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KEMPER SYSTEM GmbH & Co. KG
Holländische Straße 32 - 36
D – 34246 Vellmar

December 01, 2005

Test Report

about the investigation of root resistance of membranes and coatings for green roofs according the FLL testing procedure (2002)

Product Name:

KEMPEROL 2K-PUR

Client:

KEMPER SYSTEM GmbH & Co. KG

Holländische Straße 32 - 36

D – 34246 Vellmar

Editor:

Lehrgebiet „Vegetationstechnik“

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Von-Lade-Straße 1

65366 Geisenheim am Rhein/Rhg.

The Report contains 27 pages and my only be used unabridged.

The Report is valid for 10 years duration.

Date of Report: December 1st, 2005

Indications of the company **KEMPER SYSTEM GmbH & Co. KG** dated 15.11.2005 to characteristic data and material properties of the examined waterproofing membrane „**KEMPEROL 2K-PUR**“

- **Product name:** KEMPEROL 2K-PUR membrane system
- **Field of application:** As waterproofing in combination with KEMPEROL fleece for details, for the fabrication of fittings and as waterproofing surface, like balconies, terraces, flat roofs and in the field of green roofs.
- **Material basis:** two-component polyurethane resin according ETAG-005, Part 1 and 6
- **Thickness:** 2 mm
- **Equipment / Build-up:** KEMPEROL 2K-PUR with KEMPEROL fleece
- **Kind of Delivery:** KEMPEROL 2K-PUR in 5 and 12.5 kg working packs. KEMPEROL fleece in rolls (Length 50 m, Width 105 / 70 / 52.5 / 35 / 26.2 / 21 / 10.5 cm).
- **Manufacturing Technology:** Mix KEMPEROL 2K-PUR thoroughly. Apply app. 2/3 KEMPEROL 2K-PUR to the surface and roll it out evenly. Roll in KEMPEROL fleece crease-fee with app. 5 cm lapping over. Roll on KEMPEROL fleece bubble-free and saturate with 1/3 KEMPEROL 2K-PUR wet in wet.
  Additional information (for example regarding details and fittings) can be taken from the manufacturer's Technical Information.
- **Material Standards:** ETAG 005, Version March 2000: Guideline for the European Technical Approval for liquid applied Waterproofing Membranes, revised March 2004, Part 1 „General Regulations“ and Part 6 „Special Regulations for liquid applied Waterproofing Membranes based on Polyurethane”
- **Test Certificates:** ETA 03/0044 dated 05.11.2003 issued by Deutsches Institut für Bautechnik
- **Manufacturing Year:** 2003
- **Root resistant Layer:** KEMPEROL 2K-PUR membrane
- **Installation Technology at the Site of Investigation, Partition of Seams, Overlapping**
  a) See Manufacturing Technology
  b) Fabric Customization: 2 pcs 80 x 35 cm² / 1 pc 140 x 52,5 cm² / 1 pc 35 x 70 cm² / 1pc 35 x 75 cm² placed according FLL-Green roof Guidelines
  c) Overlapping 5 respectively 7,5 cm placed according FLL-Green roof Guidelines
  d) Corners implemented according the Technical Information of Manufacturer („Fabric Customization“ and others)
- **Joining Technique:** See „Manufacturing Technology”
- **Declaration regarding plant damaging substances contained in the membrane and regarding the observation of laws and regulations for plant protection and sustainability.**
  The manufacturer of the tested membrane KEMPEROL 2K-PUR declares hereby that the way things are the waterproofing system does not contain any components which may damage plants or the environment if used as intended and applied according instructions. Also the membrane has been manufactured with national and State laws and regulations for plant protection and sustainability in mind.

1 Problem Definition

A root barrier must prevent durably damages of the waterproofing by penetrating or intersecting plant parts. Therefore, a high ruggedness is to be demanded from root barriers in respect to stress caused by plant roots and –rhizomes (underground rungs).

In the accomplished examination the membrane „KEMPEROL 2K-PUR"of KEMPER SYSTEM GmbH & Co. KG, 34242 Vellmar, was tested on root and rhizome resistance. The installation in the test vessel was single ply.

2 Test Model and Procedure

The examination took place according to the "Procedure for investigating resistance to root penetration at green roof sites"with 2 year duration (FLL, 2002). This test had been developed by the Institute for Pedology and Plant Nutrition, University of Applied Science, Weihenstephan on behalf of the FLL. Respectively the latest draft at the beginning of the test has been considered. Differences between the requirements of the draft and the final version have been acknowledged.

Testing period was from Nov. 2003 until Nov. 2005. Installation took place on 18. Nov. 2003, disassembly on 18. Nov. 2005. It comprised 8 containers equipped with the membrane which had to be tested, as well as 3 containers with a protection/separation fabric (200g/m^2) as control. The membrane was fitted and installed into the vessels by KEMPER SYSTEM GmbH & Co. KG at the research institute "Vegetation Technique" of the University of Applied Science, Wiesbaden at their Geisenheim facilities. The preparation of the protection/separation fabric and their installation into the control vessels were accomplished by members of the research team. The containers were placed in a heat able green house.

