Process for examining the root resistance of membranes and coatings for roof greening

FLL
Forschungsgesellschaft
Landschaftsentwicklung Landschaftsbau e.V.

(Research Society for Landscape Development
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Contents Page

Introduction 3

1. Scope 3

2. Definitions 4

3. Brief description of the process 7

4. Test facilities and materials 7

5. Sampling and manufacturer's data 11

6. Test conditions 11

7. Evaluations 14

8. Test report 15

9. Areas of responsibility 16

Introduction

In order to rule out any vegetation-related structural damage caused by roof greening, a "process for examining the rooting resistance of root protection membranes" was worked out by a work group of the Research Society for Landscape Development and Landscape Construction (FLL) in 1984, geared to the stresses caused to the membrane by plant roots. The process is based essentially on experience and findings gained from many years of experiments with different sealing membranes and different plant species which were carried out at the Institute for Soil Science and Plant Nutrition, FH Weihenstephan, from 1975 to 1980. The FLL process was revised in 1992 and most recently in 1995.

This process is held in high regard by manufacturers, planners and executing firms, as is documented by the large number of examinations already completed and those still ongoing.

In 1993 the FLL decided again to review the process applying up to then with examinations lasting for 4 years once with a view to reducing the duration of experiments to 2 years, but without making any reduction in the intentionally strict standards of the previous tests. After a large number of experiments at the Institute for Soil Science and Plant Nutrition, FH Weihenstephan, agreement was finally reached on these specifications: the 2-year examination will be carried out in a climate-controlled greenhouse, whereby the plant species used are in a growth phase throughout the entire year with corresponding temperature and light conditions. Thus an effective growth period of 24 months is achieved, which is of a duration similar to a 4-year test taking into account the annual resting phase of vegetation lasting for several months under open-air conditions. Both examinations are deemed to be equivalent and are described jointly in the present new version of the process.

In the course of changes in the content of the examination process, there was also a reorganization of the formal design to make the process more easily understandable and to facilitate assessment of the results achieved by the testing institutions.

1. Scope of validity

The process applies for determining the resistance to infiltration and penetration of roots and rhizomes for the test plants used of

- roof protection membranes
- roofing and sealing membranes and
- coatings applied in liquid form

for all forms of roof greening (intensive greening, simple intensive greening, extensive greening).

The process comprises testing of products including the associated jointing techniques. It is thus only admissible for testing of individual membranes and coatings. The examination of a roof sealing system, in other words a roof sealing structure made up of several layers jointed together, is not possible.
For experiment-specific reasons, it can be necessary to install a separate layer under coatings applied in liquid form. This is permitted if the manufacturer states clearly that the root resistance is provided solely by the coating first applied on top.

Lining, in other words a separate layer on the membrane or coating to be examined, is ruled out in all cases.

The results for the examined membrane or coating are not transferable to the infiltration and penetration resistance against plants with strong rhizome growth (e.g. bamboo and Chinese reed species). If such plant species are used, structural measures extending beyond the infiltration and penetration protection found must be taken and special care measures must be provided.

The process does not contain any appraisal of environmental soundness of the products tested.

2. Definitions

The following definitions apply for the application of this process:

2.1 Experimental vessels

Vessels specially fitted out for the examination with minimum dimensions, which are equipped with the membrane or coating to be examined (test vessels) or with a non-woven material (control vessels).

2.2 Moisture layer

The moisture layer consists of coarse-grained mineral material which is arranged beneath the membrane or coating to be tested. It is kept permanently moist and thus permits further growth of roots and rhizomes which penetrate through the membrane or coating down to the transparent vessel base and thus early recognition of penetrations.

2.3 Protective layer

Non-woven material compatible with the membrane or coating material that is placed directly beneath the material to be tested on the moisture layer, in order to achieve a uniform pressure distribution.

2.4 Vegetation carrier layer

Uniform culture substrate (material mix) that is available or can be produced at any time and at all examination locations.
It is structure-stabilized, has a favorable water/air regime and weak basic fertilizing and thus promotes optimal root development of the test plants. The vegetation carrier layer is in direct contact with the membrane to be examined.

