



WEIHENSTEPHAN · TRIESDORF
University of Applied Sciences

Test Report

**Determination of resistance
to root damage to flexible sheets and coatings
for roof planting according to FLL (2018)**

Product name:

General Garden

Principal/Manufacturer:

GENERAL MEMBRANE S.P.A.

Via Venezia 538

30022 Ceggia (Venice)

ITALY

The report comprises 33 pages and is only allowed to be used unabridged.

The report has a validity until 2032-03-08.

Date: 2022-03-08

**Information given by the customer GENERAL MEMBRANE S.P.A., Ceggia, Italy
concerning data and characteristics of the membrane**

General Garden

Date: 2019-05-31

- **Product name:** General Garden
- **Intended use:** Sealing of flat roofs
- **Material code/type of material:** Polymer modified bitumen (APP)
- **Thickness of the sheeting (without lamination):** 4 mm
- **Product design/structure/colour:**
 - Upper and lower layer: polymer modified bitumen;
 - middle layer: combination carrier layer of polyester, black
- **Supply form:** Rolls from 5.0 or 7.5 m²
- **Manufacturing technique:** Modified bitumen impregnation of polyester felt
- **Material standards/norms:** EN 13707
- **Test certificates:** None
- **Year of manufacture:** 2019
- **Layer which is responsible for the function of root resistance:**
 - Entire polymer modified bitumen sheet
- **Installation method at test site:**
 - **Overlap:** Approx. 80 mm
 - **Joint technique:** Welding by torch flame (propane gas)
 - **Jointing agent:** None
 - **Type of joint seal:** None
 - **Cover strip over joints:** None
 - **Special corner and angle joints:** None
- **Addition of root inhibition agents with details of concentration:**
 - 1% Preventol B5, referred to covering mass.

1 Problem task

In order to prevent damage, protection sheets and coatings are required to perform permanent resistance against penetration or perforation by plant roots and plant rhizomes (subterranean sprouts). In this test the resistance to root and rhizome damage of the membrane Genral Garden manufactured by GENERAL MEMBRANE, S.P.A., 30022 Ceccia – Venice, Italy was determined according to FLL method.

2 Test facility and procedure

The 2 year-long test was carried out in accordance with the "Procedure for investigating the root penetration resistance of membranes and coatings for green roofs" (FLL, 2018). The test took place between December 2019 and December 2021 comprising 8 containers equipped with the sheet to be tested General Garden. Another 3 containers without sheet were serving as control that allows to compare the plant development in the different containers.

According to the guideline the sheet was installed in the containers at the test site of the Institute of Horticulture, Weihenstephan-Triesdorf University of Applied Science by GENERAL MEMBRANE, S.P.A., Italy. Four seams at the corners where the walls meet, two seams along the base at the corners and two T-seams were created.

The containers were installed in a climate-controlled glass house. The test plant *Pyra-cantha coccinea* 'Orange Charmer' is a Firethon variety with satisfying growth at the defined climatic conditions also during winter half year. The other test plant, *Agropyron repens* (Couch Grass), is forming rhizomes which can damage protection sheets as well as roots.

The complete description of the FLL test procedure can be found in annex 3 of this report.

Check samples of the flexible sheet General Garden were taken before and after the test and stored at the testing institute.

3 Data given by the manufacturer of the flexible sheet

The test of resistance against root and rhizome perforation refers to the data and material characteristics of the tested sheet and to the applied manufacturing technique. The data given by GENERAL MEMBRANE, S.P.A., Ceccia (Venice), Italy concerning the flexible sheet General Garden are listed on page 2 of this report.

4 Results

4.1 Plant development

Firethorn developed well during the whole test period. The required growth of the plants in the test containers (80 % of the average vigorousness of growth in the control containers) was at all four evaluations with 98-108 % clearly exceeded.

Even Couch Grass performed well during the two years test period with a middle up to high density of stand. In the eight test containers on average 43–96 % (nominal value \geq 40 %) of the surface were covered with Couch Gras.

Detailed information concerning vigorousness of growth are given in annex 2.

4.2 Penetration and perforation of roots and rhizomes

4.2.1 Couch Gras rhizomes

At the test end the Couch Gras rhizomes didn't perforate the membrane at any point. Also no penetrations of rhizomes into the seams could be observed (see photos in annex 1).

4.2.2 *Pyracantha* roots

As well occurred neither in the surface nor in the joints of the flexible sheet General Garden perforated or penetrated *Pyracantha* roots after the two years test period in December 2021.

5 Summary

In accordance with the “Procedure for investigating the root penetration resistance of membranes and coatings for green roofs“ (FLL, 2018) a two year-long test was carried out from December 2019 up to December 2021 with the flexible sheet General Garden. In no one of the eight test containers the membrane showed any perforations or penetrations caused by *Pyracantha* roots or Couch Gras rhizomes.

The flexible sheet General Garden is therefore considered to be resistant to roots and to Couch Grass rhizomes according to FLL standard.

The FLL method involves all relevant elements of the method according to the European Standard EN 13948. Furthermore the FLL method is more extensive and is considered to be more significant among experts. So from the technical point of view the tested flexible sheet General Garden can be regarded as being resistant to root penetrations according EN 13948 as well.

The results of the test relate only to the tested flexible sheet General Garden with its defined material characteristics and applied manufacturing technique (see page 2 of this report). Check samples of the tested sheet were taken and are stored at the Institute of Horticulture, Weihenstephan University of Applied Science.