Pyracantha coccinea 'Orange Charmer' and *Agropyron repens* (Couch Grass) were used as test plants. Under the adjusted conditions they show good growth even during winter. Coach Grass, a native grass, develops rhizomes (subterranean shoot part extensions), which are able to damage membranes like roots.

The complete description of the procedure is specified in Appendix 3 of this report. Before and after the examination retaining samples of the membrane were taken and stored at the testing institute.

3 Indications of the Manufacturer to the tested Waterproofing

The examination of the root resistance depends on the characteristic data and material properties of the examined waterproofing and the welding and manufacturing technology. Respective information about "KEMPEROL 2K-PUR" provided by the manufacturer is listed on page 2 of this report.

4 Results

4.1 Plant Development

The planted shrubs, as well as the sowed Couch Grass developed well during the period of examination. Data to vitality and growing performance of the test plants are summarized in Appendix 2. Differences regarding plant development between the control and the testing vessels could not be recognized.

4.2 Root Ingress and Root Penetrations (see Appendix 1 for images)

4.2.1 During the Test

Already with the first planting examination of the control vessels in May 2004 numerous roots could be recognized on the transparent container bottom. Hence the protection/separation fabric (200 g/m²) has been already penetrated by the test plants within 6 month, what points to considerable root pressure of the plants used.
Whereas the tested membrane didn't show any recognizable penetrations at the vessel bottom during the whole testing period. Penetrated Coach Grass rhizomes growing upward in the overlapping areas of vertical seams also couldn't be detected.

4.2.2 At the End of the Test

After emptying the control and the test vessels at the end of the test (18. Nov. 2005)

an exact examination of the fabrics and of the tested waterproofing took place regarding ingress and penetrations of roots and rhizomes.

4.2.2.1 Control Vessels with Protection/Separation Fabric

The protection/separation fabric (200 g/m²) of the control vessels showed multiple cases of ingress and penetration of roots and rhizomes. Therefore the evaluation was limited to counting exemplarily the number of penetrated roots and rhizomes in a section of approx. 20x20 cm, which corresponds to nearly 6% of the entire surface of the protection/separation fabric. In this section *Pyracantha coccinea* 'Orange Charmer' and *Agropyron repens* (Couch Grass) showed between 6 and 13 penetrated roots and between 2 and 4 penetrated rhizomes (s. Table 1) in the 3 vessels.

Tab. 1: Number of penetrated roots and rhizomes on the protection/separation fabric (200 g/m²) in the control vessels after 2 years (exemplarily counted at a section of app. 20x20 cm))

Control vessel	Number of penetrated roots	Number of penetrated rhizomes
N°. 1	8	2
N°. 2	6	4
N°. 3	13	3

4.2.2.2 Test Vessels with membrane „KEMPEROL 2K-PUR"

After 2 years the tested waterproofing „KEMPEROL 2K-PUR"didn't show any root or rhizome ingress or penetrations neither in the area nor at the seams (s. Tab. 2).

Tab. 2: Number of roots and rhizomes intruding ore penetrating the membrane „KEMPEROL 2K-PUR" "in the control vessels after 2 years

Test vessel	Penetrated roots (W) and rhizomes (R)		Ingress by roots (W) and rhizomes (R)	
	in the area	into seams	in the area	into seams
N°. 1	none	none	none	none
N°. 2	none	none	none	none
N°. 3	none	none	none	none
N°. 4	none	none	none	none
N°. 5	none	none	none	none
N°. 6	none	none	none	none
N°. 7	none	none	none	none
N°. 8	none	none	none	none

5 Conclusions

After 2 years the tested membrane „KEMPEROL 2K-PUR“ didn't show any root or rhizome ingress or penetrations neither in the area nor at the seams in all of the 8 test vessels.

The membrane „KEMPEROL 2K-PUR“ of KEMPER SYSTEM GmbH & Co. KG therefore is classified as root resistant and rhizome resistant to Couch Grass according the FLL procedure.

The examination of root resistance is linked to the indicated data and material properties of the tested waterproofing listed on page 2 of this report and to the used welding and manufacturing technology.

Retained samples of the tested membrane are kept at the specialist field “Vegetation Technology” at the University of Applied Science Wiesbaden.

The test certificate has been issued December 2005 and is valid for ten years.

The report contains 27 pages and may only be used in its unabridged version.

