

## 2 • Installation

### 2.1 Earthwork

#### 2.1.1 Site layout

The site layout may be executed by means of:

- *Excavating natural soil*
- *Building raised embankments*
- *Partial excavation with raised embankments*

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

System	Advantages	Disadvantages
Fully excavated	<ul style="list-style-type: none"><li>• little soil movement (naturally consolidated)</li><li>• lowest cost</li></ul>	<ul style="list-style-type: none"><li>• removing the excavated earth</li><li>• water drainage problems</li></ul>
Raised embankments	<ul style="list-style-type: none"><li>• easier drainage</li><li>• the work is above the water level</li></ul>	<ul style="list-style-type: none"><li>• higher cost</li><li>• compacting required</li><li>• risk of unstable embankment</li></ul>
Partial excavation	<ul style="list-style-type: none"><li>• compromise of both systems</li></ul>	<ul style="list-style-type: none"><li>• moderate cost</li></ul>

#### 2.1.2 Preparation of the support

All soils supporting Firestone Geomembranes must be compacted between 85% and 95% of the Proctor Optimum value. The compaction is achieved by either natural compaction or by mechanical methods. In the latter case, the material is deposited in layers of 200 to 500 mm maximum and the settling is completed with a vibrating machine or road roller. The compaction operation can be followed by a weed killer treatment.

The supporting surface must not contain any loose stone with a diameter exceeding 5 mm. If the base of the pond consists of soft materials, such as sand or clay, the Geomembrane can be laid directly onto such surface. In most cases however, a geotextile of at least 300 g/m<sup>2</sup> must be installed.

#### 2.1.3 Inspection of excavation work

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

## **2.2 Firestone Geomembrane installation**

### **2.2.1 Product information**

All elements of the Firestone Lining System must be Firestone products, as described in the Technical Data Sheets, or products which are approved by Firestone.

The Firestone Geomembrane is a synthetic rubber membrane. The panels are assembled in the factory prior to vulcanization, in order to limit on-site splicing. The rubber sheets are folded and packed on 3,30 m long cores.

The sheets are available in the following sizes :

- *width (m)* : 3,05 - 6,10 - 7,62 - 9,15 - 12,20 or 15,25
- *length (m)* : 15,25 - 30,50 - 45,75 or 61,00
- *thickness (mm)* : 1,02 - 1,14 - 1,52

Each roll is labelled with the brand name, thickness, dimensions, date and production lot, as well as an arrow indicating the direction for unrolling.

### **2.2.2 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 and clean surface, free of sharp protrusions.

Firestone Geomembranes do 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), protected against the weather conditions.

### **2.2.3 Panel layout**

If particular site conditions demand so, the contractor must establish a sheet layout. This plan must be made on the basis of the specification and detail plans, and indicate the position of the sheet splices. The on-site layout of the panels must be done according to this plan.

### **2.2.4 Placing the Firestone Geomembrane**

The rolls are unwound and unfolded according to the layout plan. Installation commences with the covering of the embankments. The Geomembrane panels are unrolled from the trench towards the embankment and the Geomembrane is temporarily fixed to avoid it slipping down. Ensure that no pebbles or sharp objects are entrapped under the Geomembrane, whilst the sheets are being unrolled.

While installing the sheets, severe folds in the geotextile and damage of the supporting surface must be avoided to enable the Geomembrane to be manoeuvred correctly. The Geomembrane must be lifted/fluttered at the perimeter allowing air to play underneath, thus moving the membrane on an air cushion.

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

All Firestone Geomembranes must relax at least 30-45 minutes before splicing the seams or executing details.

## 2.2.5 Anchoring of the Firestone Geomembrane

The Geomembrane must be kept in place to prevent it slipping down the embankment and/or it being lifted by the wind. Depending upon the situation, the Geomembrane can be anchored in various ways:

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

### Top anchoring

The anchoring must be realized by burying the Geomembrane in a trench or by holding it in place through ballasting. The dimensions of the trench depend on the expected stress. The minimum section should be 0.40 m x 0.40 m 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, etc.

The Firestone Geomembrane must extend at the bottom of the trench over at least 300 mm.

If considerable soil movements are expected after filling the pond, temporary clamping must be provided at the crest, so that the Firestone Geomembrane 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 pond must be filled prior to filling and compacting the anchoring trench. Filling and compacting the anchoring trench must be performed without subjecting the Geomembrane to stress or being punctured.