The test report was compiled in February 2022 and has a ten years period of validity until February 2032. This report comprises 33 pages and is only allowed to be used unabridged.

gez. Heinz-Josef Schmitz
Dipl.-Ing. (FH) Heinz-Josef Schmitz
2022-03-08

gez. Elke Meinken
Prof. Dr. Elke Meinken
2022-03-08

Weihenstephan-Triesdorf University of Applied Sciences,
Institute of Horticulture, Am Staudengarten 14, D-85354 Freising
Tel.: +49 (0) 8161/71-5659, Fax: +49 (0) 8161/71-3348
E-Mail: heinz-josef.schmitz@hswt.de

Annex 1

Photos concerning the tested flexible sheet General Garden



Fig. 1: Complete test specimen at the end of the test in December 2021



Fig. 2: T-joint at the end of the test



Fig. 3: Corner of the test specimen at the end of the test

Annex 2

Data on plant development

Tab. 1: Height and trunk diameter of Firethorn in 8 test containers

Cont. No.	Plant No.	Jun 20		Dec 20 ²⁾		Jun 21		Dec 21	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
C. 1	1	0,9	194	1,3	285	1,3	284	1,5	310
	2	1,2	175	1,6	265	1,7	282	1,8	320
	3	1,1	167	1,4	250	1,6	275	1,8	300
	4	0,9	159	1,4	280	1,4	290	1,8	315
C. 2	1	0,9	242	1,4	315	1,4	195	1,6	255
	2	0,9	166	1,4	245	1,5	230	1,6	270
	3	1,1	248	1,4	280	1,6	265	1,7	290
	4	0,8	218	1,4	290	1,4	290	1,6	290
C. 3	1	1,2	213	1,5	290	1,7	270	1,9	312
	2	1,0	233	1,4	320	1,4	280	1,6	295
	3	1,0	188	1,4	275	1,6	260	1,7	265
	4	1,1	170	1,7	285	1,7	270	1,8	270
C. 4	1	0,9	201	1,3	270	1,4	230	1,5	280
	2	1,1	186	1,6	295	1,6	242	1,7	310
	3	1,1	197	1,5	250	1,6	225	1,7	270
	4	0,9	192	1,3	280	1,4	275	1,5	280
C. 5	1	1,2	200	1,7	280	1,8	265	1,9	270
	2	1,2	173	1,5	245	1,7	250	1,7	250
	3	1,2	205	1,7	300	1,7	270	1,8	278
	4	1,0	205	1,4	350	1,4	280	1,5	284
C. 6	1	1,0	236	1,5	295	1,6	275	1,8	275
	2	1,1	154	1,5	265	1,6	260	1,7	275
	3	1,0	222	1,4	305	1,5	250	1,5	290
	4	1,1	192	1,5	255	1,5	255	1,7	275
C. 7	1	1,3	205	1,6	290	1,7	270	1,8	294
	2	1,0	203	1,3	265	1,5	252	1,7	267
	3	1,0	174	1,4	315	1,5	275	1,6	301
	4	1,0	196	1,4	275	1,8	267	1,8	267
C. 8	1	0,9	182	1,4	280	1,4	240	1,6	280
	2	1,2	186	1,8	310	1,8	265	1,9	280
	3	0,9	217	1,4	290	1,5	265	1,8	265
	4	1,1	146	1,5	295	1,6	245	1,7	245
Average C. 1 - C. 8	1-4	1,04	195	1,47	284	1,56	261	1,70	282

¹⁾ Trunk diameter 20 cm above substrate surface ²⁾ cut after the measuring in the height of 150 cm

Tab. 2: Height and trunk diameter of Firethorn in 3 control containers

Cont. No.	Plant No.	Jun 20		Dec 20 ²⁾		Jun 21		Dec 21	
		Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm	Ø cm ¹⁾	Height cm
K. 1	1	0,9	173	1,3	275	1,4	250	1,5	285
	2	1,1	168	1,3	280	1,5	175	1,5	260
	3	1,1	177	1,5	225	1,6	190	1,7	230
	4	0,9	169	1,3	290	1,3	260	1,4	295
K. 2	1	0,9	157	1,3	280	1,4	227	1,4	280
	2	1,2	251	1,7	350	1,7	295	1,9	315
	3	1,3	232	1,9	310	1,9	240	1,9	295
	4	1,1	145	1,4	260	1,5	220	1,6	225
K.3	1	1,0	163	1,4	260	1,5	270	1,6	280
	2	1,1	173	1,5	245	1,6	225	1,7	265
	3	1,0	204	1,4	310	1,6	270	1,7	280
	4	1,1	185	1,3	280	1,6	267	1,7	305
Average K. 1- K. 3	1-4	1,06	183	1,44	280	1,55	241	1,63	276

¹⁾ Trunk diameter 20 cm above substrate surface ²⁾ cut after the measuring in the height of 150 cm

Tab. 3: Average values of height and trunk diameter of Firethorn in 8 test containers related to the values of the plants in 3 control containers (data in %, nominal value: ≥ 80 %)

Cont. No.	Plant No.	Jun 20		Dec 20 ²⁾		Jun 21		Dec 21	
		Ø %	Height %	Ø %	Height %	Ø %	Height %	Ø %	Height %
Average C. 1 - C. 8	1-4	98	107	102	101	101	108	104	102

Tab. 4: Classification of the stand density of Coach Grass in 8 test containers (nominal value: ≥ 40 %)

Cont. No.	Jun 20	Dec 20	Jun 21	Dec 21
	stand density (%)	stand density (%)	stand density (%)	stand density (%)
C. 1	40	70	80	100
C. 2	40	80	80	100
C. 3	50	70	70	90
C. 4	40	70	80	100
C. 5	50	70	70	90
C. 6	40	70	80	100
C. 7	40	80	80	100
C. 8	40	80	70	90
Average C. 1 - C. 8	43	74	76	96

Tab. 5: Classification of the stand density of Coach Grass in 3 control containers

Cont. No.	Jun 20	Dec 20	Jun 21	Dec 21
	stand density (%)	stand density (%)	stand density (%)	stand density (%)
K. 1	40	80	80	100
K. 2	50	80	80	90
K. 3	40	80	80	100
Average K. 1 - K. 3	43	80	80	97

Annex 3

- Green Roof Guidelines – Guidelines for the Planning, Construction and Maintenance of Green Roofs

Appendix C:

Procedure for investigating the root penetration resistance of membranes and coatings for green roofs¹

1999 Edition, with editorial changes 2002, 2008 as well as
Supplement to "Requirements for transcription/renewal of test certificates"
(Approved and adopted by the FLL Presidency at the end of 2016, see section 9)

FLL

**LandscapeDevelopment and
Landscaping Research Society e.V.**

Friedensplatz 4
D-53111 Bonn

2018

¹ Arbeitskreis „Dachbegrünung“ der FLL, Arbeitsgruppe „Durchwurzelungsschutz“: Prof. Dr. P. Fischer, Freising-Weihenstephan (Leitung), Dipl.-Ing. R. Bohlen, Ladbergen; R. Klein, Wächtersbach-Neudorf; Prof. Dr. H.-J. Liesecke, Hannover; Prof. Dipl.-Ing. G. Lösken, Hannover; Dipl.-Ing. P. Siegert, Tornesch; Dipl.-Ing. W. Tebart, München; Dipl.-Ing. R. Walter, Stuttgart

Introduction

In order to exclude vegetation-related structural damage caused by green roofs, in 1984 a working group of the Landscape Development and Landscaping Research Society (FLL) developed a "method for investigating the root penetration resistance of root barrier membranes", which is based on the strain exerted by plant roots on the membranes. The method is essentially based on experience and findings of several years of experiments with different waterproofing membranes and various plant species, which were carried out at the Institut für Bodenkunde und Pflanzenernährung, FH Weihenstephan, [Institute of Soil Science and Plant Nutrition], from 1975 to 1980.