2.5 Test plant species

2.5.1 For the 2-year test

- *Pyracantha coccinea* "Orange Charmer", firethorn, a decorative shrub that has root growth suitable for the test all year round under the given greenhouse conditions, and
- *Agropyron repens,* couch grass, a native grass with weak-growing rhizomes, whose settlement on greened roofs can hardly be avoided and which also grows sufficiently throughout the entire year under the test conditions.

2.5.2 For the 4-year test

- *Alnus incana,* gray alder, a wild shrub that shows root growth suitable for the test during the vegetation period under the given open-air conditions and
- *Agropyron repens*, couch grass.

2.6 Adequate growth performance of the test plants

The shrubs (firethorn and alder) in the test vessels must show on average at least 80 % of the average growth performance (height, stem diameter) of the plants in the control vessels throughout the entire experimental period. This makes it possible to record any impairment of the test plants due to plant-harming materials given off by the membrane or coating, if appropriate.

The spread of the couch grass on the substrate surface is rated visually (bonitation, see 2.7). For this the plants in the test vessels must as a minimum have a medium stock density on average throughout the entire duration of the experiment (see 2.7) from the first intermediate assessment onwards.

2.7 Bonitation of the couch grass stock

In the visual assessment figures are allocated to the stock density of the couch grass growth. These are to be divided up as follows:
1 = hardly any couch grass present (about 0-20 % of the area covered)
2 = scant stock (about 20-40 % of the area covered)
3 = medium stock (about 40-60 % of the area covered)
4 = dense stock (about 60-80 % of the area covered)
5 = very dense couch grass stock (about 80-100 % of the area covered)

2.8 Equivalent jointing techniques

It is admissible to combine differing jointing techniques in the test insofar as these are all geared to material-homogeneous seam joints without exception (e.g. swelling sealing - with a solvent that volatilizes - and hot gas sealing). Such seam joints are considered to be equivalent.

By contrast with this combinations of non-bonded joints and joints with bonding compound or of joints with two different bonding compounds are not considered to be equivalent.

2.9 Root infiltration

Roots, which grow into the surface or into the seams of a tested membrane or coating, whereby the underground plant parts actively create cavities and have thus, damaged the membrane or coating.

The following are not to be assessed as root infiltration but are to be listed in the test report:

- Roots which have grown into already existing pores of a membrane or coating (surface or seam or work interruption joint), in other words no damage. In order to be able to assure a clear assessment here it is necessary to observe the corresponding membrane or coating sections under the microscope.
- Roots which have grown into the surface or seam or work interruption joint less than 5 mm on membranes and coatings, which contain radicidal agents (roof inhibitors), since here the root inhibiting effect can only develop after infiltration of the roots. In order to permit such an assessment, such membranes or coatings are to be clearly defined as "containing radicidal agent" by the manufacturer prior to the start of the experiment.
- Roots which have grown into the surface of products composed of several layers (e. g. asphalt membrane with copper belt inlay or PVC membrane with polyester non-woven inlay), if the course which takes over the infiltration and penetration protection is not damaged. In order to allow such an assessment this course must be clearly defined by the manufacturer prior to the start of the experiment.
- Roots that have infiltrated in seam seals (without damaging the seam).

2.10 Root penetration

Roots, which grow through the surface or in the seams of a tested membrane, or coating, which have already used the pores present in the membrane or coating or have actively created cavities.

2.11 Attestation "root resistant"

A membrane or coating is considered to be root resistant if no root infiltration in accordance with section 2.9 and no root penetration in accordance with section 2.10 is ascertained in all test vessels after expiry of the experimental period.
Furthermore, the precondition is that the shrubs used in the test have shown sufficient growth performance in accordance with section 2.6 in the test vessels throughout the duration of the experiment.

2.12 Couch grass rhizomes

Since a distinction is made in evaluation between roots and rhizomes, reliable determination of these underground plant organs is indispensable. The following data can be used for orientation purposes:

The couch grass rhizome spreading in the vegetation layer (underground shoot trailing stems) shows a uniform thickness of approx. 2 mm and slight branching. They are segmented in individual sections, limited by knots, on which inconspicuous leaflets wrapping the stalk and thin roots are arranged. The couch grass rhizomes are hollow between the knots (see figure 1).

By contrast with this, roots of firethorn have a strongly varying thickness and are substantially branched. Moreover they never bear leaves and are not hollow. If the test institute cannot distinguish clearly between the rhizomes and roots, expert advice is to be called in.

