

Test report no.: 214080/20-I

Client: Holcim Solutions and Products EMEA BV
Ikaroslaan 75
B-1930 Zaventem
BELGIEN

Order: Determination of resistance to root damage to flexible sheets and coatings for roof planting according to FLL (2018) on the flexible sheet "Elevate RubberGard EPDM" nominal thickness 1.1 mm

Letter of:	2020-06-29	Ref.:	Detlef Luers
Sample received:	2020-09-07	Sample taken:	-
Test period:	2020-09-07 till 2022-09-07		

This test report comprises 32 pages including two annexes.

Würzburg, 2022-10-25
Har/mo/

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The original language of the test report is German. In case of doubt the German version is obligatory.

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1 Order

The company Holcim Solutions and Products EMEA BV, Ikaroslaan 75, B-1930 Zaventem, Belgien, ordered the SKZ – Testing GmbH with letter dated 29 June 2020 with the determination of resistance to root damage to flexible sheets and coatings for roof planting according to FLL (2018) on the flexible sheet “Elevate RubberGard EPDM” nominal thickness 1.1 mm.

2 Test material

On 7 September 2020 SKZ – Testing GmbH received the following samples for testing:

- 8 testing containers equipped with a black coloured with a nominal thickness of 1.1 mm, seam coverage with Pourable Sealer

According to the client the membrane was made from ethylene propylene diene monomer rubber (EPDM) in a nominal thickness of 1.1 mm and is denominated “Elevate RubberGard EPDM”. The other dates given by the client are listed in annex 1.

3 Execution of test

Usually we carry out tests according to standards for which we have an accreditation. The list of all standards for which we are accredited is shown on the homepage at www.skz.de. All non-accredited procedures are marked with a *.

The 2 year-long test was carried out in accordance with the ” Procedure for investigating resistance to root penetration at greenroof sites“ (FLL, 2018)*. The complete description of the FLL test procedure can be found in annex 2 of this report. The test was carried out between September 2020 and September 2022 comprising 8 containers equipped with the membrane to be tested. Another 3 containers without membrane were serving as control that allows the comparison of the plant development in the different containers. The membrane was cut, jointed and installed into the containers at the test site of the SKZ-Testing GmbH by Holcim Solutions and Products EMEA BV. A reference sample of the flexible sheet was taken and stored at the test institute. The final inspection included the noting of any root and rhizome penetration into and through the tested membrane.

4 Test results

4.1 Plant development

The plants, Firethorn and Coach Grass, performed well during the whole test period. Growth of the test plants in the control containers (without membrane) was on average not significantly differing from plant growth in the test containers covered by the membrane "Elevate RubberGard EPDM". The required minimum vigorousness of Firethorn in the test containers (80 % of the average vigorousness of growth in the control containers) was reached (> 100 %). Coach Grass performed during the whole test period a high density of stand. Detailed information concerning vigorousness of growth is given in Table 1 - 5.

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

Cont. No.	March 2021		September 2021		March 2022		September 2022	
	Ø	Height	Ø	Height	Ø	Height	Ø	Height
	mm ¹⁾	cm	mm ¹⁾	cm	mm ¹⁾	cm	mm ¹⁾	cm
P 1	3,9	70	6,8	110	7,9	173	9,7	220
P 2	4,8	93	7,1	133	8,3	168	9,5	233
P 3	4,1	85	7,6	136	8,8	168	10,2	203
P 4	5,3	106	9,9	166	10,6	198	12,2	238
P 5	3,9	66	6,2	106	6,0	110	7,9	143
P 6	5,0	88	7,2	110	8,7	188	11,7	233
P 7	4,7	78	9,4	145	10,3	178	11,2	215
P 8	4,7	100	7,8	133	9,5	165	10,5	200
P1 – P8	4,6	86	7,7	130	8,8	168	10,4	210