The FLL procedure was revised in 1992, 1995 and for the last time in 1999. Editorial changes were made in 2008. In 2016, adjustments were required based on new requirements of FLL for the transcription and renewal of test certificates (see 9).

It has a high status among manufacturers, planners and contractors, which can be documented by, among other things, the large number of completed and ongoing investigations.

In 1993, the FLL decided to re-examine the previous procedure with a test period of 4 years, with the aim of reducing the test duration to 2 years, without weakening the intended strict standards of the previous test.

After experiments at the Institut für Bodenkunde und Pflanzenernährung, FH Weihenstephan, these specifications were finally agreed: The 2-year test takes place in a climate-controlled greenhouse, the plant species used at corresponding temperature and light conditions grow throughout the year. Thus, an effective growth period of 24 months is achieved, which is of similar duration to the 4-year test, taking into account the annual multi-month dormancy period of the vegetation under field conditions. Both tests are considered equivalent and are described together in the present reformulation of the procedure.

In the course of changes in content, a formal redesign was also carried out to make the process easier to understand and to make it easier for the testing institutions to evaluate the results obtained.

1 Area of validity

This procedure covers investigations into resistance to root penetration of roots and rhizomes of different test plants for

- root barrier membranes
- roof and waterproofing membranes, and
- liquid surface treatments

for all types of green roofing (intensive greening, simple intensive greening and extensive greening).

This procedure includes testing of products including all jointing techniques linked to them. Therefore, it is admissible only for testing purposes related to individual membranes and/or surface coatings. The investigation of a roofing system, i.e. composite construction of several layers for the roof waterproofing is not possible.

For technical reasons, it may be necessary to install a separate layer under the coating for coatings in the liquid application. This is permitted, provided that the manufacturer clearly states that the root resistance is effected solely by the top layer coating. Any lamination, i.e. a separate layer on top of a membrane and/or coating to be tested is to be excluded.

The result of the tested membrane or coating is not transferable to the ingress and penetration resistance of plants with strong rhizome growth (e.g. bamboo and Zebra grass). If such plant species are used, structural precautions beyond the proven ingress and penetration protection must be taken and special care measures provided.

This procedure does not extend to investigations into environmental compatibility of any product tested.

The European Standard DIN EN 13948 "Flexible sheets for waterproofing - Bitumen, plastic and rubber sheets for roof waterproofing - Determination of resistance to root penetration" emerged from the FLL method for investigating the root resistance of membranes and coatings for green roofs.

Although both procedures have almost identical contents there are some important differences:

- The FLL procedure tests 8 instead of 6 trial containers for each product tested and is therefore more comprehensive.
- The FLL procedure takes rhizome forming Couch Grass as a second testing

plant besides *Pyracantha*, while the DIN EN 13948 uses only one test plant, *Pyracantha*. This means that products fitting the DIN EN 13948 can only be certified as root resistant and not rhizome resistant as per FLL.

The FLL procedure includes all relevant elements of the European standard DIN EN 13948, goes beyond their requirements and is therefore considered to be of higher quality in the professional world. Therefore, from a technical point of view, a root barrier membrane tested according to the FLL method can also be designated as root-resistant according to DIN EN 13948.

2 Definitions

For the application of this procedure, the following definitions shall be applied:

2.1 Trial containers

Containers, with minimal dimensions, which have been specially equipped for the examination. The containers are equipped with the membrane or coating to be tested (trial containers) and with a geotextile fabric (control container).

2.2 Moisture course

The moisture layer consists of coarse-grained mineral material which is arranged below the membrane or coating to be tested. It is kept moist all the time and thus enables the further growth of roots and rhizomes that have penetrated through the membrane or coating to the transparent bottom of the vessel and thus allow the early detection of penetrations.

2.3 Protective ply

With the membrane or coating-compatible geotextile, which is placed directly under the material to be tested on the moisture layer to achieve a uniform pressure distribution.

2.4 Vegetation stratum

Standard cultivation substrate (materials mixture) readily available, or which can be made up, in a consistent form at any investigation site. The structure of this layer shall be stable, offer good water and air management properties and be lightly fertilized. These conditions favor an optimum root development of the test plants. The vegetation stratum is in direct contact with the membrane to be tested.

2.5 Test plant species

2.5.1 For the 2-year test

- *Pyracantha coccinea* 'Orange Charmer', ornamental shrub which under greenhouse conditions shows an all year round root growth suitable for the test, and
- *Agropyron repens*, Couch Grass, an indigenous grass with slow growing rhizomes which settle readily on green roofs and which also grows sufficiently all year through under the given testing conditions

2.5.2 For the 4-year test

- *Alnus incana*, Grey Alder, a wild woody plant which shows root growth suitable for the test under the given outdoor conditions during the vegetation period, and
- *Agropyron repens*, Couch Grass.

2.6 Sufficient growth performance of the test plants

The woody plants (*Pyracantha* and Alder) in the trial containers have to show an average growth performance of at least 80 % (height, diameter of the stem) of the plants in the control containers during the entire duration of the investigation. This enables any harmful effect to the test plants, which may have been caused by substances emitted by the test materials, to be detected.

The spreading of the Couch Grass on the substrate surface will be evaluated visually (see 2.7). In this case, the plants in the test vessels from the first interim evaluation (see 7.1) must have on average at least one average population density during the entire test period (see 2.7).