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Hereby I declare that the present translation complies with the wording of the “Test Report about the investigation of root resistance of membranes and coatings for green roofs according the FLL testing procedure (1999), Product Name: „KEMPEROL 2K-PUR“of the Company “KEMPER SYSTEM GmbH & Co. KG“ dated Dec 1st, 2005

Geisenheim, June 25, 2007

Prof. Dr.-Ing. Stephan Roth-Kleyer

Field of Science „Vegetation Technique“

University of Applied Sciences, Wiesbaden

Appendix 1

Pictures of the tested membrane **„KEMPEROL 2K-PUR" (Nov. 2005)**

Image 1: Top of membrane without root ingress

Image 2: Bottom side without root ingress

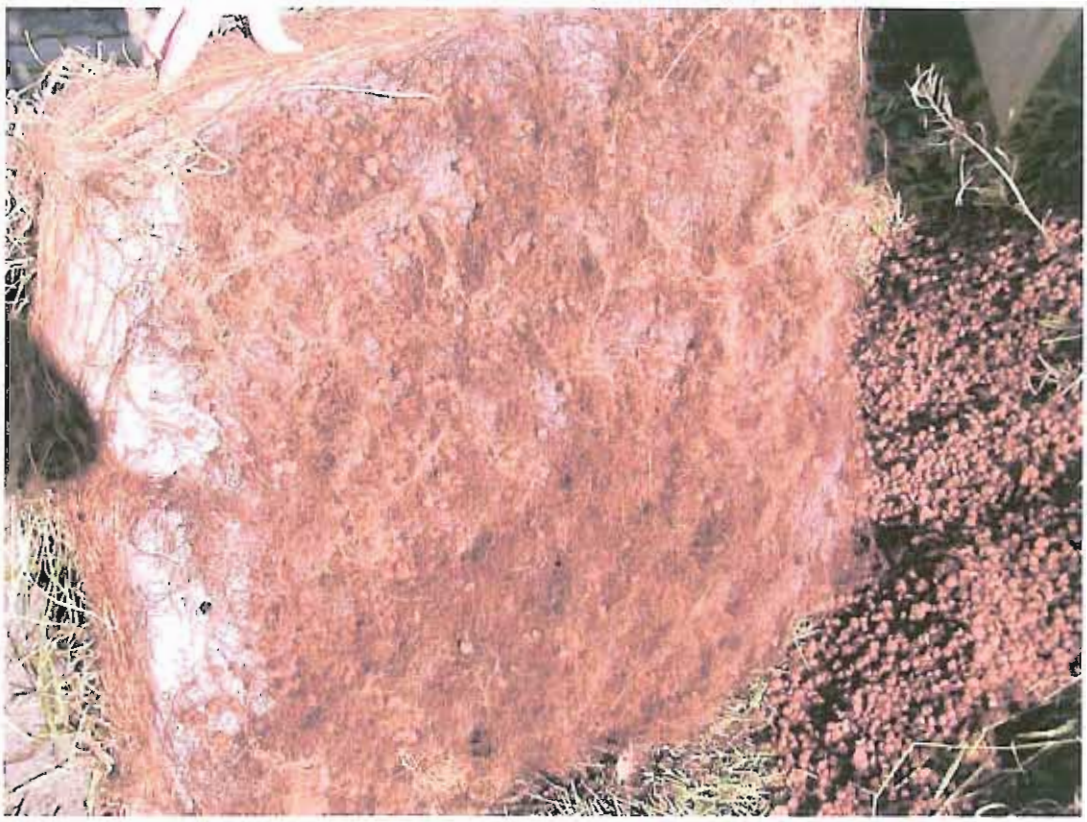

Image 3:

Protection/separation fabric (200 g/m²) of the control vessel well penetrated by roots

Appendix 2

Plant Development Data

Tab. 1: Vitality of Planting

Evaluation accomplished in	*Pyracantha coccinea* 'Orange Charmer'	*Agropyron repens* (Couch Grass)
May 2004	well growing	lush growth
November 2004	well growing, pruning to app. 150 cm height in Nov. 2004	lush growth, pruning to app. 10 cm height
May 2005	well growing	well growing
November 2005	well growing	well growing

Differences regarding plant development between the control vessel with protection/separation fabric (200 g/m²) and the testing vessels with membrane „KEMPEROL 2K-PUR"could not be recognized.

Tab. 2: Height and trunk diameter of *Pyracantha coccinea* in the control vessels with protection/separation fabric (200 g/m²)

Vessel N°.	Shrub N°.	May 2004		November 2004		May 2005		November 2005	
		∅ cm[1)]	Height cm	∅ cm[1)]	Height cm	∅ cm[1)]	Height cm	∅ cm[1)]	Height cm
K 1	1	1.0	165	1.1	175	1.2	200	1.4	190
	2	1.0	170	1.2	180	1.3	210	1.4	185
	3	0.9	1605	1.2	175	1.3	200	1.4	180
	4	1.0	165	1.2	175	1.3	205	1.5	185
K 2	1	0.9	170	1.0	190	1.2	210	1.3	180
	2	1.1	180	1.2	195	1.3	215	1.5	185
	3	1.0	175	1.1	190	1.3	215	1.4	180
	4	1.1	180	1.2	190	1.4	210	1.5	180
K 3	1	1.0	180	1.1	195	1.3	220	1.4	185
	2	1.1	180	1.2	195	1.3	210	1.4	180
	3	1.1	175	1.3	190	1.4	205	1.5	180
	4	1.0	180	1.2	195	1.3	215	1.5	175

