



Test Report

**Determination of resistance
to root damage to flexible sheets and coatings for
roof planting according to FLL-method (1999)**

**Product name:
GENERAL GARDEN**

**Principal/Manufacturer:
GENERAL MEMBRANE SpA
Via Venezia 28, I-30022 Ceggia (VE), Italy**

**The report compiles 33 pages and is only allowed to be used un-
abridged.**

The report has a 10 years period of validity.

Date of the report: 1999-08-02

**Information given by GENERAL MEMBRANE SpA concerning data
and characteristics of the tested sheet GENERAL GARDEN
(dated 1999-07-27)**

- **Name of the product:** GENERAL GARDEN
- **Scope:** Sealing of flat roofs
- **Type of material:** Polymer modified bitumen (APP)
- **Thickness of waterproofing layer:** 4 mm
- **Product design/structure:** Upper and lower layer: polymer modified bitumen;
middle layer: combination carrier layer of polyester

Delivery form: Rolls à 5.0 m² oder 7.5 m²

- **Manufacturing technique:** modified bitumen impregnation of polyester felt
- **Product standards:** EN 13707
- **Test certificates:** None
- **Year of manufacture:** 1997
- **Layer resisting to perforation:** Entire polymer modified bitumen sheet
- **Installation method at the test site:**
 - **overlap:** Approx. 80 mm
 - **jointing technique:** Welding by torch flame (propane gas)
 - **jointing agent:** None
 - **type of joint seal:** None
- **wall corner joint reinforcing:** None
- **cover strip over joints:** None
- **Addition of biocides incl. concentration:** 1 % referred to covering mass

1 Problem task

In order to prevent damage, root protection sheets are required to perform permanent resistance against penetration or perforation by plant roots and plant rhizomes (subterranean offshoots).

In this test the resistance to root and rhizome damage of the sheet GENERAL GARDEN of GENERAL MEMBRANE SpA, 30022 Ceggia (VE), Italy was determined.

2 Test facility and procedure

The 2 years lasting test was performed in accordance with the draft of the „Method of testing resistance to root damage to flexible sheets and coatings for roof planting“ (FLL, 1997). The complete description of the test procedure (FLL, 2002) can be found in annex 3 of this report.

The test was performed from July 1997 to July 1999 comprising 8 containers equipped with the sheet to be tested. Another 4 containers with an non-root resistant bituminous layer were serving as control that allows to compare the plant development in the different containers.

The sheet was cut, jointed and installed in the containers at the test site of the Institute of Horticulture, University of Applied Science Weihenstephan.

A check sample of the sheet was taken and stored at the testing institute.

The containers were filled with growing substrate, planted and installed in a climate-controlled glass house.

The final inspection included the noting of any penetration and perforation of roots and rhizomes concerning the non-root-resistant bitumen layer on the tested sheet GENERAL GARDEN.

3 Data given by the manufacturer of the sheet

The results of the test relate only to the tested sheet GENERAL GARDEN with its defined material characteristics, applied jointing technique and manufacturing technique. The data given by GENERAL MEMBRANE SpA concerning the sheet GENERAL GARDEN are listed on page 2 of this report.

An extension of the results to other sheets is not admissible.

4 Results

4.1 Plant development

The plants *Pyracantha coccinea* and *Solanum rantonnetii* performed well throughout the test period. Growth of the test plants in the control containers (with a non-root-resistant bitumen layer) was only slightly differing from plant growth in the test containers with the sheet GENERAL GARDEN.

Agropyron repens (Coach Grass) showed only in 3 containers with the sheet GENERAL GARDEN a satisfying development. In the other 5 containers with the sheet only a sparse stand density of Coach Grass could be detected - in spite of repeated seed. On the other hand the Coach Grass showed a very dense stand density in the containers with the non-root-resistant bitumen layer.

Detailed informations concerning growth of the test plants are given in annex 2.

4.2 Penetration and perforation of roots and rhizomes at the end of test period

At the end of the test period the containers were emptied for a detailed check of the non-root-resistant bitumen layer and the tested sheet GENERAL GARDEN for root or rhizome penetration and perforation.

4.2.1 Containers with the non-root-resistant bitumen layer

The non-root-resistant bitumen layer showed a multitude of penetrations and perforations caused by roots and rhizomes. Therefore the final inspection was reduced to perforations of a section of 200 mm x 200 mm of the layer (about 6 % of the whole surface of the layer).

In this sections of the 4 containers could be found 10 to 28 perforations caused by roots and 1 to 5 perforations caused by rhizomes (see table 1).

Table 1: Number of perforations caused by roots or rhizomes concerning the non-root-resistant bitumen layer after the test period of two years (relating to a section of 200 mm x 200 mm of the layer)

Cont. No.	Perforations caused by roots	Perforations caused by rhizomes
Nr. 1	10	5
Nr. 2	18	2
Nr. 3	12	1
Nr. 4	28	4

4.2.2 Containers with the tested sheet GENERAL GARDEN

The sheet (surface and joints) did not show any perforations caused by roots or rhizomes after the 2 years period (see table 2 and photos in annex 1).

Some roots and rhizomes had grown into the upper layer of the sheet without damaging the internal carrier (polyester felt). The maximum depth of root penetration was 2 mm. With sheets which, as in the case tested here, contain root inhibitors and therefore can exert their root-inhibiting action only after surface penetration by the roots, penetrations to a depth of ≤ 5 mm are not evaluated.

Table 2: Number of perforations caused by roots or rhizomes concerning the the tested sheet GENERAL GARDEN after the test period of two years

Cont. No.	perforations caused by roots (ro) and rhizomes (rh)		penetrations caused by roots (ro) and rhizomes (rh)	
	surface	joints	surface*	joints
1	none	none	2 (ro) / 2 (rh)	none
2	none	none	1 (ro)	none
3	none	none	3 (ro) / 1 (rh)	none
4	none	none	5 (ro) / 2 (rh)	none
5	none	none	2 (ro)	none
6	none	none	none	none
7	none	none	6 (ro) / 4 (rh)	none
8	none	none	2 (ro)	none

*maximum depth of penetration: 2 mm

5 Summary

In accordance with the „Method of testing resistance to root damage to flexible sheets and coatings for roof planting“ of FLL a two years lasting test was carried out with the sheet GENERAL GARDEN.

