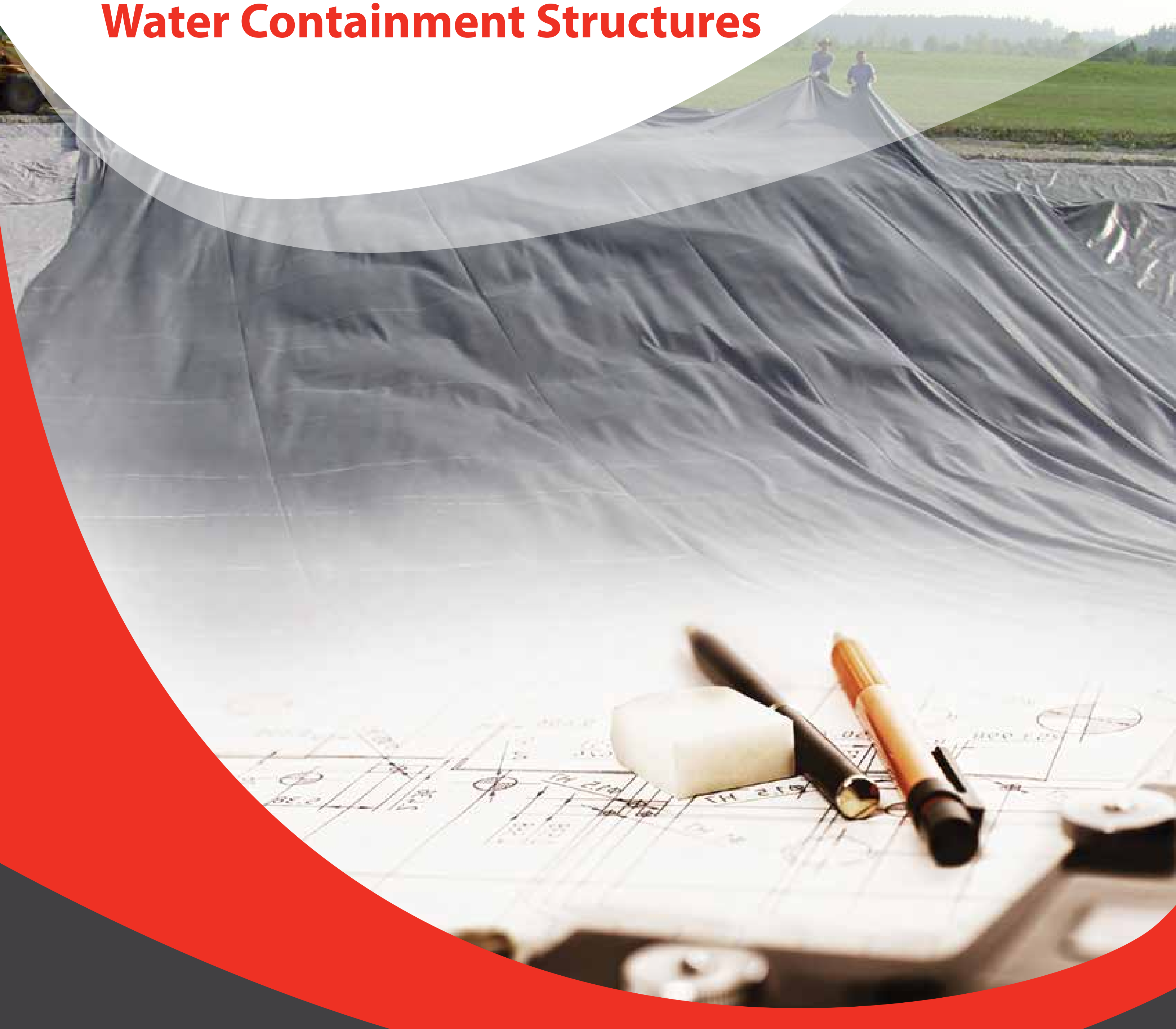
EPDM Geomembrane

General Technical Guide for Water Containment Structures



Firestone GeoGard™

Lining in Action™

Introduction

Geomembranes are the most widely used products for solid waste containment (such as landfill liners), mining and water containment applications. They are designed as relatively impermeable liners for use in a variety of applications.

This manual contains information on lining systems using Firestone GeoGard™ EPDM geomembrane. Apart from general recommendations on the use and installation of the EPDM geomembrane, it also gives information on design, site preparation, excavation works, control and quality assurance.

Generally, for simple projects, the design may be carried out by the owner or the contractor. However, in the case of larger reservoirs the design is often considerably more complex and the contractor should request the advice of a specialist in hydraulic structures. The specialist should be able to answer specific questions on excavation, drainage, protection of the liner, etc.

Before initiating any project, a study of the site should be carried out for the purpose of obtaining correct information regarding:

- Nature of the soil
- Presence of cavities (chalk rocks, chalky soil,...)
- Depth and variation of the groundwater level
- Presence of gases in the soil (peat, organic matter,...)
- Risk of differential settling (poorly consolidated soil, recent backfill,...)
- Risk of internal erosion (karst soil, sand,...)

In any case, the rules of soil mechanics must be complied with in order to ensure the stability of the support and consequently, a durable lining system. All these subjects are covered in chapter 2 of this manual.

Chapter 3 deals with the installation of the Firestone GeoGard™ EPDM System. This section covers site preparation, compaction of the soil, installation of the drainage, installation of the geomembrane, splicing and execution of details.

Chapter 4 is dedicated to making sure the installation is done as per Firestone specifications and explains different control procedures and repair techniques.

Some installation guidelines are specific to a certain type of application. These are highlighted in chapter 5.

Finally, the manual is completed with:

- Chapter 6: Technical Information Sheets
- Chapter 7: Detail Drawings
- Chapter 8: Case studies and Technical Papers

The Firestone GeoGard EPDM membrane must be installed by an official GeoGard installer in accordance with Firestone's specifications. It is also essential that all local regulations and codes are complied with.

Firestone Building Products has been in the lining business for over 40 years. Projects installed 40 years ago are still functional and are living proof of this durability.

For further information regarding Firestone GeoGard EPDM, please contact your local Firestone representative.

1 Firestone GeoGard™ EPDM

1.1 Why Firestone, Why EPDM

Firestone has been a world-recognized leader in rubber polymer technology for over 100 years. Building on this broad legacy, Firestone Building Products has become a global leading manufacturer of rubber roofing and waterproofing systems. Firestone Building Products is part of the Bridgestone Corporation, the world's largest tire and rubber company.

The first use of Firestone rubber membranes in irrigation reservoirs is located in the South of Spain and dates from 1973. Today, even after many years of exposure to UV and ozone, the rubber liner continues to provide a dependable waterproof solution. Currently, Firestone has thousands of references worldwide which are living proof of the exceptional performance of Firestone GeoGard™ EPDM.

Firestone offers contractors educational programs covering all aspects of a Firestone GeoGard EPDM System installation. The company's installation support extends on the jobsite where field technicians offer training, professional assistance and inspection of finished installations.

The company's state-of-the-art EPDM manufacturing facilities follow stringent quality control guidelines from raw material selection to finished product testing. Firestone's operations have been certified according to ISO 9001 and ISO 14000. Firestone GeoGard EPDM has obtained the CE-marking and has been tested and certified to various international and national standards.

Firestone GeoGard EPDM is a rubber geomembrane offering unique features and benefits for a wide variety of agricultural, industrial and environmental applications.

- Long term durability (UV and ozone).
- High elasticity (> 300% of elongation).
- High flexibility even at low temperatures down to -45°C (-49°F).
- Excellent puncture resistance.
- High friction angle (27°).
- Chemically inert.
- Low environmental impact.

More detailed information on Firestone GeoGard EPDM properties is given in chapter 1.5.

1.2 Composition

EPDM is a synthetic elastomer produced as a copolymer of ethylene and propylene, with small amounts of a pendant diene in order to cross link the material during the vulcanization (curing) process. The terpolymer is referred to as EPDM: ethylene-propylene-diene with "M" referring to the saturated backbone structure.

The backbone carbon chain structure is made synthetically by combining ethylene and propylene. The ethylene and propylene monomers combine to form a chemically saturated (no double bonds), stable polymer backbone providing excellent ozone resistance and weather performance.

These copolymer chains can move independently relative to each other, which would enable the material to change shape. Cross-linking therefore has to be introduced in order to prevent polymer chains from moving independently. As a result, when stress is applied the cross-linked polymer will deform, but upon release of the stress, the membrane will revert to its original shape (referred to as elastic behavior).

Controlled amounts of diene are added during polymerization in a manner to maintain a saturated backbone and place the reactive unsaturation in a side chain available for cross-linking during vulcanization.

In the terpolymer structure, the double bond is thus not in connection with the main chain and therefore does not affect the strength of the main ethylene-propylene chain (with no double bonds in the backbone). This explains the excellent heat, UV and ozone resistance of EPDM.

Cross-linking individual terpolymer chains in order to ensure mechanical properties of EPDM is ensured by a curing agent.

Curing or vulcanization is primarily a process generating a 3-dimensional network of polymer chains as a result of the formation of different chemical bridges. The reaction transforms the soft, weak gum-like material into a strong thermoset elastic product.

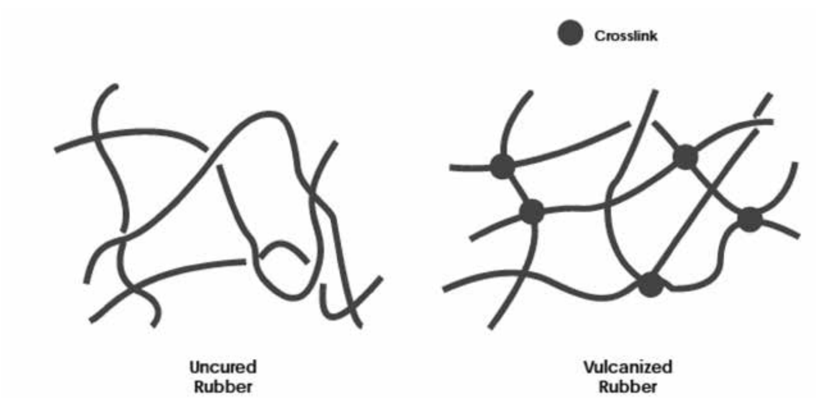


Figure 11: 3-dimensional network of vulcanized EPDM.

For processing issues and in order to increase the mechanical properties and durability of the EPDM geomembrane, some filler material is added to the EPDM composition:

- **Carbon black** is a reinforcement filler which improves UV and heat resistance. Due to the shape and size of the carbon black particles, it also improves the tensile strength.
- **Fillers (e.g. clay)** which improve the dimensional stability of the sheet and add fire protection properties.
- **Process oils** are paraffinic oils necessary to soften the compound during processing. They ease the mixing process and provide flexibility.
- **Sulfur** is used as curing agent.
- **Accelerators** limit the amount of sulfur required, reduce the curing time, and optimize the performance of the membrane.

1.3 Production

The production of the Firestone GeoGard™ EPDM geomembrane starts with the combination of all the raw materials listed in the previous section into a homogenous mixture. This is done using high shear mixing machines.

At this point in the process the EPDM sheet is still uncured, meaning that it can be molded or formed using heat into other shapes and is very tacky to the touch. At this time the EPDM is similar in consistency and tackiness to chewing gum.

Due to the calendered width, EPDM is initially produced in maximum sizes of 3.05 m (10 ft.) x 15.25 m (50 ft.). While in its uncured state, the 3.05 m (10 ft.) x 15.25 m (50 ft.) panels can be spliced to each other to produce a "master roll" of 15.25 m (50 ft.) x 122 m (400 ft.).

This is accomplished by moving the panels along an assembly machine, overlapping them by 5 -10 cm (2 in. - 4 in.), then applying pressure to the seam area to splice or fuse the two panels together.

As the EPDM is very tacky and has yet to be cured, it would stick to itself if rolled up without some type of anti-blocking agent. So, a "dusting agent" (mica) is applied immediately after the panels are spliced and just before they are rolled up for curing. This is why EPDM actually appears dark grey and not black in color.

After rolling, the master rolls are loaded into an autoclave for a pre-determined length of time to cure under heat and pressure (cross-linking the individual polymer chains). The curing process changes the material from an uncured state to a thermoset material, making it elastic, extremely durable and resilient to ultraviolet exposure, ozone as well as extreme cold and hot temperatures.

After the EPDM membrane "master roll" is cured, it is cut into pre-determined lengths and widths, folded, rolled, packed and stored ready for shipment.

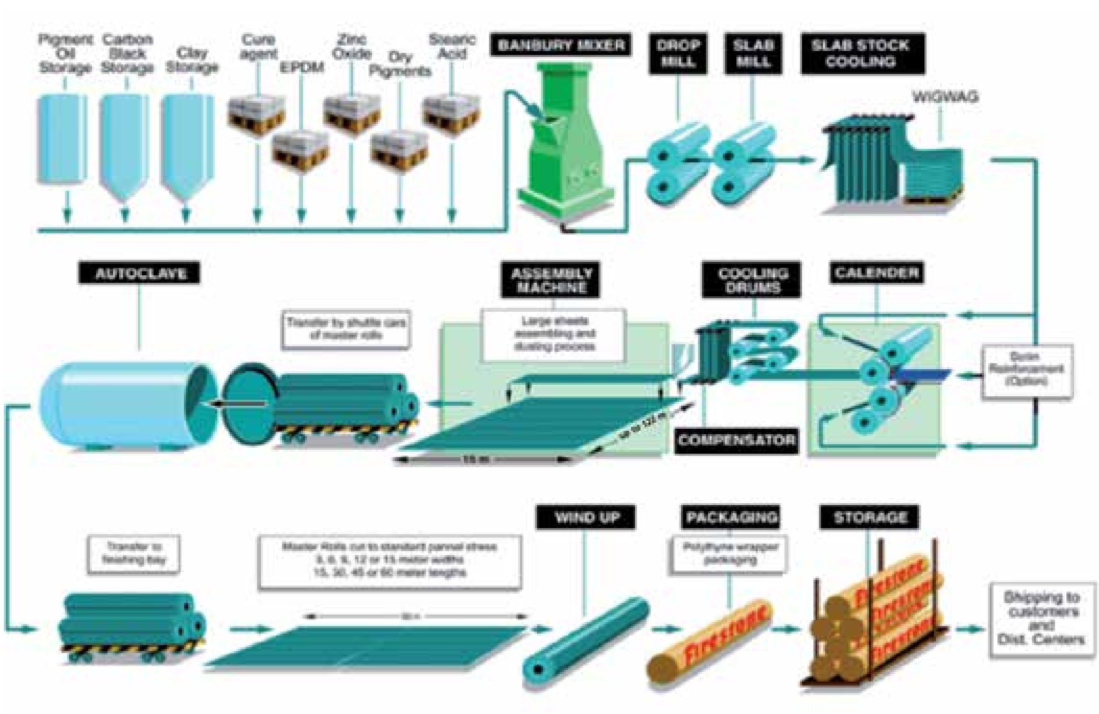


Figure 12: Production process

1.4 Splicing mechanism

There are two types of seams in the Firestone EPDM lining systems:

- Factory seams: splicing is performed during the production of the EPDM sheet prior to vulcanization. The material of the seam is homogeneous and 100% cured.
- Field seams: splicing is performed on site using QuickSeam™ Seaming Products.

When leaving the factory, the Firestone GeoGard™ EPDM is a thermoset material. Heat welding techniques or solvents cannot be used to melt the EPDM membrane. Two adjoining sheets therefore have to be joined with a material that is chemically reactive, the self-adhesive QuickSeam™ Seaming Products combined with the QuickPrime™ Plus primer. A successful splice will depend on a sound contact of the bonding agent and the membrane. For this reason the surface has to be prepared with utmost care.

The surface of the EPDM sheet examined under a microscope is not completely smooth - it looks like an orange skin, full of small irregularities and ridges. It is important to observe that the surface is not clean but covered with dust and talc. By scrubbing the surface with a scrubber pad, soaked with QuickPrime™ Plus, the irregularities are changed, creating a receptive surface for contact.

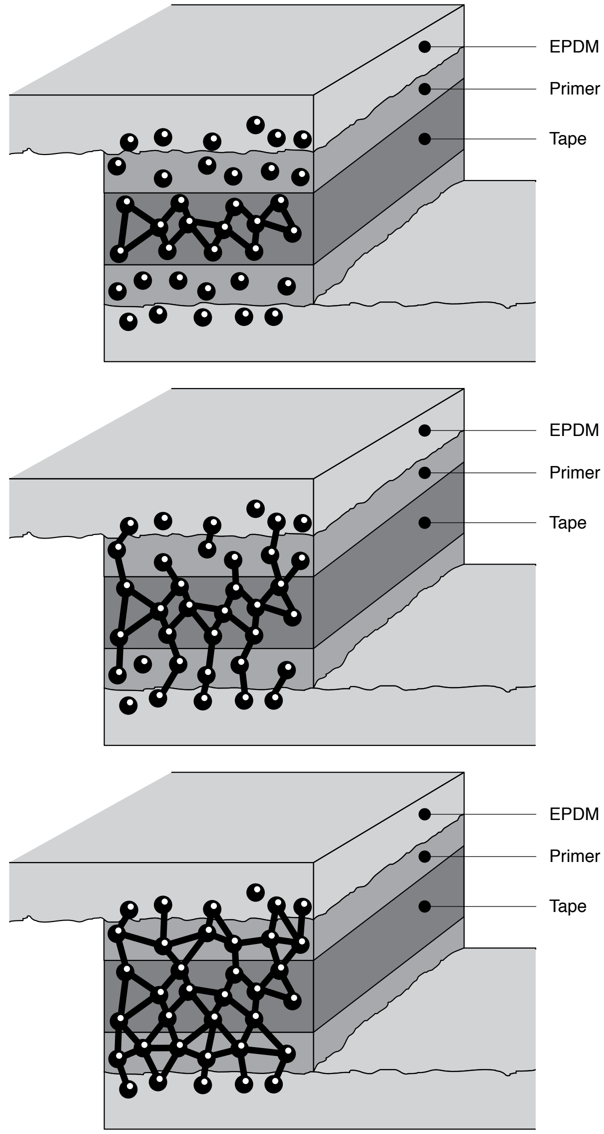


Figure 3: Splicing mechanism

The active molecules of the QuickPrime Plus are carried by a solvent, which provides a proper coating and a deep penetration of the components into the surface irregularities. When most of the solvent is evaporated, the QuickPrime Plus is still chemically active and provides a tacky surface for the Splice tape to be installed to complete the splicing procedure.

In addition to the adhesion mechanism (attraction between adhesive and surface molecules), the membrane surfaces are mechanically interlocked by the components of the QuickPrime Plus. Both mechanisms create high-resistance molecular links. It will take 7 to 28 days for the seam to reach maximum strength.

Experience to date has demonstrated that the EPDM field splicing technique using QuickSeam seaming products and QuickPrime Plus is very “friendly” and durable.

This installation method satisfies the normal day-to-day variations such as climatic conditions, different applicators and job conditions.

1.5 Review of technical performances

The table below details the declared technical specifications of Firestone GeoGard™ EPDM 1.1 mm (45 mil) and 1.5 mm (60 mil).

Property	Test method	Units	ASTM D-7465		ASTM D-7465	
			1.14 mm (0.045 in.)		1.52 mm (0.060 in.)	
			SI	Eng	SI	Eng
Specific Gravity	ASTM D-792	gm/cc	1.1	1.1	1.1	1.1
Unit Weight	ASTM D-751	kg/m (lb./ft.)	1.4	0.29	1.8	0.40
Thickness, Type 1	ASTM D-412	mm (in.)	1.02 +10/-10%	.045 +10-10%	1.52 +10/-10%	.060 +10-10%
Tensile Strength, Die C min	ASTM D-412	MPa (psi)	9.0	1305	9.0	1305
Ultimate Elongation, Die C min	ASTM D-412	%	300	300	300	300
Tear Resistance, Die C	ASTM D-624	kN/m (lbf/in)	26.27	150	40.28	230
Puncture Resistance	ASTM D-4833	N (lbs.)	133	30	181.56	43
Shore A Durometer	ASTM D-2240		65-10	65-10	65-10	65-10
Resistance to Ozone 7 days/100 @ 37.8° C (150° F) 50% ext.	ASTM D-1149		No Cracks	No Cracks	No Cracks	No Cracks
Multiaxial Elongation	ASTM D-5617	%	100	100	100	100
Oven Aging At 116° C (240° F) for 670 hours	ASTM D-573					
Tensile strength Die C	ASTM D-412	MPa (psi)	8.3	1205	8.3	1205
Ultimate elongation, Die C	ASTM D-412	%	200	200	200	200
Tear Resistance,Die C	ASTM D-624	kN/m (lbf/in)	21.9	125	37.32	213
Xenon Arc for 5040 kJ/(m².nm) @ 340 nm @ 80°C	ASTM G-155/G-151					
Visual Inspection 7X	ASTM D-518		Pass	Pass	Pass	Pass
No cracks or crazing bent loop @10% strain						
Brittleness Point	ASTM D-2137		-45°C	-49°F	-45°C	-49°F
Water Resistance weight after immersion 166 hrs @ 70° C (158° F)	ASTM D-471	%	+8,-2	+8,-2	+8,-2	+8,-2
Water Vapor Permeability (max.)	ASTM E-96	Perm-mils	2.0	2.0	2.0	2.0
Linear Dimensional Change,max	ASTM D-1204	%	+/- 1.0	+/- 1.0	+/- 1.0	+/- 1.0
Chronic Toxicity Screening	EPA/600/4-89/ 001 ASTM E-729	Method 1000.0	passes passes	passes passes	passes passes	passes passes

Table 11: Declared technical specifications – Firestone GeoGard EPDM 1.1 mm & 1.5 mm (45 mil & 60 mil)

1.5.1 Exceptional durability

The chemical composition of Firestone GeoGard EPDM (high proportion of carbon black and saturated carbon chains) and the fact that it is vulcanized means that the EPDM geomembrane benefits from an unmatched resistance to UV, heat, ozone, microorganisms and extreme weather conditions.

The membrane does not contain any plasticizers or antioxidants likely to migrate or degrade and cause the EPDM geomembrane to age prematurely.

Tests conducted on the Firestone GeoGard EPDM and the observations made on membranes exposed to actual weather conditions (exposure to water, UV, ozone, heat, thermal variations and microorganisms, etc.) over several years have shown that under normal exposure in Western Europe and when properly installed, the Firestone GeoGard EPDM has a service life of more than 50 years, without any apparent signs of ageing such as cracks, crazing, bleaching, etc.

1.5.2 High elasticity and tensile strength

Given the significant level of cross-linking in its carbon chains, the Firestone GeoGard EPDM can be elongated by over 300% in all directions and return to its initial form afterwards. This high elasticity allows Firestone GeoGard EPDM to absorb substrate movements without its physical properties being affected.

1.5.3 Highly flexible, even at low temperatures

Firestone GeoGard™ EPDM is highly flexible even at low temperatures down to -45°C (-49°F). This facilitates installation as the geomembrane adapts to irregular shapes and lays flat on the substrate, whatever the outside temperature.

When mechanically stressed at low temperatures, Firestone GeoGard EPDM retains all of its flexibility and its resistance is not jeopardized.

1.5.4 High puncture resistance

Because of its highly flexible and elastic nature, Firestone GeoGard EPDM also offers excellent static puncture resistance. This is a very important characteristic in withstanding the mechanical stresses which the geomembrane sustains during installation and service and consequently guarantees long term watertightness of the lining system.

1.5.5 High resistance to hydrostatic pressures

Firestone GeoGard EPDM has almost unlimited resistance to hydrostatic pressure, which allows for its use in deep, large capacity water reservoirs. Firestone has conducted laboratory pressure tests which have shown that the EPDM geomembrane can withstand pressure up to 35 kg/cm^2 (243 lbs./ft.) (equivalent to 350 m (1150 ft.) water column or 3.4MPa [493 psi]).

Tests carried out according to the EN 1928:2000 standard showed that, when an equivalent pressure of 40 m (131 ft.) water column (400 KPa) (58 psi) is applied, Firestone GeoGard EPDM and its seams remain watertight.

1.5.6 Stable chemical composition

As a result of its chemical composition (saturated highly cross-linked carbon chains, without lixiviation of plasticizers and antioxidants) and its production method (heat vulcanized), the Firestone GeoGard EPDM is considered an inert material as its chemical composition is very stable over time (when in contact with authorized products).

A stable chemical composition is vital in guaranteeing the mechanical properties of the geomembrane on a long term basis.

Unlike thermoplastic geomembranes, no reduction in density has been noted on Firestone GeoGard EPDM following loss of membrane components.

1.5.7 Highly compatible with living organisms

Due to its very stable chemical composition, the Firestone GeoGard EPDM does not release components on contact with water.

Tests have demonstrated that the Firestone GeoGard EPDM can be used for the storage of irrigation water, as a liner for aqueous food production and aquaculture and for the storage of water prior to the necessary treatment required for human consumption.

1.5.8 Environmentally friendly geomembrane

As a result of the chemically inert nature of Firestone's GeoGard™ EPDM, it has no effect on air or water quality and does not release any pollutants into the environment.

The environmental impact of a geomembrane essentially takes place during its production and disposal. Taking into account its exceptional durability (compared with other geomembranes) and the numerous possibilities for recycling, the Firestone GeoGard EPDM offers an environmentally friendly solution.

1.5.9 Root penetration resistance

The Firestone GeoGard EPDM and its seams have successfully passed various root penetration resistance tests (DIN 4062, CEN/TS 14416: 2005, FLL). Nevertheless, it is necessary to remain extremely careful with regard to certain plants which develop particularly aggressive rhizomes (see enclosure 9.4 page 9.25 for a non-exhaustive list of plants which develop rhizomes). When confronted with such plants, a root barrier must be implemented to protect the EPDM geomembrane.

1.5.10 Broad range chemical resistance

The Firestone GeoGard EPDM has a relatively broad spectrum chemical resistance. Nevertheless, some products are not compatible with EPDM membranes (hydrocarbons, grease, etc.). A list of non-compatible chemical compounds is available in enclosure 9.3 (page 9.6). In case of doubt, it is strongly advised that the technical department of Firestone Building Products is consulted.

In addition to water storage, the Firestone GeoGard EPDM is also highly suitable for applications such as livestock effluent storage and waste water storage. The Firestone GeoGard EPDM must not, under any circumstances, be used for storing chemical products.

1.5.11 Resistance to microorganism corrosion

The high level of cross-linking in its carbon chains and the presence of sulfur in its molecular structure (a compound which bacteria, likely to corrode the geomembrane, are not able to withstand), making the Firestone GeoGard EPDM almost impervious to microorganism corrosion.

1.5.12 High friction angle

Friction tests conducted on the Firestone GeoGard EPDM demonstrated that the friction angle between the geomembrane and a standardized ground surface is 27.5° (± 1°).

The Firestone GeoGard EPDM friction angle is relatively high compared to other geomembranes. A high friction angle means that the geomembrane is easier to install (workers do not slide on it and the membrane stays in place), and that it is more stable on the slopes thus not requiring the use of a textured membrane.

1.5.13 Quick and easy installation

The combination of its dimensions, mechanical characteristics and seaming method make the Firestone GeoGard EPDM quick and easy to install. In an industry which is highly dependent on weather conditions, the speed of installation of Firestone GeoGard EPDM represents a major advantage.

Dimensions

The Firestone GeoGard™ EPDM is available in large panel sizes, up to 15.25 m (50 ft.) wide and 61 m (200 ft.) long in a single piece, that works out to 930 m^2 (10,000 sq. ft.) without any seam. This allows for a significant reduction in the number of seams to be carried out on site and considerably reduces the risks involved in installation.

The panels are available in numerous sizes which can be selected to accommodate the dimensions of the project. This reduces losses and limits the cutting and field seaming. The list of available Firestone GeoGard EPDM panel sizes can be found on page 2.2.

Characteristics

Installation of the Firestone GeoGard EPDM is greatly facilitated by its flexibility, as it adapts to the substrate and is easy to manipulate (moving unfolded sheets on an air cushion), as well as by its high friction angle as workers do not slide on the membrane when it is dry and the membrane is less likely to slip on the slopes.

Field seaming method

The Firestone GeoGard EPDM field seaming method using Firestone QuickSeam Cover Strip or Splice Tape presents the following advantages:

- The quality of the seams is consistent over the entire length.
- The completion of seams is only slightly dependent on weather conditions.
- The tools used do not risk damaging the geomembrane.
- It does not require the use of electricity or special equipment.

The completion and quality of the seams are not affected by folds or waves which are likely to form with temperature variations.

1.5.14 High quality installation details

For the sealing of pipe flashings and penetrations, Firestone uses Firestone QuickSeam™ FormFlash, an uncured EPDM flashing (progressively cures after installation) laminated to self-adhesive Firestone QuickSeam Splice Tape. This material dresses each sealing detail perfectly and without any stress, regardless of its shape.

Firestone also offers accessories for carrying out waterproof mechanical connections on concrete structures and adhesives which allow the membrane to be adhered to any type of surface (concrete, wood, steel etc).

1.5.15 Quality installation

The performance of a lining system is directly linked to the quality of the installation.

For this reason the Firestone GeoGard EPDM is exclusively installed by Firestone trained and approved lining contractors. They guarantee that the installation meets the quality standards set by Firestone.

Firestone Building Products' technical department offers its contractors first class support in theoretical and practical training with professional technicians. Firestone also provides on-site technical assistance and inspection of finished works.

1.5.16 Seam testing

There are 2 main types of seaming control methods which provide accurate information regarding the quality of the field seams:

- Non-destructive seam testing:
  - Visual inspection: in the case of the Firestone GeoGard™ EPDM, a series of elements may be easily checked visually and give a very good indication of the quality of the seams.
  - Air lance: enables to control the seams on a continuous basis.
  - Vacuum chamber: enables inspection of individual points on field seams.
- Destructive seam testing: tensile and peel tests conducted on seam samples at least 24 hours after a seam has been made.

A more detailed description of the seam testing methods is given in chapter 4.1. (page 4.5 - 4.7).

1.5.17 Easy to repair

Given the inert nature of Firestone GeoGard EPDM, its composition does not vary over time. Consequently, the geomembrane can still be assembled and/or repaired many years after being installed and having been exposed to climatic elements. The only requirement is cleaning the membrane thoroughly before commencing the repair.

The repair techniques do not differ from the techniques used for the initial installation of the Firestone GeoGard EPDM. Therefore, repairs are quick and easy to carry out.

1.5.18 National and International Technical Approvals

The Firestone GeoGard EPDM has obtained CE marking, which proves that it meets current European requirements for health, safety, consumer protection and environment.

The Firestone GeoGard EPDM is CE marked for the following applications:

- **EN 13361:** Construction of reservoirs and dams
- **EN 13362:** Construction of canals
- **EN 13492:** Construction of liquid waste disposal sites, transfer stations or secondary containment
- **EN 13493:** Construction of solid waste storage and disposal sites

Firestone's EPDM manufacturing facility also holds ISO 9001 and ISO 14000 certification which respectively reflect Firestone's commitment to quality and the environmental management system.

Firestone GeoGard EPDM has been tested and certified by many national and international bodies (for example, French ASQUAL certification and ASTM International).

Within the context of these certifications, regular audits are conducted at Firestone Building Products' factory to verify the production process, quality control monitoring and the quality of the end product. Consequently, Firestone Building Products can guarantee that its membranes are of a consistently high quality.

The main approvals and certifications are available upon request from the technical department of Firestone Building Products, or can be downloaded from our website www.firestonebpco.com.

1.6 Applications

Firestone GeoGard EPDM is used successfully in a wide variety of applications worldwide:

- Agricultural applications:
  - Irrigation reservoirs and canals
  - Agricultural ponds and dung pits
  - Aquaculture ponds
  - Algae ponds
  - Hydroponic farming
  - Ensilage covers
- Environmental protection:
  - Constructed wetlands
  - Waste water reservoirs
  - Storm water reservoirs
  - Landfill capping
  - Mining waste containment
- Industrial applications:
  - Settlement lagoons
  - Artificial snow reservoirs
  - Hydroelectric reservoirs and canals
  - Fire reservoirs
- Artificial lakes

The recommendations in this manual mainly apply to water reservoirs. Some applications need specific recommendations which are described in chapter 5.

Non-acceptable applications for the Firestone GeoGard EPDM are:

- Applications where gas generation or hydrostatic pressure could disturb the functioning of the Firestone GeoGard EPDM.
- Applications where the Firestone GeoGard EPDM could come in contact with chemical substances that affect the EPDM geomembrane.

2 Design Considerations

There is no single solution to build a water reservoir. Before constructing a water reservoir, it is essential to carry out some site visits and specific analysis in order to optimize the location of the installation, its characteristics (size, shape, etc.) and the means to be employed (materials used, etc.). The following are some of the important points that need to be considered:

- Project basics:
  - Volume of liquid to store
  - Characteristics of the stored liquid (chemical composition, temperature, etc.)
- Site environment:
  - Available space (geometric constraints)
  - Nature of the soil (composition, stability)
  - Topography
  - Depth of underground water
  - Risk factor (human, environmental, economical)
  - Materials availability
- Methods of use and maintenance:
  - Expected in-use constraints
  - Filling/emptying
  - Water speed
  - Cleaning

2.1 Membrane selection

2.1.1 Panel size

Once the final shape of the reservoir has been designed, the panel size is chosen based on the panel and seam layout drawing. The goal is to reduce losses and facilitate the installation process (limit on-site splicing and cuts). The design process of the panel and seam layout is described in chapter 2.12.

The Firestone GeoGard™ EPDM is factory-assembled into large, fully vulcanized seamless membranes. The Firestone GeoGard™ EPDM is supplied in the following dimensions:

Thickness	1.1 mm (.045”)	1.5 mm (.060”)
Max. surface	930.30 m² (15.25 m x 61.00 m) (10,000 sq. ft., 50 ft. x 200 ft.)	
Length	30.50 m, 61.00 m (50 ft., 100 ft.)	15.24 m, 30.50 m, 45.75 m, 61.00 m (50 ft., 100 ft., 150 ft., 200 ft.)
Width	3.05 m, 6.10 m, 7.62 m, 9.15 m, 12.20 m, 15.25 m (10 ft., 20 ft., 25 ft., 30 ft., 40 ft., 50 ft.)	

Note: Not all roll widths are available in all possible roll lengths

Table 21: Panel sizes

Depending on the panel size, the rubber sheets are folded and packaged onto 1.83 m, 2.13 m, 2.44 m, 3.35 m or 4.27 m (6 ft., 7 ft., 8 ft., 11 ft., 14 ft.) long cores. It is strongly recommended that the longest available core is always used in order to minimize fold lines and wrinkles in the sheet.

Thickness

The Firestone GeoGard EPDM is produced in two thicknesses: 1.1 mm (45 mil) and 1.5 mm (60 mil) (Note: Firestone PondGard™ EPDM is specifically designed for decorative pond applications and is not treated in this guide).

Increasing the thickness of an EPDM membrane will result in a higher puncture and tear resistance.

Firestone GeoGard EPDM 1.5 mm (60 mil) puncture resistance is almost 30% higher than the Firestone GeoGard EPDM 1.1 mm (45 mil). The thickness of the membrane has to be related to the project specificity. The use of a 1.5 mm (60 mil) EPDM membrane can be required for lining applications with an increased security level due to potential human or environmental risks and/or for applications requiring a higher mechanical performance because of high applied pressure (water, ice crust), specific uses, maintenance operations, surface irregularities, expected differential settlement, covering (risk of damage during the installation of the cover)...

A double layer of membrane can be installed on sites where no leakage can be tolerated (subsoil presents risks of internal erosion or dissolution, storage of polluted liquids in a environmentally protected zone, etc.). Between the two membranes a geocomposite drainage system must be connected to a leak detection system. In some specific applications, national legislations can ask for a double layer.

2.1.2 Chemical compatibility

Due to its chemical composition and production process (vulcanization) the Firestone GeoGard EPDM has a wide spectrum of chemical resistance. Nevertheless, Firestone GeoGard EPDM cannot be used to store chemicals. When another product than clear water is expected, it is essential to contact the Firestone technical department to confirm the compatibility of the EPDM membrane with the product stored. Some products, such as hydrocarbons and greases, are not compatible with EPDM membranes.

A chemical resistance chart for the Firestone GeoGard EPDM is enclosed (see enclosure 9.3 page 9.6). The enclosed table is to be used solely in case of accidental contact.

The effect of chemicals on the membrane is highly dependent on the following factors:

- Temperature: an increase in temperature accelerates the chemical reaction and affects the durability of any type of membrane.
- pH: in standard conditions, EPDM cannot be used when pH is lower than 4 or higher than 10.
- Type and concentration of the chemicals.
- Duration and frequency of exposure.
- Liner installation quality and details: in certain conditions, tensions in the installed liner can affect the lifetime.

It is also very important to make sure that the support structure or the cover material are chemically compatible with the membrane. In case of suspected pollution of the ground (hydrocarbon smell when excavating, old factory site, etc.), it is strongly recommended that a chemical analysis of ground samples and, if required, some compatibility tests are conducted.

2.2 Site selection

When selecting the construction site, several elements must be considered to ensure long-term performance of the lining system and to avoid any future problems. Site selection is the responsibility of a specialist engineer.

The following is a general overview of a few of the critical site selection parameters which should be investigated.

2.2.1 Preliminary studies of the site

Firstly, all existing data on the site will be collected and studied: topographical and geological maps, existing geotechnical studies of the zone, historical data (previous activities, old aerial pictures and maps, exceptional natural events, etc.), pluviometry and wind statistics, among other things.

A detailed visual inspection of the site will be carried out by experienced engineers and geologists. The specifics of the site will be identified: topography, geology, hydrology, vegetation, existing infrastructure, accessibility, surroundings. Special attention will need to be given to detect former landfill and dump areas.

In order to learn about the characteristics of the ground located inside the limits of the project and the ground used to raise the embankments, it is necessary to make on-site field trials (trial pits, static and dynamic penetration tests, deep boreholes, geophysical prospection,...) and laboratory tests (particle size, plastic limit, dry and wet natural density, content in organic material, carbonates, sulfates and gypsum, compactness (proctor), shear test, permeability test, dispersion test, etc.).

The number, location, type of on-site field trials and laboratory tests will depend on the importance of the project and the national applicable code of practice and legislation.

2.2.2 Nature of the soil

A thorough investigation of the site must be carried out in order to design the section of the reservoir and ensure underlying soil stability throughout the life of the project.

Under no circumstances may the project be located in landfills or dumps. In addition, waste material cannot be used to build the embankments.

In standard building conditions a site with the following geotechnical characteristics should be acceptable[1]:

- Particle size: uniformity coefficient (D60/D10) > 2 (important for compaction)
- Plastic limit: liquid limit < 50% (if LL > 40 % then PL > 0.73 (LL-20))
- Organic mater content: < 1%
- Gypsum content: < 2%
- Soluble salts (excepted gypsum): < 1%
- Collapse potential: < 1%
- Free cell swelling oedometer: <1%
- Dispersion test (Crumb): degree 1

If the site inspected does not fulfill the above conditions, some extra investigations will be needed to see if it can be used and if a specific installation process is to be planned.

1 Information provided on page 15 of the "Manual para el diseño, construcción, explotación y mantenimiento de balsas" – see bibliography for full reference

The table below outlines some risks associated with general soil type:

Soil Type	Risk	Solution
Compressible (peat)	• Considerable gas generation • Pressure under the geomembrane • Differential settlement	• Change site • Gas drainage • Slope must be adapted to facilitate gas drainage
Loose backfill	• Settling • Over-consolidation of the backfill materials	• Appropriate compaction
Soil containing organic matter (old sugar or paper industry ponds, landfill)	• Pressure under the geomembrane (gas) • Differential settlement	• Gas drainage • Extra membrane on penetration details
Soil with internal erosion hazard (backfill material containing waste, limestone-type soil, gypsum chalk)	• Dissolution of the soil by liquid in case of a leakage • Collapse caused by eroding water circulation	• Change sites or provide a good geological assessment in order to find cavities, if any • Double waterproofing layer
Volcanic soil (soft clay, compressible silt)	• Absorption capacity • Differential settling	• Add an intermediate layer • Particular drainage and special compacting around the details

Table 22: Associated risks with general soil type

2.2.3 Topography

The topographical study is very important in the selection process of the site in terms of available surface, slopes, accessibility, excavation and fill calculations, as well as the hydrology of the site.

If the underground water table is not so deep, the topographical study will help to find the highest location in order to avoid the underground water table being higher than the bottom of the reservoir.

Where possible, a location will be chosen to permit water circulation by gravity for the filling and emptying of the reservoir and evacuation of the water collected underneath the membrane by the water drainage system.

The altitude of the reservoir has an impact on the formation of an ice-crust on top of the water and therefore the pressure applied on top of the membrane as well as the risk of damage by floating or falling ice blocs.

2.2.4 Hydrology

It is not recommended that a water reservoir be installed in a river bed as the site will likely encounter technical complications:

- High underground water level.
- High quantity of sediment and floating objects inside the reservoir.
- Risk of overflows in case of flooding.

In projects where the reservoir has to be installed in a river bed, with a direct input from the river, it is essential to make a hydrological study of the site. The hydrological study will evaluate the flood design in order to design the dimensions of the spillway and the high water level. If large quantities of sediment are expected, it is recommended that there is a settlement pond upstream or that the membrane is covered in order to facilitate sediment removal. The underground water table will have to be properly drained in order to protect the substrate from water erosion.

For projects located close to a river bed, it is important to evaluate if the outside embankments are protected from any potential erosion effect in case of flooding from the river.

In very large surface water reservoirs, the direct input of rain can have an impact on the dimension of the overflow system.

2.2.5 Underground water table

The groundwater level should never be higher than the bottom of the water reservoir.

If the groundwater level exceeds the bottom of the reservoir, the geomembrane risks being lifted (hydrostatic pressure), the support structure can be damaged (small ground particles removed by the water flow, exposing larger stones and increasing the risk of puncture) and the functioning of the gas drainage system can be disturbed (causing gas pressure). In this case, an appropriate drainage system under the geomembrane must be provided. Groundwater drainage systems must be designed by a specialized project engineer.

The main characteristics of the groundwater table must be studied during the design process:

- Depth: both the average level and the extreme level over the course of at least one year.
- Estimated flow of the underground water level.
- Type of groundwater table:
  - Perched water
  - Temporary underground water
  - Underground water under pressure

Knowing the underground water characteristics is also very important during the excavation and installation process. It is important to verify that it is possible to work in dry conditions without jeopardizing the stability of the excavation and adjacent infrastructures.

2.2.6 Human and natural environment

The reservoir and its building process may have some human and environmental impacts that need to be studied during the design process.

Depending on the type of reservoir and country, an environmental study may be mandatory during the design process.

If the stored product is likely to disturb the neighborhood (smell) or to be dangerous to the environment, the installation should be located as far as possible from residential accommodation and/or sensitive areas (rivers, potable water wells, natural ponds, etc.).

Consideration should also be given to the integration of the reservoir into the landscape.

2.2.7 Accessibility

Accessibility to the site must be guaranteed during construction, use and maintenance.

The implementation of the new project should not reduce the accessibility of existing facilities.

2.3 Geometry of the reservoir

One of the essential design factors in the geometry of a reservoir is the volume of water stored, taking into account the availability and necessity of water.

Generally, simple geometric shapes are recommended (square or rectangular) so as to facilitate the building of the pond, and to reduce the loss percentage. The shape of the reservoir will take into account the land surface available within the site.

2.3.1 Excavation and backfill

Mainly for economic reasons, the most common design is an excavation and backfill reservoir. Starting from the desired stored water volume, the designer will calculate the amount of ground to be excavated at the bottom of the reservoir and used for backfilling the dam. If required, some extra soil will be brought from outside to match the backfill quantities.

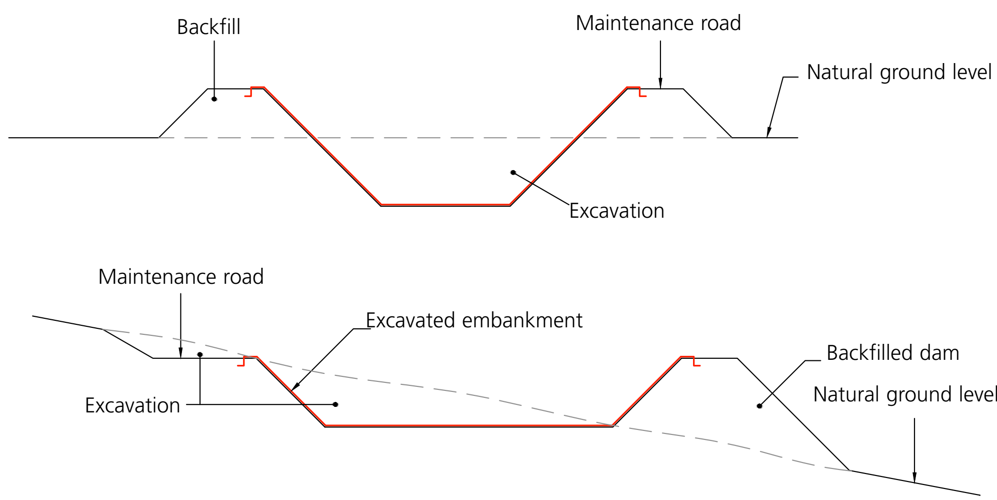


Figure 21: Different situations of excavation and backfill designs for reservoirs

2.3.2 Bottom

Depending on the size of the reservoir, one or two slopes with a minimum incline of 2% will be built into the bed. The aim is to facilitate the emptying and cleaning of the reservoir and the drainage of water and gasses under the geomembrane. The fall becomes more important as the surface increases, and must be adapted to the calculated settling level.

The change in angle between the bottom and the side slopes must be rounded (curvature of 0.5 m [1.5 ft.]).

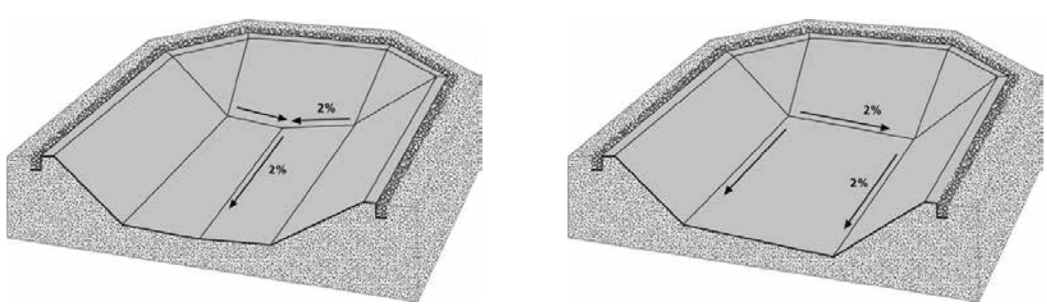


Figure 22: Bottom slope

2.3.3 Embankment incline or side slopes

The stability of the excavated and/or backfilled embankment is a geotechnical issue. The presence of groundwater and the nature of the soil play an important role in the stability of the embankment. The embankment needs to be freestanding. The Firestone GeoGard™ EPDM must not be used to ensure stability of the embankment.

The stability study must deal with the following:

- Ground characteristics
- Height of the dam
- Foundation quality
- Groundwater
- Stability of the drainage system and of other layers between the foundation of the reservoir and the geomembrane
- Effects of waves
- Maximum water height
- Consequences of rapid drop in water level
- Consequences of excessive leakage
- Stability of the geomembrane protection layer, if any
- Seismic conditions
- Safety factor
- Ease of installation

Figure 23: Example of a 1V/2H slope

The slopes given below are indicative values for initial design to be verified in the stability study. If the reservoir is less than 5 m (16 ft.) deep, the contractor shall provide a maximum slope of 1V/2H.

If the height of the embankment above the base of the reservoir is between 5 m (16 ft.) and 10 m (32 ft.), a slope of 1V/3H is recommended.

If the membrane is going to be covered by a protective layer, a slope of 1V/3H is recommended in order to guarantee the stability of the protective layer. If the protective layer is made of concrete, the slope can be higher.

The indicative values mentioned in the table below may be used as a general guide. These values are given according to the nature of the soil. They should be considered with extreme care for the reasons mentioned above.

Nature of soil	Incline
Clay soil	1V/2.5H
Clay and sandy soil	1V/2-3 H
Sandy gravel	1V/2H
Soft rock	1V/1.5H

Table 23: Indicative slope according to the nature of the soil

The change in angle between two slopes must be rounded (curvature of 0.5 m [1.5 ft.]).

Outside slopes should not exceed 1V/2H (depending on the length of the slope) so as to avoid subsidence and gulley erosion of the banks over time. The materials should not contain any turf, vegetable debris, topsoil, peat, silt, etc. It is essential that the outside slopes are planted up as quickly as possible for erosion control. At the toe of the outside slope, a water collection ditch is recommended in order to reduce the erosion risk caused by running water.

Sometimes, designers decide to install a berm into the inside slope for intermediate anchoring or in order to partially cover the embankment for esthetic reasons. The design of the berm must consider the risk of cover material falling into the reservoir and the non-continuity of the water and gas drainage. An example is given in chapter 2.4.2.

In places where a thick ice-crust is expected and the reservoir is used during the winter, it is recommended that the toe of the covered berm is located just underneath the normal water level. Otherwise, the partial cover could hold some ice blocs and release them when the reservoir is empty, risking damage to the membrane.

2.3.4 Embankment crest (top of the slope)

The crest width must guarantee the dam stability and be large enough to accommodate a maintenance road over its entire length.

The embankment crest width is related to the height of the embankment and must have the following minimum values:

- 4.0 m (13 ft.) for installation of anchor trench and the maintenance road
- 5.0 – 6.0 m (16-19 ft.) if machines or vehicles are used during the construction and operation of the water reservoir For deep water reservoirs (> 5 m) (16 ft.), the minimum width of the embankment crest (C) can be estimated from the height of the dam (H) using the formula[2] below:

$$C\,(m)=3+\frac{H\,(m)}{5}$$

Also a slight incline of 1-2% towards the outside of the reservoir is recommended to avoid runoff water and ground entering inside the reservoir.

The change in angle between the side slopes and the embankment crest must be rounded (curvature of 0.5 m [1.5 ft.]). The material used for the crest needs to be non-erodible and resist to engine circulation (if expected).

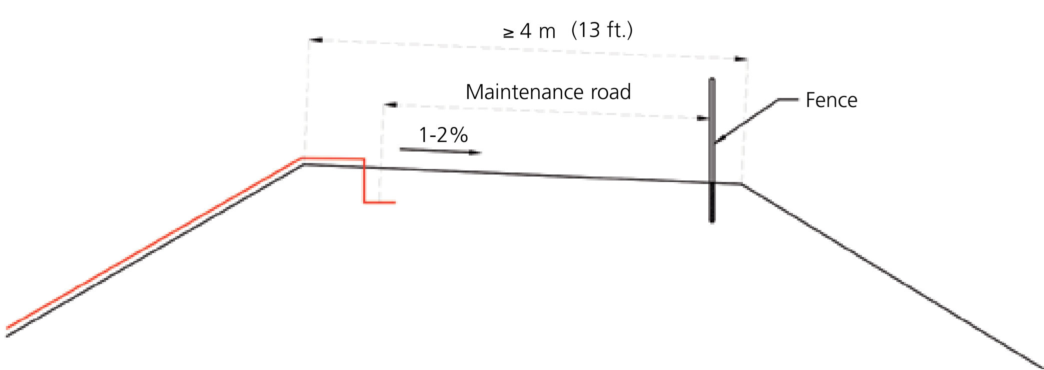


Figure 24: Embankment crest

The crest needs to be equipped with a running water collection system. In case of an excavated embankment, it is strongly recommended that a water ditch be installed on the embankment crest in order to collect the upstream running water. The size of the ditch will be designed according to the amount of running water expected.

2 Information provided on page 70 of the “Manual para el diseño, construcción, explotación y mantenimiento de balsas” – see bibliography for full reference

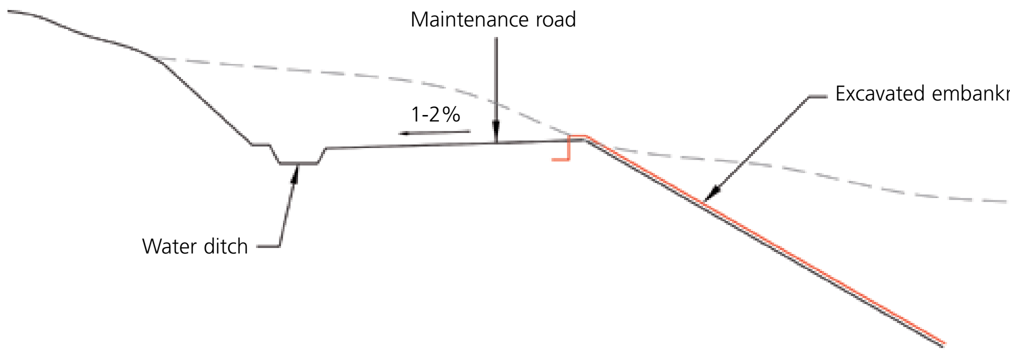


Figure 25: Water ditch for running water

2.3.5 Waves

Waves created by the wind or by boats impact the side slopes. Over time, waves may deteriorate the quality of the substrate. In case of strong winds, there is a risk of water overflow that can endanger the stability of the embankment. The greater the length of the reservoir in the direction of the prevailing winds and the steeper and smoother the slope of the embankment, the stronger the wave action will be.

Wave impact can be reduced by:

- Building a smaller but deeper pond
- Selecting another shape, with a shorter dimension in the direction of the prevailing winds
- Building several smaller ponds, instead of one large pond

According to the specific height of the waves, the nature of the soil and the slope of the embankments, we recommend the following:

- Protection of the geomembrane adapted to the incline (concrete, riprap, soil cover)
- Adequate anchoring of the geomembrane
- Adequate compaction of the soil
- A thicker protective geotextile under the geomembrane
- Extra protection on the crest

Picture 21: Extra protection on the crest against waves overflow

2.3.6 Water level

The normal liquid level is determined by the required water volume, the topography of the site, the volumes to excavate, the highest expected liquid level (calculated for a specific design flood), the designed freeboard and the expected settlements. Increasing pond deepness will increase the volume as well as reduce the water surface and therefore the evaporation rate. On the other hand, the excavation/backfilling costs increase, as well as the pumping costs and hydrostatic pressure.

2.3.6.1 Hydrostatic pressure

The higher the water level in the reservoir, the higher the hydrostatic pressure. The hydrostatic pressure will have a significant impact on the stability requirements (bearing capacity of the reservoir, deformability of the foundation) and the pressure/tensions applied to the geomembrane.

Even considering the flexibility and the high elongation at break properties of the Firestone GeoGard™ EPDM, cavities may be present in the soil that may cause the geomembrane to perforate. To avoid this risk, it is essential to have a smooth, well compacted support layer (fine grained intermediate layer of sand or clean soil) and to install a protective geotextile under the geomembrane.

2.3.6.2 Freeboard

One of the most serious problems that can occur in the case of a water reservoir is water overflow. Water flow will drag ground particles from the top of the embankment and can lead to a total ruin of the structure. Therefore a freeboard needs to be designed and scrupulously respected during the building and the use of the reservoir.

Freeboard on highest water level (HWL) is the difference in level between the top of the crest and the HWL, different from the normal water level (NWL). This volume held in reserve is intended to prevent wind generated waves from overtopping the crest and to minimize chances of water overflow in case of heavy rainfall. The freeboard is specifically calculated for each project but in any case must always be more than 50 cm (20 in.) or the minimum value mentioned in the applicable legislation.

Firestone recommends that the distance between the normal water level (NWL) and the level of the top of the crest must always be more than 100 cm (39 in.) or the minimum value mentioned in the applicable legislation.

Depending on the expected wind, the length and depth of the pond, the slope and roughness of the embankment, the expected settlement, the freeboard on HWL can go up to 2.0 m (7 ft.) for some projects.

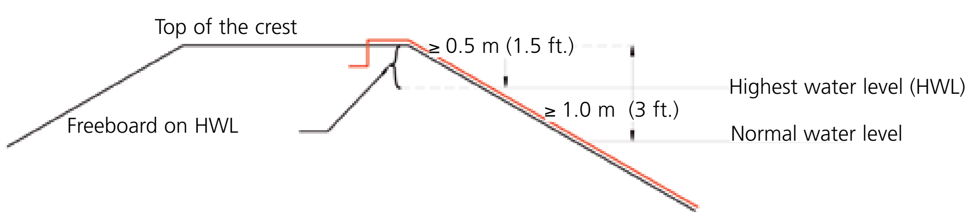


Figure 25: Freeboard on highest water level

2.4 Anchoring the geomembrane

The geomembrane must be kept in place to prevent it from sliding down the embankment, being lifted by the wind and/ or displaced by water movements. Dependent upon the situation, the geomembrane can be anchored in various ways (see chapter 7.5 for drawings):

- At the top of the embankment
- At an intermediate platform
- At the bottom of the reservoir

If the membrane is going to be covered, the covering will serve as final anchoring. A trench can be used for intermediate membrane anchoring during installation and while waiting for the final covering.

If the membrane is installed on top of a concrete structure, it can be mechanically anchored (see chapter 7.5 for drawings) or glued to the concrete.

2.4.1 Top anchoring

The anchoring is executed by burying the geomembrane in a trench (prefered) or by holding it in place by means of ballast. The dimensions of the trench depend on the expected stress. The minimum section should be 0.40 m x 0.40 m (1.3 ft. x 1.3 ft.) in cohesive soil. Moreover, this section depends on the length of the geomembrane between two anchor points, the distance between a clamping point and the water level, the wind speed, the slope, the different friction angles, etc.

The Firestone GeoGard™ EPDM must extend at the bottom of the trench over at least 300 mm (117 in.). The distance between the anchor trench and the crest of the embankment will be 1.0 m (3 ft.) minimum to preserve the stability of the ridge.

It is recommended that the reservoir is filled prior to final filling and compaction of the anchoring trench. Filling and compacting the anchoring trench must be performed without subjecting the geomembrane to stress and without it being punctured. After compaction, the anchoring trench needs to have an external slope of a minimum of 1%.

If considerable soil movements are expected after filling the pond, temporary clamping must be provided at the crest, so that the Firestone GeoGard EPDM can move without being subjected to excessive tension. Partial ballasting in the ditch is immediately provided and final anchoring is done at a later stage.

The table below shows a few practical values for the minimal anchoring section (or backfill section) using a filling material with a density of 20 kN/m^3 (2040 kg/m^3) (127 lbs/ft^3) and for a standard embankment slope (1V/2H to 1V/3H). The final size of the anchor trench needs to be designed by a specialized engineer.

Length of embankment (m)	**Anchoring section (m²)**	
	Low or medium wind speed (< 100 km/h)	**High wind speed (> 100 km/h)**
< 3 (10 ft.)	0.16 (.01 mph)	0.16 (.01 mph)
3 - 5 (10 - 16 ft.)	0.16 (.01 mph)	0.16 (.01 mph)
5 - 15 (16 - 49 ft.)	0.16 (.01 mph)	0.25 (.16 mph)
15 - 40 (49 - 131 ft.)	0.25 (.16 mph)	0.36 (.22 mph)
> 40 (131 ft.)	> 0.36 (.22 mph)	> 0.49 (.3 mph)

Table 24: Minimal anchoring section .16 = 15 fps, .25 = 23 fps, .36 = 33 fps, .49 = 45 fps

An alternative using ballast is possible as long as measurements are taken so the ballast does not erode over time.

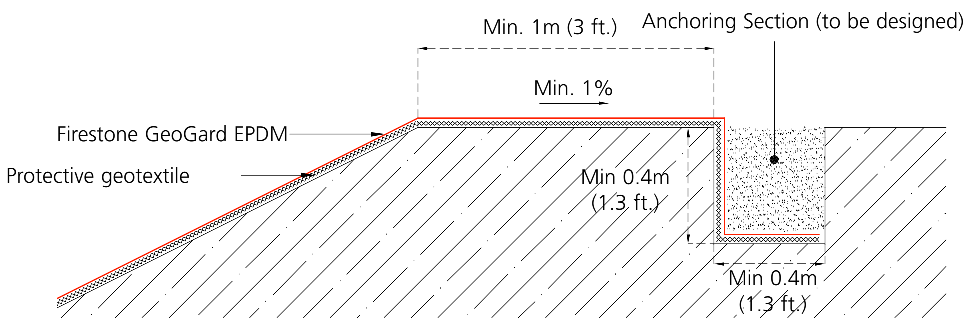


Figure 27: Top anchoring in a trench

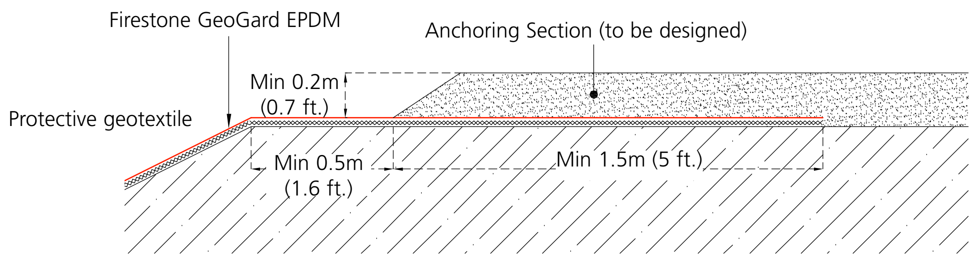


Figure 28: Top anchoring with ballast

2.4.2 Intermediate anchoring

If the embankment is long and strong winds are expected, it may be necessary to provide an intermediate clamping to accommodate geomembrane movements caused by the wind. Such clamping can be carried out using ballast or an anchor trench (perpendicular or parallel to the slope). For perpendicular anchoring, a berm can be added to the slope in order not to endanger the stability of the embankment. The continuity of the water and gas drainage must be ensured.

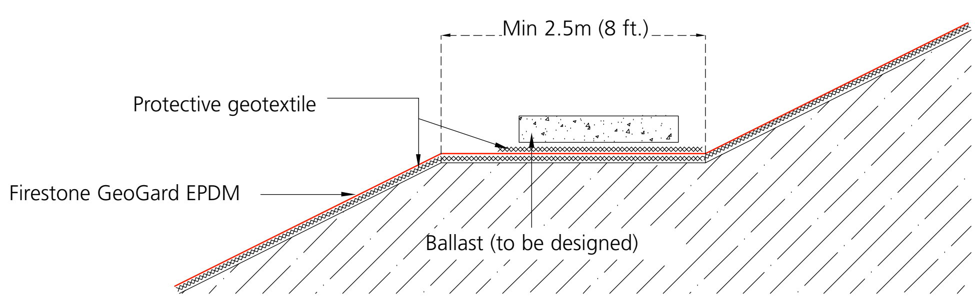


Figure 29: Intermediate anchoring on a berm with ballast

2.4.3 Base anchoring

If the reservoir base is sufficiently low in permeability (waterproof geological layer, imported clay, treated ground, etc.), the base anchoring of the geomembrane will ensure a mechanical function and watertight continuity between the embankment and the bottom of the pond (see drawings in chapter 7.5).

Depending on the geotechnical characteristics of the impermeable material and the water pressure, the designer will have to determine following distances:

- Length of the geomembrane inside the impermeable ground (minimum 2.5 m [8 ft.]).
- Minimum thickness of impermeable ground under the geomembrane.
- Minimum thickness of well compacted clay or treated ground on top of the geomembrane (greater or equal to 0.5 m (1.5 ft.) and H/10, HWL being the maximum water height) In order to increase watertight connection efficiency, a bentonite layer can be added on top of and under the geomembrane.

If water movement is expected, it is recommended that a filtration geotextile and some cover stones are installed on top of the clay in order to prevent its erosion in the anchoring zone.

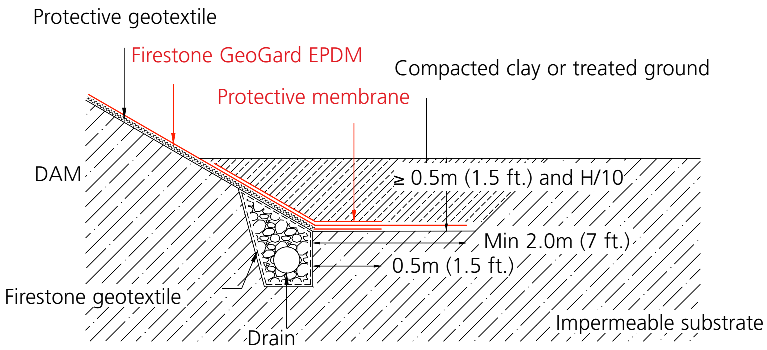


Figure 210: Base anchoring in impermeable ground (solution 1)

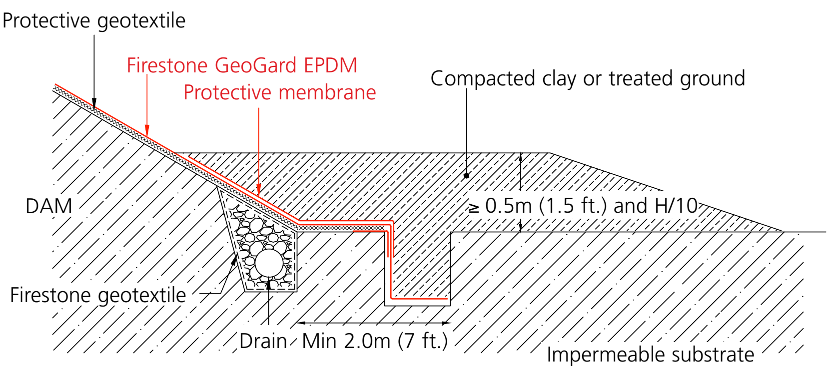


Figure 211: Base anchoring in impermeable ground (solution 2)

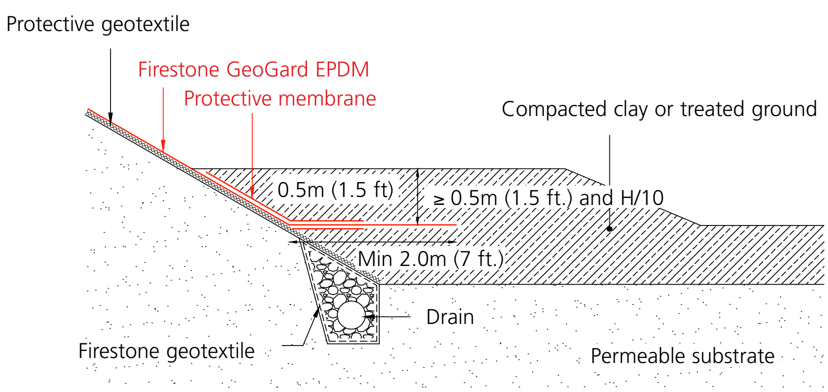


Figure 212: Base anchoring in permeable ground covered with compacted clay or treated ground

2.5 Foundation

To ensure the correct performance and life expectancy of the geomembrane, it is essential that the foundation is adapted to the geological and geotechnical conditions of the site.

The foundation has to be stable. Most of the time, an excavation of the ground is done in order to gain storage capacity and to have ground to raise the embankments. The slopes of the excavation need to be stable, in the short and long term, also when exposed to the designed maximum stress (water load, interstitial pressure, earthquake hazard).

The risk of differential settlement needs to be studied carefully in order to avoid excessive tension on the membrane. Any compressive materials like mud or peat need to be dried or removed. Differences in compressibility between different areas of the foundation should be avoided (e.g. partly rocks and partly soft ground). The required degree of compaction of the foundation has to be considered during the geotechnical study.

Some materials can erode (karst, sand, etc.) or dissolve (gypsum) in the event of a significant intake of water. This could be one reason to apply a double layer of membrane or change the location of the project. The internal erosion risk of the ground (leakage, rain water infiltration, etc.) will be studied carefully. Dispersive soils cannot be used.

Vegetation (trees, shrubs) and organic ground (more than 1% of organic content) must be removed.

The type of soil particle of the foundation, after excavation, will determine the characteristics of the support structure. If the foundation ground is too aggressive, a protective ground layer will have to be applied.

The depth of underground water under the foundation will have serious impact on the building process, the stability of the reservoir and the drainage system.

2.6 Support structure

The support structure is the layer(s) between the foundation and the geomembrane. Its main functions are the following:

- Protect the membrane against mechanical damage:
  - Due to excessive tensions (well compacted ground generates only permissible deformations of the geomembrane)
  - Avoid puncture (smooth surface, geotextile)
- Reduce pressures under the geomembrane (water and gas drainage)
- Collect the stored liquid in case of a leakage (water drainage)
- Facilitate the installation process of the geomembrane (smooth and well compacted substrate)

2.6.1 Support layer

The support layer is the soil layer, part of the support structure. The support layer must be clean, smooth, compacted, and free from aggressive angle changes, stones and small cavities. This layer must also be able to compensate for the differential settling of the soil and facilitate the installation of the drainage system and the geomembrane.

The support layer can be installed in various ways:

- Excavated reservoir base after removing stones, rocks, vegetation etc., followed by smoothing and compacting
- Backfill layers (minimum 20 cm [8 in.] thick) with controlled particle size (maximum 20 mm [.75 in.]) and compacted (sand, stable earth, etc.). It is important to be able to guarantee the quality of the support layer over time. Ground erosion in case of a leakage or intake of natural ground water can convert a smooth support layer into a very aggressive ground (leaching of small ground particles, leaving sharp stones in contact with the geomembrane).

Picture 22: Good quality support layer

Picture 23: Unacceptable support layer

2.6.1.1 Vegetation

The decomposition of organic matter is likely to result in different levels of settlement and the release of gas. Therefore the support layer must be cleared of all vegetable matter and topsoil stripped of any eventual deposits of organic matter.

According to the conditions, the use of a durable weed killer is recommended. The weed killer must not contain any components which might affect the Firestone GeoGard™ EPDM.

2.6.1.2 Compaction

The geomembrane support layer must be optimally compacted (to a density of 95% of the normal Proctor Optimum[3]), either by natural or by mechanical compacting. The compaction at the crest of the embankments must be carried out with the utmost care.

The compaction of the support layer must be such as to allow access to the construction equipment without risk of damaging the surface (e.g. tire tracks). The embankments must be stable and resist the impact of waves.

If necessary, in order to obtain a well compacted embankment with a uniform slope, the embankment can be built by the excess fill method: a width greater than the project profile is compacted, then the poorly compacted faces are scraped.

The mechanical properties of some types of ground (shale, sandstone, soft limestone, marlstone) can change during the compaction process. In such cases, an on-site trial is recommended. The smoothness of the support layer can also be modified during compaction (some stones can break leaving sharp edges in contact with the geomembrane).

If some differential settlements are expected and cannot be avoided it is important to evaluate these expected settlements and adapt the installation details in order to avoid tensions.

2.6.2 Hard substrates (concrete, treated soils,...)

The hard substrate surface needs to be smooth and without any cavities. It is recommended that the geomembrane is fully adhered to the smooth concrete. In case adhesion is not possible, it is always necessary to install a protective layer (geotextile).

In order to avoid settling of the natural soil next to a concrete structure, the compaction must be performed with particular care up to 95% of the normal Proctor Optimum. At the junction between the ground and the concrete, it is recommended that a minimum of two geotextile layers are applied.

2.6.3 Geotextile

The installation of a protective geotextile between the support and the geomembrane is always strongly recommended. It is an absolute necessity on embankments where installing an additional support layer is often difficult.

The geotextile will protect the geomembrane against potential mechanical damage (puncture, friction) during the installation process and its entire life. It will also help with gas and water drainage, to absorb tensions induced by small cavities, to protect the embankment against erosion (waves) and facilitate the installation process (move the membrane, no dust on seams).

The type of geotextile will be selected by a specialized engineer depending on the properties of the support soil (particle size, slope, etc.), the type of geomembrane used (thickness) and stresses anticipated during installation and operation (water pressure, waves, etc.).

The minimum properties of the geotextile are given below, for reference only:

- Type: non-woven, needled, short fiber, 100% polypropylene, 100% virgin material
- Mass per unit area (EN 965): ≥ 300 g/m² (9 oz./sq. yd.)
- Thickness at 2 kPa (EN ISO 9863-1): 2.0 mm (0.08 in.)
- Tensile elongation (EN ISO 10319): 50%
- Tensile strength (EN ISO 10319): ≥ 20 kN/m (3 psi) (machine and cross machine direction)
- Dynamic perforation test (EN ISO 13433): < 30 mm (1.2 in.)
- Puncture resistance (EN ISO 12236): ≥ 3 kN (674 lbs. force)
- Durability (annex B EN 13254): 25 years (covered in 2 weeks)

3 The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density (Wikipedia).

When the geotextile also has a drainage function, it must be checked for sufficient transmissibility (EN ISO 12958).

The use of geotextiles containing natural fibers is not recommended as they will rot and lose their protective properties. It is also not recommended that woven geotextiles are used because these do not have good protective properties and are too rigid. Geotextiles made from recycled material should not be accepted.

In places where the membrane could be damaged by roots or rhizomes, it is necessary to install a root resistant geotextile.

2.7 Drainage system

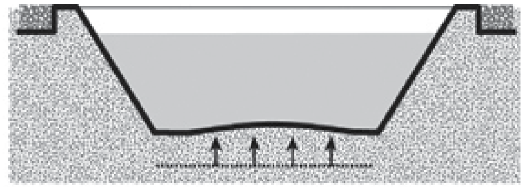
The drainage layer under the geomembrane is part of the support structure. The drainage system is an essential safety feature of the reservoir as one of its functions is the detection of leaks. The drainage system needs to be designed by a specialized design company depending on the specifics of each project.

2.7.1 Application criteria

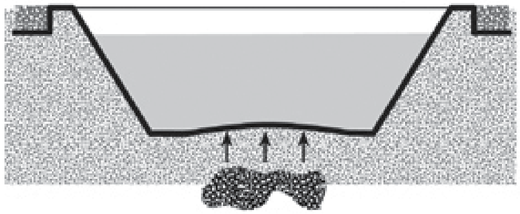
The application of a drainage system is not required if the permeability of the entire supporting layer exceeds 10^{-4} m/s, or if no gas or water pressure is anticipated. However, the presence of a drainage layer is essential for the rapid detection of leaks. Water/gas drainage is always required under the following conditions:

- When the underground water level may be higher than the bottom of the pond (not recommended in good practice construction).
- Soils containing organic matter (gas generation).
- Embankments containing clay (stability when emptying).
- Whenever variations of the groundwater level can be anticipated.
- Whenever the geomembrane is not fixed and can move.
- Reservoir containing organic matter or a liquid potentially harmful to the environment (to avoid ground and/or water pollution in case of a leakage). The following figure summarizes the main causes of pressures under a geomembrane.

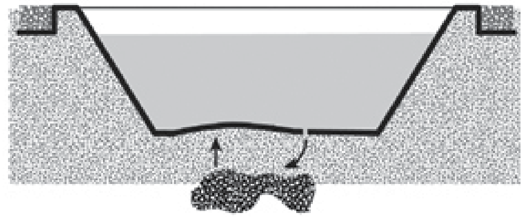
Temporary underground water table



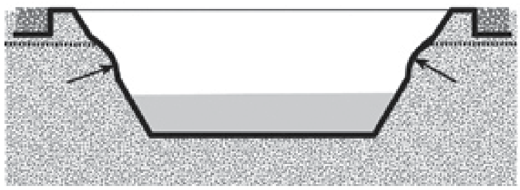
Rise in groundwater level



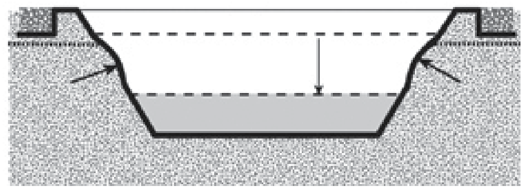
Soil containing organic matter



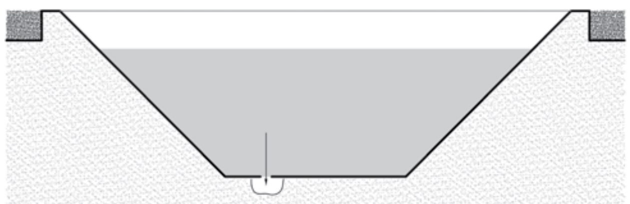
Organic matter coming from a leakage



Groundwater higher than pond water level



Quick decrease in pond water level



Erosion of the substrate due to a leakage

Figure 213: Some causes of excessive pressure

2.7.2 Water drainage

It is strongly recommended that the water drainage system is separate from the gas drainage system. If both drainage systems are combined, gases cannot be evacuated while water is drained.

The water drainage system of the pond is very important for the following reasons:

- Detects and measures any leakage of the geomembrane.
- Protects the support structure from internal erosion mechanisms: water removes the thin ground particles and leaves the geomembrane in contact with the bigger stones, increasing puncture risk.
- Avoids loading capacity problems of the foundation.
- Ensures the stability of the slopes when emptying the pond or in case of external water intake with low water level inside the pond.
- Prevents geomembrane movements due to water pressure under the membrane (low water level inside the pond and high underground water level). There are two main causes for water under the membrane:
  - Underground water (temporary or permanent water table, infiltration of surface water), affecting excavated embankments, the bottom of the reservoir and the base of the backfilled embankment.
  - Water coming from a leakage in the lining system, affecting backfilled and excavated embankments and the bottom of the pond.

For large scale projects, two water drainage systems are recommended. The first one is designed to collect underground water and the second one, located under the membrane, is designed to detect, measure and collect any water coming from a leakage. The collectors of these two water drainage systems are separated.

In some cases (large water reservoirs, high human risk down-stream), it may be necessary to install a drainage system inside the backfilled embankment. This will not be addressed in this guide. When present, the water drainage system of the dam body must be separate from the drainage system under the membrane.

The water drainage may be implemented at the bottom of the reservoir and on the slopes by means of one of the following:

- **Drainage through permeable material:** this bed may be made with sand or gravel (5/20). Its thickness depends on the transmissivity of the drainage product. A minimum thickness of 20 cm (8 in.) is recommended. A filtering geotextile must be provided between the drainage layer and the neighboring soil (see standard EN 13254).
- **Drainage by a drainage geocomposite:** the geocomposite will be chosen according to its cross-sectional flow rate (under load), its filtering geotextiles and its friction coefficient (preferably self-stable on slopes). See standard EN 13252. The use of a drainage geocomposite has many advantages:
  - Low weight
  - Quick and easy installation (especially on slopes)
  - Low capacity loss
- **Network of drainage ditches (preferred solution at the bottom):**
  - Trenches of min. 0.3 (1 ft.) x 0.3 (1 ft.) m for the installation of drains:
    - Peripheral at the base of the banks (at 1.0 m [3 ft.] distance from the toe of the slope)
    - On the pond bed, pipe network between 5 m (16 ft.) and 30 m (98 ft.) inter-distance (depending on the permeability of the ground)
  - The slope necessary for run off is in the order of 0.5 to 1 %.
  - Installation of an anti-contaminant geotextile between the draining rubble present in the trench and the natural soil. In no case can a puncture resistant geotextile be used to provide a filtration function (see standard EN 13254).
  - Agricultural drains (PVC or PE of min. 60 mm (2.5 in.) diameter – depending on the expected water quantity) are placed in these trenches which are covered with 10/14 gravel or similar on top of the trench.
  - Depending on the ground permeability, a covering over the whole surface could be needed: layer of permeable material grade 8/10, (washed gravel), at least 10 cm (4 in.) deep.

The information above contains general recommendations. For each project the final water drainage design is the responsibility of a specialized design company.