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

The table below shows a few practical values for the section in compacted clay soil.

Length of embankment (m)	Section of trench (m <sup>2</sup> )	
	Low or medium wind speed (< 100 km/hr)	High wind speed (> 100 km/hr)
< 3	0,16	0,16
3 - 5	0,16	0,16
5 - 15	0,16	0,25
15 - 40	0,25	0,36
> 40	0,36	0,49

An alternative using ballast is possible if necessary measures are taken for the ballast not to erode over time.

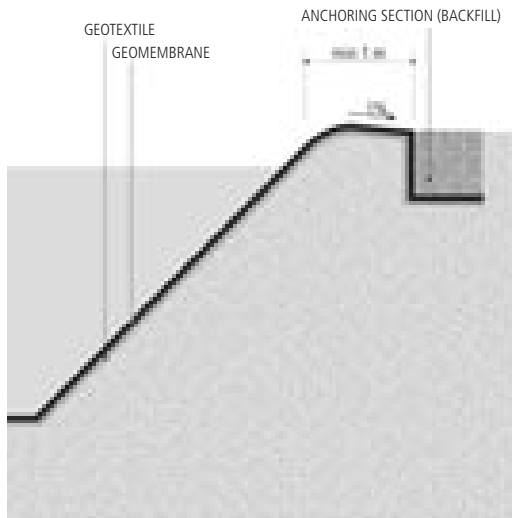


Fig. 6 : Top anchoring in trench

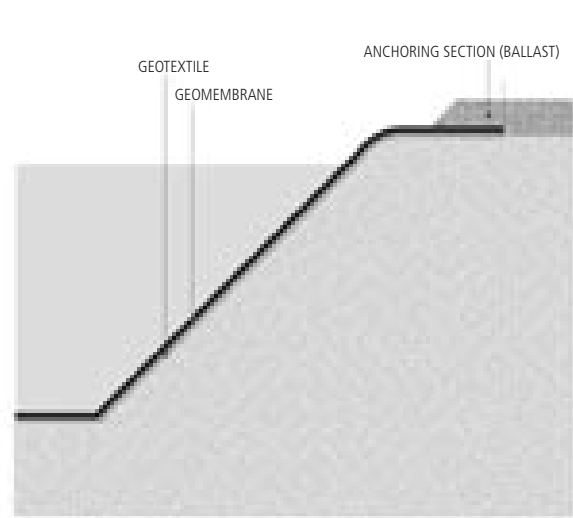


Fig. 7 : Top anchoring with ballast

### **Intermediate anchoring**

If the embankment is high, it can be necessary to provide an intermediate clamping to accommodate the Geomembrane movements. Such clamping can be carried out using ballast or anchor trench. A platform can be added to the incline, in order not to endanger the stability of the embankment.

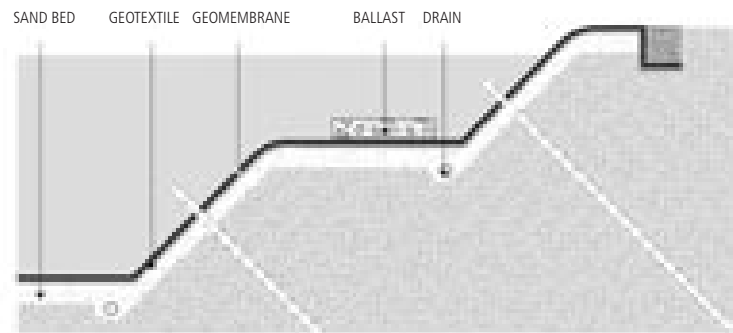


Fig. 8 : Intermediate anchoring

### **Base anchoring**

If the natural soil of the pond base is sufficiently low in permeability (clay, waterproof geological layer,...) anchoring at the base of the pond with ballast is sufficient to provide adequate waterproofing (see fig. 9).

Another practical solution is to provide a 1 m deep ditch at the base of the embankment. When the waterproof layer is situated at a great depth, it is indeed possible to extend enough Geomembrane at the base of the pond to keep the pond losses within acceptable limits (see fig. 10).