¹⁾ Trunk diameter measured at 20 cm above substrate surface

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

Cont. No.	March 2021		September 2021		March 2022		September 2022	
	Ø	Height	Ø	Height	Ø	Height	Ø	Height
	mm ¹⁾	cm	mm ¹⁾	cm	mm ¹⁾	cm	mm ¹⁾	cm
K 1	4,9	84	7,0	133	7,9	155	8,9	185
K 2	3,6	75	5,1	95	7,3	123	8,5	140
K 3	3,5	58	5,6	106	6,8	144	8,6	200
K 1 – K 3	4,0	72	5,9	111	7,3	140	8,7	175

¹⁾ Trunk diameter measured at 20 cm above substrate surface

Table 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.	March 2021		September 2021		March 2022		September 2022	
	Ø	Height	Ø	Height	Ø	Height	Ø	Height
	%	%	%	%	%	%	%	%
P 1 – P 8	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100

Table 4: Classification of the stand density of Coach Grass in 8 test containers

Cont. No.	March 2021	September 2021	March 2022	September 2022
	Classification	Classification	Classification	Classification
P 1	4	4	5	5
P 2	5	4	4	4
P 3	4	4	5	5
P 4	5	5	5	5
P 5	4	5	5	5
P 6	4	4	5	4
P 7	3	4	4	4
P 8	3	4	4	4
P 1 – P 8	4	4	5	5

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

Cont. No.	March 2021	September 2021	March 2022	September 2022
	Classification	Classification	Classification	Classification
K 1	5	5	5	5
K 2	4	4	5	5
K 3	5	5	5	5
K 1 – K 3	5	5	5	5

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

At the end of the test period (September 2022) the containers were emptied for a detailed check of the membrane “Elevate RubberGard EPDM” for root or rhizome penetration and perforation. The surface and the seams of the tested membrane did not show any perforations or penetrations caused by roots and rhizomes, see figure 1 – 3.



Figure 1: Membrane surface



Figure 2: Membrane surface with T-joint



Figure 3: Membrane surface with wall corner.

5 Summary

In accordance with the “Method of testing resistance to root damage to flexible sheets and coatings for roof planting” (FLL, 2018) a two year-long test was carried out with the membrane “Elevate RubberGard EPDM” manufactured by Holcim Solutions and Products EMEA BV, Ikaroslaan 75, B-1930 Zaventem, Belgien.

The surface and the seams of the tested membrane did not show any perforations or penetrations caused by roots and rhizomes. The membrane “Elevate RubberGard EPDM” is therefore considered to be resistant to roots and rhizomes according to FLL standard. The test on root resistance relates to the data and material characteristics as well as the applied jointing technique and manufacturing technique described in Annex 1 of this report. This test result can be transferred to other members of the product family with higher nominal thickness. The FLL procedure not only contains all relevant elements of the DIN EN 13948, but exceeds those requirements and is therefore achieves higher recognition in the industry. A root-resistant membrane to FLL standards can also be seen as fitting the DIN EN 13948. Reference samples of the tested membranes were taken and are stored at SKZ - Testing GmbH. This test report was compiled in October 2022 and has a 10 years period of validity. This report comprises 32 pages and is only allowed to be used unabridged.

Annex 1

Auftrag Wurzelprüfung

Hiermit beauftragen wir die SKZ-Testing GmbH mit der:

- Untersuchung der Wurzelfestigkeit von Bahnen und Beschichtungen für Dachbegrünungen nach den „FLL-Dachbegrünungsrichtlinien – Richtlinien für Planung, Bau und Instandhaltung von Dachbegrünungen“¹
- Bestimmung des Widerstands gegen Wurzelpenetration nach DIN EN 13948: „Abdichtungsbahnen - Bitumen-, Kunststoff- und Elastomerbahnen für Dachabdichtungen - Bestimmung des Widerstandes gegen Wurzelpenetration“¹
- Bestimmung der Rhizomfestigkeit von Gewässerabdichtungen nach FLL „Empfehlungen für Planung, Bau und Instandhaltung von Abdichtungssystemen für Gewässer im Garten- Landschafts- und Sportplatzbau“²