Figure 1: Schematic representation of a couch grass rhizome (left) with knots (1), roots (2) and leaves (3) by comparison with a firethorn root (right).

2.13 Assessment of couch grass rhizomes

Couch grass rhizomes, which have infiltrated and penetrated the membrane or coating (surface or seam) are ascertained and listed in the test report, but are not appraised with regard to the root resistance. If no damage is found to the product caused by the rhizomes, however, this is noted expressly in the test report (see 2.13).

2.14 Attestation "rhizome resistant to couch grass"

A membrane or coating is deemed to be resistant to couch grass rhizomes if after expiry of the experimental period - by analogy with root infiltration (see 2.9) and root penetration (see 2.10) - no rhizome infiltration and no rhizome penetration can be ascertained in all the test vessels.

Furthermore, a precondition is that the couch grass has shown sufficient growth performance in the test vessels throughout the course of the experiment (see 2.6).

2.15 Circumstances for premature discontinuation of the test

In the case of evident penetration of roots or rhizomes through the membrane or coating to be tested in the course of evaluations during the test (see 7.1), the party ordering the examination shall be notified. The experiment will be discontinued if the penetration of roots has taken place. In the case of penetrating rhizomes, the tests can be continued in agreement with the party ordering the test.

If more than 25 % of the shrubs fail in the course of the experiment, the experiment is to be started again, i.e. new planting is to be carried out, whereby the vegetation carrier layer is to be replaced by a new mixture. The start of the experiment is to be dated anew.

The same procedure is to be followed if no sufficient growth performance of the test plants is achieved in the course of the experiment (see 2.6).

3. Brief description of the process

The penetration resistance of root protection and roof and sealing membranes or coatings to the roots and rhizomes of the test plant species acting on them is examined in a vessel experiment with standardized conditions.

In the test with a 4-year duration this is carried out under open-air conditions, with alder and couch grass being used as test plants. The 2-year test is carried out in a climate-controlled greenhouse using firethorn and couch grass.

The membrane or coating to be examined, which must have several seams or work interruption joints, is installed in 8 test vessels. A further 3 vessels without membrane or coating are included in the experiment. They serve as a control for the plant growth.

A thin vegetation carrier layer is filled in the vessels treated in this way. The desired, high root pressure is to be produced with dense planting, moderate fertilizing and restrained watering.

At the end of the experiment the vegetation carrier layer is removed and the membrane or coating is examined in the light of root or rhizome infiltration and penetration. Reserve samples of the membrane and coating examined are kept in storage at the test institute.

4. Experimental facilities and materials

4.1 Location for performance

4.1.1 4-year tests

A hall that is equipped with a transparent roof covering but is otherwise open on all sides is to be provided. This creates approximate open-air conditions, but precipitation which could lead to pent-up wetness in the drain-free vessels is kept off.
An unheated greenhouse is also admissible as location provided that it has sufficient ventilation facilities and allows the influence of frost.

4.1.2 2-year tests

A greenhouse is to be provided, equipped with controllable heating and ventilation. The heating is to be set in such a way that the indoor temperature is (18±3)°C during the daytime and (16±3)°C at night. As of an indoor temperature of (22±3)°C the greenhouse is to be ventilated. A sustained indoor temperature > 35 °C is to be avoided.

The natural light conditions in the Central European region secure favorable growth of the test plants throughout the year at the temperatures stated. Shading of the plants in summer or artificial lighting in winter are not necessary.

The area required per vessel (800 x 800 mm) observing the required minimum distance in accordance with section 6.1 is about 1.5 to 2 m² depending on the arrangement of the vessels.

4.2 Experimental vessels

The experimental vessels must have inner dimensions of at least 800 x 800 x 250 mm. Taking into account installation-specific requirements, it may be necessary to large larger test vessels.

The experimental vessels are to be provided with a transparent base (e.g. acrylic glass), so that penetrating roots can be recognized during the experiment without disturbing the vegetation carrier layer. The base is to be blacked out (e.g. with light-impermeable film), in order to prevent the growth of algae in the moisture layer. The transparent vessel base can be expediently constructed as an insert with a 20 mm high upward edge, in order to be able to supply the moisture layer sufficiently with water. The water supply into the moisture layer is carried out via a filling pipe flush with the upward edge of the insert base, directed upwards at an angle (diameter approx. 35 mm), that is fitted on the outside of the vessels (see figure 2).