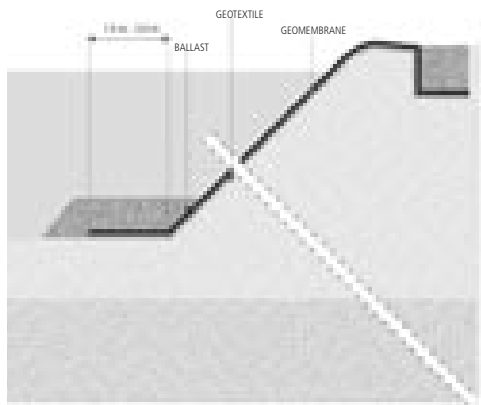


Fig. 9 : Base anchoring with ballast

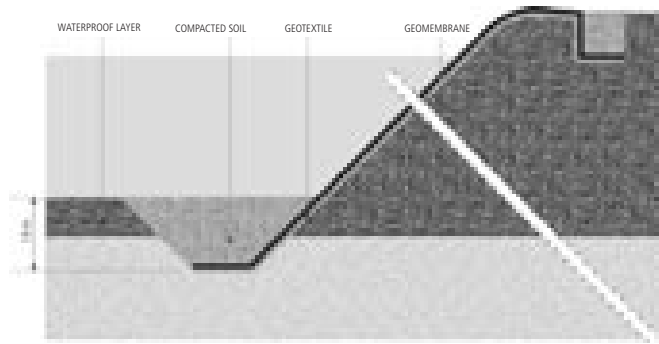


Fig. 10 : Base anchoring with trench

## 2.2.6 Seaming adjoining Firestone Geomembrane panels

The splicing of adjoining panels should be performed immediately after the relaxation of the Firestone Geomembrane.

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

For soft subsoils, a wooden board, a piece of insulation, or a laminated panel must be used under the Geomembrane, in the area of the splice. The panel is moved by means of a rope as the splicing process progresses.

### Seaming procedure

Two overlapping Firestone Geomembrane panels are assembled by means of a self-adhesive tape. Below are the various steps required for proper splicing.

#### Step 1 : Position the Geomembrane

- Both Geomembrane panels must be positioned with sufficient overlap ( $\pm 200$  mm).
- The Geomembranes must lay flat and without any tension.
- Use a marker to indicate on the lower sheet the exact location where the tape is to be installed.
- The mark must be situated between 10 and 20 mm from the edge of overlapping sheets, and is repeated every metre.

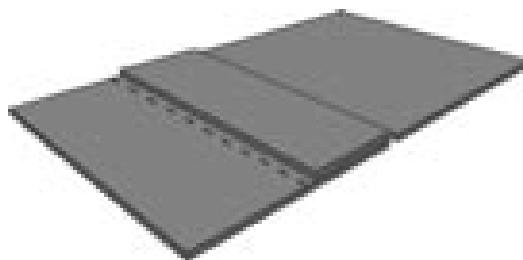


Fig. 11

### **Step 2 : Tack-back the overlap**

- The upper Geomembrane panel is folded back 250 mm, the fold is glued down every metre with QuickPrime.
- In case the Geomembrane is covered with mud or very dirty, we recommend to pre-clean the overlap area, using a cloth soaked in Splice Wash. Soil should not be allowed to contaminate the Geomembrane in the splicing area.

### **Step 3 : Apply the QuickPrimer**

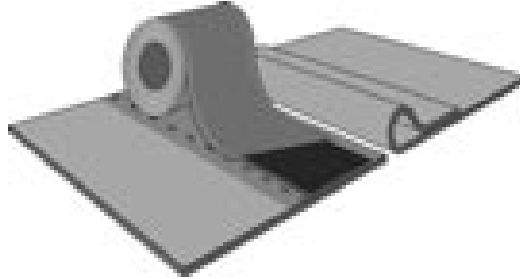
- Stir the QuickPrime before and during use and transfer a small quantity (1.5 l) to a bucket. The Primer is applied with a scrubbing pad.
- Immerse the scrubbing pad in the QuickPrime, keeping the pad horizontally and let excess of QuickPrime drip off.
- Apply the QuickPrime uniformly along the length of the splicing area, with long back and forth strokes, both to the lower face of the top sheet and the upper face of the lower sheet, until the surfaces become a dark grey in colour. Avoid traces and wet spots. Each pad immersed in QuickPrime will cover a splice of about 1,00 m, over a width of 100 mm (one side).
- Change scrubbing pads each 60 m 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 splices and to areas covered with adhesive.
- Both sides to be spliced are treated simultaneously, so as to obtain an identical drying time.
- Test QuickPrime for readiness. Allow the primer to flash off. The primer needs to dry completely ( $\pm 10$  minutes) before installing the tape. Check its dryness by touching the primed surface with a clean and dry finger to make sure 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 throughout 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,...).