für folgendes Produkt

1. Produktnamen:
RubberGard EPDM
2. Anwendungsbereich:
Dachbegrünung
3. Werkstoffbezeichnung:
Vulkanisiertes EPDM
4. Dicke der Bahn (ohne Kaschierung):
1,1 mm
5. Ausrüstung/Aufbau:
Homogenes EPDM
6. Lieferform:
Rollenware in verschiedenen Breiten
7. Herstelltechnik:
Mischen, Kalandrieren, Vulkanisieren

¹ gilt für Wurzelschutzbahnen, Dach- und Dichtungsbahnen und Beschichtungen im Flüssigauftrag.

² gilt für Bitumenbahnen, Kunststoff- und Elastomerbahnen, Flüssigabdichtungen, Gussasphalt, GUP-Beschichtungen

8. Stoffnormen:

CE nach EN 13956

9. Prüfzeugnisse:

abP P-20190202_MPA Dresden

10. Herstellungsjahr:

Klicken Sie hier, um Text einzugeben.

11. Schicht/Lage, welche die Funktion des Durchwurzelungsschutzes übernimmt:

EPDM

12. Bei mehrschichtigen Bahnen/Bahnen mit Verstärkungslage:

Beschriftete Skizze zum Aufbau (bitte Wurzelschutzschicht einzeichnen)

Skizze:

13. Zusatz von Bioziden mit Angaben zur Konzentration und der Schichten, die biozidhaltig sind (Schichten bitte in obiger Skizze einzeichnen):

keine

14. Bei **biozidhaltigen** Produkten, mit **mehrschichtigem** Aufbau (bitte ein Feld ankreuzen):

die biozidhaltige Schicht gewährleistet den Durchdringungsschutz

oder

die Wurzelschutzschicht/Verstärkungslage (Schicht siehe Skizze) gewährleistet den Durchdringungsschutz

15. Einbautechnik am Untersuchungsort:

- a. Überlappung: 15 cm
- b. Fügetechnik: Kaltvulkanisation mittels Nahtfügeband
- c. Fügemittel: QuickPrime Plus
- d. Nahtversiegelung: Pourable Sealer
- e. Eckverstärkung: keine
- f. Abdeckstreifen über Nähten: keine
- g. Unverträglichkeiten mit z. B. XPS: keine

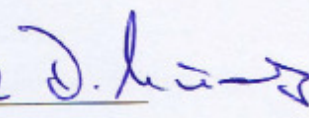
Produktdatenblätter

befinden sich im Anhang

werden am Klicken Sie hier, um ein Datum einzugeben. übermittelt.

Anschrift des Auftraggebers:

Holcim Solutions and Products
 EMEA BV; Ikaroslaan 75; B-1930 Zaventem

10.10.2022 

Datum, Name, Unterschrift

Annex 2

Procedure for investigating resistance to root penetration at greenroof sites

Forschungsgesellschaft

Landschaftsentwicklung Landschaftsbau e.V.

(Research Society for Landscape Development and Landscape Building)

Friedensplatz 4

D-53111 Bonn

Introduction

In order to exclude vegetation-dependant structural damage due to roof greening, in 1984 a “Procedure for investigating resistance to root penetration” was devised by a working group of The Landscape Development and Landscaping Research Society e.V. (FLL) which focused on the stress exerted on root protection barriers due to plant roots. The procedure is mainly based on experience and findings gathered in tests carried out over a period of several years with different waterproof membranes and various plant species. All tests were executed between 1975 and 1980 at the Institute for Soil Science and Plant Nutrition, University of Applied Science Weihenstephan (FH).

The FLL procedure was revised in 1992, 1995 and most recently in 1999.

