MACCAFERRI

GUIDELINES FOR INSTALLATION OF MACLINE HDPE GEOMEMBRANE

Summary:

General description of the product..... 2
Welding and tests of PE-HD geomembranes 4
Preparation of an installation..... 9
An installation 12

Basic description

The HDPE (high density polyethylene) MACLINE geomembrane is made from high quality raw material - granulate by extrusion technology. Material is resistant to chemicals, alkaline, acid and salt solutions. However, various combinations of chemical agents with different concentration and temperature can appear and that is why we suggest to contact us to consult individual cases. Material resists to mildew, microorganisms and to roots penetrating. The geomembrane is safe to health, it also does not affect drinking water. The geomembrane is UV stabilized.

Compared to other polymers, the geomembrane is characterized by high resistance to chemicals (an aggressive environment of waste landfills), excellent mechanical properties (high strength, tensile), long lifetime.

The PE-HD geomembrane JUNIFOL is produced in the standard:

- width of sheet: 5,10 or 8,0 m
- thickness: 0,60; 0,75; 1,00; 1,50; 2,00; 2,50 mm
- type: smooth/smooth; smooth/textured; textured/textured
- length of roll: according to the type and thickness

An advantage of a wide sheet is a significant reduction of a number of welds that are generally the most sensitive point of the sealing system. At the same time the width of the sheet enables relatively easy handling with individual rolls.

Each roll is marked with a self-adhesive label containing specifications of the product. The labels help with the product identification. An ispection certificate is issued for each roll. Those steps are a part of an internal control system.

Recommendation for use of the MACLINE HDPE geomembrane

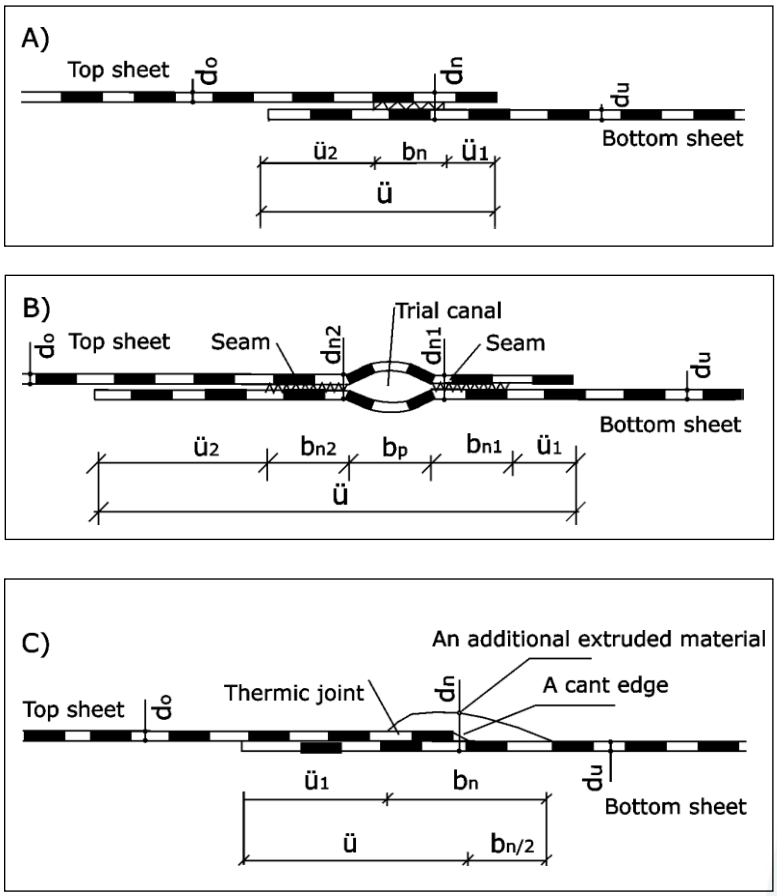
Geomembrane th. (mm)						
Application	**0,6**	**0,75**	**1**	**1,5**	**2,0**	**2,5**
Insulation against radon	x	x	x	x	x	x
Insulation against dampness	x	x	x	x	x	x
Hydro-insulation of buildings		x	x	x	x	x
Reservoirs sealing			x	x	x	x
Sealing of fuel supplies and supplies of chemicals			x	x	x	x
Landfills sealing S II				x	x	x
Landfills sealing S III				x	x	x
Landfills sealing S IV					x	x
Landfills capping			x	x	x	x
Sealing of water constructions - ponds and rivers		x	x	x	x	x

Most of the information stated in the following chapters applies to waste landfills insulation and to insulation against pressure water. A use of the MACLINE geomembrane for insulation against dampness, radon and for hydro-insulation of buildings follows different principles.

Welding
Welding can be carried out only at temperatures above +5°C and at relative humidity of air 85% max. It is necessary to carry out special steps in special cases. Before welding begins, it is necessary to carry out test welding with material intended for the process while relevant welding parameters (temperature, speed, pressure) are set (or determined) on the welding machine. Test welding should be carried out 1x/day at least, or with each change of welding conditions. Data regarding the test welding and welding samples should be recorded in a protocol.
If the geomembrane is being joined, separate sheets have to overlap each other longitudinally and transversally.

Ways of welding
a) welding by hot wedge - welding without welding additives
b) welding by hot air - welding without welding additives
c) extrusion welding - welding with a welding additive, i.e. extrudate
- a raw material of the extrudate and the geomembrane has to be identical

Types of welds
a) overlapped welds without a trial canal (simple joint)
b) overlapped welds with a trial canal (double joint)
c) deposit welds (extrusion joint)



b_p = width of trial canal
d_o = thickness of top sheet
d_u = thickness of bottom sheet
d_N = thickness of seam
d_{N1} = thickness of front partialseam
d_{N2} = thickness of back partialseam

ü = total lapping
$ü_1$ = front total lapping
$ü_2$ = back total lapping
b_N = total width of seam
b_{N1}= width of front partial seam
b_{N2}= width of back partial seam

It can be proved that dimensions of the weld meet regulations in regard to the material and to the use, or requirements in regard to a project:

» back loose lapping should be at least 40 mm, also because of a trial-technical reason. Front loose lapping should be max. 5x the thickness of the sheet. Locally terminated deviations do not affect the quality of the seam.

» a width of seams and canals concluded in a contract, or written in regulations for a specific use, must be kept;

» thicknesses of seams should be regular along the width and length and should be limited by the sort of thickness and by working process.