The sheet GENERAL GARDEN (surface and joints) did not show any perforations caused by roots and rhizomes after the 2 year period.

A few roots and rhizomes had grown into the body of the sheet. The maximum depth of penetrations of the roots and rhizomes was 2 mm (reaching to the carrier layer). The carrier layer was not damaged by roots or rhizomes. No roots and rhizomes had grown into the joints of the sheet.

The sheet GENERAL GARDEN is therefore considered to be root resistant and resistant to rhizomes of Coach Grass according to FLL-standard.

The results of the test relate only to the tested sheet GENERAL GARDEN with it's defined material characteristics, applied jointing technique and manufacturing technique (s. page 2 of this report). An extension of the results to other sheets is not admissible.

Check samples of the tested sheet were taken and are stored at the Institute of Horticulture, University of Applied Science Weihenstephan.

The test report was compiled in August 1999. The report has a 10 years period of validity. This report comprises 33 pages and is only allowed to be used unabridged.

Person responsible for the test and the report:

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Annex 1
Photos concerning the tested sheet GENERAL GARDEN
(July 1999)



Figure 1: Sheet surface with root penetration



Figure 2: Cut through the sheet with root penetration

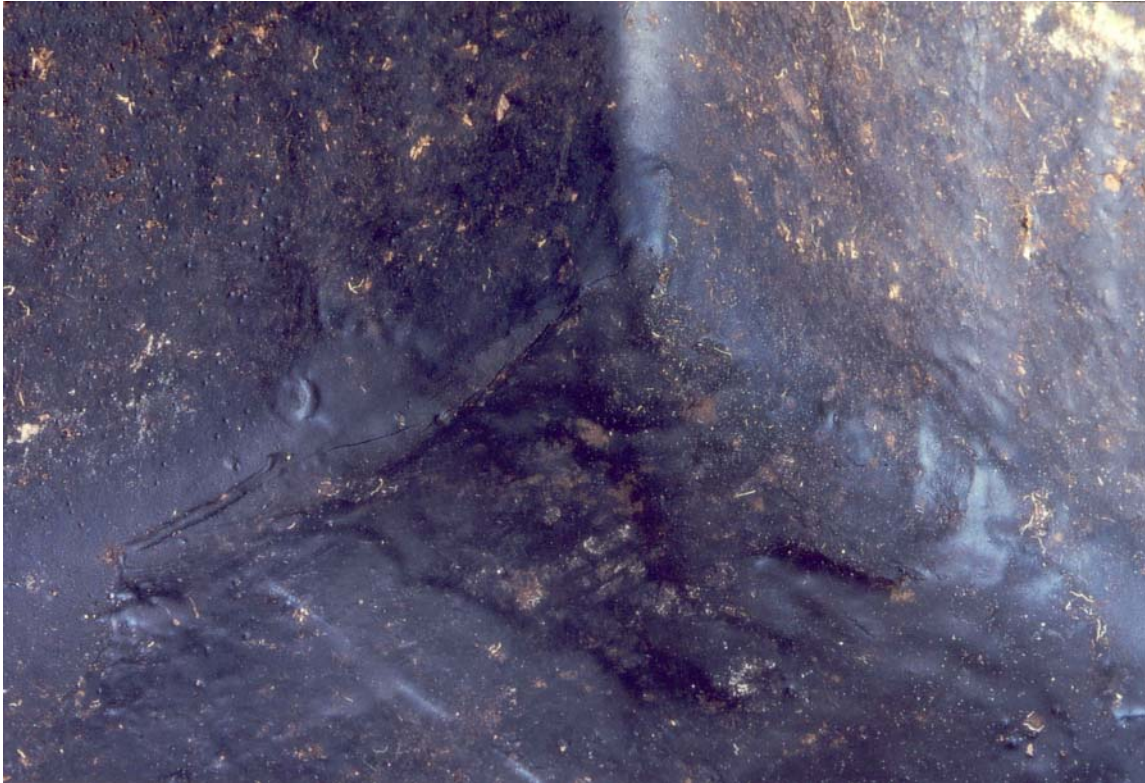


Figure 3: Sheet surface (area of a corner joint)



Figure 4: Sheet surface (area of the central T joint)

Annex 2 Data of the plant development

Table 3: Height and trunk diameter of Firethorn and *Solanum* in the 4 containers with the non-root-resistant bitumen layer (December 1997)

Cont. No.	Plant No.	Firethorn		<i>Solanum</i>	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
1	1	1.4	177	1.4	160
	2	1.5	173	1.6	163
2	1	1.7	168	1.7	153
	2	1.9	183	1.7	168
3	1	1.8	200	1.4	188
	2	1.8	170	1.5	175
4	1	1.5	166	1.5	158
	2	1.6	186	1.6	162

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Table 4: Height and trunk diameter of Firethorn and *Solanum* in the 4 containers with the non-root-resistant bitumen layer (June 1998)

Cont. No.	Plant No.	Firethorn		<i>Solanum</i>	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
1	1	1.7	176	2.2	165
	2	1.8	174	2.1	176
2	1	2.0	176	2.0	185
	2	2.2	178	1.9	193
3	1	2.2	174	2.2	180
	2	1.9	176	2.2	191
4	1	2.0	175	1.9	184
	2	1.9	183	1.9	174

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Table 5: Height and trunk diameter of Firethorn and *Solanum* in the 4 containers with the non-root-resistant bitumen layer (November 1998)

Cont. No.	Plant No.	Firethorn		<i>Solanum</i>	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
1	1	1.6	173	1.9	165
	2	1.8	178	1.9	164
2	1	2.0	169	1.8	175
	2	2.0	173	1.8	170
3	1	2.1	174	1.9	182
	2	1.9	168	1.9	176
4	1	1.9	168	1.7	168
	2	1.8	168	1.8	167