Figure 2: Structure of the experimental vessels (minimum dimensions, data in mm, *1 = transparent base with upward edge)

8 test vessels are required for each membrane or coating to be examined. In addition - irrespective of the number of membranes or coatings to be tested - 3 control vessels (without membrane or coating) are to be provided for each experimental run.

4.3 Moisture layer

This layer consists of expanded slate or expanded clay (grain size 8 -16 mm), which must be of the quality stated in table 1. So that the test institute need not carry out any analyses of its own, it is expedient only to use products which are subjected to regular quality control as regards the stated standard values, so that the manufacturer can assure the necessary properties.

For the required layer thickness of (50±5) mm (see 6.1) the material requirement is about 32 l per experimental vessel (800 x 800 mm).

4.4 Protective non-woven material

A non-woven material made of synthetic fibers with a weight of approx. 200 g/m² is to be used. The material compatibility of the non-woven with the membrane or layer to be examined must be assured. The material requirement is 0.64 m² per experimental vessel (800 x 800 mm).

4.5 Membrane or coating to be tested

The membrane or coating is to be installed or applied in accordance with section 6.1. On a calculated basis an area of approx. 1.3 m² (without overlap) is to be covered per vessel with minimum dimensions (800 x 800 x 250 mm), minus the 50 mm thick moisture layer.

4.6 Vegetation substrate

The substrate consists of:
- 70 % by volume high-moor peat and
- 30 % by volume expanded clay or expanded slate (grain size 8-16 mm) which

must have the qualities listed in table 1. As described under section 4.3, it is expedient to use only quality-tested products.

The substrate is to be set at a pH-value ($CaCl_2$) between 5.5 and 6.5 by adding carbonated lime (see 4.7).

The basic fertilizing defined in accordance with section 4.8 is mixed in with the vegetation carrier layer homogeneously prior to filling in.

The substrate requirement for a 4-year test with the required layer thickness of (150 ± 50) mm is about 96 l per experimental vessel (800 x 800 mm), and for the 2-year test (taking into account the substrate feed with pot bails of the plant) about 88 l per experimental vessel (800 x 800 mm).

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

Soluble salts (calculated as KCl)	< 0.25 g/100 g
CaO	< 120 mg/100 g
Na_2O	< 15 mg/100 g
Mg	< 15 mg/100 g
Cl	< 10 mg/100 g
F	< 1.2 mg/100 g

4.7 pH-adjustment

Various quantities of carbonated lime may be necessary in the vegetation carrier layer in order to set a desired pH value of 5.5-6.5.
The required quantity can be determined by following the procedure described below:
- draw 5 samples of the well mixed vegetation carrier layer of 1 l each,
- moisten the samples with tap water,
- add carbonated lime to the individual samples in differing quantities (4, 5, 6, 7 or 8 g),
- place the samples in plastic bags, seal and label,
- store the samples in the bags for approx. 3 days at room temperature,
- send the samples in to an examination laboratory working in accordance with the VDLUFA methods and request a pH analysis in $CaCl_2$.

- extrapolate the quantity of lime that leads to the desired pH value in a 1 l sample to the overall volume of the vegetation carrier layer.

4.8 Fertilizer

A multi-nutrient fertilizer with approx. 15% N, 10% P_2O_5, 15% K_2O, 2% MgO and less than 0.5% Cl as well as trace nutrient fertilizer with iron (Fe), copper (Cu), molybdenum (Mo), manganese (Mn), boron (B) and zinc (Zn) is to be provided as basic fertilizer. 30 mg multi-nutrient fertilizer is applied per vessel (800 x 800 mm). The trace nutrient fertilizer is used in the quantity recommended by the manufacturer for substrates.

In the case of subsequent fertilizing a slow acting, coated multi-nutrient fertilizer with approx. 15 % N, 10 % P_2O_5, 15 % K_2O and an active period of 6-8 months is to be scattered. The fertilizer requirement is approx. 30 g/vessel (800 x 800 mm) per application.

4.9 Tensiometer

A tensiometer with a measuring range of 0 to -600 hPa is to be used to monitor the irrigation of the vegetation carrier layer.