Conclusive definitive standards for thicknesses of seams

f_{NA} = a factor of seam thickness for an applied weld = $d_N/(d_o + d_u)$

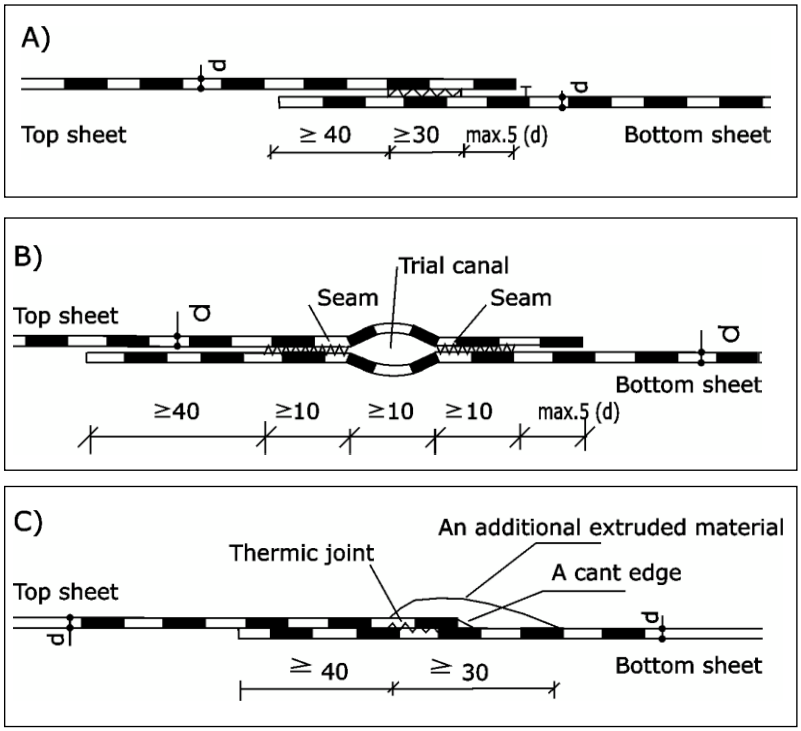
d_a = a joining track (a change of thickness) for a lapped seam = $(d_o + d_u) - d_N$

Lapped seams without additional material

Sheets made of partly crystallic materials, for example PE-HD $0{,}2<d_a<0{,}8$

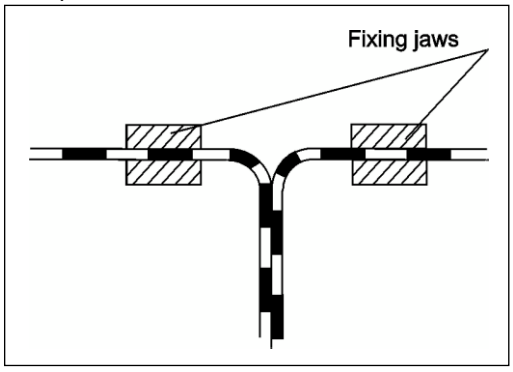
Sheets made of unformed materials $0<d_a<0{,}6$

Lapped welds $1{,}25<f_{NA}<1{,}75$



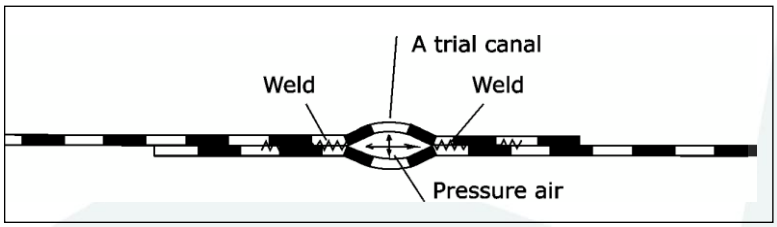
Inspection of welds quality
a) visual check
Skilled rewiev of external condition requires special professional knowledge and experience. Conclusions about tightness and strength of a weld can be deduced generally only.
b) a check of seam dimensions
This test finds out characteristic dimensions of a seam on strip trial bodies from a weld, or on the weld itself.
Measured values should meet dimensions stated in the chapter 5.1.2. (seam types)
c) seam tests - tests can be destructive and undestructive.

c.1. destructive
To find out strength of a joint properly, destructive Peel Test in Traction (peeling tests) are carried out on random samples.
As trial pieces, samples taken upright to the weld are taken the way so that they have a sufficient length of a fix.
The peeling test is carried out on each weld during the insulating system assembly directly at a waste landfill by a mobile tearing device, one test per each 100 m of the weld at least.



The peeling test is considered successful if a sealing sheet has been prolonged next to the weld (so-called a plastic deformation) and then the geomembrane sheet **has been torn outside the weld.**
c.2. undestructive tests
During parallel testing of welds for tightness it is necessary to adjust the testing process to a particular form of the weld. According to that, the following processes are used:
Lapped seams without a trial canal
A test by a high voltage
A test by vacuum
Lapped seams with a trial canal
A test by compressed air
Deposit welds
A test by a high voltage
A test by vacuum

A test by compressed air
A test by compressed air tests a tightness of lapped welds with a trial canal (double-weld) at a defined mechanic stress.
Testing conditions, as a trial pressure and duration of the test, have to be adjusted to a sheet material, a sheet thickness, to trial canal dimensions and to temperature.
The test can be carried out 1 hour after the joining soonest. Temperature of the sealing sheet can be max. 60°C.
At one end, a device for supply of compressed air with a manometer or a pressure register is installed, it closes the trial canal hermetically. Here the compressed air is brought and then clearness of the seam is tested. The other end of the weld is closed hermetically, for example by welding with hot gas or by a clamp device.
A trial pressure itself is adjusted not until one minute of preliminary stress so that initial deformations are conditioned. The preliminary stress is set to same values of the final test pressure.
A trial time for testing by compressed air is 10 minutes. When the trial time is out, a canal at the opposite end has to be opened. Air must escape at once.
Welds that cannot be tested parallely are tested section by section. If there are some mistakes that cannot be determined instantly we have to appoint suitable shorter trial sections to limit the problem sections.



A seam is considered tight if the pressure in the trial canal does not fall more than 10% of the initial value during a specified trial time.

geomembrane thickness (mm)	pressure (bar)
1,0	1,5 - 2
1,5	2,3 - 3
2,0	3 - 4
2,5	3,5 - 4,5

A vacuum test

A vacuum test can be used to control tightness either lapped seams, or deposit welds. The test proceeds by means of a see-through trial cover (bell) connecetd to a vacuum pump. The cover has a pressing sealing ring on its rim to close the tested area hermeticaly.

During the test, a vacuum (depression), that needs to be adjusted to the material and thickness of sheets and to dimension of the trial cover, is ran into the cover.

Non-destructive tightness tests of of lapped seams with joined (closed) front edges and of deposit welds can be done by the vacuum test section by section.

Relevant shaped trial covers are used for corners, edges and angles.