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Table 6 Height and trunk diameter of Firethorn and *Solanum* in the 4 containers with the non-root-resistant bitumen layer (July 1999)

Cont. No.	Plant No.	Firethorn		<i>Solanum</i>	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
1	1	1.8	188	2.4	180
	2	1.8	175	2.2	181
2	1	2.1	185	2.1	175
	2	2.4	182	2.0	185
3	1	2.3	179	2.3	181
	2	2.0	180	2.2	188
4	1	2.1	181	2.1	180
	2	2.1	174	1.9	181

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Table 7: Height and trunk diameter of Firethorn and *Solanum* in the 8 containers with the tested sheet GENERAL GARDEN (December 1997)

Cont. No.	Plant No.	Firethorn		<i>Solanum</i>	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
1	1	1.7	165	1.6	168
	2	1.5	162	1.6	153
2	1	1.6	172	1.7	162
	2	1.5	185	1.6	168
3	1	1.8	181	1.7	170
	2	1.7	184	1.8	170
4	1	1.6	171	1.5	177
	2	1.6	185	1.6	168
5	1	1.6	170	1.7	171
	2	1.6	181	1.7	184
6	1	1.7	165	1.7	174
	2	1.6	180	1.8	181
7	1	1.8	182	1.8	171
	2	1.8	180	1.7	174
8	1	1.8	178	1.6	170
	2	1.7	174	1.5	175

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Table 8: Height and trunk diameter of Firethorn and *Solanum* in the 8 containers with the tested sheet GENERAL GARDEN (June 1998)

Cont. No.	Plant No.	Firethorn		<i>Solanum</i>	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
1	1	1.8	174	1.8	175
	2	1.7	182	1.8	174
2	1	1.7	182	1.8	181
	2	1.8	191	1.8	181
3	1	1.9	175	1.9	178
	2	1.9	180	2.0	175
4	1	1.9	185	1.7	182
	2	1.8	181	1.8	176
5	1	1.9	178	1.9	183
	2	1.9	177	1.8	190
6	1	2.0	185	1.9	185
	2	1.8	180	2.0	177
7	1	2.0	185	1.9	184
	2	1.9	191	1.9	173
8	1	2.0	175	1.8	181
	2	1.9	178	1.8	180

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Table 9: Height and trunk diameter of Firethorn and *Solanum* in the 8 containers with the tested sheet GENERAL GARDEN (November 1998)

Cont. No.	Plant No.	Firethorn		<i>Solanum</i>	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
1	1	2.0	178	1.9	184
	2	2.0	188	2.0	178
2	1	1.8	178	2.0	178
	2	1.9	184	2.1	183
3	1	2.1	180	2.1	180
	2	2.1	175	2.2	185
4	1	2.2	181	1.8	181
	2	2.0	183	1.9	176
5	1	1.9	173	2.0	173
	2	2.1	181	2.0	184
6	1	2.2	178	1.9	192
	2	1.9	191	2.1	190
7	1	2.1	179	2.1	187
	2	2.1	190	2.0	184
8	1	2.2	178	2.0	183
	2	2.0	182	1.9	178

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Table 10: Height and trunk diameter of Firethorn and *Solanum* in the 8 containers with the tested sheet GENERAL GARDEN (July 1999)

Cont. No.	Plant No.	Firethorn		<i>Solanum</i>	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
1	1	2.2	191	2.1	190
	2	2.2	182	2.1	187
2	1	2.0	188	2.2	184
	2	2.1	185	2.3	185
3	1	2.3	181	2.2	181
	2	2.3	182	2.4	178
4	1	2.4	188	2.0	185
	2	2.1	190	2.1	181
5	1	2.0	178	2.2	180
	2	2.2	185	2.1	188
6	1	2.4	181	2.1	184
	2	2.1	188	2.3	185
7	1	2.2	191	2.2	192
	2	2.3	195	2.2	197
8	1	2.4	175	2.3	193
	2	2.2	185	2.0	185

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Annex 3

Method on Testing Resistance to Root Damage to Flexible Sheets and Coatings of Roof Planting

issued 1999

revised January 2002

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Forschungsgesellschaft

Landschaftsentwicklung Landschaftsbau e.V.

(Research Society for Landscape Development and Landscape Building)

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Translation from German into English:

**University of Applied Sciences
Research Institute of Horticulture**

Institute of Horticulture

Introduction

In order to prevent building damage by roof plantings a working group of the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL) composed a „Method for testing resistance to root perforation for flexible sheets for roof waterproofing“ with emphasis on strain by plant roots. The method refers mainly to the experience and knowledge gathered in experiments with various types of waterproofing flexible sheets and several plant species at the University of Applied Sciences Weihenstephan which lasted for several years between 1975 and 1980.

The FLL method was revised in 1992 and for the last time in 1995.

Its high reputation with manufacturers, planners, and workshops, is documented by a large amount of terminated and actually still running tests.

In 1993 the FLL decided to revise the test procedure lasting four years in order to reduce the test period to two years while doing so not neglecting the purposely high standards.

After a series of tests at the University of Applied Sciences Weihenstephan these criteria were met: the two-year test procedure is carried out in an air-conditioned greenhouse, where the test plants are growing all year round with controlled temperature and light conditions. Thus the actual growing season of 24 months comes close to the growing season in a test lasting four years considering the natural dormant period of the vegetation under outdoor conditions. Both tests are considered to be equal and are described in the actual reprint of the test procedure.

While the test procedure was changed also formal changes of the test description were carried out in order to lead to a better understanding and to facilitate the assessment of the results by the test institutions.

1 Scope

This test procedure determines the resistance to invasion and perforation by the roots and rhizomes of the used test plants to

- root resistant sheets
- sheets for roof waterproofing
- coatings of liquid application

for all kinds of roof planting methods (intensive, simple intensive, extensive).

The test method includes the test of products including the appropriate jointing techniques. Therefore the test method is only to be applied on testing single sheets or coatings. The test does not apply to testing a complete roof protection system i.e. a construction consisting of several layers for roof protection.