The procedure is highly recognised among manufacturers, planners and executing contractors which is also documented by the large number of already completed and still ongoing investigations.

In 1993 the FLL decided to re-examine the existing procedure of testing over a period of 4 years with the aim to reduce the test period to 2 years without watering down the desired exacting standards of the current tests.

After a series of tests at the Institute for Soil Science and Plant Nutrition, Technical College Weihenstephan, agreement was reached regarding the following requirements: the 2-year test takes place in a climate-controlled greenhouse which allows the plant species used to grow throughout year with optimal light and temperature conditions. Thus, an effective growth period of 24 months can be achieved. This equates to the duration of a 4-year test, when taking into account the yearly, extended dormant phases of vegetation in outdoor conditions. Both tests are considered to be equal and have been described in the present new edition of the procedure.

Whilst affecting changes to its content this edition has also been subjected to editorial changes in format, to facilitate comprehension and to make it easier for the testing institutions to evaluate the test results obtained.

1 Scope

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

- root protection membranes
- roof and waterproof lining sheets, and
- liquid surface treatment materials

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. No examination of an entire roof protection system, i.e. of a protection course consisting of several layers for roof protection purposes, can be affected.

For reasons related to the testing procedure it may be necessary to apply a separate course underneath the surface treatment in order to test coating products using liquid surface treatment materials. This method is admissible as long as the manufacturer clearly guarantees that resistance to root penetration is effected only by means of the top coating applied to the construction.

Any lamination, i.e. a separate layer on top of a membrane and/or coating to be tested, has to be excluded.

The findings for any membrane and/or coating which has been tested cannot be transferred to resistance to root penetration in relation to plants with strong rhizome growth (e.g. bamboo or Chinese reeds species). When using these types of plants on top of a regular root-resistant membrane, additional structural measures have to be taken and special maintenance provided.

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

The European Norm DIN EN 13948 "Waterproofing membranes, bitumen, plastic and elastomeric membranes for roof waterproofing — Determining the resistance to root penetration" supersedes the FLL-procedure for testing the root resistance of membranes and coatings.

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

- The FLL procedure tests 8 instead of 6 samples 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 not only contains all relevant elements of the DIN EN 13948, but exceeds those requirements and is therefore achieves higher recognition in the industry. A root-resistant membrane to FLL standards can also be seen as fitting the DIN EN 13948.

2 Definitions

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

2.1 Trail 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 fleece fabric (control container).

2.2 Moisture course

The moisture course consists of a coarse mineral aggregate laid underneath the membrane and/or coating to be tested. It is kept constantly damp and therefore allows for continuous growth of roots and rhizomes penetrating the protective membrane and/or coating down to the transparent bottom of the container. Thus any penetration can be detected early.

2.3 Protective layer

Fleece fabric, which is compatible with the membrane/coating, is laid directly underneath the material to be tested and onto the moisture course in order to create an equal distribution of compression.

2.4 Growing substrate

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 course shall be stable, offer good water and air management properties and be lightly fertilised. These conditions favour an optimum root development of the test plants. The vegetation support course is in direct contact with the membrane to be tested.

2.5 Test plant species

2.5.1. Plants for 2-year-test

- *Pyracantha coccinea* 'Orange Charmer' Firethorn, 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 the settling of which can hardly be avoided on green roofs and which also grows sufficiently all year through under the given testing conditions

2.5.2 Plants for 4-year-test

- *Alnus incana*, grey alder, a wild woody plant which shows a 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). Hereby the plants in the trial containers, from the interim evaluation onwards (see 7.1), have to show at least a medium growth density throughout the entire test period (for evaluation see 2.7).

2.7 Evaluating of the couch grass growth

For the visual evaluation of the growth 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 seam 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 2 different types of glues are not considered to be equivalent.