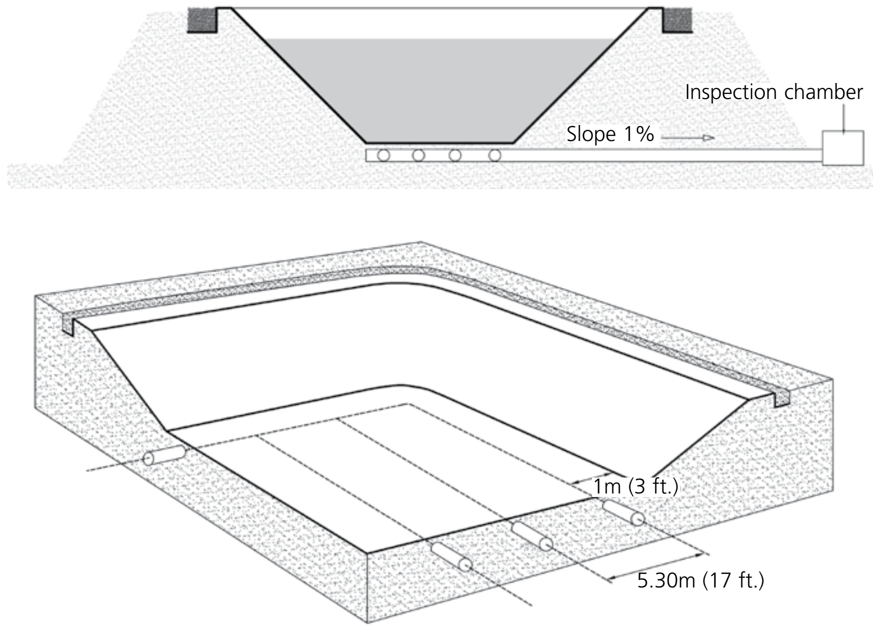


Figure 214: Water drainage with drainage ditches

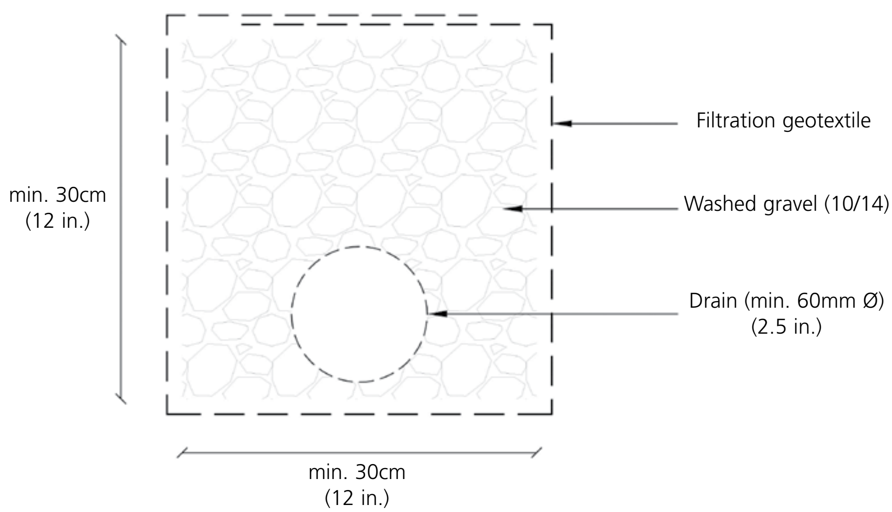


Figure 215: Drainage ditch section

Picture 24: Drainage ditch

For draining the water at the bottom of the pond, it is very important to respect a minimum 2% slope of the base. The size and gradient of the water drainage system depends on the following factors:

- Leak flow rate that is acceptable.
- Flow rate of water coming from outside the pond.
- Maximum pressures that are acceptable under the geomembrane.

For smaller projects, the use of perforated drain pipes with a diameter of 60 mm (2.5 in.) should be sufficient. For larger structures, the size and the density of the network, as well as the compressive strength of the drain pipes must be carefully calculated. Consult the manufacturer for advice.

If a berm is used, a water collection/drainage system must be provided to secure the continuity of the water drainage on the slopes.

For larger structures, a compartmentalized drainage network is recommended to facilitate leak detection. This is mandatory when the geomembrane is covered by a protective structure. In any case, it is recommended that the water coming from the embankments (peripheral draining collector) and the water coming from the base of the pond is kept separate.

The water drained on the embankments is collected at the bottom of the slopes by a peripheral drainage collector (perforated on the upper part and closed on the lower part).

At the lower point of the pond, one or several blind pipes go through the embankment for water evacuation towards the hydrographic network (by gravitational means or pumping). The hydraulic capacity of the collectors needs to be bigger than that of the water drainage system. The slope of the collectors must be bigger than 1%.

The type of collector pipe depends on the vertical pressure that is going to be applied on the pipe.

The collector pipes will have to go through the embankment into a trench that will be covered afterwards with reinforced concrete, sized according to the expected ground weight. The trench is usually the same as the one used for the outlet pipe (see chapter 2.9.2). For very big projects, the collector pipes can go through a service tunnel.

At the exit, the collector pipes need to be connected to an inspection chamber in order to see and measure the outlet flow and evaluate its turbidity (internal erosion). The inspection chamber can be equipped with an automatic leak detection system (sonorous).

2.7.3 Gas drainage

Pressure caused either by the production of gas from the fermentation of organic material in the soil or by a rise in the underground water table, requires the installation of a gas drainage system under the geomembrane. This system will be constructed in addition to the water drainage system (two completely separate networks). The gas drainage system will be connected to vents positioned on the crest of the embankment. Gas drainage must always be designed in such a way that its flooding is avoided.

Gas drainage may be achieved either by using perforated 40 to 80 mm (1.5 to 3 in.) diameter pipes positioned every 10 m (33 ft.) or using draining layers (geocomposite: geonet in high density polyethylene covered with an anti-contaminant geotextile) positioned every 5 m (16 ft.). The distance between the pipes or the geocomposite needs to be adapted to the conductivity of the ground (low interdistance for poor conductivity) and the expected quantity of gases. Depending on the permeability of the substrate, a bed of permeable material of 8/10 grade (washed gravel), a geotextile or another synthetic permeable material could be required between the pipes.

The vents are protected to avoid obstructions and the ingress of water (rain or running water).

Any direct contact between the geomembrane and agressive surfaces of the drainage systems must be avoided.

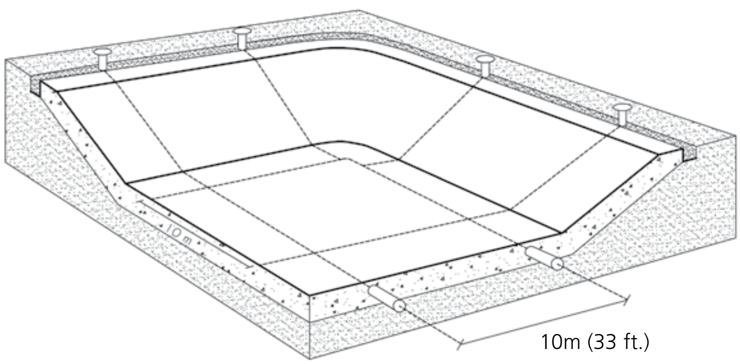


Figure 216: Gas drainage with pipes

Picture 25: Gas drainage with pipes

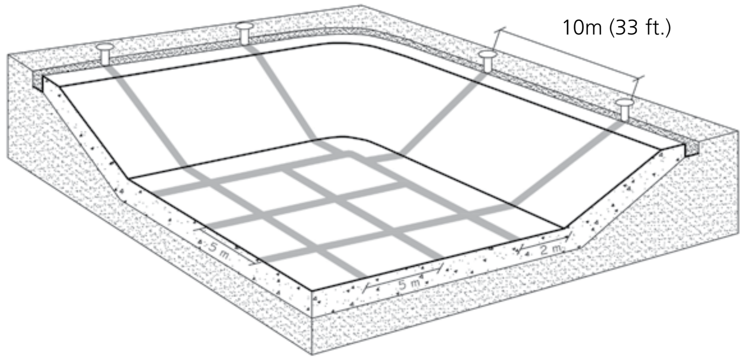
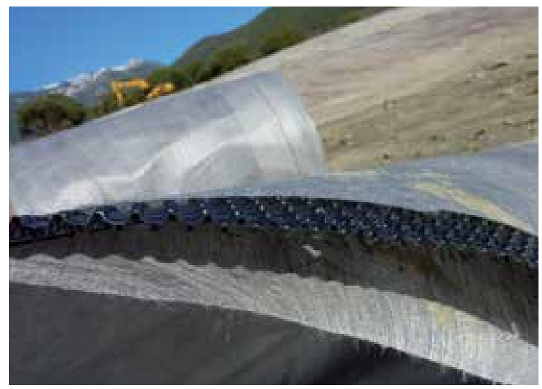


Figure 217: Gas drainage with geocomposite



Picture 26: Gas drainage with geocomposite

Picture 27: Gas vent

Picture 28: Gas trapped under the geomembrane

2.8 Top protection of the Firestone GeoGard™ EPDM membrane

In some cases, protection of the Firestone GeoGard EPDM will be required. In the table below you will find some recommendations for the protection against potential damage.

Protection against	Precautions
Wind	• ballast at the bottom and/or on slopes (in case of temporary emptying) • correct section of the anchor trench
Waves	• mechanical protection of the embankments depending on the slope: rock covering, concrete pavement, cast concrete
Floating objects (drift wood, boats)	• small ponds, cleaning larger ponds, protection
Ice	• mechanical protection of embankments
Animals, vandalism	• ladders • enclosure around the reservoir • mechanical protection of embankments
Operating vehicles (remove sediments)	• protection of the geomembrane with soil, a sand bed, concrete slab • access ramp
Local turbulence with water speed exceeding 1 m/sec. (internal agitator or canals)	• protection with ballast

Table 25: Potential damage and related precautions

Covering the membrane can also be done for aesthetic reasons, i.e. for a better integration of the pond into the landscape.

Covering the geomembrane will have a positive impact on the durability of the geomembrane (e.g. protection against mechanical aggressions) and it will ballast the liner (wind, water movement). Nevertheless, the cover can have some disadvantages:

- The risk of damaging liner during the installation process is high and special care is required (see paragraph 3.9).
- When the membrane is covered, it is very difficult to locate a leakage. It is therefore strongly recommended to subdivide the water drainage system under the membrane in order to detect more easily the damaged area.
- The slopes cannot be higher than 1V/3H to guarantee the stability of the cover (unless using concrete).
- The price of the cover is usually high.
- The installation time for the project is longer.

Protection of the Firestone GeoGard EPDM can be executed as described in the following chapters.

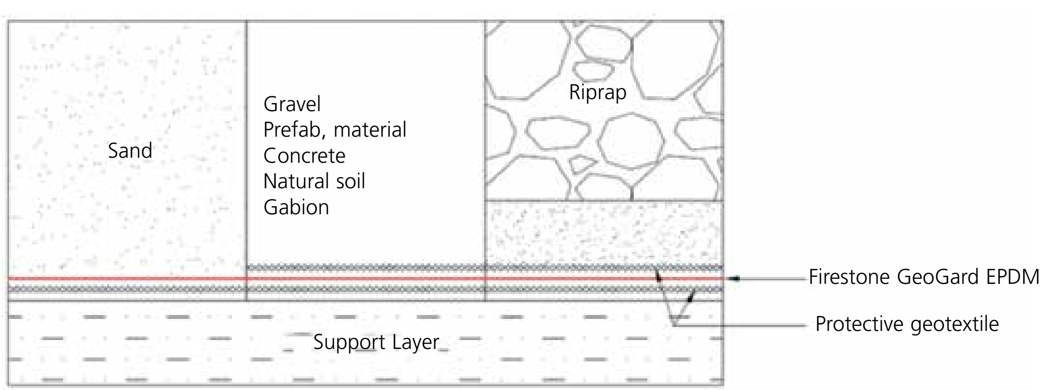


Figure 218: Top protection of the geomembrane

2.8.1 Bottom cover

Considering the low slope of the base and the lower stresses, the covering may be less robust in this area unless operating vehicles will circulate on it for maintenance (e.g. removing sediment at the bottom...).

The following material can be used to cover the base of the pond:

- Sand bed (minimum thickness[4]: 200 mm [8 in.]): protection with geotextile not required.
- Gravel (minimum thickness[4]: 200 mm [8 in.]): protection with geotextile required.
- Prefabricated materials (tiles): protection with geotextile required.
- Concrete: protection with geotextile required.
- Riprap: protection with geotextile and sand/gravel bed (minimum thickness: 200 mm [8 in.] required).
- Natural soil: protection with geotextile required.

If, for any specific reason (maintenance, ballast), the bottom of the pond is covered and not the slopes, it is recommended that the cover be slightly raised onto the embankments (see figure 219).

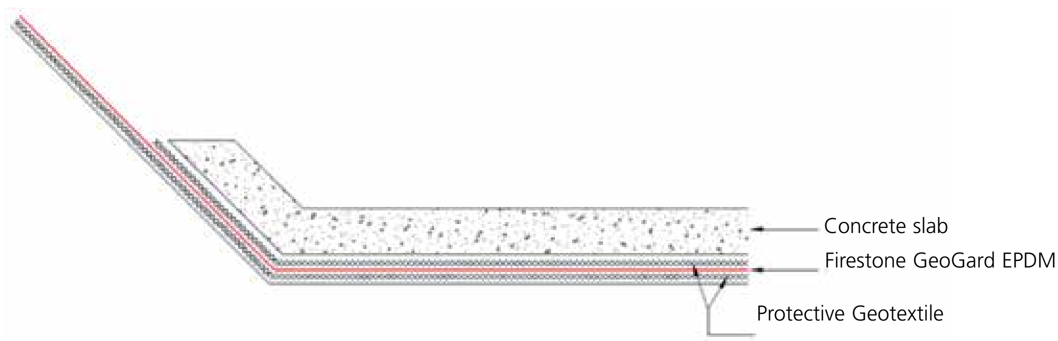


Figure 219: Raising the bottom cover onto the embankments

2.8.2 Embankments cover

The following material can be used to cover the embankments (see drawings at chapter 7.6):

- **Riprap:** this solution is applicable for slopes up to 1V/3H. A transition layer (geotextile + sand/gravel bed) with a minimum thickness of 200 mm (8 in.) is required. Rock covering depends on the level of the impacting forces (waves, ice crust...).
- **Gabion:** protection with geotextile required.
- **Prefabricated tiles, Cast Concrete:** a protective geotextile is required. Stability measures of the tiles/concrete at the foot of the embankment are required. The geotextile must have sufficient transmissivity to permit drainage under the tiles/concrete and prevent uplifting pressure. The support structure must be very flat.
- **Natural soil:** protection with geotextile or draining geocomposite required.

4 If no operating vehicles are expected

Example of a riprap cover:

A riprap covering must be sized so as to resist wind driven waves and ice crust formation:

- **Thickness:** between 0.3 and 0.8 m (12 in. and 32 in.)
- **Block diameter:** Maximum diameter < covering thickness (0.3 – 0.8 m) (12 in. - 32 in.), minimum diameter > 0.1 m (4 in.). It is considered that the median diameter of the blocks must be between 0.2 and 0.5 m (8 in. and 20 in.)
- **Typical structure:**
  - Firestone GeoGard EPDM
  - Geotextile between 600 and 1200 g/m^2 (18 oz./sy and 36 oz./sy)
  - 0.2 - 0.3 m (8 - 12 in.) bed of sand or gravel
  - Blocks
- **Stability:** the effect of the slope is heavily impacting the stability of the riprap. It is very important to respect the 1V/3H slope. If necessary, an abutment at the toe of the slope and/or geosynthetic reinforcement anchored at the top of the slope shall be provided.
- **Permeability:** permeability of the covering structure must be sufficient to avoid developing hydraulic pressure at its base.
- **Test plate:** in order to select the puncture resistant geotextile and to check the stability of riprap on the slope, it is strongly recommended to use an on-site test plate.

Picture 29: Riprap cover installation

2.8.3 Stability of the cover

The stability of a cover is an important issue that needs to be studied carefully in order to avoid significant damage caused by any sliding of cover material down the slope or excessive tension on the membrane.

The stability of the cover is determined by following parameters:

- Slope and length of the embankment
- The thickness of the cover
- The cohesion and density of the cover material when dry or wet
- The friction angle between the cover, the geotextile and the geomembrane
- The hydraulic pressure when the cover is not made of free-draining material
- The expected weight (cover, ice crust, construction machinery,...)

In general a maximum slope of 1V/3H is recommended when the geomembrane is to be covered. Coverings of poured concrete may have a somewhat steeper slope.

When performing stability calculations, it is necessary to consider sustainable operations (weight of materials, ice, snow, etc.), transient situations (weight of machinery and excess material during construction, rapid emptying, etc.) and accidental situations (seismic, blocked drain, etc.).

In order to stabilize the cover, some geosynthetic materials can be used:

- Geotextile or draining geocomposite between the cover and the geomembrane. Depending on the type of cover, the interface geosynthetic will have to assume several functions:
  - Resist to the tensile forces induced by the cover weight
  - Water drainage at the base of the cover in order to limit the hydraulic pressure when the cover is saturated (thaw, heavy rain, emptying of the pond). Not needed for free-draining material (sand, gravel)
  - Protection against puncture of the geomembrane during installation process of the cover and use of the pond
- Cellular geogrids filled with cover material. Experience shows that the ground is more likely to remain inside the cells if they are partially permeable. In order to retain the ground weight, the cells will have to be connected together or attached to rods running from the top of the embankment to the toe of the slope or to a reinforcement geogrid anchored into the anchor trench.
- Anti-erosive geotextiles installed on top of the cover. This geotextile will protect the cover against erosion, will promote the growth of plants and their roots will stabilize the cover.

Picture 210: Cellular geogrids filled with cover material

The geotextile installed on top of the membrane has to take most of the tensions induced by the cover. Therefore, the friction angle between the geomembrane and the geotextile needs to be lower than the friction angle between the geotextile and the covering material.

Stability may also be improved by applying a cover of variable thickness (thicker at the base and thinner at the top of the slope) or by applying an abutment at the toe of the slope.

If the cover is made of natural ground with no free-draining capacity, emptying the pond will be done slowly in order to prevent excessive hydraulic pressure at the base of the cover.

2.9 Inlet/outlet of the water

Inlet and outlet water systems are essential elements of the infrastructure to control and secure the proper functioning of the reservoir. They need to be designed by a specialized design company taking into account the specifics of each project.

2.9.1 Inlet

The characteristics of the inlet are designed following the expected inflow, the water provenance, the geometry of the pond and local topography.

The water inlet can be located at the top of the embankment, in the slope or at the bottom of the pond. The inlet is usually made using a pipe or a concrete structure. In any case, it is essential to dissipate the water energy in order to protect the membrane and the support layer from erosion. It is therefore strongly recommended that there is a concrete slab on top of the geomembrane in places where the water hits the geomembrane with high energy.

Picture 211: Concrete water inlet from the top of the embankment

Picture 212: Pipe water inlet from the top of the embankment without geomembrane protection

When located at the top of the embankment, the inlet level needs to be higher than the maximum water level in order to avoid water running out of the pond via the inlet.

When the inlet pipe is located at the top of the embankment and construction/maintenance vehicles are expected to drive on the crest, the pipe needs to be designed in order to withstand the pressure induced.

When the inlet is located under water (slope or bottom of the pond) it is obvious that the water entering the reservoir needs to have a higher energy than the water pressure inside the reservoir. In this case, it is strongly recommended that a good quality concrete structure is built around the pipe that will allow for a strong connection between pipe and membrane (see drawings at chapter 7.3) and reduce the risk of tensions caused by differential settlement (the ground around the concrete structure will be compacted with special care). The pipe going through the embankment is installed into a trench that will be covered afterwards with reinforced poured concrete (see Picture 215).

If the pond is covered with granular material, the cover could be eroded where the inlet water impacts the soil. The soil will have to be protected with a concrete slab or some riprap in this area.

Picture 213: Pipe water inlet with covered embankments

When the reservoir is filled with water coming from a river, it is recommended that a derivation pipe/canal is installed from the river to the pond. The direct ingress of the river water into the reservoir is certainly not recommended. In the event of a big storm, the river could introduce into the reservoir:

- Large quantities of sediments. This can cause maintenance difficulties when the membrane is not protected.
- Large amounts of water in a short period:
  - This can create big waves inside the reservoir. The run off needs to be properly calculated.
  - If the spillway is obstructed or not properly designed, the reservoir could overflow, damaging the embankments.
- Potentially aggressive objects with the risk of damaging a non-covered membrane (branches, rocks).

If the reservoir is located in a river bed (although not recommended) and a diversion of the river is not feasible, the geomembrane will be covered or/and a hydraulic infrastructure will be constructed upstream, in order to promote the sedimentation of small particles, capture the floating objects and decrease water energy. A water drainage system will be provided under the geomembrane in order to avoid the erosion of the support layer. Special care will be given at the water inlet in order to avoid water running under the geomembrane. A system of bypass will have to be installed to divert the incoming water during the reservoir maintenance.

Picture 214: Hydraulic infrastructures upstream (river bed) to remove sediments and floating objects and for the bypass

2.9.2 Outlet pipe

The outlet pipe is usually located at the bottom of the pond or at the toe of the slope. Therefore, it is an essential detail for the watertightness of the pond as it is going to be exposed to a high water pressure. The pipe has to go through the base of the embankment. The design of the outlet pipe therefore has to be done with special care.

The diameter of the pipe needs to be designed according to the required flow for downstream infrastructures. It is recommended that the water speed inside the pipe is higher than 0.6 m/s (2 ft./s) (to avoid sedimentation) and lower than 2.0 m/s (6.5 ft./s) (to avoid erosion). The entrance of the outlet pipe will be higher than the bottom of the pond in order to avoid its obstruction by sediments (estimate the annual income of sediments). The complete emptying of the pond will be done through the discharge pipe (see chapter 2.9.3).

When the outlet pipe is located on the embankment, it is recommended that the outlet pipe comes through the membrane perpendicular to the slope so as to facilitate the connection to the geomembrane.

The outlet pipe will have to go through the embankment into a trench that will be covered afterwards with reinforced concrete designed according to the expected ground weight. For very big projects, the collector pipes can go through a service tunnel.

The valve system depends on the scale of the reservoir. For large scale structures, valves are to be installed in a dry and accessible valve house. It is essential that valves are also accessible in winter. It is recommended that a valve system is installed which can also be serviced when the reservoir is full.

Additional information regarding water outlet pipes:

- Pipes are to be in steel or cast iron.
- Minimum diameter of 300 mm (12 in.).
- In order to prevent piping phenomena (water eroding the ground next to the pipe) in case of leakage, the pipe shall be placed in a trench that will be filled with reinforced poured concrete.
- Drainage shall be provided around the pipe for the downstream half of the dam body, to collect water under pressure coming from leakage of the pipe or failure of a connection between the pipe and the geomembrane. Drainage can also be provided around the connection between the geomembrane and the pipe.
- Expansion/compensation joints are to be provided.
- Special attention must be given to the connection between the pipe and the geomembrane. The connection will be made through mechanical anchoring of the geomembrane to a concrete block in which the pipe is embedded and finished with Firestone QuickSeam™ FormFlash (see drawings of the chapter 7.3). The concrete block shall be constructed so as to limit differential settlements and present a smooth surface in the area for connection with the geomembrane. It is essential that the concrete is of excellent quality and is applied in accordance with the best code of practice.

Galvanized trash retention racks are to be provided to prevent obstruction of the outlet pipe. In the case of an inlet chamber, it is recommended that bars (spaced about 1/3 the diameter of the pipe or sluice gates) are installed and an opening placed at such a height as to prevent obstruction (sedimentation).

In order to avoid membrane movements while pumping the water, which could obstruct the outlet pipe and cause tensions on the geomembrane, the application of a concrete slab is recommended on top of the membrane (with a protective geotextile) with a minimum surface of 2 m^2 (21.5 sq. ft.).

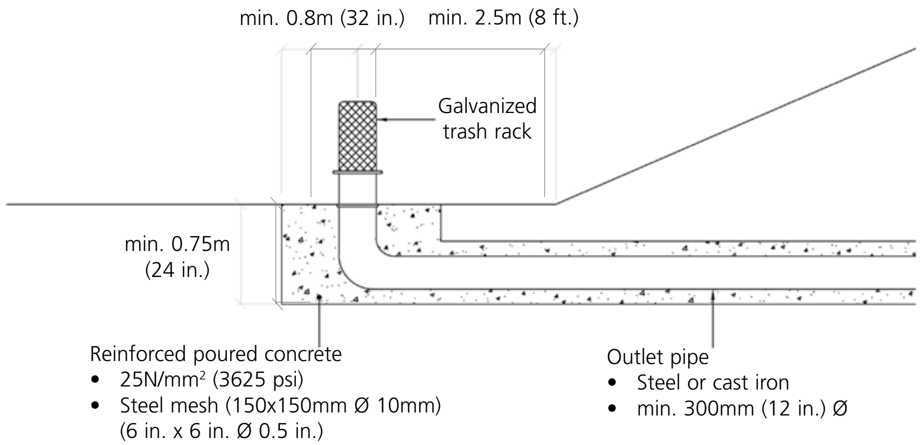


Figure 220 : Cut of the water outlet pipe

Picture 215: Outlet pipe through the embankment

Picture 216: Water outlet pipe in the embankment with ballasting concrete slab

Picture 217: Water outlet pipe at the bottom


Picture 218: Concrete water outlet combined with the spillway

Picture 219: Good quality concrete structure around water outlet pipe

2.9.3 Discharge pipe

In large scale projects, presenting a high human risk in case of disruption, it is recommended that a discharge pipe be installed for safety measures. It allows the reservoir water level to be rapidly and completely lowered when a major failure is observed. The discharge pipe can also be used to totally empty the reservoir for maintenance reasons.

The discharge pipe must be dimensioned so as to empty the entire volume of water within 1 or 2 days (depending of the volume stored). It is strongly recommended that discharge is facilitated by gravity.

The entrance of the discharge pipe will be protected with a galvanized trash retention rack in order to avoid any obstruction. The discharge pipe will be installed in the same trench as the outlet pipe. All the recommendations given for the outlet pipe will be followed for the discharge pipe (see chapter 2.9.2).

2.9.4 Spillway

In order to prevent the overflow of the reservoir an emergency spillway should be designed by a registered professional engineer and properly constructed in the reservoir sidewall to allow water to spill over onto a non-erodible hydraulic structure in case of emergencies such as a plugged pipe or extreme rainfalls.

- **Type:** it is recommended to build a free weir spillway of which the discharge threshold is at the same height as the normal reservoir level. Other frequent types of spillway are the pipe and tower spillway.
- **Hydrological dimensioning:** the dimension of the spillway must allow evacuation of excess water for flooding of the facility so that the reservoir level stays equal to or lower than the high water level. A safety coefficient must be applied.
- **Obstruction:** the spillway risks being obstructed. This must be considered in its construction. It is recommended that the spillway be constructed with gentle slopes and splayed walls to allow access by maintenance machines.

- **Threshold:** a reinforced concrete threshold is recommended to resist hydrostatic and ice pressure. Its foundation must not be subject to freezing. Special attention must be given to the connection between the threshold and the geomembrane.
- **Sluice:** the sluice may be built of various materials (reinforced concrete, gabions, concrete permeated riprap, etc.). In all cases it is essential that the support resists erosion, especially at the exit downstream of the threshold. It is usually helpful to provide underside drainage in order to avoid erosion of the subsoil and uplift pressure.
- **Discharge:** may be built from the same materials as the sluice. Its design dissipates the energy of the water before discharge into the natural environment.
- **Downstream discharge:** an energy dissipater shall be provided at the discharge outlet in order to prevent erosion of the downstream slope.

Picture 220: Free weir spillway upstream

Picture 221: Discharge of the free weir spillway

Picture 222: Pipe spillway

Picture 223: Spillway tower

2.10 Wind Uplift

When the reservoir is not always filled to the normal water level, exposed geomembranes must be weighted to prevent uplift by wind action. Wind uplift protection needs to be designed based on the expected winds, the length of the slope, and the exposure of the pond. The designer will define the type of ballast, its weight and its location (grid).

The highest wind uplift forces are situated on the first 5 - 6 m (16 ft. - 20 ft.) of the slope (from the top) due to the induced turbulences caused by the embankment. It is therefore strongly recommended to at least ballast this area.

At the top of the embankment, the anchoring/ballast of the membrane is described in chapter 2.4.1. On the embankments, wind uplift protection can be done in different ways (see also chapter 2.4.2):

- Parallel to the slope:
  - Ballast (precast concrete slabs, PE bags) coming from the top of the embankment and anchored on the crest. This solution can only be applied on the first few meters of the slope.
  - Ballast on the entire length of the slope (precast concrete slabs). In this case, an abutment at the toe of the slope will be needed.
  - Anchor trench running parallel to the slope.
- Perpendicular to the slope. In this case it is needed to make a berm on the embankment in order to ballast or anchor the membrane. This solution is difficult to operate, expensive and requires special solutions to insure the continuity of the water and gas drainage.
- Mechanical anchoring or gluing to concrete structures.

In any case it is very important that the geomembrane is well protected from the ballast (geotextile, extra piece of geomembrane) and that the ballast will not move.

At the bottom of the pond, even when empty, it is always recommended that a minimum quantity of water be left for ballast. If this is not possible, ballast will be placed at least at the toe of the slope.

In order to avoid movement and lifting of the geomembrane during installation, temporary ballast must be used. Such ballasting also facilitates the splicing operations. The ballast can consist of sand bags, tires or wooden planks

Picture 224: Wind ballast with precast concrete slabs anchored on the crest

Picture 225: Wind ballast with PE bags filled with gravel and anchored on the crest

Picture 226: Wind ballast with precast concrete running on the entire slope

Picture 227: Wind ballast with precast concrete on intermediate berm, at the toe of the slope and the bottom surface

2.11 Dimensional movements

Exposed membranes will undergo dimensional changes due to temperature differences. Furthermore, like any other geomembrane, EPDM is going to retract during its lifetime. In the case of EPDM, this is mainly due to the continuation of the vulcanization process. Therefore, the retraction will be accelerated when the membrane is exposed to high temperature. Dimensional movements will be increased by exposure time, weather conditions and the size of sheets. Dimensional movements need to be taken into consideration during design in order to avoid excessive tension on the geomembrane and seams.

Depending on project specifics, the following can be done:

- Cover or ballast the geomembrane (see chapters 2.8 and 2.10)
- Mechanically anchor and/or glue the geomembrane to concrete structures
- Anchor the geomembrane in trenches

Folded panels have a lot of stress from the folding and winding built into the sheet. These stresses will dissipate causing the membrane to shrink (shrinkage due to relaxation). Leaving the membrane ample time to relax before seaming is an easy way to anticipate this shrinkage effect.

2.12 Panel and seam layout

A panel and seam layout indicates the location of the geomembrane panels and their seams. The panel and seam layout will be made in three different stages:

- Before building the reservoir: this step is important to evaluate the type and quantity of needed materials and estimate the cost of the project. The details of the project will be studied to see if they are adapted to EPDM membrane installation.
- Following acceptance of the support, the panel layout will be adapted to the final shape of the reservoir based on the as-built drawing provided by the groundworks contractor. The goal is to evaluate the exact quantities, reduce losses and facilitate the installation process (panel orientation, distribution of the material, limit on-site splicing and cuts which are very important in corners).
- After geomembrane installation the as-installed panel layout will have the following information:
  - Panel location with geomembrane reference numbers
  - Seam location with QuickSeam seaming products and QuickPrime Plus reference numbers
  - Location of patches (T-joints, repairs)
  - Gas drainage and vents
  - Pipe penetrations and details
  - Destructive seam control samples
  - Anchor trench
  - Operation facilities

The panels need to be installed so as not to have seams perpendicular to the slope. The as-installed panel layout will be very important for the quality control and the maintenance process (even more for covered membranes). This will be the identity card of the geomembrane waterproofing system.

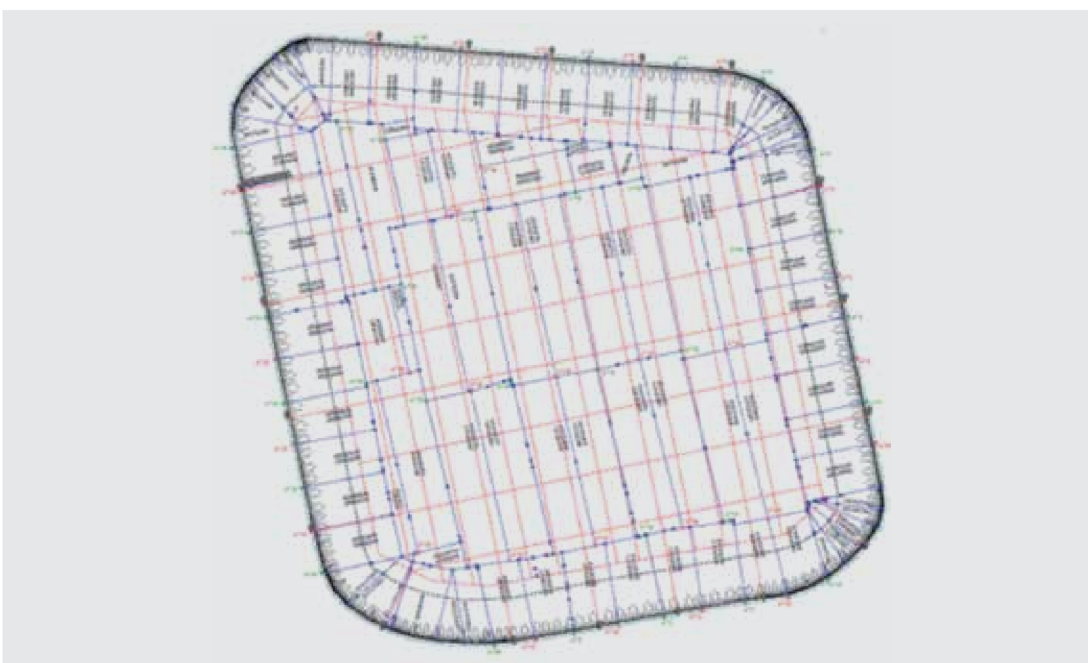


Figure 221: Example of as-installed panel and seam layout

2.13 Operation facilities

The main operation facilities needed for the normal use of a water reservoir are already described in the chapters above (water inlet, outlet, spillway).

To avoid damaging the installation during use, it is necessary to plan suitable infrastructures at the design stage:

- Service road, manoeuvering and parking areas: the use or maintenance of the reservoir could require the manoeuvering of machinery in the immediate proximity of the installation. It is therefore necessary to strengthen the access areas and ensure the security of workers. All such infrastructure will be equipped with a running water collecting system.
- Cleaning: access and manoeuvering of machines on the bed of the reservoir can only be achieved if provisions were made during the planning stage through a protected access ramp and a layer of concrete laid over the whole bed.
- Pumps, valves and pipes facilities will be located close to the external embankment, in line with the pipes going through the embankment, in an enclosed, dry engine room.

Picture 228: Engine room

2.14 Risk level

The whole design of the project will be conditioned by the incurred risk in case of failure of the reservoir (human, environmental, economical).

Depending on the potential risk incurred, the safety factors will be adapted in the stability calculation for each potential situation concerning the infrastructure:

- Finished project
- Full pond
- Break of the geomembrane waterproofing system
- Earthquake at full pond
- Quick emptying of the pond

2.15 Legislation

There may be various legislations involved when creating a new project:

- Town planning legislation
- Water legislation
- Agricultural legislation
- Environmental legislation
- Forestry legislation

Those different legislations can have a major impact on various aspects of the project:

- Preliminary studies (geotechnical, environmental)
- Site location (distance from housing, wells, rivers, buildings, protected areas)
- Storage capacity (permitted pumping, minimal storage capacity)
- Shape of the pond (free board, landscape integration)
- Safety measures (leakage detection system, cover, double layer)

It is therefore essential to study the different legislations in force during the design process.

3 Installation

The installation must be carried out in good climatic conditions to ensure the quality and durability of the finished installation.

During the construction and installation process, a conflict between quality and speed of installation can arise. It is therefore essential to have a quality assurance plan that defines precisely the required control actions which will help ensure quality of the installation (see paragraph 4.1).

The information provided below approximately follows the different installation stages.

3.1 Site preparation

The preparation of the worksite consists of the following operations:

- Building of site access routes (with sufficient load bearing capacity).
- Temporary drainage works to avoid the ingress of water into the storage reservoir, to lower the groundwater, evacuate rainwater, divert any water inlet.
- Brush cutting of the whole site.
- Laying out and leveling of the site.
- Removing topsoil (humus, grass, roots). Some of this soil may be used to construct the exterior banks.
- Preparing a storage place outside the working zone. It must be flat, clean, dry and with enough load capacity.

It is important that marking and leveling of the site is done in accordance with construction drawings. A site meeting will be organized after marking out and before starting the excavations, between the client, the project manager and the contractor, to verify conformity and validate the installation.

3.2 Earthworks

3.2.1 Site layout

The site layout may be obtained by means of:

- Excavating natural soil.
- Building raised embankments (for stability reasons a minimum excavation of 1 m (3 ft.) is recommended).
- Partial excavation with raised embankments.

The table below shows the advantages and disadvantages of the three systems.

System	Advantages	Disadvantages
Fully excavated	• Little soil movement (naturally consolidated) • Lower cost	• Removing the excavated earth • Water drainage problems
Raised embankments	• Easier drainage • The work is above the water level	• Higher cost • Compacting required • Risk of unstable embankment
Partial excavation	• Compromise of both systems	• Moderate cost

Table 31: Advantages and disadvantages of three groundwork systems

3.2.2 Foundation

The type of machinery used to build the foundation and the obtained productivity will depend on the type of ground on site.

Usually the ground is excavated at the base of the pond with a digger. In case of a rocky substrate, stronger machines (excavator with Jackhammer) or controlled blasting will be needed.

The excavated ground is loaded onto trucks and brought to the embankment zone, leveled using a bulldozer and a grader in uniform horizontal layers of 200 to 500 mm (8 in. to 20 in.) maximum (depending on the type of ground) and then compacted (at the right moisture content) with a compactor (road roller, chevron tamping wheels). The entire layer thickness needs to reach the desired compaction strength.

Before starting the excavation works, the general contractor needs to drain the site and protect the site from any potential flooding.

Before raising the embankments, it is strongly recommended to excavate a minimum of 1 m (3 ft.) of natural ground and compact the base of the embankment properly.

In places where the natural slope is greater than 10%, the excavation will proceed with terracing.

At the start of on-site installation, test sections will be made in order to define the adequate compaction process (machine type, humidity, layer-by-layer thickness, compaction speed, number of passes). The entire foundation must be compacted at 95% of the Proctor Optimum value. On-site density and humidity measurements will be taken every day.

Around concrete structures, the compaction will be done manually in order to avoid future differential settlements that could put the geomembrane under stress.

The bottom of the pond will be leveled with a minimum slope of 2%. The top of the embankment will be leveled with an external slope of 1-2%.

At the end of the project, the external embankment will be protected from erosion (grassed by hydroseeding).

Picture 31: Excavation of the base of the pond and truck loading

Picture 32: Unloading of excavated ground and levelling with bulldozer on the embankments

Picture 33: Compaction of the embankments with chevron tamping wheels compactor

Picture 34: Foundation overview


Picture 35: External embankment (before and after seeding)

3.2.3 Preparation of the support layer

The degree of compaction of the entire support layer needs to reach the 95% of the Proctor Optimum value. The compaction is achieved by either natural compaction or by mechanical methods. The smoothness of the interior sides of the pond (slopes and bottom) must be of impeccable quality. The supporting surface must not contain any loose stone with a diameter exceeding 20 mm (1 in.) (with a geotextile of minimum 300 g/m² (10 oz./sy) and outside the seaming zone). If needed, a stone crusher will be used before compaction or a backfill layer (sand, stable earth) of minimum 20 cm (8 in.) thick with controlled particle size (maximum 20 mm [1 in.])[1] will be installed and compacted.

All the angle changes of the support structure (crest/embankment, embankment/embankment, embankment/bottom) will have a curvature radius of minimum 0.5 m (1.5 ft.).

Particular care must be taken to ensure that construction equipment does not cause deformation or a change in the surface texture (grooves, exposing of stones).

The compaction operation can be followed by an authorized weed killer treatment (compatible with EPDM).

Picture 36: Support layer overview

1 Information provided on page 142 of the "Retenues d'altitude" – see bibliography for full reference

Picture 37: Stone crusher and final compaction

3.2.4 Inlet/outlet structures

The outlet pipe will be installed as soon as possible and certainly before raising the embankments.

It is strongly recommended that the outlet pipe and in general all pipes going through the embankment (inlet under pressure, discharge, drainage) are covered with reinforced concrete over their entire length and in continuity with the upstream concrete structure.

The type of concrete used and its installation process will be selected so as to ensure a good contact between the concrete and the pipe. The external face of the concrete will be rugged to guarantee good contact with the surrounding ground.

The compaction of the ground located close to the concrete covered pipes will be done with special care. The compaction process will proceed layer-by-layer in small thickness section, with a light compactor and numerous passes. The surrounding ground will have a good auto-drainage capacity in order to avoid erosion in case of leakage (ending in a leak detection structure).

The inlet pipe or concrete structure will be installed when the raising of the embankment is almost complete (close to the crest level).

The spillway will be installed at the same time as the inlet pipe.

A special care will be given to the pipe installation. Their water tightness will be tested.

The concrete structures onto which the geomembrane will be mechanically anchored need to be of very good quality (smooth, strong). Special care will be afforded to the compaction of the ground next to those structures.

The inlet and outlet valves will be installed in a way that they can be easily removed for maintenance and replacement.

In places where the geomembrane is subjected to water impact, water movements, or debris impact it is recommended that a structure be installed that will protect the membrane from damage (concrete slab on top of a geotextile, extra piece of geomembrane).

In countries where temperatures drop well below zero, special measures are required so as to avoid damage to pipes from freezing.

3.2.5 Acceptance of excavation work

The lining contractor must visit the project site to check whether the excavation works have been executed correctly. The surface condition must be inspected and any harmful element removed or corrected. Any correction must be made prior to the start of the waterproofing works.

A formal acceptance of the excavation works is required, before installation of the Firestone GeoGard™ EPDM lining system.

Excavation works are accepted based on following factors:

- The general appearance of the earthworks.
- Conformity of dimensions.
- The standard of surface compaction.
- The geometry of the surface of the embankment crest.
- The absence of foreign bodies which might damage the waterproofing layer (roots, iron bars, projecting stones, other sharp objects, etc).
- The management of water infiltration on the inner slopes and the bottom of the reservoir.
- Compliance with the slope of the reservoir bed.
- Water and drainage systems (if not made by the lining contractor).

It is important to note that the lining contractor is only supposed to approve the excavation works by means of a visual inspection of the surface of the support structure.

The installation of the geosynthetics (geotextile and geomembrane) will be done as soon as possible after acceptance of the excavation work in order to avoid any erosion of the support.

3.3 Water and gas drainage

The installation of drainage pipes must be carried out with great care to:

- Avoid crushing drains during the movement of site machinery and the compaction process.
- Avoid the formation of counter-slopes.
- Ensure the continuity of the drainage network (e.g. between the drainage system of the embankment and the drainage pipe at the toe of the slope).
- Ensure the connection of the pipes to manholes.
- Ensure the segmentation of the drainage network.
- Ensure the proper installation (quality and compaction) of the gravel inside the draining trench.
- Respect the installation rules for a filtration geotextile.
- Identify buried networks.

If due to the lack of permeability of the ground, the installation of a bed of permeable material (minimum 20 cm (8 in.) of sand or gravel [5/20]) is required for proper drainage, its installation will follow the same recommendations given for the construction of the foundation and the support layer. Special care will be given to the stability of this drainage layer if installed on the slopes. The drainage bed will be made of different layers and the particle sizes will respect the filtration law.

If the drainage system is composed of a geocomposite, its installation will be made respecting the panel layout, the slope and the recommendations of the manufacturer. The connection between the different panels needs to guarantee the continuity of the drainage and the filtration. If the connection is made by simple overlap, this overlap will be a minimum of 50 cm (20 in.). On the embankments, perpendicular connections will be avoided.

Special care will be taken when unloading, storing and installing the water drainage geocomposite to avoid any damage. No machine may be permitted to drive on top of a geocomposite unless properly protected (min. 30 cm (12 in.) of ground and specific care, see chapter 3.9). When a geocomposite is cut, it must not leave any sharp protrusion that could puncture the geomembrane.

3.4 Anchor trench

Anchor trenches are excavated just before the installation of the geomembrane, so that they can be used for temporary ballasting of the geotextile and the geomembrane.

The anchor trench has minimum recommended dimensions of 40 x 40 cm (16 in. x 16 in.) section and is positioned at least 1.0 m (3 ft.) from the crest of the embankment.

The time of excavation of the anchor trench is based on the levels of the flow sheet. Make sure that, under no circumstances, climatic conditions can damage the trench and/or cause it to fill.

The back filling and the compaction of the anchor trenches will be carried out in accordance with the rules of good practice, with a slight slope (> 1-2%) towards the outside of the installation so as to avoid any ingress of parasitic water and ground. Running water must always flow around the installation.

In order to reduce the induced stresses/forces while digging the trench, it is recommended that a trapezoidal bucket is used.

Picture 38: Trapezoidal bucket

Picture 39: Anchor trench with geotextile before and after back filling

3.5 Geotextile

The geotextile rolls need to be stored with an opaque and watertight packaging. The packaging is removed only just before installation.

The installation of the puncture resistant geotextile is carried out as follows:

- Hoisting of the roll using lifting machinery to the crest of the embankment.
- Unrolling of the geotextile along the length of the embankment or in the direction of the slope.
- Unfolding of the strips so as to cover the entire surface of the pond.
- Flattening of creases on the slopes and formation of angle pleats.
- The strips are joined either by thermo-welding or sewing.
- Temporary ballast is required.

The installation of the protective geotextile should not damage the quality of the support layer.

The number of folds of the geotextile will be limited in order to guarantee a lay flat installation of the geomembrane.

The rolls of geotextile are to be sewn or thermo-bonded together (min. 20 cm (8 in.) overlap) in order to avoid any movement of the geotextile while installing the EPDM geomembrane. Only sewn seams can be installed perpendicular to the slope.

Unless specially formulated for UV and weather resistance, the protective geotextile will be covered as soon as possible after installation.

3.6 Membrane installation

3.6.1 Panel and seam layout

Following acceptance of the support, the panel layout will be adapted to the actual shape of the pond based on the as-built drawings provided by the ground working contractor.

The panel and seam layout will facilitate the installation process as the foreman will know where to position the rolls, how to unroll them, how to deal with the corners, and where to reuse cut offs.

The panel and seam layout needs to be implemented every day by the foreman following the information provided in chapter 2.12. This document will also be used at the end of the installation to draw the as-built panel and seam layout.

3.6.2 Transport and storage

Care should be taken not to damage the geomembrane during transport, loading and unloading. The rolls must be stacked on a flat, dry and clean surface, free from any sharp protrusions.

Firestone GeoGard™ EPDM does not require any special protection against weather conditions. However, all accessories need to be stored in a dry and cool place between 10°C and 25°C (50ºF and 75ºF).

The use of specific machines or equipment is recommended for transporting the rolls to where they need to be installed. The use of a pin will facilitate transportation of the rolls.


Picture 310: Rolls storage and transportation

3.6.3 Placing the membrane

The rolls are unwound and unfolded according to the layout plan. Installation starts with covering the embankments. The geomembrane panels are unrolled from the trench towards the embankment and the geomembrane is temporarily fixed/ballasted at the top to avoid it sliding down. Ensure that no pebbles or sharp objects are trapped under the geomembrane, whilst the sheets are being unrolled. Be sure that nobody is standing downward of the roll before letting it go onto the slope.

If the panel needs to be moved after unfolding, the geomembrane can be lifted at the edge allowing air to play underneath, thus moving the membrane on an air cushion.

The geomembrane must be installed with some slack to allow for some shrinkage (continuation of the membrane vulcanization) and dimensional variations due to temperature changes and prevent overstretching in case of differential settlement. However, it should not be installed leaving excessive wrinkles or creases, especially not in seaming areas.

Excess membrane must be left at the foot of the embankment for connecting with adjoining panels. Horizontal splices on the embankments must be avoided.

In the corners, the membrane will be either folded or cut. The folds will be fixed with Firestone QuickPrime™ Plus. It is recommended to cover the folds with QuickSeam™ Batten Cover Strips or QuickSeam™ SA Flashing.

Firestone GeoGard™ EPDM must relax for at least 30-45 minutes before attachment, cutting or splicing the seams or executing details. Straight cuts are very important for a neat and easy application. Firestone recommends the use of scissors, markers and chalklines to achieve this. Do not use a razor knife.

While installing the sheets, folds in the geotextile and damage to the supporting surface must be avoided. It is not recommended that EPDM geomembrane sheets are installed when there are heavy winds.

Machines are not allowed to circulate on top of the installed membrane unless it has been specially protected.

Picture 311: Unrolling, unfolding

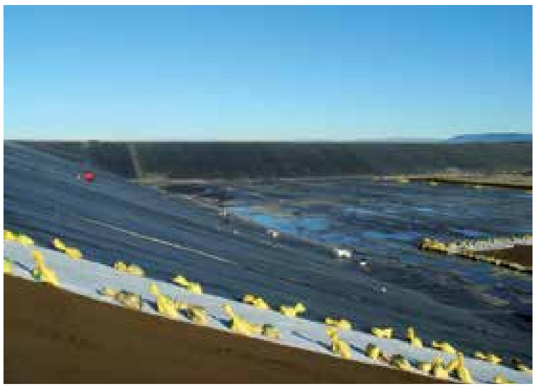
Picture 312: Moving the geomembrane on air cushion

3.6.4 Temporary ballast

Directly after unfolding the geomembrane, some temporary ballast needs to be installed in the anchor trench and on the geomembrane in order to avoid the geomembrane sliding down the slope or being lifted by the wind.

When different panels are seamed together, the wind can enter under the geomembrane and move large quantities of seamed panels. It is then impossible to replace the panels without making some cuts. Great care therefore needs to be taken at the end of every working day to make sure that the installed panels are properly ballasted.

Temporary ballasting can be done with sand bags (connected or not by ropes) or any other non-abrasive material such as rubber tires, etc.



Picture 313: Temporary ballast of the geotextile and the geomembrane with sand bags

3.6.5 Seaming adjoining geomembrane panels

The splicing of adjoining panels should be performed immediately after the relaxation of the Firestone GeoGard™ EPDM.

All panels must be installed without tension and without major wrinkles in the seam area, overlapping by at least 150 mm (8 in.). All seams on slopes must run up and down the slope with no horizontal seams allowed

Seaming procedure

Two overlapping Firestone GeoGard EPDM panels are assembled by means of 76 mm (3 in.) wide self-adhesive tape, QuickSeam™ Splice Tape. Below are the various steps required for correct splicing.

- **Step 1: Position, fold back the lap edge and temporary bond adjacent panels**

  Position the sheets at the splice area with an overlap of ± 200 mm (min. 150 mm) (8 in., min. 6 in.). The geomembranes must lay flat and without any tension. The upper geomembrane panel is then folded back ± 200 mm (min. 150 mm) (8 in., min. 6 in.). A line of primer (scrubber width) will be applied simultaneously on the two panels along the entire inside length of the joint. The upper panel is released and contact is made between the 2 panels by walking on the primed zone.

  Temporary bonding the 2 panels will secure their position during the entire seaming process and avoid any dust coming from the substrate into the seaming zone.

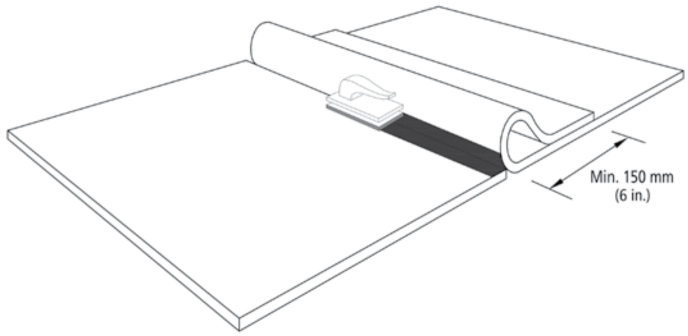


Figure 31: Seaming – Fold back and temporary bond

- **Step 2: Mark the sheets**

Once both membranes are in place, mark the bottom sheet 10 to 20 mm (0.5 in. - 1 in.) from the edge of the seam every 300 mm (12 in.) with the white crayon provided.

Use an index finger as a guide along the top edge; this gives an accurate measurement for this step. The marks will serve as a guide for the application of the QuickPrime™ Plus and installation of the QuickSeam™ Splice Tape.

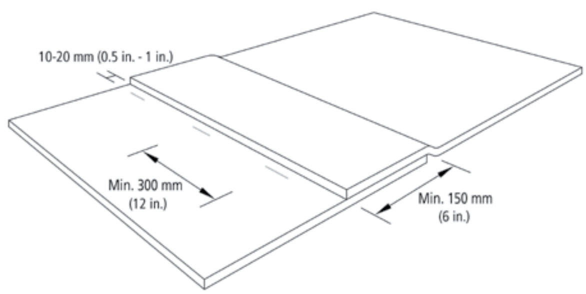


Figure 32: Seaming – Position and mark of the panels

- **Step 3: Tack-back the overlap**

Tack the top sheet back with QuickPrime Plus at 3.0 m (10 ft.) centres and at factory seams. This holds the fold in place during the splicing operation.

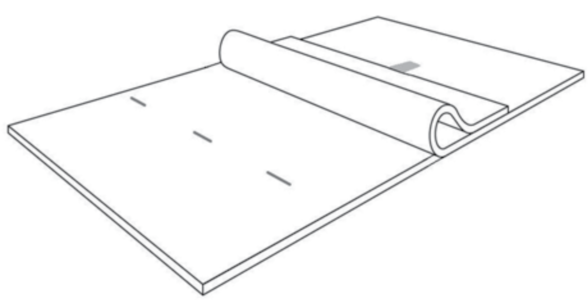


Figure 33: Seaming – Tack-back the overlap

- **Step 4: Apply QuickPrime Plus**

If needed remove excess dust and dirt on the sheet and at factory seams, using a stiff broom. Pre-scrubbing is required at all areas that have excess amounts of dust, mica and at all factory seams. Dip the QuickScrubber™ Pad into the QuickPrime Plus, keeping the scrubber horizontal and flat so that no primer drips out prematurely.

Apply the QuickPrime™ Plus using long back and forth scrubbing strokes, parallel to the seam along the length of the splicing area, until the surface becomes dark grey in color with no streaking or puddling. Scrub both surfaces at the same time to allow the same time to go off, start on the folded overlap. Be sure to overlap the guide marks on the bottom sheet and go beyond the edge of the top sheet.

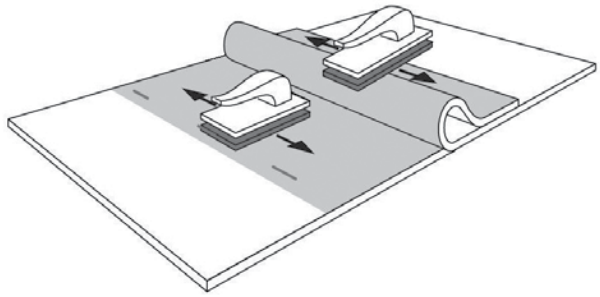


Figure 34: Seaming – QuickPrime™ Plus application

- **Step 5: Check QuickPrime Plus for dryness**

Allow the QuickPrime Plus to flash off completely. To test for dryness, use the touch-push test by pushing straight down onto the QuickPrime Plus with a clean, dry finger. Push forward on the primer at an angle. The primer should feel tacky but not stringy to the finger.

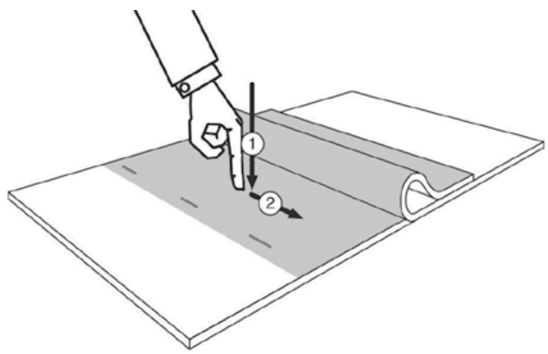


Figure 35: Seaming – Check for dryness of QuickPrime Plus

- **Step 6: Install 76 mm (3 in.) QuickSeam™ Splice Tape**

Position the 76 mm (3 in.) QuickSeam Splice Tape on the bottom sheet with the release paper facing upwards. Align the edge of the release paper with the marks. Roll the tape immediately using a 50 mm (2 in.) wide silicone rubber hand roller, applying firm pressure across the tape to remove any air that may be trapped between primer and tape. Hand pressure is not sufficient to seal the seam, since it does not provide uniform compression.

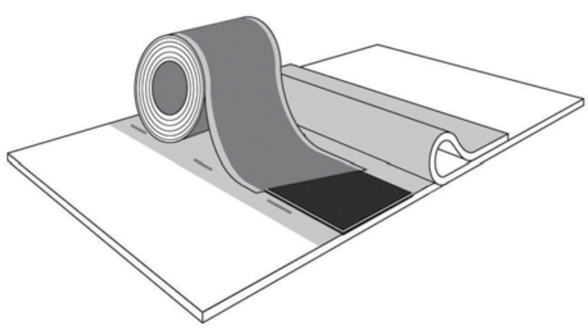


Figure 36: Seaming – QuickSeam Splice Tape installation

- ## Step 7: Check tape alignment

Untack the top sheet and allow it to fall freely onto the tape. Trim the top sheet back at all areas where the tape does not extend 5 to 15 mm (0.2 in. to 0.5 in.) (maximum 22 mm [0.9 in.]) outside the seam edge.

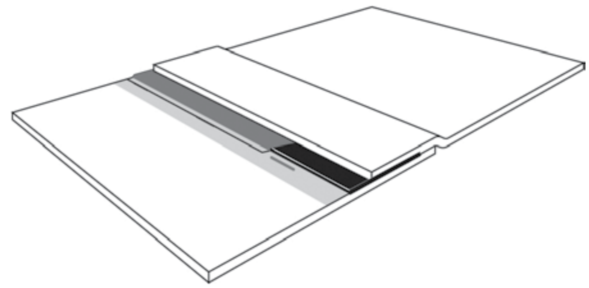


Figure 37: Seaming – Check tape alignment

- ## Step 8: Remove paper backing

To remove the release paper from the tape, peel the paper off the Splice Tape, by pulling it away from the seam at a 45° angle to the tape. Pull the paper at a steady pace and keep it low to the pond surface as it is removed to reduce air pockets. Close the entire length of the seam by hand, when the release paper is being removed.

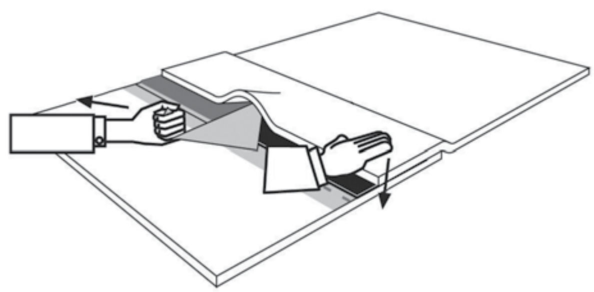


Figure 38: Seaming – Paper backing removal

- ## Step 9: Roll the seam

Roll the seam with the 50 mm (2 in.) wide silicone rubber handroller, both across the seam (1) and along its entire length (2) above both edges of the tape.

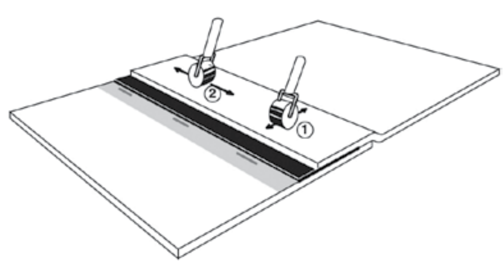


Figure 39: Seaming – Final rolling

- **General recommendations**
  - The support structure needs to be well compacted in order to guarantee a good seam (proper rolling).
  - All splicing surfaces must be free from dirt, moisture, adhesive or sealant and any other contaminants before the installation of QuickSeam™ Products. When necessary, pre-clean with the cleaning agent Splice Wash prior to the application of QuickPrime™ Plus. Other cleaning products, such as unleaded gasoline are not recommended. They may be contaminated with traces of products that may react adversely with EPDM membrane and fail to activate the surface in the same manner as Splice Wash.
  - All seaming products (QuickSeam Splice Tape, QuickPrime Plus) have product limitations. Follow the technical specifications outlined in the Technical Information Sheets to ensure correct application. Store all Firestone materials in their original sealed pails or unopened packages and rotate perishable materials so that they are used prior to the end of their shelf life.
  - Firestone recommends storing primers and sealants at room temperature between 10°C and 25°C (50ºF and 75ºF). Restore to room temperature 3 to 4 hours prior to use. Splicing activities may continue in cold weather provided adhesive, QuickPrime Plus and sealants are at room temperature prior to application and are used within a 4-hour period after being taken to the seaming zone. Stir primer thoroughly before and during use. This is a critical step that assures that the material performs properly; do not alter the products by adding solvents.
  - Firestone recommends seaming the membranes between 5ºC and 30°C (40ºF and 85ºF).
  - Precautions should be taken when using QuickPrime Plus in cold weather conditions (below 5ºC [40ºF]). Certain combinations of temperature and humidity may cause condensation to form on the surface of the primer. If this occurs, stop priming, wait for better ambient conditions prior to drying the surface and re-application of the QuickPrime Plus.
  - Complete a test splice to determine the risk of condensation. Never use heat guns or torches to accelerate the drying process of QuickPrime Plus. In normal conditions QuickPrime Plus will go off in 5 to 10 minutes, quicker in hot weather.
  - In hot weather Firestone recommends applying QuickPrime Plus first onto the bottom sheet and then installing the tape. After the tape has been rolled, apply QuickPrime Plus to the top sheet. Extreme warm weather may dry out the solvents quickly. This can be avoided by protecting the primer pails against hot temperatures by installing an insulation board between the can and membrane on hot summer days and by keeping the pails out of direct sunlight.
  - Before using the QuickPrime Plus, ensure that it is thoroughly stirred and poured into a small bucket.
  - Assemble the QuickScrubber™ Pad by twist-locking it into the Scrubber handle. Scrubber pads will last for approximately 60 lm (200 ft.) of seam. Replace with a new pad when the pad becomes compressed or when it has dried primer on it. Change the pad at the start of each working day.
  - In normal application, three strokes are typical. The first stroke is to spread the QuickPrime Plus and scrub the membrane; second stroke is to scrub the membrane and penetrate the primer, the third stroke is to eliminate puddles of QuickPrime Plus.
  - Pre-scrubbing the areas with excess dirt will help the priming process. Three to five strokes with the QuickScrubber™ Pad, perpendicular to the seam edge is necessary.
  - During the positioning of the tape on the bottom sheet, misalignment may occur. Stop the operation, cut the Splice Tape, make an overlap of minimum 25 mm (1 in.) with the end of the installed tape and continue the alignment with the markings. Mark the area for future reference (installation of reinforcement patch). Cutting the tape should be done with the tape sandwiched between 2 pieces of release paper for a clean cut.
  - Any "fish mouth" gap that occurs during installation of the tape should be cut away and repaired with a piece of QuickSeam FormFlash, covering the perimeters of the cut by minimum 75 mm (3 in.) in all directions.

– After closing the seam, it is important to observe a continuous mark of primer beyond the fold line of the top sheet.
– Moving the Firestone GeoGard™ EPDM during application of the Splice Tape and during the first few minutes after application should be avoided.
– Positioning of a larger number of panels than can be spliced in one day is not allowed.
– Field seams on side slopes must run parallel with the slope i.e. up and down the slope. Horizontal field seams on slopes are not permitted.

Special considerations

- **End of Splice Tape**

The adjoining roll of tape must overlap a minimum of 25 mm (1 in.). At these areas a patch of QuickSeam™ FormFlash should be installed as illustrated. Apply Lap Sealant around all exposed edges of the QuickSeam FormFlash.

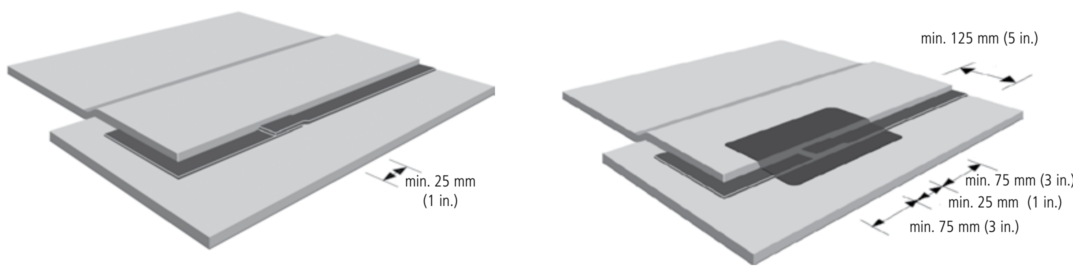
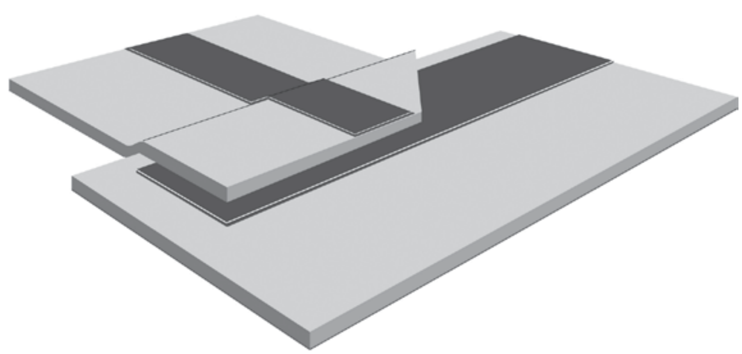


Figure 310: End of splice tape

- **T-joints**

There are two types of T-joints possible, depending whether the transversal joint covers the longitudinal or vice versa. In both cases, a QuickSeam FormFlash patch is necessary to the dimensions as illustrated below.

When the transversal seam lies on top, trim the QuickSeam Splice Tape so that the edge of the tape and the edge of the EPDM membrane are flush. Cut away any excess EPDM membrane at the inside of the seam at a 45° angle. Install a QuickSeam patch over the T-joint area as illustrated below. Seal all exposed edges of the covering piece with Lap Sealant.



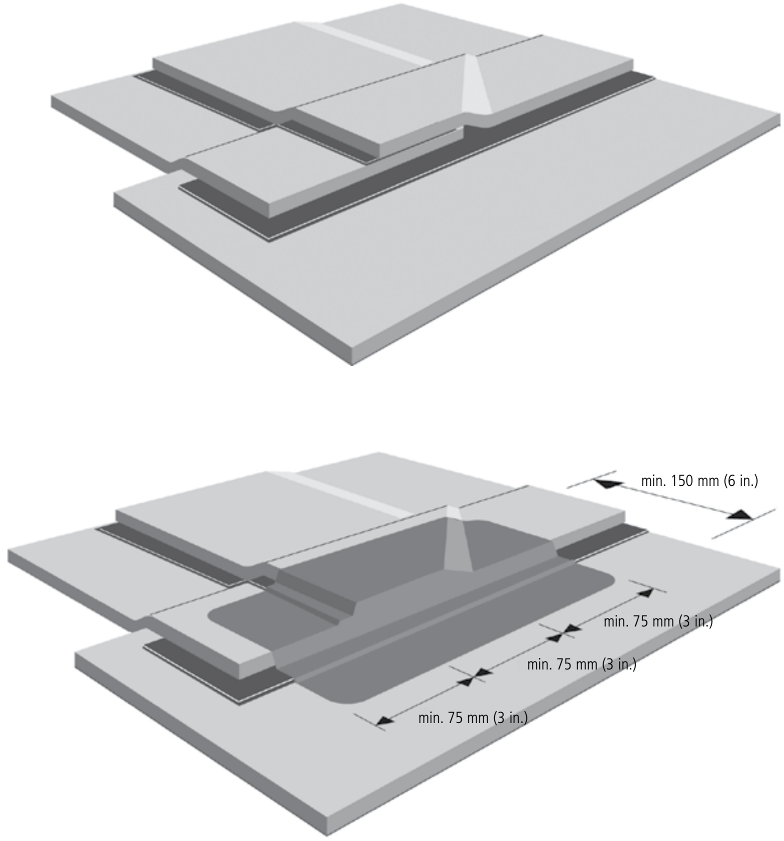
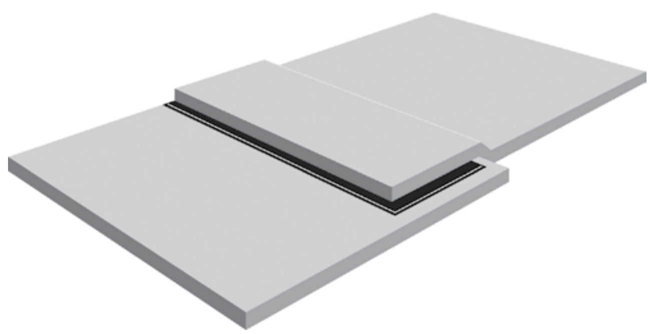
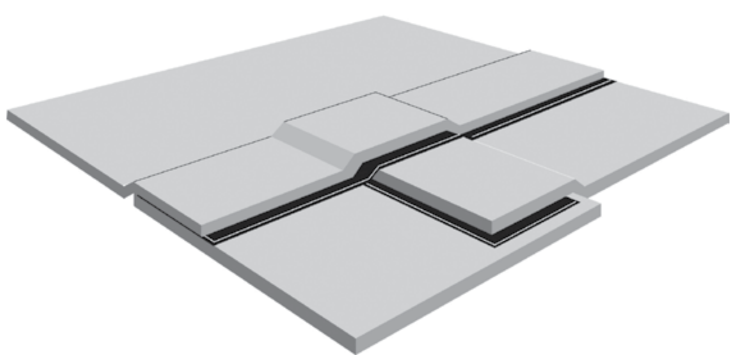


Figure 311: T-joint – Transversal seam lies on top

When longitudinal seam lies on top, install a QuickSeam™ patch over the T-joint area as illustrated below.





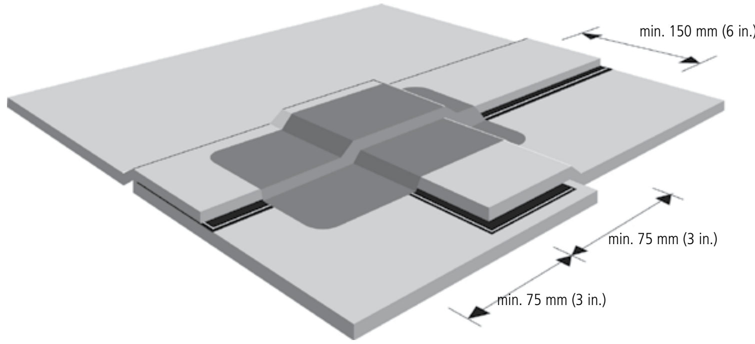


Figure 312: T-joint – Longitudinal seam lies on top

- **Vertical splice reinforcement**

In the area where a field splice runs from the horizontal area into any slope of the embankments or when there is an angle change bigger than 15% requires a joint cover piece at the base. The QuickSeam™ FormFlash patch with a minimum of 150 (6 in.) by 150 mm (6 in.) will be centered over the seam edge. Seal with Lap Sealant.

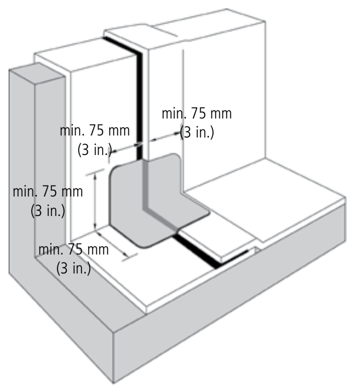


Figure 313: Vertical splice reinforcement

Seaming procedures

150 mm (6 in.) wide cover strip seaming tape system

- **Step 1: Position the PondGard™ membranes**
  - Both adjacent panels are positioned with sufficient overlap 100 mm (4 in.).
  - The panels should lay flat and without any tension.

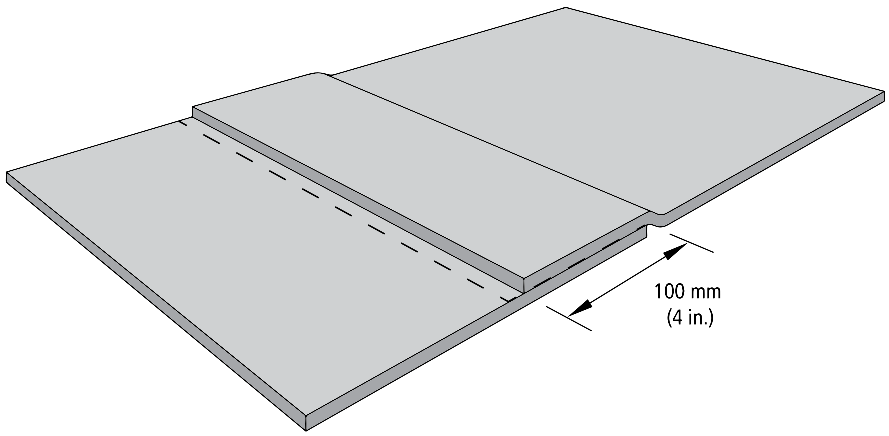


Figure 314: Position the PondGard membranes

- **Step 2: Clean the overlap**
  - If there is dirt in the overlap area, clean the overlap area using a clean cotton cloth. Soil should not be allowed to contaminate the PondGard membrane in the splicing area.
- **Step 3: Apply the QuickPrime™**
  - Stir the QuickPrime Plus before and during use and transfer a small quantity 1.5 l (0.4 gal.) to a bucket. The Primer is applied with a scrubbing pad.
  - Immerse the scrubbing pad in the QuickPrime Plus, keeping the pad horizontal and let excess of QuickPrime Plus drip off the pad.
  - Each pad immersed in QuickPrime Plus will cover an area of about 0.9 m (3 ft.) in length, over a width 100 mm (4 in.) (one side).
  - Change scrubbing pads every 61 m (200 ft.) or when the primer has dried on the pad. Used pads are to be discarded at the end of the working day.
  - Additional priming is required at factory seams, at the intersection of two seams and to areas covered with adhesive.
  - Both sides to be seamed are treated simultaneously so as to obtain an identical drying time.
  - Test QuickPrime Plus for readiness. Allow the primer to flash off. The primer needs to dry completely (approximately 5-10 minutes) before installing the tape. Check its dryness by touching the primed surface with a clean and dry finger (as indicated in the sketch) to be certain that the primer does not string. When touching the primer, push forward on the primed surface at an angle to ensure that the primer is dry through out its thickness. If either motion exposes a stringy primer when the finger is lifted, then the splice is not ready for installing the tape. Flash-off time will vary depending on ambient air conditions (relative humidity, wind...).

- **Step 4: Apply the QuickPrime™ Plus to the overlap**
  - Prime a minimum of 75 mm (3 in.) on either side of the overlap edge.

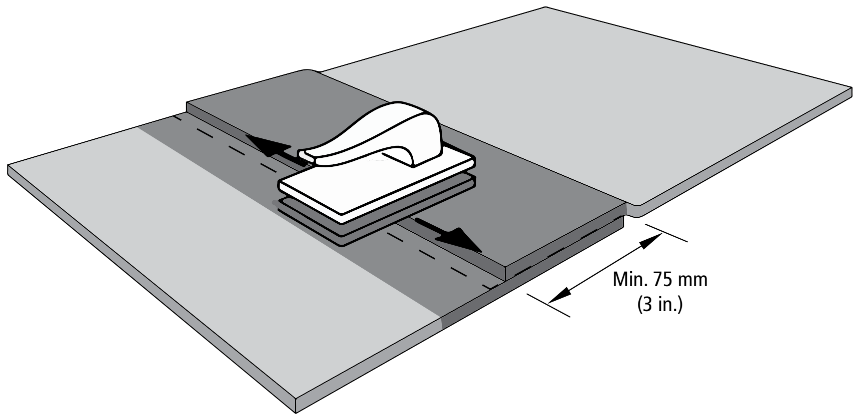


Figure 315: Apply the QuickPrime Plus to the overlap

- **Step 5: Install the cover strip**
  - Place the roll of QuickSeam™ Cover Strip on ground a few feet ahead of the overlap starting point, positioned so that it unrolls from the top of the roll (release paper will be on top).
  - Starting a minimum of 75 mm (3 in.) ahead of the edge of the panel, center the QuickSeam Cover Strip roll on the overlap edge and unroll onto the clean and primed surface.

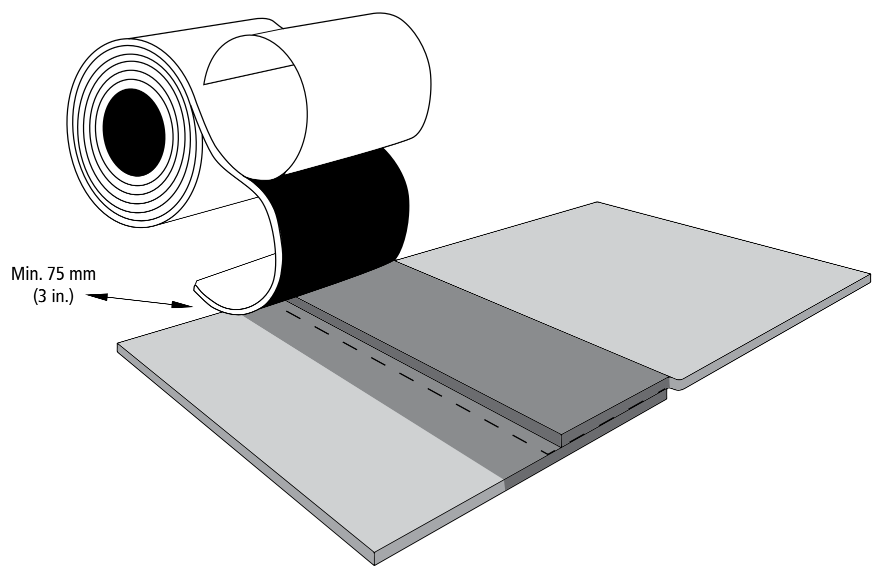


Figure 316: Install the cover strip

  - Advance the roll keeping the cover strip centered over the overlap edge. Peel the release paper as you apply the cover strip.
  - When it is necessary to cover a longer overlap edge than the length of one roll of cover slip, it is required to overlap the next roll a minimum of 25 mm (1 in.) onto the installed roll before continuing to unroll the second roll. When the end of the overlap is reached, extend the cover strip 75 mm (3 in.) before cutting.

- **Step 6: Roll the cover strip**
  - Apply pressure along the entire length of the cover strip by hand to completely mate the two surfaces. Using a 38 mm (1.5 in.) wide silicone rubber roller, roll the QuickSeam™ Cover Strip with positive pressure towards the outside edge then along the entire length of the cover strip.

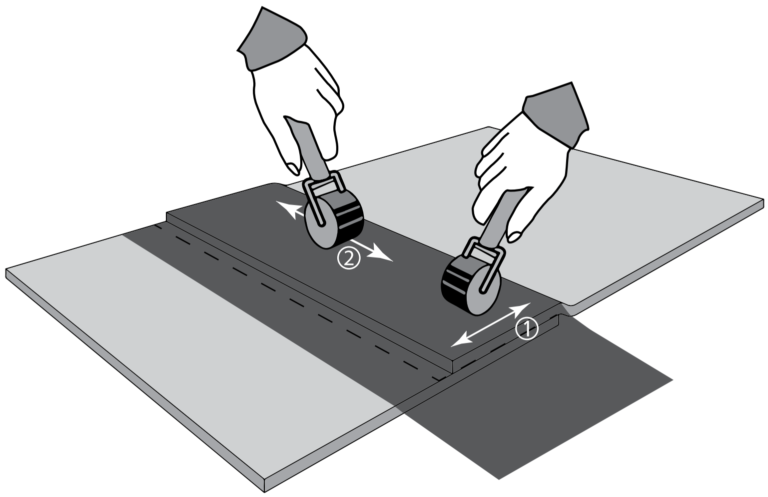


Figure 317: Roll the cover strip

- **Step 7: Install cover strip at the end of seaming runs or T-joints**
  - At the 25 mm (1 in.) laps of the cover strip it is required to install a 300 mm (12 in.) long section of cover strip parallel with the lap edge and centered over it. Before installing the cover strip, the area to be covered must be cleaned and primed in the normal fashion.
  - When cover strips intersect at any point, a 300 mm (12 in.) long section of cover strip shall be installed centered over each T-joint area.
  - Round the corners on the 300 mm (12 in.) section and then install it onto the dry-primed area. Roll with the silicone rubber roller in the same manner as done to the cover strip.
- **Step 8: Apply QuickPrime™ Plus to the cover strip section**
  - Use the QuickScrubber to apply the primer a minimum of 25 mm (1 in.) on either side of the cover strip section edge.
- **Step 9: Apply lap sealant to the cover strip section edge**
  - At the end of seaming runs and T-joints, allow the primer to flash off. Apply a continuous bead of Lap Sealant 9.5 mm x 6.35 mm (0.375 in. x 0.25 in.) around the cover strip section edge. Using the supplied Lap Sealant tool, feather the Lap Sealant immediately, taking care to leave a mound of sealant directly over the cover strip section edge.