[1)] Trunk diameter, measured 20 cm above the surface of the growing medium

Tab. 3: Coverage[1)] of *Agropyron repens* (Couch Grass) in the test vessels with „KEMPEROL 2K-PUR"and the control vessels (K1 – K3)

	May 2004	November 2004	May 2005	November 2005
P 1	3	4	4	4
P 2	3	4	4	3-4
P 3	3	4	4	4
P 4	3	4	4	4
P 5	3	4	4	4
P 6	3	4	4	3-4
P 7	3	4	4	4
P 8	3	4	4	3-4
K 1	3	4	4	4
K 2	3	4	4	3-4
K 3	3	4	4	4

1) The coverage of *Agropyron repens* has been evaluated according the following scheme:

1: almost no *Agropyron repens*	(app. 0 – 20% coverage)
2: sparse stock	(app. 20 – 40% coverage)
3: medium stock	(app. 40 – 60% coverage)
4: dense stock	(app. 60 – 80% coverage)
5: very dense stock	(app. 80 – 100% coverage)

Tab. 4: Height and trunk diameter of *Pyracantha coccinea* in the test vessels (P 1 - P 8) with membrane „KEMPEROL 2K-PUR“

Vessel N°.	Shrub N°.	May 2004		November 2004		May 2005		November 2005	
		∅ cm[1)]	Height cm	∅ cm[1)]	Heigh cm	∅ cm[1)]	Heigh cm	∅ cm[1)]	Heigh cm
P 1	1	1,1	180	1,2	195	1,3	210	1,5	180
	2	1,1	180	1,2	195	1,3	210	1,4	180
	3	1,0	170	1,1	190	1,2	210	1,3	175
	4	1,0	180	1,1	200	1,2	215	1,3	180
P 2	1	0,9	170	1,1	185	1,2	205	1,3	175
	2	1,1	175	1,2	190	1,3	205	1,4	165
	3	1,2	180	1,3	195	1,4	210	1,5	175
	4	1,1	175	1,2	185	1,3	200	1,4	180
P 3	1	1,0	165	1,1	180	1,2	195	1,3	170
	2	1,1	155	1,2	175	1,3	190	1,4	165
	3	1,2	180	1,3	190	1,4	205	1,5	175
	4	1,0	175	1,1	185	1,2	205	1,4	180
P 4	1	0,9	165	1,0	180	1,2	195	1,3	170
	2	1,1	170	1,2	185	1,3	195	1,4	180
	3	1,2	170	1,3	190	1,4	215	1,5	180
	4	1,1	170	1,2	185	1,3	210	1,4	180
P 5	1	1,1	165	1,2	180	1,3	205	1,5	175
	2	1,0	160	1,1	170	1,2	190	1,3	170
	3	1,1	170	1,2	190	1,3	210	1,4	185
	4	1,2	170	1,4	195	1,5	205	1,6	180
P 6	1	1,0	175	1,1	190	1,3	210	1,4	175
	2	1,1	180	1,2	205	1,3	220	1,4	185
	3	1,1	175	1,2	190	1,3	210	1,4	180
	4	1,1	175	1,3	190	1,4	210	1,5	190
P 7	1	1,2	175	1,3	190	1,4	205	1,5	175
	2	1,0	170	1,2	195	1,3	210	1,4	175
	3	1,1	170	1,3	190	1,4	205	1,5	170
	4	1,0	175	1,2	185	1,3	205	1,4	170
P 8	1	1,1	175	1,2	195	1,3	215	1,4	175
	2	1,1	170	1,2	185	1,3	205	1,4	165
	3	1,0	170	1,1	185	1,2	205	1,3	170
	4	1,1	175	1,2	195	1,3	210	1,4	175

[1)] Trunk diameter, measured 20 cm above the surface of the growing medium

Procedure for investigating resistance to root penetration at green-roof sites[3]

1999 edition
with editorial changes dated January 2002

Introduction

In order to exclude vegetation-dependant structural damage due to roof-greening, in 1984 a "Procedure for investigating resistance to root penetration" was elaborated by a working group team of The Landscaping and Landscape Development 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 damp-proof sheets and various plant varieties. All tests were executed between 1975 and 1980 at the Institute for Pedology and Plant Nutrition, Technical College (FH).

The FLL procedure was revised in 1992 and, for the last time so far, in 1995.

The procedure is highly acknowledged among manufacturer, 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 with a test period of 4 years with the aim to reduce the test period to 2 years without watering down the desired particularly strict standards of the current tests.

After a series of tests at the Institute for Pedology and Plant Nutrition, Technical College Weihenstephan agreement was reached regarding the following requirements: the 2-year-test takes place in a climate-controlled greenhouse in which the plant varieties put to the test will find a test climate with temperature and light conditions which allow them to grow over the entire year. Thus, an effective growth period of 24 months can be achieved, a similar duration as for the 4-year test, when taking the yearly, several-months lasting dormant phase of vegetation in outdoor conditions into account. Both tests are considered to be equal and have been described in the present new edition of the procedure.