A minimum of 1 hour should pass between joining and testing to create a time space for conditioning. A tested seam area is smeared, or sprinkled, by a liquid creating bubbles, for example a soap solution. (It has to be insured that this liquid, in given conditions, does not affect unfavourably a longtime seams behaviour.)

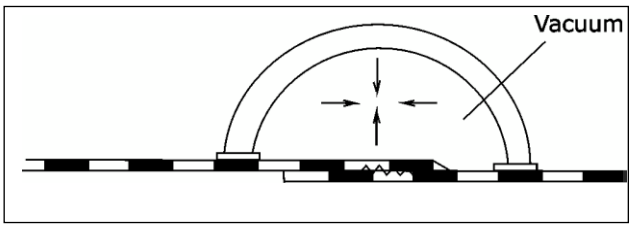
The trial cover is applied and compressed the way so that the tested seam lies approximately centrally to the axis of the trial cover. During removing of the cover, it is necessary - due to longer tested sections - to keep the overlap of the tested areas = 10 cm. Sheets are tested under the pressure of 0,4 bar. These trial pressures (depressions) have to be constant for at least 10 sec.

The vacuum is indicated by manometer. Bubbles appear if the seam is not tight. These locations are marked.

The seam is considered tight if the vacuum is increased fluently, stays constant during the trial time and no bubbles appear in the seam.

Due to a big time absorption for testing of long seams, the vacuum test is usually limited to short seams and partial areas as corners, connectors, T-joints and so on. The vacuum test can be an additional test for other testing methods.

The trial pressure follows the geomembrane thickness. Values are stated in the following chart:



A test by a high voltage

This testing process is based on a principle of discharge in gas, an application of a high voltage on a discharging track.

Testing device composes of a voltage source and a brush electrode.

The process expects an opposite electrode made from conductive material at the back side of the seam.

Basically we can test tightness of all kinds of seams by this process. The test is used mostly for deposit welds, i.e. for welds which do not have a trial canal.

The seam area has to be dry and clean; dirt particles can create an insulating layer and influence the test this way.

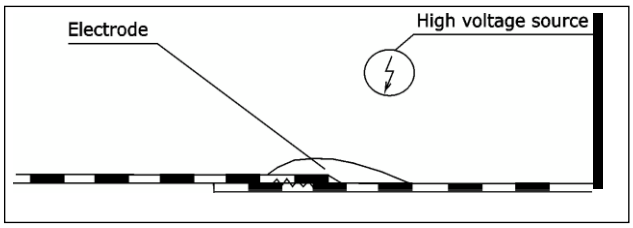
A trial voltage has to be adjusted to the material and thickness of the sheet and also to the weld width (the trial voltage is 15 - 40 kV).

For example, for HDPE sheets 2,0 mm thick and more is 40 kV an acceptable trial voltage. If the trial voltage is 40 kV, a width of discharge is more than 15 mm in dry air. That is why, for example, cca 30 mm wide deposit welds can be tested if the electrode lies in the middle of the weld, non-tightness is parallel and runs approximately upright the weld. The moister the air is the bigger the widths of discharge are.

A brush electrode is run over the weld at speed 10 m/min. It has to be ensured that the power creating flashover of the sparkle can be created. Flashover of sparkles between electrodes that can be seen and heard happens at non-tightnesses parallel with the whole length (a half of the weld width).

The weld is considered tight if there is no sparkle discharge.

It is possible to prove only no-tightnesses which are parallel and they run upright the weld. The distance of the brush from the weld has to be adjusted the discharge width in the air.



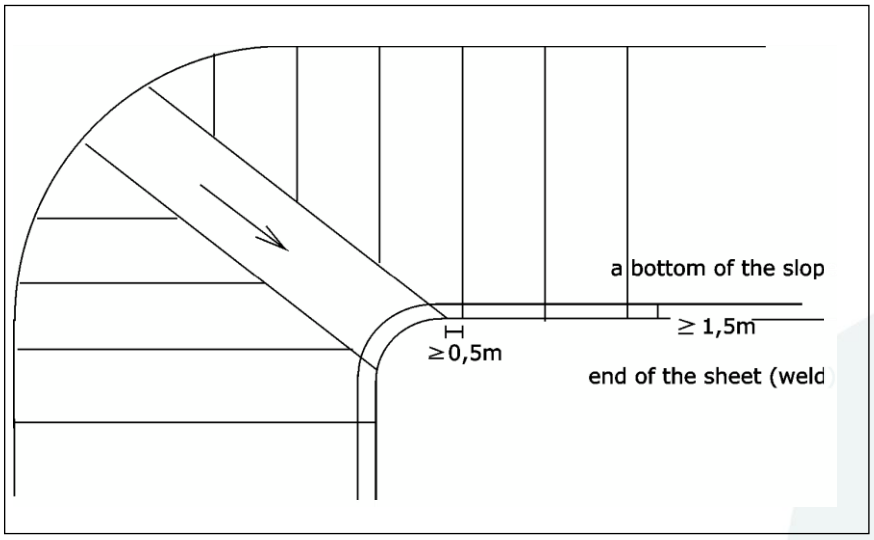
Test protocols
Results of tests at the building site are stated in the
test protocols.

An installation plan
Geomembrane sealing is laid in accordance with an ahead prepared istallation plan which determines dimensions and mutual position of separate sheets of the geomembrane laid to the sealing. On the slopes of the waste landfill the geomembrane should be laid the way so that it could be unrolled down the hill. Lay-out of the geomembrane sheets at horizontal parts is adapted to this requirement. Lay-out of separate sheets has to be placed so that the joints will not cross at a single spot.
Joining of separate geomembrane sheets is done by welding. The way of welding has to meet the geomembrane producer´s requirements. In order to join separate parts of the geomembrane after they had been put down, they have to overlap each other sufficiently at longitudinal and transversal direction (see part 5 - welds).
Before installation works begin it is necessary that the supplier proposes a plan of the installation with marked welding seams to the inspection body. It is necessary to remember that cross joints should not appear in the plan and also there was as few extruded welded joints as possible. Deviations during the installation works are acceptable with an agreement of the inspection body. A plan base for the installation plan has to be provided by a planner in time.