3.6.6 Tool list

Below you will find the necessary tools to install Firestone GeoGard™ EPDM:

- **Job preparation**
  - Tape measure (50 m and 5 m) (150 ft. and 15 ft.)
  - Chalk line
  - Scissors
  - Claw hammer
  - Stiff bristle brooms
  - Squeegee
- **Cleaning Firestone GeoGard EPDM**
  - Clean Cotton Rags
  - Cleaning Agent – Firestone Splice Wash
- **Mechanical fixation**
  - Drilling machine with key
  - Drill bits (masonry and steel)
  - Hack-saw with blades
  - Screw-driver
  - Mastic gun
  - Tin snip
- **Installation details**
  - QuickScrubber™ pad + handle
  - Small plastic bucket
  - Marker (white)
  - Roller – 50 mm (1.5 in.) width (silicone rubber)
  - Brushes (solvent resistant, short hair and 100 mm (4 in.) width)
  - Paint rollers (solvent resistant, short hair and 225 mm (10 in.) width)
  - Hot air gun
- **Additional tools**
  - Electrical leads
  - Rubber gloves
  - Tool box with lock
  - Mixer
  - Cutter
  - Insulated storage box
  - Temporary ballast
  - Safety tools

3.7 Timing

The installation speed of Firestone GeoGard™ EPDM is greatly facilitated by its large panels, flexibility, high friction angle and splice tape seaming process.

The installation speed will be greatly affected by the following factors:

- Weather conditions
- Available machines
- Accessibility
- Experience of the contractor
- Number of details
- Length and angle of the slope
- Shape of the pond

An area of 150 m^2 (1600 sq. ft.) per day per person (including geocomposite, geotextile, geomembrane and details) is feasible for projects with experienced contractors, with adapted equipment and easy access. In general, for big projects, we recommend a team of minimum 6 people (2 trained operators + 4 assistants), not counting the equipment operator for the anchor trench.

3.8 Weather conditions

EPDM geomembranes have been applied at temperatures as low as -40°C (-40ºF) and as high as +50°C (122ºF) without the use of any special equipment. However, at extreme temperatures, there are a couple of points to consider in order to achieve a quality installation.

- EPDM geomembrane panels usually relax within 30 minutes of placement. Colder weather extends this waiting time. EPDM geomembrane will remain flexible at temperatures as low as -45°C (-49ºF).
- The temperature of EPDM geomembrane can rise up to 80°C (175ºF) when exposed to the sun. It is recommended to wear gloves when handling the geomembrane and wear knee protection when waterproofing seams and detail work.
- Placement of EPDM geomembrane must not be performed during any form of precipitation (rain, snow, hail), heavy wind, fog and/or in the presence of any surface moisture or in an area of standing water.
- Installation and positioning of large EPDM geomembrane panels may be difficult in windy conditions. Prevent any wind from getting under the geomembrane during installation. Use temporary ballast to keep the geomembrane in place until finally secured to the substrate.
- Precautions should be taken when using Firestone QuickPrime™ Plus, adhesives and sealants in cold weather conditions (below 5°C [40ºF]):
  - Start working with QuickPrime Plus, sealants and adhesives at room temperature (10-25°C [50ºF-77°F]). The use of insulated, heated boxes may be advantageous.
  - Cold weather will extend the drying time of QuickPrime Plus and adhesives, since the solvents will take longer to evaporate.
  - Seaming a geomembrane at temperatures between +5°C to -7°C (+40ºF to -20ºF) is going to require special attention, whereas seaming at temperatures below -7°C (-20ºF) is possible, but needs a specific installation process. However, the temperature mentioned is the temperature of the geomembrane, which is influenced by the sun (significant warming) and wind (wind chill factor). Preheating the EPDM geomembrane in the seaming area might – in some extreme conditions of cold and wind – be necessary to reduce drying time and make seaming possible.
- When using Firestone QuickPrime Plus in warm weather conditions > 30°C (> 86ºF) the following changes should be made to the installation technique:
  - Do not store the QuickPrime Plus directly onto the heated geomembrane but insulate the product from the geomembrane.
  - Do not leave primer cans open as the solvents will evaporate quickly.
  - As temperature increases, the drying time of the QuickPrime Plus is reduced. In order not to exceed the open time (time during which the primer remains active) shorten the length of the seaming section to 10 lm (33 ft.). Alternatively the primer can be applied to top and bottom side of the geomembrane separately, starting with the lower membrane. Apply the QuickSeam Splice Tape before priming the top membrane.
- Certain combinations of temperature and humidity may cause water condensation to form on an area of drying primer or adhesive. The actual appearance of condensation is somewhat unpredictable and its occurrence should continuously be monitored as work progresses. To determine if condensation has occurred, the following test can be performed. Approximately five minutes after the primer or adhesive is applied, touch the surface with a clean dry finger. If the primer or adhesive is tacky to touch, there is no condensation. If the primer or adhesive is coated with a film of moisture, it will not stick to the finger. If this condition occurs, seaming work must stop until the ambient air conditions no longer cause water condensation after which a thin additional layer of primer or adhesive needs to be applied.
- Never use open flame sources (propane torches, etc.) to expedite drying of the primer, adhesives, sealants, etc. Air-dry only.

3.9 Top protection installation

Often during installation of the cover layer, the membrane is subjected to the critical stresses. It is therefore essential to take all possible precautions when applying the cover layer over the geomembrane. Movement of machinery on the membrane should be prohibited unless absolutely necessary and with the use of special precautionary measures.

The installation of the cover layer will start with the positioning of a protective geotextile. The installation process will be the same as for the geotextile located under the geomembrane (see chapter 3.5). The different panels need to be connected by sewing (preferred) or thermo-welding.

The granular layers will be installed following the installation of the membrane in order to avoid any machinery running on the installed geomembrane.

If the installation process requires machinery to run on top of the geomembrane and the protective geotextile, some specific tracks will be created. The thickness of the track will depend on the characteristics of the project: geomembrane thickness, protective geotextile, granular material, machinery, substrate. It is strongly recommended that a test plate is made with the expected material and machinery before installation.

The trucks will run on tracks of minimum 1.0 m (3 ft.) wide and will unload onto an already covered surface (minimum 1.0 m (3 ft.) wide). The tracked excavator will run on tracks of minimum 0.5 m (1.6 ft.) wide. The machinery needs to drive slowly, straight (no u-turns) and brake softly.

The cover material will first be located in windrows and then gently spilled with an excavator on top of the geomembrane. The cover material will not be pushed onto the geomembrane in order to avoid wrinkles.

On the embankments, the granular material will be installed from the bottom to the top. If possible, the use of long arm excavators is recommended. Under no circumstances will the granular material be unloaded from the top of the embankment and allowed to slide on top of the geomembrane.

The cover layer will be softly compacted. On the embankments, compaction will be done from the bottom to the top following the line of greatest slope.

3.10 Details

If possible, avoid cutting the Firestone GeoGard™ EPDM at details. In some cases, however, as with corner details against concrete walls and connections to pipes, a cut in the geomembrane will simplify the installation. In such cases, QuickSeam™ FormFlash (unvulcanized rubber sheet) will be used in order to provide a watertight seal of the detail.

3.10.1 Corners

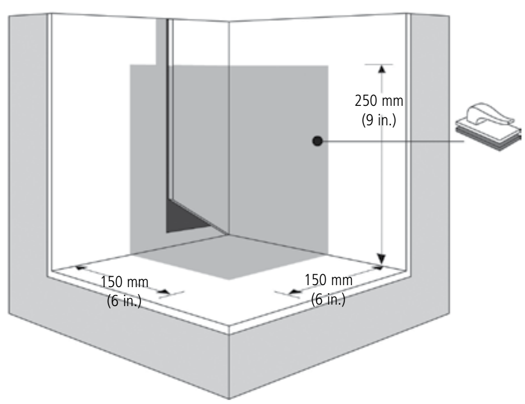
Inside corner using 229 mm (9 in.) QuickSeam FormFlash of QuickSeam, Corner Flashings (round)

- **Applicability**

  When flashing onto a concrete structure, the EPDM membrane is cut at the corners so that a vertical seam can be made at the angle change. The vertical seam is completed with 76 mm (3 in.) QuickSeam Splice Tape in accordance with general seaming techniques.

- **Installation instructions**

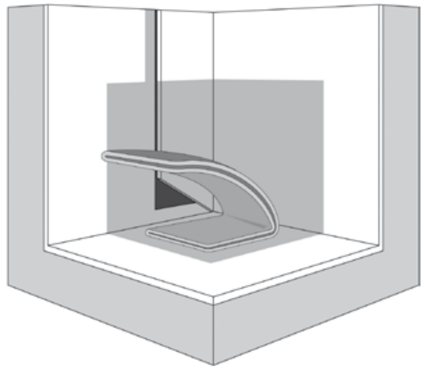
  The inside corner detail is a two step process using two identical pieces of QuickSeam FormFlash to cover the pinhole in the corner. Apply QuickPrime™ Plus on the membrane, to an area covering 150 mm (6 in.) from the pinhole on the horizontal and 250 mm (9 in.) on the vertical surface. In case the hole is larger than a pinhole, one should install first a piece of QuickSeam™ SA Flashing.

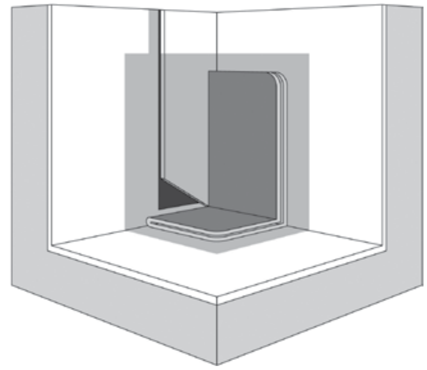


Both pieces of QuickSeam FormFlash are 229 mm (9 in.) wide and 300 mm (12 in.) long. Make sure to round all corners of the cut QuickSeam FormFlash pieces. Allow the QuickPrime Plus to go off completely before closing the QuickSeam FormFlash.

Fold the first QuickSeam FormFlash piece back on itself lengthwise, making sure the fold is approximately 10 mm (0.5 in.) offset from the center of the piece. Fold back a square base on the smaller half and remove the release paper.

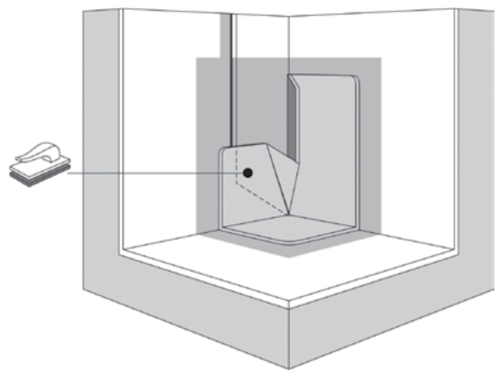
Position the folded base on the horizontal surface, 10 mm (0.5 in.) out from the upstand, as illustrated. Work the flashing piece tightly into the angle change and continue up against the upstand opposite to the vertical seam.





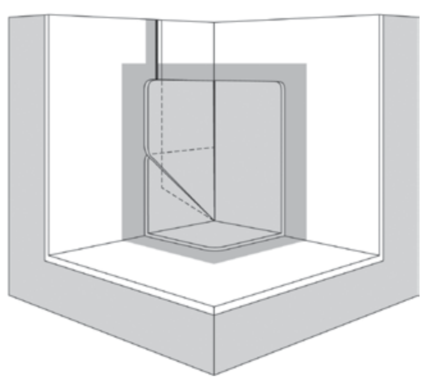
Note: A QuickSeam™ Corner Flashing may be used in place of FormFlash.

Work the QuickSeam FormFlash piece into the two remaining angle changes, forming a pig ear as illustrated. Beginning at the base, press the piece onto the vertical wall to form the pig ear fold. Work from the base of the fold to remove any entrapped air. Roll the QuickSeam FormFlash gently with a silicone rubber roller.



Note: A QuickSeam Corner Flashing may be used in place of FormFlash.

Apply QuickPrime™ Plus to the area that will be covered by the pig ear as illustrated and adhere the pig ear on the side of the vertical seam. Roll all adhered parts of the QuickSeam FormFlash piece with a small 50 mm (2 in.) wide silicone roller.



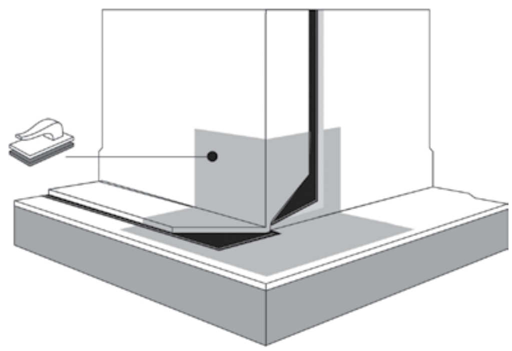
Note: A QuickSeam Corner Flashing may be used in place of FormFlash.

Use the second piece of QuickSeam FormFlash to cover the pig ear fold after reapplying QuickPrime Plus to the designated area. Be sure to center the width of the second piece over the side edge of the first piece and work it completely into the angle change. Roll the entire flashing piece with a silicone roller. Seal all exposed edges with Lap Sealant.

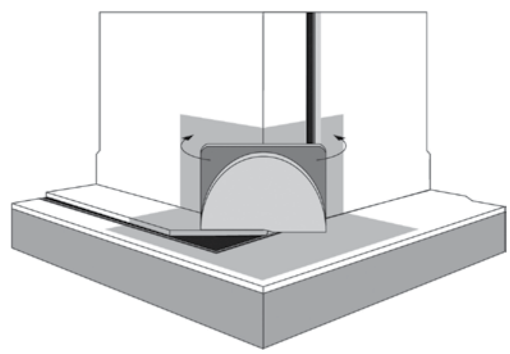
Outside corner using 229 mm (9 in.) QuickSeam™ FormFlash, Corner Flashings (round)

At outside corners, the EPDM flashing can be continuous (wrap piece on smaller penetrations), or in separate flashing pieces that are spliced together with a vertical seam at the corner. In both cases, the pinhole at the bottom of the outside corner will be waterproofed using a square piece of QuickSeam FormFlash of 229 mm (9 in.) wide that is cut circular at one end. Round off the cut corners on the opposite side. In case the hole is longer than a pinhole one should first install a piece of QuickSeam SA Flashing.

After completion of the vertical seam at the corner (if required), clean the corner area with QuickPrime™ Plus as illustrated. Fold the QuickSeam FormFlash piece in half with the release paper on the outside. Remove the paper from the square half.

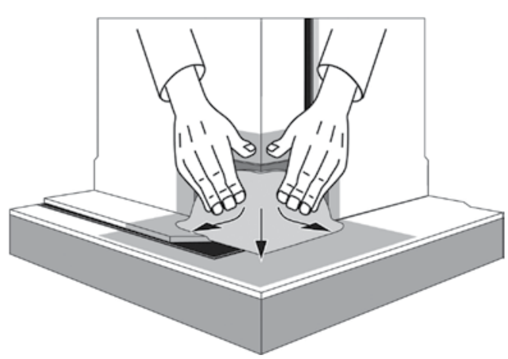


Position the flashing piece with the center aligned at the corner. Wrap both sections around the corner and close them to the vertical upstand.



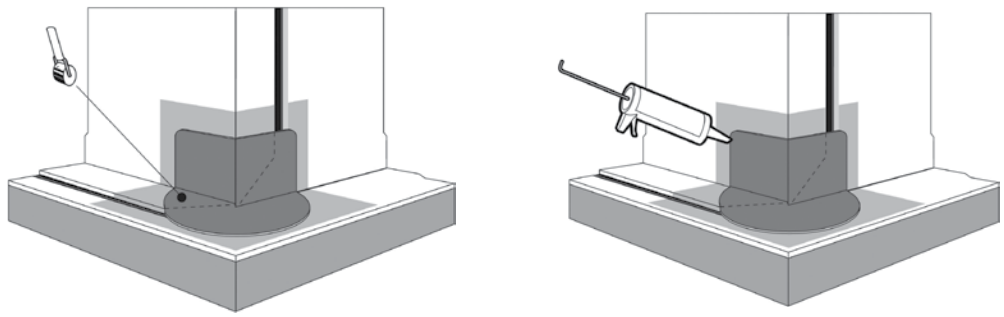
Note: A QuickSeam Corner Flashing may be used in place of FormFlash.

Remove the second half of the release paper and work the QuickSeam FormFlash from the tape side down to the angle change, as illustrated. Work the piece into the angle and continue out approximately 20 mm (1 in.) onto the horizontal surface, without overstretching. The diamond pattern into the material should remain visible. Fold the remainder of the circular part onto the horizontal surface, taking care to evenly distribute the stresses.



Note: A QuickSeam Corner Flashing may be used in place of FormFlash.

Roll the corner detail with a silicone roller from the inside towards out. Apply Lap Sealant along all exposed cut edges of the QuickSeam FormFlash.



3.10.2 Connection to concrete structures above the normal water level

Connections of Firestone GeoGard™ EPDM to concrete or masonry structures above the normal water level must comply with the following rules:

- Soil around the concrete structure must be compacted to minimum 95% of the Proctor Optimum Value.
- Concrete surface must be smooth, clean, dry and without any sharp protrusion.

Firestone GeoGard EPDM is adhered to walls using Bonding Adhesive. Make sure that the sheet is placed in its final position and fold it back evenly onto itself so as to expose the underside. Wipe any dust or dirt from the reverse side of the geomembrane and the wall prior to application of the adhesive. Stir the bonding adhesive thoroughly before and during use. Apply bonding adhesive at about the same time to the underside of the sheet and the substrate to which it will be adhered to (starting by the vertical substrate), so as to allow the same drying time. In case of roller application, use a paint roller with solvent resistant short bristles to apply a uniform film thickness. Care must be taken not to apply bonding adhesive over an area of geomembrane which is to be cleaned and spliced to another sheet or flashing. Allow the adhesive to go off until tacky. Follow the same method to verify as indicated in the splicing section (chapter 3.6.5). Starting at the fold, slowly roll the previously coated part of the sheet into the coated substrate, and work evenly so as to minimize wrinkles. Compress the bonded sheet with a stiff broom to ensure full adhesion.

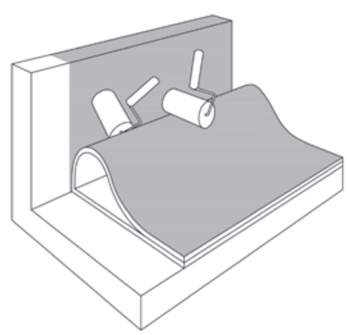


Figure 318: Bonding Adhesive application

Adjoining wall flashings are overlapped using standard seaming techniques. At the base, install a vertical splice reinforcement of minimum 150 by 150 mm (6 in. by 6 in.) centered over the seam edge as illustrated in Figure 313.

The Firestone GeoGard EPDM is fixed at the top (above the waterline) using a termination bar. Keep a minimum space of 5 mm (0.2 in.) between two adjoining bars. The termination bar must be installed directly onto the wall surface. Pre-drill holes into the brick, masonry or concrete but not into the soft mortar joint. A termination bar must be cut at inside and outside corners. Do not bend the bar around the corners. Prior to installation of the termination bar, pull back the topside of the membrane flashing 20 mm (1 in.) and apply a bead of Water Block between the membrane and the wall.

Install the termination bar with an acceptable hammer plug system at 200 mm (8 in.) o.c. Continuous compression is required and if needed additional fastening must be installed. Each termination bar must be fastened a maximum of 25 mm (1 in.) from the end.

Apply a bead of Lap Sealant or an acceptable High Grade Sealant on the topside of the bar.

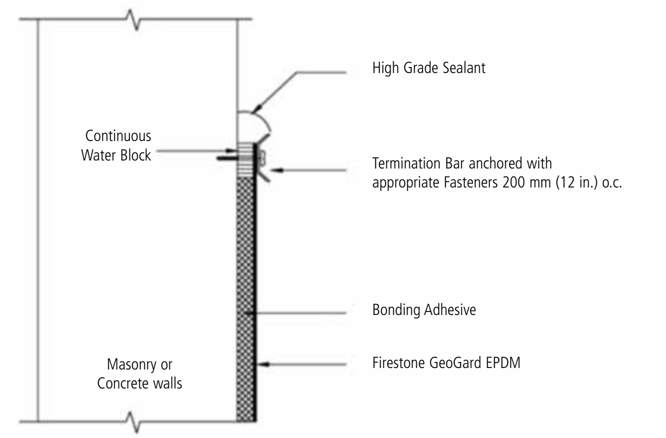


Figure 319: Connection to concrete structures above the normal water level

3.10.3 Penetrations above the normal water level

Connections to penetrations above the normal water level or under low water pressure (less than 2.0 m (6 ft.) water pressure) can be made by means of unvulcanized rubber sheet, QuickSeam FormFlash, as follows:

- Pipe needs to be firmly anchored and the pipe temperature may not exceed 60°C (140ºF).
- Make a circular cut in the geomembrane panel, measuring approximately 50% of the pipe diameter. Pull the geomembrane over the pipe.
- Pipe and geomembrane are flashed together by means of a piece of QuickSeam™ FormFlash and QuickSeam SA Flashing whenever possible.
- Finally, the assembly is mechanically secured with a stainless steel clamping collar (with a protection strip). This technique cannot be used for multiple penetrations, flexible conduits and cables.

If the geomembrane has been cut to accommodate the penetration, repair the cut as per Firestone specifications before installing the pipe flashing.

The area around the cut in the geomembrane needs to be reinforced. This will be done with a piece of QuickSeam SA Flashing whenever possible or two pieces of QuickSeam FormFlash.

Base flashing using QuickSeam SA Flashing

Cut a piece of QuickSeam SA Flashing that will overlap a minimum of 100 mm (4 in.) in all directions onto the geomembrane and cut a hole 20 mm (1 in.) smaller in size than the base of the pipe (D x d in Figure 320). Apply QuickPrime™ Plus on the designated area on the geomembrane and the pipe. Allow the primer to flash off and apply the piece of QuickSeam SA Flashing.

QuickSeam FormFlash application

The base flashing of the pipe consists of two identical pieces of QuickSeam FormFlash.

The dimensions of the QuickSeam FormFlash pieces are such that a base overlap of 100 mm (4 in.) with the field membrane in all directions and a 100 mm (4 in.) overlap between the two FormFlash pieces is provided.

This results in an overall dimension of (200 mm + Ø) (8 in. + Ø) x (100 mm + 50 mm + Ø/2) (4 in. + 2 in. + Ø/2). Pipes larger than 225 mm (9 in.) in diameter require the use of one or two EPDM base pieces, applied with normal seaming techniques.

Apply QuickPrime™ Plus to the pipe and the base membrane around the pipe in the designated area. Allow the QuickPrime Plus to go off completely. Apply the first piece of QuickSeam FormFlash and roll it towards the pipe, mark the diameter of the pipe on the reverse side of the QuickSeam™ FormFlash and make a horseshoe shape cut ensuring a 25 mm (1 in.) overlap up the pipe.

Mate the QuickSeam FormFlash without stretching to the primed area. Start at both outside edges, maintaining a straight line. Finally work the QuickSeam FormFlash into the base of the pipe. Apply QuickPrime Plus to the overlapping area and repeat the same procedure for the installation of the second piece forming an overlap of 100 mm (4 in.) minimum. Roll both pieces with a 50 mm (2 in.) wide silicone rubber roller.

Measure the third piece (pipe wrap) of QuickSeam FormFlash. This piece should overlap a minimum of 50 mm (2 in.) onto the base flashing. The appropriate length is determined by the circumference of the pipe plus 75 mm (3 in.) for the overlap. Fold back the wrap piece 50 mm (2 in.) and maintaining the fold, initiate contact at the base of the pipe. Stop when the first third of the piece is adhered vertically around the pipe. Use thumbs and forefingers to work the first part of the fold down and outward. Transfer all the stress in the QuickSeam FormFlash to the outside edge.

Apply QuickPrime Plus to complete the overlap and complete the wrap. Finally, work in the opposite direction to work down the remaining part of the fold. Roll the wrap piece and seal all exposed edges with Lap Sealant.

The pipe wrap edge is mechanically secured with a clamping collar installed over a geomembrane protection strip (figure 322).

Alternate Pipe Flashing Method

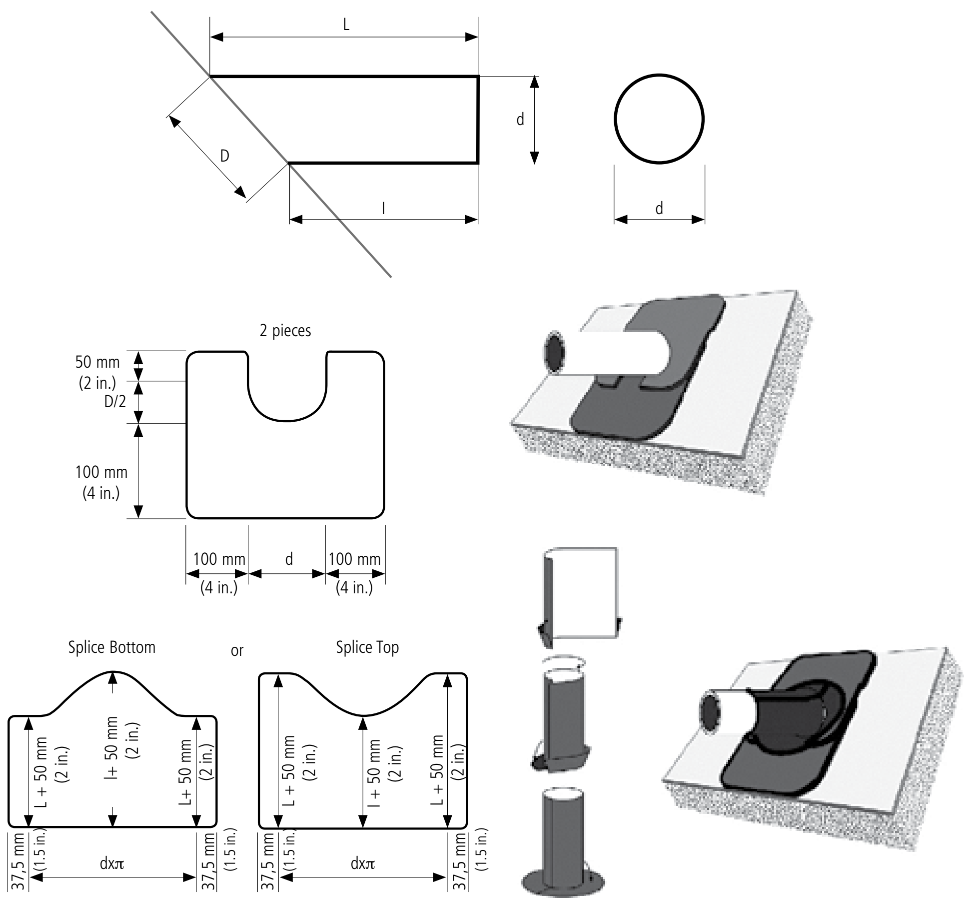


Figure 320: Penetration above normal water level

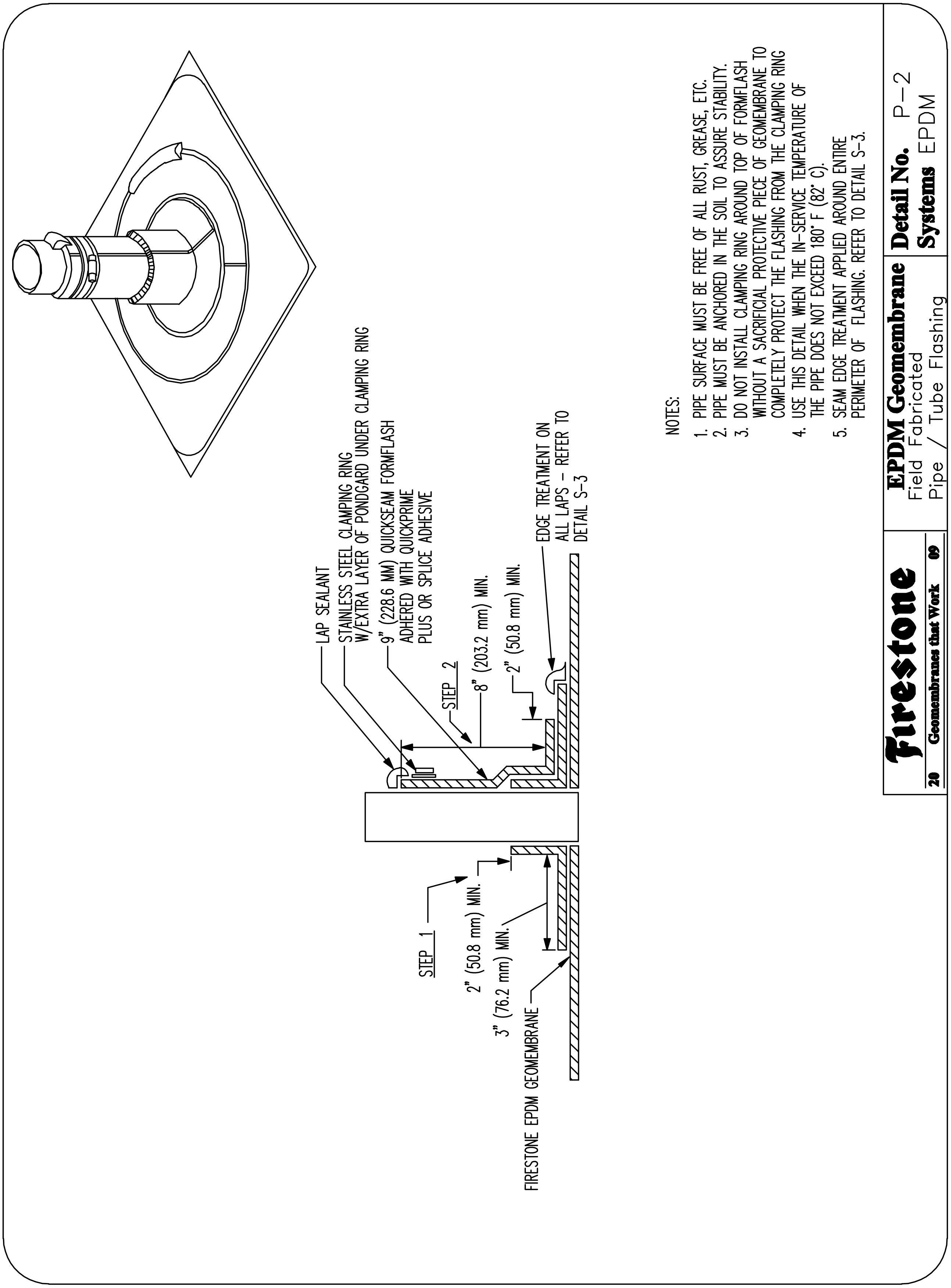


Figure 321: EPDM Geomembrane

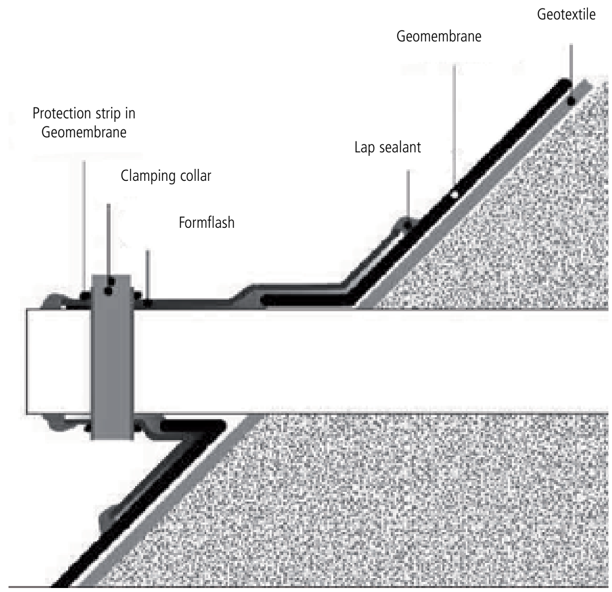


Figure 322: Mechanical securing with clamping collar

3.10.4 Connection to concrete structures located below normal water level

Mechanical anchoring of the geomembrane to concrete structures needs to be executed with the utmost care.

There are several ways of realizing this detail. Some solutions are presented below but they need to be adapted to the specifics of each site (water pressure, concrete quality).

In any case, the following recommendations should be followed:

- Very good ground compaction near the concrete structure (minimum 95% of the Proctor Optimum Value).
- Concrete slab must be smooth, flat and resistant.
- The anchoring metal bar needs to be rigid and the distance between fasteners properly designed in order to apply a constant pressure over the entire surface.
- The geomembrane has to be glued to the concrete structure over minimum 100 mm (4 in.) starting from the mechanical anchoring. For vertical connections, it is recommended to glue the geomembrane onto the entire vertical surface.
- Double or triple the protective geotextile at the junction between the ground and the concrete. The geotextile needs to be glued to the concrete slab.

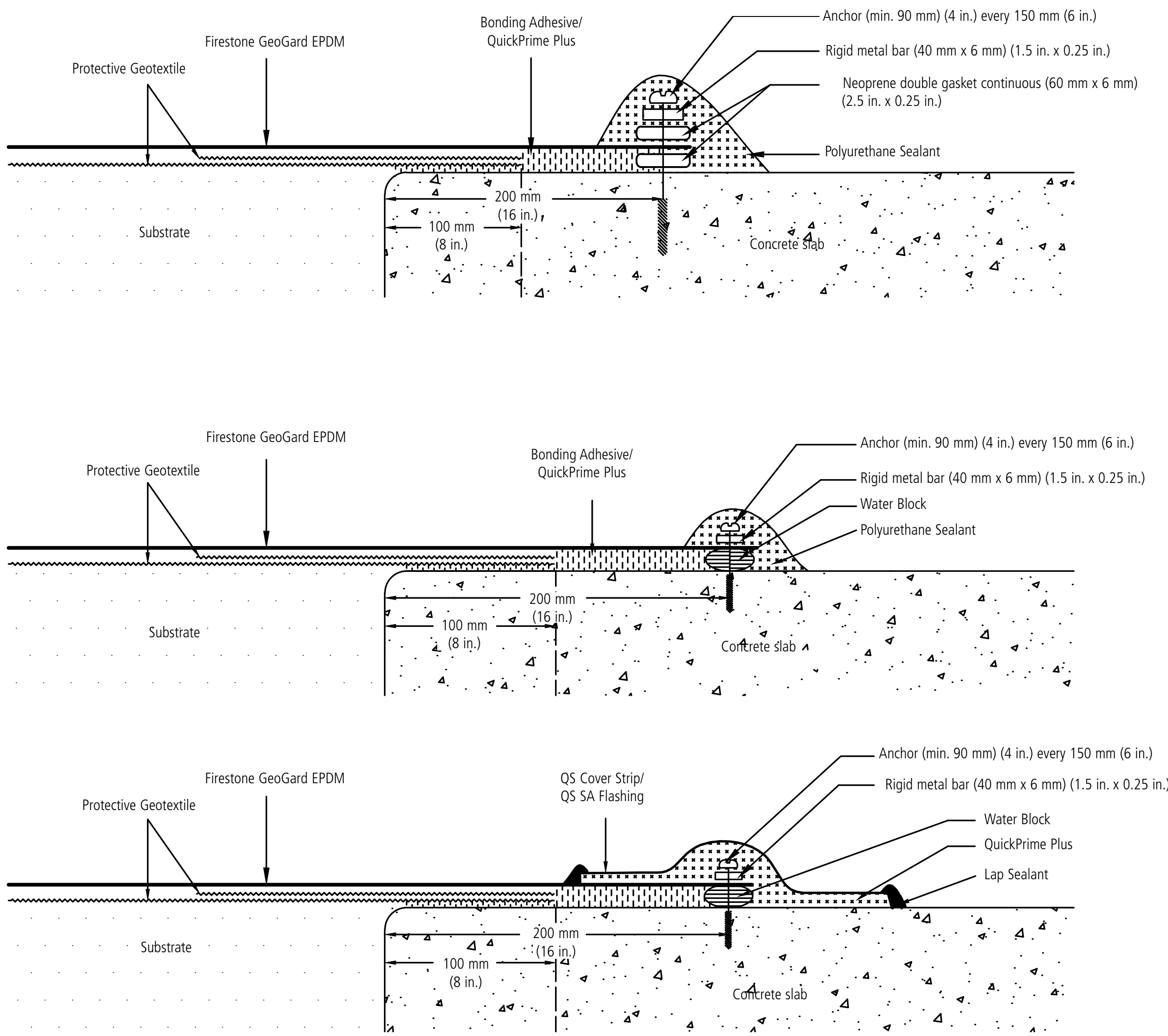


Figure 323: Mechanical attachment below water line

3.10.5 Penetrations located below normal water level

Special attention must be paid to the connection between the pipe and the geomembrane in order to avoid any tension on this detail. The pipe should be embedded in a concrete block constructed so as to limit differential settlements and present a smooth surface (see pictures in chapter 2.9.2).

The geomembrane will be first mechanically anchored to the concrete block as described in chapter 3.10.4. It is then strongly recommended that the geomembrane be mechanically clamped to a flange embedded to the concrete block and connected to the pipe (see Figure 324). If no flange is available, the pipe will be finished with geomembrane and QuickSeam Form Flash (see Figure 325).

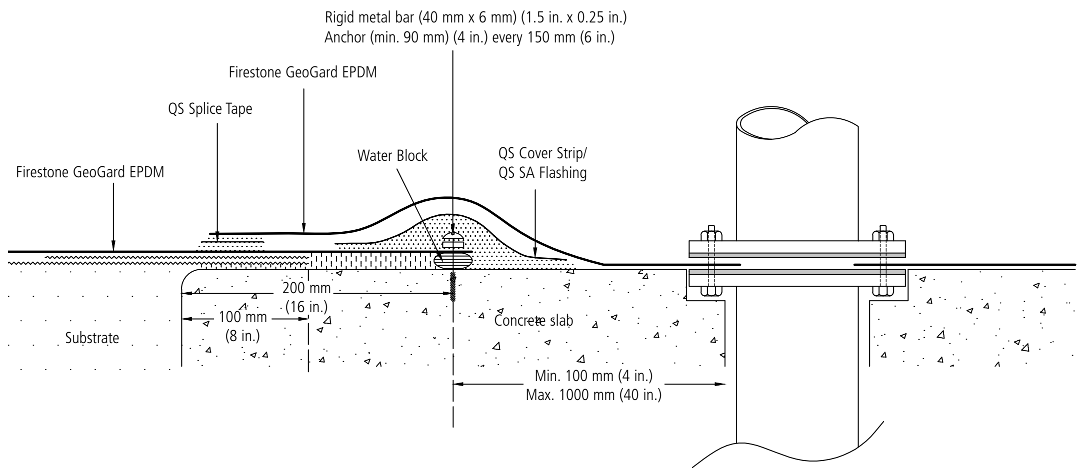


Figure 324: Mechanical attachment below water line and connection to a flange

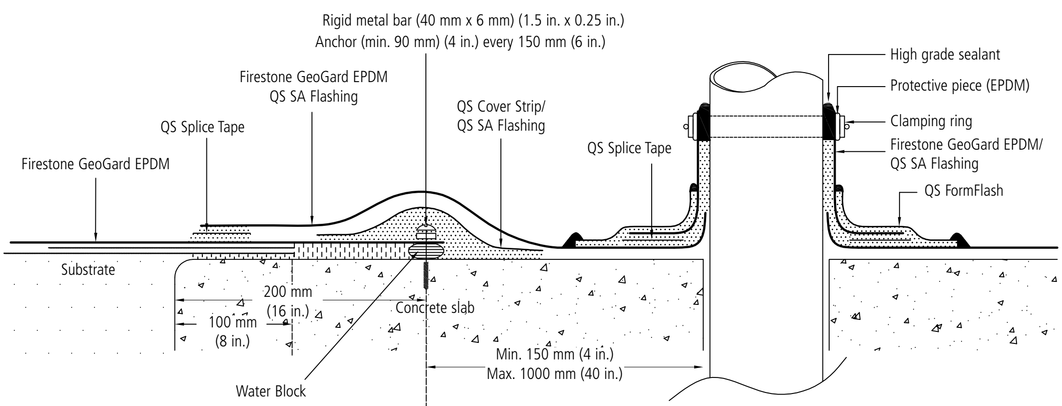


Figure 325: Mechanical attachment below water line and connection to a pipe

3.11 Safety

Specific precautions are to be taken to ensure safety of people and animals on site, especially when the reservoir has been installed close to residential and/or tourist areas.

The following precautions should be taken:

- Safety ladder or climbing rope permanently available for humans.
- Low gradient embankment.
- Impenetrable fence, 2 m (6 ft.) high, around the project.
- All required elements to protect workers and machines during maintenance and used in operations.
- A rodent ladder in order to avoid damages to the geomembrane by rodents trying to get out of the reservoir.
- Adherence to national and local legislation.

Picture 314: Safety ladder

Picture 315: Rodent ladder

4 Control and Quality Assurance

4.1 Control

A construction quality assurance inspector is appointed by the owner or the main contractor (with the approval of the owner), as the quality assurance person who is accountable to the owner and the main contractor for matters concerning quality. The CQA (Construction Quality Assurance) inspector is responsible for monitoring and documenting activities related to the quality assurance of the Firestone GeoGard™ EPDM from delivery through installation. The inspector must have relevant experience with EPDM products and be independent from the manufacturer and lining contractor.

An independent geosynthetics laboratory is hired by the owner or the main contractor (with the approval from the owner), as a third party quality assurance laboratory, independent from the manufacturer and lining contractor. The independent geosynthetics laboratory is responsible for laboratory quality assurance geomembrane testing when required by the owner. The independent geosynthetics laboratory must have relevant experience.

4.1.1 Earthwork

- The general contractor is responsible for preparing the supporting soil according to the specifications. Prior to geomembrane installation, the CQA inspector will observe that:
  - The surveyor has verified all lines and grades.
  - The general contractor has provided to the owner or main contractor all CQA documentation that is needed to demonstrate that the supporting soil meets the density specification.
  - The surface to be lined has been rolled and compacted and the general contractor has verified that the surface is free of irregularities, protrusions, loose soil, and abrupt changes in grade.
  - The general contractor has verified that the surface of the supporting soil does not contain stones which may be damaging the geomembrane.
  - The general contractor has verified that no area is excessively softened by high water content or water income.
  - The general contractor has verified the presence of a water and a gas drainage network and corresponding evacuation vents as per the guidelines of the designer.
- Lining contractor certifies, in writing, that after visual inspection (in presence of the CQA inspector, the prime contractor and the general contractor), the surface and details on which the Firestone GeoGard™ EPDM is to be installed is acceptable (smooth, free of aggressive angle changes, stones, vegetation and small cavities). The certificate of acceptance is issued by the lining contractor to the CQA inspector prior to commencement of the geomembrane installation in the area under consideration.

4.1.2 Anchor trenches

- Anchor trenches are excavated by the general contractor or lining contractor to the lines and widths shown on the design drawings, prior to geomembrane placement. The CQA inspector inspects anchor trench construction to verify that anchor trenches have been constructed according to drawings.

- Slightly rounded corners are provided in trenches where the Firestone GeoGard™ EPDM adjoins the trench to avoid sharp bends in the membrane. Loose soil under the geomembrane in the anchor trenches is not permitted.
- Backfilling of anchor trenches is conducted in accordance with chapter 2.4.

4.1.3 Delivery of materials on site

The lining contractor will have to be present on site when unloading the materials so as to ensure the correctness of the delivery and to monitor the unloading and storage of all materials. The CQA inspector needs to control the compliance between the delivered material, the technical data sheet and the specifications of the project.

4.1.4 Geotextile placement

The CQA inspector observes the geotextile placement procedure to verify that:

- The geotextile panels are fixed together (sewn or thermo-bonded) with an overlap of 200 mm (8 in.) minimum. The seams will not be perpendicular to the slope unless if they are sewed.
- Temporary ballast is used to keep the geotextile in place.

4.1.5 Firestone GeoGard EPDM placement

- Panel layout: following acceptance of the support, a sheet layout plan will be established or adapted. The aim should be to facilitate the installation process and minimize the number of T-joints, the amount of seaming on site and the Firestone GeoGard EPDM loss percentage.
- Field panel identification:
  - A field panel is the unit area of geomembrane which is to be seamed in the field.
  - It is the responsibility of the lining contractor to ensure that each field panel is given an "identification code" (numeric or alphanumeric). This identification code is agreed with the main contractor, general contractor, lining contractor, and CQA inspector. This field panel identification code should be simple and logical. The panel number shall be marked in a location agreed upon by the main contractor, general contractor, lining contractor and CQA inspector.
- Location: The CQA inspector observes that field panels are installed in the location indicated in the proposed panel layout drawing, as approved or modified.

4.1.6 Installation schedule

- Field panels are placed one at a time and each field panel shall be seamed immediately (after the relaxation time) after its placement.
- The CQA inspector evaluates every change in the schedule proposed by the lining contractor and advises the main contractor of the acceptability of that change. The CQA inspector and the lining contractor verify that the condition of the support soil has not changed since the acceptance of the support.
- The lining contractor must record the identification code, location and date of installation of each field panel and submit the documentation to the CQA inspector no later than the following day.

4.1.7 Weather conditions

- Firestone GeoGard™ EPDM placement will not be performed during snow, heavy wind or in an area of standing water.
- Firestone GeoGard EPDM weather conditions for seaming are described in chapter 4.1.10.5.
- The CQA inspector observes that the conditions above are fulfilled. Additionally, the CQA inspector observes that the supporting soil has not been damaged by weather conditions and informs the main contractor of any discrepancies.

4.1.8 Method of placement

- The CQA inspector inspects the lining contractor's work to ensure the following:
  - Any equipment used does not damage the Firestone GeoGard EPDM.
  - The prepared surface beneath the geomembrane has not deteriorated since previous acceptance.
  - Personnel working on the Firestone GeoGard EPDM do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane.
  - The method used to unroll and unfold the panels does not cause damage to the Firestone GeoGard EPDM and does not damage the supporting soil.
  - The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels).
  - Suitable temporary ballast (e.g. sand bags, tires) is not likely to damage the Firestone GeoGard EPDM.
- The CQA inspector informs the engineer if the conditions listed above are not fulfilled. The lining contractor is solely responsible for protecting the Firestone GeoGard EPDM against wind uplift during the construction process.

4.1.9 Damage

The CQA inspector must visually observe each panel, after placement and prior to seaming, for damage and advise the lining contractor which panels should be rejected, repaired or accepted. Damaged panels or portions of damaged panels which have been rejected are marked and their removal from the work area is recorded by the lining contractor. Repairs are completed in accordance with Firestone Repair Guidelines (see chapter 4.5).

4.1.10 Field seaming

4.1.10.1 Seam layout

- The lining contractor provides the main contractor, the general contractor and the CQA inspector with a seam layout drawing, i.e. a drawing of the facility to be lined showing all expected seams and T-joints. The CQA inspector, main contractor and general contractor review the panel layout drawing and verify that it is consistent with the accepted standards of practice and this CQA plan. No panels may be seamed in the field before the engineer and the CQA inspector approve the panel layout drawing.
- Seams are oriented parallel to the line of maximum slope, i.e. oriented along, not across, the slope.
- A seam numbering system compatible with the panel numbering system must be agreed.

4.1.10.2 Personnel requirements

- All personnel performing Firestone GeoGard™ EPDM seaming operations shall be trained and qualified by the manufacturer.
- Prior to any seaming activities, the lining contractor shall provide the CQA inspector with a list of proposed seaming personnel and their experience records. This document shall be reviewed by the CQA inspector.

4.1.10.3 Seaming equipment and products

- The only approved process for field seaming the Firestone GeoGard EPDM is the Firestone QuickSeam™ Splice Tape system.
- The lining contractor logs the ambient temperatures at appropriate intervals. The ambient temperature is measured 150 mm (6 in.) above the geomembrane surface. This documentation is provided to the CQA inspector at the end of each day of seaming.
- The CQA inspector verifies that:
  - Equipment used for seaming is not likely to damage the Firestone GeoGard EPDM and is used in a manner that minimizes the possibility of damaging the geomembrane.
  - Firestone GeoGard EPDM is protected from damage in heavy traffic areas.

4.1.10.4 Seam preparation

- The CQA inspector observes seam preparation as needed to verify that:
  - Prior to seaming, the seam area is prepared by the lining contractor ensuring it is clean and free of moisture, dust, dirt, debris of any kind and foreign materials.
  - Seams are aligned with the fewest possible number of wrinkles and “fish mouths”.

4.1.10.5 Weather conditions for seaming

The required weather conditions for seaming are as follows:

- Unless authorized in writing by the main contractor, no seaming is performed at an ambient temperature below 5°C (40ºF).
- At ambient temperatures below 5°C (40ºF), seaming is allowed if the weather is dry and using specific implementation techniques.
- At ambient temperatures above 30°C (86ºF), seaming must be performed using specific implementation techniques.
- Seaming must not be performed during any precipitation, snow, fog and in the presence of any surface moisture or in an area of standing water.
- In all cases, the Firestone GeoGard EPDM must be dry and protected from the wind.
- Ambient temperatures must be measured 150 mm (6 in.) above the membrane surface.
- The CQA inspector must verify that these weather conditions are fulfilled and shall advise the engineer if they are not. The engineer must then decide if the installation should be stopped or postponed.

4.1.10.6 Overlapping and temporary bonding

The CQA inspector observes the Firestone GeoGard EPDM placement procedure as needed to verify that:

- The panels of Firestone GeoGard EPDM have a finished overlap of a minimum of 150 mm (6 in.) for seaming.
- The procedure used to temporarily bond adjacent panels together does not damage the membrane.

4.1.10.7 Trial seams

- Trial seams are made on pieces of Firestone GeoGard™ EPDM to verify that seaming conditions are adequate. Such trial seams are made at the beginning of each seaming period. Trial seams are made under the same conditions as the actual seams. Visual inspection of condensation risk should be evaluated.
- A trial seam sample must be at least 1.5 m (5 ft.) long by 30 cm (12 in.) wide (after seaming) with the seam centered lengthwise. The seam overlap shall be in accordance with Firestone's recommended procedures.
- The trial will start by applying primer at the bottom liner. After the drying time, the primed zone has to be checked for any signs of condensation (visually and by touch). If condensation is observed, a new trial will have to be operated when appropriate weather conditions are met. If no signs of condensation are observed, the seam is completed. If there is a good adhesion between the tape and the liner, the seaming work can start.
- The CQA inspector must observe all trial seam procedures as needed to verify that the above procedures are met. The trial seam samples are marked by the lining contractor with the seamer's initials, identification, date, hour and ambient temperature and the samples are provided to the CQA inspector.

4.1.10.8 General seaming procedure

Unless otherwise specified, the general seaming procedure used by the contractor is as follows:

- Seaming must be carried out in accordance with Firestone's recommended procedures.
- "Fish mouths" or wrinkles in the seam are eliminated by pulling the membrane softly.
- Seaming must extend to the outside edge of panels to be placed in the anchor trench.
- The CQA inspector must observe the seaming process as needed to verify that the above seaming procedures are followed and must inform the main contractor if they are not.

4.1.10.9 Non-destructive seam testing

Concept:

- The contractor must perform a non-destructive test on all field seams over their full length using an air lance test or other approved method. The purpose of non-destructive tests is to check the continuity of seams. Continuity testing is carried out as the seaming work progresses, not at the completion of all field seaming.

The CQA inspector will:

- Observe continuity testing as needed to verify that the contractor performs the test properly.
- Inform the main contractor of any repairs required.

The lining contractor will complete any repairs required in accordance with Firestone Lining Repair Guidelines.

The CQA inspector will also: observe the repair procedures as needed to verify that the lining contractor is adequately repairing problems - Review lining contractor's report documentation of the retesting of repairs.

4.1.10.9.1 Visual inspection

Visual inspection of the completed seam is executed to verify the following:

- QuickSeam™ Splice Tape must extend approximately 5 -15 mm (0.25 in. - 0.75 in.) (22 mm (0.9 in.) maximum) past the seam edge.
- QuickPrime™ Plus primer shall be visible on bottom sheet, exceeding the QuickSeam Splice Tape over its entire length. This indicates that the QuickPrime has been applied to a sufficient width to ensure adherence of the edge of the tape to the Firestone GeoGard™ EPDM sheet.
- Continuous trace of QuickPrime Plus is visible on the top sheet at approximately 150 to 200 mm (6 in. to 8 in.) from the edge of the top sheet.
- No "fish mouths" or wrinkles within the QuickSeam Splice Tape are present.
- Air bubbles within the seam should only be spotted occasionally. If air bubbles have a diameter >15 mm (0.5 in.), a repair is required.
- Any defect or non-conformance with the above must be marked with a marker that will not damage the Firestone GeoGard EPDM and repaired in accordance with Firestone Lining Repair Guidelines.

4.1.10.9.2 Air lance testing (ASTM D4437 Standard)

- Air lance testing is performed on all seams. The lining contractor must follow procedures and the CQA inspector observes the contractor's work as needed to verify that lining contractor is properly implementing the procedure. Air lance testing equipment consists of a compressed air source that delivers air at the exit pressure of 345 kPa (50 psi) minimum to a 4.8 mm (0.188 in.) diameter hand-held nozzle.
- The following procedures must be followed:
  - The nozzle is directed to the upper edge of the field seam in a near perpendicular direction to the length of the field seam.
  - The nozzle is held a maximum 25 mm (1 in.) from the seam and travels at a rate not to exceed 12 m (40 ft.) per minute.
  - Any defect that is identified by a distinct change in sound by the air passing through an opening in the seam is marked with a marker that will not damage the membrane and is repaired in accordance with Firestone Lining Repair Guidelines.
  - It is recommended to air lance test seams that have aged for a minimum of 24 hours.

Picture 41: Air lance testing

4.1.10.9.3 Vacuum chamber (for critical points)

- The following procedure must be used at all locations that require specific attention (patches, T-joints, tape overlaps, questionable points revealed by air lance testing).
- The equipment is comprised of the following:
  - A compressor-pump to apply the vacuum.
  - A rectangular (approximately 200 by 650 mm [8 in. by 26 in.]), transparent vacuum chamber.
- The following procedure must be followed:
  - Moisten part of the seam to be tested with a soapy solution.
  - Place the chamber onto the area to be tested ensuring an airtight connection between the Firestone GeoGard™ EPDM and the deformable seal of the vacuum chamber. Apply pressure, not to exceed -0.15 bar (-15 kPa) (2 psi) so as not to lift the membrane too much into the chamber.
  - If the seam is not watertight or a capillary is present, soap bubbles will be formed and it will be difficult to create the vacuum.
  - Due to the pressure applied, this test can only be executed on seams that have aged for a minimum of 24 hours.
- Up to 5 lin. m. of seam can be tested in 2 minutes or 8 feet per minute with vacuum chamber testing.

Picture 42: Vacuum chamber

4.1.10.10 Destructive seam testing

4.1.10.10.1 Concept

Destructive seam tests will be performed at locations selected by the CQA inspector. The purpose of these tests is to evaluate seam strength. Seam strength testing for field seams will be done as the seaming work progresses, not on completion of all field seaming.

4.1.10.10.2 Location and frequency

The CQA inspector must select and mark locations where seam samples will be cut out for laboratory testing. The locations shall be established as follows:

- A minimum frequency of one test per 150 to 300 lin.m (500 ft. to 1,000 ft.) of seam. This minimum frequency is to be determined as an average taken throughout the entire facility and has to be adapted for each project.
- Preferred locations for taking samples are in non-critical areas such as anchor trenches etc.

4.1.10.10.3 Sampling procedure

- Samples are cut by the lining contractor as the seaming progresses in order to have laboratory test results before the membrane is covered by another material. The CQA inspector performs the following as needed to verify that the installer is properly performing sampling:
  - Observe sample cutting.
  - Note that the lining contractor assigns a number to each sample and marks it accordingly.
  - Note that the lining contractor records the sample location on the as-built panel layout.
- All holes in Firestone GeoGard™ EPDM resulting from destructive seam sampling are immediately repaired in accordance with repair procedures described in Firestone Lining Repair Guidelines. The continuity of the new seams in the repaired area is tested in accordance with chapter 4.1.10.9.

4.1.10.10.4 Size of samples

For destructive testing, samples are taken as described below:

- The destructive sample are 30 cm (12 in.) wide by 90 cm (36 in.) long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:
  - One portion to the owner, 30 cm (12 in.) by 30 cm (12 in.) for his archive.
  - One portion to the lining contractor for his on-site testing, 30 cm (12 in.) by 30 cm (12 in.).
  - One portion to the CQA inspector, 30 cm (12 in.) by 30 cm (12 in.) for Geosynthetics CQC Laboratory testing if required.
  - Final determination of the sample sizes shall be made at the pre-construction meeting.

4.1.10.10.5 Field testing

- A minimum of two 50 mm (2 in.) shear and two 50 mm (2 in.) peel specimens will be tested in the field by the tensiometer. If any field test sample fails to pass (peel < 0.8 kN/m (55 lbs./sq.ft.), shear < 3.2 kN/m (2,200 lbs./sq.ft.) after 24h or peel < 1.0 kN/m (69 lbs./sq.ft.), shear < 4.0 kN/m (275 lbs./sq.ft.) after 21 days, then the procedure outlined in this section is followed.
- The CQA inspector reviews the lining contractor's report of field tests, which is to be submitted to the CQA inspector by the end of the day on which the samples are tested. The lining contractor marks all samples with test number and date and time tested and submits the samples to the CQA inspector for archiving. The lining contractor logs the date and time, ambient temperature, name of technician, value, and attaches a copy to each sample portion.

4.1.10.10.6 Geosynthetics CQC Laboratory testing (if required by client)

- Destructive test samples are packaged and shipped in a manner that will not damage the samples. The CQA inspector is responsible for storing the archived samples. Test samples are tested by the Geosynthetics CQC Laboratory. The Geosynthetics CQC Laboratory is selected by the owner or the main contractor (with the approval of the owner). The Geosynthetics CQC Laboratory must be familiar with ASTM D7465 and ASTM D7272.
- Testing must include "Seam strength" and "Peel adhesion". The minimum acceptable values to be obtained in these tests are those specified in section 4.1.10.5. At least 3 specimens must be tested for each test method.
- Specimens are selected alternately by test from the samples (e.g. peel, shear, peel, shear,..). A minimum of 2 out of 3 specimens must meet the requirements of the specifications previously mentioned to be considered a pass.

The Geosynthetics CQC Laboratory provides test results to both the lining contractor and CQA inspector no more than 24 hours after they receive the samples. The CQA inspector must review the laboratory test results as soon as they become available and make appropriate verbal recommendations to the main contractor. The verbal recommendations are followed by written recommendations.

4.1.10.10.7 Procedures for destructive test failure

The following procedures will apply whenever a sample fails a destructive test, whether the test is conducted by the laboratory or by field tensiometer. The lining contractor has two options:

- The lining contractor can reconstruct the seam (i.e. remove the old seam and re-seam) between any two passed destructive seam test locations.
- The lining contractor can trace the seaming path to an intermediate location a minimum of 3 m (10 ft.) from the point of the failed test in all directions and take a small sample for additional field testing at each location. If these additional samples pass tensiometer testing, then full destructive laboratory samples are taken. If these destructive laboratory samples pass the test, then the seam is reconstructed between these locations by capping. If either sample fails, the process is repeated to establish the zone in which the seam should be reconstructed.
- Acceptable capping methods are described in Firestone Lining Repair Guidelines.
- The CQA inspector observes that all actions taken are in conjunction with destructive test failures.

4.1.10.10.8 Defects and repairs

All repairs are done in accordance with Firestone Lining Repair Guidelines.

Each repair is numbered and logged on the as-built layout plan. Each repair is non-destructively tested using the methods described in section 4.1.10.9, as appropriate. Repairs that pass the non-destructive test are accepted as an adequate repair. Failed tests will require the repair to be redone and retested until a test pass result is achieved. The lining contractor must document all repairs and submit the documentation to the CQA inspector no longer than the following day after a repair is made. The CQA inspector must observe non-destructive testing as needed to verify that the installer is performing the repairs properly.

4.1.11 Backfilling of anchor trench

Anchor trenches must be adequately drained to prevent standing water or otherwise softening of the adjacent soils while the trench is open. Anchor trenches are backfilled and compacted by the general contractor or the lining contractor in a timely fashion. The anchor trench back fill material must comply with the requirements of this guide. Care must be taken when backfilling the trenches to prevent any damage to the membrane. The CQA inspector will observe the backfilling operation and advise the main contractor of any problems.

4.2 Acceptance of work

The acceptance of work will be performed and notified by the owner assisted by the main contractor during a site visit upon request of the lining contractor.

The acceptance of work will be based on following information:

- The CQA inspector report.
- The quality of the finished installation.
- The as-built file communicated by the general contractor.
- Result of the acceptance testing.

Acceptance testing is usually completed during the first impoundment of the pond. Water will be introduced in stages at a controlled rate. An auscultation protocol will be set up with the help of the monitoring device (repeated control of the water drainage outlet, vertical and horizontal distortion). The step by step water inlet is important in order to let the structure adapt to the new mechanical and hydraulic stress.

On delivery of the installation, the general contractor will hand over to the owner the as-built file with the following information:

- Documents relating to the design of the project, detailing all the factors taken into account during the planning of the project (volume of water to be stored, depth of the water table, type of supporting ground).
- Documents relating to the construction of the project showing the positions and techniques employed, the as-built panel layout, methods of connection to other facilities, as well as the methods of installation of different materials (aggregate, membrane) and the results of internal controls.
- The specifications of the membrane, geotextile and the geocomposite used.
- Copies of quality certificates (membrane, fitters).
- A guide to good practices allowing management of the installation with care for the integrity of the membrane.

4.3 Monitoring devices

The monitoring devices of the structure need to be considered during the design process taking into account the size of the project and the risks in case of failure.

The water drainage network located under the membrane must be equipped with a flow measurement system that can evaluate the quality of the membrane and its drainage system. The measurement system must be accessible throughout the year. It is strongly recommended to compartmentalize the drainage system so as to be able to localize the area that is leaking. This is especially important for systems where the membrane is covered.

In projects where no leakage can be tolerated (soil with internal erosion hazard) and the site cannot be changed, it is strongly recommended that a double waterproofing layer is installed separated with a water drainage geocomposite connected to a water detection system equipped with a water flow measurement system.

It is also recommended that a water level measurement system (staff gauge, pressure sensor) is set up and episodic topographical controls of the embankments (vertical and horizontal distortion) are made.

In sensitive projects, the installation of control piezometers may be recommended.

4.4 Inspection and maintenance guidelines for fresh water ponds

Inspection and maintenance are important to the long-term performance of the lining system as a whole. These guidelines will assist the project owner in maintaining the liner performance over many years. Cooperation on the part of the owner in this effort is important.

4.4.1 Inspection

The pond inspections must be organized by the owner. They are made to check the condition of the structure and evaluate the maintenance and repair work (if any) required in order to guarantee a long service life of the pond.

The frequency and importance of inspections will depend on the project size, the consequences in case of failure, its general condition and after an important or unexpected natural phenomenon (e.g. important floods, earthquake).

It is recommended that frequent routine visits (minimum every 1 or 2 months) are undertaken and an extensive technical inspection spaced between 1 and 5 years (depending on the importance of the project) is also scheduled. Whenever the pond is empty, the opportunity should be taken to run a routine visit.

Routine visits can be done by the owner or the operator, following a specified protocol. The extensive technical inspection will be done by an external expert (engineer, qualified independent expert, Firestone distributor or installer…). For safety reasons, it is recommended that the work be conducted in pairs.

Main points to observe during the inspection visits:

- Visual inspection:
  - Geomembrane: seams, connections to details, patches, punctures, animal damage, tears.
  - Internal embankment: deterioration of the substrate, sediments, floating objects, stones, vegetation, aquatic life (fish, larvae, insects, snails…) with special attention to animal infestation
  - External embankment:
    - Water or humidity on the embankment
    - Gullies, slips and erosion
    - Vegetation
    - Animal damage (e.g. rabbit holes)
    - Water ditch
  - Crest:
    - Water ponding
    - Cracks
    - Settlement
    - Service road
  - Geomembrane cover: sliding, vegetation, deterioration
  - Hydraulic elements: spillway, inlet, outlet, discharge pipe, valves
  - Fences and security elements
  - Access
  - Surroundings

- Monitoring devices:
  - Water level inside the pond
  - Outlet water drainage system:
    - Outflow
    - Temperature
    - Water color and presence of sediment
  - Topographical inspection
  - Other monitoring devices

After each visit, a detailed visit report should be written and stored with all the referential documents relating to the pond. The visit report should describe the visual aspect of the pond and record the monitoring statistics. Conclusions should be given about the general condition of the pond and maintenance actions to be taken.

4.4.2 Maintenance

For each project, depending on its size and risk level, the designer will draft a specific maintenance plan (frequency and protocol).

After acceptance of the work, the general contractor will communicate to the owner a best practice guide explaining operating limits of the pond and maintenance obligations.

In order to ensure a long service life and avoid costly repairs to the Firestone GeoGard™ EPDM membranes, Firestone recommends maintenance of the pond at least every year. Maintenance actions and frequency will be guided by the monitoring inspections of the pond.

- Do not change the type of content or the temperature range for which the storage pond was designed without first having contacted Firestone. Ensure that the membrane is not exposed to liquids such as solvents, greases, oils, animal fats and petroleum products or other hazardous waste that may adversely affect the membrane.
  - If the membrane is subject to contact with any type of chemical, you should contact Firestone immediately.
  - Should petroleum products, solvents, greases, oils, etc. come into contact with the membrane, clean the area immediately with Firestone Splice Wash or solvent naptha.
- Over the lifetime of the pond, many expected or unexpected events could jeopardize the durability of the pond structure or membrane water tightness. Some examples of risks and solutions are given below:
  - As a general rule, avoid any traffic on the membrane after installation unless properly protected.
  - The outside embankment needs to be protected from erosion and digging animals (e.g. rabbits). Erosion can be avoided by seeding plants (avoid plant with strong roots and rhizomes, see below).
  - All the safety systems must be well maintained and functional to reduce the risk of damages in case of an accident.
  - Fences should be kept all around the installation to avoid people or animals falling in. Animals that fall into the pond could damage the liner as they try to escape. Fences also prevent for vandals deliberately entering.
  - Make provisions for small animals which fall into the pond to escape. They need to have an easy way out in order to reduce the risk of membrane damages.
  - Avoid the growth of plants that develop strong roots and rhizomes inside or outside the pond (e.g. bamboos, reed). Where roots and rhizomes can contact the membrane a reliable root barrier must be installed.

- To reduce the clogging risk of the outlet, limit algae growth mechanically, chemically (only if safe for animals, plants and humans) or by introducing algae eating fish (e.g. carps).
- Avoid infestation of any invasive pest species and especially snails, insects and their larvae (e.g. mosquitoes, caddisflies, butterflies). Management of pest invertebrates (e.g. snails and insect larvae) may be achieved mechanically (e.g. nets filled with vegetables), chemically (e.g. copper sulfate and pond ionizers - only if safe for animals, plants and humans) or by introducing fish species feeding on snails and insects (e.g. Black Carp, Gudgeon Gobio gobio, Sticklebacks, European Sturgeon). In order to avoid ecological imbalance, please promote local species introduction. Controlling snails, insect and larvae growth inside the pond is essential for the integrity of the liner.

Warn all tradesmen servicing project equipment that you have a rubber liner, and that they should proceed accordingly. Any possible damage is immediately reported. Firestone recommends that you keep a log of all activity.

- All flashings, mechanical terminations, anchoring, pipe terminations, metal work, drains, vents, monitoring systems and any other accessories functioning in conjunction with the lining system must be properly maintained and watertight at all times. Remove all foreign bodies inside the pond. Particular attention is given to the water drainage outlet, which should be systematically checked at every use or upkeep operation on the installation. The outside embankment will also be maintained in perfect condition (erosion, plants, animal holes, water ditches, stagnant water). Special attention needs to be given to the maintenance of the vegetation growing on the external embankment and on the crest. Herbaceous vegetation needs to be mowed once or twice a year. Shrub and tree species are prohibited in the vicinity of the structure.
- It is essential to do everything possible to avoid the pond overflowing during filling.
- The general condition of all fixed or mobile installations (agitators, recuperation systems) should be checked on each use. Mobile installations will be operated with the greatest care to avoid contact with the geomembrane.
- Should there be an alteration of the project, contact a Firestone representative to ensure that the alterations are in accordance with Firestone's specifications. Should a leak be detected:
  - Try to determine the cause of the leak and to measure the leak flow rate.
  - Contact a Firestone representative immediately and also send notification in writing.
  - If necessary, make temporary repairs with Firestone GeoGard™ EPDM and accessories.
  - Never use oil-based products.
- Firestone recommends that an inspection of the drainage system and the visible parts of the lining system (geomembrane, splices, patches) be conducted by a qualified professional. Should you have problems with the earthwork or substrate under the membrane, groundwater, vegetation, or drainage system:
  - Contact a specialized engineer immediately.
  - Notify a Firestone representative in writing.

4.5 Repair guidelines

4.5.1 Introduction

Even with periodic inspection and maintenance, lining systems will require repair from time to time. Although membrane repair is typically conducted as a response to some type of damage to the pond, a pro-active approach to membrane repair and renovation can improve the performance and extend the service life of the liner. The procedures and specifications contained in this section provide valuable general information about the efficient and effective repair of Firestone EPDM lining systems.

These guidelines apply to repairs of the Firestone GeoGard™ EPDM (cuts and punctures in the membrane, contamination of the Firestone GeoGard EPDM with hazardous products) and the field seams (wrinkles in a splice, QuickSeam™ Splice Tape is not showing, QuickSeam Splice Tape is showing more than 25 mm (1 in.), seam is showing possible water entry points).

These repair procedures are offered as a complementary service only and Firestone disclaims any liability, under any theory of law, arising from the use of these procedures. Repairs and renovations of Firestone EPDM lining systems should only be performed by a professional lining contractor who is licensed and trained by Firestone.

4.5.2 Repair of cuts and punctures on the Firestone GeoGard EPDM

As soon as any damage to Firestone GeoGard EPDM is identified (during installation or inspection), mark the damaged area with a white crayon for use on rubber. The repair must extend a minimum of 75 mm (3 in.) beyond the perimeters of the damaged area in all directions in case of repairs using Firestone QuickSeam products and 100 mm (4 in.) in case of repair using Firestone GeoGard EPDM. Round all corners of the repair piece.

- Pinholes and small punctures in the membrane may be repaired with a cover piece of Firestone QuickSeam FormFlash or Firestone QuickSeam SA Flashing (the latter is preferred: better physical properties and more economical).
- Cuts and punctures in the membrane should be repaired with cured geomembrane. Round all edges of the cut so that it cannot propagate underneath the target piece. If this has been done properly, the target EPDM repair piece can be applied using Firestone QuickSeam Splice Tape and Firestone QuickPrime Plus. A valid alternative is to fully adhere a piece of QuickSeam SA Flashing using QuickPrime™ Plus.
- Firestone Lap Sealant is used to seal and mechanically protect the exposed edge of Firestone QuickSeam products. Lap Sealant is also recommended where edges of QuickSeam FormFlash make a T-crossing with QuickSeam Splice Tape, QuickSeam™ Batten Cover or QuickSeam SA Flashing, in order to avoid any risk of possible capillarity.

NOTE: The application of new Firestone QuickSeam products to existing in service membranes requires special cleaning and priming procedures. Refer to section 4.5.5.

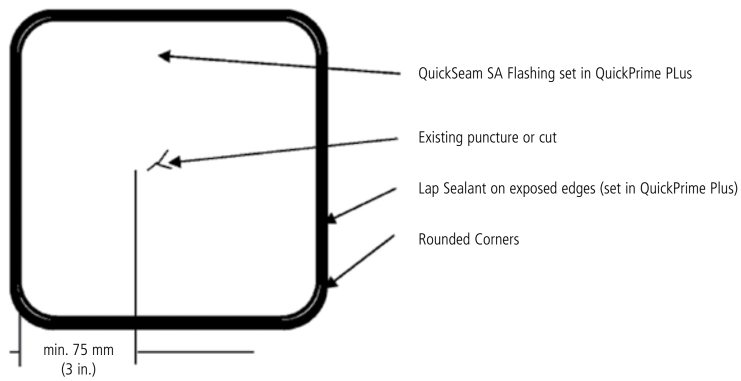


Figure 41: Typical repair of GeoGard EPDM: using QuickSeam SA Flashing

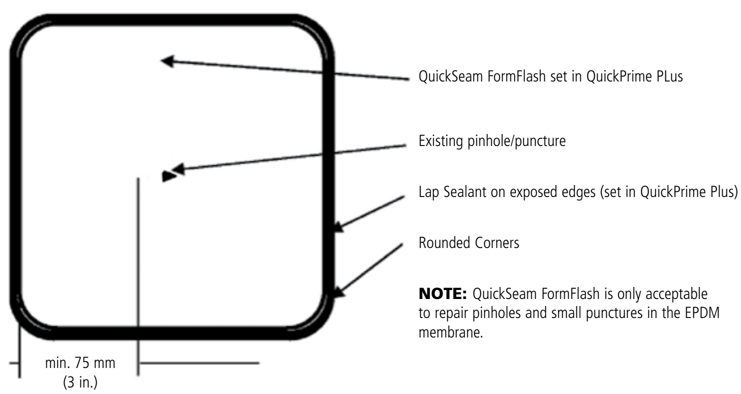


Figure 42: Typical repair of GeoGard EPDM: using QuickSeam FormFlash

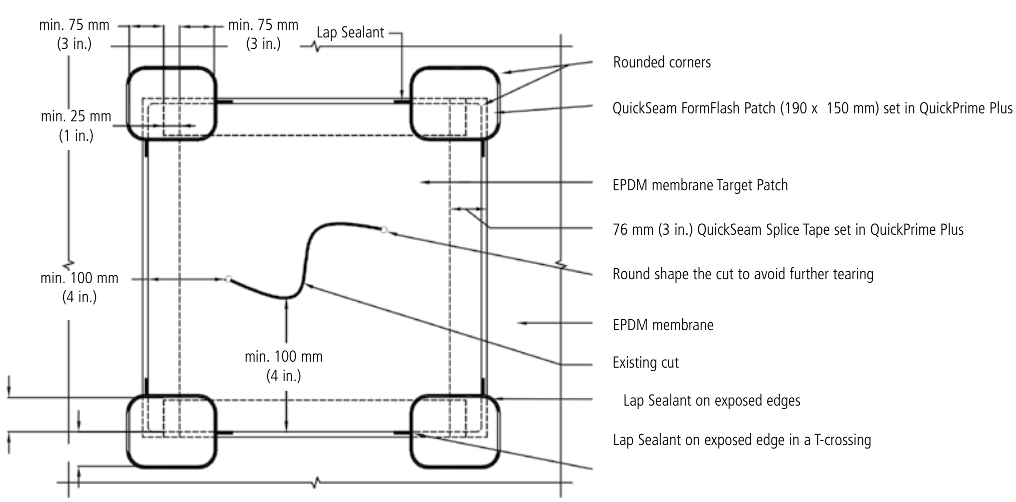


Figure 43: Typical Repair of EPDM geomembrane: using EPDM geomembrane (190 x 150 mm (7 in. x 6 in.) QuickSeam FormFlash patches) and QuickSeam Splice Tape

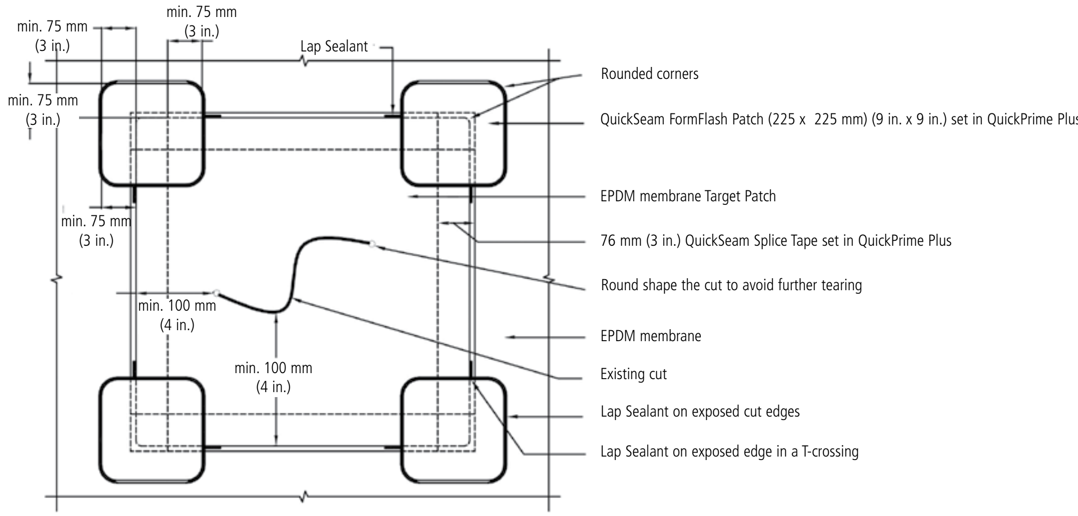


Figure 44: Typical Repair of EPDM geomembrane: using EPDM geomembrane 225 x 225 mm (9 in. x 9 in.) QuickSeam FormFlash patches and QuickSeam Splice Tape

The way of connecting two QuickSeam Splice Tapes in the corners is going to determine the size of the QuickSeam FormFlash Patch.

4.5.3 Repair of contaminated Firestone GeoGard™ EPDM

Any Firestone GeoGard EPDM that has been in contact with hazardous chemical discharges such as fresh bitumen, petroleum products, greases, oils, animal fats or oil based solvents needs to be inspected for damage.

Remove immediately any excess of the contamination materials and replace the damaged area with a new piece of membrane. Repairs should be completed as described in figure 43 and figure 44.

4.5.4 EPDM field seam repair

As soon as any non-conformity is identified during installation or inspection, mark the damaged area with a white crayon for use on rubber.

- **Punctual defaults or damages on field seams** (e.g. wrinkles) in a field splice must be cut out and repaired with a covering piece of uncured EPDM (QuickSeam FormFlash). Provide a patch that extends a minimum of 75 mm (3 in.) beyond the perimeter of the damaged area. Wrinkles in a field splice must be cut out using scissors, laying them flat on the Firestone GeoGard EPDM, before applying the patch. Clean the area around the damage and adhere the QuickSeam FormFlash with QuickPrime™ Plus. Use small silicone rubber roller to roll the edges flat and seal with Lap Sealant.
- **Non-punctual non-conformities on seams** (QuickSeam Splice Tape is not showing, QuickSeam Splice Tape is showing more than 25 mm (1 in.), possible water entry points) can be repaired using QuickSeam SA Flashing or QuickSeam Cover Strip set in QuickPrime Plus.

