane is required.

Another problem associated with the mechanical attachment of geomembrane to foundation walls is that it completely relies on compression between geomembrane wall and a sealing gasket. Due to inability to control the even distribution of the geomembrane over the subgrade, there is potential for: the geomembrane to be damaged as result of the slab load, or pinching and gaps, or anchor bolt makes contact with rebar and create voids in the batten bar system, possibly creating cracks in the concrete. These cracks can create passage for harmful gases into the building passing the installed and tested geomembrane.
Penetrations

It is generally accepted that the main problem in gas proofing is penetrations into the geomembrane liner. Pipes and other penetrations through the liner can be sealed by using pipe boots. This is a flanged tube usually factory fabricated and made from the same type of liner material. The boot fits over the pipe and a flange is connected to the liner by extrusion weld or special tapes. Typically, the top end of the boot can be sealed with specialty tapes or gaskets and mechanically sealed.

But very often it’s the penetration location itself that makes it almost impossible to seal properly. If penetration is located too close to the building’s wall (quite a natural trend in construction – to install pipes and electrical conduits close to the walls), or too low to the ground, installation crews are not able to securely install penetration or to properly inspect and test the seal, therefore, this can later result in gas contamination leaks inside the building.

All three - geomembrane seaming, mechanical attachment to the foundation wall, and penetration sealing requires only skilled with installers having passed the IAGI (International Association of Geomembrane Installers) Approved Installation Contractor program and thereby ensuring only properly qualified installers undertake this critical work. It takes many years to perfect skills of installation and therefore all sheeting membranes are extremely installer dependant.

Typical Quality Assurance for sheeting geomembranes includes non destructive and destructive tests. The coupon, taken from installed geomembrane for destructive testing, needs to be patched and then tested with appropriate methods of testing. Most common test methods for patches and extrusion welds is the Spark Test. However presence of electrical sparks in the environment, potentially exposed to methane gas is potentially hazardous, and can be disrupted by moisture and dust.

Non Destructive Geomembrane Tests:
- Pressure Testing Seams (Fusion Welds)
- Vacuum Testing (Extrusion Welds)

Destructive Geomembrane Tests:
- Cut Samples of Welds done on site
- Peel and Shear of both types of Welds
  - Penetrations and Attachment:
- Installer Dependent
- Spark Test and Water Test most common

LIQUID BOOT

Liquid Boot Spray Applied Geomembrane can be chemically described as a double-component chloroprene modified asphaltic (CMA) emulsion. Both components are water based and are cold applied, forming a seamless single course geomembrane, suitable for both, large scale industrial applications as well as smaller residential type installations. Liquid Boot is also a system, consisting of:
- Liquid Boot™ cold-applied sprayable double-component emulsion, forming flexible and strong geomembrane.
- Liquid Boot™ base fabric (Typar Heat Bonded non-woven Geotextile – extremely thin and strong)
- Sometimes 300 micron polyethylene plastic material as a first protection course (Optional)
- Liquid Boot™ Ultra Shield 1000 non-woven Geotextile – for protection of the geomembrane
- Geo-Seal Vapour Barrier gas-releasing component.

**The advantages of Liquid Boot™ over other methods:**

1. A spray application completely covers all protrusions such as venting, pipe work, steel work, columns, pads, etc. Usually it takes a lot of time with traditional sheet materials where the integrity of the product, fastened to walls, footing and protrusions can be compromised by the very conditions under which they are installed. Liquid Boot™ allows completing installation times faster with more confident security of the geomembrane along structures. Seamless, monolithic membrane.

2. Liquid Boot™ is fast to install. Installation of traditional sheet materials takes much longer and deployment is restrained by weather conditions and restricted by site preparation.

3. Liquid Boot™ can be applied to any surface type, including service channels, below footing, above footing, walls, etc. The very types of surfaces which make other methods extremely expensive and time consuming to perform.

4. With coefficient of elasticity of 1,300 % Liquid Boot™ is ideal in projects with high seismic activity and weak grounds. The membrane will accommodate structural settlement issues due to its unique feature.