For technical reasons liquid coating may require an additional layer under the coating. It is allowed if the manufacturer declares that the resistance to root invasion is only due to the upper coating layer.

Bonding, i.e. a separate layer covering the sheet or coating to be tested is not allowed in any case.

The result for a particular sheet or coating is not transferable as far as plants with strong rhizomes (e.g. Bamboo or Miscanthus species) are concerned. When using these plant species further provision to protection of the roof against invasion and perforation must be carried out by means of construction and special care must be taken during plant growth.

The test procedure does not contain any rating as far as environmental compatibility of the tested products is concerned.

2 Definitions

For the application of this test method the following definitions do apply.

2.1 Container

Specially designed containers of dimensions sufficient for the accommodation of the sheet or coating to be tested (test container) or of a felt in the control containers respectively.

2.2 Moisture layer

The layer to maintain the moisture consists of coarse mineral granulates placed under the sheet or coating respectively to be tested. It is permanently kept moist to encourage root growth after perforation of the sheet or coating. A transparent base provides a means of inspection of early root perforation.

2.3 Protection layer

A fleece which is compatible with the sheet or coating is placed directly under the test specimen on the layer to maintain the moisture in order to achieve a uniform pressure distribution.

2.4 Growing substrate

Homogenous substrate (substrate mixture) which is available or producible at any of the test sites at any time. It is structurally stable, has a favourable water/air ratio and a low base fertilizer content to encourage optimal root development of the test plants. The growing substrate is in direct contact with the sheet or coating to be tested.

2.5 Test plant species

2.5.1. Plants for 2-year-test

- *Pyracantha coccinea* 'Orange Charmer' Firethorn, an ornamental shrub with appropriate root development throughout the year under the specific test conditions and thus suitable for the test. And
- *Agropyron repens*, Couch Grass, an indigenous grass with weak rhizome growth. Colonisation of roof gardens by *A. repens* can almost not be avoided. Under the given test conditions it shows sufficient growth throughout the year as well.

2.5.1 Plants for 4-year-test

- *Alnus incana*, Grey Alder, a wild shrub performing sufficient root growth during the growing season under the given open air conditions. And
- *Agropyron repens*, Couch Grass.

2.6 Adequate vitality of the test plants

The shrubs (Firethorn or Grey Alder resp.) in the test containers shall average at least 80 % of the average growth (height, trunk diameter) of the test plants in the control containers. Thus a supposed harming of the test plants by harmful substances being emitted by the sheet or coating can be recognized.

The propagation of the Couch Grass on the surface of the growing substrate is evaluated by visual means (classification, see 2.7). From the first interim evaluation (see section 7.1) the plants in the test containers must show at least an average stand density during the whole test period (see 2.7).

2.7 Classification of the Couch Grass stand

The average stand density is visually evaluated and classified by the following numbers:

- 1 = almost no Couch Grass (about 0-20 % of the area covered)
- 2 = sparse stand density (about 20-40 % of the area covered)
- 3 = average stand density (about 40-60 % of the area covered)
- 4 = dense stand density (about 60-80 % of the area covered)
- 5 = very dense stand density (about 80-100 % of the area covered)

2.8 Equivalent jointing techniques

It is allowed to combine different jointing techniques in this test provided that these techniques produce homogenous joints (e.g. solvent welding - with a volatile solvent - and hot gas welding). These joints are considered to be equal.

As opposed to these combinations of glue free joints and joints with adhesive or joints with two different adhesives are not considered to be equal.

2.9 Root penetration

Roots having invaded the surface area or seams of the sheet or coating to be tested while subterranean plant organs have actively created cavities and thus damaged the sheet or coating.

The following are not considered as root invasion but should be mentioned in the test report:

- Roots growing into already existing pores in a sheet or coating (surface area or seam or gap due to work interruption) (i.e. no damage). To make sure that the evaluation is carried out without ambiguity it is necessary to view the sheet or part of coating in question under the microscope.
- Roots having invaded ≤ 5 mm into the surface area or joint or the gap due to work interruption respectively while the sheet or coating contains radicide substances (root inhibitors) as the root inhibiting effect can only develop after root invasion. These sheets or coatings must be characterized as „radicide containing“ by the manufacturer before the test procedure is started to enable such an evaluation
- Roots having invaded the surface area of test specimen composed by several layers (e.g. bitumen sheet with copper strip insert or PVC sheet with polyester fleece insert), if the layer providing the protection against invasion and perforation is not damaged. To enable such an evaluation this particular layer shall be defined clearly by the manufacturer at the beginning of the test procedure.
- Roots having invaded joint seals (without damage of the seam)

2.10 Root perforation

Roots having perforated the surface area or joints of a sheet or coating to be tested when either already existing pores were used or cavities were actively created.

2.11 Certificate „root resistant“

A sheet or coating is regarded to be root resistant if after the test period no root penetration according to section 2.9 as well as no root perforation according to section 2.10 in any test container is observed. Furthermore the shrubs used in the test plants must show satisfying root growth according to section 2.6.

2.12 Rhizomes of *Agropyron repens* (Couch Grass)

As for the evaluation of the results a distinction is drawn between roots and rhizomes, an exact determination of these subterranean plant organs is imperative.

The following information instructs about the procedure:

The rhizomes of Couch Grass spreading into the growth substrate (subterranean offshoots) show a regular thickness of about 2 mm and poor branching. They divide into single segments limited by nodes carrying inconspicuous small stem embracing leaves as well as thin roots. The rhizomes of Couch Grass are hollow between the nodes (see table 1).

In the opposite, roots of Firethorn perform irregular thickness and excessive branching. They never carry any leaves and are not hollow.

If the test institute can not distinguish exactly between rhizomes and roots, professional advice must be asked for.