4.10 Experimental plants

In the case of a 4-year test the following 2 species are to be used as experimental plants in the qualities stated:
- *Alnus incana* - gray alder, 2-year bedded seedling, height 60-100 cm and
- *Agropyron repens* - couch grass, seed

For the 2-year test the following 2 species are to be used as experimental plants in the qualities stated:
- *Pyracantha coccinea* "Orange Charmer" - firethorn in 2-liter container, height 60-80 cm and
- *Agropyron repens* - couch grass, seed

For each experimental vessel of 800 x 800 mm 4 shrubs (alder, firethorn) and 2 g couch grass seed are to be provided. On an arithmetical basis this thus results in a plant density of 6.25 shrubs/m² and 3.13 g seed/m². If larger experimental vessels are used, the above plant density is to be achieved as a minimum by increasing the number of plants and seed.

If the shrubs are bought in, care should be taken to ensure that the plant quality if uniform.

4.11 Watering water

The watering water must have the minimum quality set out in table 2.
Enquiries should be made of the local waterworks regarding the water quality.

If one of the values stated in table 2 is exceeded, the watering water should be blended appropriately with completely desalinated water or with rainwater.

Table 2: Minimum quality of watering water

Conductivity	< 1000 µS/cm
Total earth alkalis	< 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 data

The test institute must take a reserve sample of the membrane or coating before and after the examination. The piece drawn as sample must contain at least one seam per jointing technique used or one work interruption joint and have an area of at least 0.5 m². The reserve sample is to be stored in dark and dry conditions at temperatures above 5 ° C and below 25 °C at the test institute.

The storage period must correspond as a minimum to the period of validity of the test report (see 8).

Material incompatibilities are to be observed during storage.

In order to be able to identify the tested product clearly, the following data must be requested from the manufacturer at the start of the examination: product name, scope of application, material designation, material standards, thickness (without lining), dressing/structure, form of delivery, manufacturing technique, test certificates, year of manufacturer, installation technique at location of examination (overlap, jointing techniques applied, jointing agents, nature of seam sealing, cover strips over seams, separate corner and angle connections), addition of biocides (e.g. root inhibitors) with details of the concentration.

As a supplement to this a product data sheet of the membrane or coating to be examined is to be deposited at the test institute.

In addition, in the case of products, which are made up of several layers (e.g. asphalt membrane with copper belt inlay or PVC membrane with polyester non-woven inlay), the manufacturer shall specify clearly at the start of the experiment which layer assumes the infiltration and penetration protection.

6 Test conditions

6.1 Preparation and installation of the 8 test vessels

The following layer structure is planned in the vessels (from bottom to top): moisture layer, protective layer, membrane or coating to be examined, vegetation carrier layer, planting.

The moisture layer is applied in a thickness of (5±5) mm as bottom layer directly above the transparent vessel base.

The protective layer is cut in accordance with the basic area of the vessel and placed directly on the moisture layer.

The membrane or coating to be tested is installed on the protective layer as described in section 6.1.1 and 6.1.2.

After installation of the membrane or coating to be examined, the vegetation substrate is filled in firmly in a layer thickness of (150±10) mm. For vessels of 800 x 800 mm this corresponds to a substrate volume of 96 l (4-year test) or 88 l (2-year test) (see 4.6).

For the 4-year test 4 *Alnus incana* (gray alder) and for the 2-year test 4 *Pyracantha coccinea* (firethorn) are to be planted, uniformly distributed over the area available (in each experimental vessel of 800 x 800 mm) (see figure 3). In addition, for both tests, 2 g seed of *Agropyron repens* (couch grass) is to be sown uniformly on the vegetation carrier layer per vessel.

In the event that larger experimental vessels are used, the number of plants must be increased in such a way that as a minimum the same plant density is achieved (see 4.10).

The ceramic cell of the tensiometer must be placed in the vegetation carrier layer directly above the membrane or coating, so that measurements can be taken in the bottom area of the root chamber. The tensiometer is to be arranged at an equal distance from the plants (see figure 3).

It is expedient to place the vessels on racks so that rooting checks can be carried out at periodic intervals. A minimum distance of 0.4 m is to be ensured between the vessels on all sides. The vessels are to be arranged in accordance with a random distribution method.

Figure 3: Arrangement of the shrubs (*1) and the tensiometer (*2) in the vegetation carrier layer in a vessel of 800 x 800 mm (dimensions in mm).