2.9 Root ingress

Any root which has established itself on 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 valued as root ingress but to be noted in the test documentation are:

- roots which have already grown into the pores of 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 of or seam and/or work interruption seam (1.5 mm of the membrane or coating 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 PVC sheeting with polyester fleece fabric inlays) 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 surface or the seams of 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 penetration according to paragraph 2.9 and no root penetration according to paragraph 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 paragraph 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 support course and show a regular thickness of ca. 2 mm minimal branching. They are divided up into different 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. 4)
- 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..

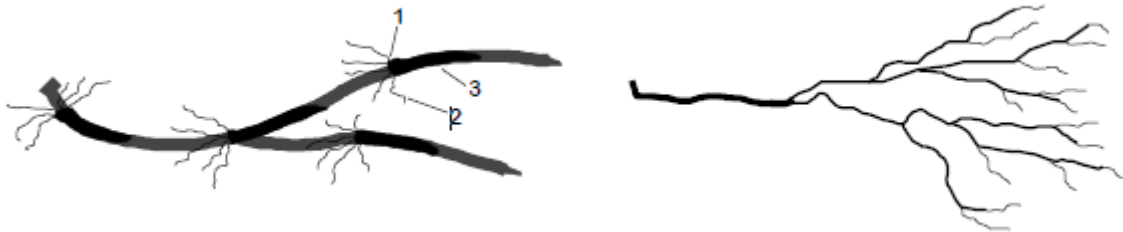


Figure 4: Schematic representation of the couch grass rhizome(left) with knots (1), roots (2) and leaves (3) as opposed to a pyracantha root(right)

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 test stop

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 a new, i.e. new planting needs to be carried out. At the same time, the vegetation support course 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-resistant membranes as well as roof and waterproof linings and/or surface coating is tested against roots and rhizomes of test plant species in a trial container and under standardised 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 support course is laid into the containers. With dense planting, moderate fertilizing and modest watering the desired high root pressure will be obtained.

At the end of the investigation, the vegetation support course is removed and an examination of the membrane and/or coating is effected, focussing 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 needs to be provided, equipped with a transparent roof cover, otherwise on its four 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.

Admissible as locations are also non-heated greenhouses as long as they provide sufficient ventilation facilities and frost can take effect.

4.1.2 For the 2-year investigation

Provide a greenhouse equipped with heating and ventilation facilities. The heating system is to be set in a way that during the day a temperature of $(18 \pm 3) \text{ }^\circ\text{C}$ and during the night a temperature of $(16 \pm 3) \text{ }^\circ\text{C}$ is achieved. At temperatures of $(22 \pm 3) \text{ }^\circ\text{C}$ and more the greenhouse shall be ventilated. Avoid a constant indoor temperature of $> 35 \text{ }^\circ\text{C}$.

The natural light conditions in Central-European regions ensure a favourable growth of the test plants at the set temperatures throughout the entire year. Any shading of the plants in summer or artificial lighting in winter is not required.

The space demand per container (800 x 800 mm), respecting the required minimum distance according to paragraph 6.1, amounts to ca. 1,5 to 2 m', 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 support course. 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 raised rim 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 raised rim of the base tray (see Fig. 5).

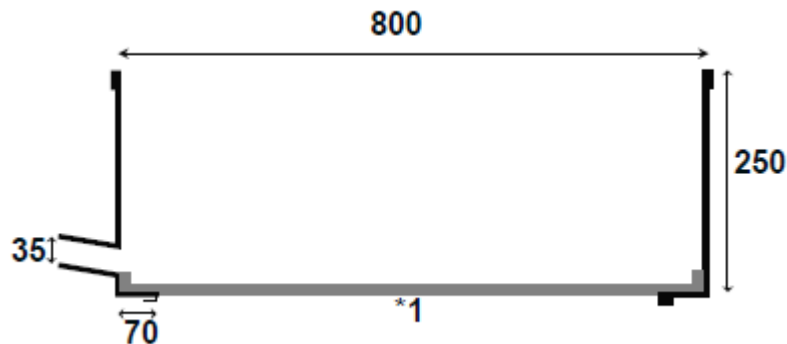


Figure 5: Construction design of the trial containers (Minimum Dimensions, all figures in mm,

*1 = transparent Base with raised Rim

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 (grain 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 guarantee the required properties.