*Fig. 12*

#### **Step 4 : Install the tape**

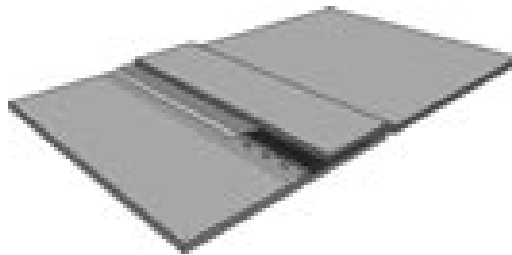
- Apply the QuickSeam Splice Tape (with release paper intact) on the bottom sheet, aligning the edge of the release paper with the markings.
- Immediately roll the splice with a 100 mm wide silicone sleeved hand roller.



*Fig. 13*

#### **Step 5 : Check the Splice Tape alignment**

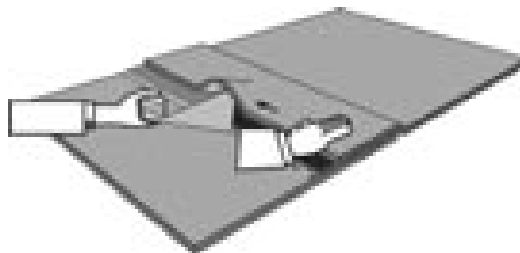
- The upper Geomembrane is released and the splice is closed with the hand. To avoid wrinkling, close the splice gently with a movement perpendicular to the splice. The upper sheet must fall without wrinkling or tension onto the lower sheet. Allow the top sheet to rest on top of the tape's paper backing.
- Trim the top sheet as necessary to assure that 10 to 15 mm of the QuickSeam Splice Tape will be exposed on the finished splice.



*Fig. 14*

#### **Step 6 : Remove paper backing**

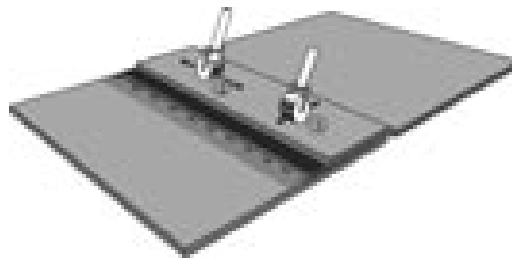
- To remove the paper backing from the tape, first roll back the Geomembrane sheet. Peel the paper backing off the QuickSeam Splice Tape by pulling against the weight of the bottom sheet at approximately a 45 degree angle to the tape and parallel with the roof surface.
- Allow the top sheet to fall freely onto the exposed QuickSeam Splice Tape. Mate the entire length of the splice as the release paper is being removed.



*Fig. 15*

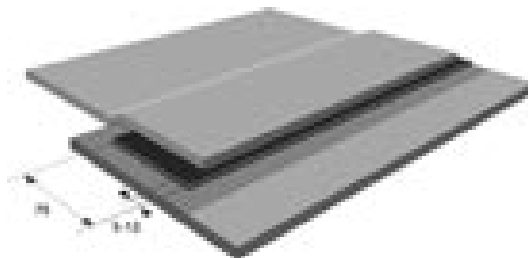
### **Step 7 : Roll the splice**

- Finally, roll the splice by means of a silicone rubber roller, first across the splice and then along the entire length of the splice.



*Fig. 16*

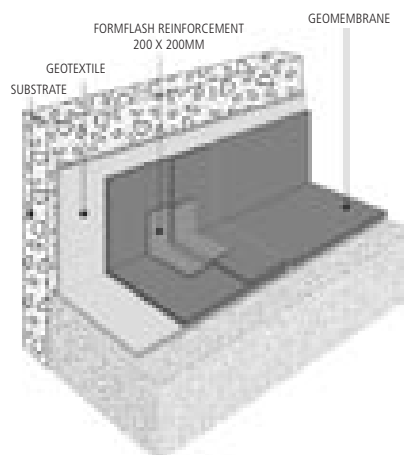
- The completed splice will eventually look as follows:



*Fig. 17*

### **Special considerations are required (End laps, T joints, etc...):**

- When the seam is greater in length than the tape, the overlap between two adjoining tapes should be at least 25 mm. A protective sealant, Lap Sealant, is applied over a length of 100 mm on either side of the overlap.
- When several Geomembrane panels meet at a common point, only three panels may overlap each other. Apply a FormFlash reinforcement (200 x 200 mm) over this joint area.
- Apply a FormFlash reinforcement (200 x 200 mm) over the area where a field splice runs from the horizontal area into the slope of the embankment as illustrated below:



*Fig. 18 : Vertical Splice Reinforcement*

- Clean the seam area with Splice Wash before applying the QuickPrime if it is contaminated (mud, etc.).
- Stop the application of the QuickSeam when the atmospheric conditions are unfavourable (humidity, condensations on the QuickPrime, rain).
- Movement of the Firestone Geomembrane 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 allowed.

### **2.2.7 Protection of the Firestone Geomembrane**

Under most conditions, protection of the Firestone Geomembrane will be required. In the table below you will find some recommendations for the protection against potential damage.

<b>Protection against</b>	<b>Precautions</b>
Wind	<ul style="list-style-type: none"> <li>• ballast at the bottom and/or on slopes (in case of temporary emptying)</li> <li>• correct section of the anchor trench</li> </ul>
Waves	<ul style="list-style-type: none"> <li>• mechanical protection of the embankments depending on the slope : rock covering, concrete pavement, cast concrete</li> </ul>
Floating objects (dead wood, boats)	<ul style="list-style-type: none"> <li>• small ponds : cleaning</li> <li>• larger ponds : protection</li> </ul>
Ice	<ul style="list-style-type: none"> <li>• mechanical protection of embankments</li> </ul>
Animals (rodents)	<ul style="list-style-type: none"> <li>• ladders</li> <li>• enclosure around the reservoir</li> <li>• mechanical protection of embankments</li> </ul>
Operating vehicles	<ul style="list-style-type: none"> <li>• protection of the Geomembrane with soil or a sand bed (min. 20 cm)</li> <li>• access ramp</li> </ul>
Local turbulence with water speed exceeding 1 m/sec. (internal agitator or canals)	<ul style="list-style-type: none"> <li>• protection with ballast</li> </ul>

Protection of the Firestone Geomembrane can be realized in the following ways :

**Base :**

- **Sand bed** (minimum thickness : 200 mm) : protection with geotextile not required
- **Gravel** (minimum thickness : 200 mm) : protection with geotextile required
- **Prefabricated materials** (tiles) : protection with geotextile required

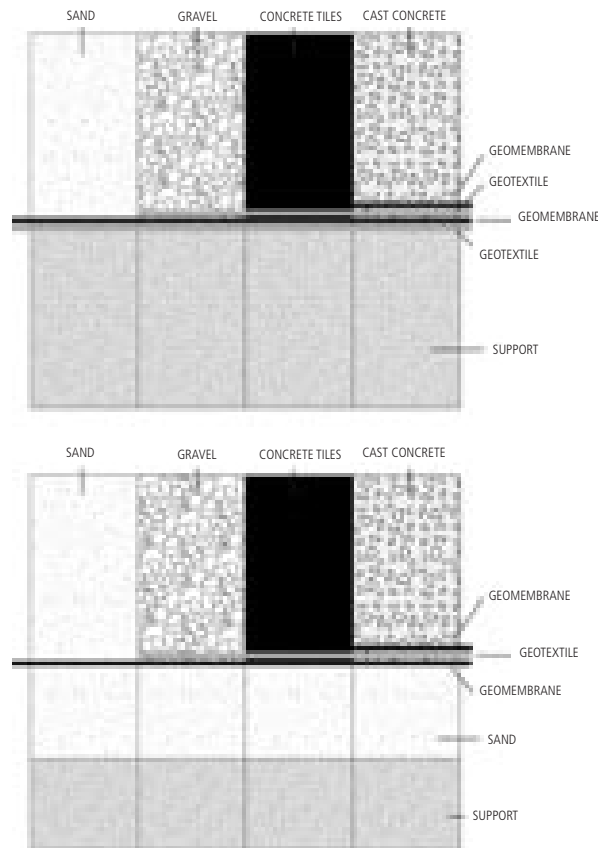


Fig. 19 : Protection of the Geomembrane

**Embankments :**

- **Rock covering** : This solution is applicable for slopes up to 3/1. A transition layer (geotextile + sand bed) with a minimum thickness of 200 mm is required. Rock covering depends on the level of the impacting forces such as waves.
- **Prefabricated tiles** : Stability measurements of the tiles and installation of a geotextile or extra layer of Firestone Geomembrane at the foot of the embankment are required.
- **Cast concrete** : Stability measurements and installation of a geotextile or extra layer of Firestone Geomembrane are required at the foot of the embankment.