6.1.1 Installation of root protection, roofing and sealing membranes to be tested

Parts of the membrane to be examined are cut out and installed and joined in sound workmanlike fashion in the vessels at the examination location under the responsibility of the party ordering the examination. Here 4 wall-corner seams, 2 base-corner seams and 1 T-seam running through the middle are to be executed (see figure 4). It is admissible to apply different jointing techniques, provided that these are equivalent (see 2.8).

The membrane is to be drawn up the walls to the edge of the vessel.

6.1.2 Installation of liquid-application coatings to be examined

The liquid application coatings are also to be installed in the vessels in sound workmanlike fashion at the examination location under the responsibility of the party ordering the examination. The coating must be carried out in 2 work steps, whereby a work interruption joint is to be arranged in the middle of the vessel from side to side. The time interval between the two work-steps must be at least 24 hours. The coating is to be drawn up the walls at the sides up to the edge of the vessel.

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

6.2 Preparation and installation of the 3 control vessels

The preparation and installation of the control vessels shall be carried out as described under section 6.1, but no membrane or coating to be tested is installed. This means that the protective layer connects directly with the vegetation carrier layer.

6.3 Care of the plants during the growth period

The substrate moisture is to be set according to the plant needs by watering the vegetation carrier layer from above. The moisture (suction tension) is to be checked with the aid of the tensiometer.
In order to ensure good germination of the seed and growing of the shrubs, watering is carried out in the first 8 weeks after greening as soon as the suction tension falls below a value of -100 hPa. In the further course of the experiment water is only added when the suction tension drops to a value between -300 and -400 hPa. The water doses are to be dimensioned in such a way that a suction tension in the substrate of almost 0 hPa is achieved.
Care should be taken to ensure that the entire vegetation carrier layer (including the edge areas) is moistened uniformly. A sustained water surplus (pent-up wet) in the bottom area of the vegetation carrier layer is to be avoided. In order to avoid damage to the tensiometer, this is to be removed when the first frost period starts in the case of the 4-year tests. Watering during vegetation rest periods is to be adapted to the very low water requirement of the plants. After the last frost in spring the tensiometers are to be replaced in the same position. Watering is then to be continued as described above.

The moisture layer is to be kept permanently moist by watering or via the filling pipe at the vessel.

Post-fertilizing is carried out at six-monthly intervals in the 2-year test with a fertilizer and an application rate as described in section 4.8. The first application is made 3 months after planting. In the case of the 4-year test, post-fertilization is carried out once a year in March or April.

Any foreign growths, which may occur, and plant parts, which have died off on the surface of the vegetation carrier layer, are to be removed.

Shrubs (firethorn or alder) which die off are to be replaced. In order not to disturb the developing roots of the remaining plants substantially, however, this is only to be done

during the first 3 months of a 2-year test or during the first 6 months of a 4-year test. If more than 25 % of the timbers fail in the course of the experiment, the experiment shall be started anew (see 2.15).

Shortening of the height of the shrubs (firethorn or alder) is not admissible. Side shoots forming an obstacle in the aisles between the vessels can be shortened.
Gaps in the couch grass stock (< 40 % of the area covered) is to be improved by re-sowing up to twice in the first 3 months (2-year test) or 6 months (4-year test).

In order to avoid lodging of the couch grass, the blades are to be shortened to a length of approx. 5 cm when they reach a growth height of about 20 cm.

In the case of heavy test infestation of the plants or occurrence of plant diseases endangering the stock, suitable plant protection measures are to be carried out.

7. Evaluations

7.1 Evaluation during the experiment

During the 2-year test and the 4-year test the transparent vessel base of all 8 test vessels is to be examined from below for visible roots and rhizomes (in other words for penetration) at intervals of six months.

In the case of evident penetration in the test vessels, the party ordering the examination shall be notified. The experiment can be broken off (see 2.15).

Apart from this no intermediate results may be passed on in written form in the course of the experiment.
At six-monthly intervals (2-year test) or annually (4-year test) the growthiness of the timbers (firethorn or alder) in all test and control vessels is to be recorded by surveying the height and stem diameter at a height of 20 cm. In the same way the spread of couch grass at the substrate surface is to be measured by bonitation (see

2.7). The average growth performance of the plants in the test vessels is to be determined and compared with the result for the control vessels. If no sufficient growth performance in accordance with section 2.6 is achieved, the experiment shall be started anew (see 2.15).