For the required course depth of (5045) mm (see 6.1) the material demand comes to 32 L per trial container (800 x 800 mm).

4.4 Protective fleece

A fleece made from synthetic fibers with a weight of approx. 200 g/m² is to be used.. The material compatibility of the fleece fabric with the sheet/coating to be tested, needs to be ensured. The material demand comes 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 Vegetation substrate

The substrate consists of:

- 70 vol. % minimally decomposed North German moorland peat and
- 30 vol. % expanded clay or slate (grain size 8 — 16 mm) of the quality indicated in Tab. 17.

As described in paragraph 4.3 it is useful to only use products which have undergone quality testing.

Add calcium carbonate (CaCO₃) to bring the pH value to figures between 5.5 and 6.5 (see 4.7).

The initial fertilization defined in paragraph 4.8 is mixed with the vegetation support course in a homogenous way before filling the container.

In a 4-year investigation, the substrate need comes to about 96 L per trial container (800 x 800 mm) with a required course depth of (150 ± 10) mm, for the 2-year investigation to about 88 L per container (taking into account a substrate supply via plant root balls).

Table 6: Required quality of expanded clay/slate. Determination with water extracted from the ground material with demineralised water in a 1:10 (weight/vol.) 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 adjustment

For the vegetation support course, 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 ask them for a pH analysis in CaCl_2

- 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 fertilization, a multiple-nutrient fertilizer with ca. 15% N_2 10% P_2O_5 , 15% K_2O , 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_2 10 % P_2O_5 , 15 % K_2O and a release time of 6 — 8 months for the repeat fertilizing. The demand on fertilizers comes 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 — 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-old transplanted seedling, height 60-100 cm and
- *Agropyron repens*, Couch Grass, seed.

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

- *Pyracantha coccinea* 'Orange Charmer' - Firethorn, height 60-80 cm, in a 2-l-container
- *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. 7. 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. 7 are exceeded, the water for watering needs to be blended with fully desalinated water or with rain water.

Table 7: Minimum quality requirements for water used for watering

conductivity	< 1000 µS/cm
sum earth alkaline	< 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

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 m. Retention samples are to be stored in dark and dry condition at a temperature above 5 °C and not exceeding 25 °C. The duration of retention has to be equal 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, mounting/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 sheeting with polyester fleece fabric inlays) 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 course, protective lining, sheet and/or coating to be tested, vegetation support course, planting.

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

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

After the installation of the sheets/coating to be tested the vegetation substrate is filled in a compacted form to a course depth of (150 ± 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 pieces of *Pyracantha coccinea* shall be planted equally spread over the entire surface (see Fig. 6). 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 tensiometers into the vegetation support course directly on top of the sheet/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. 6).

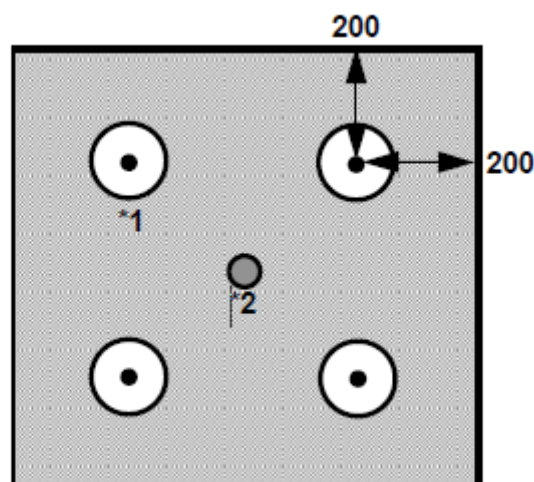


Figure 6: Arrangement of woody plants (*1) and tensiometer (*2) in the vegetation support layer in a 800 x 800 mm container (dimensions in mm)

6.1.1. Laying of root protection membranes, roof and waterproof linings

Cut out parts of the membrane/lining to be tested and lay 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. Execute 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. 7). 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.