In the course of changes regarding its content this edition has also been subject to editorial changes in format in order to facilitate comprehension and to make it easier for the testing institutions to evaluate the test results obtained.

[3] FLL Work Party "Roof-Greening", team "Root-penetration barrier": Prof. Dr. P. Fischer, Freising–Weihenstephan (Chairman); Dipl.–Ing. R. Bohlen, Ladbergen; R. Klein, Wächtersbach–Neudorf; Prof. Dr. H.–J. Liesecke, Hanover; Prof. G. Lösken, Hannover; Dipl.–Ing. P. Siegert, Tornesch; Dipl.–Ing. W. Tebart, München; Dipl.–Ing. R. Walter, Stuttgart

1 Area of validity

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

- root protection barrier sheeting
- roof and damp-proof lining sheets, and
- liquid surface treatment materials

for all types of roof-greening (intensive greening, simple intensive greening, 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 sheeting and/or surface coating. No examination of an entire roof protection system, i.e. of a protection course consisting of several layers for roof protection purposes, can be effected.

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 sheeting and/or coating to be tested, has to be excluded.

The findings for any sheeting 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 varieties). When using these types of plants on top of a regular root penetration barrier additional structural measures have to be taken and special care activities to be provided.

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

2 Definitions

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

2.1 Trial containers

Containers which have been specially equipped for the examination with minimum dimensions. The containers are equipped with the sheeting or coating to be tested (trial containers) and respectively with a nonwoven fabric (control container).

2.2 Moisture course

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

2.3 Protective course

Nonwoven fabric which is compatible (material) with the sheeting/coating and which is laid directly underneath the material to be tested onto the moisture course in order to reach an equal distribution of compression.

2.4 Vegetation support course

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 stabilised and shall offer good water and air management properties. It shall be given light basic fertilisation and therefore favours an optimum root development of the test plants. The vegetation support course is in direct contact with the sheeting to be tested.

2.5 Test plant varieties

2.5.1 For the 2-year test

- *Pyracantha coccinea* 'Orange Charmer', ornamental coppice 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 For the 4-year test

- *Alnus incana*, grey alder, a wild coppice 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 coppices ('Orange Charmer' 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. Hereby, if necessary, any impairment which may have a harmful effect onto the test plants and which may be caused by any substance emit by the sheeting and/or surface coating harming the plants can be detected.

The spreading of the couch grass at the substrate surface will be evaluated visually (in a valuated way, see 2.7). Hereby, the plants in the trial containers have to show at least a medium stock density (see 7.2).

2.7 Valuation of the couch grass stock

For the visual valuation of the stock density of the couch grass growth 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 stock	(about	20 – 40	% of the surface covered)
3 = medium stock	(about	40 – 60	% of the surface covered)
4 = dense stock	(about	60 – 80	% of the surface covered)
5 = very dense couch grass stock	(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 in the surface or in the seams of a tested sheeting and/or surface coating (root ingress), where subterranean plant parts have actively created cavities and have thus damaged the sheeting and/or coating.

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

- roots which have already grown into a sheeting or coating (surface or seam and/or work interruption seam (i.e. no damage). In order to ensure a clear valuation the sheeting 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 ≤ 5 mm on sheeting or coatings, which contain radicide substances (root protecting agents), since here any root banning effect can only act upon penetration of the root into the sheeting/coating. In order to ensure a clear valuation such sheeting/coatings have to be clearly coded as "radicide-containing" by the manufacturer before the investigation is carried out
- roots which have grown into the surface made of products which are composed of several layers (e.g. bituminous sheeting with copper band inlays or PVC sheeting with polyester nonwoven fabric inlays) if the layer taking over the function of an ingress and penetration barrier has not been damaged. In order to ensure a clear valuation 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 a tested sheeting and/or coating. These roots have used pores present in the sheeting or coating and have actively created cavities.

2.11 Certificate "root-resistance proofed"

A sheeting and/or coating is considered to be "root-resistance proofed" if, upon termination of the test phase, in no trial container any root penetration according to paragraph 2.9 and no root penetration according to paragraph 2.10 was found. Furthermore, one of the preconditions is that all coppices 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 expanding in the vegetation support course (subterranean shoot part extensions) show a regular thickness of ca. 2 mm and few ramifications. 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. 1)
- in contrast to this phenomenon roots of the 'Orange Charmer' vary in thickness and show multiple ramifications. Leaves do never form, and they are not hollow.