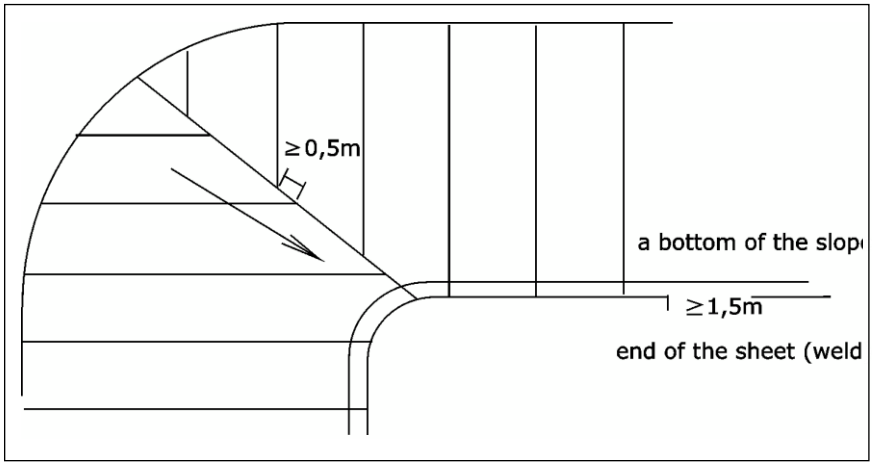
The installation plan should include the following points at least:
- the weld position
- uniform marking of all welds
- a position of special constructions (for example - ends of pipes, connecting with present constructions)
- according to their types (see the chapter 5.1.2.)
- a conventional width of used plastic sealing sheets

Possible ways of geomembrane sheets modification at the corners of the waste landfill are shown on the following pictures.

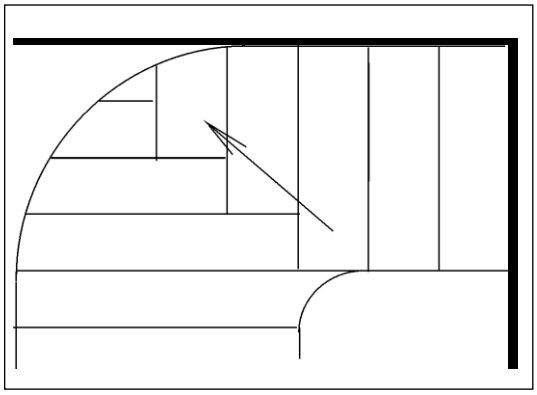
A) a tree with an inserted sheet.The method is a classic solution of the waste landfill corner.



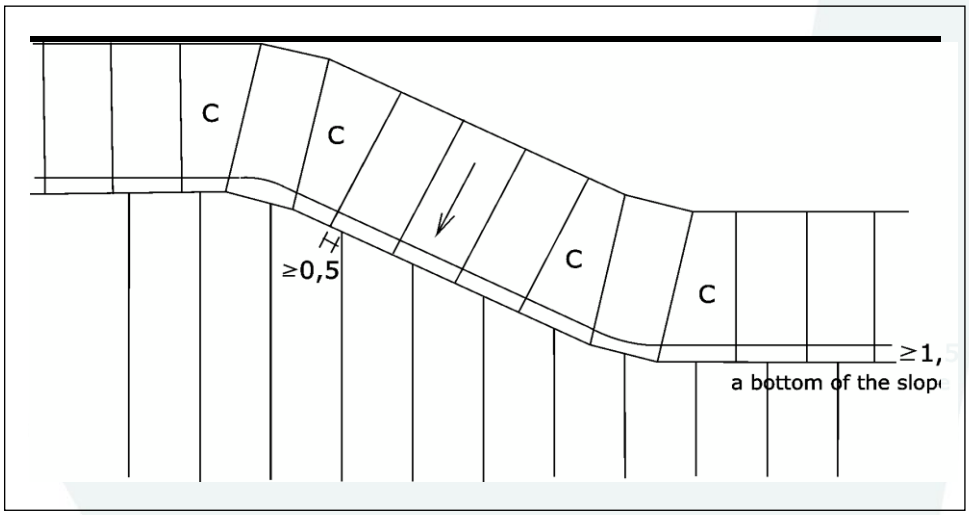
B1) a tree - a waste landfill - This method is used on short slopes in the waste landfill corners.



B2) a tree - overlapping - This method is mostly used for waste landill capping



C) a slope - Corners - This method is used mostly for shorter slopes to cap waste landfills or for fractional slopes of oblong waste landfill shapes.



Ending of the geomembrane sheet laid on the slope must not be done at the bottom of the slope. A minimal distance from the bottom is 1,5 m. A minimal distance of two (T) joints from each other should be 0,5 m.

Handling, transport and stocking

In order not to damage the matrial during the transport and handling, it is necessary to adhere to the following policies:

The transport has to be done by suitable clean vehicles with sufficient load carrying capacity. A special attention has to be paid to loading and unloading of the geomembrane, to ensure that it will not be damaged mechanically. A common transport is in three layers. 4 rolls at the bottom layer, 3 rolls at the middle layer and 2 rolls at the top layer. Rolls must be secured against movement by wedges and belts. A suitable vehicle has to be used for unloading - a crane or a forklift truck. We suggest using textile belts with a sufficient carrying capacity.

It is necessary to put rolls on a flat surface, free of sharp objects (stones, branches etc.) at the construction site. To protect the geomembrane, a base layer of geotextile can be used.

It ispossible to store the rolls in three layers this way. Rolls must be secured against movement. Whole manipulation with sealing materials must be carried out the way so that they will not be damaged or degraded. If that happens, they must not be used in the sealing system.

A base for geomembrane sealing

Establishing of subgrade conditions should be done in sections by geotechnical supervision, a base layers supplier and by an installation company. A report needs to be made and it will be passed to the installation company as an agreement with starting of installation works. The installer carries out a visual control of the surface and marks it in the inspection protocol before the sealing sheets are unrolled. It is necessary to ensure determined values of requirements regarding the sealing area before the sealing sheets are laid.

The geomembrane can be laid only on a firm, level and smooth surface of the base without sharp objects. If it is necessary to lay the geomembrane on a coarse-grained material subgrade, it is necessary to underlay the geomembrane with more suitable material or with geotextile of corresponding parameters.

Climatic conditions
Surrounding conditions can have an essential influence on the way of joining and thereby on the quality of the joint. It is necessary to keep the following:

» welding is not allowed without safety arrangements if it rains (a local covering etc.)