2.7 Evaluating of the Couch Grass growth

For the visual evaluation of the population density of the Couch Grass, the following figures are assigned. The classification is as follows:

- 1 = hardly any Couch Grass present (about 0 – 20 % of the surface covered)
- 2 = thin growth (about 20 – 40 % of the surface covered)
- 3 = medium growth (about 40 – 60 % of the surface covered)
- 4 = dense growth (about 60 – 80 % of the surface covered)
- 5 = very dense couch grass growth (about 80 – 100 % of the surface covered)

2.8 Equivalent joining techniques

In the investigation, it is admissible to combine different joining techniques as far as they aim exclusively at producing material-homogenous seamed joints (e.g. solvent bonding – with a solvent which evaporates – and hot gas welding). Such types of seam bonding are considered to be equivalent.

In contrast to this, combinations of bonding-free joints and joints with bonding glue or joints using two different types of glues are not considered to be equivalent.

2.9 Root ingress

Any root which has established itself in the surface or in the seams of a tested membrane and/or surface coating (root ingress), where subterranean plant parts have actively created cavities and have thus damaged the membrane and/or coating.

Not to be evaluated as root ingress but to be noted in the test documentation are:

- roots which have already grown into the pores of the membrane or coating (surface or seam and/or work interruption seam, i.e. no damage). In order to ensure a clear evaluation, the membrane or coating section in question needs to be inspected with a microscope
- roots which have grown into the surface or seam and/or work interruption seam of the membrane or coating ≤ 5 mm which contains radicide substances (root retardant agents), since any root retarding effect can only act upon penetration of the root into the membrane/coating. In order to ensure a clear evaluation, such membranes/coatings have to be clearly marked as “radicide-containing” by the manufacturer before the investigation is carried out
- roots which have grown into the surface of products which are composed of several layers (e.g. bituminous sheeting with copper band inlays or elastomer membranes with inlays or reinforcements) if the layer taking over the function of a penetration barrier has not been damaged. In order to ensure a clear evaluation, this layer has to be clearly defined by the manufacturer before the investigation is carried out
- roots which have penetrated seam sealing (without damaging the seam).

2.10 Root penetration

Roots which have penetrated the area or the seams of the tested membrane and/or coating. These roots have used pores present in the membrane or coating or have actively created cavities.

2.11 Certificate “root resistant”

A membrane and/or coating is considered to be “root resistant” if, upon termination of the test phase, no root ingress according to section 2.9 and no root penetration according to section 2.10 was found in any of the containers. Furthermore, one of the preconditions is that all woody plants used in the investigation have shown sufficient growth performance according to section 2.6 throughout the entire test phase.

2.12 Couch Grass rhizomes

Since the evaluation differentiates between roots and rhizomes a reliable determination of these subterranean plant organs is indispensable.

The following indications serve as a basis for the evaluation:

- the couch grass rhizomes (subterranean shoots) spread through the vegetation stratum and show a regular thickness of ca. 2 mm and minimal branching. They are divided into individual sections with knots forming the boundaries between the sections. Around the knots inconspicuous small leaves surrounding the stem as well as thin roots have formed. In between the knots the couch grass rhizomes are hollow (see Fig. 1)
- in contrast, roots of the *Pyracantha* vary in thickness and show vigorous branching. Leaves never form, and they are not hollow.

If the testing institute has difficulties to clearly differentiate between rhizomes and roots, expert consultation is required.

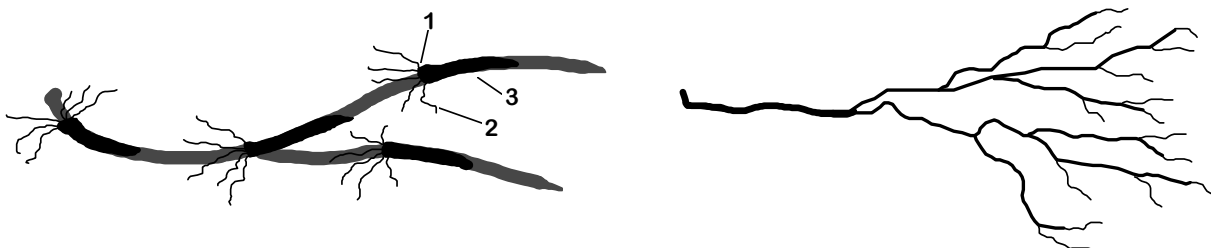


Fig. 1: Schematic representation of the Couch Grass rhizome (left) with knots (1), roots (2) and leaves (3) as opposed to a *Pyracantha* root (right)

2.13 Evaluation of couch grass rhizomes

Couch Grass rhizome penetration into the membrane and/or coating (surface or seams) is detected and noted in the test report, but not evaluated in regard to resistance to root penetration. If no damage of the product due to rhizomes is found, an explicit statement stressing this fact is to be included into the test report (see 2.14).

2.14 Certificate “rhizome resistant against Couch Grass”

A membrane and/or coating is considered to be “rhizome-resistant against Couch Grass” if, upon termination of the test phase, - parallel to root ingress (see 2.9) and root penetration (see 2.10) - no rhizome ingress nor rhizome penetration is found in any container.

This assumes that all couch grasses used in the investigation have shown sufficient growth performance throughout the entire test phase (see 2.6).

2. 15 Incidents leading to a premature termination of test

If during the test phase, visible penetrations of roots or rhizomes into the membrane and/or coating to be tested are identified (see 7.1), the client who has commissioned the investigation needs to be informed. The test is stopped if the penetrations are caused by roots. If any rhizomes have penetrated the test material, the investigation may be continued upon mutual agreement with the client.

Should more than 25 % of the woody plants die off during the test phase, the investigation has to be started anew, i.e. new planting needs to be carried out. At the same time, the vegetation stratum needs to be replaced. A new date has to be assigned to the beginning of the test phase.

The same procedure shall be applied if during the test phase no sufficient root growth of the test plants can be achieved (see 2.6).

3 Brief description of the procedure

The resistance to root penetration of root barrier membranes as well as roof and waterproofing membranes and/or surface coating is tested against roots and rhizomes of test plant species in a trial container and under standardized conditions.

During a 4-year test, the examination is carried out outdoors. Alders and Couch Grasses are used as test plants. The 2-year test is carried out in a climate-controlled

greenhouse using *Pyracantha* and Couch Grass.