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

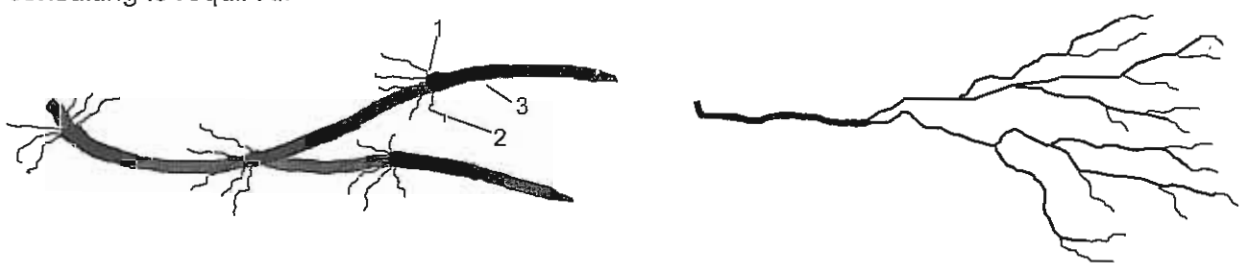

Fig. 1: Schematic representation of the couch grass rhizome (left) with knots (1), roots (2) and leaves (3) as opposed to an 'Orange Charmer' root (right)

2.13 Evaluation of couch grass rhizomes

Couch grass rhizome root ingress and penetration into the sheeting and/or coating (surface or seams) are 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 sheeting and/or coating is considered to be "rhizome-resistant against couch grass" if, upon termination of the test phase, - in analogy to root ingress (see 2.9) and root penetration (see 2.10) - in no trial container neither rhizome ingress nor rhizome penetration is found.
Furthermore, one of the preconditions is 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 in the course of the evaluations during the test visible penetrations of roots or rhizomes into the sheeting 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.

If during the test phase more than 25 % of the coppices are lost, the investigation has to be started anew, i.e. new planting needs to be carried out. At the same time, the vegetation support course needs to be replaced by a new aggregate mixture. 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

In a trial container under standardised conditions the resistance to root penetration of root-penetration sheeting as well as roof and damp-proof linings and/or surface coating vis-à-vis any roots and rhizomes of test plant varieties affecting them is examined.

During a 4-year test the examination is carried out in outdoor conditions where alders and couch grasses are used as test plants. The 2-year test is carried out in a climate-controlled greenhouse by testing 'Orange Charmer' and couch grass.

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

A thin vegetation support course is laid into the pre-treated containers. With dense planting, moderate fertilizing and modest watering the desired high root pressure will be obtained.

Towards the end of the investigation the vegetation support course is taken out of the receptacle and an examination of the sheeting and/or coating is effected focussed on the detection of any root and/or rhizome ingress or penetration.

Control samples of any sheeting 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, but open on its four sides. Hereby, conditions similar to outdoor conditions are created. At the same time, any precipitation which may lead to waterlogging in the run-off-free receptacles is shielded off.

Admissible as locations are also non-heated greenhouses as far 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±3)°C and during the night a temperature of (16±3)°C is achieved. As of an indoor temperature of (22±3)°C and more the greenhouse shall be ventilated. Avoid a constant indoor temperature of > 35 °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 receptacle (800 x 800 mm), respecting the required minimum distance according to paragraph 6.1, amounts to ca. 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 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 course. 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 course is effected by means of a filling pipe. This pipes 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. 2).

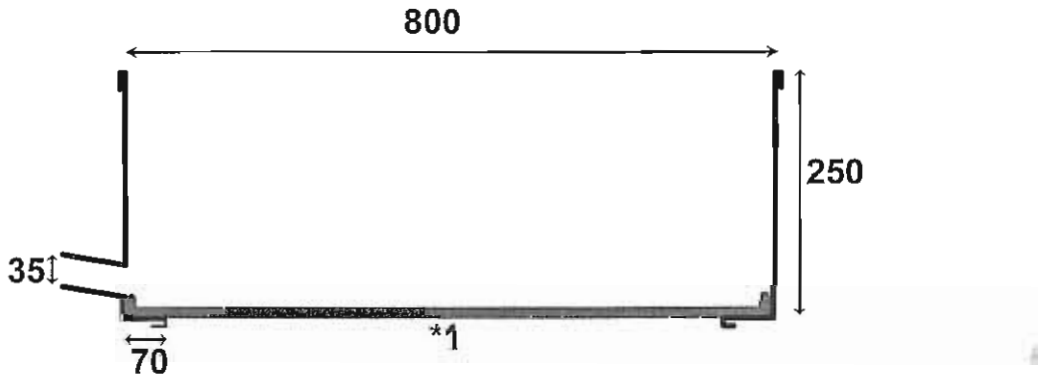

Fig. 2: Construction design of the trial containers (minimum dimensions, all figures in mm, *1 = transparent base with raised rim)

For each sheeting 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 sheeting/coating) shall be provided.

4.3 Moisture course

This course 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 effort it is useful to only use products which are subject to a permanent quality control in regard to the defined guidelines. Thus, the manufacturer will guarantee the required properties.

For the required course depth of (50±5) mm (see 6.1) the material demand comes to 32 l per trial container (800 x 800 mm).