» welding should not be carried out if the temperature is lower than +5°C; in exceptional cases it is necessary to do special arrangements (a tent) and to pre-heat geomembrane sheets

» a continuous weighting of geomembrane sheets has to be ensured if it is windy

» with welding machines working on a principle of geomembrane heating during welding with a hot air it is necessary to ensure a protection of the welding machine against a direct influence of the wind on the hot air flow. The same arrangements stand for an extrusion welding - a danger of cooling and "blowing away, overheat"

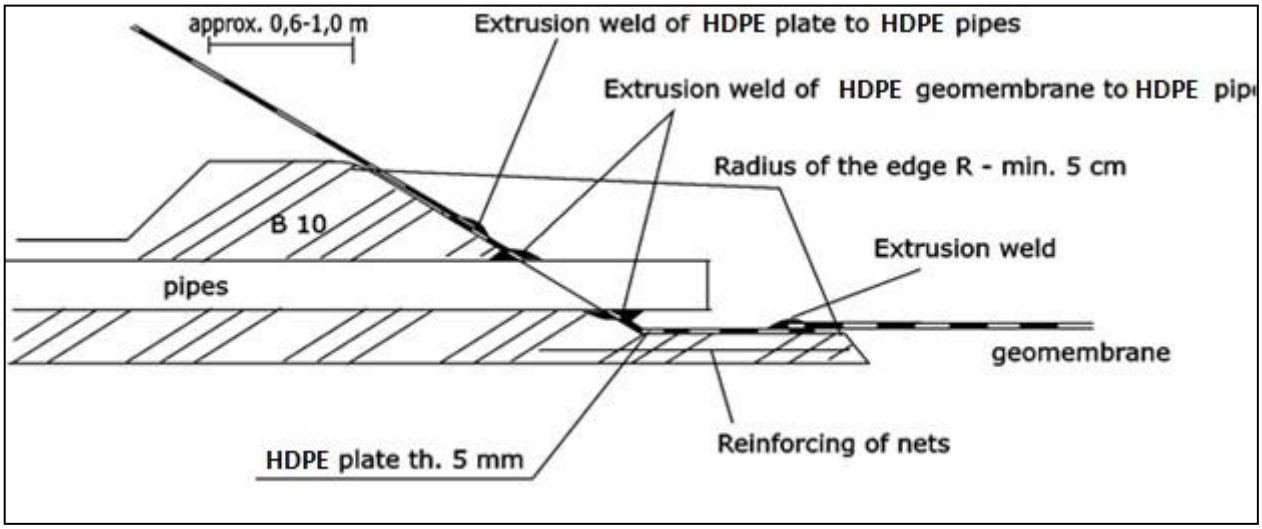
An installation and securing of geomembrane sheets
Laying down a sealing sheet can start only if there cannot appear any permanent changes of conditions regarding the subgrade during the installation. It is necessary to remember the protection against wind. A thermical expansion ("waving") conditioned by heat is permissible, it follows material properties (a heat expansivity) and it cannot be prevented practically. That is why a technological process must count on it, however folding of "waves" must not happen. A coefficient of a plastic sealing sheet thermal expansion should be used the way so that pouring of protection drainage layers takes place when "waving" of geomembrane sheets is minimal. We recommend a presence of an external supervision during this process.
The geomembrane is protected against possible damage by wind by an adequate weighting of the surface (for example tyres, sacks with sand etc.) and by anchoring to anchoring grooves (notches) immediately after its installation. All control steps need to be done before covering the geomembrane to ensure a quality of the geomembrane coat.
For each geomembrane sealing we recommend an installation of equipment for geomembrane integrity control which will be carried out when drainage or covering layers have been laid down.

A testing weld
Before the welding works begin, it is necessary to carry out - 1x a day at least or before each change of welding conditions - test welding with the material determined for process while there have to be set, or determined, relevant welding parameters on the welding machine. Then it is necessary to take sample every 100 lm of the weld, the same with bigger temperature changes, wind power or air dampness, and also if the process of welding has been interrupted and if there have been detected defects on the used welding machine. The welding test is considered positive if there is an extention (a plastic deformation) along the weld during the peeling test by the weld.

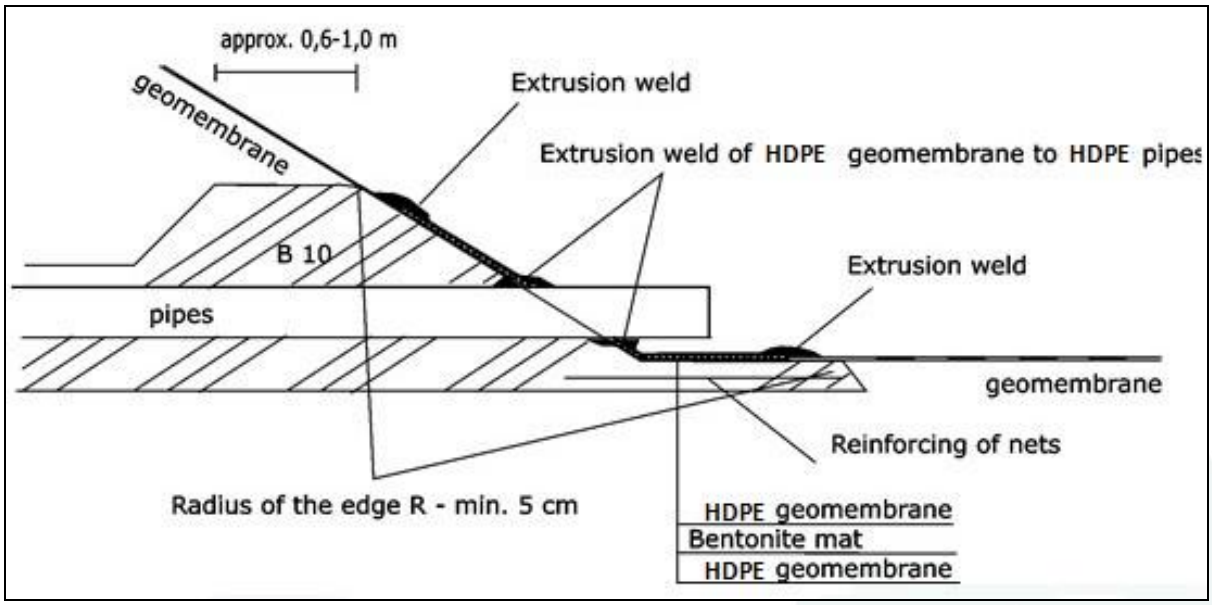
Welding and tests
Procedures during welding and geomembrane tests are described in detail in the chapter 5.

Details
Design of details around penetrating bodies
If some waste landfill device (for example shafts, pipes) penetrates the sealing, the sealing system must be connected to this device safely and waterproof so that the sealing cannot be affected by influence of various vertical and horizontal deformation of adjoining structures.
Joining of the sealing geomembrane to other waste landfill structures and sealing penetrations must be taken care of in details of the sealing system project. Some of possible penetrations and joining to concrete constructions follow.