5. A single Permathene installation crew can install over 500 m² of Liquid Boot™ Geomembrane per day even in most complicated structural conditions. As the speed of installation is unrestricted by protrusions and penetrations, an accurate cost of construction can be estimated by the QS. In the case of sheeting materials any variations in surface shape, protrusions and penetrations lead to increase in the membrane’s price and are usually charged as variations.

6. Liquid Boot™ will provide designers and engineers with customised geomembrane details in pdf or AutoCAD formats, making design process more straightforward.

7. Liquid Boot™ has a well-established Quality Control and Quality Assurance protocol, including applicators training, methodical destructive membrane thickness testing, and comprehensive smoke testing procedure, allowing control geomembrane’s integrity, thickness, and take control over even smallest “pinholes” immediately.
SMOKE TESTING

The smoke testing method is designed to ensure that a membrane is impermeable and free of holes. Smoke is pumped under the membrane for a specified period of time, while the surface of the membrane is observed for minor holes, where the smoke is clearly visible. One of the benefits of this is that the applicator is present during the smoke test and can immediately repair any holes detected. This test method has been field tested on hundreds of buildings and found to be highly successful. The smoke testing process assures engineers, developers, and owners alike that they are getting a fully tested, gas-tight membrane installation.

Liquid Boot™ Geovent

Liquid Boot™ Geovent is a low profile pressure relief, collection and venting system (PRCVS), that has been successfully utilised at hundreds of installations. Liquid Boot™ Geovent has several advantages over a trenched installation:

1. Installed directly on subgrade; it eliminates the need for trenching and potential interference or damage to existing underground utilities.
2. Placed in closer proximity to the gas vapour barrier, which allows for more effective venting of any accumulated gases.
3. Has a greater opening area per linear meter or pipe and integral filter fabric, which allows for higher ventilation efficiency.
4. Penetrates interior footing or stiffener beams at a higher elevation than trenched piping; the higher penetration level occurs at a location where the footing are typically less heavily stressed and is therefore desirable from a structural perspective.
5. Installed at a higher elevation and is therefore less susceptible to inundation from perched groundwater, which may accumulate beneath the building foundation from rainfall or over irrigation.
6. Flow characteristics meet or exceed that of a typical trenched installation. The overall capacity of the system is far in excess of typical gas flux rates.

CONCLUSION

Contaminated sites, or brownfields, are very often located in the heart of the local community, and their development and / or redevelopment proven to be not only an economical, but also a social issue. Structures built on contaminated sites very often require protection from gases
which are the result of processes naturally occurring in contaminated soils. The buildings can be protected by installation under foundation slabs, gas extraction systems and gas proofing geomembranes.

Traditional geomembranes, recognised for their chemical resistance, very often have limitations in construction and properties which are a cause for faulty installation and/or very far higher construction costs with the slowing down of building.

Sheet membrane seaming, mechanical attachment of the membrane to the foundation walls, sealing around pipes and electrical conduit penetrations require excessive cutting, welding, patching and testing.

Most commonly used methods for non-destructive testing of extrusion welds is the spark test, and is potentially hazardous on the sites where methane and other gases are present.

Liquid Boot, in turn, allows fast, seamless installation of the membrane, which completely covers all protrusions, voids, columns etc. It can be installed in virtually every surface type, including service channels, below footings, above footings, walls, under floors, etc.

Extremely elastic, with a coefficient of elasticity of 1300 %, it can accommodate most foundation settlement issues and is very useful for the protection of buildings in seismic active areas.

Liquid Boot Quality Assurance protocol includes a comprehensive thickness and smoke test, allowing finding and operative repair of the smallest of pinholes.

The Liquid Boot Gas Collection System is GeoVent, a trenchless geocomposite with greater opening area to allow for more effective gas extraction.

Liquid Boot has more than 25 years application history, with more than 4,000,000 m² of membrane installed in more than 2,200 buildings and structures.

Because of its unique properties and excellent performance as a gas-proofing geomembrane Liquid Boot should be a first choice for protection of buildings and structures against intrusion of harmful gases on development and redevelopment of contaminated sites.

REFERENCES


   http://www.epa.gov/landfill/faq-3.htm