The membrane and/or coating, which needs to show several seams/joints and/or one work interruption joint, is installed in 8 trial containers. 3 more containers without any membranes or coatings are included into the test. They serve as a control for plant growth.

A thin vegetation stratum is laid into the containers. With dense planting, moderate fertilizing and modest watering the desired high root pressure shall be obtained.

At the end of the investigation, the vegetation stratum is removed and an examination of the membrane and/or coating is effected, focusing on the detection of any root and/or rhizome ingress or penetration.

Control samples of any membrane and/or coating tested are stored at the test institute.

4 Test facilities and material

4.1 Location of the testing

4.1.1 For the 4-year investigation

A hall is to be used equipped with a transparent roofing, otherwise open on all sides.

This creates conditions similar to outdoor conditions. At the same time any precipitation, which might lead to water logging in the non-draining containers, is held off.

An unheated greenhouse is also permissible as long as it has sufficient ventilation and allows a frost effect.

4.1.2 For the 2-year investigation

Provide a greenhouse with adjustable heating and ventilation. The heating should be set so that the inside temperature is $18 (\pm 3) ^\circ\text{C}$ during the day and $16 (\pm 3) ^\circ\text{C}$ during the night. At an internal temperature of $22 (\pm 3) ^\circ\text{C}$ the greenhouse must be ventilated. A persistent internal temperature $> 35 ^\circ\text{C}$ should be avoided.

The natural light conditions in Central Europe ensure favorable growth of the test plants throughout the annual cycle at the indicated temperatures. A shading of the plants in summer or an artificial exposure in winter are not required.

The space demand per container (800 x 800 mm), respecting the required minimum distance according to section 6.1, amounts to approx. 1.5 to 2 m², depending on the arrangement of the containers.

4.2 Trial containers

The internal dimensions of the containers used in the trial shall not be less than 800 x 800 x 250 mm, but larger containers may be needed if the circumstances under which they are to be installed so require.

Trial containers are to be fitted with transparent bases (e.g. acrylic glass) so that root penetration can be detected even during the test phase without interfering with the vegetation stratum. The base of the container shall be darkened (e.g. by means of a foil which is impervious to light), in order to avoid the growth of algae in the moisture layer. Ideally, the transparent container base will be a tray with a 20 mm upstand to maintain a constant supply of water in the moisture course. The water supply into the moisture layer is affected by means of a filling pipe. This pipe shall have a diameter of 35 mm and is mounted on the outside of the container, pointing upwards and abutting onto the upstand of the base tray (see Fig. 2).

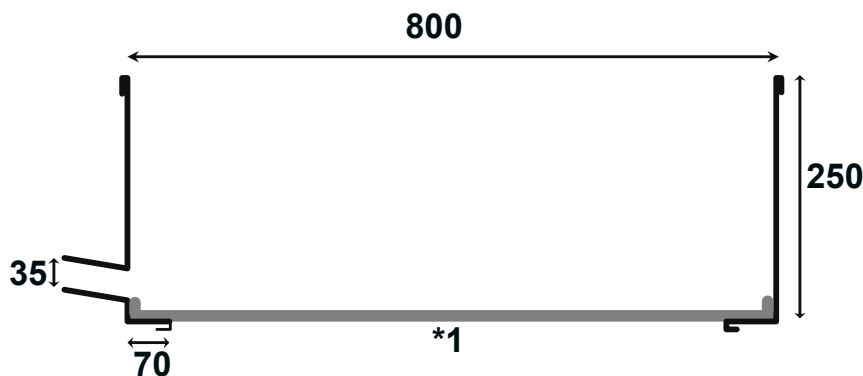


Fig. 2: Construction design of the trial containers (minimum dimensions, all figures in mm, *1 = transparent base with upstand)

For each membrane and/or coating to be tested, 8 trial containers are required. In addition, per experimental run – regardless of the number of sheets/coating to be tested – 3 control containers (without any membranes/coating) must be provided.

4.3 Moisture layer

This layer consists of expanded slate or expanded clay (particle size 8 – 16 mm) which has to meet the quality requirements indicated in Tab. 1. In order to avoid any in-house analysis necessity, it is useful to only use products which are subjected to permanent quality controls in regard to the described guidelines. Thus, the manufacturer will guar-

antee the required properties.

For the required course depth of 50 (\pm 5) mm (see 6.1) the material requirement amounts to 32 l per trial container (800 x 800 mm).

4.4 Protective geotextile fleece

A geotextile fleece made from synthetic fibers with a weight of approx. 200 g/m² is to be used. The material compatibility of the geotextile fleece fabric with the membrane/coating to be tested, needs to be ensured. The material requirement amounts to 0.64 m² per trial container (800 x 800 mm).

4.5 Membrane and/or coating to be tested

The membrane/coating has to be laid and/or applied according to paragraph 6.1. The surface to be treated (minus the 50 mm depth of the moisture course) amounts to a calculated figure of about 1.3 m² (without overlapping) per container with the minimum dimensions (800 x 800 x 250 mm).

4.6 Growing media

The media consists of:

- 70 vol. % minimally decomposed North German moorland peat and
- 30 vol. % expanded clay or slate (particle size 8 – 16 mm) of the quality indicated in Tab. 1. As described in paragraph 4.3, it is useful to only use products which have undergone quality testing.

Add calcium carbonate to bring the pH value (CaCl₂) to figures between 5.5 and 6.5 (see 4.7).

The initial fertilizing defined in paragraph 4.8 is mixed with the vegetation stratum in a homogenous way before filling the container.

In a 4-year investigation, the substrate requirement amounts to about 96 l per trial container (800 x 800 mm) with a required layer depth of 150 (\pm 10) mm, for the 2-year investigation to about 88 l per container (taking into account a substrate supply via plant root balls).

Tab. 1: Required quality of expanded clay/slate. Determination with water extract of the ground material with demineralized water in a 1:10 (weight/volume) ratio

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 settings

For the vegetation stratum, different quantities of calcium carbonate may be necessary in order to set the desired pH value to 5.5 – 6.5.