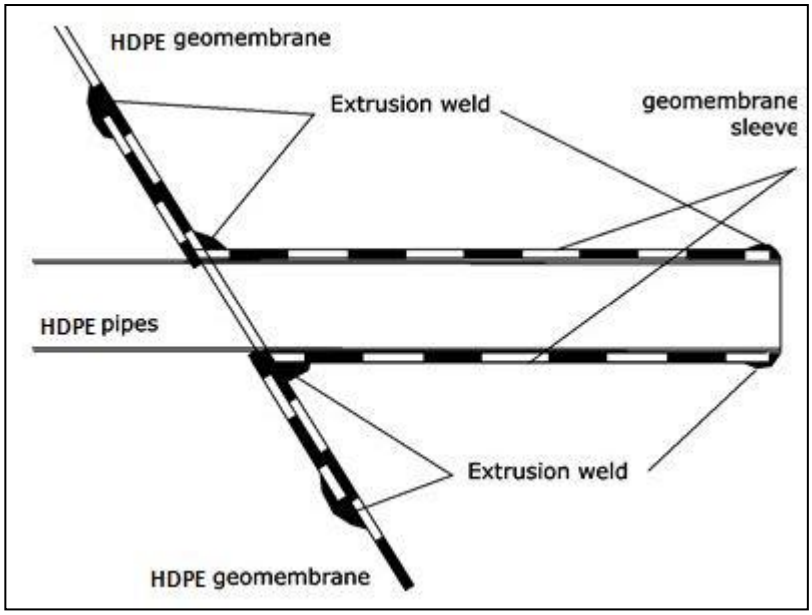
A) Pipe penetration through sealing by means of HDPE plate

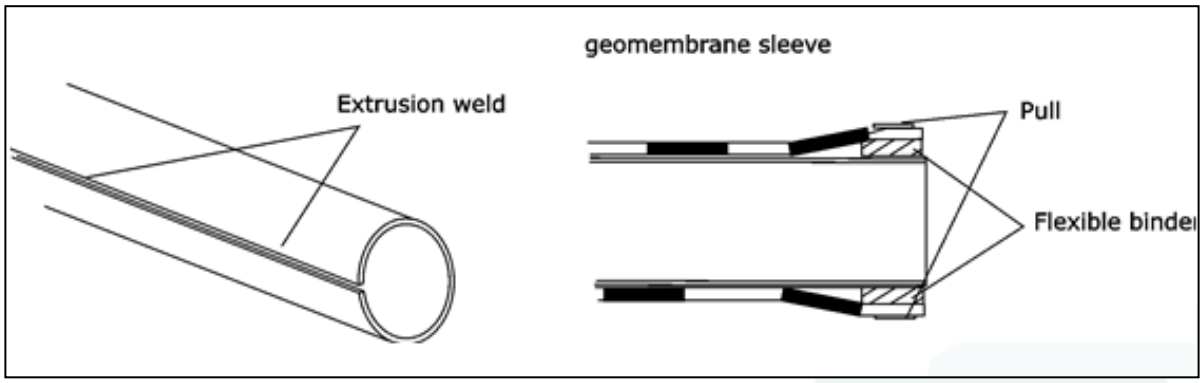


B) Pipe penetration through sealing with use of more sealing layers



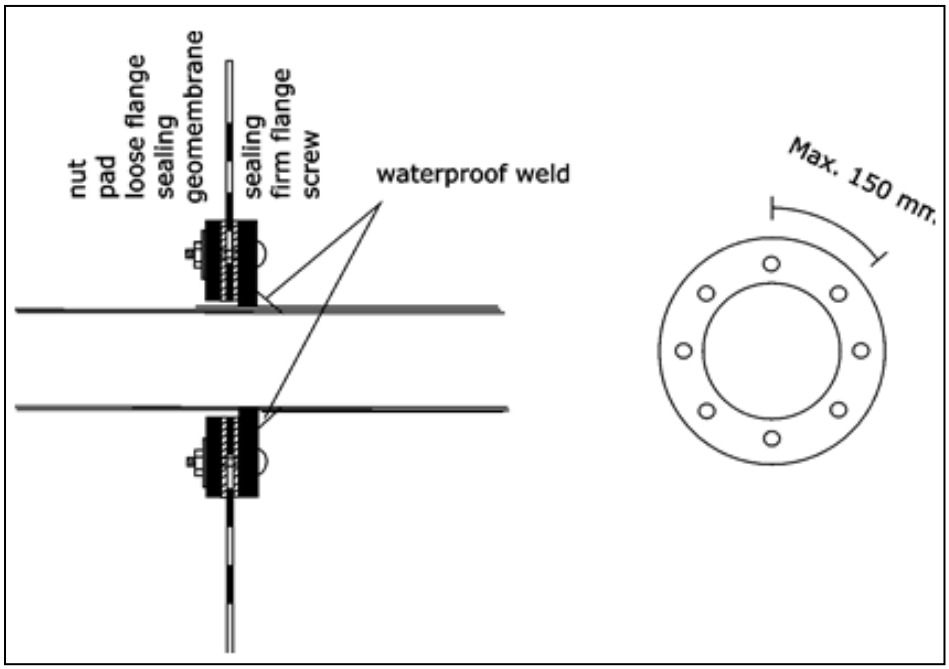
C) If some material other than geomembrane penetrates, it is possible to use a penetration by means of a sleeve (cuff) from MACLINE geomembrane





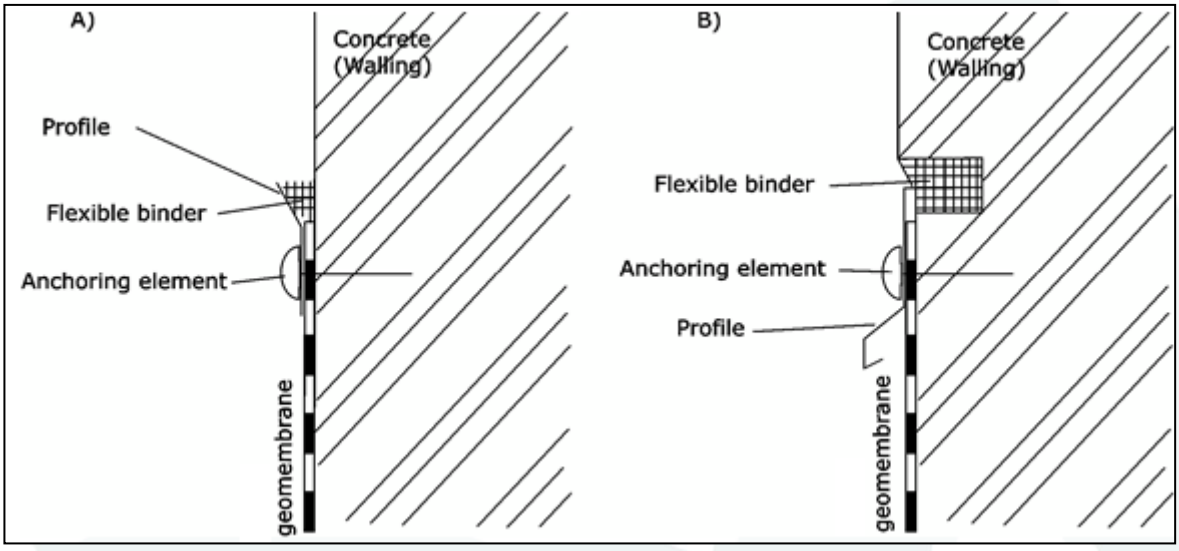
A pipe is fastened to the geomembrane sleeve by a pulling collar (the pull) and by sealing material. We recommend to use two pulling collars.