NOTE: The application of new QuickSeam™ products on Firestone GeoGard EPDM that is in service requires special cleaning procedures. Refer to chapter 4.5.5.

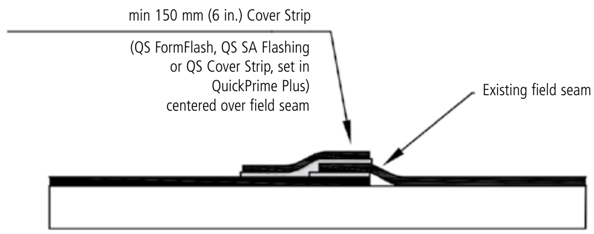


Figure 45: Typical seam repair cross section

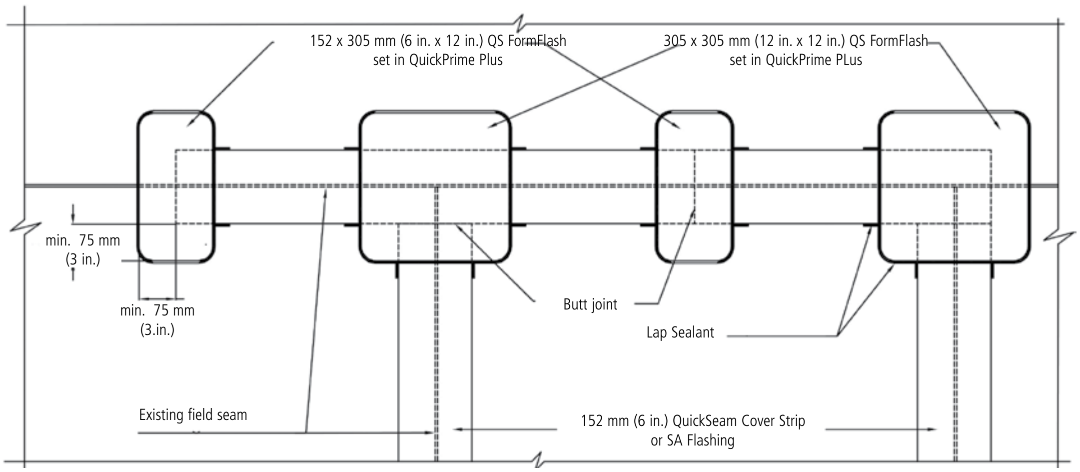


Figure 46: Typical joint details for non-punctual damages in a splice

4.5.5 Cleaning of in service Firestone GeoGard™ EPDM

When repairing a Firestone GeoGard EPDM that has been in service for some time, it is necessary to prepare the surface to be spliced thoroughly prior to starting the splicing operation.

This is a performance specification. It is required that the Firestone GeoGard EPDM be dark gray in color without streaks before proceeding with any bonding or splicing activity. The cleaned area must be larger than the repair area.

- Cleaning may be achieved by one of the following methods:
  - Brush wash by hand with a solution of mild dish soap and water and a stiff bristle brush. Rinse the receiving surface with water until clean. Take care not to flood the receiving surface.
  - Use a power water washer and a wet vacuum. Take care not to flood the receiving surface.
- Allow the receiving surface to dry thoroughly. If necessary, dry the washed surface with clean towel or rags. Make sure that no moisture can be trapped.
- It is also acceptable to sweep the Firestone GeoGard EPDM with a broom in the repair area and apply Firestone Membrane Pre-Wash using a garden sprayer at the rate of 7 to 12 m²/l (300 to 500 sq.ft./gal.) - contact the Firestone Technical Department for exact procedure. After the Pre-Wash has dried for approximately ten minutes, use a power water washer providing 15 l (4 gal.) per minute at 20 MPa (3000 psi) to remove the Pre-Wash and any accumulated dirt and debris. A 40° fan spray nozzle for pressure washer is suggested.
- Wash the existing Firestone GeoGard EPDM twice with Firestone Clear Splice Wash, or solvent naptha, and clean, white, cotton rags, allowing the surface moisture to evaporate and dry between washing. Change cleaning rags often.

NOTE: After cleaning the in service Firestone GeoGard EPDM, proceed with the application of the new Firestone GeoGard EPDM membrane, QuickSeam FormFlash, Lap Sealant and QuickSeam Splice Tape in accordance with current Firestone application specifications.

5 Application Guidelines

5.1 Animal Waste Containment

This document constitutes specific technical guidelines for the use of Firestone GeoGard™ EPDM in livestock effluent storage ponds (dung pits). This document complements the Firestone general technical guidelines for installation of Firestone GeoGard™ EPDM in waterproofing systems.

Firestone GeoGard EPDM has been used since 1992 in livestock effluent storage ponds with great success as it offers many advantages for this application:

- **Exceptional durability:** very high resistance to weathering (particularly ultraviolet rays and ozone).
- **Good chemical resistance:** numerous tests carried out in laboratories, and the results of more than 20 years of experience in this area, show that Firestone GeoGard EPDM resists chemical attacks from livestock effluents.
- **Good puncture resistance:** reduction of risks.
- **Great flexibility and elasticity:** ease of installation and adaptation to irregularities in the supporting bed.
- **Available in large sheets up to 930m² (10,000 sq. ft.):** fewer seams and a reduction in the risks of errors during installation on site -> reduction in the risk of leaks.
- **Ease of repair:** when a leak is detected, it can be repaired easily, even if the geomembrane has been exposed for several years.
- **Excellent resistance to temperature variations:** expansion and contraction phenomena caused by temperature variations as a result of effluent fermentation or climatic conditions do not affect the waterproofing qualities of Firestone GeoGard EPDM.

Livestock effluents are likely to have a major environmental impact if they are not correctly managed. The storage pond must, therefore, guarantee a maximum degree of waterproofing. It is essential that the work be carried out in accordance with best practice so as to avoid any leaks or premature ageing.

This document gives guidelines for the installation of a dung pit. Nevertheless, it is essential to proceed systematically with a case by case analysis to adapt the plan and the installation to the site conditions (topography, height of water table, type of effluent, …).

Essential factors to be taken into account during installation of a livestock effluent storage pond are summarized in the document *"General specifications for lining dung pits using Firestone GeoGard EPDM"*.

5.1.1 Characteristics of livestock effluents

5.1.1.1 Definitions

Several types of effluent exist within an agricultural business:

- Milking effluents:
  - White water: washing water from milking stalls containing detergents, disinfectants and milk residue.
  - Green water: washing water from the quay, drainage channel and waiting area.
- Grey water: domestic water.
- Slurry: urine, dung water.
- Brown water: soiled water from open exercise areas.
- Rainwater: (more or less soiled).

Slurry is the term for the ensemble of animal rejects (faeces and urine) which are more or less diluted by rainwater, washing water and general watering, in which may be found animal bristles and food waste. It is mainly produced by the raising of pigs, bovines and poultry which use little or no litter for the evacuation of waste (slatted floor). If litter is used, they produce manure. Slurry may be used as an organic fertilizer.

In slurry pits, depending on the type of exploitation, a mixture of different livestock effluents can be found. However, it is not recommended to mix white water with other effluents because they then become much more difficult to treat and the presence of cleaning agents containing chlorine risks to produce chloramine (a dangerous gas).

▲ Firestone GeoGard™ EPDM cannot be used for the storage of effluents with high grease or chlorine content.

Firestone GeoGard EPDM is not designed to store exclusively white water, dairy wash water and silage effluents (with pH < 4). Nevertheless, in normal operation conditions, it is common that those products are stored with the slurry inside the dung pit. Firestone therefore recommends to mix/dilute those products with the slurry before it enters into contact with the liner.

Tank washing residues: If the disinfectants used to clean the tanks are compatible with EPDM and highly diluted, the tank washing residues can be stored inside the dung pit. Firestone technical service can be consulted to check chemical compatibility.

Silage effluents: effluents with pH lower than 4 should not enter in direct contact with the liner.

5.1.1.2 Environmental impact

Slurry is not itself a pollutant, because the nitrates that it contains can be absorbed rapidly by vegetation. Spreading slurry contributes to the nitrogen cycle; nitrogen being essential to plant growth.

Pollution results from excessive spreading of slurry or heavy rain falls just after spreading, before the plants had time to absorb the nitrates. This flow of water washes the nitrates into the water table and/or water courses and causes the phenomenon of eutrophication.

To avoid this kind of pollution, the following jointly implemented measures may be put into action:

- Have available a storage pond of sufficient capacity to store all the slurry produced until the end of the rainy season.
- Have sufficiently large spreading areas available.
- Limit the supply of nitrogen to the strict requirements of the plants.

5.1.1.3 Gaseous emissions

The breakdown of organic substances during the storage of slurry or urine emits ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4) and, in anaerobic conditions, hydrogen sulphide (H_2S – a very toxic gas). To avoid the production of H_2S, it is necessary to agitate (aerate) the stored material frequently.

5.1.1.4 Chemical properties of slurry

The composition of slurry varies greatly depending on the type of animal, its diet and its physiological stage. The unit weight of slurry is arbitrarily fixed at 11 kN/m³ (230 lbs./sq. ft.). The temperature variation linked to fermentation equates to 30 °C (86ºF). Its pH is close to neutral.

Slurry is a fairly aggressive mixture; it is therefore essential that all materials designed to come into contact with it be resistant to such conditions. This is the case in particular for slabs of concrete (+ reinforcement) positioned into the pond to protect the membrane.

The average composition of slurry is listed in the table below.

Table 51: Average chemical composition of slurry

	pH	%ms	N	P2O5	K2O	CaO	MgO	Na2O	Cu	Mn	Zn	Fe	S	B	Mo
Pig	7.6	8	4.8	3.4	2.9	2.4	0.7	0.8	18	31	56	173	696	12	0,2
Cattle	7.0	12	3.2	1.5	3.7										
Poultry	7.1	26	25	23	15.6										

Units: Kg/m³ for macro-elements and g/m³ for trace elements

5.1.2 Planning of works

During planning of the works, the general considerations given in the general technical guide for Firestone GeoGard EPDM waterproofing applications should be taken into account, as well as the specific considerations listed below.

There is no single solution for the building of a dung pit. Before construction of a storage pond, it is therefore essential to carry out a specific analysis and a visit to the site in order to optimise the location of the installation, its characteristics and the means to be employed. The characteristics of the storage pond and the materials used will be defined on the basis of the information gathered:

- Effluent characteristics:
  - Volume of slurry: variations in the level of filling result in variations in weight and pressure.
  - Variations in temperature: a function of the type of effluent.
  - Chemical toxicity of the effluents stored.
  - Quantity of effluent stored.
- Environment of the site:
  - Nature of the soil.
  - Topography.
  - Depth of underground water.
  - Potential for fermentation of the soil.
  - Soil stability.
  - Possible pressure loads nearby.
  - Implementation of the farm.
  - Geometric constraints.
  - Materials available locally.

- Methods of use and maintenance:
  - Filling.
  - Swirling/agitation.
  - Effluent pumping.
  - Pond cleaning.

5.1.2.1 Positioning of the animal waste containment pit :

The choice of position must take into account a series of differing criteria:

- Environment: the installation will be located as far as possible from residential accommodation (smells) and sensitive areas (rivers, wells, ponds…), in accordance with current legislation. Consideration will also be given to the integration of the pond into the landscape.
- Location of other farm installations.
- Topography: where possible, a location will be chosen to permit the filling with slurry and the draining of water by gravity.
- Underground: the infrastructure should not be located in the water table. At the same time, areas where the soil has a high fermentation potential (old manure storage areas), should be avoided.
- Stability: it is essential to evaluate the bearing capacity of the soil in the area of installation. Any loads to be supported in the vicinity must also be considered.
- Site accessibility, both during construction and use.

As an example, French legislation requires that a slurry storage facility be located at:

- 100 m (330 ft.) from human habitation.
- 35 m (115 ft.) from watercourses, ponds, …
- 50 m (165 ft.) from wells, sources destined for human consumption.
- 200 m (655 ft.) from a bathing area or a beach.
- 500 m (1640 ft.) from a fish farm, shellfish area.

5.1.2.2 Layout of the animal waste containment pit

Generally, simple geometric shapes are recommended so as to facilitate the building of the pond, limit the number of parts and folds. Square or rectangular shapes are preferred. The shape of the storage pond will take account of the area available within the farm.

Photo 51: Example of landscaping of an animal waste containment pit

5.1.2.3 Dimensions of the animal waste containment pit

Sizing a slurry pond is a relatively delicate task which must be carried out by professionals from the trade. As an illustration, some of the factors to be taken into account when sizing are listed below:

- The volume produced: varies depending on the number and the types of animals, the feeding regime, the way of supplying feed stuffs and the physiological stage of the animals.
- The possible spreading dates: it is discouraged/forbidden to spread in winter whilst the plants are in their latency stage (loss through leaching and streaming). The slurry pond should, therefore, have a storage capacity of several months, (e.g. 10 months for corn, 4 months for wheat and rape).
- Rainfall: if the pond is not covered.
- The "clearance" or safety margin to avoid overflowing, 40 cm (16 in.) if not covered and 25 cm (10 in.) if covered.

It should be noted that some legislations demand a minimum storage capacity: Ministry of Agriculture norms, (France-1993), for the production of pork slurry (milk sow: 0.6 m³/month (21 cf/month); gestating: 0.4m³/month (14 cf/month); post-separation: 0.08m³/month (28 cf/month) and fattening: 0.12m³/month) (4 cf/month). Clearance height 40 cm (16 in.).

The table below lists slurry production per month depending on the type of stock rearing.

Table 52: Monthly production of slurry in function of the type of livestock

Type of animal	Type of building	Production/month
1 Dairy cow 1 Milk cow 1 Heifer 1 to 2 years	Free stabling Free with exercise area not covered	1.2 m³* (42 cf) 0.8 m³ (28 cf) 0.5 m³ (18 cf)
1 Veal calf	Group stabling	0.375 m³ (13 cf)
1 Gestating sow 1 Milk sow 1 Piglet after separation 1 Fattening pig	Group stabling	0.45 m³ (16 cf) 0.6 m³ (21 cf) 0.08 m³ (3 cf) 0.12 m ³ (4 cf)
1000 Ducks 0-4 weeks ready to force-feed	Fully slatted floor	8-10 m³ (282 - 353 cf)

*** excluding milking effluent**

5.1.2.4 Operational limitations

Normal use of a slurry pond involves filling, swirling, pumping of effluents and flushing of the pond.

Regular swirling has the function of ensuring homogenous slurry, assisting in the complete drainage of the pond. This swirling also helps to avoid the formation of H_2S (a toxic gas produced in anaerobic conditions). Swirling is not generally necessary in ponds containing white or green water or filtered slurry.

To avoid damaging the installation during use, it is necessary to plan, at the design stage, suitable infrastructure:

- Manoeuvring and parking areas: the swirling and the recuperation of effluent require the use of agricultural machinery in the immediate proximity of the installation. It is therefore necessary to strengthen the access areas and to plan abutments.
- Swirling: this operation is performed by a fixed or mobile agitator. It is necessary to plan ballast in this area to avoid repetitive lifting of the geomembrane causing premature ageing and protection to prevent the agitator coming into contact with the geomembrane.
- Recuperation of effluent from the pond: it is imperative that this installation remains fixed in place. The suction system must be ballasted top and bottom.
- Cleaning: access and manoeuvring of machines on the bed of the pond can only be achieved if provisions were made during the planning stage through a layer of concrete laid over the whole bed. If the correct slope has been adhered to, the collection point well sighted and the slurry well mixed, provisions for dynamic cleaning of the pond are unnecessary.

5.1.2.5 Animal waste containment pit covering

Some laws require the covering of slurry storage sites. Covering has several benefits:

- Reduction in the emission of smells and germs.
- Reduction in gas emissions: ammonia (harmful to health), nitrous oxide and methane (harmful to the atmosphere).
- Easier recuperation of combustible gasses (methane).
- Reduction in the ingress of rainwater: increase in storage capacity and maintenance of the agronomic value of the slurry (not diluted).

There are three distinct methods of covering livestock slurry ponds: floating cover, covering with a rigid supporting structure and an inflated cover.

There are some problems with a floating cover:

- During swirling of the slurry, its agitation will cause movement of the membrane. The membrane will deform (heavy stresses) and risks being pulled under and coming into contact with the agitator if it's not well protected.
- It is necessary to plan a method of evacuation of accumulated gasses under the membrane and of rainwater above the membrane.
- It is essential to take into account the wind pressure when designing the anchorage for the floating cover so as to avoid it being blown away.
- The presence of a cover does not allow visual inspection of the bed membrane.
- The finish is aesthetically poor.

With due consideration of the technical problems, Firestone does not support the use of Firestone GeoGard™ EPDM for covering animal waste containment pits.

In the case of covering using a rigid support, the structure must be able to withstand strong mechanical stresses (snow, wind…) and biochemical attack of the slurry gasses. Minimal ventilation (under all climatic conditions) of the covering is essential to avoid the formation of explosive gasses. Firestone GeoGard EPDM is not suitable for this type of use (too flexible).

It is also possible to install a cover with a membrane inflated to a high pressure. In this case it is necessary to be particularly precise with the sizing of the anchorage of the membrane and the pressure control system. Firestone Building Products does not support the use of its EPDM geomembrane for this type of application.

Methane is particularly harmful as a greenhouse gas. For large covered installations it is recommended that flaring is used to burn off the recuperated methane.

Generally speaking, the installation of a conical roof structure increases the cost of a pond by 40 to 50%.

5.1.3 Installation

During installation, the general considerations given in the General technical guide for Firestone GeoGard EPDM waterproofing applications should be taken into account, as well as the specific considerations listed below.

The information given below approximately follows the different installation stages.

Generally speaking, the various operations of installation must be carried out under optimal climatic conditions; this to ensure the quality and the durability of the finished installation.

5.1.3.1 Site preparation

The preparation of the worksite consists of a series of operations listed below:

- Building of access routes to the site.
- Drainage: temporary works to avoid the ingress of water into the storage pond, groundwater lowering, evacuation of rainwater …
- Brush cutting of the whole site.
- Laying out and levelling of the site.
- Removal of topsoil. Some of this soil may be used for facing the exterior banks.

Great care must be taken over the marking out and levelling of the site in accordance with construction drawings. A site meeting will be organised after marking out, between the client, the project manager and the entrepreneur, to verify conformity and validate the installation.

For more details on the preparation of the site, we refer the reader to the general technical guide for Firestone GeoGard™ EPDM waterproofing applications.

5.1.3.2 Earthworks

5.1.3.2.1 Bed configuration

Depending on the size of the storage pond, one or two slopes of minimum 2% will be built into the bed. The aim being to facilitate the emptying of the pond and the evacuation of gasses under the geomembrane (see Fig. 51 and Fig. 52).

The decomposition of organic matter is likely to result in different levels of packing down and the release of gas. Therefore the bed must be cleared of all vegetable matter and topsoil stripped of any eventual deposits of organic matter.

If Firestone GeoGard EPDM is applied in old existing effluent ponds you must make sure that the soil is not saturated with effluents that will give off gas when it decomposes.

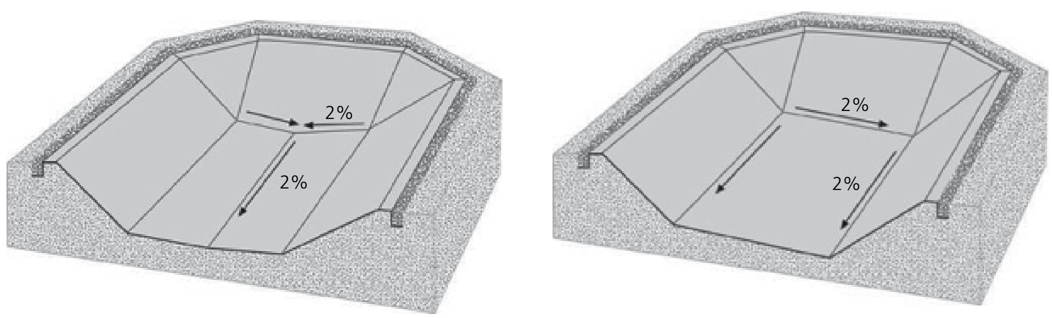


Fig. 51: Pond bed slope

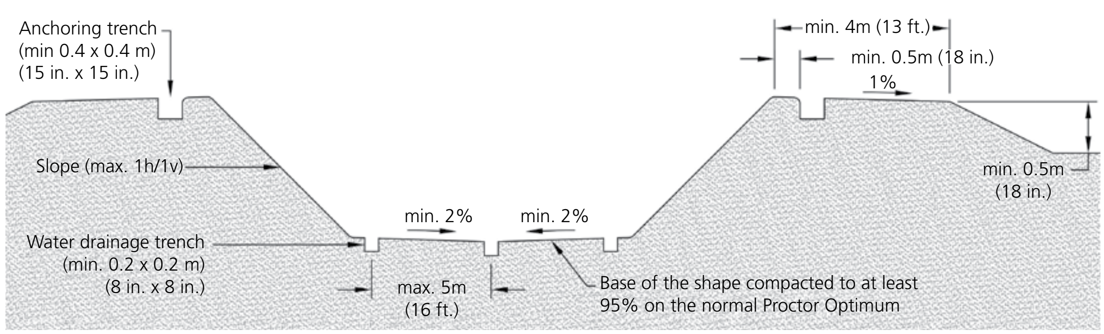


Fig. 52: Cross section after earthworks, (bed configuration)

5.1.3.2.2 Embankments

In no case will the geomembrane be used as a reinforcement for the slopes.

If the pond is excavated from stable materials with the help of adequate machinery (hydraulic excavators of 20-tonne (20 tons) minimum), the slope of the banks can go to 1h/1v (maximum, to be controled by a specialist).

Outside slopes are of 1v/2h so as to avoid, as far as possible, subsidence and gulley erosion of the banks with time. The materials should not contain any turf, vegetable debris, sandy or stony material, topsoil, peat, silt …

5.1.3.2.3 Embankment crests

The embankment crests must be at least 4 m (13 ft.) wide if anchorage is achieved by burial in a trench and 6 m (20 ft.) if machinery is required to maneuver. It is advisable to plan a 1% slope outwards from the installation to allow the drainage of rainwater.

The materials extracted from the soil area are used to form the surrounding platform so as to obtain an embankment crest level at least 0.5 m (1.5 ft.) above the highest point of the area occupied by the installation.

Photo 52: Width of embankment crests

5.1.3.2.4 Compaction

The bed must be compacted with a particular care up to 95% of the normal Proctor Optimum and conforming to the rules defined by the Soil Mechanics Analysis for the work in question.

If the ground water content is too high or too low, the company will do everything possible to rectify this.

5.1.3.3 Water drainage and inspection well

It is absolutely essential that a water drainage system be planned (see Fig. 53 and Fig. 54) with the function of leak detection and avoiding under pressures. It will be constructed in the following way:

- Excavation of trenches (min. 0.2 [8 in.] x 0.2 m [8 in.]) for the installation of drains:
  - Peripherally at the base of the banks;
  - On the pond bed, no more than 5 m (15 ft.) apart.
- The slope necessary for runoff is in the order of 0.5 % to 1%.
- Installation of an anti-contaminant geotextile between the draining rubble present in the trench and the natural soil. In no case can a puncture resistant geotextile be used to provide a filtration function.
- Agricultural drains are placed in these trenches which are covered with 10/14 gravel (or similar) to the top of the trench.
- Installation of a covering over the whole surface: layer of permeable material grade 8/10, (washed gravel), at least 10 cm (4 in.) deep.

It is recommended that the bed of the storage pond always be situated above the highest level of the water table.

▲ We insist on the importance of the installation of the 10 cm (4 in.) layer of permeable material. In fact, as well as its role in draining water, this layer has a vital environmental purpose. It allows the detection of a leak in the waterproofing even when the leak is far from a draining pipe.

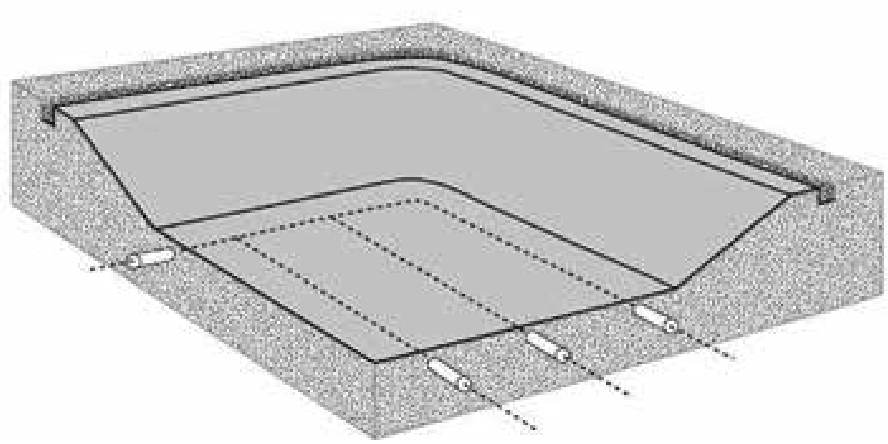


Fig. 53: principle of the water drainage system

▲ Water evacuation towards the hydrographic network will only be done if accepted by local legislation. It will be achieved either by gravitational means or by pumping. In either event, the drainage network must be connected to an inspection well (see Fig. 54), so as to be able to detect any eventual leak from the storage pond. The inspection well can be located inside or outside the dung pit. One example of inspection well is given below:

- Trenches across the embankment: given the depth of the pond, safety measures will be put in place when excavating the evacuation trench.
- A PVC pressure pipe is positioned in this trench to a T connector to the network, following the same slope. This pipe terminates in the inspection well.
- An inspection well (concrete or PVC, minimum diameter 40 cm (16 in.), will be positioned outside the embankment in accordance with a predefined location and following similar safety procedures to the previously mentioned trench. This well will be composed of parts (plug + collar of at least 50 cm (20 in.) + cover) allowing it to reach the required depth for receiving the water and allowing decantation.

Photo 53: Trench for the peripheral drain at the foot of the embankment

Photo 54: Filling of trenches with draining gravel

- A new trench is dug for the placement of an outlet channel from the well to the low point (exit decided between the client and the project manager). If the topography does not permit gravitational evacuation of collected water, the inspection well must allow the installation of active pumping.
- If evacuation is by gravity, the installation of a sluice valve before discharge into the network will be planned. This valve will be closed immediately in the event of a leak from the pond.
- It is recommended to equip the control well with an automatic leak detection system (sonorous).

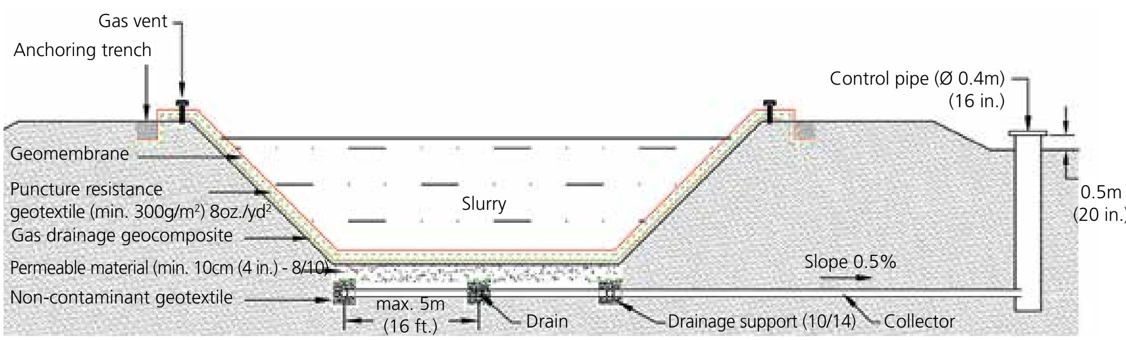


Fig. 54: Principle of the drainage system (water + gas) and inspection well

The installation of water and gas drainage must be carried out with great care to:

- Avoid crushing drains during the movement of site machinery;
- Avoid the formation of counter-slopes;
- Ensure the continuity of the network;
- Respect the rules for the installation of geotextile;
- Identify buried networks.

5.1.3.4 Effluent inlet

Livestock effluent normally contains various solids (straw, sand,...). Because of this, the arrival of effluent in the storage pond must be done with minimum impact and turbulence to the geomembrane to avoid any local abrasion. If this is not the case, the installation of a safety system (concrete slab + geotextile) is recommended.

The pipe (type and dimensions to be decided by the client) carrying the effluent into the pond must pass across the embankment. Where machinery will be manoeuvring on the crest, it is necessary to install a reinforced pipe.

The following photographs show solutions with direct filling of the tank.

Photo 55: Effluent inlet pipe

Photo 56: Direct filling of effluent

5.1.3.5 Support layer

The flatness of the bed and the embankment tops and the smoothness of the interior sides of the pond must be of irreproachable quality.

Particular care must be taken to ensure that the construction equipment does not cause deformation or a change in the surface texture (grooves, unearthing of stones …).

Photo 57: Quality of the support layer

5.1.3.6 Anchorages

Anchoring trenches are excavated before the installation of the waterproofing, so that they may be used for the provisional ballasting of the geotextile and the geomembrane.

The dimensions of the anchoring trenches are determined on the basis of the length of the slope and the wind speed, as described in the general technical guide for installation of Firestone GeoGard™ EPDM. The minimum recommended is an anchoring trench of 40 cm x 40 cm (16 in. x 16 in.) section positioned at least 0.5 m (20 in.) from the crest of the embankment.

The opening of the anchorages is based on the levels of the flow sheet. Make sure that, in no circumstances, climatic conditions can damage the filling of these anchorages.

The back filling and the compaction of the anchoring trenches will be carried out in accordance with good practice, with a slight slope towards the outside of the installation so as to avoid any ingress of parasitic water. Running water must always flow around the installation to avoid damaging it.

Photo 58: Anchoring trenches

5.1.3.7 Gas drainage

Pressure caused either by the production of gas from the fermentation of organic material in the soil, or by the raising of the level of the water table, requires the installation of a gas drainage system under the geomembrane. This system will be constructed in addition to the water drainage system (two completely separate networks). The gas drainage system will be connected to vents positioned on the crest of the embankment.

Gas drainage may be achieved either by using perforated 40 to 80 mm (1.5 in. to 3 in.) diameter pipes positioned every 10 m (32 ft.) or using draining layers (geocomposite: cellular framework in high density polyethylene covered with an anti-contaminant geotextile) positioned every 5 m (16 ft.). A bed of permeable material of 8/10 grade (washed gravel), a geotextile or another synthetic permeable is required between the pipes. The geocomposite network is preferred.

The vents are protected to avoid obstructions and the ingress of water (rain or running water).

The requirements for the installation of water drainage described at chapter 3.3 are equally valid for gas drainage.

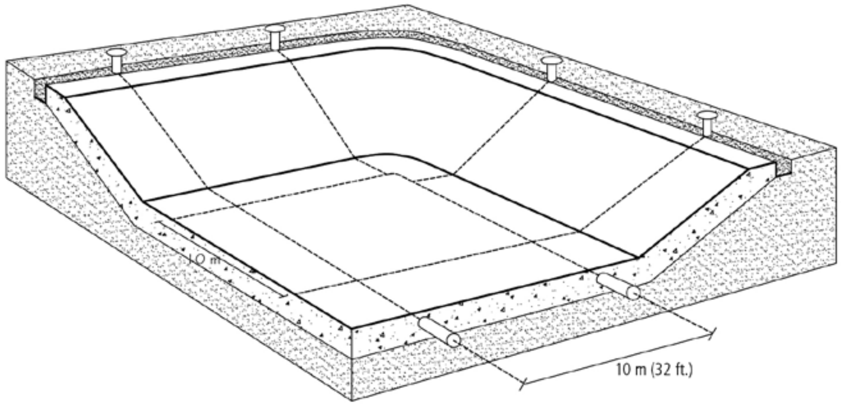


Fig. 55: Principle of a gas drainage network (perforated pipes)

Photo 59: Gas drainage network (geocomposite) + draining layer of 10 cm (4 in.)

Photo 510: Gas drainage network, (perforated pipes)

5.1.3.8 Acceptance of building grounds

A site meeting is required for the acceptance of the building grounds before installation of the Firestone GeoGard™ EPDM lining system.

Approval of the support structure is based on the following factors:

- The general appearance of the earthworks (evenness of the foundation).
- Conformity of dimensions.
- The standard of surface compaction.
- The flatness of the surface of the embankment crest.
- The absence of foreign bodies which might damage the waterproofing (roots, iron bars, projecting stones, other sharp objects, etc).
- The management of water infiltration on the inner slopes and the bed of the pond.
- Compliance with the slope of the pond bed.

It is important to note that the membrane applicator is only supposed to approve the state of the support structure.

5.1.3.9 Geotextile

Considering the potential environmental risks resulting from a possible leak within a dung pit, it is recommended that a puncture resistance geotextile liner always be installed before installation of the geomembrane and this, even if the support layer is of very good quality.

The type of geotextile will be selected depending on the properties of the support soil (particle size, slope,...) the type of geomembrane used (thickness) and stresses anticipated during installation and operation. The minimum properties of the geotextile are given below, for reference only:

- Type: non woven, needled, short fiber, 100% polypropylene, 100% virgin material.
- Mass per unit area (EN 965): ≥ 300 g/m² (9 oz. /sq. yd.).
- Thickness at 2 kPa (EN ISO 9863-1): 20 mm (0.08 in).
- Tensile elongation (EN ISO 10319): 50%.
- Tensile strength (EN ISO 10319): ≥ 20 kN/m (3 psi) (machine and cross machine direction).
- Dynamic perforation test (EN ISO 13433): < 30 mm (1.2 in.).
- Puncture resistance (EN ISO 12236): ≥ 3 kN (674 lbs. force).
- Durability (annex B EN 13254) 25 years (covered in 2 weeks).


Photo 511: Installation of the geotextile

The installation of the puncture resistance geotextile is carried out as follows:

- Hoisting of the roll using lifting machinery to the crest of the embankment.
- Unrolling of the geotextile along the length of the embankment using lifting machinery.
- Unfolding of the strips so as to cover the whole surface of the pond.
- Flattening of creases on the slopes and formation of angle pleats.
- Thermo welding of the panels.
- If necessary, temporary ballast will be planned.

During the installation, great care will be taken to avoid removing material from the capping layer.

5.1.3.10 Table 53: Firestone GeoGard™ 1.1 mm (0.045 in.) and 1.5 mm (0.060 in.) Technical Specifications

Property	Test method	Units	ASTM D-7465		ASTM D-7465	
			1.14 mm (0.045 in.)		1.52 mm (0.060 in.)	
			SI	Eng	SI	Eng
Specific Gravity	ASTM D-792	gm/cc	1.1	1.1	1.1	1.1
Unit Weight	ASTM D-751	kg/m (lb./ft.)	1.4	0.29	1.8	0.40
Thickness, Type 1	ASTM D-412	mm (in.)	1.02 +10/-10%	.045 +10-10%	1.52 +10/-10%	.060 +10-10%
Tensile Strength, Die C min	ASTM D-412	MPa (psi)	9.0	1305	9.0	1305
Ultimate Elongation, Die C min	ASTM D-412	%	300	300	300	300
Tear Resistance, Die C	ASTM D-624	kN/m (lbf/in)	26.27	150	40.28	230
Puncture Resistance	ASTM D-4833	N (lbs.)	133	30	181.56	43
Shore A Durometer	ASTM D-2240		65-10	65-10	65-10	65-10
Resistance to Ozone 7 days/100 @ 37.8° C (150° F) 50% ext.	ASTM D-1149		No Cracks	No Cracks	No Cracks	No Cracks
Multiaxial Elongation	ASTM D-5617	%	100	100	100	100
Oven Aging At 116° C (240° F) for 670 hours	ASTM D-573					
Tensile strength Die C	ASTM D-412	MPa (psi)	8.3	1205	8.3	1205
Ultimate elongation, Die C	ASTM D-412	%	200	200	200	200
Tear Resistance,Die C	ASTM D-624	kN/m (lbf/in)	21.9	125	37.32	213
Xenon Arc for 5040 kJ/(m².nm) @ 340 nm @ 80°C	ASTM G-155/G-151					
Visual Inspection 7X	ASTM D-518		Pass	Pass	Pass	Pass
No cracks or crazing bent loop @10% strain						
Brittleness Point	ASTM D-2137		-45°C	-49°F	-45°C	-49°F
Water Resistance weight after immersion 166 hrs @ 70° C (158° F)	ASTM D-471	%	+8,-2	+8,-2	+8,-2	+8,-2
Water Vapor Permeability (max.)	ASTM E-96	Perm-mils	2.0	2.0	2.0	2.0
Linear Dimensional Change,max	ASTM D-1204	%	+/- 1.0	+/- 1.0	+/- 1.0	+/- 1.0
Chronic Toxicity Screening	EPA/600/4-89/ 001 ASTM E-729	Method 1000.0	passes passes	passes passes	passes passes	passes passes

Firestone GeoGard EPDM is placed in the following manner:

- Unrolling and unfolding in accordance with the basic plan.
- Positioning of the roll at the top of the embankment.
- Unrolling in the direction of the slope.
- Manual unfolding of the panels so as to cover the whole pond.
- Elimination of excessive pleats.
- Forming of angle folds. Folded angles should be closed with QS Cover Strip.
- Temporary ballasting of the geomembrane.
- Execution of field seaming after the geomembrane panels have settled for 30 – 45 minutes. On the embankments, seams are made parallel to the slope.
- Comprehensive checking of field seams (non-destructive: visual check, vacuum tester, air lance – destructive: tests of peeling strength (min. value ≥ 110 kN/m) (8 lbs./in.), test of shearing resistance (average value ≥ 206 kN/m) (30 lbs./in.) per ASTM D7272.

Photo 512: Installation and assembly of the geomembrane

During the installation, great care will be taken to avoid causing large creases in the geotextile.

Seaming and execution of waterproofing installation details will be carried out following the recommendations in the general technical guide for the installation of Firestone GeoGard™ EPDM in waterproofing systems.

In all cases, it is necessary to take account of two important differences which apply solely to the installation of Firestone GeoGard EPDM in livestock effluent ponds:

Where seams are made with Firestone QuickSeam™ Splice Tape, a bridging strip of Firestone QuickSeam Cover Strip must always be added.

Execution of installation details must be done with Firestone QuickSeam Cover Strip or Firestone QuickSeam SA Flashing. In no case will Firestone QuickSeam FormFlash be used in areas where the membrane is in contact with effluent. Systems with physical enclosure are recommended (see Fig. 56).

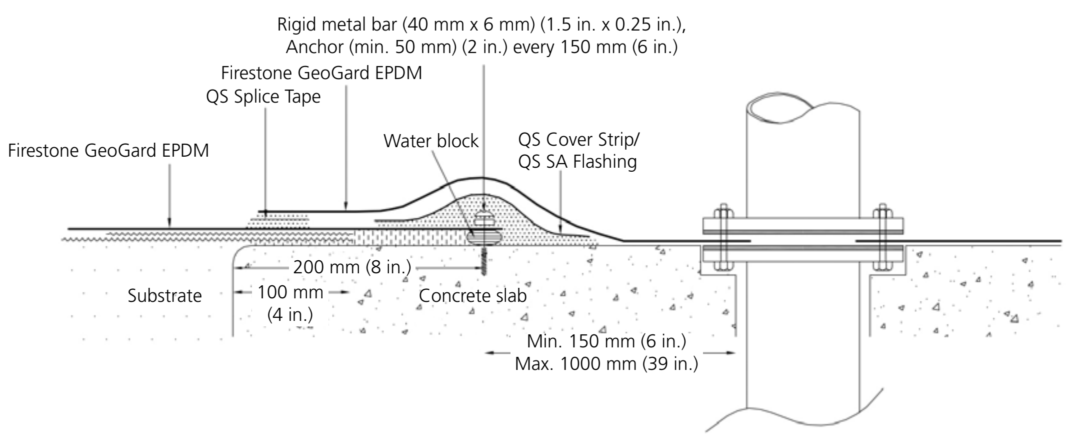


Fig. 56: Pipe penetration detail in contact with slurry

5.1.3.11 Effluent recuperation system

It is imperative that the outlet system is fixed. The sucking out of effluents risks snagging, deforming and tearing of the geomembrane, so it is essential to plan a ballasted fixture on the bed and at the top the embankment crest. This outlet system remains permanently in the pond.

In countries where winters are very cold, it is necessary to provide special measures to avoid damage to pipes from freezing.

There are different effluent recuperation designs:

- If the pond is less than 3-4 m (10 ft. - 13 ft.) deep, effluent may be pumped from the surface.
- If the pond is more than 4 m (13 ft.) deep, it is no longer possible to suck out the effluent, so it is necessary to use a pressure pump.

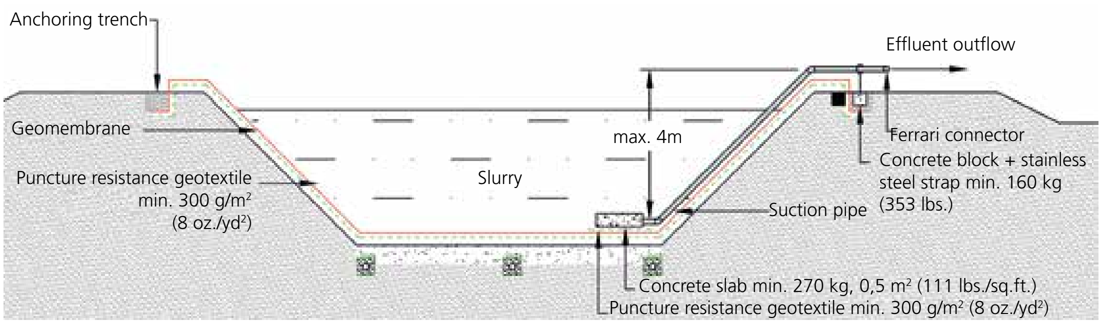


Fig. 57: Principle of evacuation by suction

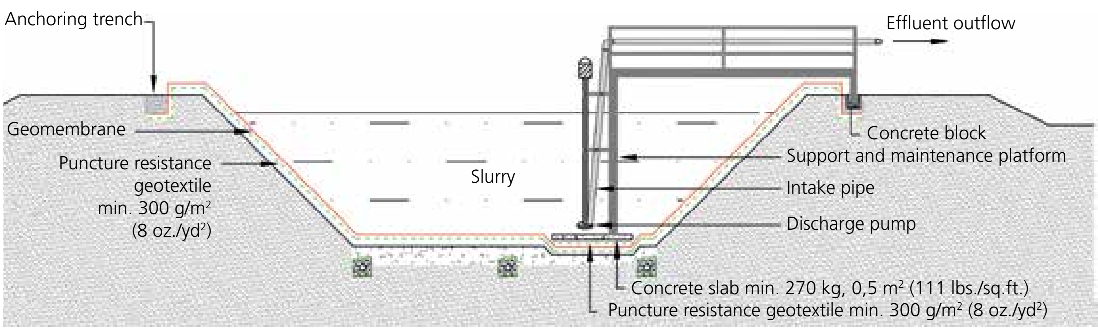


Fig. 58: Principle of active pumping (pressure pumping)

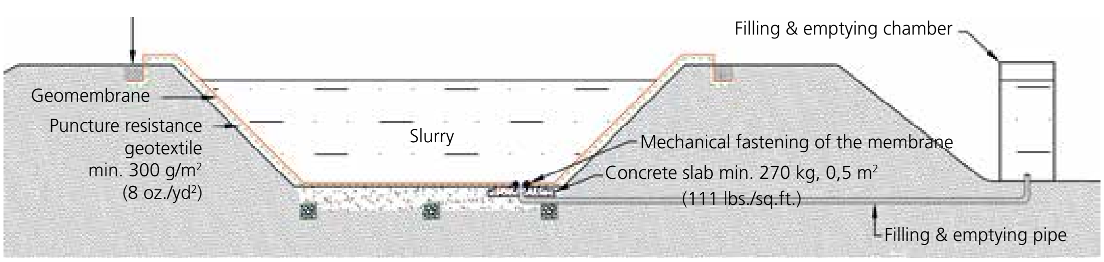


Fig. 9: Principle of outlet and inlet using the communicating vessels principle

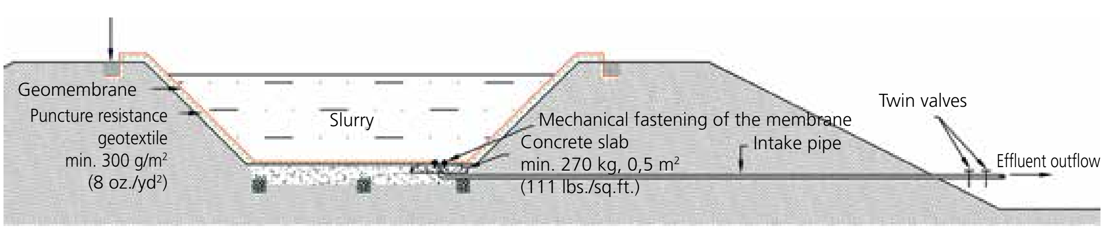


Fig. 510: Principle of the gravity flow outlet method

When slurry is recuperated from the bed, it is recommended to mechanically fix the membrane and the geotextile on a concrete slab. Details of the mechanical fastening are described in the general technical guide of Firestone GeoGard™ EPDM and in figure 56.

An example of recuperation pumping system from the surface is proposed below.

One solution consists of placing a concrete slab on the bed of the pond, with a minimum weight of 270 kg (595 lbs.) under which the suction tube will be held (PVC DN 160 pressure Pn16). The concrete slab will have a surface area of at least 0.5 m² (5.38 ft.²).

A protective geotextile (non-woven, knitted of at least 300 g/m²) (8 oz./sq. ft.) must be inserted between the concrete slab and the geomembrane.

At the head of the pond, the pipe will be fixed to a holding pin positioned in the anchorage trench. The holding pin consists of a stainless steel strap (DN 160 soldered onto the pipe) held in a concrete cube. Weight of the assembly: 160 kg minimum (350 lbs.).

The connection between the suction pipe and the expansion tank will be achieved with the help of a FERRARI connector positioned at the exit of the holding pin (male connector with galvanised steel collar). The FERRARI connector will be attached with a holding collar (stainless steel with M 8/60 nuts and bolts). Pipe diameters will be adapted to the user's equipment.

Photo 513: Pond outlet system (suction pumping)

Photo 514: Pond drainage system (pressure pumping)

Photo 515: System of outlet and inlet using the communicating vessels principle

5.1.3.12 Pond swirling system

Swirling can either be done mechanically (the most popular) or by injecting air into the mixture, or by pumping / injecting slurry in a closed circuit. It may not be necessary for white or green water storage or filtered slurry.

Mechanical swirling is achieved either by a fixed or mobile agitator (connected to the back of a tractor). In neither case must the agitator be allowed to come into contact with the membrane.
In the case of the installation of a fixed agitator, it is essential to plan for a ballast slab of at least 9 m² surface area and a minimum thickness of 20-25 cm (8 in.-10 in.) so as to avoid snagging, distortion or lifting of the geomembrane.

If the swirling is achieved with a mobile agitator, it will be necessary to designate a specific swirling area. A slab of reinforced concrete, 2-3 m (7-10 ft.) wide, will be placed on the bed of the pond and will extend up the sides as far as the tractor parking area. In countries where winters are very cold, concrete may crack due to frost action. It is then recommended to place a fixed mixer.

The concrete slab will, necessarily, lie on a protective geotextile (non-woven, knitted and of at least 300 g/m²) (8 oz./sq. yd.).

Photo 516: Fixed agitator system

Photo 517: Mobile swirling system

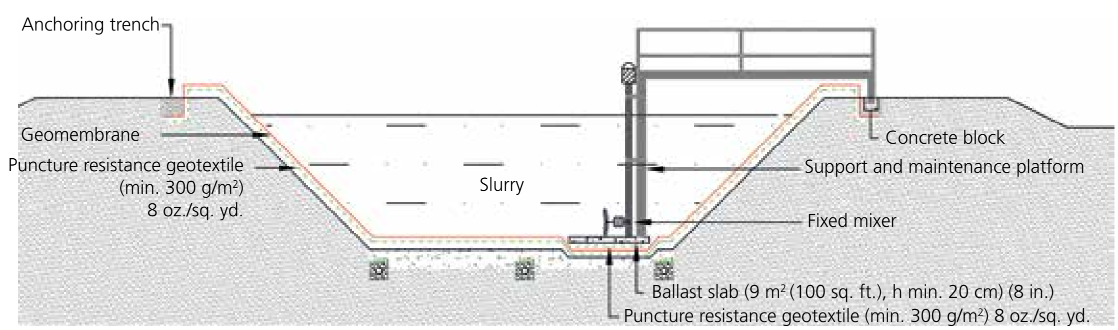


Fig. 511: Principle of the fixed agitator system

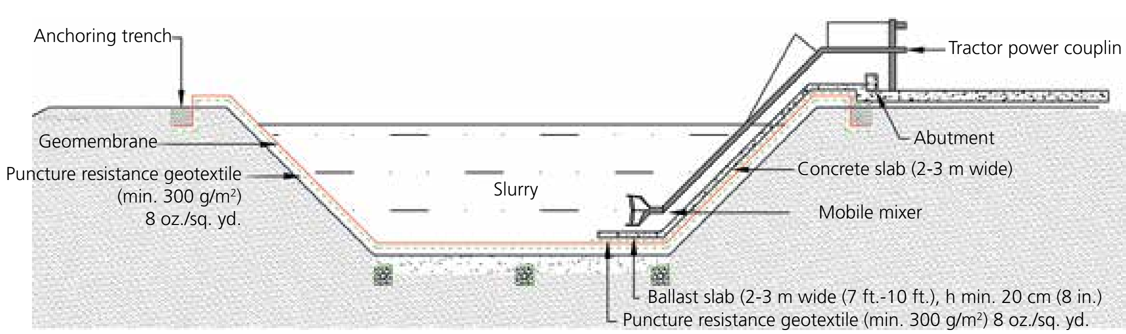


Fig. 512: Principle of the mobile swirling method

5.1.3.13 Safety measures

In the areas where vehicles are expected to approach the edge of the pond (swirling, pumping) it is necessary to plan a barrier at a reasonable distance from the edge to avoid any machine falling into the pond.

An impassable fence, 2 m (7 ft.) high, must be planned around the slurry pond to avoid the possibility of people or animals falling in.

Inside the pond, a safety ladder will be permanently available. Rodent ladder is also to be provided.
Depending on the type of effluent, it is sometimes useful to consider a non-return valve at the level of the effluent inlet pipe so as to avoid smells in the stables during effluent swirling.

Photo 518: Safety ladder

Photo 519 : Rodent ladder

5.1.4 Site inspection

5.1.4.1 Technical inspection

If the capacity of the effluent storage installation exceeds 250 m³ (8,829 cu. ft.), a technical survey by an accredited exterior agency is obligatory/recommended.

The in-house technical controls by the project manager and the third party controls by the accredited agency will be carried out before, during and after installation of the geomembrane.

There are two main types of seaming control methods which provide accurate information regarding the quality of the field seams:

- **Non-destructive seam testing:**
  - Visual inspection: in the case of Firestone GeoGard™ EPDM, a series of elements may be easily checked visually and which give a very good indication of the quality of the seams.
  - Air lance: enables the watertightness of the seams to be checked on a continuous basis.
  - Vacuum chamber: enables inspection of individual points on field seams.
- **Destructive monitoring:**
  - Tensile and peel tests conducted on seam samples at least 24 hours after a seam has been made.

A more detailed description of the seam testing methods and general quality control is given in the Firestone Quality Assurance Plan (available upon request)

5.1.4.2 Acceptance of work

The approval of the work will be confirmed by the client, assisted where necessary by his site manager, during a site visit.

On delivery of the installation, the project manager will hand over to the client:

- Documents relating to the design of the installation, detailing all the factors taken into account during the planning of the dung pit (type and volume of effluent to be stored, depth of the water table, type of supporting ground,…).
- Documents relating to the construction of the dung pit showing the positions and techniques employed, the layout drawings, methods of connection to other facilities, as well as the methods of installation of the different materials (aggregate, geomembrane, …).
- The specifications of the geomembrane, geotextile and the geocomposite used.
- Copies of quality certificates (geomembrane, fitters).
- A guide to good practices allowing management of the installation with care for the integrity of the geomembrane.

The waterproofing of the installation must be verified, among other things, by checking the inspection well after the storage pond is filled.

5.1.5 Repair and renovation

Even with periodic inspection and maintenance, lining systems will require repair from time to time. Although geomembrane repair is typically conducted as a response to some type of damage to the pond, a **pro-active** approach to geomembrane repair and renovation can improve the performance and extend the service life of the liner. The procedures and specifications contained in this section provide valuable general information about the efficient and effective repair of EPDM lining systems applied in dung pits.

Those guidelines apply only to dung pits applications. They describe the procedure to repair the membrane (cuts and punctures in the EPDM membrane, contamination of the membrane with hazardous products) and the field seams (wrinkles in a splice, tape is not showing, tape is showing more than 25 mm (1 in.), seam is showing possible water entry points…).

In animal waste containment pit applications, waterproofing will be done with QuickSeam™ Cover Strip. QuickSeam FormFlash cannot be used in areas where the membrane is in contact with effluent (except detail in Fig. 517).

In animal waste containment pits applications where joints are made with QuickSeam Splice Tape, a bridging strip of QuickSeam Cover Strip must always be added. Typical seam bridged with a strip of QuickSeam Cover Strip cross-section:

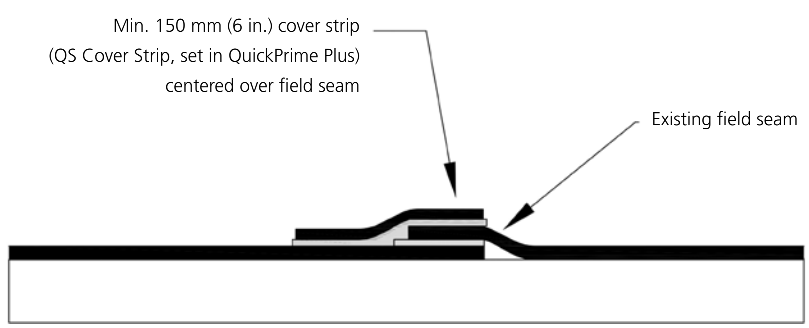


Fig. 513: Seam bridged with QuickSeam Cover Strip

These procedures and specifications are offered as a complementary service only and Firestone disclaims any liability, under any theory of law, arising out of the use of these procedures.

Note: *These drawings show general procedures for typical lining system repair and renovation for dung pit applications. Please refer to Firestone Technical Specification Manuals for additional information. Lining repairs and renovations should be performed only by a professional lining contractor who is licensed and trained by the lining system manufacturer.*

5.1.5.1 Repair of cuts and punctures on the EPDM membrane

As soon as a damage to the membrane is identified (during installation or inspection), mark the damaged area with a white crayon for rubber. The repair must extend a minimum of 75 mm (3 in.) beyond the perimeters of the damaged area in all directions in case of repairs using QuickSeam™ Cover Strip and 100 mm (4 in.) in case of repair using EPDM membrane. Round all corners of the repair piece.

Pinholes and small punctures in the membrane may be repaired with a cover piece of QuickSeam Cover Strip.

Cuts and punctures in the EPDM membrane should be repaired with cured membrane. Round all edges of the cut so that it cannot propagate underneath the target piece. If this has been done properly, the target EPDM repair piece can be applied using QuickSeam Tape and QuickPrime™ Plus.

Lap Sealant is used to seal and mechanically protect the exposed edge of QuickSeam Cover Strip. Lap Sealant is also recommended where QuickSeam Cover Strip make a T-crossing with another QS Cover Strip in order to avoid any risk of possible capillarity.

Note: *The application of new QuickSeam products to existing in-service EPDM membrane requires special cleaning and priming procedures. Refer to chapter 4.5.5 - "Cleaning of In-Service EPDM Membrane".*

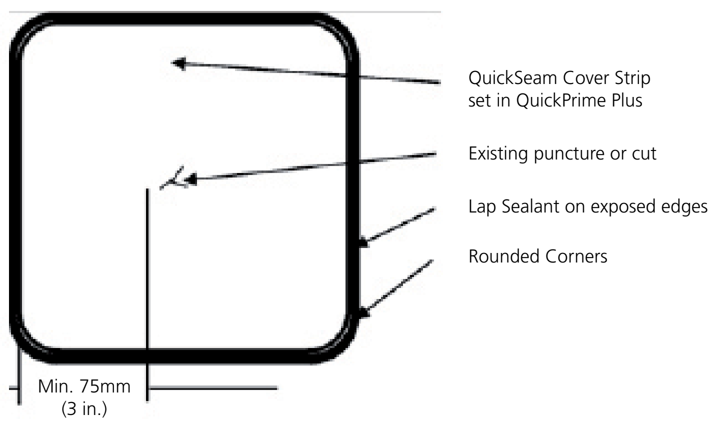


Fig. 514: Typical Repair of EPDM Membrane: using QuickSeam Cover Strip

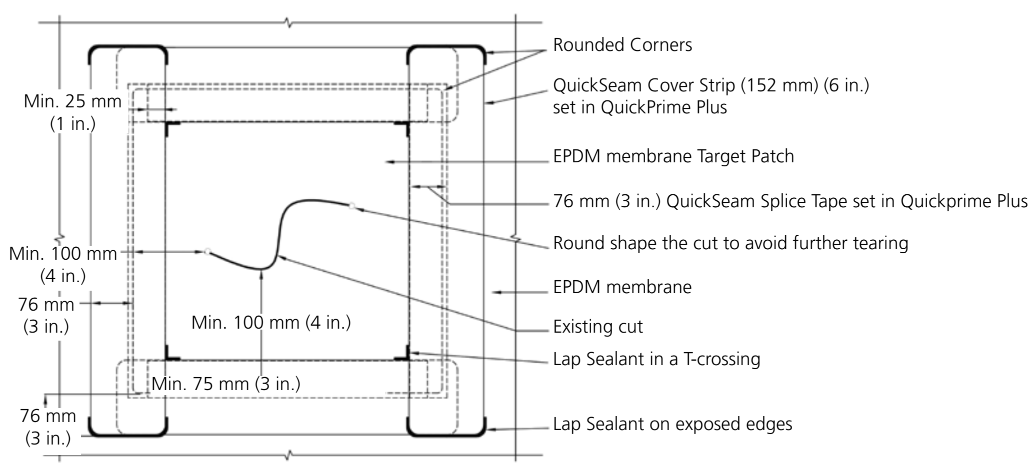


Fig. 515: Typical Repair of EPDM Membrane: using EPDM geomembrane

The seams made with QuickSeam Splice tapes need to be bridged with QuickSeam Cover Strip.

5.1.5.2 Repair of contaminated membrane

Membrane that has been in contact with hazardous chemical discharges such as fresh bitumen, petroleum products, greases, oils, animal fats, oil based, coal tar based or plastic roof cements needs to be inspected for damage.

Remove immediately all excess of the contamination materials and replace the damaged area with a new piece of membrane. Repairs should be done like described in Fig. 515.

5.1.5.3 EPDM field seam repair

As soon as a non-conformity is identified on the seam (during installation or inspection), mark the damaged area with a white crayon for rubber.

In dung pits applications where joints are made with QuickSeam™ Splice Tape, a bridging strip of QuickSeam Cover Strip must always be added.

If the damage/default occurs before bridging the seam with QuickSeam™ Cover Strip:

- **Punctual defaults or damages** on seams (e.g.: wrinkles) in a splice must be cut out before covering with QS Cover Strip. Wrinkles in a splice must be cut out using scissors, laying them flat on the membrane and then covered with QS Cover Strip set in QuickPrime™ Plus.
- **Non-punctual non-conformities** on seams (tape is not showing, tape is showing more than 25 mm (1 in.), possible water entry points…) are going to be covered with the QS Cover Strip set in QuickPrime Plus.

If the damage/default occurs after bridging the seam with QS Cover Strip:

- **Punctual defaults or damages** on bridged seams can be repaired with 2 patches of QS Cover Strip set in QuickPrime Plus (see Fig. 516). Pieces that exceed need to be cut before applying the patches.
- **Non-punctual non-conformities** on seams are going to be covered with a piece of EPDM geomembrane (see Fig. 517). Seams need to be covered with QS Cover Strips. In this detail and only on this detail, patches of QS FormFlash (152 x 305 mm) (6 in. x 12 in.) are used in order to avoid any risk of possible capillarity.

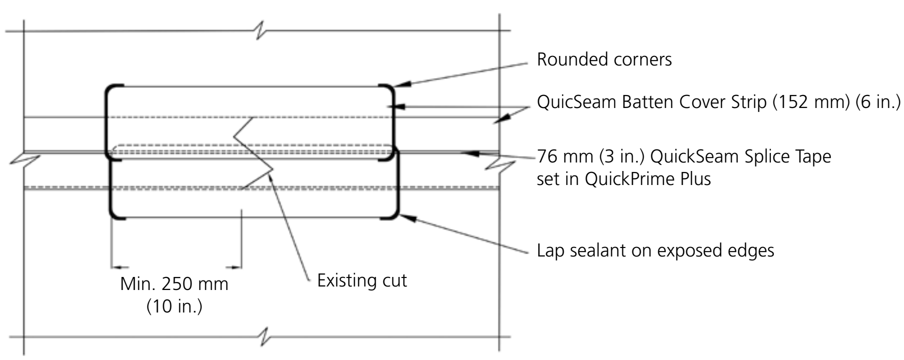


Fig. 516: Typical Repair of EPDM bridged seam: using QS Cover Strip

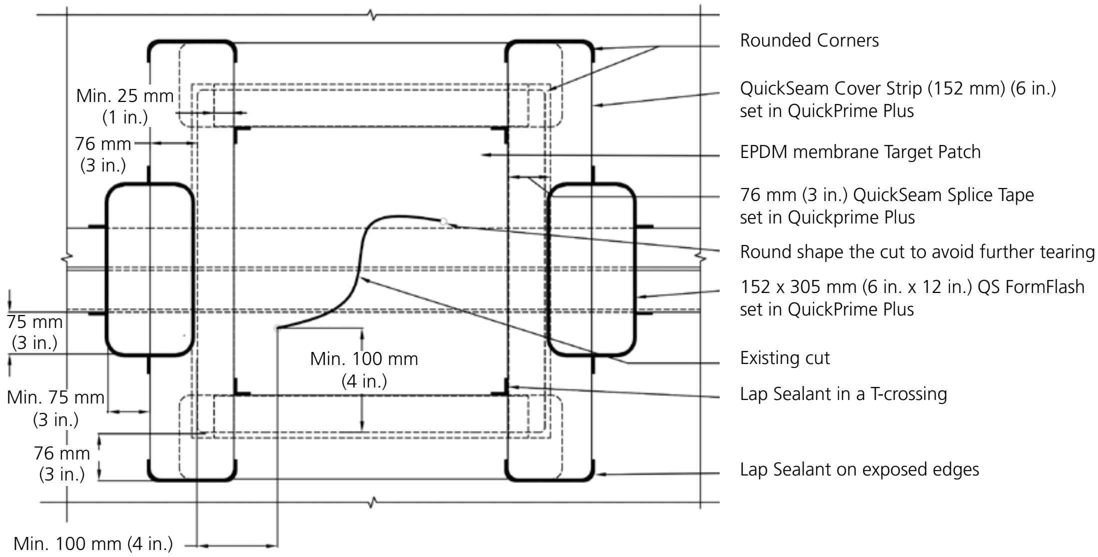


Fig. 517: Typical Repair of EPDM bridged seam: using EPDM geomembrane

Note: *The application of new QuickSeam™ products to existing in-service EPDM membrane requires special cleaning procedures. Refer to chapter 4.5.5 - "Cleaning of In-Service EPDM Membrane".*

5.1.5.4 Cleaning of in service EPDM membrane

When repairing a membrane that has been in service for some time, it is necessary to prepare the surface to be spliced thoroughly prior to starting the splicing operation.

THIS IS A PERFORMANCE SPECIFICATION. It is required that the **membrane be dark gray in color without streaks** before proceeding with any bonding or splicing activity. The cleaned area must be larger than the repair area.

- Cleaning may be achieved by one of the following methods:
  - Brush wash by hand with a solution of mild dish soap and water and a stiff bristlebrush. Rinse the receiving surface with water until clean. Take care not to flood the receiving surface.
  - Use a power water washer and a wet vacuum. Take care not to flood the receiving surface.
- Allow the receiving surface to thoroughly dry. If necessary, dry the washed surface with clean towel or rags. Make sure that no moisture can be trapped.
- It is also acceptable to broom the membrane in the repair area and apply Firestone Membrane Pre-Wash using a garden sprayer at the rate of 7 to 12 m²/l (300 to 500 sq. ft./gal.) - see Technical Department for exact procedure. After Pre-Wash has dried for approximately ten minutes, use a power water washer providing 15 L (4 gal.) per minute at 20 MPa (3000 psi) to remove the Pre-Wash and accumulated dirt and debris. A 40° fan spray nozzle for pressure washer is suggested.
- Wash the existing EPDM twice with Firestone Clear Splice Wash and clean, white, cotton rags, allowing the surface to evaporate and dry between washings. **Change cleaning rags often**.

Note: *After cleaning the in-service membrane, proceed with the application of the new EPDM membrane, QuickSeam Tape, QuickSeam Cover Strip and Lap Sealant in accordance with current application specifications.*

5.1.6 Use of installation

Once all work is finished, the designer must advise the client of the operating limits of the storage pond as well as advice on maintenance. An example of the list of recommendations is given in the chapter 5.1.6.2. It is essential that the user does not store chemically active products, other than those for which the installation has been designed, without first checking on the compatibility of the geomembrane with the product in question.

Any hydrocarbon or oil-based residue is forbidden inside the pond.

Recuperation and swirling of slurry must only be carried out in the areas designed for the purpose.

5.1.6.1 Checks

The user must carry out regular checks of the storage pond in order to ensure its long life and to avoid any environmental damage. The necessary checks must be clearly explained by the general contractor at the time of acceptance of the work. Below is a non-exhaustive list of indispensable checks:

- Filling: verify that there is no overflow.
- Pipe work: check for waterproofing and obstructions.
- Geomembrane: check the condition of visible parts.
- Vents: check that they are free and unobstructed (no swelling of the geomembrane).
- Absence of foreign bodies inside the pond.
- Evacuated water draining freely.
- Inspection well: check systematically and as often as possible that there is no trace of slurry.
- Check that running water is draining correctly. Stagnant water should never be left around the pond edges.
- Check that the safety systems are functional: fencing, ladder, non-return valve …

The user will begin routine maintenance of the whole of the installation following control visits. In the case that any dysfunction of the Firestone GeoGard™ EPDM waterproofing system is noted (leaks or tears in the geomembrane…) the user must contact the company immediately so as to begin repairs as quickly as possible.

5.1.6.2 Maintenance

In order to ensure a long service life and avoid costly repairs, Firestone requires the following for the care and maintenance of Firestone GeoGard™ EPDM.

- Do not change the type of contents for which the storage pond was designed without first having contacted Firestone. Ensure that the membrane is not exposed to liquids such as solvents, greases, oils, animal fats and petroleum products or other hazardous wastes that may adversely affect the membrane.
  - If the membrane is subject to contact with any type of chemical, you should contact Firestone immediately.
  - Should petroleum products, solvents, greases, oils, etc. come in contact with the membrane, clean the area immediately with Splice Wash.
- If there is to be traffic on the membrane for equipment maintenance or other reasons, make sure to protect the membrane. All contact with the membrane must be avoided. Fencing will be positioned all round the installation to avoid people or large animals falling in, vandalism… Also, make provisions for small animals which fall into the pond to escape. It is essential to manage and plan for any potential damage caused by animals (rodents, birds…).Caution all tradesmen servicing project equipment that you have a rubber liner, and that they should proceed accordingly. Any possible damage should be immediately reported. Firestone recommends that you keep a log of all activity.
- All flashings, mechanical terminations, pipe terminations, metal work, drains, equipment, and any other accessories functioning in conjunction with the lining system must be kept properly maintained and watertight at all times. Particular attention should be given to the inspection well, which should be systematically checked at every use or upkeep operation on the installation. The general condition of the embankment will also be checked.
- It is essential to do everything possible to avoid the pond overflowing during filling.
- The general condition of all fixed or mobile installations (agitators, recuperation systems …) should be checked at each use. Mobile installations will be operated with the greatest care to avoid contact with the membrane.
- Should there be an alteration of the project, contact a Firestone representative to ensure alterations are in accordance with Firestone’s specifications.
- Should you have a leak:
  - Try to determine the cause of the leak, if possible.
  - Contact immediately a Firestone representative and notify him in writing.
  - If necessary, make temporary repairs with Firestone GeoGard EPDM system.
  - Never use oil-based products.
- Firestone recommends that an inspection of the drainage system and the visible parts of the lining system be conducted once or twice a year by a qualified professional. Should you have problems with the earthwork or substrate under the membrane, groundwater, vegetation, or drainage system:
  - Contact **immediately** a qualified engineer.
  - Notify a Firestone representative in writing.

While the Firestone GeoGard EPDM requires no maintenance, maintenance is important to the long-term performance of the lining system as a whole. We, at Firestone, feel that the preceding guidelines will assist the project owner in maintaining the liner to perform for many years. The cooperation of the owner in this effort is important.

5.1.6.3 Safety

When swirling the slurry, large quantities of gas are released. The installation must allow the gasses to escape and the user must make sure that there is no danger to humans or animals.

Safety systems need to be always functional.

5.1.6.4 Table 54: Firestone GeoGard™ 1.1 mm (0.045 in.) and 1.5 mm (0.060 in.) Technical Specifications

Property	Test method	Units	ASTM D-7465		ASTM D-7465	
			1.14 mm (0.045 in.)		1.52 mm (0.060 in.)	
			SI	Eng	SI	Eng
Specific Gravity	ASTM D-792	gm/cc	1.1	1.1	1.1	1.1
Unit Weight	ASTM D-751	kg/m (lb./ft.)	1.4	0.29	1.8	0.40
Thickness, Type 1	ASTM D-412	mm (in.)	1.02 +10/-10%	.045 +10-10%	1.52 +10/-10%	.060 +10-10%
Tensile Strength, Die C min	ASTM D-412	MPa (psi)	9.0	1305	9.0	1305
Ultimate Elongation, Die C min	ASTM D-412	%	300	300	300	300
Tear Resistance, Die C	ASTM D-624	kN/m (lbf/in)	26.27	150	40.28	230
Puncture Resistance	ASTM D-4833	N (lbs.)	133	30	181.56	43
Shore A Durometer	ASTM D-2240		65-10	65-10	65-10	65-10
Resistance to Ozone 7 days/100 @ 37.8° C (150° F) 50% ext.	ASTM D-1149		No Cracks	No Cracks	No Cracks	No Cracks
Multiaxial Elongation	ASTM D-5617	%	100	100	100	100
Oven Aging At 116° C (240° F) for 670 hours	ASTM D-573					
Tensile strength Die C	ASTM D-412	MPa (psi)	8.3	1205	8.3	1205
Ultimate elongation, Die C	ASTM D-412	%	200	200	200	200
Tear Resistance,Die C	ASTM D-624	kN/m (lbf/in)	21.9	125	37.32	213
Xenon Arc for 5040 kJ/(m².nm) @ 340 nm @ 80°C	ASTM G-155/G-151					
Visual Inspection 7X	ASTM D-518		Pass	Pass	Pass	Pass
No cracks or crazing bent loop @10% strain						
Brittleness Point	ASTM D-2137		-45°C	-49°F	-45°C	-49°F
Water Resistance weight after immersion 166 hrs @ 70° C (158° F)	ASTM D-471	%	+8,-2	+8,-2	+8,-2	+8,-2
Water Vapor Permeability (max.)	ASTM E-96	Perm-mils	2.0	2.0	2.0	2.0
Linear Dimensional Change,max	ASTM D-1204	%	+/- 1.0	+/- 1.0	+/- 1.0	+/- 1.0
Chronic Toxicity Screening	EPA/600/4-89/ 001 ASTM E-729	Method 1000.0	passes passes	passes passes	passes passes	passes passes

5.2 High altitude reservoirs

Construction of high altitude reservoirs is a delicate operation which is subject to many hazards and for which the consequences of poor design, construction or maintenance can be disastrous for people and property located downstream.

This document sets out a series of points which must be studied in detail by project engineers in the design of high altitude reservoirs. This informative document does not purport to be exhaustive. The various points raised refer to very specific skills that must be studied by experts in the subject. Firestone accepts no liability for any design failure or for resultant damages.

5.2.1 Site selection

The high altitude environment is extremely complex and fragile. Site selection therefore results from a detailed study of different factors:

- Topography.
- Availability of water supply.
- Existing facilities (villages, ski slopes, etc.).
- Altitude (implementation, thickness of ice crust on the pond, etc.).
- Environmental impacts (high ecological value, fragile environments).
- Hydrology (watershed study).
- Seismology.
- Geology and geotechnical study (slope slip, collapse, rock falls, water depth, differential settlement, cavitation collapse, karst topography, ground susceptible to water solubility (gypsum), etc.).
- Hazards specific to mountain areas (avalanches, torrential phenomena, etc.).
- Downstream basin in the event of breach (determining the safety level applied to the reservoir).

5.2.2 Embankment

The classic design of high altitude mountain reservoirs is an excavation-embankment design.

- **Compacting:** in order to have a well compacted embankment with a uniform slope, it is strongly recommended to build the embankment by the excess fill method: a width greater than the project profile is compacted, then the poorly compacted faces are scraped.
- **Slope:** depends on the material used, the foundation quality, the height of the embankment, the position of the saturated zone. An accurate stability calculation must be made. The slopes recommended below are also a function of the presence of a covering over the membrane:
    - Covered geomembrane: upstream slope of 1:3 and downstream slope of 1:2-2.5.
    - Non-covered geomembrane: upstream slope of 1:2.25-2.5 and downstream slope of 1:2-2.5.
- **Berm:** use of a berm is not recommended for high altitude reservoirs (drainage discontinuity, difficulty of construction, damage from ice crust).
- **Crest:** the minimum crest width must be 4 m (12 ft.), with a slight slope towards the outside of the structure (1 %).
- **Downstream embankment:** necessary to protect against erosion (grassed topsoil) and freezing (draining materials).

- **Freeboard:** freeboard is the difference in level between the top of the crest and the highest water level. It is intended to prevent wind generated waves from overtopping the crest. The freeboard is specifically calculated for each project but in any case must always be more than 50 cm (20 in.) or the minimum value from the current regulation.
- **Drainage:** in order to protect the embankment from internal erosion mechanisms or downstream slope slippage in the event of leakage of the GSS (geomembrane sealing system) on the upstream embankment, it is essential to provide a water drainage system under the GSS and under embankments. The type of drainage envisaged will be adapted depending on the scale of the structure and construction of the embankment.

5.2.3 Excavation

- **Slope:** the excavation must not destabilize the terrain slope. The slope will be determined by a stability study. It must never exceed 1:2.
- **Drainage:** in the case of natural water inflow upstream of the reservoir, it is essential to provide a water drainage system to ensure stability of the excavation slopes and avoid pressure under the membrane. This drainage system is separate from the GSS drainage system.
- **Ring road:** with a minimum width of 4 m (12 ft.), this shall be equipped with a culvert to collect upstream runoff.

5.2.4 Spillway

All high altitude reservoirs must be equipped with a spillway to allow removal of excess water entering the basin (inflow flooding, heavy rains, etc.).

- **Type:** it is strongly recommended to build a free weir spillway whose discharge threshold is at the same height as the normal reservoir level. Use of "overflow" sluice openings are not recommended.
- **Hydrological dimensioning:** the dimension of the spillway must allow evacuation of excess water for flooding of the facility so that the reservoir level stays equal to or less than the high water level. A safety coefficient must be provided for (freezing over, snow accumulation, etc.).
- **Obstruction**: the spillway risks being obstructed by snow accumulation. This must be considered in its construction. It is recommended to build the spillway with gentle slopes and splayed walls to allow access by maintenance machines. In all cases accumulated snow and ice must be removed from the spillway at the end of winter.
- **Threshold:** a reinforced concrete threshold is recommended to resist hydrostatic and ice pressure. Its foundation must not be subject to freezing. Special attention must be given to the connection between the threshold and the geomembrane.
- **Sluice:** the sluice may be built of various materials (reinforced concrete, gabions, concrete permeated riprap, etc.). In all cases it is essential that the support resists erosion, especially at the exit downstream of the threshold. It is usually helpful to provide underside drainage to avoid erosion of the subsoil and uplift pressure.
- **Discharge:** may be built from the same materials as the sluice. Its design dissipates the energy of the water before discharge into the natural environment.

5.2.5 Drainage under embankments

- **Emptying:** the discharge drain is an essential part of the structure's safety. It allows the reservoir water level to be rapidly and completely lowered. The minimum discharge drain must be dimensioned so as to discharge half the contents within 8 days and completely empty the basin within 21 days. It is strongly recommended that discharge is by gravity.
- **Intake:** it is preferable to provide several intakes in case of unavailability. Trash racks are to be provided to prevent obstructions (ice blocks).
- **Valves:** the valve system depends on the scale of the reservoir. For large scale structures, upstream valves are to be provided in a dry and accessible valve house. It is essential that valves are also accessible in winter. It is recommended to provide a valve system that may be serviced when the reservoir is full.
- **Pipes:**
  - Pipes are to be in steel or cast iron.
  - Minimum diameter of 300 mm (12 in.).
  - In order to prevent piping phenomena in case of leakage, the pipe shall be placed in a trench that will be filled with poured concrete.
  - Drainage shall be provided around the pipe for the downstream half of the dam body, to collect water under pressure coming from leakage of the pipe or failure of a connection between the pipe and the GSS.
  - Expansion/compensation joints are to be provided.
  - Special attention must be given to the connection between the pipe and the geomembrane. The connection will be made by mechanical anchoring of the geomembrane to a concrete block in which the pipe is embedded. The mechanical connection to the membrane shall follow the requirements described in the Firestone Technical Manual (Rigid Metal Bar + Water Block Seal + Lap Sealant HS + QS Cover Strip). The concrete block shall be constructed so as to limit differential settlements and present a smooth surface in the area for connection with the geomembrane. It is essential that the concrete is of excellent quality and is applied in accordance with the rules of the art.
- **Inlet:** it is recommended that the inlet chamber be provided with bars (spaced about 1/3 the diameter of the pipe or sluice gates) and an orifice placed at such a height as to prevent obstruction.
- **Downstream discharge:** an energy dissipater shall be provided at the discharge outlet in order to prevent erosion of the downstream slope.

5.2.6 GSS

- **Geometry of the structure:**
  - Favour simple shapes.
  - Use a bottom slope of at least 2%.
  - The change in angle between the bottom and the side slopes must be rounded (curvature of 0.5 m) (1.5 ft.).
- **Support structure:**
  - **Subgrade:** good capacity, uniform, free of organic material or sharp objects.
  - **Granular bed:** protecting the membrane from puncture is essential to ensure sealing of the structure in the long term. It is strongly recommended to set down a granular bed at least 20 cm (8 in.) thick, having aggregate size of maximum 20 mm (0.75 in.).
  - **Water drainage:** it is mandatory to place a water drainage network under the geomembrane that will allow any leakage of the GSS to be detected and drained.
    - **Separate:** the GSS drainage system must be distinct and separate from the drainage network for natural water inflow and drainage of the embankment.

- **Divided:** the drainage network shall be subdivided into several zones so that any leak can be localised (very important for covered membranes).
- **Drainage through aggregates:** this bed may be made with sand or gravel (5/20). Its thickness depends on the transmissivity of the product's drainage. A minimum thickness of 10 cm (0.5 in.) is recommended. A filtering geotextile must be provided between the drainage layer and the neighbouring soil. In some cases (subgrade of fine particle size), the granular bed may be replaced by the drainage aggregate bed.
- **Drainage by a drainage geocomposite:** the geocomposite shall be chosen depending on its cross-sectional flow rate (under load), its filtering geotextiles and its coefficient of friction (preferably self-stable on slopes).
- **Basin:** in the basin, the drainage system shall be complemented by collectors.
- **Berm:** if a berm absolutely must be used, a water collection/drainage system must be provided at the berm.