The required quantity can be determined by using the following procedure:

- take 5 samples of 1 l each from the well mixed vegetation support course
- moisten the samples with tap water
- mix the samples with different quantities (4, 5, 6, 7 or 8 g) of calcium carbonate
- put the samples into a plastic bag; close and label them
- store the samples in the bag for about 3 days at room temperature
- send the samples to a laboratory which works to the regulations of the VDLUFA association methods and request a pH analysis in CaCl₂
- extrapolate the quantity of calcium carbonate which has led to the desired pH value in the 1 l sample to the entire volume of the vegetation support course.

4.8 Fertilizer

For an initial fertilizing, a multiple-nutrient fertilizer with approx. 15 % N, 10 % P₂O₅, 15 % K₂O, 2 % MgO and less than 0.5 % Cl as well as a fertilizer containing nutrient trace elements with Fe, Cu, Mo, Mn, B and Zn is to be used. Per container (800 x 800 mm), 30 g of a multiple-nutrient fertilizer are to be applied. The fertilizer containing nutrient trace elements is used in the quantity recommended for substrates by the manufacturer. Use slow release fertilizer capsules with approx. 15 % N, 10 % P₂O₅, 15 % K₂O and a release time of 6–8 months for the repeat fertilizing. The requirement on fertilizers amounts to 30 g/container (800 x 800 mm) each time.

4.9 Tensiometer

In order to monitor the watering of the vegetation support course, each container needs a tensiometer with a measuring range of 0 up to -600 hPa.

4.10 Test plants

For the 4-year investigation the following 2 plant species, meeting the defined quality requirements, shall be used:

- *Alnus incana* – Grey Alder, 2-year replanted seedling, height 60–100 cm, and
- *Agropyron repens* – Couch Grass, seeds

For the 2-year investigation the following 2 plant species, meeting the defined quality requirements, shall to be used:

- *Pyracantha coccinea* ‘Orange Charmer’ - *Pyracantha* – in a 2 liter container, height 60–80 cm
- *Agropyron repens* – Couch Grass, seeds

Each trial container, with dimensions of 800 x 800 mm, is to be planted with 4 woody plants (Alder, *Pyracantha*) as well as 2 g of Couch Grass seeds.

This leads to a calculated plant density of 6.25 woody plants/m² and 3.13 g seeds/m². If larger trial containers are used, the plant density has at least to reach the figures indicated above by increasing the number of plants and the quantity of seeds.

When buying the plants, it must be ensured that plant quality does not vary.

4.11 Watering

The water used for watering shall meet the minimum quality requirements listed in Tab. 2. Enquiries must be made as to the local water quality at the waterworks responsible for the supply of the facility. If any of the values laid down in Tab. 2 are exceeded, the water for watering needs to be blended with fully desalinated water or with rain water.

Tab. 2: Minimum quality requirements for water used for watering

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 Samples and information provided by the manufacturer

Samples from the membrane/coating under investigation are to be taken by the test institute for retention before and after the investigation. The material taken as a sample has to include at least one bonding seam per jointing technique and/or one work interruption joint and shall have a size of at least 0.5 m². Retained samples are to be stored in dark and dry conditions at a temperature above 5 °C and not exceeding 25 °C. The duration of retention has to be equal to or exceed the period of validity of the test report (see 8). Care must be taken during storage to ensure no contact with incompatible materials.

In order to ensure a clear identification of the tested product, the following information needs to be provided by the manufacturer before the test is started: product name, area of application, material description, material standards, thickness (without lamination), finish/structure, form of delivery, manufacturing technique, test certificates, year of manufacture, installation/laying technique at the location of the investigation (overlapping, jointing techniques, jointing agents, type of seam sealing, covering strips over seams, special corner and angle joints), additives of biocides (e.g. root inhibitors) with details regarding the concentration of the substances.

In addition, a product data sheet of the membrane/coating to be tested, has to be handed in for retention at the test institute.

Moreover, for products consisting of several layers (e.g. bituminous sheeting with copper band inlays or PVC or elastomer membranes with inlays/reinforcements) the manufacturer has to define, in an unambiguous way before the start of the investigation, which layer is meant to take over the function of an ingress and penetration barrier.

6 Testing conditions

6.1 Preparation and installation of the 8 trial containers

The trial containers shall be prepared with the following layered structure (from bottom to top): moisture lay, protective ply, membrane and/or coating to be tested, vegetation stratum, planting.

Directly above the transparent base of the container, the bottom layer, the moisture layer is laid with a depth of 50 (± 5) mm.

The protective ply is cut to size, based on the base area of the container and laid directly onto the moisture layer. On top of the protective lining the membrane/coating is applied as described in paragraphs 6.1.1 and 6.1.2.

After the installation of the membrane/coating to be tested, the vegetation substrate is filled firmly to a layer depth of 150 (\pm 10) mm. This corresponds to a substrate volume of 96 l (4-year test) and 88 l (2-year test) respectively (see 4.6) for a receptacle of 800 x 800 mm.

Per trial container of 800 x 800 mm and for a 4-year investigation 4 *Alnus incana* plants (Grey Alder), for a 2-year test 4 *Pyracantha coccinea* shall be planted equally spread over the entire surface (see Fig. 3). Furthermore, for both investigation types and per receptacle 2 g of seeds of *Agropyron repens* (Couch Grass) are to be equally sown onto the vegetation support layer.

If larger trial containers are necessary, the number of plants and the quantity of seeds needs to be increased so that the minimum plant density is reached (see 4.10).

Place the ceramic cell of the tensiometer into the vegetation stratum directly on top of the membrane/coating. Thus measurements can be carried out in the lowest part of the root area. The tensiometer shall be placed at an equal distance to the plants (see Fig. 3).

It is advisable to place the containers on stands to facilitate root penetration checks at regular intervals. Keep a minimum distance of 0.4 m between and around the containers, which are to be arranged in a random order.