D) Other was of joining pipes from other material than the geomembrane is made of is joining by means of a firm and a loose flange.



Ways of anchoring to concrete constructions:
Against descending water
(anchoring of insulations at top parts of shafts, reservoirs etc.; at which the anchoring will not be strined by pressure water for even a short time).

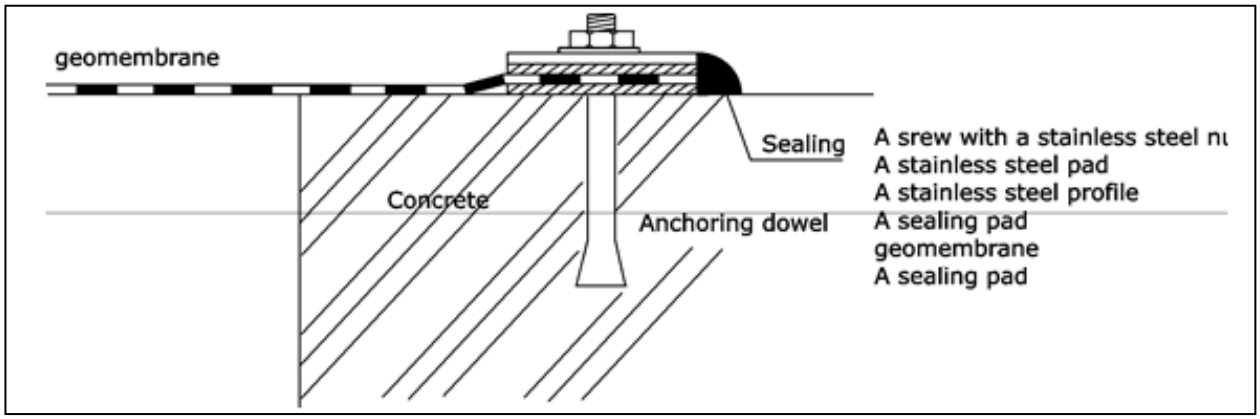
For those applications, a ledge made from Pz, Cu or Al plate with a corresponding mastic is a sufficient anchoring element, distance of anchoring elements (rivets, anchoring dowels, anchors etc.) is 100 - 200 mm.



Against pressure water or short-time strain by pressure water

To join the MACLINE geomembrane to a concrete construction, it is possible to use a plate that is anchored in the concrete by screws and anchoring dowels. Distance of separate screws depends on a solidity of the ledge and on the type of anchoring.

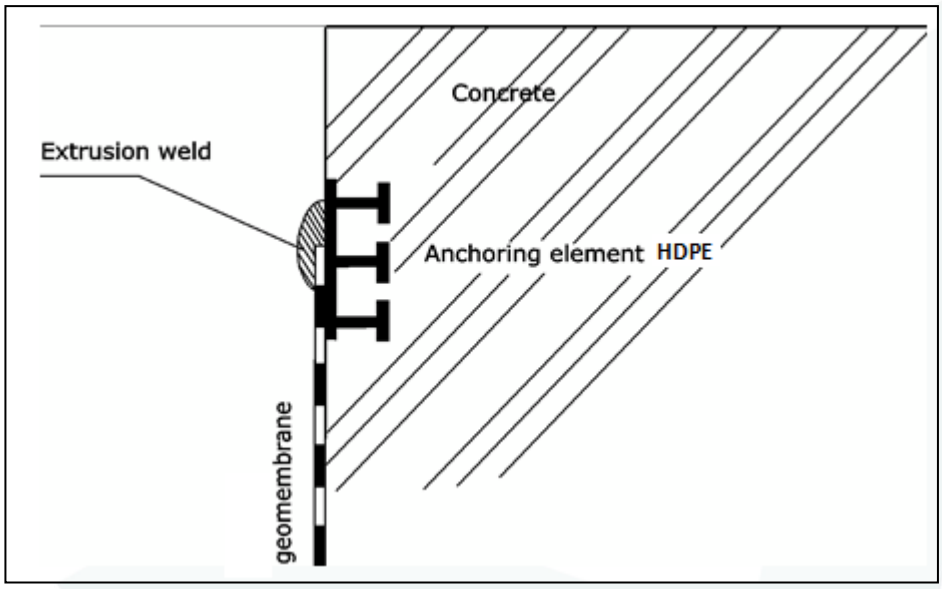
Anchoring of the geomembrane to concrete by a stainless steel ledge



Distance of screws depends on a solidity of an anchoring ledge, or of an anchoring profile (for steel amchoring plate 10 mm thick the distance should not be bigger than 150 mm).

It is also possible to anchor the MACLINE geomembrane to concrete by a HDPE anchoring element. This anchoring element is installed already during concreting itself and the MACLINE geomembrane is anchored to it by an extrusion weld.

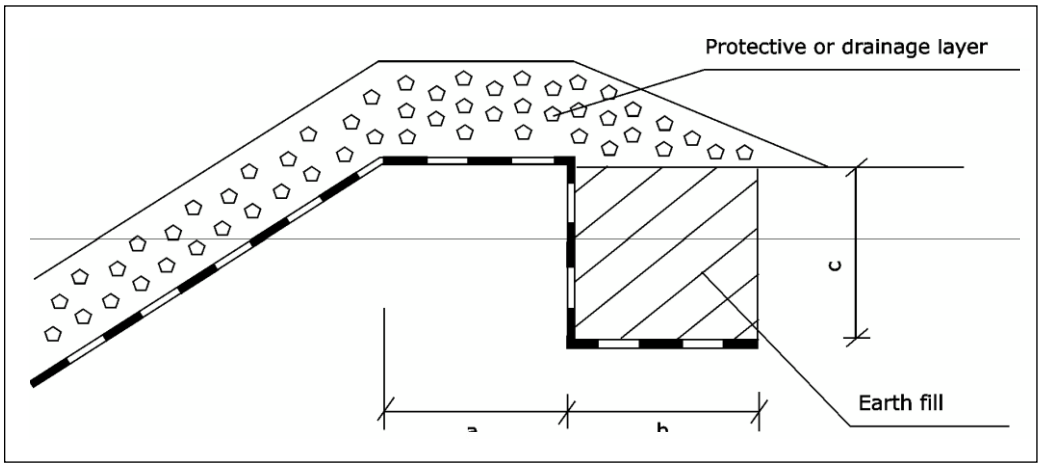
Anchoring of the geomembrane with a HDPE anchoring element