4.4 Protective nonwoven fabric

Use a nonwoven fabric made of synthetic fibres with a weight of ca. 200 g/m^2. The material compatibility of the nonwoven 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 Sheeting and/or coating to be tested

The sheeting/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 presenting the indicated minimum dimension (800 x 800 x 250 mm).

4.6 Vegetation substrate

The substrate consists of:

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

Add calcium carbonate to bring the pH value to figures between 5,5 and 6,5 (see 4.7).

The basic 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 receptacle (taking into account a substrate supply via plant earth-clumps).

Tab. 1: 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 (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 settings

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 them and label them
- store the samples in the bag for about 3 days at room temperature
- send the samples to a laboratory which works on the basis of the regulations of the VDLUFA Association 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

As a basic fertilization a multiple-nutrient fertilizer with ca. 15% N, 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 shall be provided. Per container (800 x 800 mm) 30 g of a multiple-nutrient fertilizer are applied. The fertilizer containing nutrient trace elements is used in the quantity recommended for substrates by the manufacturer.

Use slow-release fertilizer capsules with ca. 15 % N, 10 % P_2O_5, 15 % K_2O and a duration of action of 6 – 8 months for the repeat fertilizing. The demand in fertilizers comes to 30 g/container (800 x 800 mm) per fertilization unit.

4.9 Tensiometer

In order to monitor watering of the vegetation support course per container a tensiometer with a measuring range of 0 – 600 hPa has to be used.

4.10 Test plants

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

- *Alnus incana* – grey alder, 2-year seedling, height60 – 100 cm, and
- *Agropyron repens* – couch grass, seeds

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

- *Pyracantha coccinea* 'Orange Charmer' – in a 2-litre container, height 60 – 80 cm
- *Agropyron repens* – couch grass, seeds

Per trial container with dimensions of 800 x 800 mm 4 coppices (alder, 'Orange Charmer') as well as 2 g of couch grass seeds have to be set/applied. This leads to a calculated plant density of 6,25 coppices/m² and 3,13 g seeds/m². If larger trial containers are in use, plant density has to reach at least the figures indicated above by increasing the number of plants and the quantity of seeds.

When buying test plants make sure that plant quality does not vary.

4.11 Watering

The water used for watering shall meet the minimum quality requirements listed in Tab. 2. Please enquire details about the local water quality at the waterworks responsible for the supply of the facility. If any of the values laid down in Tab. 2 is 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 purposes

Conductivity	< 1000 µS/cm
Sum total alkaline earths	< 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 sheeting/coating under investigation are to be taken by the test institute for retention before the investigation starts and at the end of the same. 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. Retention samples are to be stored in the dark and in 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 that they are not kept with any incompatible material.

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), admixture of biocides (e.g. root inhibitors) with details regarding the concentration of the substance.

In addition, a product data sheet of the sheeting/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 nonwoven 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 superstructure (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 receptacle as 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 in a compacted form and a course depth of (150±10) mm. This corresponds to a substrate volume of 96 l (4–year test) respectively 88 l (2–year test) (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 pieces of *Alnus incana* (grey alder), for a 2-year test 4 pieces of *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 equally sawn onto the vegetation support course.

If larger trial containers are necessary, the number of plants and the quantity of seeds needs to be increased so that at least the same 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 in a symmetrical distance with the plants (see Fig. 3).

It is advisable to place the receptacles on stands to facilitate root penetration checks in regular intervals. Keep a minimum distance of 0,4 m between and around the different receptacles. Receptacles shall be allocated at a random basis.

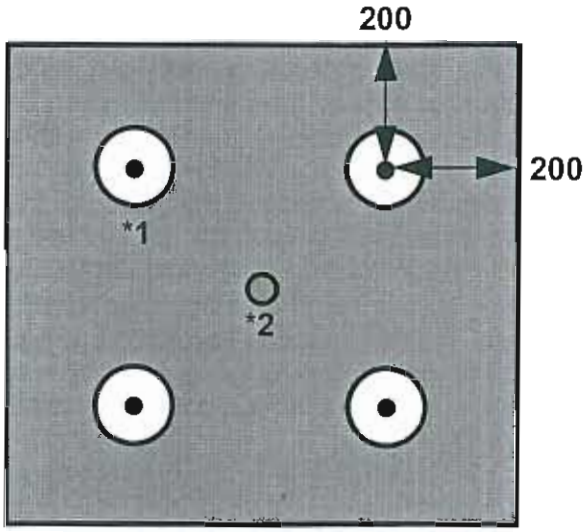

Fig. 3: Arrangement of coppices (*1) and tensiometer (*2) in the vegetation support course in a receptacle of 800 x 800 mm (dimensions in mm)

6.1.1 Laying of root protection sheeting, roof and damp-proof lining

Cut out parts of the sheeting/lining to be tested and lay them as required into the trial containers. The client who commissions the investigation shall be held responsible for a 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. 4). Hereby it is admissible to use different jointing techniques as long as these are equivalent (see 2.8).