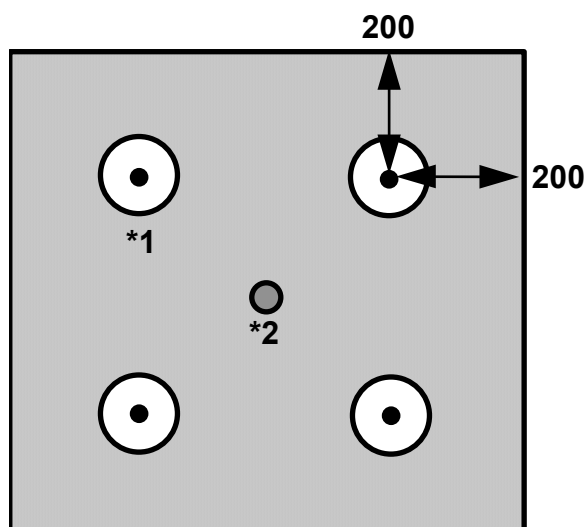


Fig. 3: Arrangement of woody plants (*1) and tensiometer (*2) in the vegetation stratum in a 800 x 800 mm container (dimensions in mm)

6.1.1 Installation of root barrier membrane, roof and waterproofing membranes

Cut out parts of the membrane/lining to be tested and install them as required into the trial containers. The client who commissions the investigation is responsible for the professional execution of the work at the testing location. Create 4 seams at the corners where the walls meet, 2 seams along the base at the corners and one T-seam running along the middle (see Fig. 4). Hereby it is admissible to use different jointing techniques as long as these are equivalent (see 2.8).

The membrane shall be brought up to the rim of the container walls.

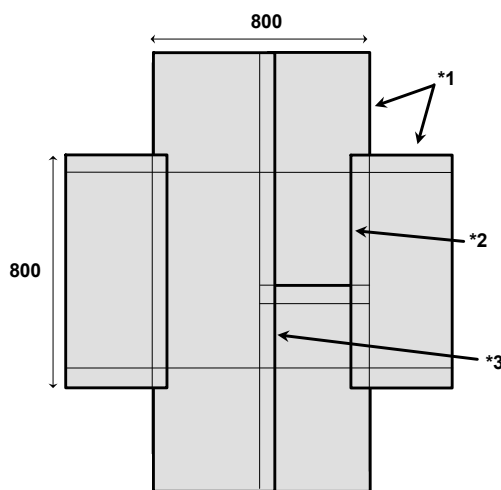


Fig. 4: Layout of the seams (*1 = wall-corner seam, *2 = base-corner seam, *3 = T-seam) in the membrane to be tested (dimensions in mm)

6.1.2 Installation of surface coating under investigation – liquid surface treatment

The liquid surface coating is applied as required at the testing location under the responsibility of the client who commissions the investigation. The coating shall be applied in 2 stages. In the center of the container, there is to be a work interruption joint going all the way through the material under testing. The time interval between both stages of work shall be at least 24 hours.

The coating shall be brought up to the rims of the container walls.

6.2 Preparation and installation of the 3 control receptacles

Preparation and installation of the control receptacles is affected as described in paragraph 6.1. However, no membrane/coating to be tested is installed, i.e. the vegetation stratum is laid immediately on top of the protective ply.

6.3 Care of the plants during the growth period

The substrate moisture content is to be set according to the needs of the plants by means of top watering onto the vegetation support course. The moisture (soil moisture tension) shall be checked by means of a tensiometer.

In order to ensure a good germination of the seeds and/or good root take of the woody plants in the first 8 weeks after the greening process, irrigation is carried out as soon as the soil moisture tension drops below a value of -100 hPa. In the course of the investigation watering is applied only if the soil moisture tension falls below values between -300 and -400 hPa. The irrigation volumes are to be dimensioned for achieving a soil moisture tension in the substrate of nearly 0 hPa. Ensure the entire vegetation support course (including peripheral areas) is equally moistened. Avoid any lasting water excess (water logging) in the lower areas of the vegetation support course. In order to avoid damaging the tensiometers, the devices need to be taken out of the containers at the beginning of the first frost season (for the 4-year investigation). Irrigation during the dormant phase of the vegetation shall be adapted to the low water demands of the plants. After the last frosts in spring, the tensiometer devices shall be placed back at the same position. Irrigation is continued as described above.

The moisture layer shall be kept constantly wet by watering via the feed pipe which is mounted to the container.

Any repeat fertilizing for a 2-year investigation shall be carried out in semi-annual intervals with a fertilizing agent and in the quantities listed in paragraph 4.8. The first feed shall be applied 3 months after planting. In the 4-year investigation repeat fertilizing is given once a year in March or April.

Any foreign growth and any plant parts which have died back and fallen onto the surface of the vegetation support course are to be removed.

Any wood plants which have died (*Pyracantha* and/or Alder) shall be replaced. In order not to interfere with root growth of the remaining plants replacement planting is admissible only during the first 3 months in the 2-year investigation and during the first 6 months in the 4-year investigation. If during the course of the investigation the losses of woody plants account for more than 25 % of the total plant number the test shall be re-started (see 2.15).

If the *Pyracantha* and/or Alder need to be pruned, a growth height of at least 150 (\pm 10) cm shall be kept. Any pruning shall be affected on the same day on plants in both trial and control containers.

In the areas between the containers, side shoots may be pruned if they are an obstacle to using the areas.

Any insufficient Couch Grass growth (< 40 % of the surface is covered) shall be improved by up to 2 units of repeat seeding in the first 3 months (2-year investigation) or 6 months (4-year investigation) of the test.

To avoid collapse of the Couch Grass all blades of grass shall be cut back to a height of 5 cm once they have reached a growth height of ca. 20 cm.

In case of strong pest attacks and/or any plant diseases threatening the survival of the plants, testing appropriate plant protection measures shall be carried out.

7 Evaluations

7.1 Evaluations during the test

In the 2-year investigation as well as in the 4-year investigation the transparent bases of all 8 trial containers shall be examined at intervals of 6 months in order to detect visible roots and rhizomes (i.e. successful root penetration).

If visible root penetration is discovered in the trial containers, the client who commissioned the investigation shall be informed. The trial may be discontinued (see 2.15).

Apart from this notification, no interim results in writing shall be disseminated during the duration of the trial.

In semi-annual intervals (2-year investigation) or annually (4-year investigation) growth performance of the woody plants shall be monitored by measuring the height and diameter of the trunk at a height of 20 cm. The propagation of the couch grass on the substrate surface is also to be evaluated (see 2.7). The average growth performance of the plants in the trial containers shall be determined and compared with the result of the control containers. If no sufficient growth is achieved in accordance with paragraph 2.6, the test shall be re-started (see 2.15).

Any plant damages, e.g. deformations of the leaves or changes in leaf colour, shall be noted separately.