## 2.3 Details

### 2.3.1 General

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

### 2.3.2 Connection to concrete structures

Connections of the Firestone Geomembrane to concrete or masonry structures must comply with the following rules :

- Soil around the concrete must be compacted
- Connection surfaces must be smooth, clean, dry and must not present any sharp protrusion
- Firestone Geomembrane is fully adhered to the 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 backside 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, so as to allow the same drying time. 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 flash off until tacky. Follow the same method to verify as indicated in the splicing section. Starting at the fold, slowly roll the previously coated part of the sheet into the coated substrate, and work evenly so as to minimise wrinkles. Compress the bonded sheet with a stiff broom to ensure full adhesion.
- Firestone Geomembrane is fixed at the top using Termination Bar and Fasteners adapted to concrete (plugs every 200 mm). Water Block is placed between the Geomembrane and the wall, as indicated below. The Termination Bar must be installed above the waterline. Lap Sealant is used at the top of the Termination Bar.

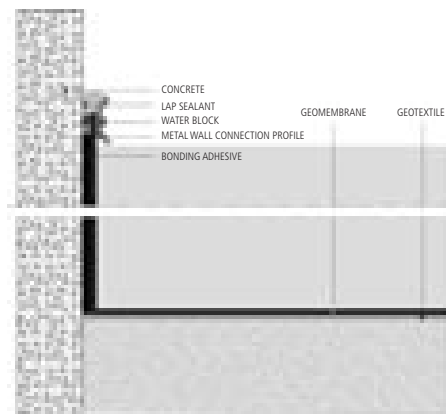
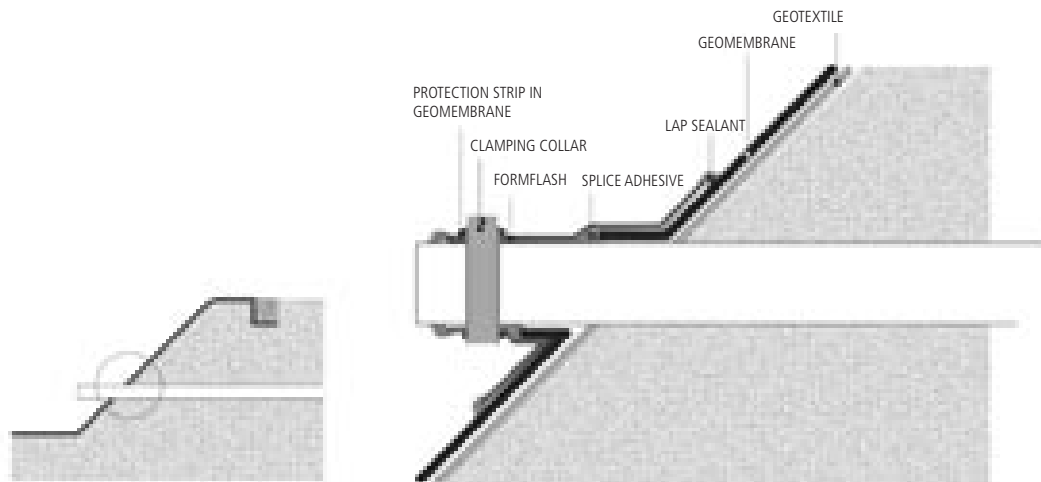