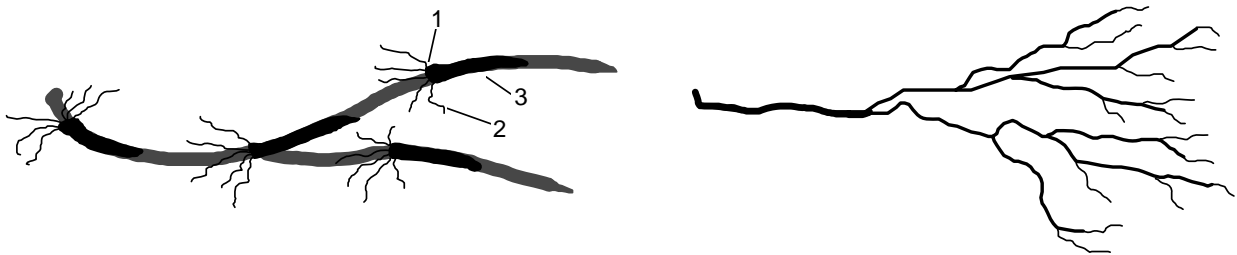


Figure 1: Scheme of Couch Grass rhizomes (left) with nodes (1), roots (2) and leaves (3) compared to a root of Firethorn (right)

2.13 Evaluation of Couch Grass rhizomes

Couch Grass rhizomes having penetrated or perforated the sheet or coating (surface area or joint) are recognized and listed in the test report but they are not evaluated as far as root resistance is concerned. If no such damage of the specimen by rhizomes is observed this fact is specifically laid down (see 2.14).

2.14 Certificate „resistant against Couch Grass rhizomes“

A sheet or coating is considered to be resistant against Couch Grass rhizomes when in analogy to root invasion (see 2.9) and root perforation (see 2.10) no invasion or perforation by rhizomes in any of the test containers is observed after the test period. Furthermore it is supposed that Couch Grass performs adequate growth in the test containers during the whole test period (see 2.6).

2.15 Observations causing early termination of the test

When root or rhizomes perforation of the sheet or coating to be tested is observed during intermediate evaluations (see 7.1) the principal must be informed. The test is stopped when root perforation is effected. If perforating rhizomes are observed the test may be continued in accordance with the principal.

If during the test procedure more than 25 % of the shrubs fail to grow the test must be restarted i.e. new plants must be planted and furthermore the growth substrate must be replaced. The start must be updated.

If insufficient root growth of the test plants is observed during the test procedure the test must be restarted the same way (see section 2.6).

3 Short description of the test procedure

Flexible sheets for waterproofing as well as bitumen, plastic and rubber sheets for roof waterproofing or coatings respectively are examined for root and rhizomes invasion and perforation by test plants in test containers under standardized conditions.

The 4-year-test is carried out in the open using Grey alder and Couch Grass as test plants. The 2-year-test is carried out in an air-conditioned greenhouse using Fire-thorn and Couch Grass as test plants.

The sheet or coating to be tested must have several joints or at least one seam where a new coating has been applied due to work interruption. The sheet or coating is installed in eight test containers. Three more containers without sheet or coating resp. are in the test to control plant growth.

The containers prepared in the described way are filled with growing substrate. The desired high impact by the roots is acquired by applying high plant density, moderate fertilization and poor watering. At the end of the test period the growing substrate is removed and the sheet or coating resp. is checked for invading or perforating roots and rhizomes.

Check samples of the sheet or coating to be tested are taken and stored at the testing institute.

4 Test facilities

4.1 Test site

4.1.1. 4-year-test

A hall open in all directions with a transparent roof should provide almost open land conditions while precipitation possibly causing water logging in the containers without drainage is eliminated.

A greenhouse without heating provided it has sufficient aeration and offers frost effects is also considered to be adequate.

4.1.2 2-year-test

In a greenhouse with monitored heating and aeration the heating should be set at a minimum temperature of $18\pm 3^{\circ}\text{C}$ in daytime and $16\pm 3^{\circ}\text{C}$ during night-time. Aeration should start at $22\pm 3^{\circ}\text{C}$ room temperature. Continuous room temperature $> 35^{\circ}\text{C}$ must be avoided. With the temperatures indicated natural light conditions as in central Europe provide favourable growth conditions for the test plant all-over the year. Shading in summer or artificial lighting in winter is not needed.

Each container (800 x 800 mm) requires a floor area of 1.5 to 2 m² depending on the arrangement of the containers when minimum distances according to section 6.1 are kept.

4.2 Test containers

The test containers must have minimum inside dimensions of 800 x 800 x 250 mm. For technical reasons it may be necessary to use larger test containers.

As perforating roots should be recognized while the test is running and disturbance of the growth substrate should be avoided the test containers must be provided with transparent base (e.g. acrylic glass). The base must be darkened (e.g. with an in-transparent foil) in order to prevent growth of algae in the humid substrate layer. The transparent base should be constructed as an insert with a 20 mm upturn beam in order to provide sufficient water for the humid substrate layer. The water supply for the humid substrate layer is effected through a vertical inlet pipe (\varnothing ca. 35 mm) fixed on the exterior wall of the container and being flush with the upturn beam of the insert base (see table 2).

8 test containers are required for every sheet or coating to be tested. For every test run - not regarding the number of sheet or coating to be tested - 3 control containers (without sheet or coating) are required in addition.

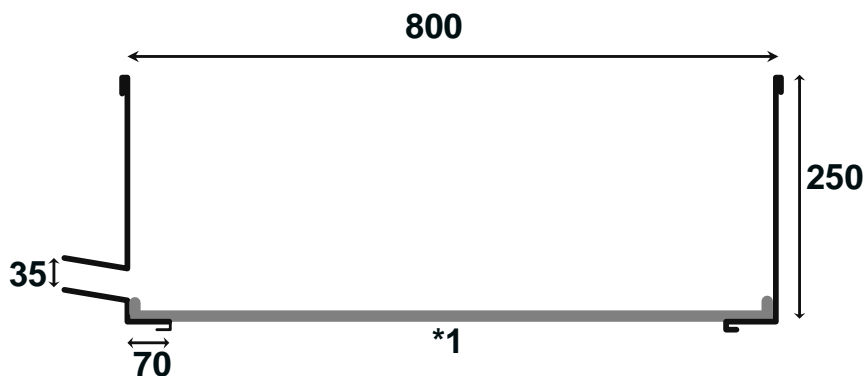


Figure 2: Construction of the test containers (minimum size in mm, *1 = transparent base with upturn)

4.3 Materials for the moisture layer

This particular layer consists of expanded slate or expanded clay (granulation 8-16 mm) possessing the properties required as indicated in table 1. In order to avoid further analytical work it is helpful to use only products undergoing strict quality checks referring to the quoted guideline values. Thus the manufacturer can guarantee the required specification.