7.2 Evaluation at the end of the test

The client commissioning the investigation shall be notified of the date and time of the planned final evaluation to enable him to personally attend the session.

The evaluation commences with a final monitoring of the growth performance of the plants as described in paragraph 7.1.

At the end of the trial, the vegetation stratum is taken out of all trial containers in order to examine the membrane/coating for root and rhizome ingress and/or penetration. According to paragraphs 2.9, 2.10 and 2.12 roots and/or rhizomes ingress and penetration into the membrane/coating shall be recorded in absolute figures.

This examination shall be done separately for the following areas

- for root barrier membranes, root and waterproofing membranes:
 - the surface and
 - the seams
- for liquid surface coating:
 - the surface and, if possible
 - the work interruption joint, if the latter is visible.

If more than 50 roots and/or rhizomes ingresses per container are found in the membrane/coating, the evaluation of these ingresses – as opposed to the above described – shall be performed only on a section of the tested material. In that case, the evaluation has to cover at least 0.2 m² (about 20 % of the membrane/coating covered with the substrate) and shall be performed in the area indicated in Fig. 5.

In case of penetration of roots/rhizomes into the overlapping area of seams, the maximum penetration depth shall be recorded.

Photographic evidence shall be provided of some evidence of root ingress or penetration (as an example).

Samples of the membrane/coating for retention purposes shall be taken to mirror the result of the investigation. The samples shall be stored in compliance with the stipulations laid down in paragraph 5.

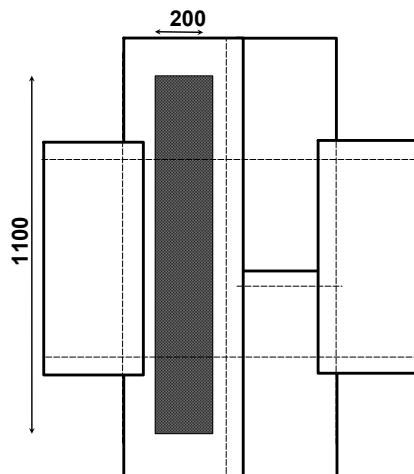


Fig. 5: Evaluation section of ingress into the surface of a membrane/coating under testing in case of > 50 ingresses/receptacle (dimensions in mm)

8 Test report

No interim results shall be announced during the trial.

Upon termination of the trial, a complete test report about the given test situation shall be written up in two copies (1 copy each for the test institute and the client), but only if the membrane/coating has proven to be “root resistant” in accordance with paragraph 2.11. Companies and products which have participated in the investigation without success shall not receive any test report but only a notification in writing with a statement and related explanations that the membrane/coating has not successfully passed the root resistance test based on FLL standards.

The report may only be used in a non-abbreviated form and shall contain the following data:

- details provided by the manufacturer in relation to the membrane under testing in accordance with paragraph 5
- detailed information as regards the preparation of the trial containers according to FLL guidelines, the guidelines used for the investigation shall be enclosed as an appendix)
- all evaluation results in accordance with paragraph 7, and
- a summary evaluation of the tested membrane according to paragraphs 2.11 and 2.13.

Furthermore, the report shall incorporate the following statements:

- “The test report encompasses pages and may only be used in a non-abbreviated form”
- “The findings of the investigation are bound to all reference data and material properties of the tested membrane listed in the test report in compliance with the requirements, as well as to the jointing techniques which have been used or which are considered to be equivalent”
- “Retention samples of the tested membrane/surface coating will be kept at the test institute”
- “The test report was compiled on (date) and has a general period of validity of 10 years”.

9 Transcription/renewal of test certificates

The following requirements apply to the transcription or renewal of test certificates:

1. In principle, transcription or renewal of test certificates is only possible if identical membranes are provided; the following changes are also acceptable:
 - Slating and sanding;
 - Thicker membrane than the tested membrane.
2. Non-identical and thus non-certifiable membranes are especially following these modifications/changes:
 - Change of the trade name/trademark of the product being tested;
 - Modification of laminations (e.g. geotextiles, foils, etc.);
 - Change of colour pigments;
 - Changes in production technology, e.g. changes in calendering or extruding;
 - Change of talc conversions;
 - Differences in the material of the carrier inserts;
 - Use of other additives (modified formula);
 - Modified additives (e.g. formulation change at Preventol).

3. Laminations or laminated layers

If possible and common in practice, laminated layers must be removed before starting the test; unless an edge area without lamination guarantees a professional jointing technique or lamination is an essential part of the root protection of the product.

(Laminations are, for example, foils that are intended only for transport and easier unrolling of the webs. Thin films which are virtually insoluble and melt when joining on the basis of the joining technique do not have to be removed).

4. Scope of Certificates

The test reports issued by the respective investigation body certify the test results. The investigation bodies cannot give additional test certificates for the installation in certain situations on the construction site. Reasons are e.g. commonly used fire retardants on site.

5. Renewal of test certificates; intervals

All test certificates first issued for a period of 10 years.

If the membranes are identical, test certificates may be renewed up to a maximum of twice for a period of 5 years each. The certificate does not come with different validity periods (e.g. 10, 15, 20 years ...) but according to the principle: 10 + 5 + 5 years).

10 Responsibilities

The client who commissions the investigation is responsible for:

- procurement and installation of the protective ply (see 2.3 and 6.1) and the membrane and/or coating to be tested (see 6.1)
- provision of a material sample (see 5), and
- details in relation to the tested membrane and/or coating (see 5).

The test institute commits itself to providing the following services:

- provision of a suitable space to carry out the investigation (see 4.1)
- taking and storage of a material sample (see 5)
- procurement and/or creation and installation of the moisture layer and the vegetation stratum (see 4.3, 4.6, 6.1 and 6.2)
- procurement and installation of the tensiometer devices (see 4.9, 6.1 and 6.2)
- procurement of the test plants and/or the seeds, as well as for the greening of the containers (see 4.10, 6.1 and 6.2)
- care of the plants during the growth period (see 6.3)
- all evaluation processes (see 7), and

- creating a final test report (see 8).

The trial containers (see 4.2) may be provided by either the client or the test institute. The responsibilities are to be subjected to contractual agreements between the client who commissions the investigation and the test institute. These contractual agreements also regulate the expenses incurred for the investigation, which shall be borne by the client.