Fig. 20 : Connecting to concrete and masonry

### 2.3.3 Flashing of round penetrations

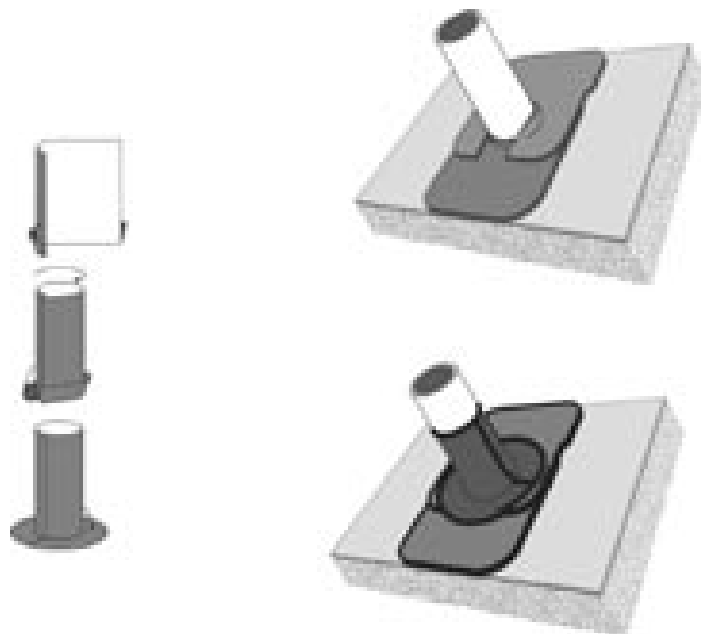
Connections to large penetrations must be made by means of unvulcanized rubber sheet, FormFlash, as follows :

- Pipe needs to be firmly anchored and the pipe temperature may not exceed 80°C
- Make a circular cutout 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 FormFlash
- Finally, the assembly is mechanically secured with a clamping collar



*Fig. 21 : Connection around pipe penetration*

Pipe penetrations are sealed using FormFlash as illustrated below:



*Fig. 22 : Flashing pipe penetration*

### 2.3.4 Drains

We recommend that a concrete base is provided underneath the Geomembrane around discharges. The Geomembrane is then mechanically fastened with a clamping system or an insert piece (lead, PVC, rubber, ...), mechanically fastened to the concrete base. Apply a waterproofing sealant (Water Block) between the Geomembrane and the concrete, as indicated in the details, prior to fixing of the clamping system or insert piece. If an insert piece is required, use FormFlash for flashing this detail.

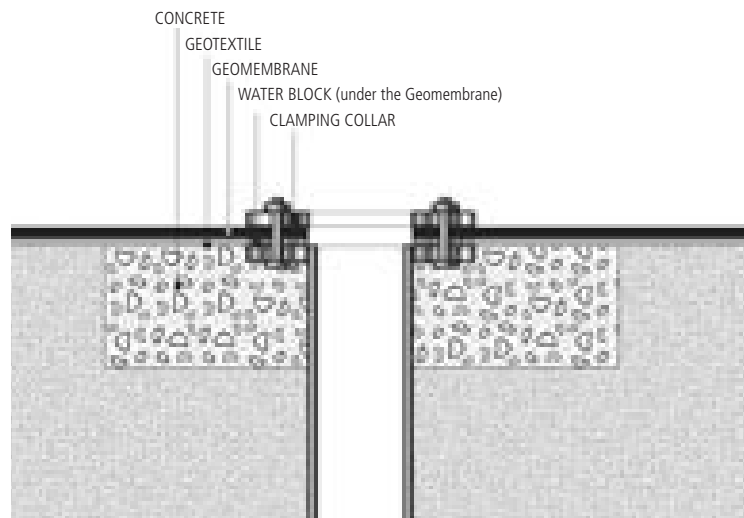


Fig. 23 : Water discharge with clamping collar

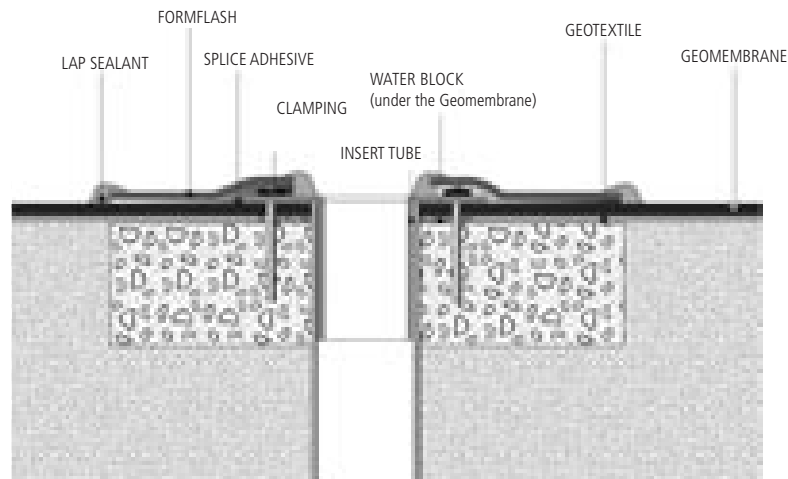


Fig. 24 : Water discharge with insert pipe

### 2.3.5 Corners

In most cases, the excess Firestone Geomembrane is folded in the corners. However, if one or both walls consist of concrete or masonry, cutting away the excess of membrane may be required to facilitate full adhesion to the wall upstands. In this situation, the corner has to be sealed with FormFlash as illustrated below:

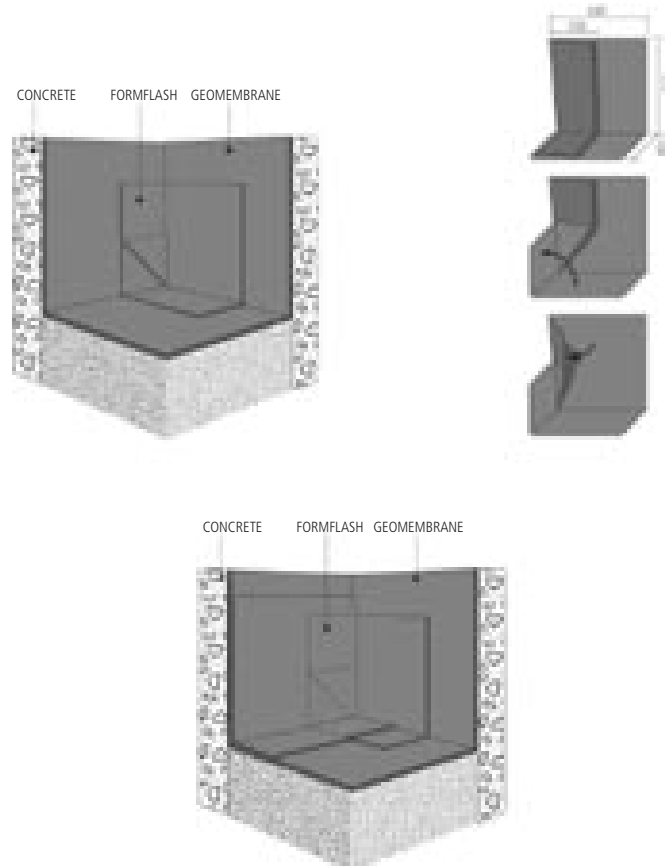


Fig. 25 : Inside corner

Outside corners are sealed using FormFlash as illustrated below :

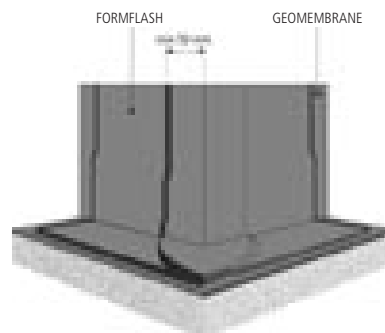


Fig. 26 : Outside corner

## **2.4 Miscellaneous**

### **2.4.1 Repair procedure**

A tear or hole in the Geomembrane can be repaired by means of a piece of FormFlash or Firestone Geomembrane covering the tear in every direction with an overlap of at least 150 mm. The patch must be adhered to the membrane with Splice Adhesive as follows:

- Clean the damaged area by scrubbing it with a cloth soaked with Splice Wash, to remove mud or any contaminant which will effect the splice. Correct cleaning has been achieved when the Geomembrane surface is dark grey in colour with no streaking.
- After drying, apply a coat of Splice Adhesive by means of a brush onto both surfaces (Geomembrane and patch). Mate both surfaces, when the adhesive is dry. Roll the patch by means of a silicone rubber roller.
- Finally, apply Lap Sealant to protect the exposed splice edges, as explained in the splicing section.

### **2.4.2 Maintenance**

An annual inspection of the installation is recommended to detect any problems which may endanger the durability of the system. This inspection process will limit costs if damage has occurred.

#### ***Recommendations :***

- Visual inspection of the Geomembrane, splices, connections and the anchoring
- Measurement of the leak flow rate and monitoring of water level
- Check all gas drainage vents
- Avoid any overflowing of the pond
- Check the chemical composition and the temperature of the liquids coming into contact with the Geomembrane
- Check the protection of the sheet, if any

### **2.4.3 Safety**

Specific precautions are to be taken to assure safety of people and animals on site, especially when the pond has been installed close to any habitation and tourist areas.

The following precautions should be taken :

- Ladder or climbing rope
- Low gradient of embankment (< 3/1)
- Intermediate platform at location with limited depth of reservoir
- Enclosure around the project