The quantity of material runs up to approximately 32 l per container (800x800 mm) for a required layer of 50 ± 5 mm (see section 6.1)

4.4 Protection layer

A synthetic fibre fleece weighting 200 g/m^2 must be used. Compatibility of the felt with the tested layer or coating shall be ascertained. Required amount of felt: $0,64 \text{ m}^2$ per container (800x800 mm).

4.5 Sheet or coating to be tested

The sheet or coating resp. must be inserted or applied according to section 6.1. Each container (minimum size 800 x 800 x 250 mm) covers an area of approximately 1.3 m² (without overlapping) when the 50 mm layer to maintain the moisture is deducted.

4.6 Growing Substrate

The growing substrate consists of:

- 70 % by volume of barely decomposed peat and
- 30 % by volume of expanded slate or expanded clay (granulation 8-16 mm) complying with the requirements as specified in table 1. As described in section 4.3 it is advisable to use only expanded slate or expanded clay that undergo continuous quality checks.

The substrate pH value (CaCl₂) shall be adjusted to between 5,5 and 6,5 by adding lime (calcium carbonate) (see 4.7).

According to section 4.8 basic manure shall be mixed homogeneously with the substrate before it is installed.

The amount of growing substrate required for the 4-year-test (substrate layer 150±10 mm) sums up to 96 l per container (800 x 800 mm). For the 2-year-test (taking into account the amount of substrate added with the pot balls of the test plants) approx. 88 l. per 800 x 800 mm container are required.

Table 1: Required quality of expanded clay or expanded slate. Analysis of water extract of the ground material in deionized water 1:10 (weight/volume)

soluble salts (KCl)	< 0,25 g/100 g
CaO	< 120 mg/100 g
Na ₂ O	< 15 mg/100 g
Mg	< 15 mg/100 g
Cl	< 10 mg/100 g
F	< 1,2 mg/100 g

4.7 pH adjustment

Various amounts of calcium carbonate may be required to adjust the desired pH value to 5,5-6,5.

The required amount of calcium carbonate can be determined by the following procedure:

- take 5 samples of 1 l each of the well mixed growing substrate
- moisten the samples with tap water
- add different amounts of calcium carbonate (4, 5, 6, 7, and 8 g resp.), to the individual samples
- place the samples in plastic bags, seal and label the bags
- store the samples in the bags for approximately 3 days at room temperature
- send samples to a laboratory operating in accordance with VDLUFA methods or CEN 13037 methods and get a pH analysis
- raise the amount of calcium carbonate correlating with the desired pH value in a 1 l sample to the total volume of growing substrate.

4.8 Fertilizer

Use a basic fertilizer containing approx. 15 % N, 10 % P₂O₅, 15 % K₂O, 2 % MgO, and less than 0,5 % Cl and a trace nutrient metal alloy based fertilizer containing iron (Fe), copper (Cu), molybdenum (Mo), manganese (Mn), boron (B), and zinc (Zn).

30 g of basic fertilizer are required per 800 x 800 mm container. Use the trace nutrient metal alloy based fertilizer according to the manufacturers recommendations.

Use a subsequent slowly working coated fertiliser effective for 6 to 8 months (composition approx. 15 % N, 10 % P₂O₅, 15 % K₂O). 30 g of fertilizer are required per each container (800 x 800 mm).

4.9 Tensiometer

Each container must be monitored by a tensiometer (measuring range from 0 to -600 hPa).

4.10 Test plants

For a 4-year-test the following two plant species of the required quality must be used:

- *Alnus incana*, Grey Alder, 2-year-old transplanted seedling, height 60-100 cm and
- *Agropyron repens*, Couch Grass, seed.

For a 2-year-test the following two plant species of the required quality must be used:

- *Pyracantha coccinea* 'Orange Charmer' - Firethorn, height 60-80 cm, in a 2-l-container and
- *Agropyron repens*, Couch Grass, seed.

Install 4 woody plants (Grey Alder, Firethorn) per 800 x 800 mm container and add 2 g Couch Grass seed leading to a calculated plant density of 6,25 woody plants per m² and 3,13 g seed per m². When the containers in use are larger than described, the amount of plants and seed must be increased to obtain the minimum plant density. When purchasing the shrubs, ensure uniform strong growth of the plants.

4.11 Irrigation water

The irrigation water must meet the minimum quality standards given in table 2.

The water quality must be ascertained at the competent waterworks.

If any of the values given in table 2 is exceeded the irrigation water must be blended adequately with deionized water or rainwater.

Table 2: Minimum water quality

conductivity	< 1000 µS/cm
sum alkaline earth	< 5,4 mmol/l
acid capacity (up to pH 4,3)	< 7,2 mmol/l
Chloride	< 150 mg Cl/l
Sodium	< 150 mg Na/l
Nitrate	≤ 50 mg NO ₃ /l

5 Sampling and manufacturer's information

A check sample of the sheet or coating shall be taken by the test institute before and after the test. The sample must at least have one joint for every jointing technique applied or one seam where a new coating has been applied due to work interruption and a minimum area of 0,5 m². The check sample shall be stored at temperatures between 5 °C and 25 °C in a dark and dry place at the test institute.

The samples must be stored at least for the period of validity of the test report (see section 8).

Material incompatibilities during storage shall be noted.

For the exact identification of the tested specimen the following information shall be requested from the manufacturer at the beginning of the test: name of the product, scope, material designation, product standards, thickness (excluding bond), equipment/structure, delivery form, manufacturing technique, test certificates, year of manufacture, installation method at test site (overlap, jointing technique, jointing agent, type of joint seal, cover strip over joints, special corner and angle joints), addition of biocides (e.g. root retardant) including details on substance concentration.