– **Gas drainage:** a gas drainage system under the membrane must be provided. The gas drainage system shall be well separated from the water drainage system.

– **Puncture resistant geotextile:** the type of geotextile shall be selected depending on the properties of the support soil (particle size, etc.), the type of geomembrane used and stresses anticipated in placing and operation. The minimum properties of the geotextile are given below, for reference only:

- Type: non woven, needled, short fiber, 100% polypropylene, 100% virgin material.
- Mass per unit area (EN 965): 500-1000 g/m² (15-30 oz./sq. yd.).
- Thickness at 2 kPa (EN ISO 9863-1): 3,5 mm (0.1 in.).
- Tensile elongation (EN ISO 10319): 60%.
- Tensile strength (EN ISO 10319): ≥ 30 kN/m (4 psi) (machine and cross machine direction).
- Puncture resistance (EN ISO 12236): ≥ 6 kN (1,350 lbs. force).
- Durability (annex B EN 13254): 25 years (covered in 2 weeks).

The rolls of geotextile are to be sewn or thermo-bonded together after setting in place in such a way as to avoid any movement while installing the EPDM geomembrane.

- **Firestone GeoGard EPDM:** a geomembrane of 1.5 mm (60 mil.) is preferably used, with 1.1 mm (45 mil.) geomembrane minimum. The choice of the type of geomembrane will depend on the properties of the support, and the presence and type of covering. Design and installation of Firestone GeoGard EPDM must follow the requirements given in the Firestone Technical Manual. In areas where the membrane must be connected to a structure, it underlines the need for particularly careful compacting to avoid any differential settlement. Inside the basin, mechanical connection of the membrane with the details is to be favoured. Properties of Firestone GeoGard EPDM:

5.2.6.1 Table 55: Firestone GeoGard™ 1.1 mm (0.045 in.) and 1.5 mm (0.060 in.) Technical Specifications

Property	Test method	Units	ASTM D-7465		ASTM D-7465	
			1.14 mm (0.045 in.)		1.52 mm (0.060 in.)	
			SI	Eng	SI	Eng
Specific Gravity	ASTM D-792	gm/cc	1.1	1.1	1.1	1.1
Unit Weight	ASTM D-751	kg/m (lb./ft.)	1.4	0.29	1.8	0.40
Thickness, Type 1	ASTM D-412	mm (in.)	1.02 +10/-10%	.045 +10-10%	1.52 +10/-10%	.060 +10-10%
Tensile Strength, Die C min	ASTM D-412	MPa (psi)	9.0	1305	9.0	1305
Ultimate Elongation, Die C min	ASTM D-412	%	300	300	300	300
Tear Resistance, Die C	ASTM D-624	kN/m (lbf/in)	26.27	150	40.28	230
Puncture Resistance	ASTM D-4833	N (lbs.)	133	30	181.56	43
Shore A Durometer	ASTM D-2240		65-10	65-10	65-10	65-10
Resistance to Ozone 7 days/100 @ 37.8° C (150° F) 50% ext.	ASTM D-1149		No Cracks	No Cracks	No Cracks	No Cracks
Multiaxial Elongation	ASTM D-5617	%	100	100	100	100
Oven Aging At 116° C (240° F) for 670 hours	ASTM D-573					
Tensile strength Die C	ASTM D-412	MPa (psi)	8.3	1205	8.3	1205
Ultimate elongation, Die C	ASTM D-412	%	200	200	200	200
Tear Resistance,Die C	ASTM D-624	kN/m (lbf/in)	21.9	125	37.32	213
Xenon Arc for 5040 kJ/(m².nm) @ 340 nm @ 80°C	ASTM G-155/G-151					
Visual Inspection 7X	ASTM D-518		Pass	Pass	Pass	Pass
No cracks or crazing bent loop @10% strain						
Brittleness Point	ASTM D-2137		-45°C	-49°F	-45°C	-49°F
Water Resistance weight after immersion 166 hrs @ 70° C (158° F)	ASTM D-471	%	+8,-2	+8,-2	+8,-2	+8,-2
Water Vapor Permeability (max.)	ASTM E-96	Perm-mils	2.0	2.0	2.0	2.0
Linear Dimensional Change,max	ASTM D-1204	%	+/- 1.0	+/- 1.0	+/- 1.0	+/- 1.0
Chronic Toxicity Screening	EPA/600/4-89/ 001 ASTM E-729	Method 1000.0	passes passes	passes passes	passes passes	passes passes

- **Double geomembrane:** use of a double geomembrane is recommended on sites where the subsoil presents risks of internal erosion or dissolution. In this case, any leakage of the GSS could have very serious consequences on the quality of the subgrade and the stability of the structure. Between the two geomembranes a geocomposite drainage system shall be connected to a leak detection system.
- **Covering:** at high altitude, the membrane risks being damaged by the ice crust on the surface of the basin, rock falls, floating objects, etc. In addition, as a general rule, high altitude basins are regularly emptied. The membrane then risks being put under tension from wind loads. For these reasons, it is recommended to cover the entire surface of high altitude basins.
- It is strongly advised not to protect only a part of the slope. Not covering a basin may be justified where it is at low altitude (<1800 m) (6,000 ft.), protected from the prevailing winds, of small size and with a support structure of sand. Geomembranes of non-covered basins must be weighted to prevent uplift of the geomembrane by wind action (minimal water layer, sandbags, concrete slabs, etc.).
  - **Different types of coverings:**
    - Riprap / layer of sand or gravel / geotextile.
    - Gabion bed / geotextile.
    - Onsite poured concrete slab / geotextile. The geotextile must have sufficient transmissivity to permit drainage under the slab and prevent uplifting pressure.
    - Interlocking concrete / geotextile.
  - **Stability:** it is essential to ensure stability of the covering on the slope. This is the reason why a 1:3 slope is recommended on covered slopes. Coverings of poured concrete may have a somewhat steeper slope. In stability calculations, it is necessary to take into account situations of sustainable operations (weight of materials, ice, snow, etc.), transient situations (weight of machinery and excess material during construction, rapid emptying, etc.) and accidental situations (seismic, blocked drain, etc.).
  - **Basin:** considering the low slope of the basin and the lower stresses, the covering may be less robust in this area.
  - **Structure of a riprap covering:** a riprap covering must be sized so as to resist ice and wind driven waves:
    - **Thickness:** between 0.3 and 0.8 m (1 ft. and 2.5 ft.).
    - **Block diameter:** Maximum diameter < covering thickness (0.3 – 0.8 m) (1 ft. and 2.5 ft.), minimum diameter > 0.1 m (1 ft.). It is considered that the median diameter of the blocks must be greater than the thickness of the ice (between 0.2 and 0.5 m) (8 in. and 18 in.).
    - **Typical structure:**
      - Geomembrane.
      - Geotextile between 600 and 1200 g/m² (16 and 32 oz./yd²).
      - 0.2-0.3 m (8 in. - 12 in.) bed of sand or gravel.
      - Blocks.
    - **Stability:** the effect of the slope is overriding the stability of the riprap. It is very important to respect the 1:3 slope. If necessary, an abutment at the toe of the slope and/or geosynthetic reinforcement anchored at the top of the slope shall be provided.
    - **Permeability:** permeability of the covering structure must be sufficient to avoid developing hydraulic pressure at its base.
    - **Test plate:** in order to select the puncture resistant geotextile and to check the stability of riprap on the slope, it is strongly recommended to use an on site test plate before starting installation.
  - **Setting in place:** it is often during setting in place of the covering bed that the membrane is subjected to the most significant stresses. It is therefore essential to take all possible precautions when applying the covering over the geomembrane. Movement of machinery on the membrane should be prohibited unless absolutely necessary and with the use of special measures.

- **Anchor trench:** anchor trenches must be sized as described in the Firestone Technical Manual.
  - Non-covered membrane: the trench is used for intermediate and final anchoring.
  - Covered membrane: the covering will serve as final anchoring. The trench is used for intermediate anchoring during setting in place and while waiting for the covering.
- **Inflow zone:** if the membrane is not covered, it is advisable to provide a reinforced area if the basin inflow is directly onto the membrane.

5.2.7 Bubbling system

Installation of a bubbling system (high pressure air injection) at the bottom of the reservoir is strongly recommended to reduce the thickness of ice on the reservoir surface.

- Network of 10 bar (140 psi) HDPE tubes spaced every 6 m (20 ft.).
- Nozzles of 0.6 m (2 ft.) diameter every 2 m (6.5 ft.).
- Pressure of 5 to 6 bars (80 to 85 psi) and flow rate equal to 5 % of the reservoir volume (m^3/h).
- Weighted and placed 10 cm (4 in.) from the bottom.
- Independent ring diffusers.

5.2.8 Monitoring device

The drainage network located under the GSS shall be equipped with a visual control system (check for water turbidity) and a flow measurement system that can evaluate the quality of the GSS and its drainage system. The monitoring system must be accessible throughout the year. It is strongly recommended to compartmentalise the drainage system so as to be able to localize the area that is leaking. This is especially important for systems where the membrane is covered (not possible to see membrane condition).

It is also recommended to set up a water level measurement system.

5.2.9 Maintenance, control and safety of facility

During design, it is necessary to take overall account of maintenance activities (snow removal, vegetation control, repair of the GSS, etc.), and of surveillance and safety needs (installation of a perimeter fence, ladders for workers, rodents, etc.).

These guidelines have been drawn from the book "Retenues d'altitude" [High Altitude Reservoirs], published by Éditions Quae, Savoir-faire collection. Authors: Laurent Peyras, Patrice Mériaux, coordinators.

5.2.9.1 Table 56: Firestone GeoGard™ 1.1 mm (0.045 in.) and 1.5 mm (0.060 in.) Technical Specifications

Property	Test method	Units	ASTM D-7465		ASTM D-7465	
			1.14 mm (0.045 in.)		1.52 mm (0.060 in.)	
			SI	Eng	SI	Eng
Specific Gravity	ASTM D-792	gm/cc	1.1	1.1	1.1	1.1
Unit Weight	ASTM D-751	kg/m (lb./ft.)	1.4	0.29	1.8	0.40
Thickness, Type 1	ASTM D-412	mm (in.)	1.02 +10/-10%	.045 +10-10%	1.52 +10/-10%	.060 +10-10%
Tensile Strength, Die C min	ASTM D-412	MPa (psi)	9.0	1305	9.0	1305
Ultimate Elongation, Die C min	ASTM D-412	%	300	300	300	300
Tear Resistance, Die C	ASTM D-624	kN/m (lbf/in)	26.27	150	40.28	230
Puncture Resistance	ASTM D-4833	N (lbs.)	133	30	181.56	43
Shore A Durometer	ASTM D-2240		65-10	65-10	65-10	65-10
Resistance to Ozone 7 days/100 @ 37.8° C (150° F) 50% ext.	ASTM D-1149		No Cracks	No Cracks	No Cracks	No Cracks
Multiaxial Elongation	ASTM D-5617	%	100	100	100	100
Oven Aging At 116° C (240° F) for 670 hours	ASTM D-573					
Tensile strength Die C	ASTM D-412	MPa (psi)	8.3	1205	8.3	1205
Ultimate elongation, Die C	ASTM D-412	%	200	200	200	200
Tear Resistance,Die C	ASTM D-624	kN/m (lbf/in)	21.9	125	37.32	213
Xenon Arc for 5040 kJ/(m².nm) @ 340 nm @ 80°C	ASTM G-155/G-151					
Visual Inspection 7X	ASTM D-518		Pass	Pass	Pass	Pass
No cracks or crazing bent loop @10% strain						
Brittleness Point	ASTM D-2137		-45°C	-49°F	-45°C	-49°F
Water Resistance weight after immersion 166 hrs @ 70° C (158° F)	ASTM D-471	%	+8,-2	+8,-2	+8,-2	+8,-2
Water Vapor Permeability (max.)	ASTM E-96	Perm-mils	2.0	2.0	2.0	2.0
Linear Dimensional Change,max	ASTM D-1204	%	+/- 1.0	+/- 1.0	+/- 1.0	+/- 1.0
Chronic Toxicity Screening	EPA/600/4-89/ 001 ASTM E-729	Method 1000.0	passes passes	passes passes	passes passes	passes passes

6 Technical Information Sheets

TECHNICAL INFORMATION SHEET

FSP-201
10/21/2008

QuickPrime™ Plus

Firestone Item Number:
W56RAC1695: 0.95 L (1-Quart Cans)
W563587041: 3.79 L (1-Gallon Pails)
W563587044: 11.36 L (3-Gallon Pails)

DESCRIPTION:
Firestone QuickPrime Plus is designed to clean and prime approved Firestone membranes prior to application of QuickSeam™ products where required by Firestone Specialty Products specifications and details. It may also be used to clean geomembrane prior to the application of Firestone Splice Adhesive (SA-1065).

METHOD OF APPLICATION:
Surfaces to be primed must be clean, dry, and free of foreign materials and excess dusting agent. Clean with broom or rags if necessary.

Stir QuickPrime Plus thoroughly before and during use. QuickPrime Plus must be applied with a QuickScrubber™ or QuickScrubber Plus™ pad and handle using long back and forth strokes with moderate-to-heavy pressure along the length of the area until surfaces become gray in color with no streaking or puddling. Allow the QuickPrime Plus surfaces to flash off completely according to the touch-push test (usually less than 10 minutes, flash off time will vary depending on ambient air conditions) before applying QuickSeam products or Lap Sealant. Complete QuickSeam product installation or Lap Sealant application in accordance with Firestone Specialty Products specifications and details.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.

PRODUCT DATA

Property	Minimum Performance
Base:	Synthetic Rubber Polymers
Color:	Translucent Gray
Solvents:	Heptane, Toluene
Solids:	16 - 18%
Viscosity:	Very thin, free flowing
Weight:	0.79 kg/L (6.62 lb/gal) (nominal)
Specific Gravity:	0.793 (nominal) (H_2O = 1)
Flash Point:	-17.8 °C (0.0 °F)
VOC:	Not to exceed 664 g/L (5.55 lb/gal)

STORAGE (Continued):
3. Keep the material out of direct sunlight until ready for application.

COVERAGE RATE:
Approximately 4.91 - 6.14 m^2/L (200 - 250 ft^2/gal) one side.

PACKAGING:
1. 0.95 L (1-qt) cans are packaged 12 per case and 50 cases per pallet.
2. 3.79 L (1-gal) pails are packaged 4 per case and 54 cases per pallet.
3. 11.36 L (3-gal) pails are packaged 75 pails per pallet.

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
3. Red caution labels are required when shipping.
4. For professional use only.
5. Use only in well ventilated areas.
6. Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
7. Use only in conjunction with QuickScrubber or QuickScrubber Plus pad and handle. Do not apply with rollers, brushes or rags.
8. Mix thoroughly before and during use.
9. Thinning is not allowed.
10. Keep out of reach of children.
11. Dispose as a hazardous waste in accordance with local, state and federal regulations.
12. Recommended cleaner is rubbing alcohol followed by soap and water.

S723-SPP-004

PRECAUTIONARY DATA (Continued):

13. Do not contaminate with foreign materials.
14. Cover can when not in use. When applying adhesive, work out of small pails with a cover to avoid skimming over of adhesive in larger can.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	South Bend, IN

Notes: This primer is applied using the process covered by U.S. Patent No. 5,520,761.

QuickScrubber Plus is protected by U.S. Patent No. 5,976,292.

QuickPrime Plus is protected by U.S. Patent No. 5,985,981.

Firestone SPECIALTY PRODUCTS

QuickPrime Plus

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Sales: (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-004

TECHNICAL INFORMATION SHEET

FSP-203
11/07/2008

Firestone
SPECIALTY PRODUCTS

Bonding Adhesive
BA-2004

Firestone Item Number:
W563587051: 18.93 L (5-Gallon Pails)

DESCRIPTION:
Firestone Bonding Adhesive BA-2004 is designed for bonding Approved Firestone membranes to wood, metal, masonry and other acceptable substrates.

METHOD OF APPLICATION:
Surfaces on or against which Bonding Adhesive is to be applied must be clean, dry, free of foreign materials and excess dusting agent. Clean with broom or rags if necessary.

Stir Bonding Adhesive thoroughly before and during use, achieving a uniform mix with no sediment on the bottom and no marbling evident. Apply Bonding Adhesive with a solvent resistant paint roller and roll at about the same time to both the exposed underside of the sheet and the substrate to which it will be adhered to allow approximately the same flash off time. Apply Bonding Adhesive evenly to avoid globs and puddles of adhesive. Bonding Adhesive may also be spray-applied, followed by rolling to ensure 100% coverage of the Bonding Adhesive. **Care must be taken not to apply Bonding Adhesive over any area that is to be later cleaned and spliced to another sheet or flashing.**

Allow the Bonding Adhesive to flash off completely according to the touch-push test (usually less than 15 minutes, flash off time will vary depending on ambient air conditions).

Starting at the fold, roll the previously coated portion of the sheet into the coated substrate slowly and evenly so as to minimize wrinkles. To ensure proper contact, compress the bonded half of the sheet to the substrate with a stiff push broom using heavy pressure.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.

PRODUCT DATA

Property	Minimum Performance
Base:	Neoprene
Color:	Yellow
Solvents:	Toluene, Hexane, Acetone
Solids:	23% (min.)
Viscosity:	2300 - 3000 Centipoise, R.V.F. Brookfield, #3 Spindle @ 10 RPM
Weight:	0.845 +/- .042 kg/L (7.05 +/- .35 lb/gal)
Specific Gravity:	0.845 +/- 5%
Flash Point:	Less than -17.8° C (0° F)
VOC:	581 g/L (4.85 lb/gal)

SHELF LIFE (Continued):
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. If exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for immediate application.

COVERAGE RATE:
Approximately 1.10 - 1.47 m^2/L (45 - 60 ft^2/gal) may be obtained depending on the substrate. Some surfaces are more uneven and porous and will result in a lower coverage rate while smooth, non-porous facers may result in higher coverage rates. Rates are based on roller application to both mating surfaces. When sprayed and back-rolled, the rate may be slightly higher than when rolled only.

PACKAGING:
18.93 L (5-Gal) pails are packaged 45 pails per pallet.

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
3. Red caution labels are required when shipping.
4. For professional use only.
5. Use only in well ventilated areas.

S723-SPP-006

PRECAUTIONARY DATA (Continued):

6. Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
7. Mix thoroughly before and during use.
8. Thinning is not allowed.
9. Keep out of reach of children.
10. Dispose as a hazardous waste in accordance with local, state and federal regulations.
11. Recommended cleaner is Toluene (while fluid).
12. Do not contaminate with foreign materials.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	South Bend, IN

Firestone
SPECIALTY PRODUCTS

Bonding Adhesive
BA-2004

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-006

Firestone SPECIALTY PRODUCTS

Water-Based Bonding Adhesive

Firestone Item Number:
W563587035: 18.93 L (5-Gallon Pails)

DESCRIPTION:
Firestone Water-Based Bonding Adhesive is a contact adhesive designed for bonding Approved Firestone membranes to wood, metal, masonry and acceptable substrates. When application procedures are followed, Firestone Water-Based Bonding Adhesive is an acceptable alternative to Firestone solvent based bonding adhesive (BA-2004 Bonding Adhesive).

METHOD OF APPLICATION:
Surfaces on which Water-Based Bonding Adhesive are to be applied must be clean, dry, and free of foreign materials. Clean with broom or rags if necessary. The ambient temperature should be 4.4° C (40° F) or higher. Do not to use Water-Based Bonding Adhesive if there is a possibility of freezing temperatures within 48 hours after application.

Stir the Water-Based Bonding Adhesive thoroughly before and during use. Apply Water-Based Bonding Adhesive with a solvent resistant paint roller and roll at about the same time to both the exposed underside of the sheet and the substrate to which it will be adhered to allow approximately the same drying time. Apply evenly to avoid globs and puddles of adhesive. Water-Based Bonding Adhesive may also be spray-applied, followed by rolling to ensure 100% coverage by the bonding adhesive. **Care must be taken not to apply Bonding Adhesive over any area that is to be later cleaned and spliced to another sheet or flashing.**

Allow Water-Based Bonding Adhesive to dry completely according to the touch-push test (usually less than 15 minutes, flash off time will vary depending on ambient air conditions). In addition, Water-Based Bonding Adhesive will change from gray to dark translucent color as the carrier evaporates.

Starting at the fold, roll the previously coated portion of the sheet into the coated substrate slowly and evenly so as to minimize wrinkles. To ensure proper contact, compress the bonded half of the sheet to the substrate with a stiff push broom using heavy pressure.

PRODUCT DATA

Property	Minimum Performance
Base:	Acrylic
Color:	Grey (when first applied), Dark translucent (when carrier evaporates)
Solids:	62.59% (min)
Viscosity:	16,000 +/- 3,000 centipoise, R.V.F. Brookfield #4 Spindle @ 10 rpm
Weight:	1.05 kg/L (8.8 lb/gal) (nominal)
Specific Gravity:	1.05 (nominal)
VOC:	18 g/L (0.149 lb/gal)

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers, at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. If exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for immediate application.
4. Do not allow to freeze.

COVERAGE RATE:
Approximately 2.45 - 3.07 m^2/L (100 - 125 ft^2/gal) may be obtained depending on the substrate. Some surfaces are more uneven and porous and may result in a lower coverage rate while smooth, less porous facers may result in higher coverage rates. Rates are based on roller application to both mating surfaces. When sprayed and back-rolled, the rate may be slightly higher than when rolled only.

PACKAGING:
18.93 L (5-Gal) pails are packaged 45 pails per pallet.

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. For professional use only.

S723-SPP-007

PRECAUTIONARY DATA (Continued):

3. Use only in well ventilated areas.
4. Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
5. Mix thoroughly before and during use.
6. Thinning is not allowed.
7. Keep out of reach of children.
8. Recommended cleaner is water while adhesive is fluid.
9. Do not contaminate with foreign materials.
10. Do not allow to freeze.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	Plainfield, IL

Firestone
SPECIALTY PRODUCTS

Water Based Bonding Adhesive

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-007

TECHNICAL INFORMATION SHEET

FSP-205
11/07/2008

Firestone
SPECIALTY PRODUCTS

SA-1065 Splice Adhesive (For Flashing)

PRODUCT DATA

Property	Minimum Performance
Base:	Synthetic Polymers
Color:	Black
Solvents:	Hexane, Toluene, Xylene
Solids:	26% (min.)
Viscosity:	2900-3700 Centipoise, R.V.F. Brookfield #3 Spindle @ 10 rpm
Weight:	0.88 +/- 0.04 kg/L (7.35 +/- 0.37 lb/gal)
Specific Gravity:	0.876 +/- 5%
Flash Point:	-17.8° C (0° F)
VOC:	615 g/L (5.13 lb/gal)

Firestone Item Number:
W563587058: 3.79 L (1-Gallon) Pails
W563587059: 11.36 L (3-Gallon) Pails

DESCRIPTION:
Firestone Splice Adhesive is designed for splicing approved Firestone membranes and adhering to various substrates as indicated in the Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
Position the geomembrane to overlap 76.2mm to 152.4 mm (3.0" to 6.0") along the entire length of the splice. Fold the top sheet back and clean the dry mating surfaces per Firestone Specialty Products specifications and details.

Stir Splice Adhesive thoroughly before and during use, achieving a uniform mix with no sediment on the bottom and no marbling evident. Apply the Splice Adhesive with a 76.2 mm or 101.6 mm (3.0" or 4.0") wide by 12.7 mm (0.5") thick solvent-resistant paint brush to both mating surfaces at about the same time so as to allow approximately the same flash-off time. Apply in a thick, even, smooth coat with long painting type strokes so that brush marks bleed out, yielding a smooth, glossy adhesive surface. (Make one short backstroke at each field and factory cross seam to leave extra adhesive at the step off.)

DO NOT USE CIRCULAR MOTIONS, PAINT ROLLERS, SPRAY EQUIPMENT, OR MECHANICAL EQUIPMENT FOR THE APPLICATION OF SPLICE ADHESIVE!

Allow the solvents in the Splice Adhesive to flash off completely according to the touch-push test (usually less than 30 minutes, flash off time will vary depending on ambient air conditions).

Once the adhesive has dried, allow the top sheet to fall freely onto the bottom sheet so as not to stretch or wrinkle the geomembrane. Roll the entire lap splice using a 38.1 mm - 50.8 mm (1.5" - 2.0") silicone or silicone-sleeved steel hand roller with positive pressure towards the outside edge of the lap, and along the entire length of the

METHOD OF APPLICATION (Con't):
lap. Apply seam edge treatment in accordance with Firestone Specialty Products specifications and details.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to ensure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers, at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. If exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for immediate application.

COVERAGE RATES:

Width Of Finished Splice	Approximate Width Of Actual Adhesive Application, One Substrate	Linear Meters Of Completed Flashing Seam Per Liter, Both Substrates Included	Linear Feet Of Completed Flashing Seam Per Gallon, Both Substrates Included
76.2 mm (3.0")	101.6 mm (4.0")	45.75 lm	150.0 lf
101..6 mm (4.0")	127.0 mm (5.0")	36.50 lm	120.0 lf

S723-SPP-008

Firestone SPECIALTY PRODUCTS

SA-1065 Splice Adhesive (For Flashing)

PACKAGING;

1. 3.79 L (1-gal) pails are packaged 4 per case and 54 cases per pallet.
2. 11.36 L (3-gal) pails are packaged 75 pails per pallet.

PRECAUTIONARY DATA:

1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
3. Red caution labels are required when shipping.
4. For professional use only.
5. Use only in well ventilated areas.
6. Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
7. Mix thoroughly before and during use.
8. Thinning is not allowed.
9. Keep out of reach of children.
10. Dispose as a hazardous waste in accordance with local, state and federal regulations.
11. Recommended cleaner is Firestone Splice Wash (while the Splice Adhesive is fluid).
12. Do not contaminate with foreign materials.
13. Cover can when not in use. When applying adhesive, work out of small pails with a cover to avoid skimming over of adhesive in larger can.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	South Bend, IN

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-008

TECHNICAL INFORMATION SHEET

FSP-206
11/07/2008

Firestone
SPECIALTY PRODUCTS

Splice Wash SW-100

Firestone Item Number:
W563587066: 18.93 L (5-Gallon) Closed-head Cans

PRODUCT DATA

Property	Minimum Performance
Solvents:	Aliphatic Hydrocarbon Mixture
Viscosity:	Very thin, free flowing
Weight:	6.75 kg/L (6.3 lb/gal) (nominal)
Specific Gravity:	0.75 (nominal)
Flash Point:	12.8° C (55° F)
Boiling Point:	119.4° C (247° F)
VOC:	745 g/L (6.21 lb/gal)

DESCRIPTION:
Firestone Splice Wash SW-100 is designed to clean and prepare approved Firestone membranes to receive adhesives where required by Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
Apply Splice Wash to the splicing area using a clean, white, natural fiber rag. Use a scrubbing motion until the splicing surface is clean of dirt and debris. Additional attention must be given to factory seams and where other excess accumulations of dusting agent may occur. Allow the washed surfaces to dry until the solvent's sheen is gone. This is usually between 10-30 minutes and may vary with ambient weather conditions. Geomembrane is clean when it is uniformly dark gray in color without streaks.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to ensure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers, at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. If exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for immediate application.

COVERAGE RATE:
Approximately 4.9 - 6.1 m^2/L (200 - 250 ft^2/gal) one side.

PACKAGING:
18.93 L (5-gal) closed-head cans are packaged 45 per pallet.

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
3. Red caution labels are required when shipping.
4. For professional use only.
5. Use only in well ventilated areas.
6. Avoid contact with skin. Use of neoprene gloves and eye protection with side shield is recommended.
7. Thinning is not allowed.
8. Keep out of reach of children.
9. Dispose as a hazardous waste in accordance with local, state and federal regulations.
10. Do not use as a pre-wash for any QuickSeam™ Tape products. QuickPrime™ Plus must be used for QuickSeam Tape products.
11. Do not contaminate with foreign materials.
12. Cover can when not in use.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	South Bend, IN

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-009

Firestone SPECIALTY PRODUCTS

Lap Sealant HS

Firestone Item Number:
W563587031: 0.33 L (11 oz) Cartridges
W563587032: 18.94 L (5-Gallon) Pails
W563587034: 0.95 L (1-Quart) Cartridges

DESCRIPTION:
Firestone Lap Sealant HS is designed to be used with SA-1065 Splice Adhesive for seam edge treatment applications and as a sealant in other applications as indicated by current Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
Surfaces to which Lap Sealant HS is applied must be clean, dry, and free of foreign materials and excess dusting agent. Clean with broom or rags if necessary.

1. **Wait Before Applying Seam Edge Treatment:**
   Wait to apply seam edge treatment a minimum of 4 hours after the completion of a flashing seam unless weather is threatening. If weather is threatening, apply SA-1065 Splice Adhesive to the edge of the flashing splice (Step 2 below) before leaving project. If weather is not threatening, the seam edge treatment must be applied no later than the end of the next day following the completion of the seam.
2. **Coat Flashing Seam Step-off:**
   Apply a layer of SA-1065 Splice Adhesive along the entire seam edge, a minimum of 25.4 mm (1.0") on each side of the step-off following current Firestone SA-1065 Splice Adhesive application procedures. Allow the SA-1065 Splice Adhesive to flash off.

   <u>**Note:**</u> If the seam edge has been contaminated, clean the seam edge a minimum of 25.4 mm (1.0") on each side of the step off with Firestone QuickPrime™ Plus and allow to dry, prior to application of the seam edge treatment.
3. **Apply Lap Sealant HS:**
   Apply a continuous bead of Lap Sealant HS approximately 9.5 mm x 6.3 mm (0.375" x 0.25") centered over the flashing seam edge, using the plastic nozzle applicator supplied by Firestone. Be sure to keep the nozzle applicator centered over the lap step-off. Refer to seam details.

PRODUCT DATA

Property	Minimum Performance
Base:	EPDM Rubber
Color:	Black
Solvents:	Light Aliphatic Solvent
Solids:	80% (min)
Viscosity:	30-50 seconds to extrude 20 grams through 2.64 mm (0.104") diameter orifice at 22.2-23.3° C (72-74° F)
Weight:	1.34-1.46 kg/L (11.2-12.2 lbs/gal)
Specific Gravity:	1.34-1.46
Flash Point:	11° C (52° F)
VOC:	Less than 250 g/L (2.09 lb/gal)

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to ensure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for immediate application.

COVERAGE RATE:
1. <u>0.31 kg (11 oz.) Cartridges:</u> Coverage rate of approximately 6.0 - 6.7 m (20 - 22 lf) of 9.5 mm x 6.3 mm (0.375" x 0.25") bead per 0.33 L (11 oz.) cartridge.
2. <u>0.95 L (1 qt) Cartridges</u>: Coverage rate of approximately 18.3 - 19.5 m (60 - 64 lf) of 9.5 mm x 6.3 mm (0.375" x 0.25") bead per 0.95 L (1qrt) cartridge.
3. <u>18.94 L (5-Gal) Pail:</u> Coverage rate of 381.0 - 390.1 m (1,250-1,280 lf) of 9.5 mm x 6.3 mm (0.375" x 0.25") bead per 18.94 L (5-gallon) pail.

PACKAGING:
1. 0.33 L (11 oz.) cartridges are packaged 28 cartridges per pail and 48 pails per pallet.
2. 0.95 L (1 Quart/32 oz.) cartridges are packed 10 cartridges per carton and 72 cartons per pallet.
3. 18.94 L (5-gallon) pails are packaged 45 pails per pallet.

S723-SPP-010

PRECAUTIONARY DATA:

1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
3. Red caution labels are required when shipping.
4. For professional use only.
5. Use only in well ventilated areas.
6. Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
7. Mix thoroughly before and during use.
8. Thinning is not allowed.
9. Keep out of reach of children.
10. Dispose as a hazardous waste in accordance with local, state and federal regulations.
11. Recommended cleaner is rubbing alcohol followed by soap and water.
12. Do not contaminate with foreign materials.
13. Cover can when not in use. When applying adhesive, work out of small pails with a cover to avoid skimming over of adhesive in larger can.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	Michigan Center, MI

Note: Seam edge treatment is protected by U.S. Patent No. 5,084,119.

Lap Sealant HS is protected by U.S. Patent No. 6,291,571 B1.

Firestone SPECIALTY PRODUCTS

Lap Sealant HS

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-010

Firestone SPECIALTY PRODUCTS

AP Sealant

Firestone Item Number:
W563587078: 0.30 L (10 oz.) Cartridges

DESCRIPTION:
Firestone AP Sealant is a single component polyurethane non-sag moisture-curing sealant. It can be used to caulk sheet metal, masonry, brick, and concrete block. It may be used as an exterior sealant at termination bar details and as a fastener sealer over fastener heads per current Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
Do not open cartridges until all substrate cleaning and preparation work has been completed. Surfaces to receive AP Sealant must be clean, dry, sound, frost-free, and grease-free. If grease/oil is present (example: form oil, etc.), it must be removed with a suitable solvent prior to the application of AP Sealant. Apply AP Sealant to substrates above 4° C (40° F).

AP Sealant can be applied with a standard caulking gun. Trim nozzle to desired size opening. Puncture seal inside nozzle just prior to application. Fill joints from the deepest point to the surface by holding a properly sized nozzle against the back of the joint.

Dry tooling is recommended. DO NOT use soapy water when tooling.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to ensure stored material will not go beyond the shelf life of one (1) year.

PRODUCT DATA

Property	Minimum Performance
Base:	Polyurethane
Color:	Gray
Solids:	92.5% +/- 2
Tooling Time:	Less than 20 minutes
UV & Ozone Resistance:	Excellent
Specific Gravity:	1.186 +/- 0.024
Cure System:	Moisture Activated
VOC:	111.44 +/- 1 g/L (0.95 +/- 0.008 lb/gal)

STORAGE:
1. Store in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for immediate application.

COVERAGE RATE:
Approximately 7.32 m in a 6.35 mm x 6.35 mm joint per 0.30 L (24.0 lf in a 0.25” x 0.25” joint per 10 oz) cartridge.

PACKAGING:
0.30 L (10 oz.) cartridges are packaged 30 cartridges per pail and 48 pails per pallet.

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. For professional use only.
3. Use only in well ventilated areas.
4. Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
5. Thinning is not allowed.
6. Keep out of reach of children.
7. Recommended cleaners are mineral spirits or SW-100 before the AP Sealant cures. After AP Sealant cures, it can be removed by abrasion or mechanical means.
8. Do not contaminate with foreign materials.
9. AP Sealant is not to be used for: aquariums, food contact surfaces, hot stack/stove pipes/fireplaces, structural glazing, or splices.
10. Solvent cleanings are recommended when using AP sealants.
11. When AP Sealant is used in non-system application, it is not covered under the terms of the Firestone warranty.

S723-SPP-011

TECHNICAL INFORMATION SHEET

FSP-208
11/07/2008

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	Plainfield, IN

Firestone SPECIALTY PRODUCTS

AP Sealant

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-011

Firestone
SPECIALTY PRODUCTS

Water Block Seal (S-20)

Firestone Item Number:
W563587071: 0.30 L (10 oz.) Cartridges

PRODUCT DATA

Property	Minimum Performance
Base:	Butyl Rubber
Color:	Gray
Solvents:	Heptane
Solids:	86%
Viscosity:	1,600,000 +/- 300,000 cps @ 27° C (80° F)
Weight:	1.32 kg/L (10.93 lb/gal)
Specific Gravity:	1.31
Flash Point:	-10.0° C (14° F), closed cup (ASTM 56-82)
VOC:	176 g/L (1.47 lb/gal)

DESCRIPTION:
Firestone Water Block Seal (S-20) is designed to provide a seal when used in compression as required by Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
Surfaces on which Water Block Seal is to be applied should be free from loose concrete, stone, mortar, foreign materials, and other contaminants.

Apply a 9.5 mm to 12.7 mm (0.375” x 0.25") bead to substrate surface. Bring the mating surface of the flashing membrane into contact with the Water Block Seal. Roll or press the flashing membrane firmly against the Water Block Seal and substrate avoiding wrinkles. Complete the detail per Firestone Specialty Products specifications and details.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to ensure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for immediate application.

COVERAGE RATE:
Approximately 3.1 m (10.0’) with a 9.5 mm to 12.7 mm (0.375” x 0.25") bead per 0.30 L (10 oz) cartridge.

PACKAGING:
0.30 L (10 oz.) cartridges, 25 cartridges per carton and 80 cartons per pallet.

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
3. Red caution labels are required when shipping.
4. For professional use only.
5. Use only in well ventilated areas.
6. Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
7. Thinning is not allowed.
8. Keep out of reach of children.
9. Dispose as a hazardous waste in accordance with local, state and federal regulations.
10. Recommended cleaners are mineral spirits, naptha, or kerosene.
11. Do not contaminate with foreign materials.
12. Water Block Seal (S-20) is not designed to be used as an exposed caulk.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	Evansville, IN

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-012

TECHNICAL INFORMATION SHEET

FSP-210
10/21/2008

Firestone
SPECIALTY PRODUCTS

7877
Spray Adhesive/Primer

Firestone Item Number:
W563587099: 0.66 L (22.4 fl. oz.) Cans

DESCRIPTION:
7877 Spray Adhesive/Primer is a web spray adhesive used to prime substrates to receive QuickSeam™ and FlashGard™ Adhesive Tape and to bond approved Firestone membranes in accordance with Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
1. Shake can well before using (5-10 seconds).
2. Turn nozzle to adjust spray to desired fan width.
3. Clean all bonding surfaces that will receive 7877 Spray Adhesive/Primer to ensure clean, dry and debris-free bonding substrates.
4. To dispense adhesive, hold can (with spray nozzle facing up) 127.0 mm - 177.8 mm (5.0" - 7.0") from bonding surface and apply at least two uniform and overlapping coats of adhesive to both bonding surfaces. Avoid over-spraying.
5. After application, allow solvents to flash off before mating. Use touch-push test to verify if solvents have flashed off; adhesive is ready to be bonded if pushing on adhesive with a clean dry finger reveals no stringing or movement of the adhesive layer. Open time usually ranges from 5 to 30 minutes.
6. After dispensing 7877 Spray Adhesive/Primer, clear valve of adhesive (to avoid clogging of spray tip) by turning can upside down and spray for at least two seconds.
7. These instructions are general in nature; refer to Firestone Specialty Products specifications and details for specifics.

PRODUCT DATA

Property	Minimum Performance
Base:	Synthetic Polymers and Resin
Color:	Light Yellow
Solids:	21.5 +/- 1.5% (nominal)
Specific Gravity:	0.68 (H_2O = 1)
VOC:	Less than 55%

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original sealed containers at temperatures between 15.6 - 26.7° C (60 - 80° F). If exposed to lower temperatures, restore to room temperature prior to use.
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to ensure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. Protect from heat sources. Closed containers exposed to heat from fire may build pressure and explode.
3. Keep the material out of direct sunlight until ready for immediate application.

COVERAGE RATE:
Approximately 4.7 - 6.5 m^2/0.5 L (50 - 70 ft^2/22.4 fl. oz.) both surfaces.

PACKAGING:
Each can contains 468 g (16.5 oz) net weight adhesive. Cans are packaged 12 per carton and 80 cartons per pallet.

PRECAUTIONARY DATA:
Review Material Safety Data Sheet (MSDS) prior to use.

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-013

Single-Ply LVOC Primer

Item Description	Item Number
3 Gallon	W563587110
1 Gallon	W563587111
1 Quart	W563587112

Product Information

Description:

Single-Ply LVOC Primer is a solvent based primer designed to clean and prime RubberGard™ EPDM membranes (FR, LS-FR, Platinum™, MAX™, and EcoWhite™) and UltraPly™ TPO membranes to receive QuickSeam™ tape products/accessories where allowed by Firestone specifications and in accordance with state regulations. Single-Ply LVOC Primer VOC content does not exceed 250 grams per liter, and can be used in air quality management districts with VOC limits of 250 grams per liter. Verify that local and state regulations allow the use of the solvents used in Single-Ply LVOC Primer in the given area independent of VOC regulations.

Method of Application:

1. Mix thoroughly before and during use. Product will appear uniform after mixing.
2. Surfaces to receive Single-Ply LVOC Primer must be clean, dry and free of foreign materials and excess dusting agent. Clean with broom or rags to remove contaminates.
3. Apply Single-Ply LVOC Primer at the coverage specified to the splicing surfaces using the QuickScrubber™ or QuickScrubber Plus pad and handle. Use back and forth strokes (four minimum) with heavy pressure along the length of the splicing area, until membrane surfaces become uniform in color, with no streaks or puddles. Additional scrubbing is required where the substrate is contaminated.
4. Bear down on the QuickScrubber Plus pad and handle system during application so the pad holder flattens to allow the total surface of the pad to contact with the substrate to receive Single-Ply QuickPrime Primer.
5. Allow the surfaces to dry completely before applying QuickSeam products. Use touch-push test to determine readiness. Dry time will vary due to ambient conditions. Complete seaming procedures per Firestone's current specifications and details.

Storage:

Keep the material out of direct sunlight until ready for immediate application.

Shelf Life:

Shelf life of 12 months can be expected if stored in original unopened container at temperatures between 60 °F to 80 °F (16 °C to 27 °C). Shelf life will be shortened if exposed to elevated temperatures.

Single-Ply LVOC Primer

Precautions:

- WARNING! Flammable! Keep away from fire (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
- Keep away from children.
- For professional use only.
- Use only in well ventilated areas.
- Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
- Do not thin.
- Mix thoroughly before and during use.
- Do not apply with rollers, brushes or rags.
- Refer to Safety Data Sheet (SDS) for additional precautionary data.

LEED® Information:

Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location: South Bend, IN

FM APPROVED

CLASSIFIED c UL US

Packaging

Property	**Value**
Pail	3 gallon (11.4 liter), 1 gallon (3.78 liter), 4-1 gallon pails per carton, 1 Quart (0.94 liter), 20-1 quart cans per carton
Coverage	200 - 250 ft²/gallon (5-6 m²/L) per side
Weight	8.0-8.8 lb per gallon (4.9-6.1 m²/L)

Typical Properties

Property	**Value**
Base	Rubber Polymers
Visual Appearance	Smooth, no lumps translucent when applied
Color	Clear to hazy yellowish color
Solvent System	Naphtha, Acetone, PCBTF (Parachlorobenzotrifluoride)
Percent Solids	11.0 - 12.5%
Viscosity	200 cPs maximum, #2 Spindle @ 20 rpm
Specific Gravity	0.961 to 1.057
V.O.C. Content	Not to exceed 250 g/l

Please contact your Firestone Building System Advisor at 1-800-428-4511 for further information.

This sheet is meant to highlight Firestone products and specifications and is subject to change without notice. Firestone takes responsibility for furnishing quality materials which meet published Firestone product specifications. Neither Firestone nor its representatives practice architecture. Firestone offers no opinion on and expressly disclaims any responsibility for the soundness of any structure. Firestone accepts no liability for structural failure or resultant damages. Consult a competent structural engineer prior to installation if the structural soundness or structural ability to properly support a planned installation is in question. No Firestone representative is authorized to vary this disclaimer.

Firestone
SPECIALTY PRODUCTS

Heavy-Duty Fastener

Firestone Item Number:

Red	White	SI	Eng
W56RAC4230:	W56RAC4390:	31.8 mm	1.25”
W56RAC4232:	W56RAC4391:	50.8 mm	2.0”
W56RAC4234:	W56RAC4392:	76.2 mm	3.0”
W56RAC4236:	W56RAC4393:	101.6 mm	4.0”
W56RAC4237:	W56RAC4394:	127.0 mm	5.0”
W56RAC4249:	W56RAC4395:	152.4 mm	6.0”
W56RAC4239:		177.8 mm	7.0”
W56RAC4240:		203.2 mm	8.0”
W56RAC4241:		254.0 mm	10.0”
W56RAC4242:		304.8 mm	12.0”
W56RAC4243:		355.6 mm	14.0”

DESCRIPTION:

Firestone Heavy-Duty Fastener is specifically designed to be used in membrane applications which require additional corrosion protection and additional pullout resistance. The Heavy-Duty Fastener may be used for attachment of Firestone Batten Strips, Termination Bars, and other accessories to steel, wood, concrete and other surfaces when used in accordance with all Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:

Using the #3 Phillips tip provided and a variable speed drill, engage the fastener into the substrate as noted below, taking care not to over or under drive the fastener. If pre-drilling of the substrate is necessary, use a hammer drill in impact mode with a 5.56 mm (0.0219”) carbide drill bit. Install fasteners by using a variable speed drill at a maximum of 1,500 RPM.

Determine required screw length as follows:

1. Steel substrate: Select fastener length to penetrate through substrate a minimum of 19.1 mm (0.75”).
2. Wood substrate: Select fastener length to penetrate into or through substrate a minimum of 25.4 mm (1.0”).
3. Concrete substrate: Select fastener length to penetrate into substrate a minimum of 25.4 mm (1.0”).

PRODUCT DATA

Property	Minimum Performance
Material:	SAE 1022, heat treated steel
Thread Size:	6.98 mm (0.275”)
Threads/inch:	13 min.
Thread design:	Buttress thread
Fastener Tip:	Drill point design
Fastener Head:	#3 Phillips drive
Corrosion Coating:	Red epoxy applied by Electrocoating

PACKAGING:

Screw Length SI	Screw Length Eng	Thread Length SI	Thread Length Eng	Pieces/ Plastic Pail	Pails/ Pallet
31.8 mm	1.25”	Full		1,000	40
50.8 mm	2.0”	Full		1,000	40
76.2 mm	3.0”	Full		1,000	60
101.6 mm	4.0”	76.2 mm	3.0”	1,000	60
127.0 mm	5.0”	101.6 mm	4.0”	1,000	40
152.4 mm	6.0”	101.6 mm	4.0”	500	60
177.8 mm	7.0”	101.6 mm	4.0”	500	60
203.2 mm	8.0”	101.6 mm	4.0”	500	60
254.0 mm	10.0”	101.6 mm	4.0”	500*	24
304.8 mm	12.0”	101.6 mm	4.0”	500*	24
355.6 mm	14.0”	101.6 mm	4.0”	500*	24

Typical color is red.
*Packaged in cardboard cartons due to fastener length and may require lead time of 30 days.

PRECAUTIONARY DATA:

1. Care should be taken at wall corners and ends - do not install fasteners too close to ends/corners to avoid spalling.
2. Fasteners are installed as required to maintain a seal to the wall with the termination bar 304.8 mm (12.0”) o.c. max. or as required).
3. Eye protection must be worn during drilling and hammering operations.

LEED INFORMATION:

Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 30%
Manufacturing Location: West Chicago, IL

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-014

Coated Drive Pin Fastener

PRODUCT DATA

Property	Minimum Performance
Body:	Zinc alloy
Drive Pin Type Expansion Device:	Carbon steel
Corrosion Protection Drive Pin:	Fluoropolymer coated
Head Shape:	Round conical taper

Firestone Item Number:

W56RAC4250: 31.8 mm (1.25")
W56RAC4252: 50.8 mm (2.00")

DESCRIPTION:
Firestone Coated Drive Pin Fastener is a compression type fastener for use with acceptable substrates such as hollow or solid concrete block, masonry, or structural concrete.

When used in accordance with all with all Firestone Specialty Products specifications and details, it can be used to:
- Attach Firestone Temination Bar subject to Firestone membrane termination details.
- Attach Firestone Metal Batten Strips or 50.8 mm (2.00") Seam plates in vertical applications.

METHOD OF APPLICATION:
Firestone Termination Bar and Batten Strips must be installed to sound and solid substrate. The substrate must be clean, dry, and free of foreign materials and contaminants. Pre-drill hole in substrate to receive fastener with 6.3 mm (0.25") diameter masonry drill bit (drill bits are not supplied).

Pre-drill substrate to a depth approximately 6.3 mm (0.25") deeper than the final embedment of the fastener into the substrate. Drill depth sensors will facilitate standardized drilling. Insert the fastener through the pre-drilled hole in the Firestone Termination Bar or Metal Batten Strip and into the pre-drilled hole in the substrate until the head of the fastener body is tight against the Bar or Batten Strip. Using a hammer, drive the nail into the body, expanding and engaging the lower portion of the fastener into the wall substrate. When field drilling Termination Bar or Metal Batten Strip, a 7.94 mm (0.313") diameter hole must be drilled for the fastener. **(If the need arises to remove the drive pin fastener, a No. 2 Phillips drive can be used to back out the pin. This allows for easy removal of the fastener shank.)**

PACKAGING:

Screw Length	Diameter	Pieces/ Carton	Carton/ Pallet
31.80 mm (1.25")	6.3 mm (0.25")	1,000	50
50.80 mm (2.0")	6.3 mm (0.25")	500	50

PRECAUTIONARY DATA:
1. Care should be taken at wall corners and ends - do not install fasteners too close to ends/corners to avoid spalling.
2. Fasteners are installed to maintain a seal to the wall with the termination bar (304.8 mm (12.0") o.c. max. or as required.
3. Eye protection must be worn during drilling and hammering operations.

LEED INFORMATION:

Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 25%
Manufacturing Location: New Rochelle, NY

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-015

Firestone SPECIALTY PRODUCTS

Concrete Drive Fastener

Firestone Item Number:

	SI	Eng
W56RAC4320:	**38.1 mm**	**1.5”**
W56RAC4321:	**50.8 mm**	**2.0”**
W56RAC4322:	**63.5 mm**	**2.5”**
W56RAC4323:	**76.2 mm**	**3.0”**
W56RAC4324:	**88.9 mm**	**3.5”**
W56RAC4325:	**101.6 mm**	**4.0”**
W56RAC4326:	**114.3 mm**	**4.5”**
W56RAC4327:	**127.0 mm**	**5.0”**
W56RAC4328:	**139.7 mm**	**5.5”**
W56RAC4349:	**152.4 mm**	**6.0”**
W56RAC4350:	**165.1 mm**	**6.5”**
W56RAC4351:	**177.8 mm**	**7.0”**
W56RAC4352:	**190.5 mm**	**7.5”**
W56RAC4353:	**203.2 mm**	**8.0”**

DESCRIPTION:
Concrete Drive Fasteners can be used in approved Firestone membrane applications for the attachment of Firestone Metal Batten Strips, Seam Plates, Termination Bars, and other accessories into structural concrete surfaces. **DO NOT USE WITH POLYMER BATTEN STRIPS**.

METHOD OF APPLICATION:
1. Use a rotary hammer or hammer drill in hammer mode to pre-drill a pilot hole with a 6.3 mm (.025”) ANSI 6.6 - 7.3 mm diameter (0.260” to 0.268”) drill bit. Pilot hole must be drilled 12.7 mm (0.5”) deeper than the required embedment.
2. Install the Concrete Drive using a 6.6 kg (3.0 lb) hammer until the fastener head is seated firmly against the plate. **Do not overdrive the fastener causing substrate damage.**

Determine required drive length as follows:
Select drive length to penetrate into structural concrete substrate a minimum of 31.75 mm (1.25”).

PRODUCT DATA

Property	Minimum Performance
Material:	AISI C-1038-1040, heat
Core Hardness:	Rc 37-43
Corrosion Coating:	Black epoxy coating
Diameter:	6.3 mm (0.25”) Nominal

PACKAGING:

Drive Length	Pieces/ Carton	Cartons/ Pallet
38.1 mm to 139.7 mm (1.5” to 5.5”) in 12.7 mm (0.5”) increments	500	40
152.4 mm to 203.2 mm (6.0” to 8.0”) in 12.7 mm (0.5”) increments	250	40

PRECAUTIONARY DATA:
1. Care should be taken at wall corners and ends - do not install fasteners too close to ends/corners to avoid spalling.
2. Fasteners are installed as required to maintain a seal to the wall with the termination bar (304.8 mm (12.0”) o.c. max. or as required).
3. Eye protection must be worn during drilling and hammering operations.
4. Do not use over structural concrete substrates which are less than 76.2 mm (3.0”) thick at the point of attachment.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	25%
Manufacturing Location:	New Rochelle, NY

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-016

TECHNICAL INFORMATION SHEET

FSP-304
11/07/2008

SPECIALTY PRODUCTS

All-Purpose Fastener

Firestone Item Number:

Red	White	SI	Eng
W56RAC4200:	W56RAC4199:	31.75 mm	1.25”
W56RAC4201:		41.28 mm	1.63”
W56RAC4202:	W56RAC4215:	57.15 mm	2.25”
W56RAC4203:	W56RAC4216:	73.03 mm	2.88”
W56RAC4204:	W56RAC4217:	82.55 mm	3.25”
W56RAC4205:	W56RAC4218:	95.25 mm	3.75”
W56RAC4206:	W56RAC4219:	114.3 mm	4.50”
W56RAC4207:	W56RAC4220:	127.0 mm	5.00”
W56RAC4208:	W56RAC4221:	152.4 mm	6.00”
W56RAC4209:	W56RAC4222:	177.8 mm	7.00”
W56RAC4210:	W56RAC4223:	203.2 mm	8.00”

*Firestone is not responsible for, nor guarantees that the white coating will remain on the fastener during or after installation

Because the coating on Firestone’s white fasteners is removed to some degree during the installation process, Firestone suggests that the owner be made aware of the expectations of the white fastener and that re-painting may be required after installation is complete.

DESCRIPTION:
Firestone All-Purpose Fasteners are used in approved Firestone membrane applications for the attachment of Firestone Batten Strips, Termination Bars, and other accessories to steel and wood substrates.

METHOD OF APPLICATION:
Using the #3 Phillips tip provided, and a variable speed drill, engage the fastener into the substrate as noted below, taking care not to over or under drive the fastener. Threads must engage the substrate material per Firestone Specialty Products specifications and details.

Determine required screw length as follows:

1. Steel substrate: Select fastener length to penetrate through substrate a minimum of 19.1 mm (0.75”).
2. Wood substrate: Select fastener length to penetrate into or through substrate a minimum of 25.4 mm (1.0”).

PRODUCT DATA

Property	Minimum Performance
Material:	SAE 1022, heat treated steel
Thread Size:	6.5 mm (0.235”)
Threads/inch:	13
Thread design:	Symmetrical
Fastener Tip:	Drill point design
Fastener Head:	#3 Phillips drive
Corrosion Coating:	Red epoxy applied by Electrocoating

PACKAGING:

Screw Length		Thread Length		Pieces/ Plastic Pail	Pails/ Pallet
SI	Eng	SI	Eng		
31.75 mm	1.25”	Full		1,000	60
41.28 mm	1.63”	Full		1,000	60
57.15 mm	2.25”	Full		1,000	60
73.03 mm	2.88”	Full		1,000	60
82.55 mm	3.25”	76.2 mm	3.00”	1,000	60
95.25 mm	3.75”	76.2 mm	3.00”	1,000	60
114.3 mm	4.50”	76.2 mm	3.00”	1,000	60
127.0 mm	5.00”	101.6 mm	4.00”	1,000	60
152.4 mm	6.00”	101.6 mm	4.00”	1,000	60
177.8 mm	7.00”	101.6 mm	4.00”	500	60
203.2 mm	8.00”	101.6 mm	4.00”	500	60

Typical color is red.

PRECAUTIONARY DATA:

1. Care should be taken at wall corners and ends - do not install fasteners too close to ends/corners to avoid spalling.
2. Fasteners are installed as required to maintain a seal to the wall with the termination bar (304.8 mm (12.0”) o.c. max. or as required).
3. Eye protection must be worn during drilling and hammering operations.

LEED INFORMATION:
Post Consumer Recycled Content: 25%
Post Industrial Recycled Content: 0%
Manufacturing Location: Bryan, OH

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-041

Firestone
SPECIALTY PRODUCTS

All-Purpose Stainless Steel Fastener

Firestone Item Number:

	SI	Eng
W56RAC4361:	**38.10 mm**	**1.5”**
W56RAC4362:	**50.80 mm**	**2.0”**
W56RAC4363:	**76.20 mm**	**3.0”**
W56RAC4364:	**101.6 mm**	**4.0”**
W56RAC4365:	**127.0 mm**	**5.0”**
W56RAC4366:	**152.4 mm**	**6.0”**
W56RAC4367:	**177.8 mm**	**7.0”**
W56RAC4368:	**203.2 mm**	**8.0”**
W56RAC4369:	**228.6 mm**	**9.0”**
W56RAC4370:	**254.0 mm**	**10.0”**
W56RAC4372:	**304.8 mm**	**12.0”**

DESCRIPTION:
Firestone #14 All-Purpose Stainless Steel Fasteners are used in approved Firestone membrane applications for the attachment of Firestone Batten Strips, Firestone Seam Plates, Firestone Termination Bars and other accessories to steel and wood substrates.

METHOD OF APPLICATION:
Using the #3 Phillips tip provided, engage the fastener into the substrate, taking care not to over or under drive the fastener. Threads must engage the substrate material per Firestone Specialty Products specifications and details.

Determine required screw length as follows:

1. Steel substrate: Select fastener length to penetrate through substrate a minimum of 19.1 mm (0.75”).
2. Wood substrate: Select fastener length to penetrate into or through substrate a minimum of 25.4 mm (1.0”).

Note: As with all stainless steel fasteners, oxidation may occur on the surface of the fastener but this is normal and not detrimental to the fastener.

PRODUCT DATA

Property	Minimum Performance
Material:	TrimRite® stainless, ASTM A493 alloy S42010, magnetic
Thread Size:	6.5 mm (0.235”) nom. diameter
Threads/inch:	13
Fastener Tip:	Two-Flute formed drill point
Fastener Head:	Phillips Truss Head with #3 Recess
Corrosion Resistance:	Meets FM 4470

PACKAGING:

Screw Length		Thread Length		Pieces/ Plastic Pail	Pails/ Pallet
SI	Eng	SI	Eng		
38.1 mm	1.5”	Full		1,000	80
50.80 mm	2.0”	Full		1,000	80
76.20 mm	3.0”	Full		1,000	80
101.6 mm	4.0”	Full		1,000	80
127.0 mm	5.0”	98.4 mm	3.875”	1,000	60
152.4 mm	6.0”	98.4 mm	3.875”	1,000	60
177.8 mm	7.0”	98.4 mm	3.875”	500	80
203.2 mm	8.0”	98.4 mm	3.875”	500	80
228.6 mm	9.0”	98.4 mm	3.875”	500	60
254.0 mm	10.0”	98.4 mm	3.875”	500	60
304.8 mm	12.0”	98.4 mm	3.875”	500	60

Stainless Steel Fasteners are special order and require a lead-time.

PRECAUTIONARY DATA:

1. Care should be taken at wall corners and ends - do not install fasteners too close to ends/corners to avoid spalling.
2. Fasteners are installed as required to maintain a seal to the wall with the termination bar (304.8 mm (12.0”) o.c. max. or as required).
3. Eye protection must be worn during drilling and hammering operations.
4. All-Purpose Stainless Steel Fasteners may not work as expected through unusual substrates. Consideration should be given to Firestone HD Fasteners in these instances.

S723-SPP-042

LEED INFORMATION:

Post Consumer Recycled Content:	20%
Post Industrial Recycled Content:	0%
Manufacturing Location:	Bryan, OH

Note: Unless otherwise specified, TrimRite is a registered trademark of CRS Holdings Inc., a subsidiary of Carpenter Technology Corporation.

Firestone SPECIALTY PRODUCTS

All-Purpose Stainless Steel Fastener

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-042

Firestone
SPECIALTY PRODUCTS

Metal Batten Strip

PRODUCT DATA

Property	Minimum Performance
Material:	Galvalume® AZ 55
Corrosion Resistance:	Meets FM No. 4470 criteria
Length:	3.05 m (10')
Width:	25.4 mm (1.0")
Thickness:	1.13 mm/1.29 mm (0.0448"/0.0508")
Holes:	7.11 mm (0.280") diameter, at 152.4 mm (6.0") o.c.

Firestone Item Number:
W56RAC3053: 25.4 mm (1.0") Wide

DESCRIPTION:
Firestone Metal Batten Strip is specifically designed to be used for anchoring approved Firestone membranes as specified in Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
Attach batten strips to the substrate or penetration using the appropriate Firestone fastener. Do not overdrive or underdrive fasteners. Start at one end of the batten strip and fasten towards the other to reduce bowing between fasteners.

STORAGE:
Store in original unopened container protected from the weather until ready for use.

PACKAGING:
3.05 meter pieces (10' pieces) are packaged 50 per cardboard tube and 39 tubes per pallet.

PRECAUTIONARY DATA:
1. Do not overdrive or underdrive fastener.
2. All cut surfaces must be rounded and filed to remove burrs and sharp edges.
3. Use only on smooth surfaces.

LEED INFORMATION:

Post Consumer Recycled Content:	8%
Post Industrial Recycled Content:	17%
Manufacturing Location:	Cleveland, OH

Note: Galvalume is a registered trademark of BIEC International, Inc

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-017

Firestone
SPECIALTY PRODUCTS

Coiled Metal Batten Strip

Firestone Item Number:
W56RAC3052: 25.4 mm (1.0”) Wide

DESCRIPTION:
Firestone Coiled Metal Batten Strip is specifically designed to be used for anchoring approved Firestone membranes as specified in Firestone Specialty Products specifications and details. Coiled Metal Batten Strip is packaged in a weather-resistant cardboard dispensing package, which contains 67.06 m (220.0’) of batten strip. Using Coiled Metal Batten Strips in lieu of conventional pre-cut strips reduces labor and storage space. Coiled Metal Batten Strip has 76.2 mm (3.0”) o.c. pre-punched holes for greater flexibility in attaching to various substrates.

METHOD OF APPLICATION:
Attach batten strips to the substrate or penetration using the appropriate Firestone fastener. Do not overdrive or underdrive fasteners. Start at one end of the batten strip and fasten towards the other to reduce bowing between fasteners.

STORAGE:
Store in original unopened container protected from the weather until ready for use.

PACKAGING:
Firestone Coiled Metal Batten Strip is packaged 67.06 m (220.0’) per coil and 52 coils per pallet.

PRECAUTIONARY DATA:
1. Do not overdrive or underdrive fastener.
2. All cut surfaces must be rounded and filed to remove burrs and sharp edges.
3. Use only on smooth surfaces.

LEED INFORMATION:

Post Consumer Recycled Content:	8%
Post Industrial Recycled Content:	17%
Manufacturing Location:	Cleveland, OH

PRODUCT DATA

Property	Minimum Performance
Material:	Galvalume® AZ 55
Corrosion Resistance:	Meets FM No. 4470 criteria
Length:	67.06 m (220.0’) per coil
Width:	25.4 mm (1.0”)
Thickness:	1.13 mm/1.29 mm (0.0448"/0.0508")
Holes:	8.74 mm (0.344") diameter 76.2 mm (3.0”) o.c. (Accommodates Firestone All-Purpose, Heavy-Duty, Heavy-Duty Plus and Concrete Drive Fasteners)
Weight:	14.5 kg (32 lb) per coil

Note: Galvalume® is a registered trademark of BIEC International, Inc.

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-018

TECHNICAL INFORMATION SHEET

FSP-403
11/07/2008

Firestone
SPECIALTY PRODUCTS

Polymer Batten Strip

Firestone Item Number:
W56RAC3071: 19.05 mm (0.75”) Wide

PRODUCT DATA

Property	Minimum Performance
Material:	Proprietary Oriented Polymer (Plastic)
Corrosion Resistance:	Corrosion-free polymer material
Length:	76.2 m (250.0’) coil
Width:	19.05 mm (0.75”)
Thickness:	Approximately 1.3 mm (0.05")
Holes:	4.8 mm (0.19") diameter, 76.2 mm (3.0") o.c.

DESCRIPTION:
Firestone Polymer Batten Strip is specifically designed to be used for anchoring approved Firestone membranes as specified in Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
Attach batten strips to the substrate or penetration using the appropriate Firestone fastener. Do not overdrive or underdrive fasteners. Start at one end of the batten strip and fasten towards the other to reduce bowing between fasteners.

Substrate must be free from dust, dirt, oil, water or other contaminants. Install polymer batten strip in a straight line by anchoring one end and stretching out 7.6 -15.2 m (25.0’ - 50.0’) and anchoring again. Set the fastener head flush with the strip. Overdriving results in kinks in the Polymer Batten Strip. The Polymer Batten Strip should show only a slight depression around the fastener head. If the strip kinks, loosen the screw slightly.

Screw placement may be varied if joists or other obstructions are encountered or the fastener does not engage the substrate. Back fastener out carefully so as not to damage the polymer batten strip. Place the next fastener from the fastener hole that hit the obstruction or did not engage the deck into the next pre-punched hole that allows for fastener engagement. If the fastener still does not engage, then cut the batten strip and overlap it so that the pre-punched holes allow for fastener engagement.

Always install fasteners in pre-punched holes. Use longest lengths practical. For 19.05 mm (0.75”) batten, overlap 3 holes a minimum of 25.4 mm (1.0”) and drive fasteners through 2 holes, 152.4 mm (6.0”) apart (see overlap detail on carton).

METHOD OF APPLICATION (Continued):
Apply Firestone All-Purpose Sealant on fastener heads when required by Firestone Specialty Products specifications and details.

STORAGE:
Store in original unopened container protected from the weather until ready for use.

PACKAGING:
Firestone Polymer Batten Strip is packaged 76.2 m (250.0’) per coil and 140 coils per pallet.

PRECAUTIONARY DATA:
1. When modifying the plastic batten strip, all cut surfaces must be rounded.
2. Batten strip is dispensed from the original carton - DO NOT OPEN THE CARTON.
3. Do not use polymer batten with Firestone Drive Pin Fasteners, Polymer Fasteners or Concrete Drives.
4. Do not use on brick, block or concrete walls.
5. Use only on smooth surfaces.
6. Always install fasteners in pre-punched holes.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	West Chicago, IL

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

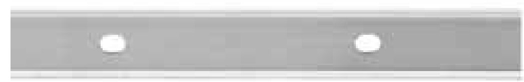
S723-SPP-019

TECHNICAL INFORMATION SHEET

FSP-404
02/01/11

Firestone
SPECIALTY PRODUCTS

Termination Bar



PRODUCT DATA

Property	Minimum Performance
Material:	3003-H14, 3105-H14 or 6063-T5, or T6 Aluminum
Length:	3.05 m (10.0') Long
Height:	27.4 mm (1.08")
Thickness:	2.7 mm (0.106")
Holes:	Slotted, 7.1 x 9.9 mm (0.28 x 0.39") 30 at 99.8 mm (3.93") o.c.

Firestone Item Number:
W56RAC3061: 3.05 m (10.0') Long

DESCRIPTION:
Firestone Termination Bar is intended for attaching and sealing approved Firestone membrane terminations as indicated in the current Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
Install Firestone Water Block Seal behind top of flashing. Anchor bar through pre-punched holes at a rate to maintain a seal (max. 304.8 mm (12.0") o.c.). Remove excess membrane above bottom of lap sealant reservoir channel. Install Firestone Lap Sealant into reservoir channel to seal the upper edge of the membrane where appropriate. Consult Firestone Specialty Products specifications and details for specifics.

STORAGE:
Store in original unopened container protected from the weather until ready for use.

PACKAGING:
3.05 m (10.0') pieces are packaged 50 per cardboard tube and 52 tubes per pallet.

PRECAUTIONARY DATA:
1. Do not use as a batten strip.
2. Where field cutting is necessary, remove any burrs from bar.
3. Clean up shavings, etc. that may occur from field cutting.
4. Install flat side of bar towards flashing so a "lip" forms a reservoir for Lap Sealant.
5. Keep each 3.05 m (10.0') length of Termination Bar separated from adjoining bar by 6.3 mm (0.25").
6. Termination bars must be installed directly to the wall surface, not to existing sheet metal, flashings, etc.
7. Install termination bar on hard, smooth surfaces only.
8. Do not install on substrates where seal is lost at mortar joints, etc.
9. Install termination bar vertically where base flashing(s) end.
10. Do not install termination bar to wood or other porous surfaces.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	67%
Manufacturing Locations:	Bryan, OH Cleveland, OH

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-020

Firestone
SPECIALTY PRODUCTS

QuickSeam™ Cover Strip

Firestone Item Number:
W56RAC1693: 152.4 mm x 7.63 m (6.0” x 25.0’) rolls
W56RAC1616: 152.4 mm x 30.5 m (6.0” x 100.0’) rolls
W56RAC1619: 228.6 mm x 30.5 m (9.0” x 100.0’) rolls
W56RAC1612: 304.8 mm x 15.2 m (12.0” x 50.0’) rolls

DESCRIPTION:
Firestone QuickSeam Cover Strip is a wide semi-cured EPDM and QuickSeam Tape laminate designed to cover and seal approved Firestone membrane seams.

METHOD OF APPLICATION:
Use QuickPrime™ Plus and QuickScrubber™ or QuickScrubber Plus™ pad and handle to clean and prime the membrane and metal components within the seaming area. Install QuickSeam Cover Strip in accordance with Firestone Specialty Products specifications and details.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for application.

Note: QuickSeam Cover Strip is protected under one or more of the following U.S. Patent Numbers 4,426,468 / 4,539,344 / 4,588,637 / 4,855,172 and Canadian Patent Numbers 1,168,396 /1,190,691.

PRODUCT DATA

Property	Minimum Performance
QuickSeam Tape:	
Base:	Rubber Polymer
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Cured
Thickness:	0.89 mm +/- 0.127 mm (0.035” +/- 0.005”)
Width:	15.56 cm, + 0.95 cm, -0 cm (6.125”, + 0.375”, -0”)
EPDM:	
Base:	EPDM
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Semi-Cured
Thickness:	1.016 mm, -0.178 mm, + 0.432 mm (0.040”, -0.01”, +0.02”)
Width:	15.24 cm, + 0 cm, -0.32 cm (6.0”, + 0”, -0.125”)

PACKAGING:

SI		Eng		Rolls/ Carton	Cartons/ Pallet
Width	Length	Width	Length		
152.4 mm	7.63 m	6.0”	25.0’	8	36
152.4 mm	30.5 m	6.0”	100.0’	2	36
228.6 mm	30.5 m	9.0”	100.0’	1	36
304.8 mm	15.2 m	12.0”	50.0’	1	36

QuickScrubber and/or QuickScrubber Plus pads and handles are included in each carton. Quantities vary depending on the QuickSeam product.

PRECAUTIONARY DATA:
Review Material Safety Data Sheet (MSDS) prior to use.

LEED INFORMATION:
Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Locations: Michigan Center, MI
Prescott, AR

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-021

Firestone
SPECIALTY PRODUCTS

QuickSeam™ Splice Tape

Firestone Item Number:

W56RAC1603: 76.3 mm x 30.48 m (3.0” x 100.0’) rolls
W56RAC1617: 177.8 mm x 30.48 m (7.0” x 100.0’) rolls
W56RAC1698: 76.3 mm x 7.63 m (3.0” x 25.0’) rolls
W56RAC1626: 152.4 mm x 30.48 m (6.0” x 100.0’) rolls

DESCRIPTION:
Firestone QuickSeam Splice Tape is designed for field splicing of approved Firestone membrane panels.

METHOD OF APPLICATION:
Use QuickPrime™ Plus and a QuickScrubber™ or QuickScrubber Plus™ pad and handle to clean and prime mating surfaces. Install QuickSeam Splice Tape in accordance with Firestone Specialty Products specifications and details.

SHELF LIFE:
1. Shelf life of one (1) years can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for application.

PRODUCT DATA

Property	Minimum Performance
Base:	Rubber Polymers
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Cured
Thickness:	0.77 mm +/- 0.127 mm (0.030” +/- 0.005”)
Width:	76.3 mm (3.0”) 152.4 mm (6.0”) 177.8 mm (7.0”)

Physical Characteristics:
1. Excellent moisture resistance.
2. Excellent resistance to heat and cold
3. Excellent green tack.

PACKAGING:

SI		Eng		Rolls/ Carton	Cartons/ Pallet
Width	Length	Width	Length		
76.3 mm	30.48 m	3.0”	100.0’	6	40
177.8 mm	30.48 m	7.0”	100.0’	2	56
76.3 mm	7.63 m	3.0”	25.0’	16	80
152.4 mm	30.48 m	6.0”	100.0’	2	56

QuickScrubber and/or QuickScrubber Plus pads and handles are included in each carton. Quantities vary depending on the QuickSeam product.

PRECAUTIONARY DATA:
Review Material Safety Data Sheet (MSDS) prior to use.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	Prescott, AR

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

Firestone SPECIALTY PRODUCTS

QuickSeam™ FormFlash™

Firestone Item Number:
W56RAC1650: 228.6 mm x 15.2 m (9.0" x 50.0') rolls
W56RAC1652: & W56RAC1653: 304.8 mm x 15.2 m (12.0" x 50.0') rolls

DESCRIPTION:
Firestone QuickSeam FormFlash is an uncured EPDM flashing laminated to cured seam tape. QuickSeam FormFlash is used to flash inside and outside corners, pipes, penetration pockets and other applications as required by Firestone Specialty Products specifications and details.

METHOD OF APPLICATION:
1. Use QuickPrime™ Plus and a QuickScrubber™ or QuickScrubber Plus™ pad and handle to clean and prime mating surfaces.
2. When cloudy conditions below 15.6° C (60° F) occur, use heat guns (without ignition sources) to heat QuickSeam FormFlash. This will ensure good formability of the QuickSeam FormFlash to the primed substrate.
3. On sunny days less than 21.1° C (70° F), lay out QuickSeam FormFlash (prior to application) with flashing side up to allow QuickSeam FormFlash to warm to ensure good formability.
4. On sunny days greater than 21.1° C (70° F), lay out QuickSeam FormFlash (prior to application) with release paper side up to prevent QuickSeam FormFlash from gaining too much heat and to ensure good formability.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.

PRODUCT DATA

Property	Minimum Performance
QuickSeam Tape	
Base:	Rubber Polymer
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Cured
Thickness:	0.635 mm +/- 0.18 mm (0.025" +/- 0.007")
EPDM Flashing	
Base:	EPDM
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Uncured
Thickness:	1.6 mm +/- 0.13 mm (0.065" +/- 0.005")

Physical Characteristics:
1. Excellent moisture resistance.
2. Excellent resistance to heat and cold
3. Excellent green tack.

STORAGE (Con't):
2. When exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for application.

PACKAGING:

SI		Eng		Rolls/	Cartons/
Width	Length	Width	Length	Carton	Pallet
228.6 mm	15.2 m	9.0"	50.0'	2	40
304.8 mm	15.2 m	12.0"	50.0'	1	48

QuickScrubber and/or QuickScrubber Plus pads and handles are included in each carton. Quantities vary depending on the QuickSeam product.

PRECAUTIONARY DATA:
Review Material Safety Data Sheet (MSDS) prior to use.

S723-SPP-023

LEED INFORMATION:
Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location: Prescott, AR
Michigan Center, MI

Note: FormFlash is protected under U.S. Patent Number 5,804,661.

Firestone SPECIALTY PRODUCTS

QuickSeam FormFlash

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-023

QuickSeam™ Joint Cover

Firestone Item Number:
W56RAC1644 146.05 mm (5.75")

PRODUCT DATA

Property	Minimum Performance
QuickSeam Tape:	
Base:	Rubber Polymer
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Spliced Tape- Cured Center Layer- Uncured & flowable- 76.2 mm (3.0")
Thickness:	Spliced Tape- 0.77 mm +/- 0.13 mm (0.030" +/- 0.005") Center Layer- 0.94 mm +/- 0.13 mm (0.037" +/- 0.005")
FormFlash:	
Base:	Uncured FormFlash, conforming to RMA minimum specifications
Color:	Black
Size:	146 mm +/- 3.17 mm (5.75" +/- 0.125") diameter
Thickness:	0.76 mm +/- 0.13 mm (0.030" +/- 0.005")

Physical Characteristics:
1. FormFlash will cure when exposed to heat and over time.
2. Uncured 76.2 mm (3.0") tape center will cure when exposed to heat and over time.

DESCRIPTION:
Firestone QuickSeam Joint Cover is uncured FormFlash™ laminated to QuickSeam Tape. A second 76.20 mm (3.0") layer of tape is applied at the center. It is a special uncured, flowable QuickSeam Tape compound. The QuickSeam Joint Cover conforms to irregular surfaces readily providing an excellent seal with good adhesion. It is designed to cover and seal T- joints.

METHOD OF APPLICATION:

Membrane Preparation:
Mating surface to receive the QuickSeam Joint Cover must be free of dust, dirt, oil, water and other contaminants. Clean with broom or rags if necessary. Clean the PondGard membrane using QuickPrime™ Plus and the QuickScrubber™ or QuickScrubber Plus™ pad and handle to remove all dusting agent, dirt and other contaminants that will affect the finished seam. Allow to dry according to the touch-push test.

QuickSeam Joint Cover Installation:
1. Remove the release paper from the joint cover. Do not touch the outside edges of the joint cover.
2. Fold the joint cover in half. Position the center of the joint cover over the target point and mate the joint cover to the prepared surface.
3. Roll the mated surface of the joint cover with a 50.80 mm (2.0") silicone roller from the center outward working the joint cover into the step-off or irregularities.
4. Install seam edge treatment per Firestone Specialty Products specifications and details.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.

SHELF LIFE (Con't):
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for application.

PACKAGING:
100 QuickSeam T-Joint Covers are packaged per carton and 60 cartons per pallet.

PRECAUTIONARY DATA:
Review Material Safety Data Sheet (MSDS) prior to use.

S723-SPP-024

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	Prescott, AR

Note: QuickSeam Joint Cover is protected by U.S. Patent Number 5,204,148.

Firestone SPECIALTY PRODUCTS

QuickSeam™ Joint Cover

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-024

Firestone
SPECIALTY PRODUCTS

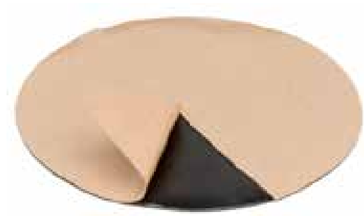
QuickSeam™ Corner Flashing

Firestone Item Number:
W56RAC1646: 215.9 mm (8.5")

DESCRIPTION:
Firestone QuickSeam Corner Flashing consists of FormFlash™ factory laminated to QuickSeam Tape. It is 215.9 mm (8.5") in diameter and is designed to flash inside and outside corners.

METHOD OF APPLICATION:
1. Use QuickPrime™ Plus and a QuickScrubber™ or QuickScrubber Plus™ pad and handle to clean and prime mating surfaces. Refer to Firestone Installation Instruction Sheet for QuickSeam Corner Flashing (included in each carton) and Firestone Specialty Products specifications and details.
2. When cloudy conditions below 15.6° C (60° F) occur, use heat guns (without ignition sources) to heat QuickSeam Corner Flashing. This will ensure good formability of the QuickSeam Corner Flashing to the primed substrate.
3. On sunny days less than 21.1° C (70° F), place QuickSeam Corner Flashing on the ground (prior to application) with flashing side up to allow QuickSeam Corner Flashing to warm to ensure good formability.
4. On sunny days greater than 21.1° C (70° F), place QuickSeam Corner Flashing on the ground (prior to application) with release paper side up to prevent QuickSeam Corner Flashing from gaining too much heat and to ensure good formability.

SHELF LIFE:
1. Shelf life of six (6) months can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of six (6) months.



PRODUCT DATA

<u>Property</u>	<u>Minimum Performance</u>
<u>QuickSeam Tape</u>	
Base:	Rubber Polymer
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Cured
Thickness:	0.64 mm +/-0.13 mm (0.025" +/-.005")
<u>FormFlash</u>	
Base:	EPDM
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Uncured
Thickness:	1.59 mm +/- 0.13 mm (0.065" +/-.005")

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for application.

PACKAGING:
20 Corner Flashings are packaged per carton and 100 cartons per pallet.

PRECAUTIONARY DATA:
Review Material Safety Data Sheet (MSDS) prior to use.

LEED INFORMATION

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Locations:	Michigan Center, MI Prescott, AR

Note: FormFlash is protected under U.S. Patent Number 5,804,661.