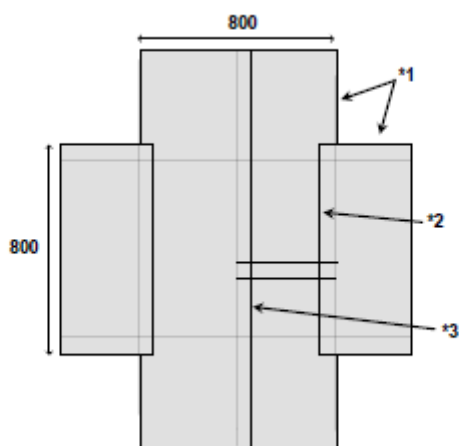


Figure 7: Layout of the seams (*1 = wall-corner seam, *2 = base-corner seam, *3 = T—seam) in the membraneto be tested (dimensions in mm)

6.1.2 Installation of surface coating under investigation — liquid surface treatment

Just like the membrane 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 support course is laid immediately on top of the protective lining.

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 fertilization 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 fertilization 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 repeated (see 2.15).

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

In the area of walkways between the containers side shoots may be pruned if they are an obstacle to using the walkways.

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 under testing appropriate plant protection measures shall be carried out.

7 Evaluations

7.1 Evaluation during the testing

In the 2-year investigation as well as in the 4-year investigation the transparent base of all 8 trial containers shall be examined in 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 has 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, such as e.g. deformations of the leaves or changes of leaf colour, shall be noted separately.

7.2 Evaluation at the end of the test

The client of 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 support course is taken out of all trial containers in order to examine the membrane/surface coating for root and rhizome ingress and/or penetration. According to paragraphs 2.9, 2.10 and 2.12 roots and/or rhizome 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 protection membranes, roof and waterproofing:
 - the surface and
 - the seams
- or 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 per container are found to have penetrated the membrane/coating, the evaluation of ingress/penetration — 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. 8.

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.

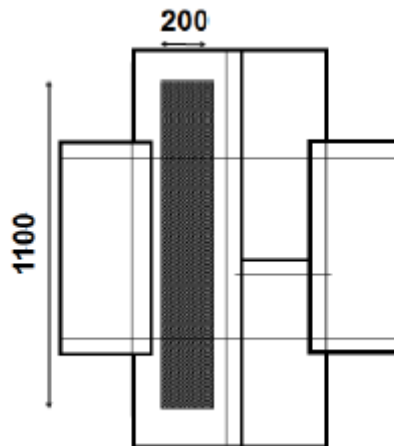


Figure 8: Evaluation section of penetrations into the surface of a membrane/coating undertesting in case of > 50 penetrations/receptacle (dimensions in mm)

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 is to be used only in 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 paragraph 6 (or a note that trial execution has been carried out in compliance with the 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 version of the evaluation regarding the tested membrane according to paragraphs 2.11 und 2.13

Furthermore, the report shall incorporate the following statements:

- “The test report encompasses..... pages and shall be used only in a non-abbreviated version”
- “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 joining 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.

After confirmation by the test institute the period of validity may be extended in intervals of 5 years, but only if:

- no major changes have been made to the investigation principles and rules, and
- the tested product is still in production and available for delivery to the client”
- new retention samples are to be supplied to the testing institute
- the producer makes a legally binding declaration that the membrane / coating, production and joining techniques are identical

Please contact the FLL to be provided with a specimen test report.

9 Responsibilities

The client who commissions the investigation is responsible for:

- procurement and installation of the protective lining (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 creating and installation of the moisture layer and the vegetation support layer (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.

Please contact the FLL to be provided with a specimen contract.