In addition, a file copy of the product data of the sheet or coating to be tested must be submitted to the test institute.

Furthermore for every product consisting of several layers (e.g. rubber sheet with copper band inlay or PVC sheet with polyester fleece inlay) the manufacturer must exactly determine the protection layer against root invasion and root perforation.

6 Procedure

6.1 Preparation and installation of the 8 test containers

The different layers are successively placed in the containers as follows (from bottom to top): moisture layer, protection layer, sheet or coating to be tested, layer of growing substrate, vegetation.

The moisture layer shall be placed right on the transparent base with a uniform thickness of 50 ± 5 mm.

Cut the protective fleece to dimensions of the basal area and place it directly onto the moisture layer.

Install the sheet or coating to be tested as described in sections 6.1.1 and 6.1.2.

When the sheet or coating to be tested is installed the substrate is filled tightly up to a 150 ± 10 mm thickness, corresponding to 96 l substrate volume (4-year-test) resp. 88 l substrate volume (2-year-test) for 800 x 800 mm containers.

Plant 4 plants of *Alnus incana* (Grey Alder) (4-year-test) resp. 4 plants of *Pyracantha coccinea* (Firethorn) (2-year-test) distributed over the surface area of every 800 x 800 mm container (see figure 3).

Furthermore 2 g of *Agropyron repens* (Couch Grass) seed are distributed regularly on the substrate layer with both tests.

In order to obtain at least the same density of vegetation increase the number of test plants in containers larger than indicated here (see section 4.10).

The ceramic cell of the tensiometer shall be placed into the growing substrate layer directly above the sheet or coating resp. as the measurement should be taken at the lowest root level. The tensiometer shall be placed at an equal distance from every plant (see figure 3).

Place the containers on stands in order to enable inspection for root invasion within periodic time intervals. A minimum clearance of 0,4 m shall be ensured between the containers. The containers shall be arranged at random.

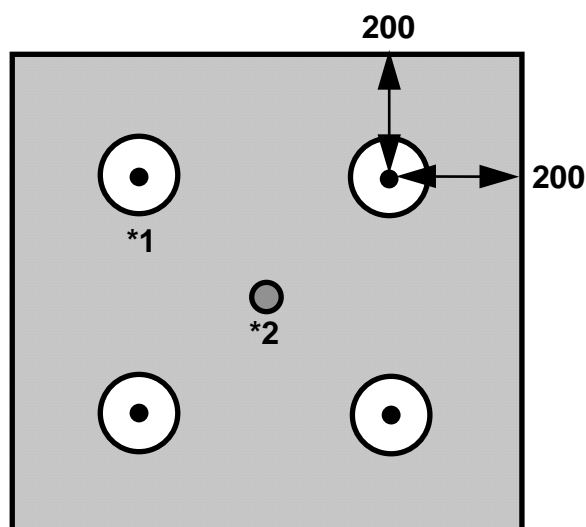


Figure 3: Arrangement of shrubs (*1) and tensiometer (*2) in the substrate layer of a 800 x 800 mm container

6.1.1. Installation of flexible sheets for water proofing and bitumen, plastic and rubber sheets for roof waterproofing

Samples are cut out from the sheet to be tested.

They are jointed and installed in accordance with the manufacturer's instructions and responsibility at the test site. 4 wall corner joints, 2 base corner joints and 1 central T joint according to figure 4 have to be realized (see figure 4). Several jointing techniques can be combined if they are considered to be equal (see section 2.8)

The sheet shall be pulled up to the edge of the test container.

6.1.2 Installation of liquid coating

Liquid coating is applied on the containers in accordance with the manufacturer's instructions and responsibility at the test site as well. The coating must be carried out in two steps leading to a seam due to working interruption in the middle of the test container. The two steps should be carried out within not less than 24 hours. The walls must be coated up to the edge.

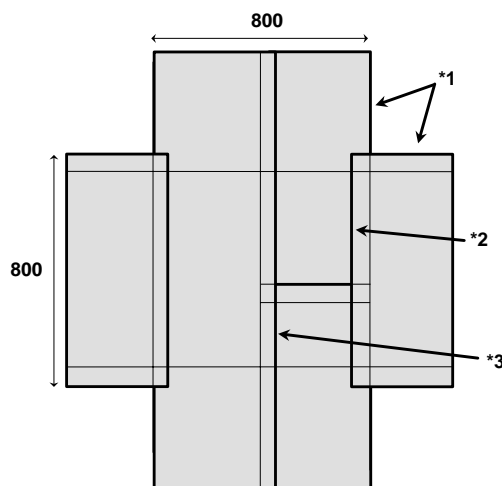


Figure 4: Arrangement of joints (*1 = wall corner joint, *2 = base corner joint, *3 = central T joint)

6.2 Preparation and installation of 3 control containers

As far as preparation and installation is concerned proceed as described in section 6.1 not installing any sheet or coating to be tested, i.e. the growing substrate layer is placed directly on the protective layer.

6.3 Care during plant growth

Substrate moisture must be adjusted in accordance with the requirements of the test plants by top watering. Moisture (suction power) must be monitored by a tensiometer. In order to ensure germination of the seed or rooting of the shrubs respectively watering is carried out during the 8 weeks after planting if the suction power drops below -100 hPa. After the rooting period the plants should only be watered if the suction power drops below a value of -300 to -400 hPa. Water doses should result 0 hPa suction power in the substrate. The whole substrate shall be watered evenly with particular attention to the container edges. Continuing excess of water (wetness due to dammed-up water) in the lower parts of the substrate layer must be avoided.

In order to avoid damage of the tensiometers they have to be removed from the containers when the first frost period begins (4-years-test). Watering must be adequate to the very low needs of the plants during vegetative rest. After the last frost in spring the tensiometers must be replaced on the same spots in the containers. Then watering continues as described above.

The moisture layer shall permanently be kept wet by using the filler pipe within the container.

Subsequent fertilization for the 2-year-test shall be applied at 6 months intervals with a fertilizer type and an application rate as specified in section 4.8 with the first rate given 3 months after planting. The 4-year-test is fertilized once a year in March or April.