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-025

Firestone
SPECIALTY PRODUCTS

QuickSeam™ Pipe Flashing

Firestone Item Number:
W563581063: Universal

DESCRIPTION:
Firestone QuickSeam Pipe Flashings are specifically designed to be used in approved Firestone membrane applications for flashing of round penetrations. Each box of pipe flashings contains universal stainless steel worm gear clamps.

METHOD OF APPLICATION:
Penetration must be clean of prior flashing and foreign materials. Cut along the top edge of the ring on the QuickSeam Pipe Flashing corresponding to one size smaller than the pipe you are flashing.

Clean the membrane to receive the QuickSeam Pipe Flashing using QuickPrime Plus™ and a QuickScrubber™ or QuickScrubber Plus™ pad and handle to remove all dusting agent, dirt and other contaminants that will affect the finished bond. Allow to dry according to the touch-push test. Remove the release paper. Install the pipe flashing and roll the flange with a silicone hand roller. Install clamping ring and lap sealant per Firestone Specialty Products specifications and details.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.

PRODUCT DATA

Property	**Minimum Performance**
QuickSeam Tape	
Base:	Rubber Polymer
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Cured
Thickness:	0.762 mm +/- 0.13 mm (0.030" +/- 0.005")
Molded Pipe Flashing	
Base:	Molded EPDM
Color:	Black
Sizes:	Fits 25.4 mm - 174.6 mm (1.0" - 6.875") O.D.
Clamp:	Stainless Steel - clamps are included
Pipe Flange:	330.2 mm (13.0") O.D.
Thickness:	1.4 mm - 1.9 mm (0.055" - 0.075")

Fits the Pipe Outside Diameters listed below:

SI	Eng
25.4 mm - 34.9 mm	1.0" - 1.375"
41.3 mm - 47.6 mm	1.625" - 1.875"
50.8 mm - 66.7 mm	2.0" - 2.625"
69.8 mm - 92.1 mm	2.75" - 3.625"
102.0 mm - 114.0 mm	4.0" - 4.50"
127.0 mm - 141.0 mm	5.0" - 5.50"
152.4 mm - 174.6 mm	6.0" - 6.875"

STORAGE (Con't):
3. Keep the material out of direct sunlight until ready for application.

PACKAGING:
10 Pipe Flashings and Universal SS clamps are packaged per carton and 54 cartons per pallet.

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Do not install over uneven substrates.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Location:	Bensenville, IL

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-026

QuickSeam™ Tape Seaming Kit

Item Description
QuickSeam Tape Kit

Item Number
W56RAC169L

Product Information

Description:

This consumer grade seaming kit contains all the items necessary to complete 7.01 m (25.0') of seams for approved Firestone membranes. Included with the kit are step by step instructions on how to complete the seaming process.

Storage:

- Store in original unopened containers at temperatures between 15.6 - 26.7 °C (60 – 80 °F) until ready for use.
- When exposed to lower temperatures, restore to room temperature prior to use.
- Keep the material out of direct sunlight until ready for application.

Shelf Life:

- Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7 °C (60 – 80 °F).
- Shelf life will be shortened if exposed to elevated temperatures.
- Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

Packaging:

The carton contains all items listed in the Product Data section.

Precautions:

- Review Safety Data Sheet (SDS) prior to use.
- Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
- Red caution labels are required when shipping.
- Use only in well ventilated areas.
- Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
- Use only in conjunction with QuickScrubber pad and handle. Do not apply with rollers, brushes or rags.
- Mix thoroughly before and during use.
- Thinning is not allowed.
- Keep out of reach of children.
- Dispose as a hazardous waste in accordance with local, state and federal regulations.
- Recommended cleaner is rubbing alcohol followed by soap and water.
- Do not contaminate with foreign materials.

QuickSeam™ Tape Seaming Kit

LEED® Information:

Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location: Prescott, AR

Product Data

Property	**Minimum Performance**
QuickSeam Seaming Tape:	7.01 m of 76.2 mm (25.0' of 3.0") QuickSeam Seaming Tape (See QuickSeam Seaming Tape for more info)
Single-Ply LVOC Primer™	1 can (0.47 l, 1 pint) (See Single-Ply LVOC Primer for more info)
QuickScrubber™ Handle:	1 each
QuickScrubber Pad:	1 each
Seam Roller:	1 each
Special Crayon:	1 each
Instructions:	1 each

Please contact the Specialty Products Department at 1-888-264-1735 for further information.

This sheet is meant to highlight Firestone products and specifications and is subject to change without notice. Firestone takes responsibility for furnishing quality materials which meet published Firestone product specifications. Neither Firestone nor its representatives practice architecture. Firestone offers no opinion on and expressly disclaims any responsibility for the soundness of any structure. Firestone accepts no liability for structural failure or resultant damages. Consult a competent structural engineer prior to installation if the structural soundness or structural ability to properly support a planned installation is in question. No Firestone representative is authorized to vary this disclaimer.

QuickSeam™ II Professional Kit

Item Description	**Item Number**
Seaming Kit	W56RAC180L

Product Information

Description:

This professional grade seaming kit contains all the items necessary to complete 7.01 m (25.0') of seams for approved Firestone membranes. Included with the kit are step by step instructions on how to complete the seaming process.

Storage:

- Store in original unopened containers at temperatures between 15.6 - 26.7 °C (60 – 80 °F) until ready for use.
- When exposed to lower temperatures, restore to room temperature prior to use.
- Keep the material out of direct sunlight until ready for application.

Shelf Life:

- Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7 °C (60 – 80 °F).
- Shelf life will be shortened if exposed to elevated temperatures.
- Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

Packaging:

The carton contains all items listed in the Product Data section.

Precautions:

- Review Safety Data Sheet (SDS) prior to use.
- Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
- Red caution labels are required when shipping.
- Use only in well ventilated areas.
- Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
- Use only in conjunction with QuickScrubber™ pad and handle. Do not apply with rollers, brushes or rags.
- Mix thoroughly before and during use.
- Thinning is not allowed.
- Keep out of reach of children.
- Dispose as a hazardous waste in accordance with local, state and federal regulations.
- Recommended cleaner is rubbing alcohol followed by soap and water.
- Do not contaminate with foreign materials.

QuickSeam™ II Professional Kit

LEED® Information:

Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location: Prescott, AR

Product Data

Property	Minimum Performance
QuickSeam Cover Strip:	7.01 m of 152.4 mm (25.0' of 6.0") QuickSeam Cover Strip (See QuickSeam Cover Strip for more info)
Single-Ply LVOC Primer™	1 can (0.47 l, 1 pint) (See Single-Ply LVOC Primer for more info)
QuickScrubber Handle:	1 each
QuickScrubber Pad:	1 each
Seam Roller:	1 each
Special Crayon:	1 each
Instructions:	1 each

Please contact the Specialty Products Department at 1-888-264-1735 for further information.

QuickScrubber™ Kit

Firestone Item Number:
W563582045: QuickScrubber Kit

DESCRIPTION:
QuickScrubber Kit consists of a scrub pad and holder that allows application of QuickPrime™. The QuickScrubber pad is secured to the bottom of the holder.

The bottom-bearing surface of the QuickScrubber holder is flat. When proper pressure is applied, the handle flattens out assuring that proper pressure is maintained.

METHOD OF APPLICATION:
Install a QuickScrubber pad on the bottom of the handle by pressing the pad onto the industrial grade Velcro® surface with firm hand pressure. Use back and forth strokes with heavy pressure along the length of the splicing area, until membrane surfaces become dark gray in color with no streaking or puddling.

Bear down on the QuickScrubber pad during application to ensure the total surface is in contact with the priming surface. Each pad will prime about 30.5 m - 61.0 m (100.0' - 200.0') by 152.4 mm - 177.8 mm (6.0" - 7.0") wide area. Change pads routinely. Do not attempt to turn pads over and re-use: discard after 30.5 m - 61.0 m (100.0' - 200.0') of priming.

Note: Additional application instructions on the use of QuickPrime Plus and QuickScrubber can be found on the QuickPrime Plus Technical Information Sheet and in Firestone's PondGard Technical Specifications Manual.

PRODUCT DATA

Property	Minimum Performance
QuickScrubber Kit Handle	
Handle Base:	High quality plastic
Color:	Tan
Pad Holding Mechanism:	Industrial grade Velcro® surface
QuickScrubber Kit Pad:	
Base:	Nylon fibers with abrasive grain bound with solvent resistant resins
Dimensions:	76.2 mm x 152.4 mm x 6.4 mm (3.0" x 6.0" x 0.25")
Color:	Gray
Grit:	240
Weight:	993 gm (35 oz)

PACKAGING:
QuickScrubber kits contain 4 handles and 30 pads per carton. There are 144 cartons pallet.

PRECAUTIONARY DATA:
Keep pads clean and dry prior to use.

Note: QuickScrubber Plus is protected under U.S. Patent Number 5,976,292.

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-031

Firestone SPECIALTY PRODUCTS

QuickScrubber Plus™ Primer Application System

PRODUCT DATA

Property	Minimum Performance
QuickScrubber Plus Handle	
Handle Base:	High quality plastic, with slight camber (upward bow)
Color:	Red
Pad Holding Mechanism:	Industrial grade Velcro® strips
Handle acceptor:	Standard broom thread with swivel
QuickScrubber Plus Pad	
Base:	Nylon fibers with abrasive grain bound with solvent resistant resins
Dimensions:	88.9 mm x 177.8 mm x 1.27 mm (3.5” x 7.0” x 0.5”)
Color:	Gray
Grit:	240
Weight:	993 gm (35 oz)

Firestone Item Number:
W563582049: QuickScrubber Plus Holder and Pads

DESCRIPTION:
QuickScrubber Plus Primer Application System consists of a scrub pad and holder that allows application of QuickPrime™ Plus from a standing position. The QuickScrubber Plus scrub pad is secured in place to the bottom of the holder and has a fitting to accept an extension handle (handle not included). The pads for the QuickScrubber Plus system are included with each kit.

The bottom-bearing surface of the QuickScrubber Plus holder is slightly concave. When proper pressure is applied, the handle flattens out assuring that proper pressure is maintained.

METHOD OF APPLICATION:
Install a QuickScrubber Plus pad on the bottom of the handle by pressing the pad onto the Velcro® strips with firm hand pressure. Use back and forth strokes with heavy pressure along the length of the splicing area, until membrane surface becomes dark gray in color with no streaking or puddling.

Bear down on the QuickScrubber Plus pad and handle system during application so the pad holder flattens to allow the total surface to contact with the priming surface. Each pad will prime about 30.5 m - 61.0 m (100.0’ - 200.0’) by 152.4 mm - 177.8 mm (6.0" - 7.0”) wide area. Change pads routinely. Do not attempt to turn pads over and re-use: discard after 30.5 m - 61.0 m (100.0’ - 200.0’) of priming.

Note: Additional application instructions on the use of QuickPrime Plus and QuickScrubber Plus can be found on the QuickPrime Plus Technical Information Sheet and in Firestone’s Specification Manual.

PACKAGING:
QuickScrubber Plus handles and pads are packaged with various QuickSeam™ products as follows:

Product	QuickPrime Plus Scrub Handle/Pad			
	QS + holder	QS + pads	Std. QS holder	Std. QS pads
76.2 mm (3.0”) QuickSeam Tape	1	3	1	3
152.4 mm (6.0”) & 177.8 mm (7.0”) QuickSeam Tape	1	1	1	1
152.4 mm (6.0”) QuickSeam Batten Cover	1	2	n/a	n/a
127 mm (5.0”) QuickSeam Flashing	1	2	n/a	n/a

QuickScrubber Plus kits are also available and contain 4 handles and 20 pads per carton; 144 cartons per pallet.

PRECAUTIONARY DATA:
Keep pads clean and dry prior to use.

Note: QuickScrubber Plus is protected under U.S. Patent Number 5,976,292.

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-027

TECHNICAL INFORMATION SHEET

Firestone
SPECIALTY PRODUCTS

QuickSeam™ Repair Kit

Firestone Item Number:
W56RAC0030: QuickSeam Repair Kit

DESCRIPTION:
This repair kit contains all the items necessary to repair up to two small holes should they occur in an approved Firestone membrane. In the kit are step by step instructions on how to complete the repair.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for application.

PACKAGING:
The kit contains all items listed in the Product Data section.
.

PRODUCT DATA

Property	Minimum Performance
QuickSeam Cover Strip:	2 - 152.4 x 152.4 mm (6.0" x 6.0") QuickSeam Patches (See QuickSeam Cover Strip for more info)
QuickPrime™ LVOC:	1 bottle 59.15 ml (2.0 oz) of primer (See Quick Prime LVOC for more info)
QuickScrubber™ Pad:	1 Each
Patch Roller:	1 Each
Disposable Gloves:	1 Pair
Instructions:	1 Each

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Flammable. Keep away from fires (open flame) and other possible ignition sources during storage and use. Do not smoke when using.
3. Red caution labels are required when shipping.
4. Use only in well ventilated areas.
5. Avoid contact with skin. Use of neoprene or nitrile gloves and eye protection with side shield is recommended.
6. Use only in conjunction with QuickScrubber pad and handle. Do not apply with rollers, brushes or rags.
7. Mix thoroughly before and during use.
8. Thinning is not allowed.
9. Keep out of reach of children.
10. Dispose as a hazardous waste in accordance with local, state and federal regulations.
11. Recommended cleaner is rubbing alcohol followed by soap and water.
12. Do not contaminate with foreign materials.
13. Cover can when not in use. When applying adhesive, work out of small pails with a cover to avoid skimming over of adhesive in larger can.

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-032

Firestone
SPECIALTY PRODUCTS

QuickSeam™ Walkway Pad

Firestone Item Number:
W56RAC1860: 76.2 cm x 76.2 cm (30.0” x 30.0”)

DESCRIPTION:
QuickSeam Walkway Pads are made from high quality rubber with QuickSeam Tape factory laminated to the bottom to secure the walkway pads to the properly primed, approved Firestone membrane.

METHOD OF APPLICATION:
Use QuickPrime™ Plus and a QuickScrubber™ or QuickScrubber Plus™ pad and handle to clean and prime the membrane. Allow QuickPrime Plus to dry according to the touch-push test. Remove the release paper on the tape and place the taped walkway pad into place on the membrane.

Position the QuickSeam Walkway pads so that the flat surface is over the membrane. Space the pads a minimum of 25.4 mm (1.0”) and a maximum of 152.4 mm (6.0”) from each other to allow for drainage. Walk on the pad to assure proper overall adhesion.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.
3. Keep the material out of direct sunlight until ready for application.

PRODUCT DATA

Walkway Pad

Property	ASTM Test Method	Minimum Performance
Base:		Rubber Polymers
Elongation, %, min.:	ASTM D-412	
Parallel to grain flow-	(Die C)	75
Perpendicular to grain flow-	(Die C)	75
Brittleness Temperature:	ASTM D-2137	-40 °C (-40 °F)
Hardness Shore A:	ASTM D-2240	60 +/- 5

QuickSeam Tape

Property	Minimum Performance
Base:	Rubber Polymer
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Cured
Thickness:	0.77 mm +/- 0.13 mm (0.030" +/- 0.005")

Physical Characteristics
1. Pad size is 76.2 cm x 76.2 cm x .762 cm (30.0” x 30.0” x 0.300”) thick.
2. QuickSeam Tape is factory laminated to walkway pads: 3 rows of 76.2 mm (3.0”) wide tape, or two rows of 177.8 mm (7.0”) wide tape.

PACKAGING:
50 QuickSeam Walkway Pads/pallet, 201.9 kg (445 lb) per pallet.

PRECAUTIONARY DATA:
1. When installing walkway pads, do not install in any areas designed to be under water.
2. Do not expose to open flame or ignition source.

LEED INFORMATION:

Post Consumer Recycled Content:	0%
Post Industrial Recycled Content:	0%
Manufacturing Locations:	Guelph, ON, Canada Wapakoneta, OH

Note: QuickSeam Walkway Pads are protected under U.S. Patent Number 6,080,458.

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-044

Firestone
SPECIALTY PRODUCTS

QuickSeam™ Conduit Flashing

Firestone Item Number:
W563581070: Universal

DESCRIPTION:
Firestone QuickSeam Conduit Flashing is specifically designed to be used for flashing of rigid round penetrations and conduit.

METHOD OF APPLICATION:
Penetration must be clean of prior flashing and foreign materials. Cut along the top edge of the ring on the QuickSeam Conduit Flashing corresponding to the size of the pipe or conduit you are flashing.

Clean the approved Firestone membrane using QuickPrime™ Plus and a QuickScrubber™ or QuickScrubber Plus™ pad and handle to remove all dusting agent, dirt and other contaminants that will affect the finished bond. Allow to dry according to the touch-push test. Remove the release paper. Install the pipe flashing and roll the flange with a silicone hand roller. Install the clamping ring and Lap Sealant per Firestone Specialty Products specifications and details.

SHELF LIFE:
1. Shelf life of one (1) year can be expected if stored in original unopened container at temperatures between 15.6 - 26.7° C (60 - 80° F).
2. Shelf life will be shortened if exposed to elevated temperatures.
3. Rotate stock to insure stored material will not go beyond the shelf life of one (1) year.

STORAGE:
1. Store in original unopened containers at temperatures between 15.6 - 26.7° C (60 - 80° F) until ready for use.
2. When exposed to lower temperatures, restore to room temperature prior to use.

PRODUCT DATA

Property	**Minimum Performance**
QuickSeam Tape	
Base:	Rubber Polymer
Color:	Black
Solvents:	None
Solids:	100%
Cured State:	Cured
Thickness:	0.762 mm +/- 0.13 mm (0.030" +/- 0.005")
Molded Pipe Flashing	
Base:	Molded EPDM
Color:	Black
Sizes:	Universal: Fits 12.7 mm - 64 mm (0.5" to 2.5") O.D.
Clamp:	Stainless Steel - clamps are included
Pipe Flange:	229 mm (9.0") O.D.
Thickness:	1.4 mm - 1.9 mm (0.055" - 0.075")

Fits the Pipe or Conduit Outside Diameters listed below:

SI	Eng	SI	Eng
12.70 mm	0.50"	45.00 mm	1.75"
19.00 mm	0.75"	51.00 mm	2.00"
25.40 mm	1.00"	57.15 mm	2.25"
32.00 mm	1.25"	64.00 mm	2.50"
37.00 mm	1.50"		

STORAGE (Con't):
3. Keep the material out of direct sunlight until ready for application.

PACKAGING:
10 QuickSeam Conduit Flashing are packaged per carton and 96 cartons per pallet.

PRECAUTIONARY DATA:
1. Review Material Safety Data Sheet (MSDS) prior to use.
2. Do not install over uneven substrates.

LEED INFORMATION:
Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location: Bensenville, IL

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-045

TECHNICAL INFORMATION SHEET

FSP-702
11/07/2008

Firestone
SPECIALTY PRODUCTS

Silicone Rubber Roller

Firestone Item Number:
W563582023: 38.1 mm (1.5") Silicone Rubber Roller

DESCRIPTION:
Silicone Rubber Roller consists of a 38.1 mm (1.5") silicone rubber covered steel roller with a wooden handle. The roller is designed to be used to mate approved Firestone membranes with Firestone's QuickSeam Cover Strip or QuickSeam Seam Tape and for rolling QuickSeam Flashing that has been applied for sealing details.

PACKAGING:
38.1 mm (1.5") roller is packaged six per carton and 42 cartons per pallet.

PRECAUTIONARY DATA:
1. Keep roller clean and free from adhesive or other contaminant buildup.
2. Roller may be cleaned with SP-100 Splice Wash or other compatible solvent.

PRODUCT DATA

Property	Minimum Performance
Handle:	101.6 mm (4.0") Long, 25.4mm (1.0") Dia., Wooden Handle
Roller:	38.1 mm (1.5") Dia., Steel with Bronze Sleeve Bearings with a Silicone sleeve
Welded Roller Shaft:	19 mm (0.75") Dia., 50.8 mm (2.0") Long, Steel

Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-034

Firestone
SPECIALTY PRODUCTS

QuickRoller™

Firestone Item Number:
W563582026: QuickRoller

DESCRIPTION:
QuickRoller consists of a 106.68 cm (42.0") steel handle attached to a rubber sleeved steel roller. The QuickRoller is designed to mate Firestone's QuickSeam™ Products with approved Firestone membranes.

METHOD OF APPLICATION:
After the QuickSeam products have been applied to the membrane roll in accordance with Firestone Specialty Products specifications and details.

Replacing The QuickRoller Sleeve:
The sleeve should be replaced when the QuickRoller sleeve becomes worn or rolls unevenly. Remove the old sleeve by cutting it off. Remove old adhesive from the roller surface. Install the new sleeve by stretching and pulling it over the open end of the roller until it is approximately centered on the roller.

Fold back one third to one half of the sleeve onto itself. Check to make sure that the opposite end of the sleeve extends about equal from the edge of the roller as it may have moved when rolling back the sleeve.

Brush on a thin coat of Bonding or Splice Adhesive to the exposed roller area and to the folded sleeve area, being careful no to puddle or glob the adhesive. Allow the adhesive to dry and test by the push-test method. When the adhesive is ready, unfold the turned-down sleeve onto the exposed roller. The adhesive over this area should keep the roller sleeve in place. If for some reason the sleeve begins to walk off the roller, repeat the same adhesive procedure on the other half of the sleeve.

PRODUCT DATA

Property	Minimum Performance
QuickRoller	
Handle:	25.4 mm (1.0") Dia., 106.68 cm (42.0") Long, Coated Steel Rod
Color:	Tan
Grip:	Red Plastic, Smooth Textured or Handle Bar Grip
Roller:	95.25 mm (3.75") Dia., Steel with Bronze Sleeve Bearings
Welded Roller Shaft:	19.05 mm (0.75") Dia., 100 mm (4.0") Long, Steel
Removable Roller Shaft:	12.7 mm x 114.3 mm (0.5" x 4.5") long, Grade 8 Bolt
QuickRoller Sleeve	
Dimensions:	100.6 mm (3.96") O.D., 6.35 mm (0.25") Wall, 96.5 mm (3.8") Nom. Length
Material:	Rubber, Either Neoprene or Silicone
Color:	Black
Hardness:	30 +/- 5 Shore A Durometer

Total weight per unit: 10.43 kg (23 lbs)

PACKAGING:
The QuickRoller is packaged two per carton and includes two extra sleeves. There are 30 cartons per pallet. Replacement parts for the QuickRoller are not available, except for replacement sleeves.

PRECAUTIONARY DATA:
1. Keep roller sleeve clean and free from adhesive or other contaminant buildup.
2. Sleeve may be cleaned with SP-100 Splice Wash or other compatible solvent.

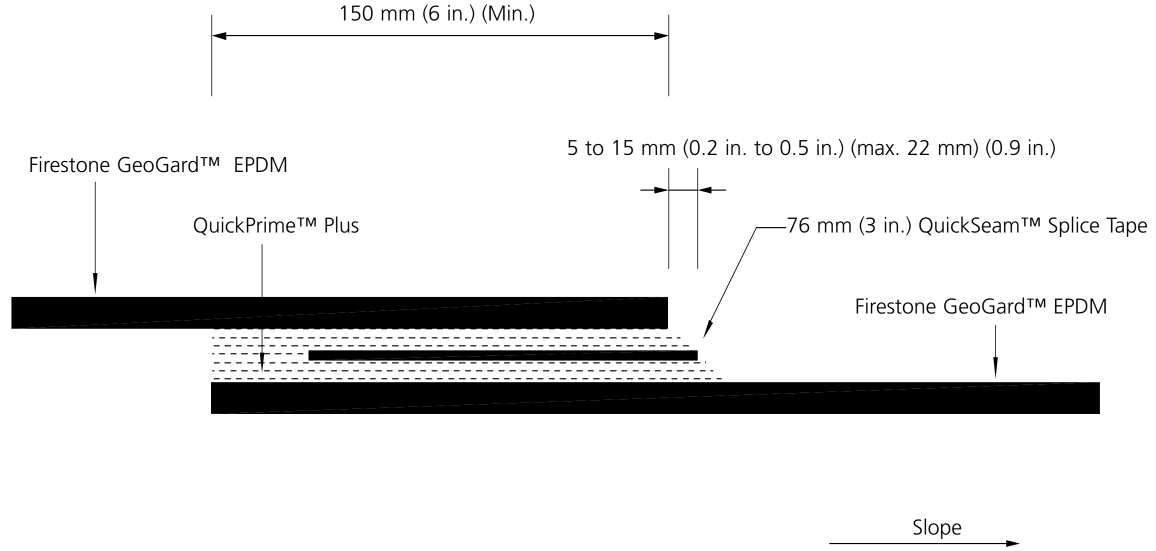
Firestone Specialty Products
250 West 96th Street, Indianapolis, Indiana 46260
Specialty Products (800) 428-4442
Internet Address: http://www.firestonesp.com

S723-SPP-028

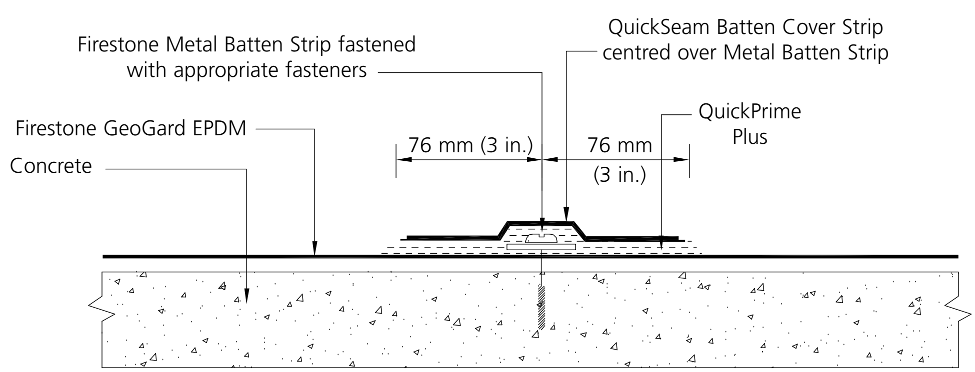
7 Detail Drawings

7.1 Lap Splices

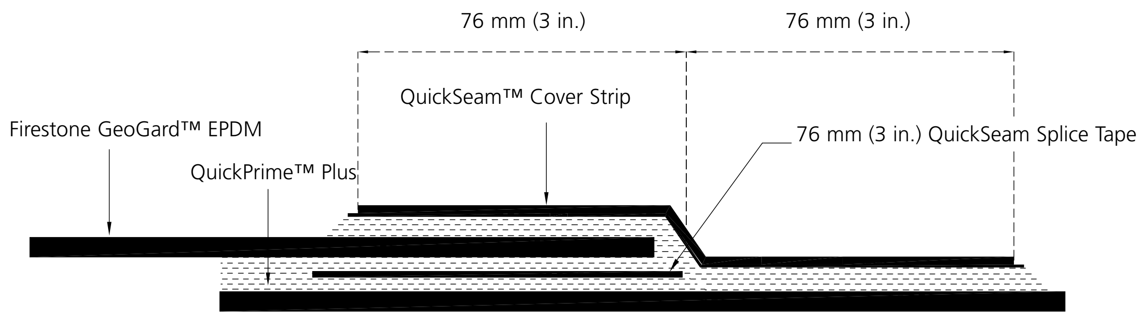
No.	Detail
Geo-E-LS-1	Standard Seam using 76 mm (3 in.) QuickSeam™ Splice Tape
Geo-E-LS-2	QuickSeam Cover Strip on Metal Batten Bar
Geo-E-LS-3	QuickSeam Cover Strip on Standard Seam



Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Standard Seam using 76 mm (3 in.) QS Splice Tape	No.: Geo-E-LS-1 11/2014



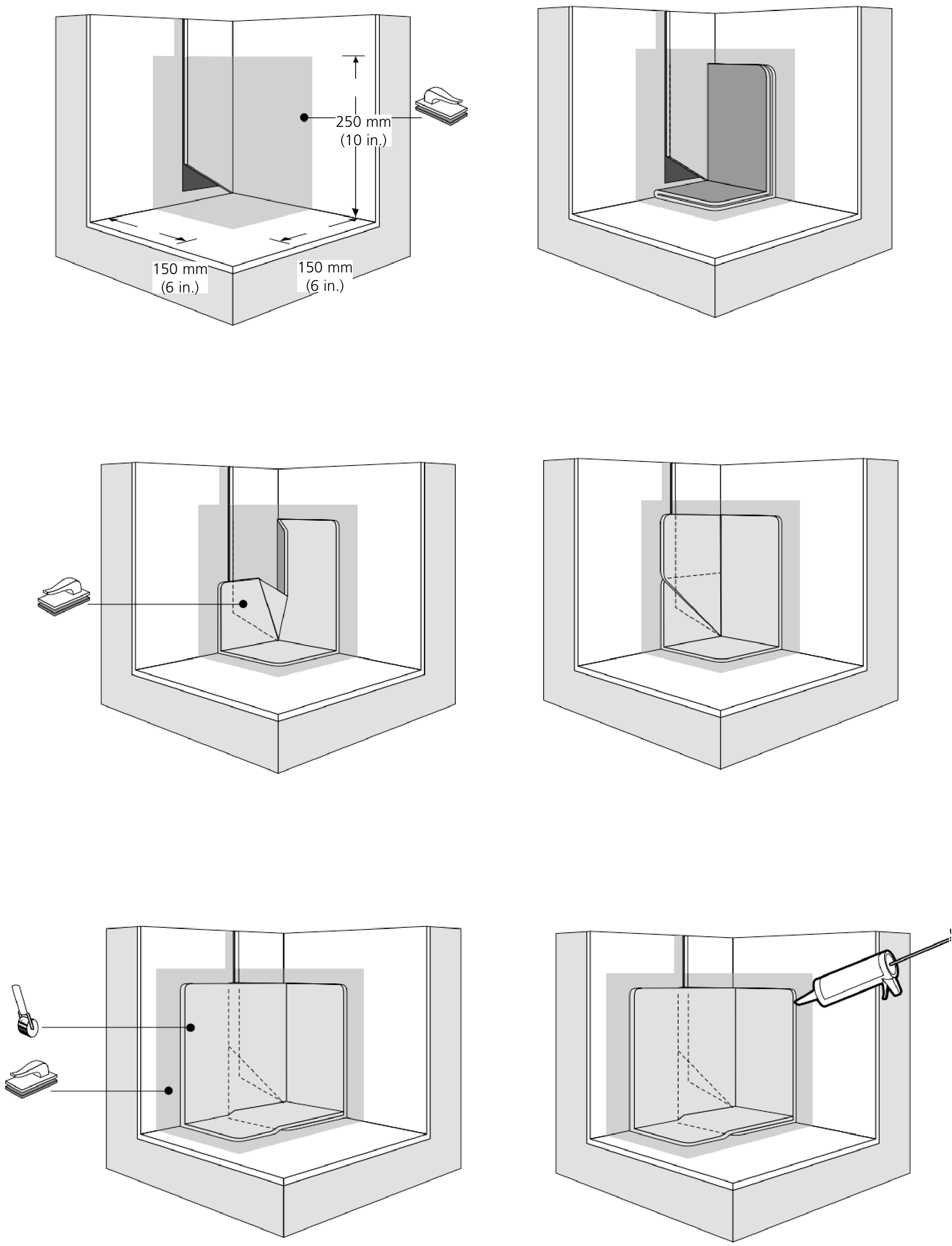
Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** QS Cover Strip on metal bar	No.: Geo-E-LS-2 11/2014



Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** QS Batten Cover Strip on Standard Seam	No.: Geo-E-LS-3 11/2014

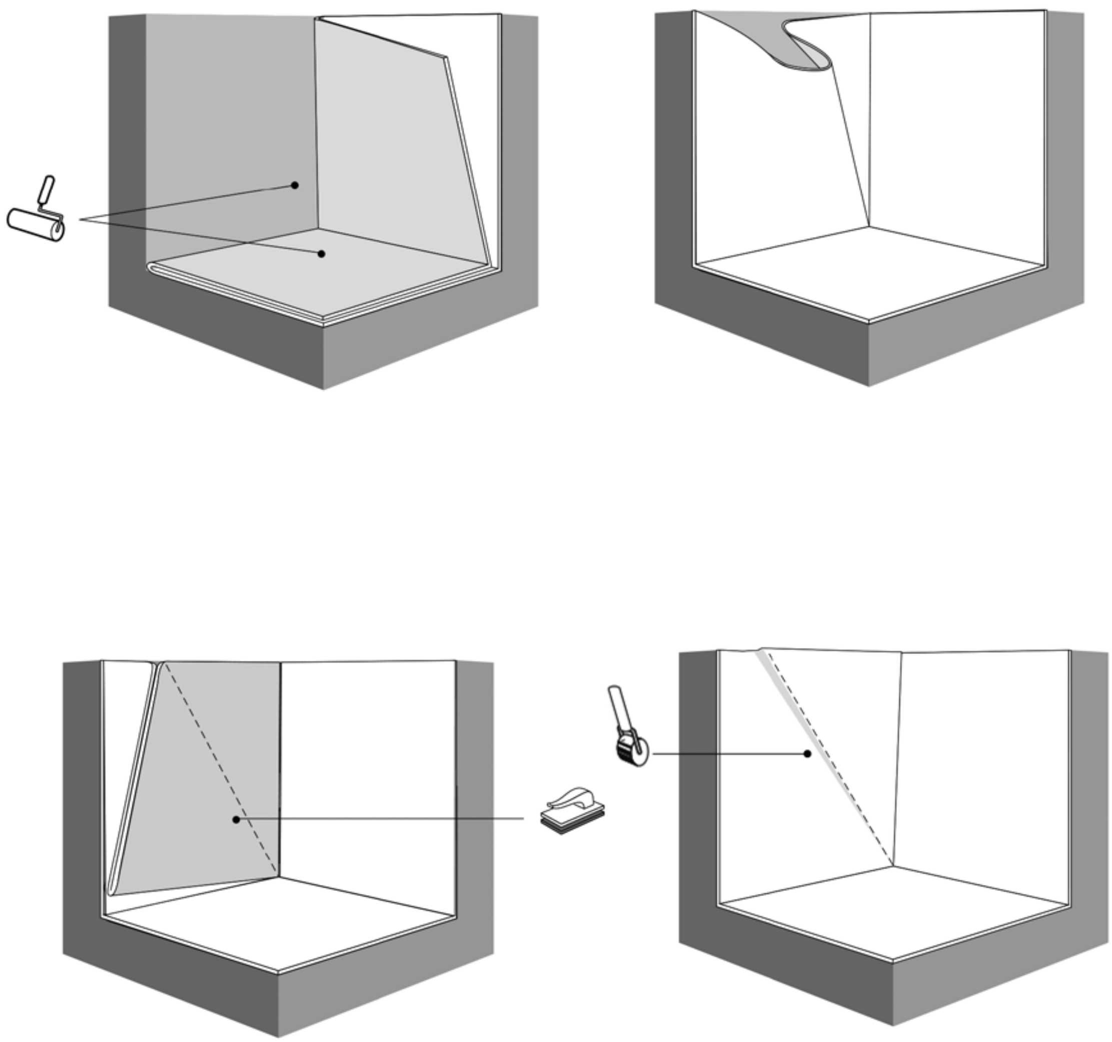
7.2 Corners

No.	Detail
Geo-E-C-1	Inside corner using QuickSeam™ FormFlash
Geo-E-C-2	Folded inside corner
Geo-E-C-3	Outside corner using QuickSeam™ FormFlash



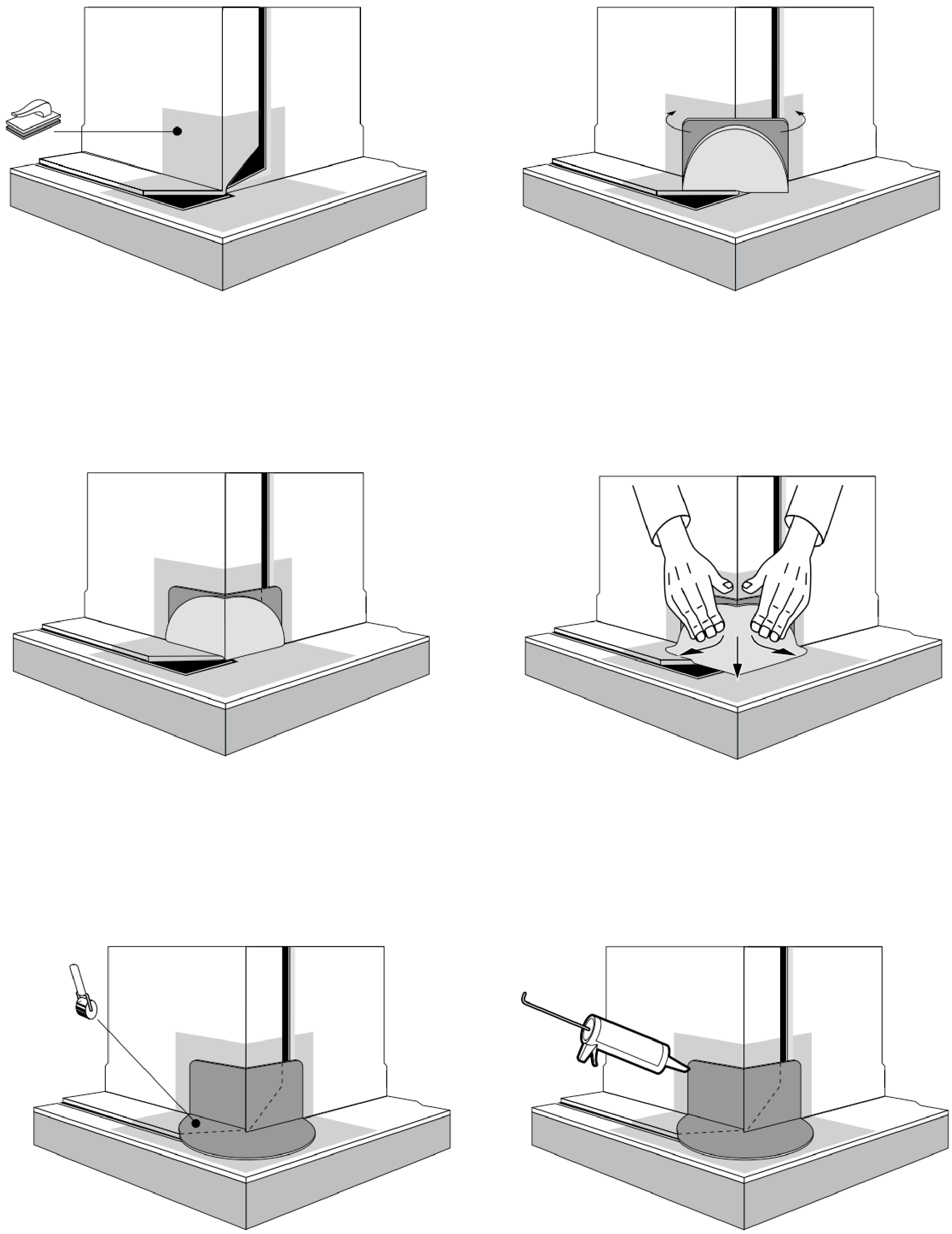
(This detail can utilize a QuickSeam™ Corner Flashing)

Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Inside Corner Using QuickSeam FormFlash	No.: Geo-E-C-1 11/2014



(This detail can utilize a QuickSeam™ Corner Flashing)

Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM**	No.: Geo-E-C-2
	Folded Inside Corner	11/2014

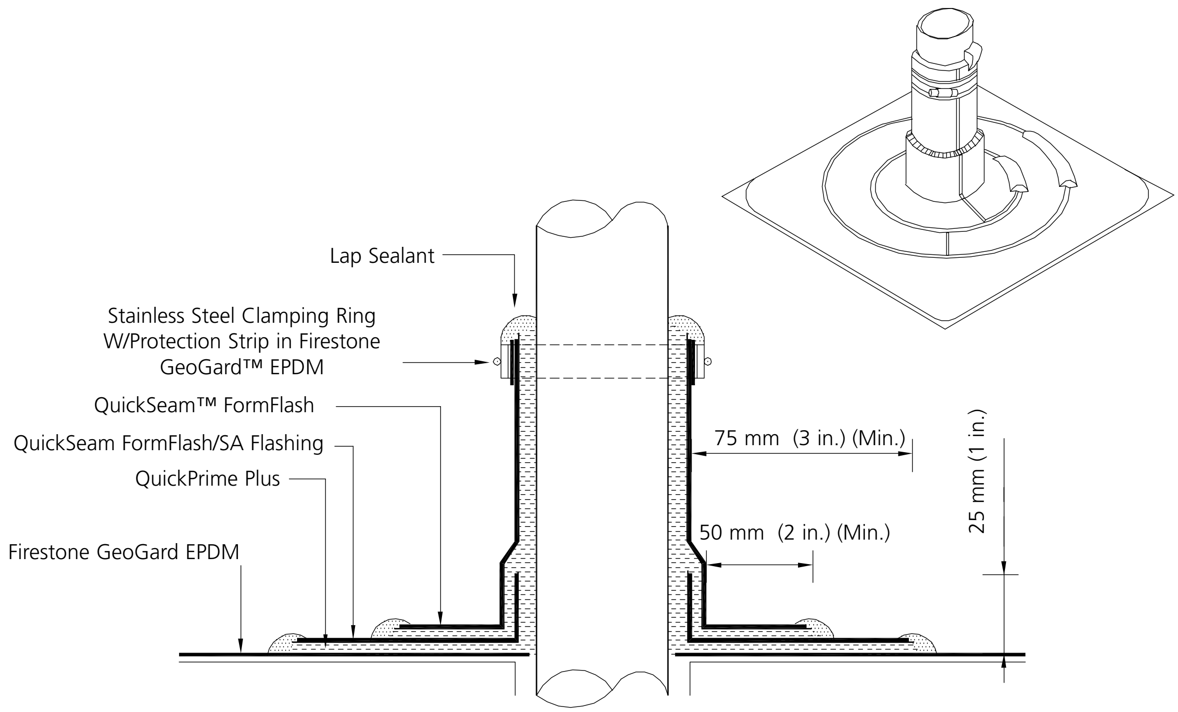


(This detail can utilize a QuickSeam™ Corner Flashing)

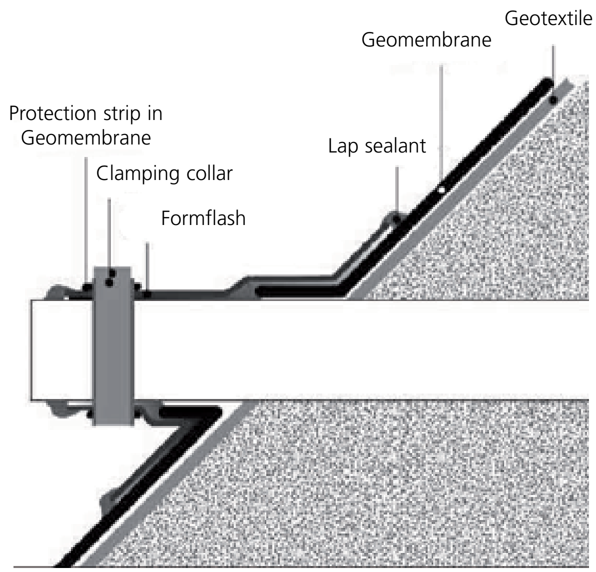
Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Outside Corner Using QuickSeam FormFlash	No.: Geo-E-C-3 11/2014

7.3 Penetrations

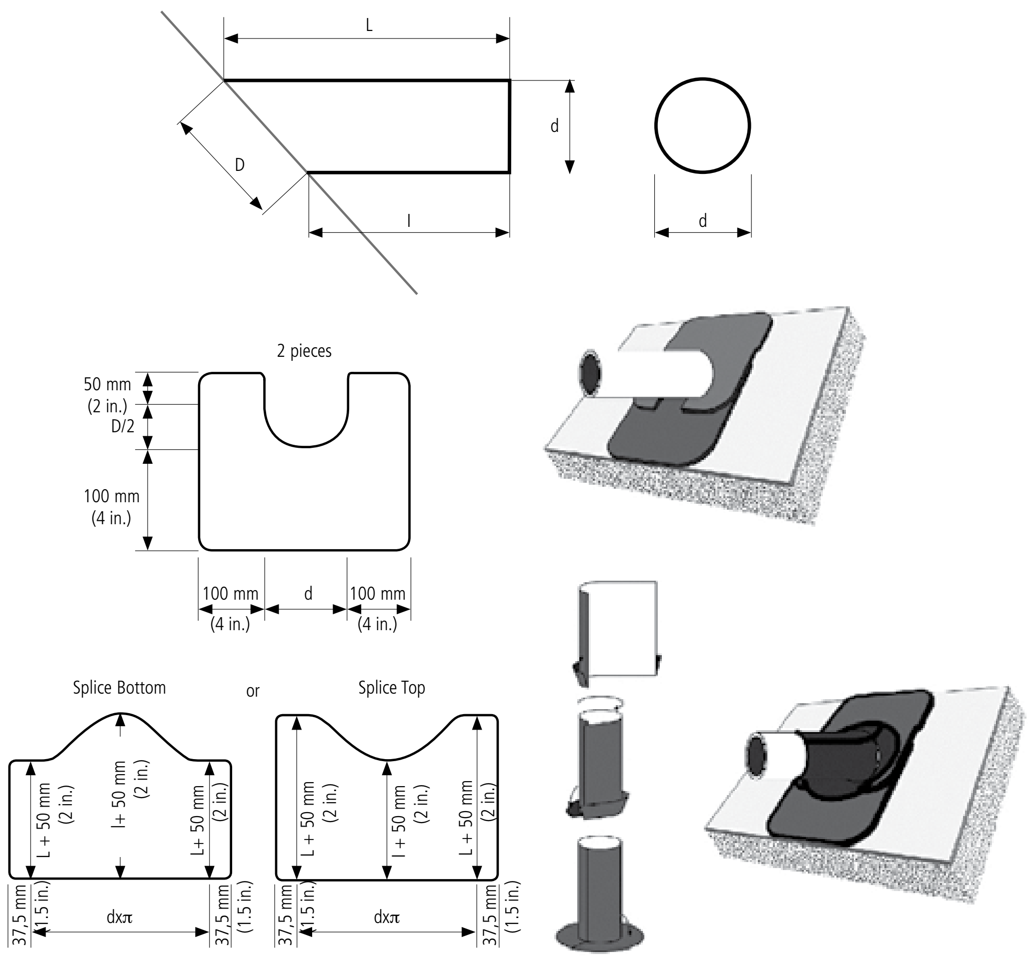
No.	Detail
Geo-E-P-1	Flashing of small penetrations exposed to low water pressure
Geo-E-P-2	Flashing of large penetrations exposed to low water pressure
Geo-E-P-3	Flashing of a pipe exposed to high water pressure
Geo-E-P-4	Connection to a flange exposed to high water pressure



Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Flashing of Small Penetrations Exposed to Low Water Pressure	No.: Geo-E-P-1 11/2014

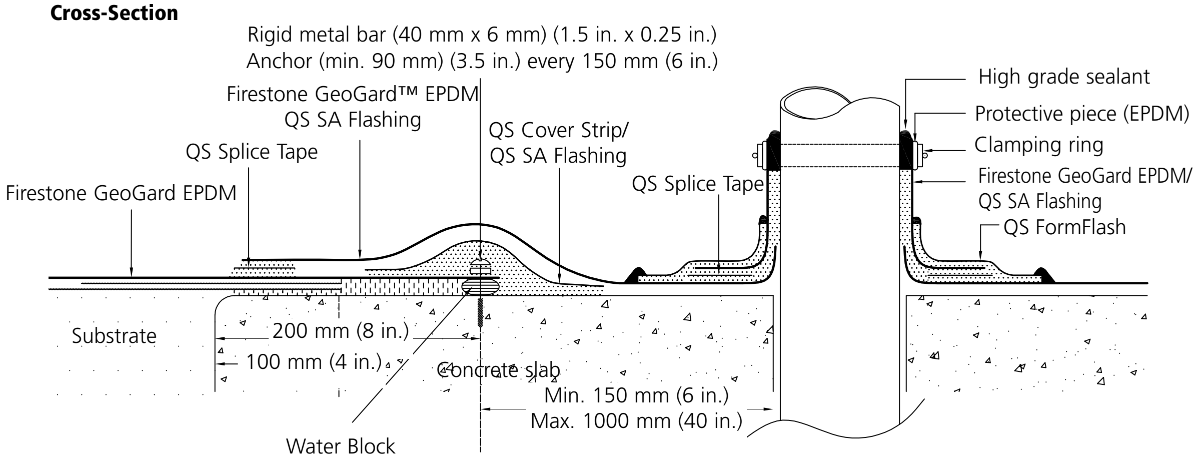


Alternate Pipe Flashing Method

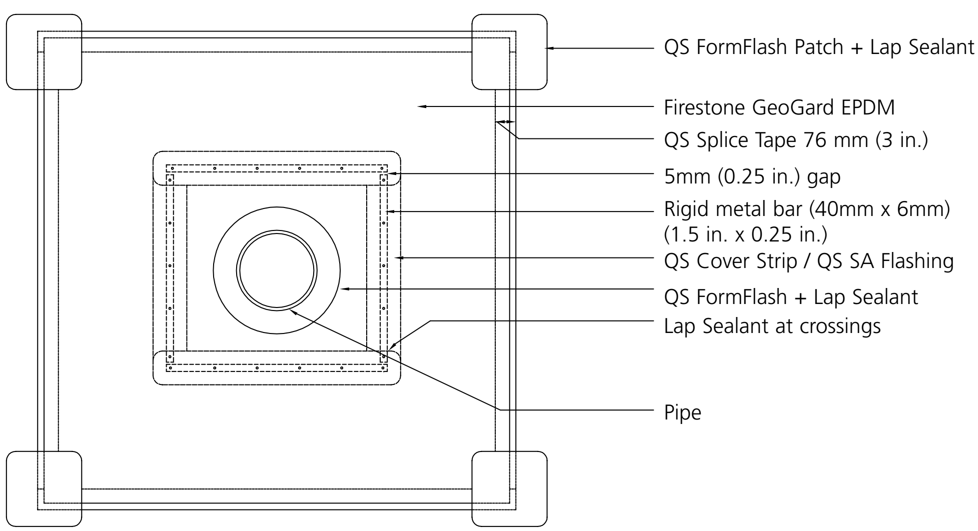


Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Standard Seam using 76 mm (3”) Tape	No.: Geo-E-P-2 11/2014

Cross-Section



Plan View

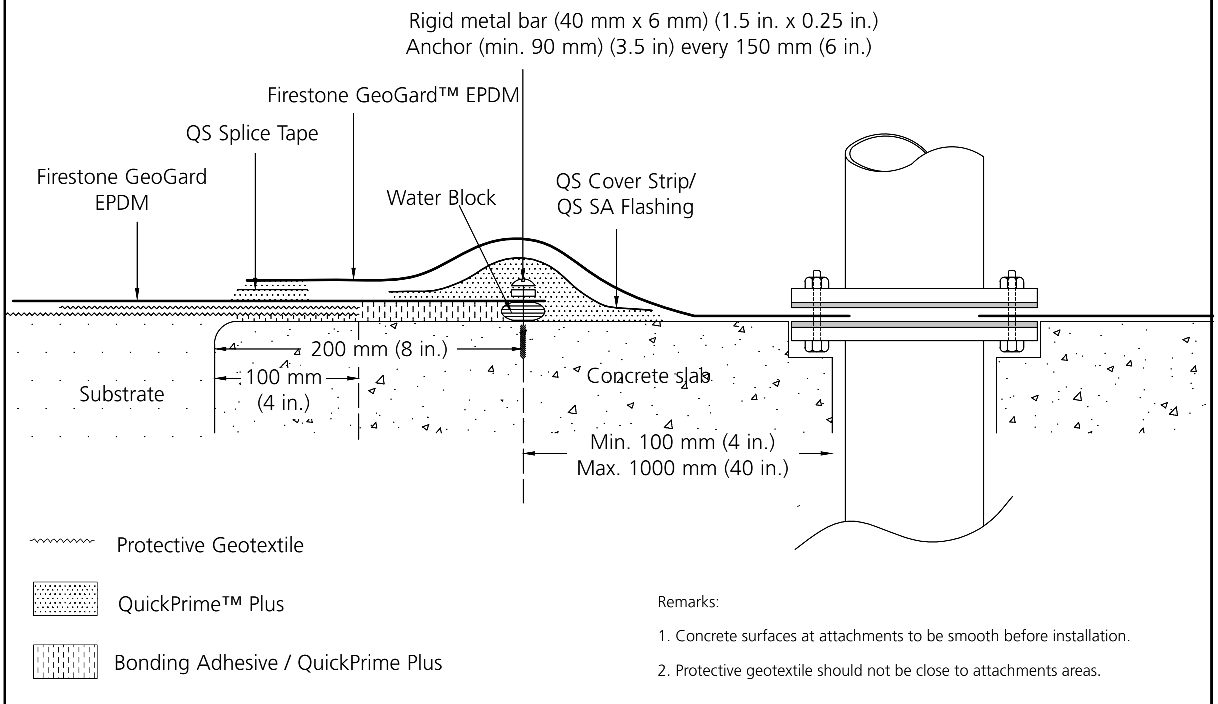


- Lap Sealant
- QuickPrime™ Plus
- Bonding Adhesive / QuickPrime Plus
- Protective geotextile

Remarks:

1. Concrete surfaces at attachments to be smooth before installation.
2. Protective geotextile should not be close to attachments areas.

Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Flashing of a Pipe Exposed to High Water Pressure	No.: Geo-E-P-3 / 11/2014



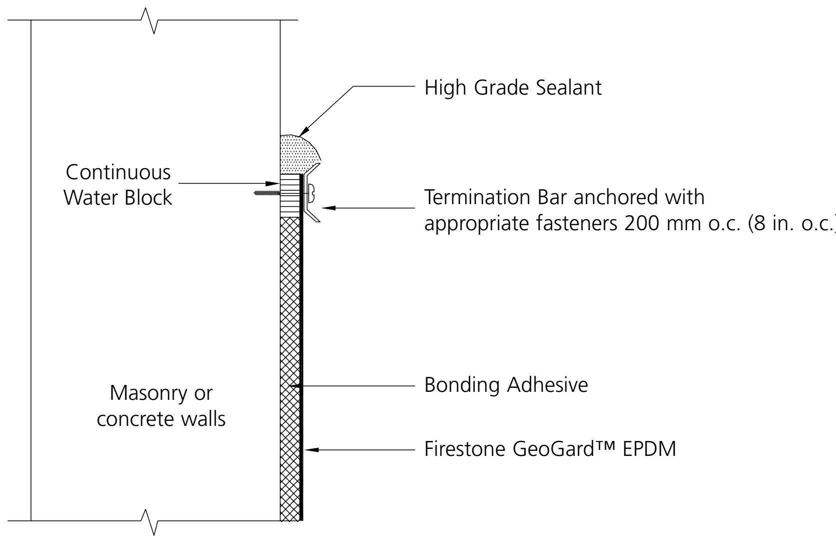
Remarks:

1. Concrete surfaces at attachments to be smooth before installation.
2. Protective geotextile should not be close to attachments areas.

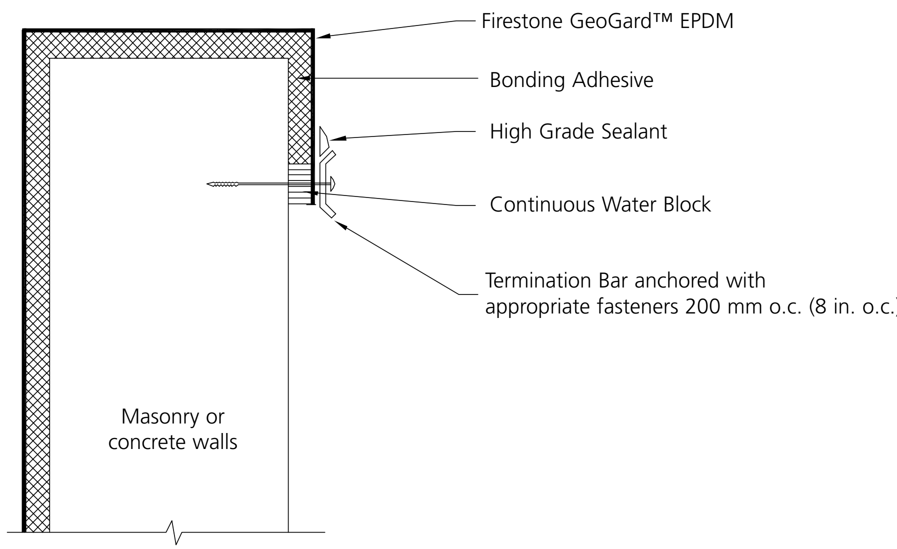
Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Connection to a Flange Exposed to High Water Pressure	No.: Geo-E-P-4
		11/2014

7.4 Terminations

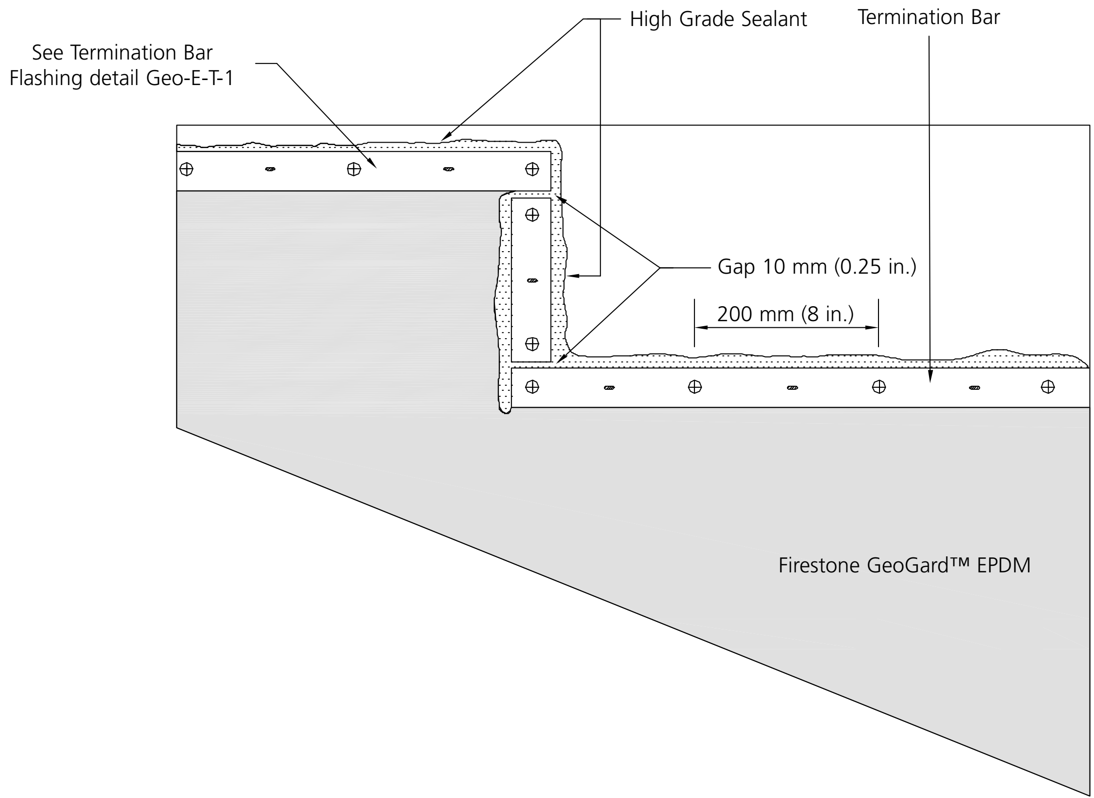
No.	Detail
Geo-E-T-1	Wall flashing termination above maximum water level line
Geo-E-T-2	Outside wall flashing termination
Geo-E-T-3	Termination step down & outside corner above maximum water line
Geo-E-T-4	Intermediate attachment at wall flashing
Geo-E-T-5	Horizontal termination below water line
Geo-E-T-6	Vertical termination below water line

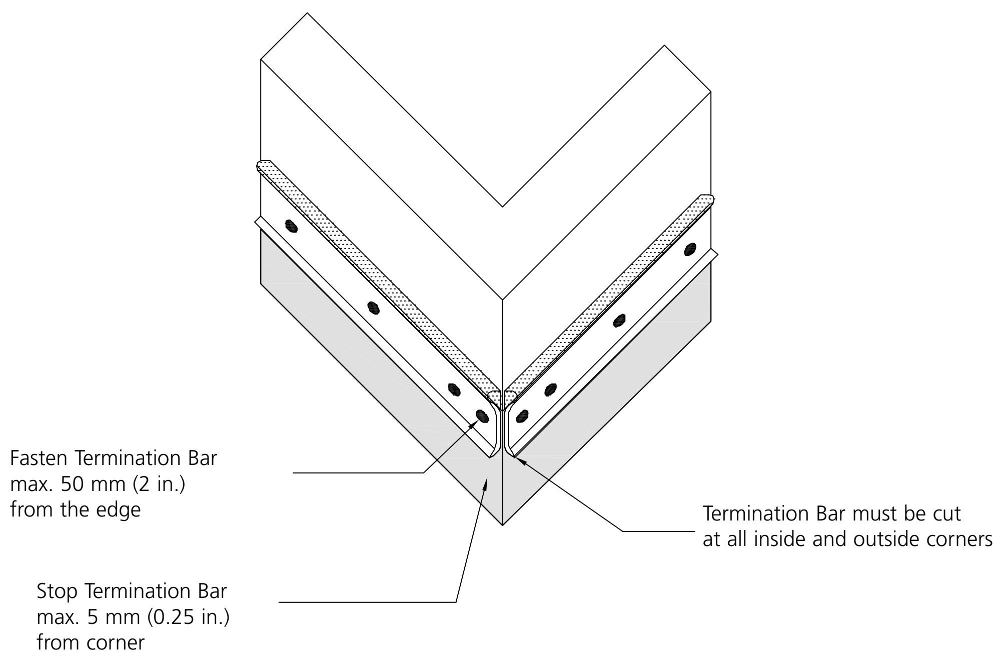


Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Wall Flashing Termination Above Maximum Water Line	No.: Geo-E-T-1 11/2014



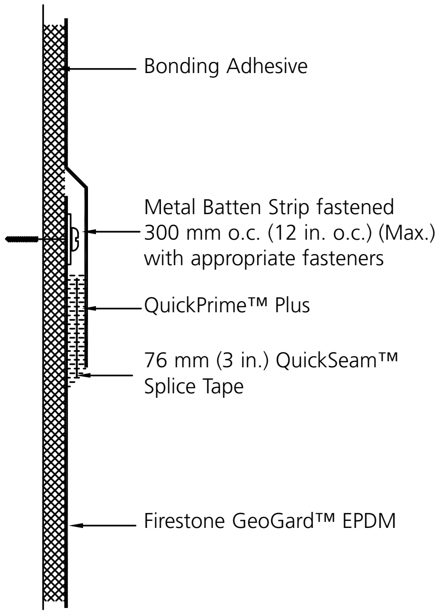
Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Outside Wall Flashing Termination	No.: Geo-E-T-2 11/2014



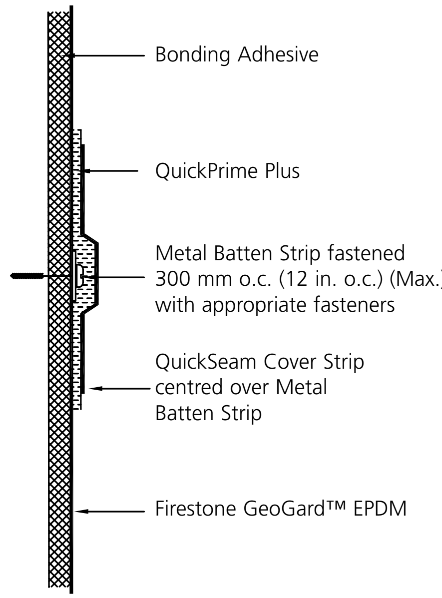


Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Termination Step Down & Outside Corner Above Max. Water Line	No.: Geo-E-T-3 11/2014

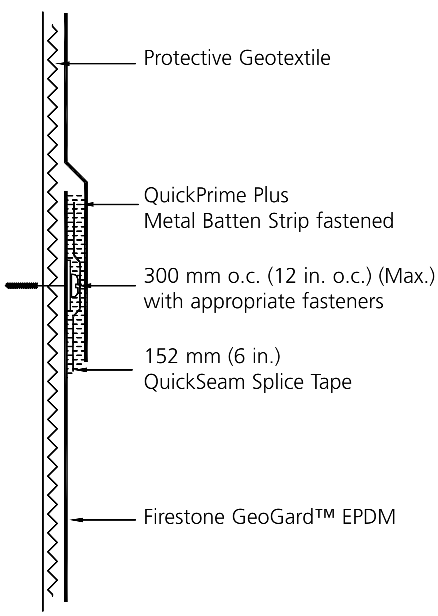
A.



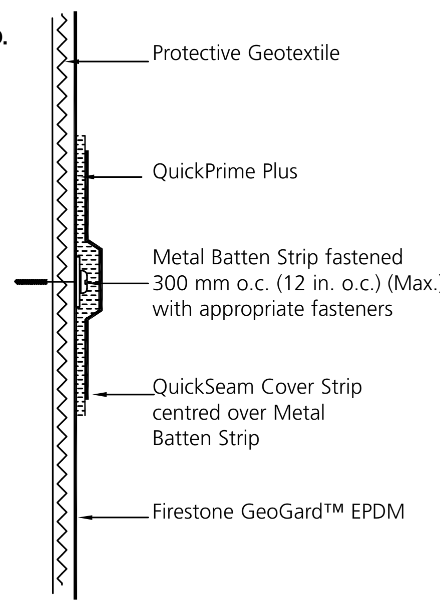
B.



C.

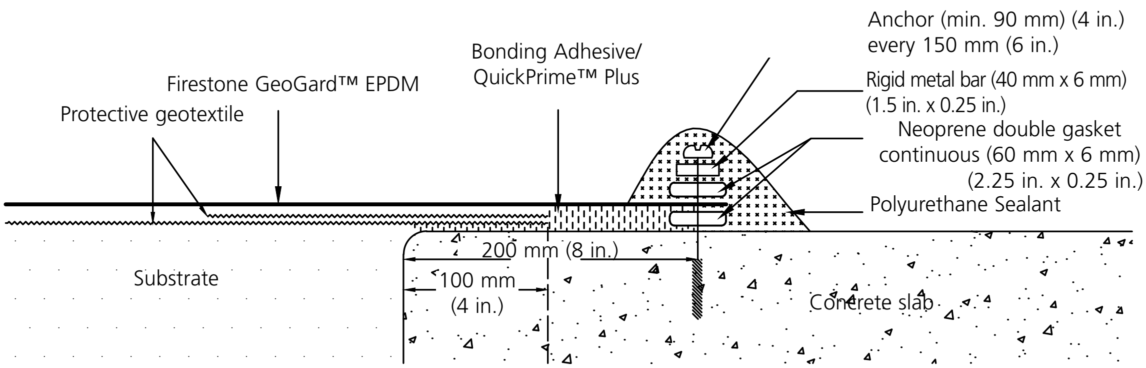


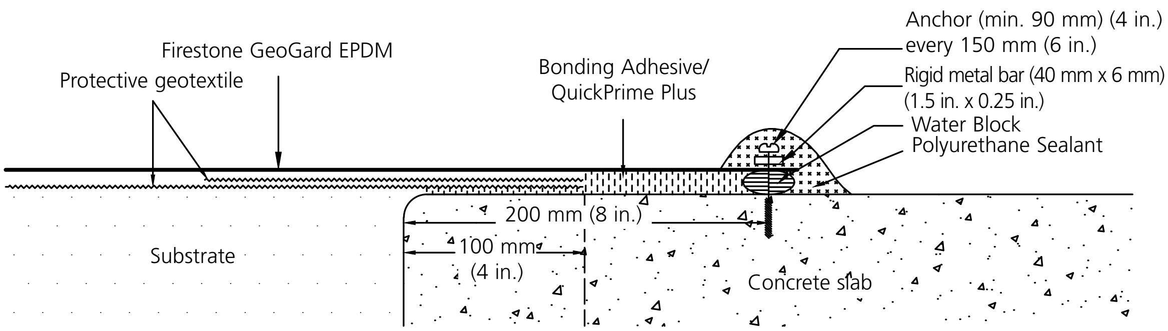
D.

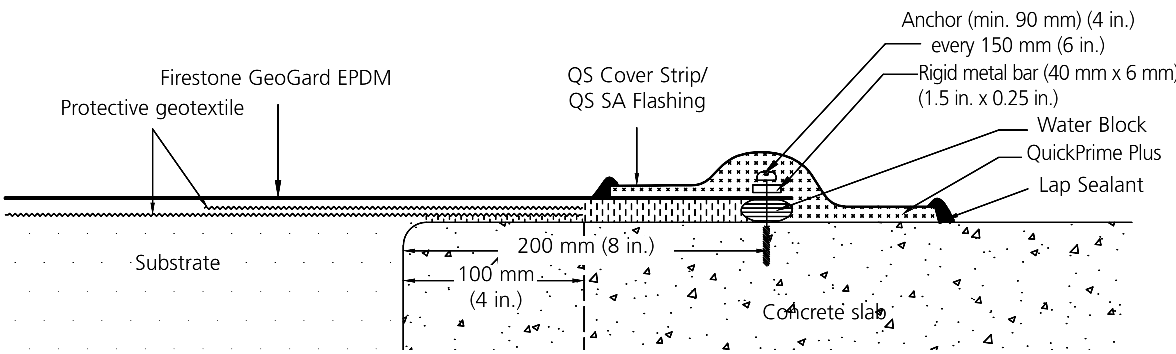


Remark: The distance between two anchorings needs to be designed depending on the details of the project.

Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Intermediate Attachment at Wall Flashing	No.: Geo-E-T-4
		11/2014



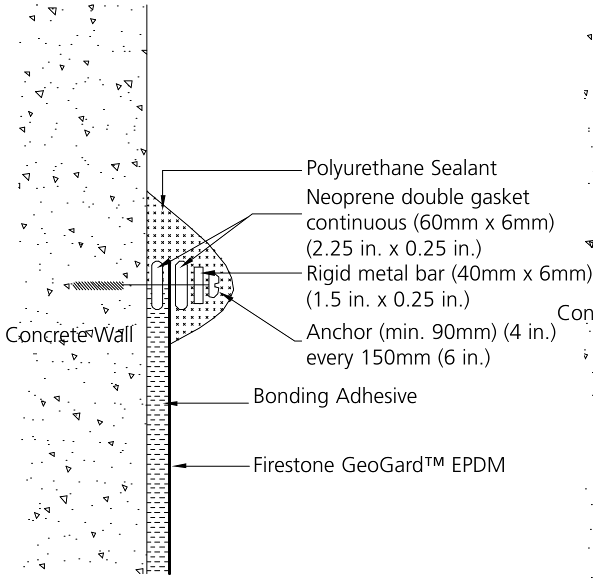


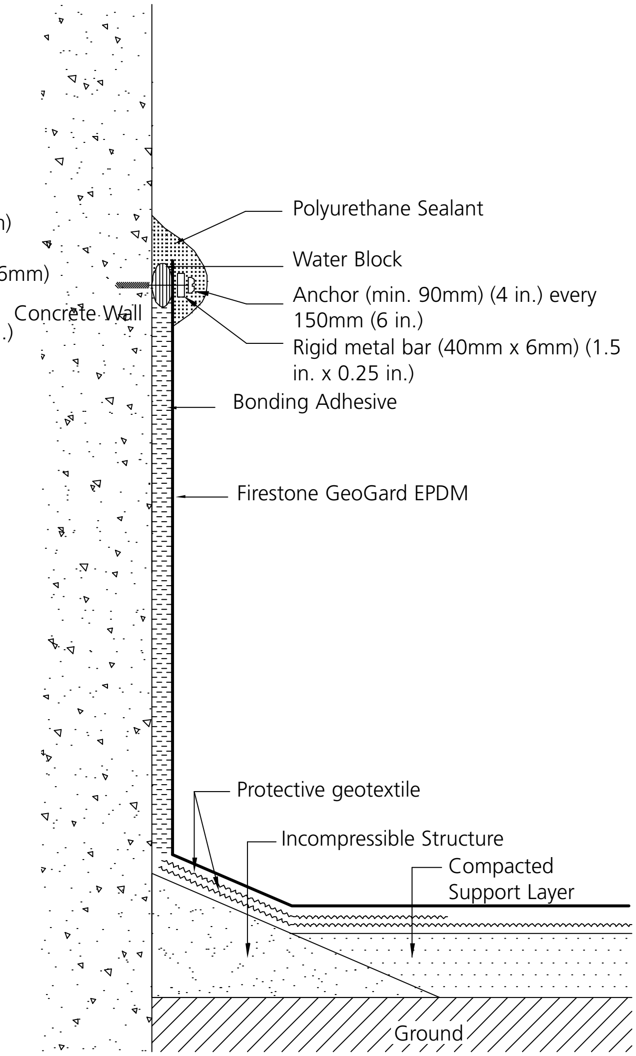


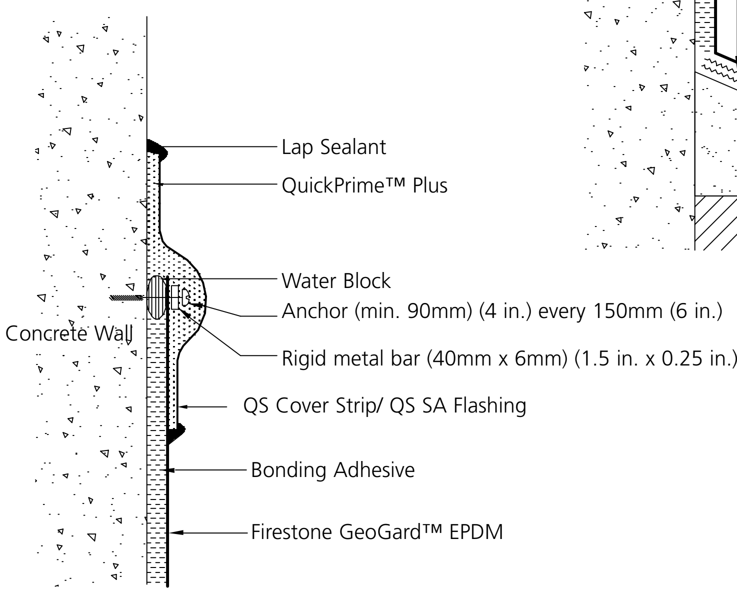
Remarks:

1. Concrete surfaces at attachments to be smooth before installation.
2. Protective geotextile should not be close to attachments areas.
3. Water Block has to be applied to junction of neoprene gasket strips.

Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Horizontal Termination Below Water Line	No.: Geo-E-T-5 11/2014







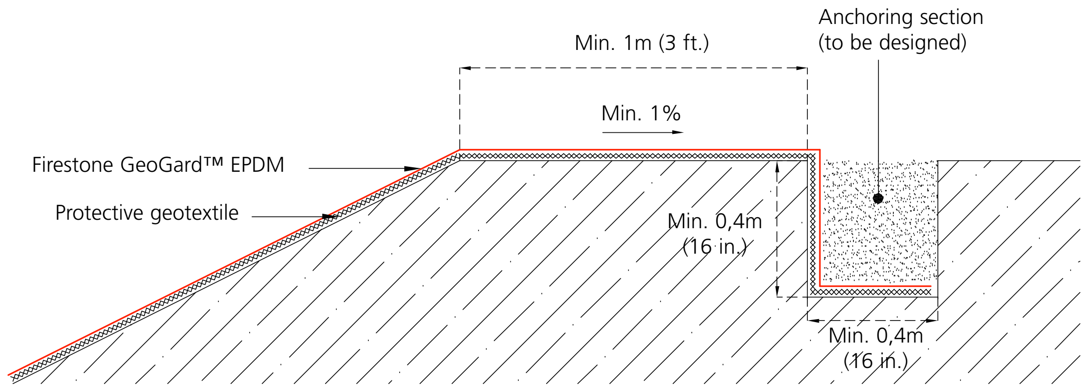
Remarks:

1. Concrete surfaces at attachments to be smooth before installation.
2. Protective geotextile should not be close to attachments areas.
3. Water Block has to be applied to junction of neoprene gasket strips.