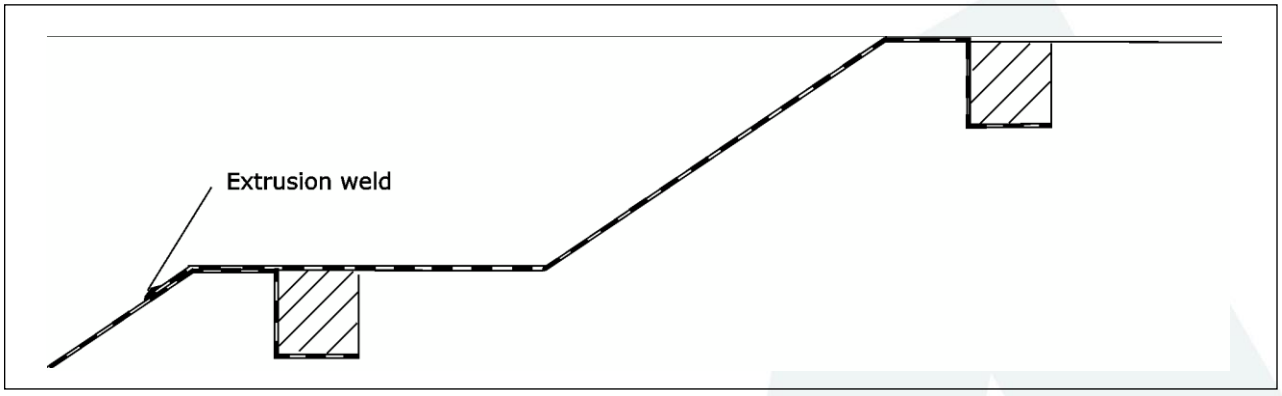
Anchoring on slopes
Geomembrane sealing and protective geotextile have to be anchored on slopes. Anchoring ditchs (notches) are usually used for this purpose. This anchoring should ensure not only reliable anchoring of the sealing to its surroundings and its ending but also to support its stability on the slope.
A rim of the geomembrane sheet in the anchoring groove is overlapped so far that it covers the whole bottom of the ditch. The ditch dimensions depend on the length and the slant of the slope, on the kind of the used geomembrane and on the kind of separate sheets of the sealing system.

Minimal recommended values for the slope slant up to 1 : 2,5 are stated in the chart

length of slope	**length in m**		
length of slope	a	b	c
<10 m	0,5	0,5	0,5
10 - 30	0,8	0,6	0,6
>30 m	1	0,8	0,8



We recommend to use bench on long slopes. Sealing can here be fixed by terrestrial inter-ditch.



An important factor is to ensure a temporary stability of the geomembrane for the time when the anchoring ditch is not finished (properly earth-filled and firmed). The geomembrane can be partly pulled out from the notch because of temperatures influence and that way its influence on the geomembrane stability can be reduced. We recommend to anchor the geomembrane by steel hooks or by a similar way to the bottom part of the terrestrial ditch.

A stability of a sealing system on slopes
A stability of separate elements of sealing and drainage system and of protective and capping layers on the slopes of a waste landfill subgrade or on waste landfill slopes during its closing have to be proved in the waste landfill design. Data about physical-mechanical characteristics of separate materials, obtained from their producers, and by carrying out relevant tests in a range of project and geotechnical and research works, are used for this purpose. In this solution of stability, especially protection against mutual displacement of sealing system separate layers and its movement on the subsoil surface have to be proved.
Friction rates between the MACLINE geomembrane and various soil materials and between the MACLINE geomembrane and the top protective or filter layer have a crucial role to determine a static safety on slopes. The safety is ensured if a sum total of sliding forces is smaller than a sum
total of frictional forces. To increase transmission of forces in a filter layer above an insulating sheet, textured sheets can be used. Strain deformations between separate terrestrial layers affect friction rates above and under the geomembrane.

Maccaferri supplies, apart from the HDPE geomembrane with a smooth surface, also a geomembrane textured on one side or on both sides.
A project designer can use the MACLINE geomembrane with a structured surface where it is needed to increase a safety coefficient and the slope slant. The use of structured geomembranes has an influence on improvement of all kinds of factors for various applications.
The geomembranes with the textured surface are specific with smooth trims cca 15 cm wide. It means that common procedures of smooth geomembrane joining can also be used for textured geomembranes. The welding technology does not require any change for direct joints. For sheets where we have to weld the sanded part it is necessary to remove the sand (grinding machine, scrape), or to re-set parameters of the welding machine.
Advantages of textured geomembranes in contact with soils or geosynthetic materials are:
- high friction coefficient with soil
- high friction coefficient with geosynthetic base
- high angle of inner friction with the top protective geotextile

A chart of friction angles of the MACLINE geomembrane with various materials

Material	**Textured HDPE geomembranes Friction angle (in grades)**	**Smooth HDPE geomembranes Friction angle (in grades)**
Sanded clay	35	18
Fine-grained clay	32	16
Nonwoven geotextile (Netex)	33	11
Bentonite mat	33	11
Sand	35	20
Concrete	42	22

Above stated values are of informative character only. The producer recommends to carry out shear tests of relevant geosythetic materials and natural components creating an insulating system for a particular application.

Protective and covering layers
When the sealing sheets have been welded and the tests done, or after they have been assumed, it is immediately necessary that the installer puts down the geotextile protective layer if it is specified by a project designer.
The sealing system in whole and its separate parts must be protected against damage during building works, during the operation and after the closing of the waste landfill.
The protection of the sealing system elements has to be included already in the design of the sealing system constructional lay-out and in the specified work processes for establishing of its separate parts. If some construction is damaged anyway, it has to be recorder and the defect removed immediately.
No vehicles or machines can wheel directly on the geomembrane sealing surface. A movement of belt machines is allowed only after a sufficiently thick (0,30 m at least) protective or drainage layer has been laid or when inner temporary communications have been built of pannels, hurdles etc.

Documentation of construction
The installer should adapt the installation plan in accordance with an actual situation, i.e. a

construction documentation (a record about relevant changes of installation, a record about the places where test samples were taken) should be disposed.

Procedure for an initiation of an installation
Heaping up of the first layer should be done by a front pouring of the layer at least 1 m thick so that the machines or trucks move only on this layer (in the case of wheeling directly on gravel drainage layer there is a danger of "earthing of the machines" or trucks and the following damage of the geomembrane sealing). Before it is laid, a protective geotextile has to be laid if it is specified by a design. The first layer of waste should be created by loose material free of bigger parts which could damage the geomembrane (metal, concrete etc.).