Any plant damage occurring such as e.g. leaf deformation or leaf discoloring shall be recorded separately.

7.2 Evaluations at the end of the experiment

The time of the proposed final evaluation is to be reported to the party ordering the examination in order to allow participation.

The growth performance of the plants is to be recorded finally as set out in section 7.1.

At the end of the experiment the vegetation carrier layer is to be taken from all test vessels and the membrane or coating is to be examined with regard to roots or

rhizomes, which have infiltrated and penetrated. In accordance with sections 2.9, 2.10 and 2.12, roots or rhizomes which have infiltrated and penetrated the membrane or coating tested are to be recorded in absolute figures.

This is to be carried out separately for the following areas:

- in the case of root protection, roofing and sealing membranes:
  - the surface
  - the seams
- in the case of coatings applied in liquid form:
  - the surface and if appropriate
  - the work interruption joint, if this can be recognized.

If more than 50 roots or rhizomes which have infiltrated the surface of a membrane or coating are ascertained per vessel, in deviation from the above method the evaluation of these infiltrations is only to be carried out on a part of the material examined. The evaluation must cover an area of at least 0.2 m² (about 20 % of the membrane or coating covered with substrate) and be carried out in the area shown in figure 5.

In the case of infiltration of roots or rhizomes in the area of overlap of seams, the maximum depth of infiltration is to be recorded.

Roots or rhizomes, which have infiltrated and penetrated, are to be documented by photographing to show examples.

Reserve samples are to be drawn from the membrane or coating examined which roughly reflect the results of the examination. The samples are to be stored in accordance with section 5.

Section 5: Area of evaluation of infiltrations in the area of an examined membrane or coating at > 50 infiltrations/vessel (dimensions in mm).

8. Test report

No intermediate results may be reported in writing during the test.
After completion of the experiment a complete test report in duplicate (1 copy each for the test institute and the party ordering the examination) shall be drawn up by the relevant test institution, but only if the membrane or coating has proved to be root resistant in accordance with section 2.11. The report may only be used in non-abridged form. It must contain the following data:

- manufacturer's data on the membrane examined in agreement with section 5,
- detailed data on the preparation of the test vessels in accordance with section 6 (or a reference to the fact that the execution of the test was in line with the specifications of the FLL guideline, whereby the guideline taken as a basis shall be annexed to the report),
- all results of the evaluations in agreement with section 7, and
- a summary assessment of the membrane examined in accordance with section 2.11.

Furthermore the report must contain the following formulations:

- "The test report comprises … pages and may only be used in non-abridged form."

- "The examination results are bound to the characteristic data and material properties of the tested membrane or coating listed in the test report in accordance with the requirements and the equivalent jointing techniques used in the test."
- "Reserve samples of the membrane or coating are stored at the test institute."
- "The test report was drawn up on … and has a basic period of validity of 10 years. By confirmation of the test institute the period of validity can be extended for periods of 5 years, however only if
  - the test bases are not modified in essential points and
  - the tested product still corresponds to the current delivery program of the applicant.
  "

A specimen test report can be requested from the FLL.

9. Areas of responsibility

The party ordering the examination is responsible for:
- procuring and installing the protective layer (see 2.3 and 6.1) and the membrane or coating to be tested (see 6.1),
- submitting a material sample (see 5) and
- data regarding the tested membrane or coating (see 5).

The test institute shall provide the following inputs:
- provision of a suitable area for performance of the experiment (see 4.1),
- drawing and storage of a material sample (see 5),
- procuring and compiling and installing the moisture layer and the vegetation carrier layer (see 4.3, 4.6, 6.1 and 6.2),
- procuring and installing the tensiometers (see 4.9, 6.1 and 6.2),
- procuring the experimental plants and the seed and greening the vessels (see 4.10, 6.1 and 6.2)
- care of the plants during the growth period (see 6.3).
- performance of the evaluation (see 7) and
- preparation of the test report (see 8).

The test vessels (see 4.2) can be procured by the party ordering the examination or by the test institute. The distribution of responsibilities is to be recorded in a contract between the party ordering the examination and the test institute. The assumption of costs incurred in the course of the test by the party ordering the examination shall also be governed in this contract.