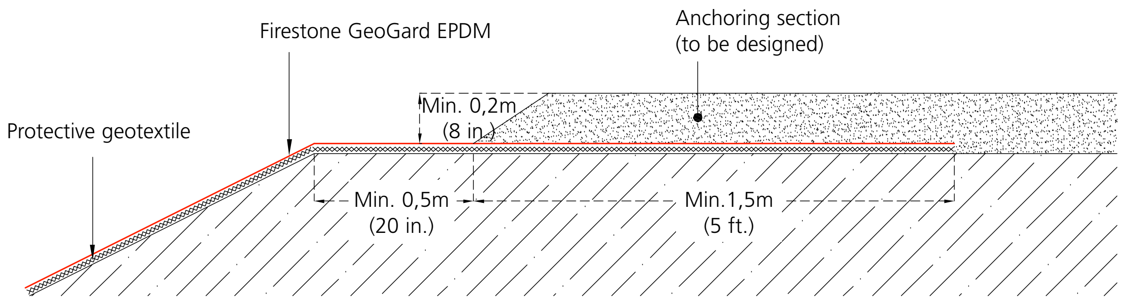
Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Vertical Termination Below Water Line	No.: Geo-E-T-6 11/2014

7.5 Anchoring

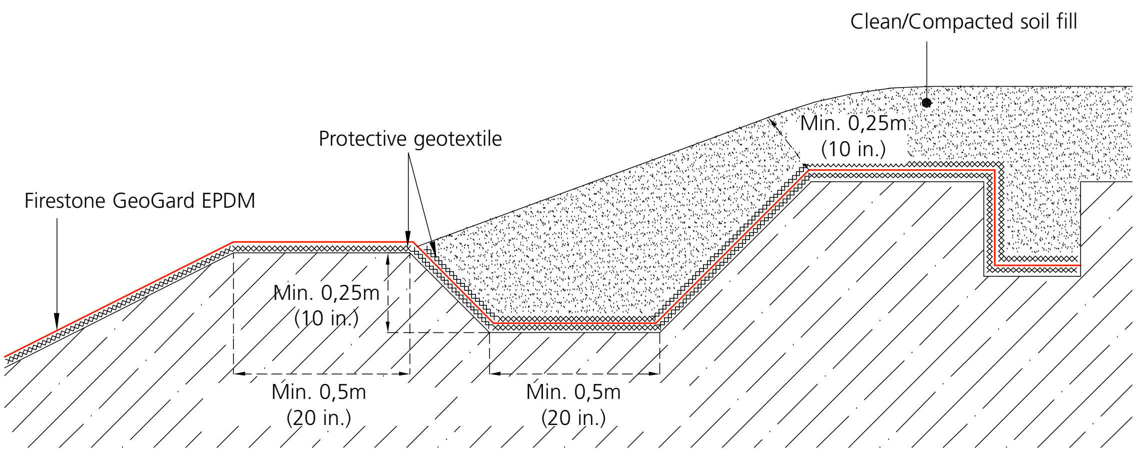
No.	Detail
Geo-E-A-1	Top anchoring in a trench
Geo-E-A-2	Top anchoring with ballast
Geo-E-A-3	Unexposed reservoir edge with soil cover
Geo-E-A-4	Intermediate anchoring on a berm with ballast
Geo-E-A-5	Toe of slope anchoring



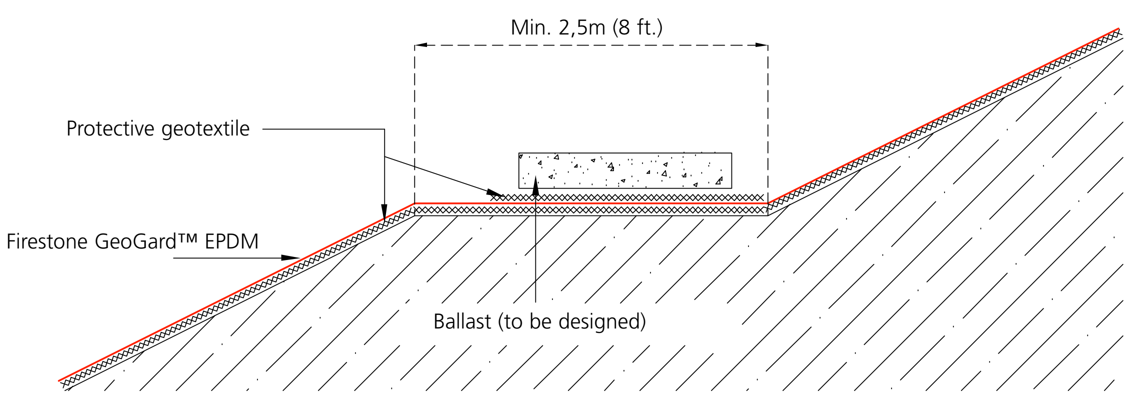
Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Top Anchoring in a Trench	No.: Geo-E-A-1 11/2014



Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Top Anchoring with Ballast	No.: Geo-E-A-2 11/2014

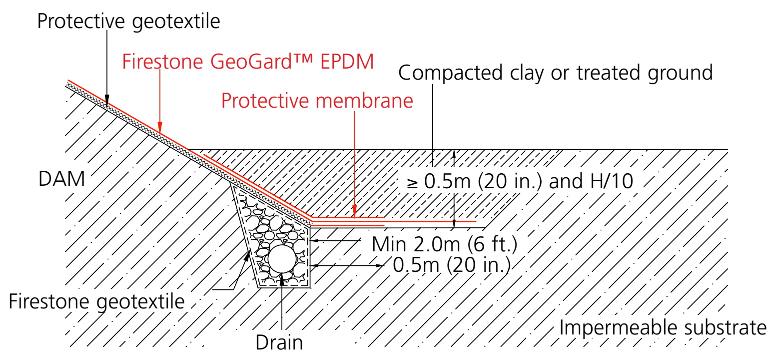


Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Unexposed Reservoir Edge with Soil Cover	No.: Geo-E-A-3 11/2014

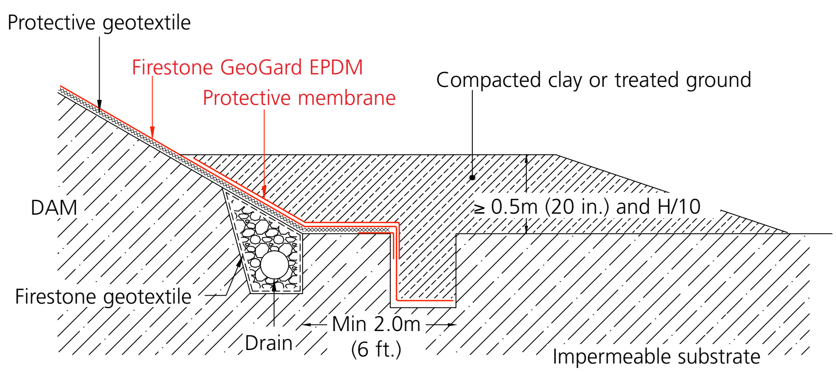


Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Intermediate Anchoring on a Berm with Ballast	No.: Geo-E-A-4 11/2014

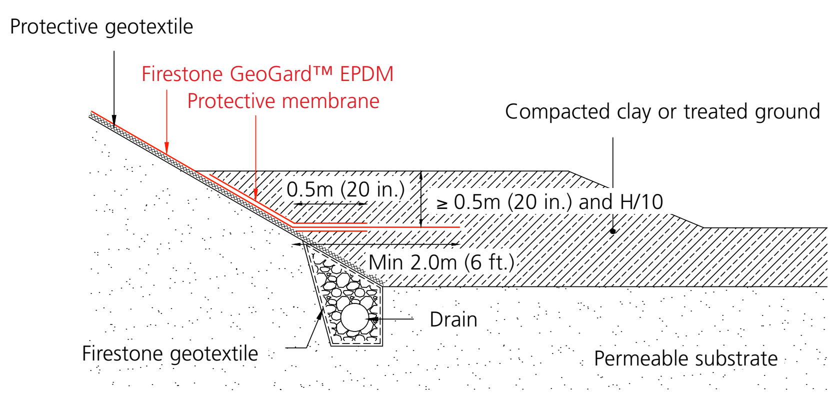
Base anchoring in impermeable ground



Base anchoring in impermeable ground



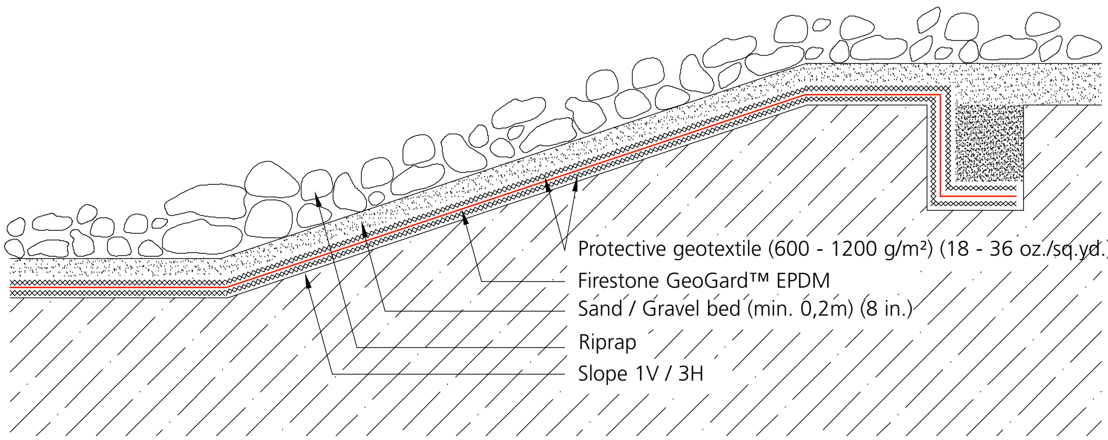
Base anchoring in permeable ground



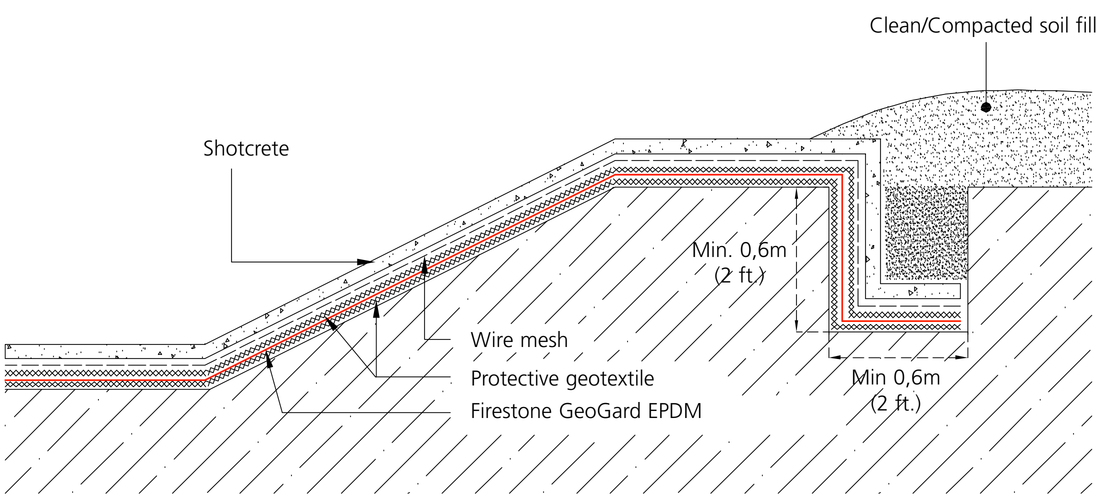
Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Toe of Slope Anchoring	No.: Geo-E-A-5 11/2014

7.6 Membrane cover

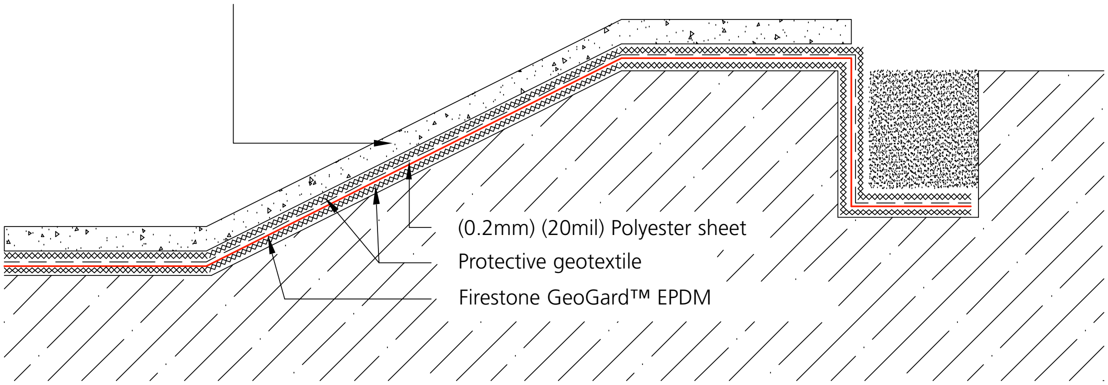
No.	**Detail**
Geo-E-Co-1	Membrane cover with riprap
Geo-E-Co-2	Membrane cover with shotcrete
Geo-E-Co-3	Membrane cover with concrete



Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Membrane Cover with Riprap	No.: Geo-E-Co-1 11/2014



Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Membrane Cover with Shotcrete	No.: Geo-E-Co-2 11/2014



Firestone BUILDING PRODUCTS NOBODY COVERS YOU BETTER.™	**Firestone GeoGard EPDM** Membrane Cover with Concrete	No.: Geo-E-Co-3
		11/2014

8 Case Studies & Technical Papers

Case Studies

Technical Papers

8.1 The London 2012 Olympic Canoe Slalom, UK

The London 2012 Olympic Canoe Slalom, UK

Firestone GeoGard™ EPDM - Lining in Action at the London 2012 Olympic Canoe Slalom

The Lee Valley White Water Canoe Centre was the first brand new venue to be completed by the Olympic Delivery Authority. The venue will host the five days of canoe slalom events during the 2012 games.

Long term durability, high flexibility, chemical resistance and minimal environmental impact were just some of the properties which resulted in the specification of 16,500 m² (177,000 sq.ft.) of 1.1mm (45 mil) Firestone GeoGard™ EPDM for lining the holding lake of the Olympic Canoe Slalom Course at Lee Valley, Broxbourne, Hertfordshire.

The specification was drawn up by P A Geotechnical in conjunction with the London Organising Committee of the Olympic Games' Consultant Engineer, Cundall. P A Geotechnical are specialists in Geosynthetics and are Authorised Distributors of Firestone GeoGard EPDM due to their specialist knowledge of this market.

Preparation

The site had been previously contaminated by chemicals and pollutants as a result of many years of use for heavy industry. Therefore Firestone GeoGard EPDM was not only chosen due to flexibility and durability but also as it would not react with the pollutants. In fact, the membrane had to undergo rigorous independent testing prior to final selection.

Excavation and preparation of the site began in 2009. The project was on a tight time frame which required the lining to be carried out in February, probably one of the worst times of the year for this type of work and February 2010 was no exception. But due to the chemical properties of the membrane it retains its flexibility at low temperatures down to -45°C (-49°F).

Quick Facts

Project scope :

- Contaminated waste land.
- Not only to be used for the Olympic Canoe Slalom event but also before and after the 2012 Olympic Games.
- Lining of 16,500m² (177,000 sq.ft.) carried out with 1.1mm (45 mil) Firestone GeoGard EPDM.
- High visibility and prestigious project.

Challenges faced:

- To avoid reaction with contaminated land.
- Tight time frame.
- Withstand the water pressure.
- Adverse weather conditions at the time of installation.
- Accommodation of significant design changes.

Solutions offered by Firestone GeoGard™ EPDM:

- Waterproofing membrane
- High elasticity (>300%)
- Long-term durability
- Large sheets reducing on site seaming
- Fast and easy installation
- Highly flexible (at high and low temperatures, adapts to irregular shapes)
- Pressure resistance (has virtually unlimited hydrostatic pressure)
- Chemical resistance
- Environmentally friendly

ISO 9001 FM 32845 ISO 14001 EMS 52644

The London 2012 Olympic Canoe Slalom, UK

Firestone GeoGard™ EPDM - Lining in Action at the London 2012 Olympic Canoe Slalom

The Lee Valley White Water Canoe Centre was the first brand new venue to be completed by the Olympic Delivery Authority. The venue will host the five days of canoe slalom events during the 2012 games.

Long term durability, high flexibility, chemical resistance and minimal environmental impact were just some of the properties which resulted in the specification of 16,500 m² (177,000 sq.ft.) of 1.1mm (45 mil) Firestone GeoGard™ EPDM for lining the holding lake of the Olympic Canoe Slalom Course at Lee Valley, Broxbourne, Hertfordshire.

The specification was drawn up by P A Geotechnical in conjunction with the London Organising Committee of the Olympic Games' Consultant Engineer, Cundall. P A Geotechnical are specialists in Geosynthetics and are Authorised Distributors of Firestone GeoGard EPDM due to their specialist knowledge of this market.

Preparation

The site had been previously contaminated by chemicals and pollutants as a result of many years of use for heavy industry. Therefore Firestone GeoGard EPDM was not only chosen due to flexibility and durability but also as it would not react with the pollutants. In fact, the membrane had to undergo rigorous independent testing prior to final selection.

Excavation and preparation of the site began in 2009. The project was on a tight time frame which required the lining to be carried out in February, probably one of the worst times of the year for this type of work and February 2010 was no exception. But due to the chemical properties of the membrane it retains its flexibility at low temperatures down to -45°C (-49°F).

Quick Facts

Project scope :

- Contaminated waste land.
- Not only to be used for the Olympic Canoe Slalom event but also before and after the 2012 Olympic Games.
- Lining of 16,500m² (177,000 sq.ft.) carried out with 1.1mm (45 mil) Firestone GeoGard EPDM.
- High visibility and prestigious project.

Challenges faced:

- To avoid reaction with contaminated land.
- Tight time frame.
- Withstand the water pressure.
- Adverse weather conditions at the time of installation.
- Accommodation of significant design changes.

Solutions offered by Firestone GeoGard™ EPDM:

- Waterproofing membrane
- High elasticity (>300%)
- Long-term durability
- Large sheets reducing on site seaming
- Fast and easy installation
- Highly flexible (at high and low temperatures, adapts to irregular shapes)
- Pressure resistance (has virtually unlimited hydrostatic pressure)
- Chemical resistance
- Environmentally friendly

ISO 9001 FM 32845 ISO 14001 EMS 52644

8.2 City of Robinson Reservoir, Robinson, TX, USA

City of Robinson Reservoir • Robinson, TX - USA

Community doubles water supply with Firestone GeoGard™ EPDM lined reservoir

In 1991, two clay lined reservoirs were installed on the outskirts of Robinson, Texas. They were designed to hold water pumped in from the Brazos River, about 6,44 km (4 miles) away, until it was pumped to a nearby treatment plant and on into Robinson.

Following the initial filling in 1991, one reservoir performed well while the other failed right from the start. Attempts were made to repair the reservoir by repacking it with new clay, but it never held water. So for 17 years the town operated on one reservoir, until the town's population threatened to exceed the single reservoir's capacity.

In 2007, city officials worked with Lockwood, Andrews and Newman, an engineering firm in Waco, Texas, to find a solution. They considered RPP, HDPE and EPDM membranes but ultimately specified 1,1 mm (45 mil) Firestone GeoGard™ EPDM for the application because of its ease of installation, membrane

Quick Facts

Project scope:

- 18,21 ha (226,000 sq.ft.) clay lined reservoir unable to hold water
- Expanding population increased water demand requiring use of 2nd reservoir
- City official and engineering firm consider RPP, HDPE & EPDM liner options

Challenges faced:

- Attempts to repair/repack clay liner proved unsuccessful
- Wave impact causing embankment erosion of clay liner
- Expedited installation schedule required rushed material delivery

Solutions:

- Install more than 185.800 m^2 (2,000,000 sq.ft.) of 1,1 mm (45 mil) Firestone GeoGard™ EPDM
- Installed an average of 11.000 m^2 (118,400 sq.ft.) of membrane daily over 17 days
- Obtain entire system, including accessories, from a single manufacturer

ISO 14001
EMS 52644

flexibility, puncture resistance and long-term performance. "City officials were unfamiliar with lining systems, so it was important our recommendation ensure a long-term solution," said Mitch Davison, project engineer, Lockwood, Andrews and Newman. "Firestone's GeoGard™ EPDM system was definitely the best choice given the unique challenges of this application."

One challenge was to design a system that addressed wave impact, erosion and potential embankment failure, according to Davison. "These were problems with the functioning clay lined reservoir," he said. "With a large, open body of water, the waves can cause significant erosion. Because the water is being held for treatment, the resulting sediment affects the water quality."

Geosynthetics Inc. (GSI), Waukesha, Wisconsin, installed the liner. The crew first installed a geotextile. Then, the geomembrane was unrolled in slightly overlapping 15,25 m (50 ft.) by 61,00 m (200 ft.) panels down the 3.1 slopes. The EPDM panels were seamed with Firestone QuickSeam™ Tape to ensure a watertight seal. Pipe boots and batten strip were installed, where necessary.

An unexpected, yet welcomed, result was that the city of Robinson has been able to cut costs by reducing chemicals used to treat the water at the plant. "We're very pleased with the outcome of this project. It has doubled our water capacity and has eased our operational burdens significantly," Hobbs stated. "The water in the lined reservoir is better quality because there is no clay sediment."

GSI is also pleased with the results. "Bad weather led to a tight installation schedule. Firestone's GeoGard™ EPDM system proved to be an excellent choice because it enabled us to cover a lot of ground very quickly," said John Tenhover, project manager, GSI. The ability to get the entire geomembrane system, including all accessories, from a single manufacturer also helped to expedite the installation.

Firestone
BUILDING PRODUCTS
NOBODY COVERS YOU BETTER.™

Europe, Middle East & Asia
Ikaroslaan 75 | 1930 Zaventem | Belgium | Phone +32(0)2 711 44 50 | Fax +32(0)2 721 27 18 | info@fbpe.be | www.firestonebpe.com

Canada
(888) 292.6265
Info@firestonesp.ca
www.firestonesp.ca

US
(0800) 428 4442
Info@firestonesp.com
www.firestonesp.com

Latin America & Caribbean
(305) 471-0117
Info@firestoneplatincaraibe.com
www.firestoneplatincaraibe.com

8.3 Greenfield Irrigation District, Fairfield, MT, USA

Greenfield Irrigation District • Fairfield, MT - USA

Firestone GeoGard™ EPDM membrane provides Cost-Effective Solution for Irrigation Canal

The Greenfield Irrigation District in Fairfield, Montana provides much needed water to area farmers, whose crops would otherwise suffer due to the region's lack of rain. After losing water in earthen and cracked, concrete canals, the district decided to rehabilitate an 8,21 km (5.1 miles) section of canal.

This rehabilitated stretch, referred to as GM47-11, serves several hundred acres of land and supplies water to Freezeout Lake, which is owned by the Montana Fish, Wildlife and Parks Department.

The GM47-11 project was funded in part by a grant from the Natural Resources Conservation Service. To abide by NRCS regulations, the landowners hired a technical service provider (TSP) to serve as a private engineer. After careful consideration, the TSP specified 1,1 mm (45 mil) Firestone GeoGard™ EPDM for the project's lining material.

While durability, life expectancy, warranty, expansion and contraction characteristics, and puncture resistance were all considerations in the liner selection, cost was the overriding factor.

Quick Facts

Project scope:

- Rehabilitate a 8,21 km (5.1 miles) sub-lateral branch of canal
- Maintain the canal's service to area's local farms
- Ensure the source water reaches farm and a local lake

Challenges faced:

- Abide by regulations of Natural Resources Conservation Service (NRCS)
- Battle high winds, permeable soil and high water tables during installation
- Accommodate water flows of up to 0,85 m^3/sec (30 cf/sec.)

Solutions:

- Excavate 1 m - 1,2 m (3-4 ft.) deep and 7,50 m - 9 m (24 ft. - 29 ft.) wide
- Install 74.300 m^2 (800,000 sq. ft.) of 1,1 mm (45 mil) Firestone GeoGard™ EPDM
- Install cross trenches and cleanouts at intervals along the canal

ISO 14001
EMS 52644

Greenfield Irrigation District • Fairfield, MT - USA

"We are a non-profit organization and this is a tax-based project," commented Bob Hardin, manager of the Greenfield Irrigation District. "The cost of concrete has escalated. Products like Firestone GeoGard™ EPDM are the most cost-effective solution for this type of project, especially given the material's life expectancy."

Irrigation district personnel served as the installers. Once they excavated the canal, a geotextile was laid into the bed. Next, the 9,15 m (30 ft.) wide by 61,00 m (200 ft.) long EPDM panels were unrolled down the center of the canal and unfolded up the sides. The panels were seamed together using Firestone's QuickSeam™ Tape System. The edges of the liner were then placed into an anchor trench and covered with dirt to secure them.

Experienced in this type of application, the Firestone representative recommended an additional step: installing cross trenches and cleanouts at regular intervals down the length of the canal. "Firestone suggested we do this because of the sheer length of the channel and the force at which water travels through it", Hardin stated. "The cross trenches more firmly anchor the membrane and serve as a means for maintaining a consistent flow during heavy rain or thawing events."

The cross trenches were prepared by digging across the canal at 152 m (400 ft.) intervals. Each trench is 0,60 m (2 in.) deep by 1,20 m (4 in.). The liner was placed across the trenches and anchored into place with large rocks.

Everyone involved with the Greenfield project is pleased with the results. "There is no doubt in my mind that this is the easiest and most cost-effective way to line a canal and conserve water," Hardin said. "We will definitely be lining additional sections of the canal network with Firestone GeoGard™ EPDM."

Firestone
BUILDING PRODUCTS
NOBODY COVERS YOU BETTER.™

Europe, Middle East & Asia
Ikaroslaan 75 | 1930 Zaventem | Belgium | Phone +32(0)2 711 44 50 | Fax +32(0)2 721 27 18 | info@fbpe.be | www.firestonebpe.com

Canada
(888) 292.6265
Info@firestonesp.ca
www.firestonesp.ca

US
(0800) 428 4442
Info@firestonesp.com
www.firestonesp.com

Latin America & Caribbean
(305) 471-0117
Info@firestoneplatincaraibe.com
www.firestoneplatincaraibe.com

8.4 The Blue Dog State Fish Hatchery, Waubay, SD, USA

The Blue Dog State Fish Hatchery • Waubay, SD - USA

Fish Hatchery uses Firestone GeoGard™ EPDM to fix leaking ponds

The Blue Dog State Fish Hatchery, owned by the State of South Dakota, is an existing 25-year-old aquaculture facility in Waubay, South Dakota. Faced with leaking ponds and subsequent maintenance issues, the state determined the ponds needed to be lined.

The site consisted of 38 unlined ponds, split into two regions. The northern ponds were installed into the low-permeability in-situ soils of the region, and performed adequately. The western ponds were constructed using embanked soil materials compacted into place. Water levels in these ponds were difficult to maintain and efforts to redirect flooding with drains and pipe trenches were unsuccessful.

When reviewing lining options, state officials considered PVC (buried), EPDM (exposed) and fPP-R (exposed) geomembranes.

In the end the state decided to go with Firestone GeoGard™ EPDM because of its large panels (up to 930 m²), (10,000 sq.ft.) membrane flexibility, durability and compatibility with fish.

Quick Facts

Project scope:

- 25-year-old aquaculture facility with 38 unlined ponds
- 21 ponds constructed with embanked soils compacted into place were leaking
- State officials considered PVC, EPDM and fPP-R membrane options

Challenges faced:

- Impact of lining material on safety of fingerlings
- Controlling oxygen levels and food materials; maintaining constant water volume

Solutions offered by:

- Removal and screening of riprap on the side slopes
- Add 7 cm (3 in.) layer to serve as substrate for geomembrane
- Installation of 111.500 m² (1,200,176 sq.ft.) of 1,1 mm (45 mil) Firestone GeoGard™ EPDM

BSI REGISTERED
ISO 14001
EMS 85828

The Blue Dog State Fish Hatchery • Waubay, SD - USA

Exceptional conformance, elongation and lay flat characteristics are some of the additional benefits that led to the decision to use Firestone GeoGard™ EPDM.

Because of these characteristics, the material did not require extra folds at installation to compensate for the expansion and contraction that takes place during normal operating conditions. This led to savings in material costs, but more importantly, it was better for the fish, as fingerlings can get caught in material folds and die.

Ease of repair was another consideration. Should the membrane ever sustain damage, whether by wildlife or mechanical means, it can easily be repaired, by hatchery personnel, without any special tools or equipment.

The work performed included the removal and screening of riprap on the side slopes, stripping of vegetation and organic material from pond bottoms, regrading of each pond's subgrade, installing an underdrain/detection piping network, installing a 7 cm (3 in.) sand layer and the geomembrane, attaching the geomembrane to concrete harvest structures, and piping installation. In total, more than 111.500 m^2 (1,200,000 sq.ft.) of Firestone GeoGard™ EPDM was installed in 21 ponds.

With Firestone GeoGard™ EPDM in place, the hatchery now has better control over the water's oxygen content, food material will no longer be lost into the soil, and there will be reduced water contamination because the liner eliminates contact with the substrate. The geomembrane will make it easier to harvest small fish, because it has a smooth surface and does not have flaps at the seams. Also, by maintaining a more constant water volume, the hatchery will be able to administer more precise dosages of medication to the fish.

Firestone
BUILDING PRODUCTS
NOBODY COVERS YOU BETTER.™

Europe, Middle East & Asia
Ikaroslaan 75 | 1930 Zaventem | Belgium | Phone +32(0)2 711 44 50 | Fax +32(0)2 721 27 18 | info@fbpe.be | www.firestonebpe.com

Canada
(888) 292.6265
Info@firestonesp.ca
www.firestonesp.ca

US
(0800) 428 4442
Info@firestonesp.com
www.firestonesp.com

Latin America & Caribbean
(305) 471-0117
Info@firestoneplatincaraibe.com
www.firestoneplatincaraibe.com

8.5 Stovall Landfill, Prescott, Arkansas, USA

Stovall Landfill • Prescott, Arkansas - USA

The first EPDM geomembrane Cap, permitted in the U.S., features Firestone GeoGard™ EPDM

When Stovall Landfill, Prescott, Arkansas, reached its capacity, the owners implemented a closure plan to minimize water infiltration, control erosion and protect the high groundwater table from leachate infiltration. The landfill covers 4,6 ha (11.4 acres) and contains approximately 360.000 m³ (3,875,000 sq.ft.) of nonhazardous, Class 3 commercial/industrial solid waste generated by a nearby manufacturing facility.

The landfill closure design team specified a cap system based on an ethylene propylene diene terpolymer (EPDM). After evaluating several options, a Firestone GeoGard™ EPDM was chosen based on its quality and performance history in both exposed and buried containment applications in the U.S. and Europe.

Requirements specified in U.S. Regulation were fulfilled by using the Firestone GeoGard™ EPDM.

Prior to landfill cap installation, the earthwork contractor placed a layer of sandy clay over the waste and graded the soil to provide a smooth surface. However, two major rainstorms damaged the subgrade, causing ponding and erosion. A post-storm survey revealed that the site required additional subgrade preparation to address problems with wet soil, ruts, loose rocks, excess debris, exposed waste and ponding surface water.

Quick Facts

Project scope:

- Create a successful landfill closure, after the landfill's 20 years of operation
- Place the first EPDM geomembrane landfill cap permitted in the U.S.
- Test soil placement and mobile machinery effects on the geomembrane

Challenges faced:

- Ensure project abides by regulations stipulated by government agencies
- Repair inadequate subgrade caused by a variety of weather issues incurred during installation
- Securely cover 4,6 ha (11.4 acres) with varying depths, ranging from 6 m to 8 m (20 ft. to 25 ft.)

Solutions:

- Firestone GeoGard™ EPDM chosen for its durability, ease of installation, tensile load strain and puncture resistance
- Layering of 30 cm (12 in.) of sandy clay over the waste to provide a level subgrade for the cap installation
- Install large, highly flexible EPDM panels, utilizing Firestone QuickSeam™ Tape at seams

ISO 14001
EMS 52644

Stovall Landfill • Prescott, Arkansas - USA

Considering the resulting poor subgrade conditions and the potential for future subsidence, the tensile load strain and puncture resistance of the EPDM geomembrane were significant factors in its selection and installation. The specified material has a working strain of more than 500 percent (ASTM D 882), which enables it to conform and resist puncture forces both during the installation process and throughout the service life of the landfill closure system.

The necessary subgrade adjustments were made, prior to geomembrane placement. Then, large EPDM panels, measuring 15,25 m (50 ft.) wide and 61,00 m (200 ft.) long, were installed. Field seams, used to join the geomembrane panels, were created using Firestone QuickSeam™ Tape Among the advantages of this technology is the ability to field-fabricate dependable, quality seams without transporting specialty equipment to the remote landfill site or the need for utilities.

Faced with high winds at the time of the installation, the geomembrane's flexibility was a significant advantage. It allowed the geomembrane to conform closely to the subgrade, providing increased surface friction to resist wind uplift.

"Our crew witnessed dust clouds 30 m (100 ft.) wide by 9 m (10 ft.) high blowing across the landfill, but the wind didn't delay geomembrane placement," said Timothy Gilligan, director of operations for Colorado Lining International, Parker, Colorado, geomembrane installation contractor for the project. "Once the panels were in place, the material laid flat despite the wind. When the dust cleared, we were able to seam the panels quickly."

Landfill closure specifications required testing to ensure the integrity of the field fabricated seams on site. Advanced Terra Testing, Lakewood, Colorado, the company responsible for on-site quality assurance, conducted testing, which verified the EPDM geomembrane cap surpassed all the peel strength, initial bond strength and shear tests.

Closure specification plans also included creating geomembrane test pads, which had a D-7 Caterpillar track-type bulldozer rolling over it to layer on sand, helping determine if construction equipment would damage the geomembrane. Another test was conducted to determine if the vehicles hauling the cover soil over the test pads would damage the seams. Advanced Terra Testing confirmed that the geomembrane and seams were not damaged by the action of the construction vehicles. The Stovall Landfill remained under the jurisdiction of the State of Arkansas for a required two-year period, with the last inspection in 2002 showing the geomembrane cap in great condition. Today, due to closely monitored closure procedures that are in full compliance with all government stipulations, the site is barely distinguishable from the lush fields nearby.

Firestone
BUILDING PRODUCTS
NOBODY COVERS YOU BETTER.™

Europe, Middle East & Asia
Ikaroslaan 75 | 1930 Zaventem | Belgium | Phone +32(0)2 711 44 50 | Fax +32(0)2 721 27 18 | info@fbpe.be | www.firestonebpe.com

Canada
(888) 292.6265
Info@firestonesp.ca
www.firestonesp.ca

US
(0800) 428 4442
Info@firestonesp.com
www.firestonesp.com

Latin America & Caribbean
(305) 471-0117
Info@firestoneplatincaraibe.com
www.firestoneplatincaraibe.com

8.6 Behavior of an EPDM geomembrane 18 years after its installation in the el boqueron reservoir (Tenerife, Spain)

Manuel BLANCO[1], Nathalie TOUZE-FOLTZ[2], Bernat AMAT[3], Francisca CASTILLO[1] and Escolástico AGUIAR[4]

ABSTRACT – The purpose of this study is to evaluate the durability of an EPDM geomembrane installed 18 years ago in the water reservoir of El Boquerón (Canary Islands, Spain). To do so, samples were regularly taken from different places of the water reservoir. Samples were laboratory tested as follows: foldability at low temperature, static and dynamic puncture resistance, Shore-A hardness, tensile strength and elongation at break, seam strength and microscopic techniques. The obtained results confirm the EPDM geomembrane is still in good condition.

Keywords: Geomembrane, Waterproofing, EPDM, Durability, Water Reservoir.

8.6.1 Introduction

In its report published in Paris in 1991, the International Commission of Large Dams indicated that the first geomembrane used in a hydraulic project was made from butyl synthetic rubber (International Commission of Large Dams, 1991). It was used in 1959 to waterproof the Kualapuu reservoir in Holokai (Hawaii).

In Spain, it was also this type of synthetic rubber which was originally used to waterproof water reservoirs. The use of this product began in the Ibi region, on the Mediterranean coast and extended across the entire country up to the Portuguese border, where Azud (small scale dam) in Matavacas (Huelva) was waterproofed in 1974 (Cea et al., 2003; Blanco et al., 2010).

Butyl rubber is a macromolecule which presents in its structure a large number of double bonds, of which the "TT" (trans-trans) chains are likely to be attacked by electrophilic reagents such as ozone and, consequently butyl geomembrane may experience significant degradation. The researchers looked for a synthetic rubber which was not susceptible to this phenomenon and they found this in the EPDM terpolymer. This macromolecule is comprised of three monomers: ethylene, propylene and diene, the latter being present in maximum concentrations of 5%. The first diene used was 1,3-butadiene which was then replaced by other types such as cyclopentadiene, considerably improving the initial performances (Davis et al., 1998).

Among the numerous hydraulic projects existing in Spain, this study decided to focus on El Boquerón reservoir, waterproofed using an EPDM geomembrane, whose evolution over time is presented in this article.

8.6.2 The reservoir

The El Boquerón reservoir is located in the area of Valle de Guerra, in the municipality of La Laguna in the north of the island of Tenerife (Figure 1 and Figure 2). The Canary Islands are located in a geographical area where the maximum UV index in clear weather (Figure 3) is considered as high (index between 6.5 and 8.5). The technical characteristics of the reservoir are presented in Table 1.

1 CEDEX (Laboratorio Central de Estructuras y Materiales [Central Laboratory of Structures and Materials]), Ministries of Infrastructure and Agriculture and Food and Environment, Madrid, Spain.
2 IRSTEA, Antony, France
3 Firestone Building Products, Zaventem, Belgium
4 BALTEN, Santa Cruz de Tenerife, Spain

Figure 1: Geographical location of the reservoir

Figure 2: El Boquerón reservoir

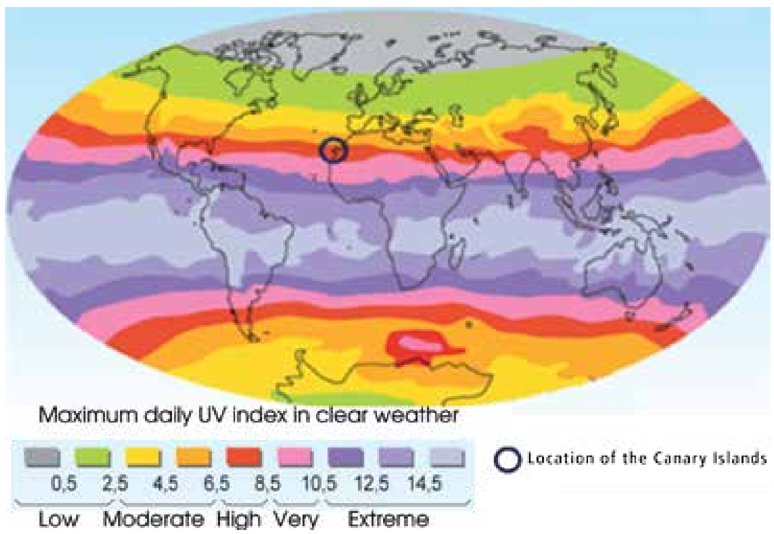


Figure 3: Maximum daily UV index in clear weather (Bournay E., UNEP/GRID-Arendal)

Table 1: Technical characteristics of the reservoir	
Location	**La Laguna (Tenerife)**
Capacity	51.747 m³ (1,827 cu. ft.)
Height	11.0 m (36 ft.)
Altitude	376.7 m (1,236 ft.)
Perimeter	340.7 m (1,118 ft.)
Thickness of the EPDM geomembrane	1.50 mm (60 mil)
Area of the geomembrane laid	8.991 m² (97 sq.ft.)
Year of installation	1992

8.6.3 Feedback

8.6.3.1 Initial Characteristics

Table 2 presents the initial characteristics of the EPDM geomembrane installed in the El Boquerón reservoir. The initial physical properties are compliant with the values declared on the manufacturer's technical data sheet. This data is consequently used as reference values for assessing the evolution over time of EPDM geomembranes.

8.6.3.2 Table 2: Firestone GeoGard™ 1.1 mm (0.045 in.) and 1.5 mm (0.060 in.) Technical Specifications

Property	Test method	Units	ASTM D-7465		ASTM D-7465	
			1.14 mm (0.045 in.)		1.52 mm (0.060 in.)	
			SI	Eng	SI	Eng
Specific Gravity	ASTM D-792	gm/cc	1.1	1.1	1.1	1.1
Unit Weight	ASTM D-751	kg/m (lb./ft.)	1.4	0.29	1.8	0.40
Thickness, Type 1	ASTM D-412	mm (in.)	1.02 +10/-10%	.045 +10-10%	1.52 +10/-10%	.060 +10-10%
Tensile Strength, Die C min	ASTM D-412	MPa (psi)	9.0	1305	9.0	1305
Ultimate Elongation, Die C min	ASTM D-412	%	300	300	300	300
Tear Resistance, Die C	ASTM D-624	kN/m (lbf/in)	26.27	150	40.28	230
Puncture Resistance	ASTM D-4833	N (lbs.)	133	30	181.56	43
Shore A Durometer	ASTM D-2240		65-10	65-10	65-10	65-10
Resistance to Ozone 7 days/100 @ 37.8° C (150° F) 50% ext.	ASTM D-1149		No Cracks	No Cracks	No Cracks	No Cracks
Multiaxial Elongation	ASTM D-5617	%	100	100	100	100
Oven Aging At 116° C (240° F) for 670 hours	ASTM D-573					
Tensile strength Die C	ASTM D-412	MPa (psi)	8.3	1205	8.3	1205
Ultimate elongation, Die C	ASTM D-412	%	200	200	200	200
Tear Resistance,Die C	ASTM D-624	kN/m (lbf/in)	21.9	125	37.32	213
Xenon Arc for 5040 kJ/(m².nm) @ 340 nm @ 80°C	ASTM G-155/G-151					
Visual Inspection 7X	ASTM D-518		Pass	Pass	Pass	Pass
No cracks or crazing bent loop @10% strain						
Brittleness Point	ASTM D-2137		-45°C	-49°F	-45°C	-49°F
Water Resistance weight after immersion 166 hrs @ 70° C (158° F)	ASTM D-471	%	+8,-2	+8,-2	+8,-2	+8,-2
Water Vapor Permeability (max.)	ASTM E-96	Perm-mils	2.0	2.0	2.0	2.0
Linear Dimensional Change,max	ASTM D-1204	%	+/- 1.0	+/- 1.0	+/- 1.0	+/- 1.0
Chronic Toxicity Screening	EPA/600/4-89/ 001 ASTM E-729	Method 1000.0	passes passes	passes passes	passes passes	passes passes

8.6.3.3 Evolution over time

After the EPDM geomembrane was installed, samples were taken regularly and tested in a laboratory. Unless otherwise indicated, the values presented refer to samples taken from the north banks of the reservoir (bank most exposed to sunlight, and consequently most exposed to high UV and temperatures).

As far as the foldability test at low temperature is concerned (-55ºC) (-67ºF), no cracks or fissures were observed in the flexing area on the samples analysed after 18 years of exposure. Similarly, during the dynamic puncture test, no fissures or any other type of degradation was noted in the impact area when the plunger was dropped from a height of 350 mm (14 in.).

8.6.3.4 Tensile characteristics

Figure 4 shows the evolution in tensile strength at break, stress at 300% elongation and elongation at break over the 18 years since installation of the EPDM geomembrane. It can be seen that the tensile strength has not changed significantly, while elongation at break decreases noticeably. It can also be seen that the force necessary to obtain the same 300% elongation increases over time.

We note that after 18 years' exposure, the elastic elongation of the EPDM geomembrane is up to 190% greater (remains elastic to breaking point), which is very high in comparison with the majority of theromoplastic geomembranes. This data is significant as the permissible elongation determines the ability of the geomembrane to adapt to differential settling and irregularities in the soil and therefore defines its tensile strength in actual conditions.

The decrease in elongation at break and increase in stress at 300% elongation in the period is explained by the fact that, in the case of EPDM, during the oxidation phenomenon (induced by the temperature and UV exposure), the combination reactions of the carbon chains (cross-linking) has a prevails upon the cleavage reaction of the principal carbon chain (Kumar et al., 2004). Consequently, a decrease in molecular mobility and an increase in molecular mass can be seen (Kumar et al., 2004). These reactions are similar to the process of curing used during EPDM geomembrane production.

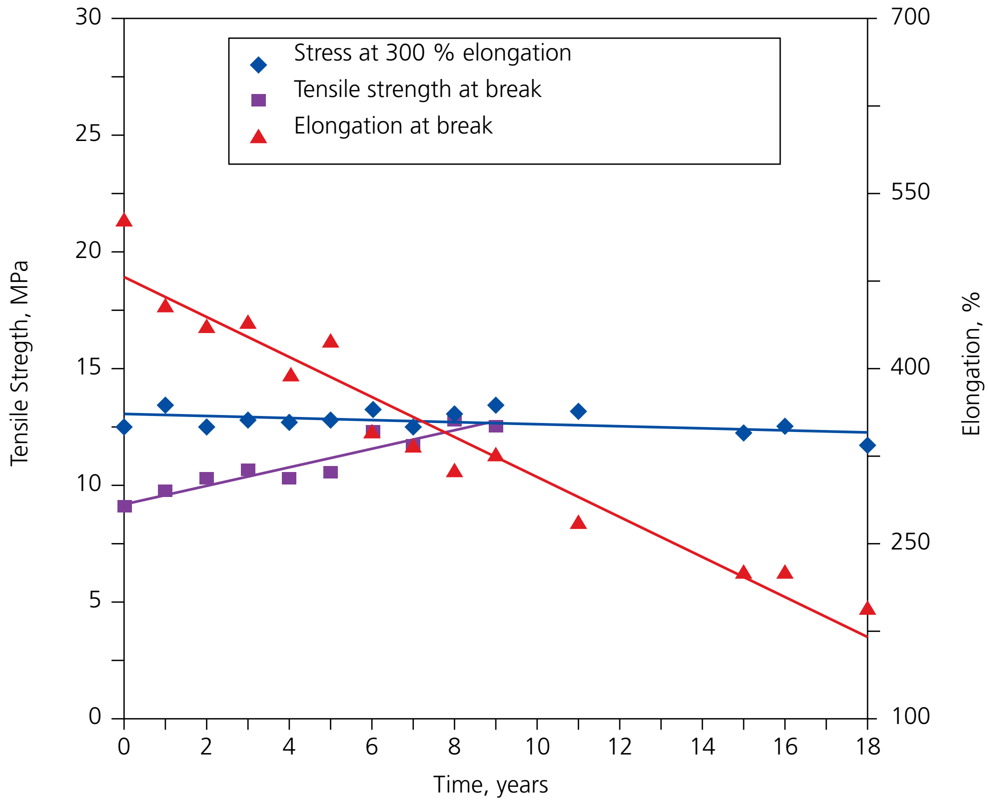


Figure 4: Evolution over time in tensile strength at break, stress at 300% elongation and elongation at break.

8.6.3.5 Shore A hardness

The Shore-A hardness value has increased over time as shown in Figure 5. The increase in the Shore-A hardness can be explained by the decrease in molecular mobility as explained in paragraph 3.2.1.

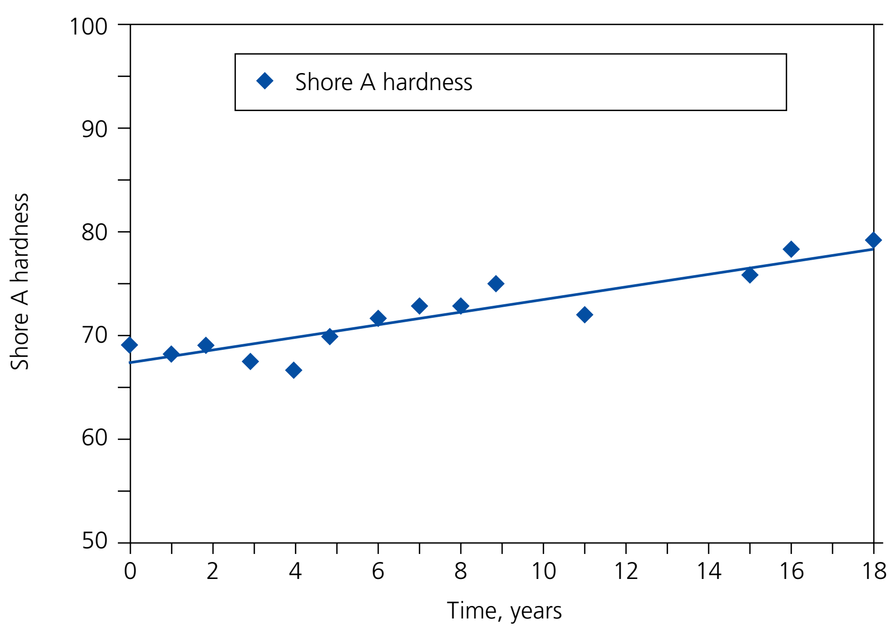


Figure 5: Change in the Shore A hardness over time

8.6.3.6 Resistance to puncture

Figures 6 and 7 respectively present the static puncture resistance and the distance travelled by the plunger before perforation. The distance travelled by the plunger before perforation is a measurement which allows for the evaluation of the resistance to puncture in actual conditions as it gives an idea of the adaptability of the geomembrane to the soil conditions. The resistance to puncture increases over time, given the increase in the degree of cross-linking of the geomembrane (the same phenomenon that explains the increase in stress at 300%). On the other hand, the distance travelled by the plunger before perforation decreases accordingly given the decrease in molecular mobility (the same phenomenon that explains the decrease in elongation at break). It should be noted that this last value (27 mm (1.1 in.) after 18 years) remains very high and well above the measurements usually recorded on the vast majority of thermoplastic geomembranes used for waterproofing (Blanco et al., 2012).

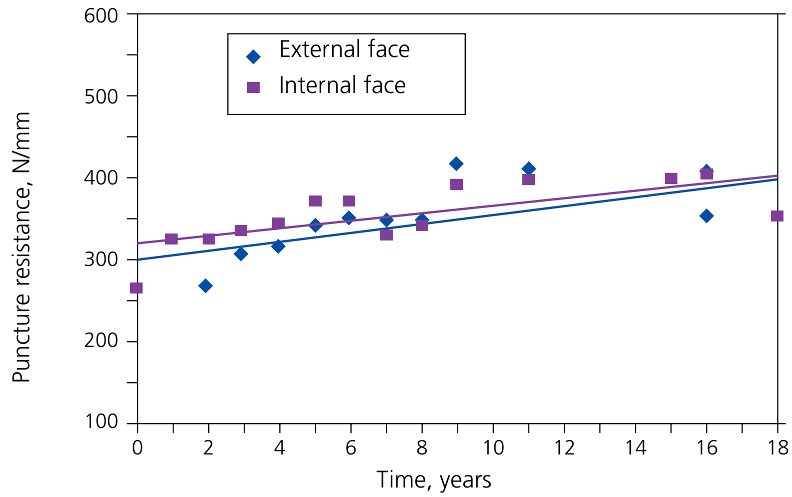


Figure 6: Evolution in the resistance to static puncture over time

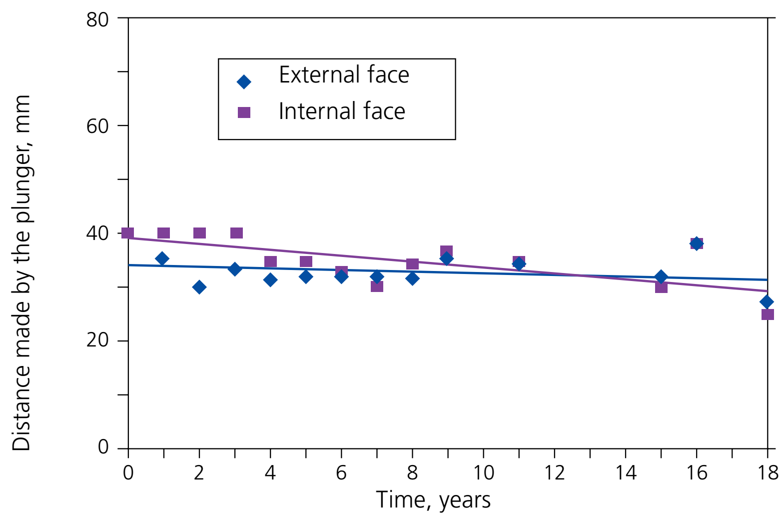


Figure 7: Evolution of the depth of the plunger before perforation over time

8.6.3.7 Seam resistance

After 18 years of exposure, the value for shear resistance of seams is 645 N/50 mm (72.5 lbf/in.). Figure 8 illustrates that, during the first 8 years, the measurements for peel resistance of seams were relatively variable. The measurements taken in the following 10 years are more consistent and show a slight tendency to increased peel resistance.

The variability of peel measurements is explained in part by the seaming method used at the time that consisted of applying a butyl based glue for which uniform application was not guaranteed. This is one of the reasons why, for a number of years already, butyl glue has been replaced by other systems such as self-adhesive tape which ensures better quality consistency.

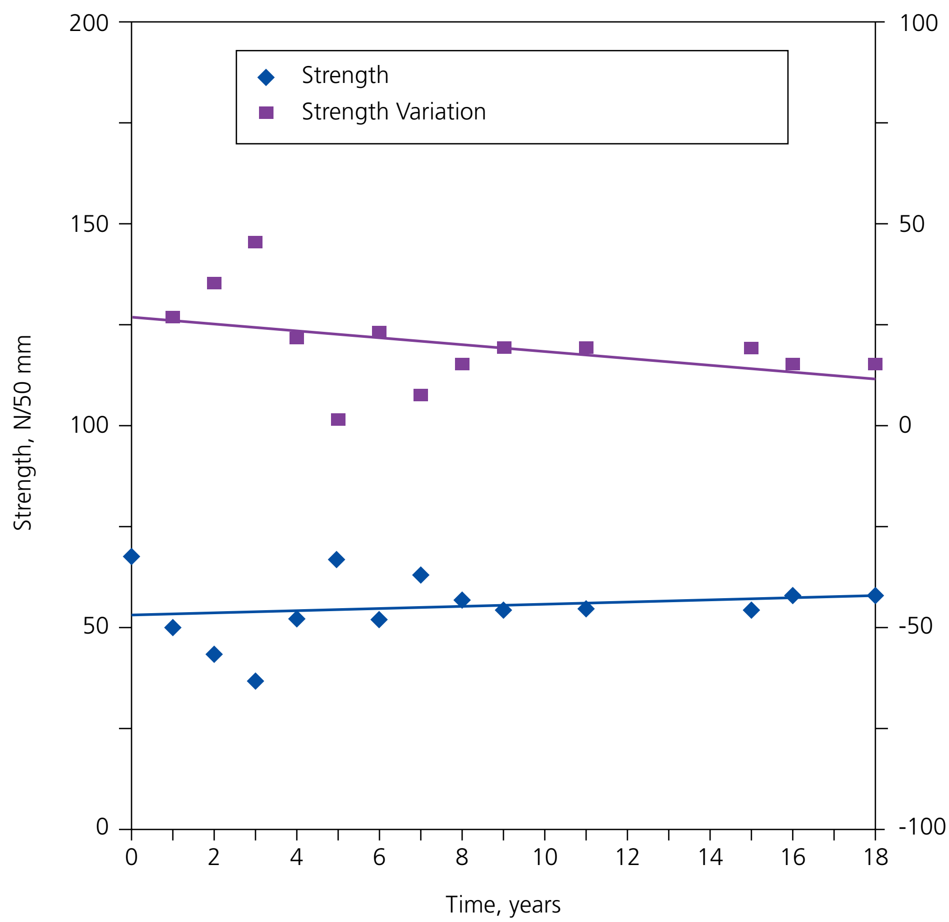


Figure 8: Evolution of peel resistance of seams over time

8.6.3.8 Microscopic analysis

Observations under reflection optical microscopy (magnified 40 times) and by scanning electron microscopy (magnified 90 times) have been conducted according to the conditions documents in the literature (Soriano et al., 2012) for the purpose of evaluating the condition of the geomembrane surface 18 years after installation (figure 9).

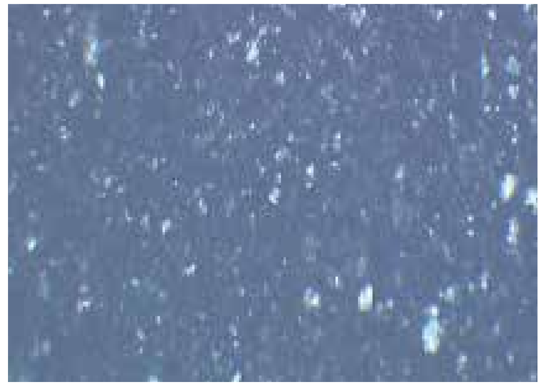
If we take into account the condition of the surface of an EPDM geomembrane that has not been exposed (Blanco et al., 2011), we can see under reflection optical microscopy that after 18 years, the internal and external surfaces of the geomembrane seem to be in a good condition, with the internal surface presenting the best state of condition.

The scanning electron microscopy shows that eighteen years after installation of the geomembrane, we can see the presence of a microporus structure confirming a slight degradation of the internal surface of the geomembrane. The external surface also presents some microfissures.

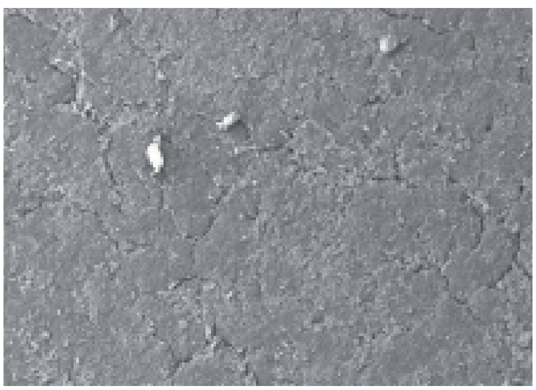
These microfissures seem relatively superficial and do not affect the mechanical resistance of the geomembrane, as proven in the evolution of the resistance at break and puncture examined above. This is explained by the highly cross-linked network of the EPDM geomembrane which distributes loads evenly across all carbon chains and limits the diffusion of potentially degrading elements (Scott, 2002).

These observations are to be compared with the results of the study on the surface condition conducted by Soriano et al. (2012) looking at different types of geomembranes. This study concluded that the impact of UV exposure is visible on these organic materials and that it is more significant on thermoplastic geomembranes than thermostable geomembranes such as synthetic rubbers (Soriano et al., 2012).

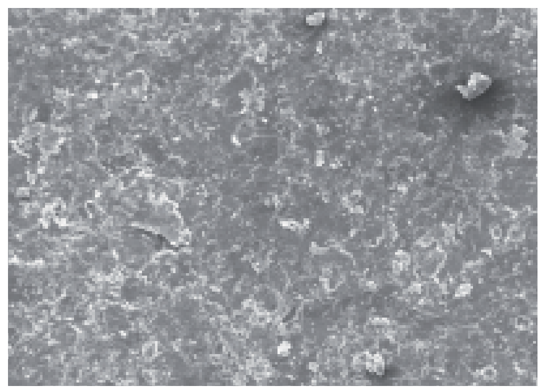
a)



b)



c)



d)

Figure 9: Microphotographs (x40) of the external surface (a) and internal surface (b) taken using reflection optical microscopy. Microphotographs (x90) of the external surface (c) and internal surface (d) - 18 years after installation, taken using scanning electron microscopy.

8.6.3.9 Influence of the sampling area on samples

For the purpose of knowing the condition of the EPDM geomembrane in other areas apart from the north bank, samples were also taken from the bottom (less exposed, due to protection from water) and the bank on the south side of the reservoir. The results obtained are presented in table 3.

Regardless of their orientation and their degree of exposure, all samples analysed after 18 years show a similar evolution in their mechanical properties. It is systematically observed that tensile strength is more or less constant, that elongation at break and the distance travelled by the plunger before perforation decreases significantly and that Shore-A hardness and resistance to static puncture increases over time. The results also show that the more apparent signs of ageing are observed on the samples taken from the north bank; the area that receives the most significant amount of solar radiation.

Table 3: Characteristics of the geomembrane according to exposure 18 years after installation				
Characteristics	**Reference**	**Bank**		**Bottom**
		North	**South**	
Tensile Strength, (MPa)	12.6 (1,827 psi)	11.6 (1,682 psi)	12.9 (1,870 psi)	10.0 (1,450 psi)
Elongation at break (%)	527	193	271	255
Resistance to puncture, (N/mm)	266 (2.35 lbf/in.)	351 (3.1 lbf/in.)	367 (3.25 lbf/in.)	371 (3.28 lbf/in.)
Depth of the plunger before perforation, mm	40 (1.5 in.)	27 (1 in.)	30 (1.1 in.)	34 (1.3 in.)
Shore A hardness	69	79	78	80
Seam resistance by tensile-shear (N/50 mm)	68 (7.6 lbf/in.)	58 (7.5 lbf/in.)	60 (7.5 lbf/in.)	45 (5 lbf/in.)

8.6.4 Conclusions

The results obtained during the periodic inspection of the EPDM geomembrane installed in the El Boquerón reservoir allows us to draw the following conclusions:

- Both foldability at low temperature (-55°C) (-67°F) and resistance to dynamic puncture showed no fissures, breaks or any other indication of degradation after conducting the tests, proving the good state of conservation of the EPDM geomembrane 18 years since its installation;
- The mechanical characteristics present tensile resistance that does not change significantly over the years; whereas elongation at break reduces significantly, a characteristic behaviour of thermostable materials, as a result of the increase in the number of links between carbon chains (cross-linking); elastic elongation is greater than 190% after 18 years' exposure, which is very high for a geomembrane; this last property provides important information on the ability of the geomembrane to adapt to differential settling and irregularities in the soil;
- The resistance to puncture and Shore A hardness measurements increase over time; this is a consequence of the increase in the level of cross-linking in the geomembrane which reduces molecular mobility; the distance travelled by the plunger before perforation, a measurement that allows us to evaluate the resistance to puncture in actual conditions, decreases over time; however, the value obtained after 18 years' exposure (27 mm) (1 in.) is greater than the measurement for the majority of thermoplastic geomembranes used in waterproofing;
- The shear resistance of the seams, testament to the quality of the seams, indicates that the seams between the panels are correct; the values for peel resistance of seams are relatively low and variable, given the use of an old seaming method which consisted of applying a butyl based glue to the seam area;
- The microphotographs taken by optical and scanning microscopy show a material in a good state of conservation; only micropores and some microfissures were detected but we note the complete absence of craters, fissures and micro-cracks;
- No significant differences in condition were observed between the samples taken from the bottom (covered by water) and the samples taken from the top of the banks (exposed to weather); the area most affected by ageing was the zone located on the north bank; given that the reservoir is located in the northern hemisphere, the north bank is the one facing the equator and consequently receives the largest amount of solar radiation (UV and temperature) which is responsible for the degradation of organic material.

After 18 years of exposure to demanding weather conditions (high temperature and UV rays), the EPDM geomembrane used in the El Boquerón water reservoir has retained the mechanical properties which are still well suited to this use.

8.6.5 Bibliographic References

- Blanco M., Aguiar E., Castillo F., Soriano J., Noval A.M., Touze-Foltz N., Pargada L., Rico G., Aguiar E. (2011) Comparative study of three different kinds of géomembranes (PVC-P, HDPE, EPDM). 5th European Geosynthetics Congress. Volume 2. 25 030 BESANCON.
- Blanco M., Aguiar E., García F., Vara T., Soriano J., Castillo F. (2011) État de la géomembrane en EPDM de la retenue d' "El Golfo" dans l'île d'El Hierro (Îles Canaries). Proc. 8eme Rencontres Géosynthétiques 283-293. Tours.
- Blanco M., Castillo F., García F., Soriano J. (2010) Las geomembranas sintéticas en la rehabilitación y mantenimiento de paramentos de presas. II. In Romeo et al. (eds.). Dam Maintenance and Rehabilitation Taylor & Francis Group: 335-341. London.
- Davis J. A., Hoff J. L., Kalwara J. J., Kane E. G. (1998) A review of EPDM Systems Development Proc. X International Congress: International Waterproofing Association: 263-274. Copenhague.
- de Cea J.C. de, Asanza E., Blanco M. (2003) Face Protection: Geomembranes Lining vs. Paint Coating. Proc. 21 International Congress on Large Dams. Montreal.
- International Commission on Large Dams. (1991) Watertigth Geomembranes for Dams. State of the Art Bulletin ICOLD Nº 78, Paris.
- Kumar A., Commereuc S.,Verney V. (2004) "Ageing of elastomers: a molecular approach based on rheological characterization"; Polymer Degradation and Stability 2004; 751-757.
- Scott G. (2002) "Degradable polymers, Principles and applications, 2nd edition"; Kluwer Academic Publishers; p.18-19.
- Soriano J., Blanco M., García M. A., Aguiar E., Leiro A., Rubín de Célix M., Mateo, B., Burgos J. (2012) Optical and scanning electron microscopy as advanced analysis methods to dertermine the condition of geosynthetic geomembranes. Proc. Eurogeo 5. Valencia.
- EN 1849-2. Feuilles souples d'étanchéité - Détermination de l'épaisseur et de la masse surfacique - Partie 2: feuilles d'étanchéité de toiture plastiques et élastomères. Comité européen de normalisation, Bruxelles.
- EN 495-5. Feuilles souples d'étanchéité Détermination de la pliabilité à basse temperature. Comité européen de normalisation, Bruxelles.
- EN 12691. Feuilles souples d'étanchéité - Feuilles d'étanchéité de toitures bitumineuses, plastiques et élastomères - Détermination de la résistance au choc. Comité européen de normalisation, Bruxelles.
- EN ISO 527. Plastiques Détermination des propriétés en traction. Comité européen de normalisation, Bruxelles.
- EN ISO 7619. Caoutchouc vulcanisé ou thermoplastique - Détermination de la dureté par pénétration - Partie 1: méthode au duromètre (dureté Shore). Comité européen de normalisation, Bruxelles.
- EN ISO 12236. Essai de poinçonnement statique (essai CBR). Comité européen de normalisation, Bruxelles.
- EN 12316-2. Feuilles souples d'étanchéité - Détermination de la résistance au pelage des joints - Partie 2: feuilles d'étanchéité de toiture plastiques et élastomères. Comité européen de normalisation, Bruxelles.
- UNE 104 317. Matériales sintéticos. Determinación del recorrido del punzón antes de la perforación en geomembranas sintéticas impermeabilizantes instaladas en balsas.

8.7 Condition of the EPDM geomembrane in the 'El Golfo' water reservoir at the island of El Hierro (Canary Islands)

Manuel Blanco[5], Escolàstico Aguiar[6], Florencio García[5], Tatiana Vara[6], Jesús Soriano[5] et Francisca Castillo[5]

ABSTRACT - In 1995 the water reservoir named "El Golfo" (Spain) was built and waterproofed with a synthetic rubber geomembrane of Ethylene-Propylene-Diene terpolymer (EPDM). The Central Laboratory of Structures and Materials CEDEX tested the initial properties of the geomembrane. Those data served as a basis to evaluate the membrane's durability. Periodically, samples were taken and tested as follows: tensile strength at break, elongation at break, tensile strength at 300% of elongation, Shore-A hardness, static and dynamic puncture resistance, foldability at low temperature, shear and peel resistance of seams, optical and electron microscopy.

Keywords: geomembrane, EPDM, durability, water reservoir

8.7.1 Introduction

Elastomer-based polymeric geosynthetic barriers (GBR-P) were the first of their kind to be used in waterproofing. The International Commission on Large Dams (ICOLD) considers that the first synthetic geomembrane used for hydraulic sealing was in 1959 in Holokai (Hawaï), in the Kualapuu reservoir; the membrane in question was made from butyl rubber (IIR) (International Commission of Large Dams, 1991). Similarly, in Spain, elastomeric materials were first used in the 1970s, at the Aiguamoix reservoir (Lleida/Lérida) and the small dam in Matavacas, "Azud de Matavacas" (Huelva) (Cea et al., 2002; Cea et al., 2003) which were waterproofed with this type of thermoset elastomer. The eastern region of Spain (Valencia area) was the pioneer in this experimental technique and has used butyl rubber to a great extent. Over time, this elastomer has been superseded by other polymeric membranes, like Ethylene Propylene Diene terpolymer (EDPM) synthetic rubber, which offer greater benefits in certain properties such as ozone resistance (Davis, 1998; Navarro, 1989).

CEDEX is in the process of conducting a large research project for the Directorate-General for Water of the Spanish Ministry for the Environment and Rural and Marine Affairs, BALTEN and the Cabildo Insular de La Palma (island governmental body). The number of reservoirs which are currently being monitored is far in excess of one hundred. These assessments with periodic sampling have enabled a greater understanding of the environmental behaviour of different types of geomembranes in use (Blanco, 2009; Blanco, 1998). EPDM geomembranes are being tested in Castile and León, Estremadura, Murcia, the Valencian Community and the Canary Islands.

This article tracks the behaviour over time of the EPDM geomembrane installed in the El Golfo reservoir (Frontera, El Hierro island). First of all, the initial characteristics of the new geomembrane were determined; this data was then used as comparative data. After installation, periodic tests were conducted on the installed material. The experimental methodology used is detailed in depth in the scientific bibliography (Blanco, 2008; Ministerio de Medio Ambiente, y Medio Rural y Marino, 2010). As referred to above, the following periodic tests were conducted:

- Thickness
- Shore A hardness
- Tensile characteristics
- Foldability at low temperature
- Dynamic puncture resistance
- Static puncture resistance
- Shear resistance of seams
- Peel resistance of seams
- Optical microscopy
- Scanning electron microscopy

5 CEDEX (Laboratoire central des structures et des matériaux), Madrid, Espagne
6 BALTEN (Retenues de Ténériffe), Ténériffe, Espagne

8.7.2 The reservoir

Today, the island of El Hierro could be regarded as the "sustainable island", in terms of energy. Apart from wind energy, water is crucially important. In 1995 the El Golfo reservoir was constructed (Fig. 1) which has the following characteristics:

- Capacity 145,000 m³ (1,560,800 sq. ft.)
- Height, m 13.0 m (42 ft.)
- Gradient of the slopes:
  - Internal 2.0/1
  - External 1.5/1
- Type of geomembrane EPDM
- Thickness 1.52 mm (60 mil)
- Area of membrane laid 20,000 m² (215,300 sq. ft.)
- Geotextile used PP at 600 g/m² (18 oz./sy.)
- Non covered membrane

Figure 1: Overall view of the El Golfo reservoir

8.7.3 Experiment

8.7.3.1 Initial Characteristics

Table 1 shows the initial characteristics determined on the polymeric geosynthetic barrier used in the El Golfo reservoir (Figure 2). It can be seen that the values obtained are greater than the minimum values required by current legislation (Ministerio de Medio Ambiente, y Medio Rural y Marino, 2010).

Table 1: Initial characteristics of the EPDM geomembrane		
Characteristics	**Standard**	**Value**
Average thickness, mm	EN 1849-2	1.6 (60 mil)
Shore A hardness	ISO 7619	64
Foldability at -55 °C	EN 495-5	No cracks
Resistance to dynamic puncture*, mm	EN 12691	>300 (>12 in.)
Tensile Strength, MPa	ISO 527	10.0 (1,450 psi)
Stress at 300% elongation, MPa	ISO 527	6.3 (914 psi)
Elongation at break, %	ISO 527	553
Static puncture		
• Resistance to puncture, load in N/mm - External surface - Internal surface	EN ISO 12236	206 (1.8 lbf/in) 280 (2.48 lbf/in)
• Displacement of the plunger before perforation, mm - External surface - Internal surface	UNE 104 307	38 (1.5 in.) 34 (1.3 in.)
Seam resistance, N/50 mm • Tensile-shear • Tensile-peel	EN 12317-2 EN 12316-2	475 (30 lb/in) 46 (8 lb/in)

(*) – Height of plunger drop

8.7.3.2 Evolution over time

Figure 3 shows the evolution of tensile characteristics over time. It can be noted that tensile strength does not vary significantly and that tensile strength at 300% elongation increases slightly. Elongation at break decreases significantly, as is usually the case with this type of elastomer.

Figure 4 shows the variation in Shore A hardness over twelve years. We can see a slight increase taking into account the greater rigidity of the macromolecular material.

Figures 5 and 6 illustrate the behaviour of static puncture resistance. The first figure shows the load values and the second shows the displacement of the plunger before perforation. The high value presented by this elastomer with regard to this last characteristic should be noted. Obviously, over time, the distance travelled by the plunger decreases.

Unlike the behaviour of some thermoplastics, and particularly plasticized polyvinyl chloride for which the geographical orientation has a major impact on the deterioration of the geomembrane (Soriano et al., 2010), with the EPDM geomembrane this effect is practically non-existent as shown in Table 2, according to the values obtained eleven years after the geosynthetic barrier was installed (Figure 7).

Stability in severe weathering conditions as detailed above is also confirmed by microscopy tests (Soriano et al., 2005; Soriano et al., 2006). Figure 9 shows how the geomembrane is in good condition after eleven years of exposure. This has been observed under reflection optical microscopy on the external surface magnified by 60 times. No difference can be detected regardless of the geographical orientation of the slope. Figure 11 presents the same samples observed under scanning electron microscopy, magnified 90 times. In this case, we see a uniform and homogeneous material with small microfissures and some isolated craters.

Figure 2: Appearance of the EPDM geomembrane

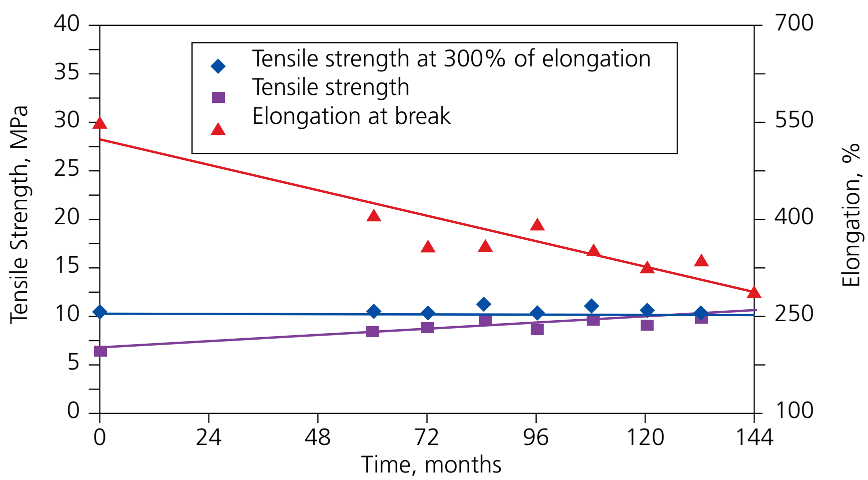


Figure 3: Evolution over time in tensile strength, tensile strength at 300% elongation and elongation at break.

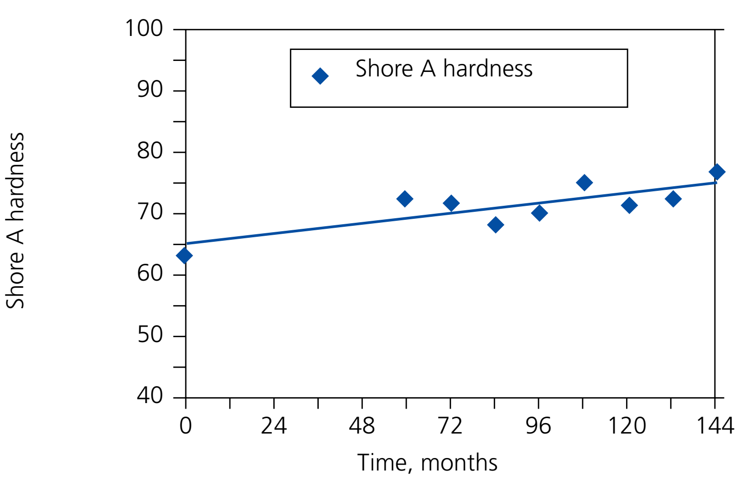


Figure 4: Change in the Shore A hardness over time

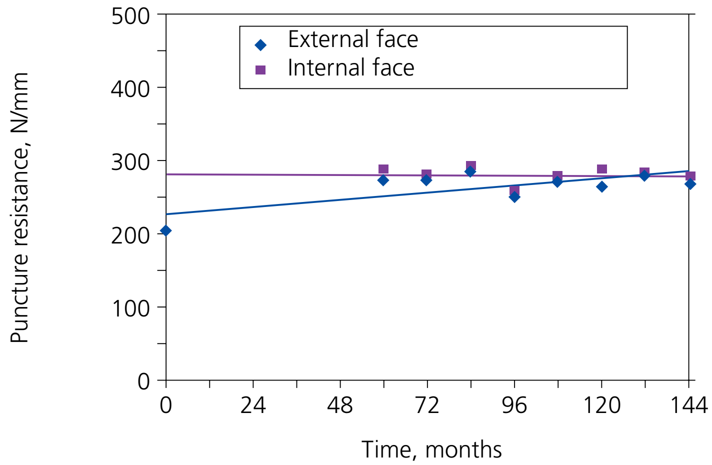


Figure 5: Evolution in the resistance to static puncture over time

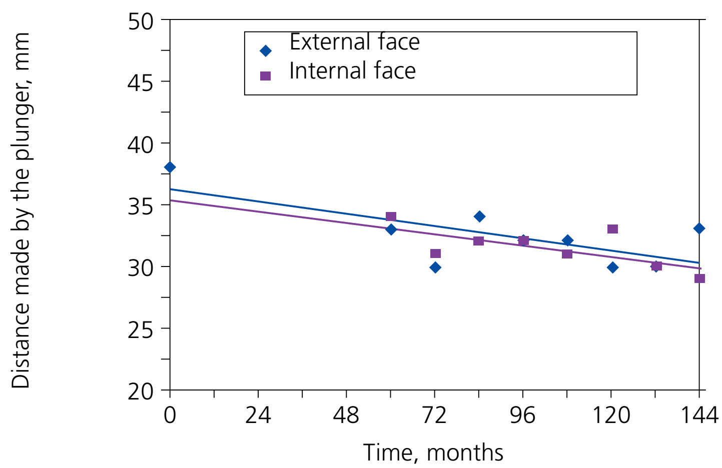


Figure 6: Evolution in the displacement of the plunger before perforation over time

Table 2: Characteristics of the geomembrane according to geographical orientation

Characteristics	Standard	Aspect of the slopes			
		North	South	East	West
Shore A hardness	ISO 7619	74	72	74	71
Foldability at -55 °C	EN 495-5	Good	Good	Good	Good
Resistance to dynamic puncture	EN 12691	Good	Good	Good	Good
Tensile Strength (MPa)	ISO 527	10.7	10.3	10.6	10.4
Stress at 300% elongation (MPa)	ISO 527	9.9	9.8	9.6	9.6
Elongation at break (%)	ISO 527	352	337	359	325
Resistance to puncture (N/mm) • External surface • Internal surface	EN ISO 12236	270 274	279 279	281 288	263 285
Displacement of the plunger before perforation, mm • External surface • Internal surface	UNE 104 307	32 31	30 30	32 32	30 33
Seam shear resistance (N/50 mm)	EN 12317-2	311	381	502	252

Figure 7: El Golfo Reservoir, Frontera (El Hierro)

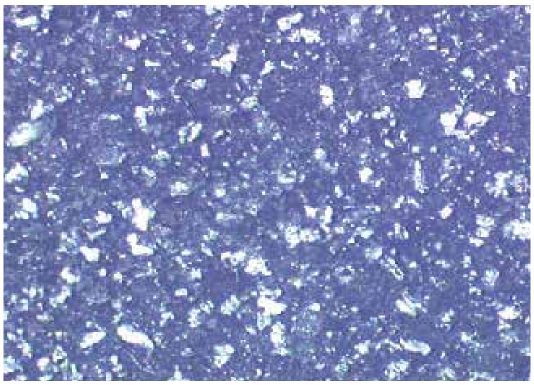
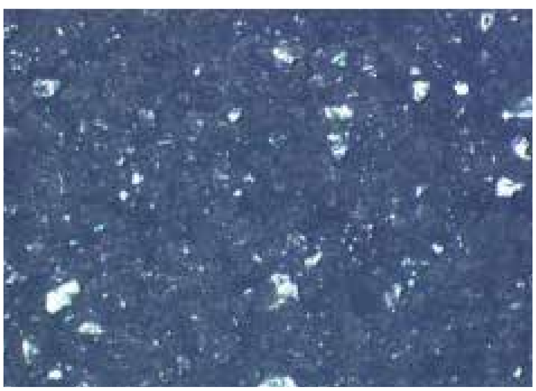
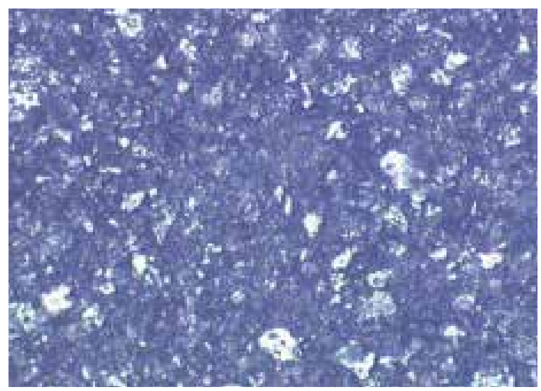


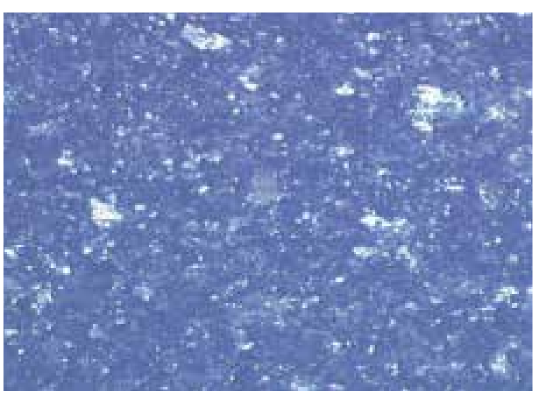
Figure 8: Microphotograph (x60) of the external surface of a new EPDM geomembrane taken using reflection optical microscopy



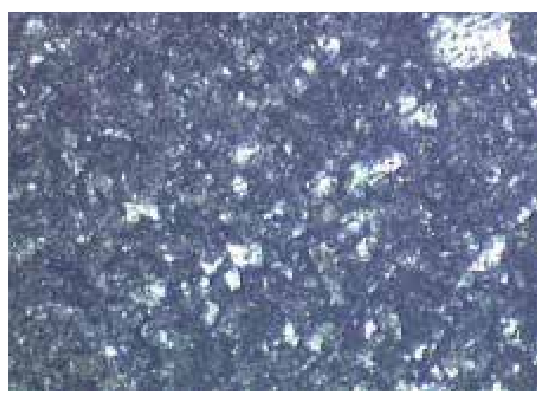
North



East



South



West

Figure 9: Microphotographs (x60) of the external surface of the EPDM geomembranes in their eleventh year of installation taken using reflection optical microscopy

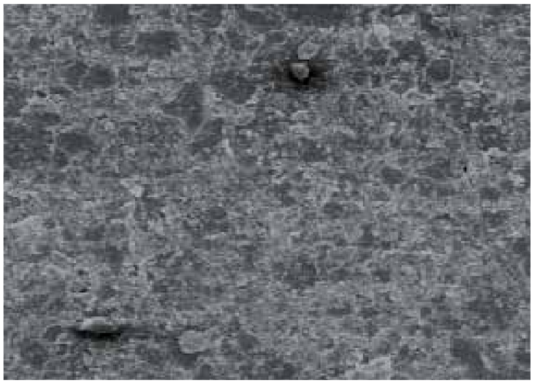
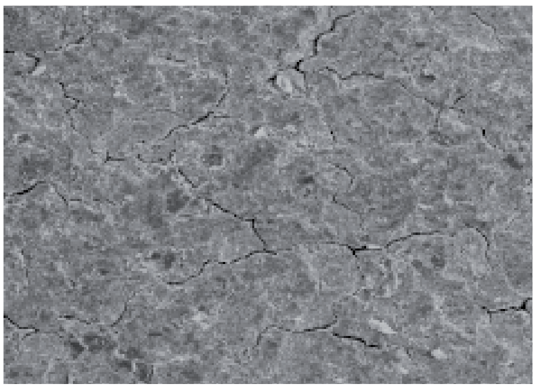
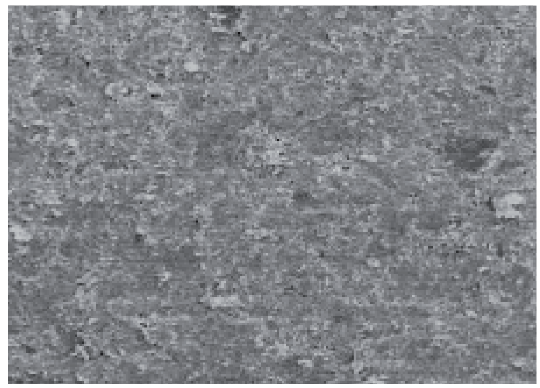


Figure 10: Microphotographs (x90) of the external surface of a new EPDM geomembrane taken using scanning electron microscopy

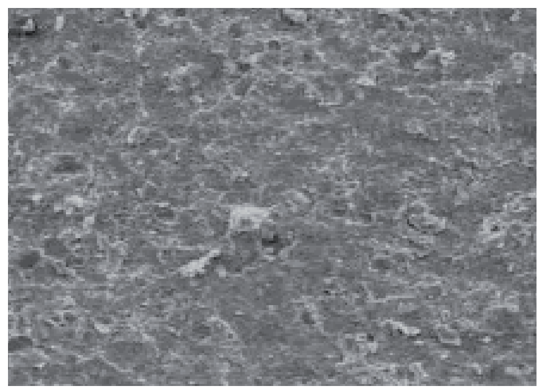


North



East

South



West

Figure 11: Microphotographs (x90) of the external surface of the EPDM geomembranes in their eleventh year of installation taken using scanning electron microscopy

8.7.4 Conclusions

- All the preliminary tests reached values which were greater than the minimum requirements stipulated by current legislation (Ministerio de Medio Ambiente, y Medio Rural y Marino, 2010) for polymeric geosynthetic barriers (GBR-P) made from Ethylene Propylene Diene terpolymer (EDPM) rubber. These initial values served as the basis for evaluating the behaviour of the geomembrane over time.
- The tensile strength at break has not changed significantly in the twelve years since the geomembrane was installed, while tensile strength at 300% elongation has seen a slight increase. The most notable result is the decrease in elongation at break, to be expected for this type of macromolecular material.
- The geomembrane samples taken over the course of the twelve years following installation, have achieved good

results wrt foldability at low temperature (-55 °C) (-67ºF), given that no cracks, fissures or any other sign of deterioration were observed in the folded area.