Where appropriate any extraneous growth and dead plant material shall be removed from the surface of the substrate.

Dead shrubs (Firethorn or Grey Alder) shall be replaced. As the developing roots of the surviving plants should not be disturbed replacement of plants is only allowed during the first three months for the 2-year-test or within the first six months for the 4-year-test.

If more than 25 % of the shrubs die during the testing time, a new test must be started (see section 2.15)

If the shrubs must be cut back (Firethorn or Grey Alder) a minimum height of 150 ± 10 cm must be left. All cut back work must be carried out the same day for test and control containers.

It is permitted to cut back obstructing side shoots on the paths between the containers.

A patchy level of Couch Grass (< 40 % of the area covered) must be improved by additional seeding up to twice within the first three months (2-year-test) or within the first six months (the 4-year-test) resp..

In order to avoid storage of Couch Grass the shoots must be cut back to 5 cm after having reached 20 cm length.

If the vegetation is threatened suitable plant protection measures shall be taken against injurious diseases or animals pest infestation.

7 Expression of results

7.1 During the test

Every 6 month the transparent base of each of the 8 test containers must be checked for visible roots or rhizomes (i.e. successive root perforation) in both tests (2-year-test and 4-year-test).

When root invasion is observed the principal must be informed. At that time the test procedure may be stopped.

Further intermediate results must not be delivered by means of a written statement.

Every half year (2-year-test) or once a year (4-year-test) the shrubs (Firethorn and Grey Alder) in all test and control containers must be checked for vitality by measuring height and trunk diameter at 20 cm above substrate level. Furthermore Couch Grass must be classified for propagation on the substrate surface (see section 2.7). The average plant growth in the test containers must be determined and compared to the result of the plants in the control containers. If insufficient growth performance - as indicated in section 2.6 - is achieved the test must be restarted (see 2.15). Any plant damage like leaf deformation or changing of colour e.g. must be recorded.

7.2 Evaluation at the end of the test

The principal must be informed of the date for the final control to allow his participation. Growth performance of the plants must be monitored as described in section 7.1.

The substrate is removed from all test containers and the sheet or coating resp. is checked for invading or perforating roots or rhizomes. In accordance with sections 2.9, 2.10 and 2.12 invading and perforating roots and rhizomes are recorded by number.

Every section is checked separately:

- flexible sheets for water proofing and bitumen, plastic and rubber sheets for roof waterproofing: area and joints
- coatings from liquid application: area and the gap due to working interruption, if it can be recognized.

If more than 50 roots or rhizomes per container have invaded the sheet or coating, only a part of the tested sheet is checked notwithstanding as mentioned above.

The evaluation must refer to at least 0,2 m² (about 20 % of the sheet or coating covered by substrate) and take place in the area designed in figure 5.

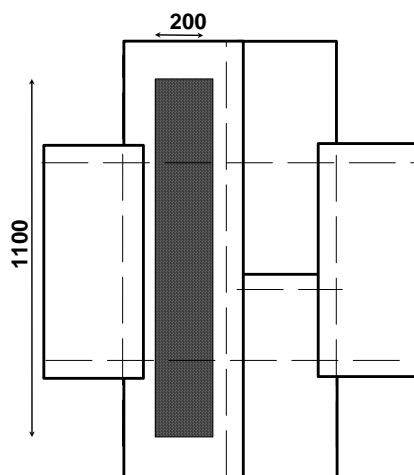


Figure 5: Evaluated area when > 50 roots per container or rhizomes have invaded the sheet or coating (mm).

If roots or rhizomes have invaded the overlapping area of the joints the maximum invasion depth must be recorded. Invading or perforating roots or rhizomes must be proved by photographs.

Check samples of the sheet or coating which show proper description of the result must be taken and must be stored according to section 5.

8 Test Report

Intermediate results must not be published by means of a written statement.

When the test is terminated the test institute must compile a complete report in two copies (one copy for each the test institute and the principal) but only if the sheet or coating has proved to be root resistant in accordance with section 2.11. Companies or products respectively having taken part unsuccessfully in the test do not receive any test report. They are given a written note indicating in detail that the sheet or coating was proved not to be root resistant according to FLL standard.

The report is only allowed to be used unabridged. It must contain the following data:

- data given by the manufacturer concerning the tested sheet according to section 5,
- detailed information about the preparation of the test containers according to section 6 (or a hint, that the test was carried out according to the FLL draft with a copy of the draft as an appendix),
- all results of the evaluation in accordance with section 7 and
- a summary assessment of the tested sheet as described in sections 2.11 and 2.13.

The report must include the following phrasings:

- „The test report compiles pages. It is only allowed to be used unabridged.“
- „The test results are related to data and material characteristics of the tested sheet or coating and to the applied jointing techniques.“
- „Check samples of the sheet or coating resp. are stored at the test institute.“
- „The test report was compiled on and has a 10 years period of validity.“

The period of validity can be extended by 5 years each time by a certificate of the test institute only if

- the fundamentals have not changed in any important aspect and
- the tested product is still part of the actual catalogue of the manufacturer.“

A sample of a test report can be requested from FLL.

9 Responsibility

The principal is responsible for:

- delivery and installation of the protective layer (see sections 2.3 and 6.1) and the sheet or coating to be tested (see section 6.1)
- delivery of data concerning the material and the installation method (see section 5)

The test institute has to contribute the following achievements:

- make available an appropriate area (see section 4.1),
- sampling and storage of the check sample (see section 5),
- supply or composition resp. and installation of the humid layer and the substrate layer (see sections 4.3, 4.6, 6.1 and 6.2),
- supply and installation of the tensiometer
- supply of the test plants and the seed resp. (see sections 4.10, 6.1 and 6.2),
- taking care of the plants during the whole time of testing (see section 6.3),
- evaluation (see section 7) and
- compiling of the test report (see section 8).

The test containers (see section 4.2) can be supplied by the principal or the test institute as well. The responsibilities must be recorded in a contract between principal and test institute. It must also record the payment by the principal.

A standard sales contract can be requested from FLL.