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

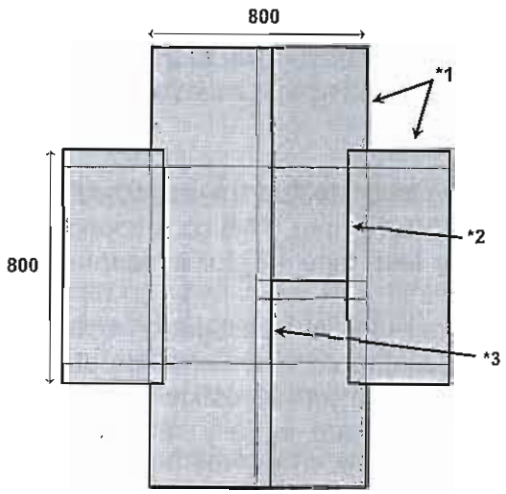

Fig. 4: Layout of the seams (*1 = wall-corner seam, *2 = base-corner seam, *3 = T–seam) in the sheeting to be tested (dimensions in mm)

6.1.2 Installation of surface coating under investigation – liquid surface treatment

Just like the sheeting 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 work steps. In the centre of the receptacle there shall 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 effected as described in paragraph 6.1. However, no sheeting/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 taking roots of the coppices 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 further course of the investigation watering is applied only if the soil moisture tension falls below values between –300 and –400 hPa. The irrigation volumes shall be dimensioned for achieving a soil moisture tension in the substrate of nearly 0 hPa. Make sure that the entire vegetation support course (including peripheral areas) is equally humidified. Avoid any lasting water excess (waterlogging) in the lower areas of the vegetation support course. In order not to damage 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 course shall be kept constantly humid by watering via the infeed pipe which is mounted to the receptacle.

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 unit shall be applied 3 months after planting. In the 4-year investigation repeat fertilization is given once a year in March or April.

Any alien growth and any plant parts which have died back and fallen onto the surface of the vegetation support course are to be removed.
Any coppices which have died ('Orange Charmer' 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 in terms of coppices account for more than 25 % of the total plant number the test shall be repeated (see 2.15).

If the coppice plants ('Orange Charmer' and/or alder) need to be pruned, a growth height of at least (150±10) cm shall be kept. Any pruning shall be effected 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 stock (< 40 % of the surface is covered) shall be improved by up to 2 units of repeat seeding in the first 3 (2-year investigation) or 6 months (4-year investigation) of the test.

To avoid a storage of 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 Evaluations 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 coppice plants ('Orange Charmer and alder) shall be monitored by measuring the height and diameter of the trunk at a height of 20 cm. In the same way the propagation of the couch grass on the substrate surface is valuated (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 leave colour, shall be noted separately.

7.2 Evaluation at the end of the trial

The client of the investigation shall be notified of the date and time of the planned final evaluation to enable him to personally assist 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 sheeting/surface coating on 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 sheeting/coating shall be recorded in absolute figures.

This examination shall be done separately for the following areas

- for root protection sheeting, roof and damp-proof lining:
  - 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 per container are found which have penetrated the sheeting/coating, the evaluation on 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 m^2 (about 20 % of the sheeting/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 overlap 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 sheeting/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.

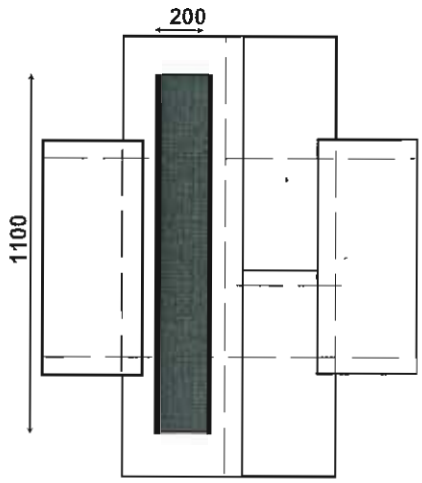

Fig. 5: Evaluation section of penetrations into the surface of a sheeting/coating under testing in case of > 50 penetrations/receptacle (dimensions in mm)

8 Test report

No interim results shall be disseminated during the trial.

Upon termination of the trial a complete test report about the given test situation shall be set up in two copies (1 copy each for both the test institute and the client), but only if the sheeting/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 the statement and related explanations that the sheeting/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 sheeting 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 appendix)
- all evaluation results in accordance with paragraph 7, and
- a summary version of the evaluation regarding the tested sheeting 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 closely related to all reference data and material properties of the tested sheeting 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 sheeting/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 compliance with the delivery programme of the client"

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

9 Competence

The client who commissions the investigation is competent for:
- procurement and installation of the protective lining (see 2.3 and 6.1) and the sheeting and/or coating to be tested (see 6.1)
- provision of a material sample (see 5), and
- details in relation to the tested sheeting 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 composition and installation of the moisture course and the vegetation support course (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 receptacles (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
- setting up a final test report (see 8)

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

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