- The test for mechanical resistance to dynamic puncture was carried out by letting a 0.5kg (1.1 lbs) plunger fall onto the samples. The plunger had a domed end, 12.7 mm (0.5 in.) in diameter and was dropped from 300 mm (12 in.); the geomembrane did not show any perforation in the impact zone, as proven by the subsequent watertightness test (UNE 104 308). It was noted that this property improved over time, given that it was possible to drop the plunger from a height of 500 mm (20 in.) without any perforation being caused. This attribute is a result of the vulcanization process of the polymer.
- The resistance to static puncture shows relatively high load values for rubber compared to the minimum requirements for rubber as per the old standard UNE 104 308. However, it is the distance travelled by the plunger before perforation which determines whether the material is in good condition; in this test the studied material performs excellently.
- The reflection optical microscopy shows the non covered geomembrane to be in good condition twelve years after installation. On both sides, the surface is seen to be uniform and homogeneous, as confirmed by the scanning electron microscopy which nevertheless detected a few microfissures and isolated craters.
- Given that EPDM is a thermoset material, the potential effects of the geographical orientation of the material are practically null.

8.7.5 Bibliography

- Blanco M. (1998) Las Geomembranas sintéticas en la impermeabilización de embalses I. Materiales. Curso de Técnicas y Utilidades de Aplicación de los Plásticos en el Sector Agropecuario. Santa Cruz de la Sierra (Bolivia).
- Blanco M., Garcia F., Soriano J. Aguiar E, Vara T. (2005) Comportamiento de geomembranas sintéticas a base de PVC-P, PEAD y EPDM utilizadas en la impermeabilización de embalses. Ing. Civil 138, pp. 39-45.
- Blanco M. (2005) Geomembranas. Jornadas sobre geomembranas y geotextiles y aplicación a balsas de materiales sueltos para riego. Universidad Politécnica de Valencia.
- Blanco M. (2005) Geomembranas. I. Simposio nacional sobre proyecto, construcción e impermeabilización de balsas. Seville.
- Blanco M., Leiro A., Segura J. (2008) Geosintéticos empleados en la impermeabilización de las balsas de Acanabre y Montaña de Tesoro. Aislamiento e impermeabilización, 48, pp. 30-36.
- Blanco M. Geomembranas (2008) Barreras geosintéticas poliméricas (GBR-P). Jornada Técnica sobre Aplicación de Geosintéticos en Obras Hidráulicas. Santa Cruz de Tenerife.
- Blanco M., Leiro A., Segura J. (2008) Características de las balsas canarias de Acanabre y Montaña de Tesoro. Proc. 2° Congreso Nacional de Impermeabilización: Edificación y Obra Pública y 2° Congreso Internacional sobre proyecto, construcción e impermeabilización de balsas, pp. 261-266 Palma de Mallorca.
- Blanco M. (2009) Seguimiento de barreras geosintéticas poliméricas (GBR-P). Jornada Técnica sobre aplicación de geotextiles de Obras Lineales. Sevilla.
- Blanco M. (2009) Experiencia española en el empleo de geomembranas en la impermeabilización de balsas. III Seminário Português sobre geossintéticos. Coimbra (Portugal).
- Davis J.A., Hoff J.L., Kalwara J.J., Kane E.G. (1998) A review of EPDM Systems Development. Proc. X international Congress: International Waterproofing Association, pp. 263-274. Copenhague (Dinamarca)
- de Cea J.C., Asanza E., Blanco M. (2002) Algunas ideas relativas a la protección e impermebilización de paramentos de presas de hormigón in Llanos ans col. (Eds.), Dam Maintenance & Rehabilitation, Editorial Balkema pp. 777-782 Rotterdam (Holanda).
- de Cea, J.C., Asanza E., Blanco M. (2003) Face Protection: Geomembranes Lining vs. Paint Coating. Proc. 21 Congreso Internacional de Grandes Presas. Montreal (Canada).
- International Commission on Large Dams (1991). Watertight Geomembranes for Dams State of the Art. Bulletin ICOLD N° 78 Paris.

- Leiro A., Blanco M., Zaragoza G. (2002) Performance of synthetic geomembranes unsed in waterproofing of spanish reservoirs. Geosynthetics 7th ICG, pp. 979-982. Delmas, Gourc & Girard eds. Editorial Balkema pp. 979-982. Rotterdam (Holanda).
- Leiro A., Blanco M. (2009) Estudio de geosintéticos utilizados en tres sistemas de impermeabilización de embalses expuestos a medios básicos. X Congreso Latinoamericano de Patología y XII Congreso de Calidad en la Construcción. Valparaíso (Chile).
- Ministerio de Medio Ambiente, y Medio Rural y Marino (2010). Manual de diseño, construcción, explotación y mantenimiento de balsas. Madrid (Espagne).
- Navarro A., Blanco M., Rico G. (1989). Materiales Opticos Orgànicos. Ed. AAEEO, Madrid.
- Soriano J., Blanco M., Burgos J., Aguiar E., Zaragoza G., García M. A. (2005) Las microscopias óptica de reflexión y electrónica de barrido como técnicas avanzadas en el conocimiento del estado de las geomembranas sintéticas.- I Simposio nacional sobre proyecto, construcción e impermeabilización de balsas. Sevilla, octubre-noviembre.
- Soriano J., Blanco M., Aguiar E., de Cea J.C. (2006) Las técnicas de microscopia óptica de reflexión y electrónica de barrido en el conocimiento del estado de las geomembranas sintéticas Ing. Civil, 143, pp. 17-22.
- Soriano J., Blanco M., Aguiar E., Burgos J. (2010) La microscopia como método de análisis en el estudio de geomembranas sintéicas de PVC-P. 3° Congreso Nacional de Impermeabilización: Edificación, Obra civil y Balsas, pp. 411-422.

8.8 Environmental and agricultural protection by creating ten irrigation reservoirs in the Autizes

Amat Bernat[7]

ABSTRACT - The Marais Poitevin is a 970 km² (239,692 acres) marshland in Western France. Two thirds of the marsh (the dry marsh) is used for farming and breeding. One third of the marsh (the wet marsh) is a maze of islets criss-crossed by canals nicknamed The Green Venice. This wet marsh is an important place for biodiversity (birds, fish, plants..). Although the area was declared a Regional Natural Park in 1979, it lost that status in 1997 as intensive agricultural development around the Marsh endangered its natural biodiversity. Cereal and corn cultures need big quantities of water during dry season and the intensive water pumping was lowering down the water level of the marsh and endangering its existence. In order to preserve the agricultural economy of the region and its unique natural environment, it was decided in 2006 to built 10 artificial irrigation reservoirs upstream of the marshland in order to store 3,2 million m³ (8.453506e+008 gal.) of water during the wet season when there is an excess of water and use it during the dry season to irrigate the cereals and corn. In parallel, a collective and equitable management of water pumping was established. This 16 million € (Euro) project took place between 2006 and 2010. Nine of those 10 water reservoirs have been made watertight using an EPDM (Ethylene Propylene Diene Terpolymer) geomembrane 1.1 mm (460.000 m²) (1,509,186 sq.ft.). EPDM geomembrane was chosen for its long durability and fast installation process. The project is too recent to already draw any conclusion but first results are very encouraging as a positive impact on the water table level during the dry season has been measured. This case study presents the use of geosynthetics for biodiversity and agricultural protection and the step by step construction of a water reservoir made watertight with a synthetic liner.

Keywords: Water reservoir, EPDM, Geomembrane, Waterproofing, Water Conservation

8.8.1 Introduction

This case study presents the use of geosynthetics as a solution for environmental and agricultural protection in the Marais Poitevin.

After introducing the unique environment of this huge marshland and the reasons why this area is endangered by intensive agriculture, the implemented solutions in the Autizes to reduce the impact of irrigation on the marsh while maintaining farming economically viable will be presented.

Finally, we will review the different construction steps of an EPDM (Ethylene Propylene Diene Terpolymer) geomembrane lined irrigation reservoir and the first results.

8.8.2 The Marshland

With a surface of nearly 100.000 ha (247,104 acres), the Marais Poitevin (Figure 1) is the second biggest marshland in France.

Figure 1: Areal view of the Marais Poitevin (www.vendeevelo.vendee.fr)

7 Firestone Building Products; Tel: +32-2 711 52 71; Fax: +32-2 721 27 18; Email: bam@fbpe.be,

Located in Western France (Figure 2), the Marais Poitevin is a very valuable and fragile ecological area. It is home to a large number of remarkable and diversified plants (over 750 species) and animals (250 bird species, 50 different mammals, 38 kinds of fish,…). It also plays an important economic role for activities like agriculture, tourism, shellfish farming and fishing.

Figure 2: Location of the Marais Poitevin (www.esrifrance.fr)

The Marais Poitevin is composed of two main ecological and landscape entities related to its hydraulic characteristics: the wet and the dry marsh.

The wet marsh (1/3 of the surface) is the most famous part of the Marais Poitevin. Partly classified as Grand Site de France, this area includes the famous Green Venice. This protected area is crossed by a maze of canals bordered by rows of trees that stabilize the banks (Figure 3). With 850,000 tourists per year the wet marsh is an important European ecotourism destination (Figure 4). In the wet marsh, the agricultural activity is mainly livestock (Figure 5).

Figure 3: Canal of the wet marsh (www.linternaute.com)

Figure 4: Ecotourism attraction of the wet marsh (www.cote-ocean.com)

Figure 5: Livestock breeding in the wet marsh (www.bons-de-reduction.com & www.voyage.portail.free.fr)

In the Middle Ages, the dry marsh has been artificially protected from flooding so as to allow agriculture. Nowadays, big open land surfaces are dedicated to farming and breeding (Figure 6).

Figure 6: Cultures in the dry marsh (www.parc-marais-poitevin.fr)

8.8.3 Endangering of the Marshland

In the eighties, as a result of the increase in cereal crops and corn (for economical reasons), the irrigation has strongly increased around the marsh. Water pumping was done from rivers, marsh canals and mainly from underground water tables. Pumping was so intense that during the dry season (summer), the level of the water table was lower than the water level of marsh canals. The marsh canals were draining into the water table when it should be the opposite. The marsh was drying out, endangering its ecological balance (Ouvrard 2012). In 1997, the wet marsh lost its status of Regional Natural Park it held since 1979.

It was therefore decided that all irrigation pumping had to stop when the water table reached a defined critical piezometric level (equivalent to the water level balance between the water table and the marsh). Despite this restrictive measure, the marsh was still too dry in summer and the farmers couldn't irrigate at the most critical moments.

8.8.4 Implemented solutions

The Marais Poitevin is linked to several drainage basin, one of them being called Autizes (affecting 1/5 of the marsh). In the Autizes it has been decided in the year 2000 to reduce the irrigation demand on the marsh by reducing pumped volumes and regulating pumping periods.

For the entire Autizes drainage basin, it was determined that in a normal year (reference was 2004) the 117 farmers needed 8 millions m³ (2.11 billion gallons) of water for irrigation. The decision was taken to reduce this reference volume by 20 %. 50 % of the remaining volume (3,2 millions m³) (8.453506e+008 gallons) is to be pumped during the dry season, the other 50 % during the raining season (winter) and stocked into 10 irrigation reservoirs.

With this solution, during the dry season, when the demand on the water table is the highest, the pumping is reduced by 60%. But at the same time, the farmers have a safer water supply as there is less risk of reaching the critical piezometric level.

In the past, farmers had a yearly allocated volume of water and were free to use it whenever they wanted until the critical piezometric level was reached. Now, pumped volumes are managed collectively and are linked to piezometric measurements, water flow in rivers and water level in marsh canals (Lepercq and Laloux 2011). At the start of each irrigation season, the 117 farmers (even those that are not connected to the reservoirs) have to decide, depending on their crop rotation, the distribution of their allocated volume of water for the entire season. During the irrigation season, a management committee meets every 2 weeks to adapt the forecasted water volumes for the next 2 weeks according to the measured piezometric levels. They make sure not to reach the critical piezometric level.

An independent company has been hired to control that the farmers respect their allowed pumping volumes.

The acceptance by farmers of the pumping restrictions and cost increase has been greatly facilitated by their involvement into the decision making process and the security of water supply throughout the entire irrigation season. The sense of responsibility of the farmers has risen sharply.

8.8.5 Ten Irrigation Reservoirs

In 2006 it was decided to built 10 artificial irrigation reservoirs into the Autizes drainage basin, upstream of the marshland (Figure 7), in order to store 3,2 millions m³ (8.453506e+008 gallons) of water.

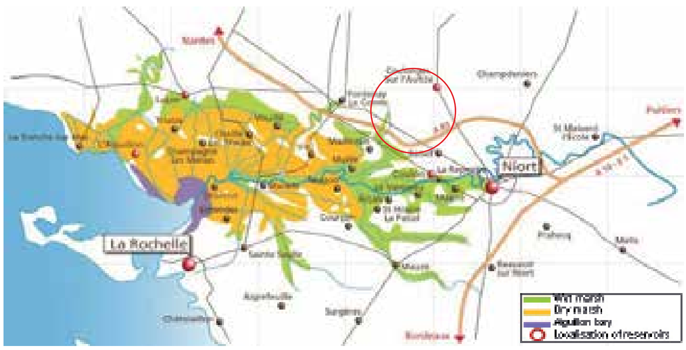


Figure 7: Location of the irrigation reservoirs

This 16 million € (Euro) project was funded with 85 % of public money and 15 % by the farmers themselves as a 12 year loan, repaid per m³ of water used.

The construction of the irrigation reservoirs took place between 2006 and 2010. The capacity of the reservoirs varies from 140.000 m³ to 650.000 m³ (37 to 171 million gallons). One reservoir was constructed in natural clay. The other nine have been artificially made watertight with an EPDM geomembrane 1.1 mm (45 mil) as the natural ground was permeable (Figure 8 and Figure 9).

Figure 8: Saint Pierre le Vieux – 485.000 m³ (1.281234e+008 gallons) - 2006

Figure 9: Oulmes Sud – 200.000 m³ (5.283441e+007 gallons) - 2010

At the end, it is 460.000 m² (4,951,400 sq.ft.) of EPDM geomembrane that was installed in this project. EPDM geomembrane was chosen for its long durability and fast installation process.

EPDM geomembrane is an elastomeric synthetic rubber membrane made by combining Ethylene, Propylene and Diene monomers to form a chemically saturated (no double bonds) backbone providing excellent heat, oxidation, ozone and weather aging resistance. The individual polymer chains are cross linked together during the vulcanisation process, generating a 3 dimensional network and giving an elastic behaviour with over 300 % of elongation. EPDM geomembrane can withstand important hydrostatic pressure and has very good puncture resistance over time (Blanco et al. 2011).

Installation process of EPDM geomembrane is made easy because of its flexibility and the large panel sizes (15,25 m x 61,0 m) (50 ft. x 200 ft.). The 930 m² (10,000 sq.ft.) panels allow for significant reduction in the number of seams to be carried out on site and considerably reduces the installation risks.

8.8.6 Step by step construction

The 9 irrigation reservoirs where an EPDM geomembrane was used are located on a limestone plain. They are built using the excavation and backfilling technique.

The limestone rocks are broken and crushed at the bed of the reservoir and the excavated ground is loaded onto trucks (Figure 10 to Figure 14).

Figure 10: Site before starting the excavations

Figure 11: Rock breaking at the base of the pond

Figure 12: Hydraulic rock breaker

Figure 13: Rock crusher

Figure 14: Excavation of the base of the pond and truck loading

Trucks unload the excavated ground at the top of the embankment were it is leveled and compacted layer by layer. Compaction is done in order to reach the 95% of the Proctor Optimum value (Figure 15 to Figure 19).

Figure 15: Unloading of excavated ground on the embankments

Figure 16: Leveling with bulldozer on the embankments

Figure 17: Compaction of the embankments with chevron tamping wheels compactor

Figure 18: Measurement of the degree of compaction

Figure 19: Embankment before final finishing

The support structure of the geosynthetic is made smooth and free from aggressive stones with a stone crusher and smooth drum roller compactor (Figure 20 to Figure 22).

Figure 20: Stone crusher

Figure 21: Final compaction

Figure 22: Support layer overview

The external embankment is protected from erosion by means of a layer of topsoil seeded with grass (Figure 23).


Figure 23: External embankment (before and after seeding)

The outlet and water drainage pipes going through the embankment are covered with concrete for protection and to avoid piping phenomena (Figure 24).


Figure 24: Outlet and water drainage pipes through the embankment

The outlet pipe is embedded in a concrete block constructed in such a way so as to limit differential settlements and present a smooth surface for mechanical anchoring of the geomembrane (Figure 25).


Figure 25: Water outlet pipe at the bottom

The water drainage system installed below the geomembrane will collect underground water and the water coming from an eventual leakage in the lining system. A drainage pipe is installed inside a trench with gravel and a filtration geotextile (Figure 26, Figure 27).

Figure 26: Water drainage ditch

Figure 27: Water drainage outlet

A gas drainage system is installed under the geomembrane to avoid any uplift pressure caused by the raising of the underground water table. The drainage géocomposites are made of 2 layers of filtration geotextile with a high density polyethylene geonet in the middle 55 cm (22 in.) large and 6 mm (0.25 in.) thick. The drainage geocomposite is connected to vents positioned on the crest of the embankment (Figure 28, Figure 29).

Figure 28: Gas drainage with geocomposite

Figure 29: Gas vent at the top of the embankment

A puncture resistant geotextile is installed between the substrate and the geomembrane. The 400 g/m² (12 oz./yd²) Asqual (French quality certificate) certified geotextile is made of 100 % polypropylene non woven, needle punched, short fibers. The different geotextile panels are hot welded together in order to avoid any movement while installing the geomembrane (Figure 30).

Figure 30: Geotextile installation

The Asqual-certified EPDM geomembrane 1.1 mm (45 mil) panels are positioned at the top of the embankments according to a pre-defined layout plan. The geomembrane is then unrolled and unfolded. The different panels are seamed together by Asqual-certified contractors using a self-adhesive EPDM/butyl tape and primer (Figure 31 to Figure 34).

In order to have a better control on installation progress, some installers decided to pre-assemble the geomembrane in a warehouse and bring on site panels of nearly 2000 m² (20,500 sq.ft.).

Figure 31: Unrolling of EPDM geomembrane

Figure 32: Unfolding of EPDM geomembrane

Figure 33: Seaming of EPDM geomembrane

Figure 34: Installed EPDM geomembrane

The geotextile and the geomembrane are anchored at the top of the embankment in an anchor trench. After installing the geosynthetics, the anchor trench is backfilled and compacted without subjecting the geomembrane to stress.

Figure 35: Anchor trench with geotextile

Figure 36: Anchor trench after back filling

In order to prevent an overflow of the reservoir a designed spillway is installed in the sidewall (Figure 37).

Figure 37: Pipe spillway

In order to avoid wind uplift, 5-6 m (16-12 ft.) long PE bags, filled with gravel, are coming from the top of the embankment and anchored on the crest (Figure 38).

Figure 38: Wind ballast with PE bags filled with gravel and anchored on the crest

Some reservoirs that can be exposed to strong winds require an extra protection of the crest against waves overflow. It is a small seeded mound of ground protected with an anti-erosion geotextile (Figure 39).

Figure 39: Waves protection

During the entire installation a strict internal and external control process is implemented on delivered materials and installation quality (Figure 40).

Figure 40: Quality control with vacuum chamber

8.8.7 Promising results

As the last irrigation reservoir was only finished in 2010, there is little feedback to evaluate the real impact of the project. Nevertheless, some preliminary results have been observed. In 2009 (with 7 reservoirs), the critical piezometric level was not reached. In 2010 (7 reservoirs), rainfall has been as poor as in 2005 (0 reservoirs). In 2010, with 7 reservoirs, the minimum water table level was 1,9 m (6 ft.) higher than in 2005 (Figure 41) and the minimum water level in the main marsh canal (situated downstream) was 0,2 m (8 in.) higher with a delayed drop of one month.

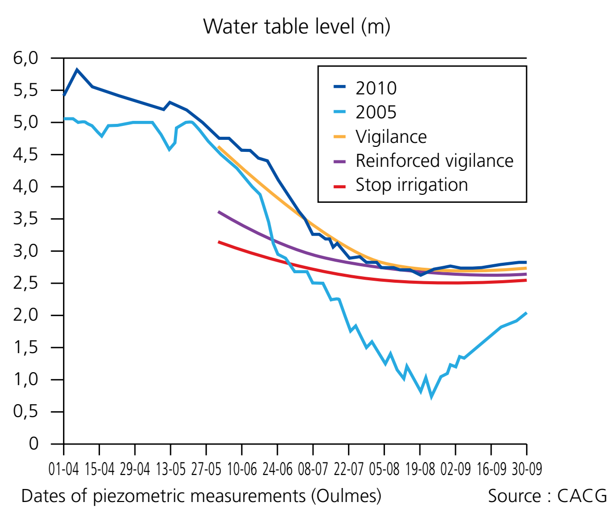


Figure 41: Water table levels in 2005 and 2010

8.8.8 Acknowledgements

First and foremost, we would like to thank the company Sodaf Geo Etanchéité for there professionalism and availability. Besides, we would like to thank the IIBSN, the Syndicat Mixte des Marais and the CACG for there valuable information. Finally, we would also like to thank Mister Nérault for his precious pictures.

8.8.9 References

Blanco M., Aguiar E., García F., Vara T., Soriano J., Castillo F. (2011). État de la Géomembrane en EPDM de la retenue d'El Golfo dans l'île d'El Hierro (îles Canaries). 8èmes Rencontres Géosynthétiques – 22-24 mars 2011, Tours.

Lepercq D., Laloux S. (2011). Des réserves de substitution associées à une gestion collective de la ressource en eau pour protéger les milieux fragiles. Hommes Terre et Eau. N° 148: 50-52.

Ouvrard N. (2012). Dix retenues pour soulager le marais. Réussir Grandes Cultures. N°260: 74-75.

- http://www.parc-marais-poitevin.fr/
- http://www.paris-normandie.fr/article/actualites/le-marais-poitevin-sort-la-tete-de-leau
- http://johan.lemarchand.free.fr/cartes/Europe1.html
- http://en.wikipedia.org/wiki/Marais_Poitevin
- http://www.fond-ecran-image.com/photo-gratuite-marais-poitevin.php
- http://voyage.portail.free.fr/partir-en-france/poitou-charentes/24-01-2011/le-marais-poitevin/diaporama.html
- http://balade-en-maraispoitevin.chez-alice.fr/index.htm
- http://www.larousse.fr/encyclopedie/autre-region/Marais_poitevin/131633
- http://www.poitou-charentes.jedecouvrelafrance.com/d-8.deux-sevres.html

8.9 Feedback on the use of an EPDM geomembrane to cover a landfill 12 years after its installation

Bernat AMAT[8], Guillaume STOLTZ[9], Didier CROISSANT[8], Nathalie TOUZE-FOLTZ[8]

ABSTRACT – This study concerns the feedback of a synthetic rubber geomembrane EPDM that was installed 12 years ago for the landfill cell cover of Lann Hir. An inspection visit has been organized to assess the condition of the geomembrane and sealing details. Part of the covering soil has been removed to allow visual inspection and take samples of the geomembrane that were subjected to analysis. The publication presents the Lann Hir landfill, the specificities of installing an EPDM geomembrane landfill cover and the test results of the showing that twelve years after its installation, the mechanical characteristics of the EPDM geomembrane and its seams are nearly unchanged.

Keywords: geomembrane, EPDM, durability, landfill cover

8.9.1 Introduction

The use of geomembranes on the bottom of and as covers for landfill sites is a very common practice. The follow-up period for a closed landfill cell, around 30 years, poses the question of durability of the materials comprising the "envelope" of the cell, notably the geomembranes. This study relates to the analysis of an EDPM geomembrane installed 12 years ago, serving as a cover at the Lann Hir municipal landfill.

EPDM geomembranes (Ethylene-Propylene-Diene terpolymer) are cured synthetic rubber geomembranes. Their highly cross-linked polymeric structure (carbon chains linked together by sulphide bonds) gives the material substantial flexibility and elasticity (> 300% elongation). Waste dumps usually present wide ranging compaction, in metric terms (Olivier, 2003), the flexibility of EDPM geomembranes may be considered for use as landfill covers.

Two studies examine on the use of this type of geomembrane in exposed conditions for hydraulic structures (Blanco et al., 2011 and Blanco et al., 2013). The Blanco et al. (2011) study concluded that the mechanical characteristics (tensile strength, resistance to static puncture) experienced only minor changes over time (12 years of use). A decrease in elongation at break under tensile stress is however observed. According to Blanco et al. (2011), this observation can be explained through the curing of the polymer.

The study on the EPDM geomembrane installed at the Lann Hir landfill site was conducted in several stages. After a visual inspection of the condition of the cover system and its details, samples were taken and sent to a laboratory for analysis. The tensile characteristics measured on the samples takes were compared against those from the virgin samples 12 years ago. The results obtained allow for an assessment to be made on the extent to which the EPDM geomembrane retains its mechanical performance after 12 years in use.

8.9.2 Presentation of the Lann Hir Landfill

The Lann Hir landfill located in the municipality of Pont Scorff (Morbihan (56), Brittany) is a site of approximately 20 ha (4.94 acres) with authorisation since 1979 and currently in post-exploitation status. In 1999, the operator and owner of the land - GEVAL, a subsidiary of the VEOLIA Propreté group decided that an area of 7 ha (19.8 acres) which had been exploited between 1992 and 1996 would be subjected to redevelopment to reduce the quantity of leachates produced in the old exploitation cells (Figure 1).

The significant input of leachates was caused by the shallow gradient of the semi-permeable cover on the cells and localised mess caused by differential settling of the waste dump.

The redevelopment consisted of levelling the ground to achieve an overall gradient of more than 3%, installing a waterproof covering of 70,000 m² (750,000 sq.ft.), installing a degassing network and leachate pumping system and to finish off, covering the entire cell with a clay and topsoil layer.

8 Firestone Building Products, Zaventem, Belgium
9 Irstea centre d'Antony, 1 rue Pierre Gilles de Gennes, Antony, France

The owner would like the location to return to its former forest usage (Figure 2). The specifications considered the compatibility of the waterproofing system with a sample of trees with a suitable root system. An access way was created above the waterproof covering and all the ditches (1500 ml) (51 oz.) for this cover are waterproofed with EPDM geomembranes (Figure 3).

The project design was awarded to SICAA Etudes consulting engineers, the execution of the earth works to SOTRAMA and the waterproofing works to SODAF Géo Etanchéité.

The owner's selection of an EPDM geomembrane was an innovative choice at the time as it represented the first use of an EPDM geomembrane on a landfill site in France for both the owner and the geomembrane manufacturer. This selection can be explained by the significant waste settling expected, the consolidation rate of which was unknown and the assurances given by Firestone that the EPDM geomembrane was compatible with the type of root system envisaged.

The works took place in 9 stages between 2000 and 2008.

Figure 1: Aerial view of the Lann Hir landfill during covering work

Figure 2: Current state of the Lann Hir Landfill

Figure 3: Peripheral ditch at the foot of the mound lined with EPDM geomembrane

8.9.3 Cover characteristics and installation details

8.9.3.1 Description of the Lann Hir landfill cover

To reduce the amount of leachates generated by the landfill cells at Lann Hir, it was decided to install impermeable covers to prevent rainwater from getting into the waste. Additionally, the impermeable cover affords better conditions for collecting biogas by the collector system and thereby prevent dispersal into the atmosphere.

The cross section illustrated in Figure 4 shows the cover system installed at the Lann Hir landfill. From bottom to the top, the following elements are noted:

- domestic waste;
- a reprofiling layer intended to level out and homogenise the ground and facilitate the installation of the cover (Figure 5);
- a gas drainage system connected to the degassing wells. The drain geocomposite is made from a filtration geotextile on the lower surface and a drainage core on the upper surface (Figure 5);
- a protective, heat bonded, 300 g/m² (8 oz./sq. yd.) geotextile made from recycled fibres;
- the Asqual certified, 1.1 mm (45 mil) thick EPDM geomembrane (Figure 6);
- a protective, heat bonded, 300 g/m² (8 oz./sq. yd.) geotextile made from recycled fibres (Figure 7);
- a protective soil layer, 0.45m (1.5 ft.) thick, made up of clayey soil (Figure 8);
- 0.4m (1.3 ft.) of topsoil with the aim of encouraging the growth of vegetation to help with integration into the surroundings and protect against erosion.

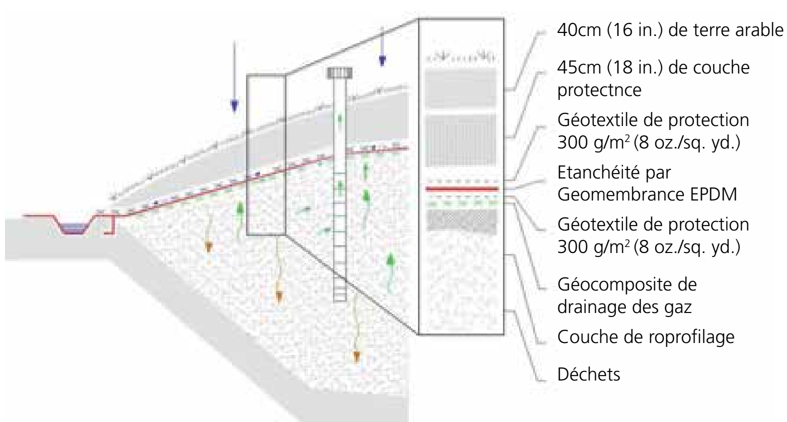


Figure 4: Schematic diagram of the Lann Hir landfill cover

Figure 5: Reprofiling layer prior to installing the impermeable geomembrane system and gas drain geocomposite

8.9.4 Initial Characteristics of the EPDM geomembrane

The average thickness and tensile strengths for the 15% and 250% deformation ratios of a new membrane, measured between 1999 and 2000 on 5 samples machine direction and 5 samples ross machine direction, are listed in Table 1.

Table 1: Average characteristics of 5 new EDPM geomembranes measured between 1999 and 2000			
Characteristics	**Standards**	**Values**	
		SP*	ST**
Functional thickness (mm)	NF P84-515	1.13	
Tensile • resistance to 15% deformation (kN/m) • resistance to 250% deformation (kN/m)	NFP 501	0.75 6.43	0.72 5.88

The standards NF P84-515 and NFP 501 have since been replaced respectively by EN 1849-2 and EN 12311-2; the thicknesses and tensile characteristics, measured according to the new standards on the new sample in 2007, are detailed in Table 2.

Table 2: Characteristics of a new EDPM geomembrane measured in 2007			
Characteristics	**Standards**	**Values**	
		SP*	ST**
Functional thickness (mm)	EN 1849-2	1.09	
Tensile • resistance to 15% deformation (kN/m) • resistance to 250% deformation (kN/m)	EN 12311-2	0.84 6.86	0.77 6.39

8.9.5 EPDM geomembrane installed at the Lann Hir site

Between 2000 and 2008, 70,000 m² (750,000 sq.ft.) of EPDM geomembrane was installed in nine phases (from 4,000 m² to 10,000 m²) (43,000 to 107,000 sq.ft.) by the company Sodaf Géo. The geomembranes used were for the most part 15.25 m x 61 m or 30 m x 61 m (50 ft. x 200 ft. x 100 ft. x 200 ft.) when they were assembled in advance in the workshop. The installation team was made up of 10 people (2 Asqual certified welders and 8 labourers) and had an installation pace of 10,000 m² (107,000 sq. ft.) per two weeks (installation of the protective geotextile and realisation of details included).

The various panels were assembled on site using self-adhesive tape made from synthetic rubber, and a primer made from solvents and EPDM (Figure 6). The seams were systematically subject to visual inspection, vacuum chamber (individual points) and destructive tests (shearing, peeling). It is also possible to test the taped seams along their length with an air lance system (ASTM D 4437) which consists of directing high pressure air onto the seam.

For the Lann Hir project several geomembranes were pre-assembled in the workshop to reach panels 2,000 m² (21,500 sq. ft.) in size. Consequently, more than half of the seams were realised in ideal conditions in terms of temperature, humidity and quality of the support. The decrease in the number of seams to be realised on site reduces the risks attached to the installation and how dependent the assembly is on climatic conditions.

Figure 6: Installation of the EPDM geomembrane. Creating a seal using self-adhesive tape

Figure 7: Installation of the peripheral ditch and high protection geotextile

8.9.5.1 Installation of the soil cover

The installation of the soil cover requires exceptionally strict installation rules to be observed given that heavy machinery needs to move around on the areas which have already been waterproofed with the geomembrane.

At the Lann Hir site, the lorries were authorised to move around on access ramps 80 cm (30 in.) thick. The levelling of the material was done from the ramp, using a caterpillar track vehicle, authorised to move around on a layer at least 40 cm (15 in.) thick.

Figure 8: Installation of the soil cover

8.9.5.2 Connection of the geomembrane to the biogas collection wells

Considering that household waste is largely composed of biodegradable elements, even if they are correctly compacted during use, it is inevitable that some differential settling will occur over time. This can pose problems for the impermeable connection between the geomembrane and the degassing wells given that the wells will not follow the same patterns of movement as the waste.

To ensure that this detail does not become strained over time, which may risk compromising the impermeability, the flexibility of the EPDM geomembranes allows for a "safety pleat" to be made outside the soil on the degassing wells (Figure 9 and Figure 10). Then, when the soil around the well settles, the excess geomembrane provided at the well (0.6 m (1.5 ft.) at Lann Hir) means that the geomembrane is not put under strain. The advantage of this feature is that it can be adapted to any diameter and the excess geomembrane can be adjusted to the anticipated differential settling.

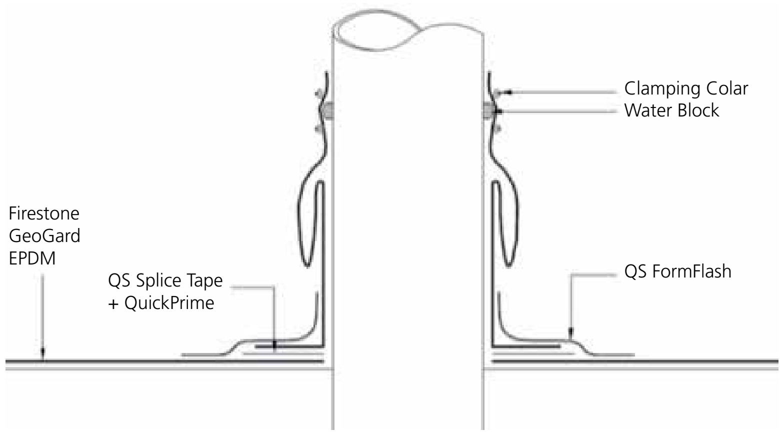


Figure 9: Schematic diagram of the "safety pleat" on the biogas collection wells

Figure 10: Degassing well before and after the addition of a safety pleat

8.9.6 Sampling and initial observations

8.9.6.1 Sampling technique

On 14 June 2012, that is to say, 12 years after installation, two geomembrane samples were taken from the first cell covered with EPDM geomembrane in 2000. The first sample was taken from the top of the mound and the second at the foot of the slope, where it meets the seam.

To begin with the soil cover was excavated using a mini digger (Figure 11). The last centimetres were removed using a scoop so as not to damage the impermeable geomembrane system.

Samples sized at approximately 1.0 m x 1.0 m (3 ft. x 3 ft.) were cut using scissors (Figure 12).

Figure 11: Starting the excavation to take the samples

Figure 12: Taking samples of the EPDM geomembrane

8.9.6.2 Carrying out repairs

After taking the samples, the sample area was repaired by an Asqual certified welder. The existing geomembrane had been carefully cleaned using a naphtha based solvent (Figure 13). A new piece of EPDM has been cut to the dimensions and fitted to the geomembrane on site using a self-adhesive tape (Figure 13).

New pieces of protective geotextile were placed above and below the geomembrane. Finally, the soil cover was put back.

Figure 13: Cleaning and repairing the EPDM geomembrane

8.9.6.3 Observations made during sampling

The pieces of geomembrane taken as samples did not present any visible fault or perforation. The protective geotextiles (above and below) were also in very good condition. It should be noted that the upper geotextile showed substantial colouration (the origin of which has not been determined) while the lower geotextile had retained its original colour (Figure 14). This observation shows the role of the geomembrane in preventing infiltration.

Figure 14: EPDM geomembrane and colour difference between the upper and lower geotextile

We were also able to observe that the thicknesses of the soil cover had been respected (Figure 15). The excavation showed that roots of the vegetation planted on the cover remained in the top 40 cm (16 in.) of the topsoil (Figure 16).

Figure 15: Top of the mound – Cross section of the soil cover and condition of the upper protective geotextile

Figure 16: Foot of the mound – Location of the root zone

The gas drain geocomposite located under the geomembrane and lower protective geotextile was still in a very good condition. No clogging was observed in the drain area.

Figure 17: Protective geotextile and gas drain geocomposite placed under the geomembrane

The foot of a biogas collection well had also been cleared in order to inspect the condition of the detail. A well was selected where the safety pleat had been clearly unfolded, a sign of a significant differential settling in that area.

The visual inspection showed that the connection between the well and the geomembrane had not suffered differential settling (Figure 18). Visually, the geomembrane has not been under strain and there is still a significant amount of surplus geomembrane to withstand any possible future settling.

Figure 18: Degassing well – inspection of connection detail

8.9.7 Analyses conducted on the samples and discussion of results

The analyses conducted on the samples taken are set out in Table 3. The types of analyses were chosen in order to be able to compare the condition of the geomembrane 12 years after its installation with the values in Table 1 measured 12 years ago. It should be noted that these tests were not conducted by the same laboratory, which could entail some variations.

We can also note that the tensile tests according to the standard EN 12311-2 and static puncture test according to the standards NF P 84-507 and EN ISO 12236, could not be carried out on the sample taken from the foot of the mound due to a lack of material.

By comparing the values of the thicknesses and tensile strengths for the 15% and 250% deformation ratios given in Tables 1 and 3, a slight change in these characteristics can be seen after 12 years. The slight increases in the values could be attributed to slight stiffening of the geomembrane following the continuation of the carbon chain cross linking which causes a decrease in molecular mobility. The environmental conditions and site location have therefore not had a significant impact on the mechanical properties of the geomembrane. We note that this comparison is made based on the values measured according to the standards which were replaced, which may be the reason behind this slight skewing. Table 2 shows that this skewing is not significant.

As a comparison, in exposed conditions, the evolution over time of the mechanical properties of thermostable materials is essentially characterised by a decrease in elongation at break following an increase in the number of links between carbon chains (Blanco et al., 2013). In the case of the El Golfo water reservoir located in the Canary Islands (Blanco et al., 2011), after 12 years' exposure in demanding climatic conditions (temperature, UV), elastic elongation of the EPDM geomembrane was between 320 and 360%. In covered conditions, the samples taken at Lann Hir 12 years after installation had elongation at break values of between 450 and 510%. In all likelihood, this difference is explained by the fact that the average yearly temperature of the geomembrane is less in unexposed conditions, temperature being an accelerating factor in the ageing process of geomembranes. We can therefore conclude an increase in the durability of EPDM geomembranes in covered conditions compared to exposed conditions.

The mechanical properties of the seam tested showed that it was in a very good condition. The values for resistance to peeling and shearing are relatively high for EPDM seams made with the self-adhesive tape and primer system.

Table 3: Results of analyses conducted on the samples 12 years after installation

Characteristics	Standards	Declared value	Top of mound		Foot of mound	
			SP*	ST**	SP*	ST**
Functional thickness (mm)	EN 1849-2	1.1	1.14			
Mass per unit area (g/m²)	EN 1849-2	1288	1321			
Tensile • Resistance to 15% deformation (kN/m) • Resistance to 250% deformation (kN/m)	EN 12311-2	0.7 5	0.92 6.96	0.85 6.39		
Strength at break, (N/mm²)	EN ISO 527	9	10.6	10.0	11.2	10.0
Deformation at break (%)	EN ISO 527	≥ 300	452	454	512	457
Static puncture • Resistance (N) • Displacement (mm)	NF P 84-507	115 33	142.7 35.44			
Static puncture (CBR) – (kN)	EN ISO 12236	0.7	> 0.7***			
Foldability at low temperature (°C)	EN 495-5	≤ -45	≤ -45		≤ -45	
Shore A – hardness (Shore A units)	ISO 7619:2011		64		67	
Seam resistance by tensile-shear, (N/50 mm)	EN 12317-2				325	
Seam peel resistance, (N/50 mm)	EN 12316-2				88	

* along the grain
** across the grain
*** the equipment reached its maximum displacement without achieving break (> 151 mm)

8.9.8 Conclusions

This study was a review of the condition of the EPDM geomembrane used as landfill cover following 12 years in use. The approach consisted of taking samples on site while simultaneously collecting a maximum number of visual observations on the state of the cover. The samples taken clearly showed a good general condition of the entire impermeable geomembrane system comprising the cover. The tests showed that the mechanical properties (tensile strength for the 15% and 250% deformation ratios) remained stable after 12 years of use. This study therefore shows some elements concerning the durability of mechanical properties of EDPM geomembranes in unexposed conditions. Further studies would be useful to determine the evolution of hydraulic, chemical and physico-chemical properties over time.

8.9.9 Bibliography

- ASTM D 4437 (2012) Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes. Vol 4.13.
- AFNOR (2001) NF EN 495-5. Feuilles souples d'étanchéité Détermination de la pliabilité à basse température Comité européen de normalisation, Bruxelles.
- AFNOR (2012) NF EN ISO 527. Plastiques Détermination des propriétés en traction. Comité européen de normalisation, Bruxelles.
- AFNOR (2001) NF EN 1107-2. Feuilles souples d'étanchéité Détermination de la stabilité dimensionnelle. Comité européen de normalisation, Bruxelles.
- AFNOR (2010) NF EN 1849-2. Feuilles souples d'étanchéité Détermination de l'épaisseur et de la masse surfacique. Comité européen de normalisation, Bruxelles.
- AFNOR (2006) NF EN ISO 12236. Essai de poinçonnement statique (essai CBR). Comité européen de normalisation, Bruxelles.
- AFNOR (2010) NF EN 12311-2. Feuilles souples d'étanchéité - Détermination des propriétés en traction - Partie 2: feuilles d'étanchéité de toiture plastiques et élastomères. Comité européen de normalisation, Bruxelles.
- AFNOR (2000) NF EN 12316-2. Feuilles souples d'étanchéité - Détermination de la résistance au pelage des joints - Partie 2: feuilles d'étanchéité de toiture plastiques et élastomères. Comité européen de normalisation, Bruxelles.
- AFNOR (2010) NF EN 12317-2. Feuilles souples d'étanchéité - Détermination de la résistance au cisaillement des joints - Partie 2: feuilles d'étanchéité de toiture plastiques et élastomères. Comité européen de normalisation, Bruxelles.
- AFNOR (2010) NF ISO 7619-1. Caoutchouc vulcanisé ou thermoplastique - Détermination de la dureté par pénétration - Partie 1: méthode au duromètre (dureté Shore). Comité européen de normalisation, Bruxelles.
- AFNOR (2000) NF EN 12316-2. Feuilles souples d'étanchéité - Détermination de la résistance au pelage des joints - Partie 2: feuilles d'étanchéité de toiture plastiques et élastomères. Comité européen de normalisation, Bruxelles.
- AFNOR (1996) NF P 84-507. Essais des géomembranes - Détermination de la résistance au poinçonnement statique des géomembranes et des dispositifs d'étanchéité par géomembranes - Cas du poinçon cylindrique sans support. BNSR/GTX-GMB.
- AFNOR (1998) NF P 84-515. Mesure du niveau d'étanchéité conventionnel des géomembranes. BNSR/GTX-GMB.
- AFNOR (1992) NF P 501. Géomembranes-Dispositif d'étanchéité par géomembranes (DEG) Détermination des caractéristiques en traction. BNSR GMB.
- Blanco M., Aguiar E., García F., Vara T., Soriano J., Castillo F. (2011) État de la géomembrane en EPDM de la retenue d' "El Golfo" dans l'île d'El Hierro (Îles Canaries). Proc. 8eme Rencontres Géosynthétiques 283-293. Tours.Blanco M., Touze-Foltz N., Amat B., Castillo F., Aguiar E. (2013) Comportement d'une géomembrane EPDM 18 ans après son installation dans la retenue d'El Boqueron (Tenerife, Espagne). Proc. 9èmes Rencontres Géosynthétiques. Dijon.
- Frobel R., Gilligan T., Kalbas J. (1999) EPDM geomembrane caps commercial landfill. First United States permitted landfill using EPDM proves successful. GFR magazine, volume 17, number 8.
- Olivier, F. (2003) Tassements des déchets en CSD de classe II: du site au modèle, Thèse de doctorat, Université Joseph Fourrier de Grenoble, 305 p.

9 Enclosures

9.1 Specifications for water containment structures

9.1.1 Scope of work

- The work covered by this specification consists of providing and installing a non-reinforced vulcanized rubber sheet made from ethylene propylene diene terpolymer (EPDM) for use as a geomembrane liner.

9.1.2 References

- ASTM International:
  - ASTM D 412 -Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension
  - ASTM D 471 -Test Method for Rubber Property - Effect of Liquids
  - ASTM D 792 -Test Method for Density and Specific Gravity of Plastics by Displacement
  - ASTM D 1149 -Test Method for Rubber Deterioration - Surface Ozone Cracking in a Chamber.
  - ASTM D 1204 -Test Method for Liner Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
  - ASTM D 2240 -Test Methods for Rubber Property - Durometer Hardness
  - ASTM D 4437- Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes
  - ASTM D 4833 -Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
  - ASTM D 5617- Test Method for Multi-Axial Tension Test for Geosynthetics
  - ASTM D 7272 -Test Method for Determining the Integrity of Seams Used in Joining Geomembranes by Pre-manufactured Taped Methods
  - ASTM D 7465- Stand Specification for Ethylene Propylene Diene Terpolymer (EPDM) Sheet Used in Geomembrane Applications
  - ASTM E 96 - Test Method for Water Vapor Transmission of Materials
  - ASTM E 729 - Standard Practice for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians
  - ASTM G151 - Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources
  - ASTM G155 - Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials
- United States Environmental Protection Agency
  - EPA/600/4-89/001 Method 1000.0- Chronic Toxicity Screening Report Survival and Growth Effects on *Pimephales promelas* Flathead Minnows

9.1.3 Submittals to owner or owner's representative

- Sheet Layout and Detail Drawings: Submit geomembrane panel layout, anchor trench and penetration detail drawings a minimum of 30 days prior to delivery of Firestone GeoGard EPDM to jobsite.
- Record "As-Built" Drawings: Provide final record "As-Built" Drawings of geomembrane installation showing panel/ sheet numbers, seam numbers, and location of patches, destructive and /or non-destructive seaming samples, and any penetrations.
- Other Submittals:
  - Submit manufacturer's specifications and details.
  - Submit certification from the installer of the acceptability of the substrate on which the Firestone GeoGard EPDM is to be placed prior to the geomembrane placement.
  - Submit one sampte measuring 12" x 12" of the appropriate thickness Firestone GeoGard EPDM with one factory seam.

9.1.4 Quality Assurance

- Manufacturer to possess a minimum of ten years or more experience in the manufacturing of Firestone GeoGard EPDM for the purpose of general containment linings.
- Installer Is responsible for field handling, deploying, seaming, anchoring, and field quality control testing of Firestone GeoGard EPDM and shall have installed a similar geomembrane material. At least one installing individual shall have experience equal to the seaming of a minimum of 100,000 square feet of Firestone GeoGard EPDM material.
- Equipment used in the performance of inspection, installation and seaming shall be in accordance with the Firestone GeoGard EPDM manufacturer's recommendations and all· such equipment should be continuously maintained in a satisfactory working condition.

9.1.5 Deliveries, storage and handling

- Protect Firestone GeoGard EPDM from punctures, abrasions, vandalism, excessive heat or cold or other damaging conditions.
- Deliver materials to the job site in their original containers or wrappings and as labeled by the manufacturer. Follow the manufacturer's directions for protection of materials before and during installation. Do not use damaged materials. Remove damaged Firestone GeoGard EPDM from the project site at no additional cost to the owner.
- Store Firestone GeoGard EPDM and accessories in accordance with the manufacturer's recommendations.

9.1.6 Site Inspection

- The installer shall visit the site to check whether the excavation work has been performed as per the contract agreement.
- In no event shall the Firestone GeoGard EPDM be placed over rocks or other materials, which are capable of puncturing or stressing the Firestone GeoGard EPDM. In some instances, a protection geotextile should be installed under the Firestone GeoGard EPDM. The project engineer should determine the type and mass per unit area of the geotextile. In the absence of a project engineer, the installer should determine the type and mass per unit area of the geotextile. The ground surface shall be free of all organic debris and sharp objects before placement of the Firestone GeoGard EPDM. The Firestone GeoGard EPDM shall be overlapped and field-seamed when Firestone GeoGard EPDM and substrate is dry.

9.1.7 Products

9.1.7.1 Materials

- The membrane shall be Firestone GeoGard EPDM.

Firestone Non-Reinforced GeoGard EPDM (Black)

PHYSICAL PROPERTIES

Property	Test Method	Units	Minimum ASTM D7465	
			SI	Eng
Specific Gravity	ASTM D792	gm/cc	1.1	1.1
Unit Weight	ASTM D751	kg/m^2 (lb/ft^2)	1.3	.28
Thickness, Type 1	ASTM D412	mm (in)	1.14 +15/-10%	.045 +15/-10%
Tensile Strength, Die C	ASTM D412	MPa (lb/in^2)	9.0	1305
Ultimate Elongation, Die C	ASTM D412	%	300	300
Tear Resistance, Die C	ASTM D624	kN/m (lbf/in)	26.7	150
Puncture Resistance	ASTM D4833	N (lbs)	133	30
Shore A Durometer	ASTM D2240		65-10	65-10
Ozone Resistance	ASTM D1149		No Cracks	No Cracks
Multiaxial Elongation	ASTM D5617	%	100	100
Heat Aging	ASTM D573			
Tensile Strength, Die C	ASTM D412	MPa (lb/in^2)	8.3	1205
Ultimate Elongation, Die C	ASTM D412	%	200	200
Tear Resistance, Die C	ASTM D412	kN/m (lbf/in)	21.9	125
Accelerated Aging: Xenon Arc	ASTM G155/G151		Pass	Pass
Brittleness Point	ASTM D2137		-45°C	-49°F
Water Absorption	ASTM D471	%	+8, -2	+8,-2
Water Vapor Permeability (max.)	ASTM E96	Perm mils	2.0	2.0
Linear Dimensional Change (max)	ASTM D1204	%	+/-1.0	+/-1.0
Chronic Toxicity Screening	EPA/600/4-89/ 001 ASTM E729	Method 1000.0	passes passes	passes passes

Notes:

1. Certified Firestone GeoGard EPDM production materials are special order items requiring a minimum of two weeks as production lead-time
2. Following all testing conditions outlined in the standards document, Firestone GeoGard EPDM meets or exceeds the minimum requirements set forth by ASTM D7465 for Type I non-reinforced Firestone GeoGard EPDM.

Firestone geomembrane meets or exceeds the minimum requirements set forth by ASTM D4637 for Type II scrim-reinforced EPDM single-ply pond lining geomembranes.

- Accessories including but not limited to seaming materials shall be as supplied or approved by Firestone Specialty Products.

Warranty

Upon notice of completion from the installer the manufacturer shall issue a written twenty-year Firestone EPDM limited material warranty.

9.2 Execution

9.2.1 Subgrade preparation

- Surface Preparation: Perform in accordance with project specifications. Loose rock larger than one half inch in diameter and other debris that could damage the Firestone GeoGard EPDM shall be removed from the substrate. Construction equipment track deformations shall not be greater than one inch in depth. Installer shall observe subgrade surface daily and shall evaluate the surface conditions for the installation of the Firestone GeoGard EPDM. Before installing Firestone GeoGard EPDM, the installer shall certify in writing to the owner that the substrate upon which the Firestone GeoGard EPDM is to rest is acceptable.
- Anchor Trenches: On a daily basis excavate only the length of anchor trench, which can be overlain with the Firestone GeoGard EPDM and properly backfilled. Anchor trench corners toward the containment shall be rounded and free of protrusions to avoid sharp bends in the Firestone GeoGard EPDM. Loose soil, rocks larger than one half inch in diameter, and other debris that could damage the Firestone GeoGard EPDM shall be removed from upper edge of trench toward the containment. Backfill anchor trench material shall meet the same requirements as the substrate.

9.2.2 Firestone GeoGard EPDM placement

- Firestone GeoGard EPDM shall be placed with a minimum of handling and in accordance with the manufacturer's current specifications. All procedures and equipment shall ensure that no damage occurs to the Firestone GeoGard EPDM. Any Firestone GeoGard EPDM damaged during installation shall be removed or repaired by the installer as specified in section 3.5 of this specification. Any replacement work required by this specification will be completed at no additional cost to the owner. Daily installation is limited to the number of Firestone GeoGard EPDM panels that can be anchored and seamed together on the same day without damaging the Firestone GeoGard EPDM and with placement of adequate ballast on the Firestone GeoGard EPDM to prevent, wind-uplift. The method or equipment used to unroll or place Firestone GeoGard EPDM panels shall not stress or damage the Firestone GeoGard EPDM. All nonvulcanized seams shall run parallel to the line of MAXIMUM slope or they must rest without tension in the bottom of the containment.
- Wrinkles: The method or equipment used to place the Firestone GeoGard EPDM panels shall seek to minimize wrinkles. The installer during installation, ballasting and coverage must seek to provide sufficient slack in the installed Firestone GeoGard EPDM to prevent tensile stresses in the Firestone GeoGard EPDM and its seams.

9.2.3 Field seaming

- All field seaming shall be in accordance with the manufacturer's current approved methods. The manufacturer must manufacture or approve all materials and accessories.
- Field Seams - General Requirements: Firestone GeoGard EPDM panels shall be overlapped a minimum of four inches. Seaming shall extend to the outside edge of panels to be placed in anchor trenches. Seaming shall not be conducted in the presence of moisture, dust, dirt, standing water or soft subgrade as determined by the installer. Wet surfaces shall be thoroughly dried and soft subgrade should be compacted and approved by project engineer before seaming. Seam area shall be cleaned of dust, dirt, and other foreign material before and during seaming.

9.2.4 Field sampling and testing

- Non-Destructive Field Seam Testing: All field seams shall be nondestructively tested over their full length in accordance with ASTM D4437 (high pressure air lance) to ensure seam continuity. Seam testing shall be performed as the seaming work progresses, not at the completion of field seaming. Seams that fail shall be documented and repaired in accordance with the manufacturer's specifications and details.

9.2.5 Repairs

- Defective Seam Test Repairs: Defective seam areas shall be thoroughly cleaned and covered with a strip of new cover strip tape, cover strip tape and a Firestone EPDM patch or a patch fashioned from Firestone GeoGard EPDM and double-face splice tape. After adding the repair strip or patch, the entire repaired seam area shall be tested in accordance with ASTM D 4437 (high pressure air lance) non-destructive testing methodology.
- Installer certified test results on repaired seams shall be submitted for all defective seamed areas.
- Repair Patches: Tears, holes, blisters, and areas with undispersed raw materials or foreign material contamination shall be repaired with patches. Patches shall have rounded corners, be made of Firestone GeoGard EPDM and extend a minimum of six inches beyond the edge of the defect. All repairs shall be tested in accordance with ASTM D 4437 (high pressure air lance) non-destructive testing methodology.

9.2.6 Penetrations, details and accessory products

- Firestone GeoGard EPDM penetration details shall be as shown on the drawings and as recommended by the Firestone GeoGard EPDM manufacturer. Factory fabricated boots shall be used wherever possible. Field seams shall be tested in a non-destructive manner in accordance with ASTM D4437. Seams that fail nondestructive testing shall be repaired and the repaired seams shall be retested using a non-destructive method.

9.2.7 Cover soils

- Firestone GeoGard EPDM may be covered with a geosynthetic or soil cover material in accordance with the project engineer's specifications.

The data in this document is for informational purposes only and does not constitute a warranty or guarantee. Firestone Building Products assumes no responsibility for the use of this information. Application of this information for any project is to be at the recommendation of the project engineer.

Contact Firestone Building Products for further information on geomembrane selection criteria.

9.3 Chemical Resistance Guide for EPDM Geomembrane

The durability of Firestone EPDM Geomembrane cannot be guaranteed if it is placed in contact with the chemicals listed below. To know the impact of chemicals not shown on this list on a Firestone EPDM Geomembrane system, please contact Firestone Technical department at www.firestonebpco.com/about-us/contact-us/

EXPOSURE OF FIRESTONE EPDM GEOMEMBRANE TO THESE CHEMICALS IS EXPECTED TO CAUSE DETERIORATION AND SO IT IS NOT RECOMMENDED.

Chemical Name	Important Limiting Factors
Acrylonitrile	≤40°C, (104°F)
Acetonitrile	≤21°C, (70°F)
Acetic acid	≤100% Concentration, ≤ 21°C, (70°F)
Acetic acid Vapor	≤32°C, (90°F)
Acetyl bromide	
Acetyl chloride	
AeroShell lubricants	
Aliphatic hydrocarbons	
Alkyl chloride	
Ammonia	≤ 60°C, (140°F)
Amyl acetate	≤99°C, (210°F); ≤21° C, (70°F), Dynamic*
Amyl naphthalene	
Animal fats	≤ Concentrated
Aqua regia /Nitro-hydrochloric acids	
Aromatic hydrocarbons	
Asphalt	
ASTM oil no. 1	
ASTM oil no. 2	
ASTM oil no. 3	
ASTM oil no. 4	
ASTM fuel oil A	
ASTM fuel oil B	
ASTM fuel oil C	
ASTM fuel oil D	
Automotive gasoline	
Automotive transmission fluids	

Benzene	
Benzine / Petroleum ether	
Benzoic acid	
Benzyl chloride	
Biphenyl	
Borneol	
Bornyl acetate	
Boron trichloride	
Bromine	Gas and anhydrous liquid
Bromobenzene	
Bromomethane /Methyl bromide	
Bromopentane	
Butane	≤50%~100% Conc., ≤ 21°C, (70°F)
Butyl acrylate	
Butyl acetate	≤ 21°C, (70°F), Dynamic*
Butyl benzene	
Butyl bromide	
Butyl chloride	
Butyl ether	
Butyl stearate	
Butylene	≤ 21°C, (70°F), Gas or liquid

Camphene Capric acid	
Carbolic acid	≤10% Conc., ≤27°C, (80°F)
Carbon disulfide	
Carbon fluoride	
Carbon sulfide	
Carbon tetrachloride	
Chassis grease	
China wood oil	
Chlorinated solvents	
Chlorine gas	
Chlorine trifloride	
Chlorobenzene	
Chlorobenzene chloride	
Chloroform	
Chloronaphthalene	

Chloropantane	
Chloropropane	
Chlorosulfonic acid	
Chlorotoluene	
Cholesterol	
Chromic acid	≤30% Conc.
Cinnamic alcohol	
Coal oil	
Coal tar	
Corn oil	
Cresol(s)	
Creosote	
Cresyl alcohol	
Crude oil	
Cumene	
Cutting oils	
Cyclohexane	
Cyclohexanol	
Cyclohexanone	
Cyclopentane	
Cymene	

DDT in toluene or Kerosene	
Decane	
Decanol	
Decreasing fluid	
Dextron ATF	
Diazinon	
Dibenzyl ether	
Dibenzyl sebacate	
Dibromobenzene	
Dibutyl amine	
Dibutyl ether	
Dibutyl thioglacolate	
Dibutyl thiourea	
Dichloroacetic acid	
Dichlorobenzene	

Dichlorobutane

Dichlorobutene

Dichlorodiphenyl dichloroethane

Dichlorodiphenyl trichloroethane

Dichloroethane

Dichloroethylene

Dichloroethyl ether

Dichlorofluoromethane

Dichloropentane

Dichlorophenol

Dichlorophenoxy acetic acid

Dichloropropane

Dichloropropene

Dicyclohexylamine

Dieldrin

Dieldrin xylene

Diesel fuel

Diester lubricants

Diethyl benzene

Diethyl ether

Diethyl oxalate

Difluoromonochloroethane

Diisobutyl carbinol

Diisobutylene

Diisoprene

Diisopropyl benzene

Diisopropyl ether

Dimethyl benzene

Dimethyldisulfide

Dimethylether

Dimethylphenol

Dimethylphenyl methanol

Dimethyl sulfate

Dimethyl sulfide

Dinitrochlorobenzene

Dinitrotoluene

Dipentene

Diphenyl or Biphenyl

Diphenyl oxide

Diphenylamine

Diphenylpropane

Dipropyl methan

Dispersion oil No.10

Divinylbenzene

Dowtherm oil

Dry cleaning fluids

DIE light oil

ESSO Fuel

Ethane

Ethers

Ethoxyethane

Ethyl benzene

Ethyl bromide

Ethyl butyrate

Ethyl caprylate

Ethyl cyclopentane

Ethyl dichloride

Ethyl isobutyl ether

Ethyl penta chlorobenzene

Ethyl phthalate

Ethyl propionate

Ethyl propyl ether

Ethyl stearate

Ethyl valerate

Ethylene

Ethylene chloride

Ethylene cyanohydrin

Ethylene dichloride

Ethylene oxide

Ethylidene chloride

Ethylmorpholine

Fatty acids	
Firedamp	
Firwood oil	
Fish oil	
Fluothane (Halothane)	
Fluorine, liquid	
Fluorobenzene	
Freon 11	
Freon 21	
Freon 23	
Freon 112	
Freon 113	
Freon 114b2	
Freon 143a	
Fuel oil	
Fuming sulfuric acid	
Furan	
Furfural	≤100°C, (212°F)

Gasoline	
Gear oil	
Grease, petroleum base	
Gulf oils	
Gulf crown grease	

Halowax oil	
Heavy benzine	
Heptachlorobutene	
Heptane	
Heptanoic acid	
Hexachlorobutadiene	
Hexachloroethane	
Hexadecane	
Hexahydropyridine	
Hexamethylene diammonium adipate	
Hexane	
Hexene	

Hexylresorcinol	
Hexyl alcohol	
Hexyl acetate	
Hexylene	
Hexylresorcinol	
Hydraulic oil, petroleum based	
Hydriodic acid / Hydrogen iodine	≤37% Conc., ≤40°C, (104°F)
Hydrocarbons, alicyclic	
Hydrocarbons, aliphatic	
Hydrocarbons, aromatic	
Hydrocarbons, chlorinated	
Hydrocarbons general	
Hydrochloric acid	≤20% Conc., ≤40°C, (140°F); Dynamic*, ≤21° C, (20°F)
Hydrofluoric acid	≤65% Conc., ≤21°C, (70°F); ≤ 40% Conc., ≤80° C, (176°F)
Hydrogen iodine / Hydriodic acid	≤37% Conc., 40° C, (104°F)
Hydrogen peroxide	≤30% Conc., 40° C, (104°F)
Hypochlorous acid	≤10% Conc., 40° C, (104°F); Dynamic*, ≤ 21° C (70°F)

Iodine pentafluoride	
Isoamyl chloride	
Isoamyl ether	
Isoamyl phthalate	
Isobutane	
Isobutyl Bromide	
Isobutyl chloride	
Isobutyl ether	
Isobutylene	
Isodecane	
Isodecanol	
Isododecane	
Isooctane	
Isopentane	
Isopropyl chloride	
Isopropyl ether	
Isopropyl methyl benzene	
Isopropyl toluene	

Jet Fuel	
Kerosene	
Lacquer solvents Lacquers	
Lard oil, Animal fat	Dynamic*, ≤ 21°C, (70°F)
Lavender oil	
Linolenic acid	
Liquid oxygen	
Liquid petroleum gas	
Liqui moly	
Lubricating oils	
Machine oil	
Margarine	
Mayonnaise	
Menthol	
Meta-cresol	
Methane	
Methyl amyl acetate	
Methyl amyl amine	
Methyl benzoate	
Methyl bromine	
Methyl butyrate	
Methyl carbonate	
Methyl chloride	
Methyl chloroform	
Methyl chloroformate	
Methyl cyclohexane	
Methyl cyclohexanone	
Methyl cyclopentane	
Methyl dichloride	
Methyl ether	
Methyl ethyl ketone peroxide	
Methyl hexane	
Methyl iodide	
Methyl methacrylate	

Methyl methane
Methyl propyl ether
Methylene bromide
MIL-C-4339
MIL-C-5545A
MIL-C-6529C
MIL-C-7024A
MIL-C-8188C
MIL-F-5602
MIL-F-7024A
MIL-F-16884
MIL-F-16929A
MIL-F-16958A
MIL-F-17111
MIL-F-19605
MIL-F-25172
MIL-F-25524A
MIL-F-25558B / RJ-1
MIL-F-25576 / RP-1
MIL-F-25578C
MIL-F-25656B / JP-6
MIL-F-81912 / JP-9
MIL-F-82552 / RJ-4
MIL-G-2108
MIL-G-3278
MIL-G-3545
MIL-G-5572
MIL-G-7118A
MIL-G-7187
MIL-G-7421A
MIL-G-7711A
MIL-G-10924B
MIL-G-15793
MIL-G-18709A
MIL-G-23827A
MIL-G-25537A
MIL-G-25760A

MIL-H-6083C

MIL-H-8846B

MIL-H-13862

MIL-H-13866A

MIL-H-13919A

MIL-H-25598

MIL-H-27601A

MIL-H-46001A

MIL-H-46004

MIL-H-46170

MIL-H-81019B

MIL-H-83282

MIL-J-5161F

MIL-J-5624G, JP-3

MIL-J-5624G, JP-4

MIL-J-5624G, JP-5

MIL-L-2104

MIL-L-2104B

MIL-L-2105B

MIL-L-3150A

MIL-L-3545B

MIL-L-5020A

MIL-L-6042C

MIL-L-6085A

MIL-L-6387A

MIL-L-7645

MIL-L-7808A

MIL-L-7808C, lubricant

MIL-L-7808F, lubricant

MIL-L-7808H, lubricant

MIL-L-7870A

MIL-L-8083B

MIL-L-9000F

MIL-L-9236B

MIL-L-7870A

MIL-L-10295

MIL-L-10324A

MIL-L-11734B

MIL-L-14107B

MIL-L-15016

MIL-L-15107

MIL-L-15108B

MIL-L-15109A

MIL-L-16958A

MIL-L-17353A

MIL-L-17672B

MIL-L-18486A

MIL-L-19701

MIL-L-21260

MIL-L-22396

MIL-L-25336B

MIL-L-25968B

MIL-L-25968B

MIL-L-26087

MIL-L-46000A

MIL-L-46002

MIL-O-3503

MIL-O-6081C

MIL-O-7808

MIL-R-25576, RP-1

MIL-S-3136, type I

MIL-S-3136, type II

MIL-S-3136, type III

MIL-S-3136, type IV

MIL-S-3136, type V

MIL-S-3136, type VI

MIL-S-3136, type VII

MIL-T-5624, JP-4, JP-5

MIL-T-83133, JP-8

Mineral naphtha

Mineral oils

Mineral pitch

Mineral spirits

Mineral thinner

Mixed acid etchants	
MLO-7277, 7577	
MLO-8200, 8515	
Mobil DTE 24	
Mobil Delvac 1100, 1110, 1120, 1130	
Mobil HF	
Mobil SHC 500 Series	
Mobil SHC 600 Series	
Mobil Therm 600, 603	
Mobil Velocite C	
Mobil Gas WA200 ATF	
Mobil Grease, HP, HTS, SM	
Mobil Oil SAE 20	
Mobilux	
Molybdenum disulfide grease	
Monobromobenzene	
Monochlorobenzene	
Monochlorophenol	
Monomethyl ether	
Mononitrochlorobenzene	
Motor oils	
Motor spirits	
Naphtha	
Naphthalene	
Naphthalene sulfonic acid	
Naphthenic acid	
Natural gas	
Neohexane	
Nitric acid	≤30% Conc., ≤21°C, (70°F)
Nitric acid, white and red fuming	
Nonane	
Nut oils	
Octachlorotoluene	
Octadecane	
Octanal	

Octane	
Octyl chloride	
Oil SAE	
Olefins	
Oleic acid	
Orthochloroethylbenzene	
Orthodichlorobenzene	
Orthoxylene	
Oxyethylene succinic acid	
Oxygen, liquid	

Paint, oil based	
Palm oil	
Paracymene / P-cymene	
Para-dichlorobenzene	
Parafins	
Parker O-lube	
Peanut oil	Dynamic*
Pentachlorodiphenol	
Pentane	
Pentyl oxypentane	
Pentyl pentanoate	
Perchloroethylene	
Petrolatum	
Petrolatum ether	
Petrolene	
Petroleum	
Petroleum ether	
Petroleum pitch	
Petroleum spirit	
Phenoxin	
Phenoxybenzene	
Phenyl benzene	
Phenyl ethyl ether	
Phenyl hydrazine	
Phosphorus oxychloride	
Photogen	

Pine oil	
Pine tar	
Pinene	
Piperidine	
Pitch	
Propane, gas or liquid	
Propylene	
Propylene chloride	
Pydraul 230C, 312C, 540C, & A200	
Pyranol hydraulic oil	
Pyranol transformer oil	
Pyranol 1467	
Pyranol 1476	
Pyrene	
Pyridine	Dynamic*
Pyrosulfuryl chloride	
Pyrrole	

Quenching oil	
Quinidine	
Quinine	
Quinizarin	
Quinoline	
Quinone	

Raffinate	
Red Line 100 oil Riboflaven	
Richfield A Weed Killer	≤100% Conc., ≤21°C, (70°F)
Richfield B Weed Killer	≤33% Conc., ≤21°C, (70°F)
Ricinoleic acid	
Rosin	

SAE No. 10 oil	
SAE No. 10-30 oil	
Santosafe 300	Dynamic*
Shell 3XF mine fluid	
Shell Alvania Grease No. 2	

Shell Carnea 19 & 29	
Shell DD	
Shell Diala	
Shell IRUS 905	
Shell Lo Hydrax 27 & 29	
Shell Macome 72	
Shell Tellus 27, Petro base	
Shell Tellus 32, Petro base	
Shell Tellus 33	
Shell Tellus 68	
Shell turbine oil 307	
Shell UMF 5% Aromatic	
Sherwood oil	
Shortening	
Silicon tetrachloride	
Sour crude oil	Dynamic*
Stauffer 7700	
Styrene monomer	
Sulfanilic Chloride	
Sulfanilimide	
Sulfonated oils	
Sulfur chloride	
Sulfur salts	
Sulfuric acid	Concentrated
Sulfuric acid fuming	
Sulfuric acid, 20-25% oleum	
Sulfur monochloride	
Sulfur dichloride	
Sulfur trioxide	
Sunoco Al Purpose Grease	
Sunoco SAE 10	
Sunoco X5 820 (EP lubricant)	
Sunoco 3661	
Sunsafe (fire resistant fluid)	
Supershell gasoline	
Swanfinch EP lubricant	
Swanfinch hypoid 90	

Tall oil	
Tar, bituminous	
Terpinyl acetate	
Tertiarybutylmercaptan	
Tetroabromoethane	
Tetroabromomethane	
Tetroachlorobenzene	
Tetroachloroethane	
Tetroachloroethylene	
Tetroachloronaphthalene	
Tetra ethyl lead	
Tetra ethyl lead blend	
Tetrahydrofuran / THF	
Tetrahydronaphthalene	
Tetramethyldihydropyridine	
Texaco Capella A & AA	
Texaco Meropa 220, No Lead	
Texaco Regal B	
Texaco Uni-temp Grease	
Texaco 3450 gear oil	
Texamatic A transmission oils	
Texamatic 1581 fluild	
Texamatic 3401 fluild	
Texamatic 3525 fluild	
Texamatic 3528 fluild	
Texas 1500 oil	
Therminol VP1, 60 & 65	
Therminol 44	
Therminol 45	
Therminol 55	
Thioamyl alcohol	
Thiofuran	
Thioglycolic acid	≤50°C, (122°F)
Thionyl chloride	
Thiophene	
Tidewater multigear 140 EP lubes	
Tidewater oil-beedol	

Titanium tetrachloride

Toluene

Toluene sulfonyl chloride

Toluidine

Toluquinone

Town gas / coal gas

Transformer oils

Tribromomethyl benzene

Trichloroacetyl chloride

Trichlorobenzene

Trichloroethane

Trichloroethylene

Trichlorofluoromethane

Trichloromethane

Trichloronitromethane

Trichloropropane

Trichlorosilane

Trichlorotrifluoroethane

Triethylphosphate

Trifluoroethane

Trifluoromethane

Trifluorovinylchloride / Trifluorochloroethylene

Triisopropylbenzylchloride

Trimethyl benzene

Trimethyl borate

Trinitrotoluene

TT-N-95a

TT-N-97b

TT-S-735 Type I

TT-S-735 Type II

TT-S-735 Type III

TT-S-735 Type IV

TT-S-735 Type V

TT-S-735 Type VI

TT-S-735 Type VII

Tung oil

Turbine Oil

Turpentine

Type I Fuel / MIL-S-3136

Type II Fuel / MIL-S-3136

Type III Fuel / MIL-S-3136

Undecylenic acid

Undecylic acid

Univis 40, hydraulic fluid

Univolt 35, mineral oil

Vanadium oxide

Vanadium pentoxide

Varnish

Vaseline

Vinyl benzene

Vinyl benzoate

Vinyl cyanide

Vinyl fluoride

Vinyl toluene

Vinylidene chloride / Vinylidene dichloride / dichloroethene

VV-G-632

VV-G-671c

VV-I-530a

VV-K-211a

VV-K-220a

VV-L-751b

VV-L-800

VV-L-820b

VV-L-825a Type I

VV-L-825a Type II

VV-L-825a Type III

VV-O-826

VV-P-216a

VV-P-236

Wax

Wax alcohol

Wheat germ oil
White oil
White pine oil
White pine tar
Wood oil
Wood tar

Xylamon, wood preservative
Xylene
Xylol

Notes:

≤ : This symbol indicates safe exposure at less than the indicated value or at a maximum of the indicated value.

Dynamic : Dynamic is when the EPDM geomembrane is exposed to external stresses or movement.

~ : A tilde is used to indicate an approximate value.

9.4 Non-exhaustive list of plants producing rhizomes

The following plants exhibit important rhizome growth and can therefore not be put in contact with the waterproofing layer. A separate root barrier is required or the plants should be confined within a space separate from the waterproofing layer by a root impermeable layer.

The depth of rhizome growth of these plants may vary. Protection of the embankments is therefore of the utmost importance.

- All bamboo
- Arundo donax
- Achnatherum calamagrostis
- Ammophila arenaria
- Brachypodium
- Calamagrostis
- Carex
- Chloris barbata
- Elymus
- Leymus
- Miscanthus
- Glyceria
- Phragmites australis
- Phragmites communis
- Scirpus
- Typha
- Spartina spectinata
- Aesculus parviflora
- Aralia elata
- Aronia melanocarpa
- Berberis vulgaris
- Cornus stolonifera
- Elaeagnus commutata
- Hippophae rhamnoides
- Prunus spinosa
- Pterocarya fraxinifolia
- Rhus
- Rosa
- Sorbaria sorbifolia
- Syringa vulgaris

This list is not intended to be exhaustive but merely serves as a guide to the designer/installer in order to make sure the necessary protective layer(s) are implemented to prevent any root and/or rhizome attack on the waterproofing layer.

Creases and folds in the membrane need to be covered with a separate piece of QS SA Flashing.

9.5 Bibliography

Some of the information present in this guide comes from the technical documents listed below:

- Laurent Peyras, Patrice Mériaux, coord. (2009) Retenues d'altitude. Editions Quae. Collection Savoir Faire
- Gobierno de España, Ministerio de Fomento, Ministerio de Medio Ambiente y Medio Rural y Marino, CEDEX, CNEGP (2010) Manual para el diseño, construcción, explotación y mantenimiento de balsas. Spancold
- John Scheirs (2009) A Guide to Polymeric Geomembranes. Wiley Series in Polymer Science, Wiley
- Comité Français des Géotextiles et Géomembranes (1991) Recommandations générales pour la réalisation d'étanchéités par géomembranes, Fascicule n°10. CFG
- AFAG (2008) Vade-Mecum de la profession d'Entrepreneur Applicateur pour la réalisation des Dispositifs d'Etanchéité par Géomembranes (DEG et DEDG) dans les ouvrages de génie civil. AFAG

Firestone Building Products
250 W. 96th St. | Indianapolis, IN | 46260
888-264-1735 | www.firestonebpco.com
/FirestoneBuildingProducts @FirestoneBPCo

| FOR FURTHER INFORMATION, PLEASE CONTACT YOUR LOCAL FIRESTONE GEOGARD EPDM DISTRIBUTOR OR FIRESTONE BUILDING PRODUCTS |

Firestone
BUILDING PRODUCTS
NOBODY COVERS YOU BETTER.™