WEIHENSTEPHAN-TRIESDORF
UNIVERSITY OF APPLIED SCIENCES

TEST REPORT

Determination of Resistance to Root Damage of Flexible Sheets and Coatings for Roof Plantings Pursuant to the FLL Standard (1999)

Product tested:
Mastic asphalt IC 40

Client:
bga Beratungsstelle für Gussasphaltananwendung e.V.
Dottendorfer Str. 86
D-53129 Bonn

This report is comprised of 33 pages and may only be used in an unabridged form.

This report is valid until 22 July, 2022
Date of report: 11 January, 2017

Information from "bga Beratungsstelle für Gussasphaltanwendung e.V." from 19 June, 2000 regarding the characteristics and material properties of mastic asphalt IC 40

- Product name: Mastic asphalt IC 40*
- Field of application: Waterproofing according to DIN 18195-5, section 8.3.7 "Waterproofing with sheeting in conjunction with mastic asphalt" and section 8.3.8 "Waterproofing with asphalt mastic in conjunction with mastic asphalt"
- Material name: Mastic asphalt according to DIN EN 12970
- Coating thickness: Nominal thickness 30 mm
- Structure / composition: Engineered, pourable and spreadable bituminous mass of chippings, sand, filler and bitumen; mixture should be composed of aggregates with little empty space.
- Form of delivery: Mastic asphalt is produced in stationary mixing plants and transported to the installation site in heated agitator tanks
- Preparation technique: Mastic asphalt is installed while hot, distributed and smoothed using a trowel and rubbed off with sand
- Material standards: DIN 18195-2
- Test certificates: None
- Year of production: 2002 (on day of installation)
- Root-resistant layer: Whole layer made from mastic asphalt
- Installation technique at testing site (layers from bottom to top):

- Load-bearing surface (in this case, aerated concrete)
- Primer according to DIN 18195-2
- Sealing layer made from polymer bitumen sheet with raised reinforcing sheet made from polyester fleece according to DIN 18195-2
- Layer of mastic asphalt according to DIN 18195-2 with a thickness of approx. 30 mm, with a day joint

- Addition of biocides, stating concentration: None

* The name of the tested product was "Gussasphalt GE 40" ("Mastic asphalt GE 40")

1 Problem

In order to prevent damage, products offering protection against roots must be permanently resistant to root penetration and root ingress by plant roots and rhizomes (underground runners). In this study, mastic asphalt IC 40 was tested for root resistance.

2 Experimental Setup and Execution

Testing was carried out according to the “Method for Determining the Resistance to Root Damage of Flexible Sheets and Coatings for Roof Plantings” and had a 2-year duration. A complete description of the test process can be found in Appendix 3 to this report.

Testing was performed between July 2000 and July 2002. It included 8 pots coated with the coating to be tested plus 3 pots without coatings as a control for plant growth.

Coating was carried out by Asphaltbau GmbH, Landshut on behalf of the Beratungsstelle für Gussasphaltananwendung e.V., Bonn, located at the Institute of Horticulture, University of Weihenstephan-Treiersdorf. It was performed in 2 work steps (with one day joint) pursuant to the specifications of the FLL method.

Samples were taken from the tested mastic asphalt and stored at the test institute.

The pots were placed in a climate-controlled greenhouse.

Orange charmer (*Pyracantha coccinea*) and couch grass (*Agropyron repens*) were used as test plants, since these also exhibit good growth during winter under the conditions provided. Couch grass, an indigenous grass species, forms rhizomes (underground runners) that are capable of damaging sheets and coatings in the same way as roots.

3 Manufacturer's Information for the Tested Coating

The testing of root resistance was subject to the characteristics and material properties of the tested coating and the associated jointing and production techniques. The information provided by the client on mastic asphalt IC 40 is listed on page 2 of this report.

4 Results

4.1 Plant Growth

The planted shrubs and the sown grass seed exhibited good growth throughout the entire test period. With regard to the growth of the test plants, there were only slight differences between the control pots (without coating) and the test pots with mastic asphalt IC 40.

At 91 - 105%, the required relative minimum growth rate of the plants in the test pots (80% of the average growth rate of the plants in the control pots) was significantly exceeded.

From the first interim analysis (January 2001) and throughout the entire test period, the couch grass exhibited a high plant density. In the 8 test pots, 73.1 - 92.5 % of the area was covered with couch grass at each of the periodic evaluation dates (target value ≥ 40%). Similar coverage was achieved in the control pots, at 68.3 - 93.3%.

Detailed information on the growth of the test plants is compiled in Appendix 2.

4.2 Root Penetration and Root Ingress at End of the Test

(see table and figures 1-4 in Appendix 1)

After the end of the 2-year test period (July 2002), the pots were emptied and examined in detail for root penetration and root ingress by roots and rhizomes.

- No widespread formation of roots or rhizomes in the mastic asphalt.
- There were occasional instances of root ingress through the numerous pores on the surface of the mastic asphalt. These cavities were already present when the coating was installed and, as such, were not caused by the root ingress. According to point 2.9 of the FLL method, ingress through the existing pores of a waterproofing coating should not be classed as root ingress for the purposes of the test.

Table: Number of instances of penetration and ingress by roots and rhizomes in the test substance mastic asphalt IC 40 after 2 years (July 2002)

Pot	Number of instances of root (R) and rhizome (Rh) penetration		Number of instances of root (R) and rhizome (Rh) ingress	
1	in the surface of the coating	in the day joint	in the surface of the coating	in the day joint
2	none	none	none*	none
3	none	none	none*	none
4	none	none	none*	none
5	none	none	none*	none
6	none	none	none*	none
7	none	none	none*	none
8	none	none	none*	none

* several pores with a diameter of up to 5 mm and a depth of up to 3 mm, some of which were showing root ingress

5 Summary and Conclusion

In the test, mastic asphalt IC 40 was tested for root resistance according to the “Method for Determining the Resistance to Root Damage of Flexible Sheets and Coatings for Roof Plantings” with a 2-year duration (FLL, 1999) on behalf of the Beratungsstelle für Gussasphaltanwendung e.V.
After 2 years, the mastic asphalt IC 40 showed no root penetration or root ingress in any of the 8 test pots. In accordance with point 2.9 of the FLL, roots that had ingressed through any of the numerous pores present at the time of installation of the mastic asphalt were not classed as root ingress for the purposes of the test.
As such, mastic asphalt IC 40 is root- and rhizome-resistant against couch grass pursuant to the FLL method.
The FLL method encompasses and goes beyond all relevant elements of EN 13948 and is therefore viewed as superior within the field. As such, from a technical perspective, mastic asphalt IC 40 tested according to the FLL method can also be deemed to be root-resistant according to EN 13948.
The testing of root resistance is subject to the characteristics and material properties of the tested coating, which are listed on page 2 of the report, as well as to the applied jointing and preparation techniques. Retain samples of the tested coating are stored at the Institute of Horticulture.
The test report, which was created in July 2002 and had an initial validity period of 10 years, was extended in 2013 taking into account the specifications of the current FLL testing method (2008). It was extended by a further 5 years in January 2017 and is thus valid until 22 July, 2022. The test report contains 33 pages and may only be used in an unabridged form.

[Signature]	[Signature]
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11 January, 2017	11 January, 2017

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Appendix 1

Photos of mastic asphalt IC 40

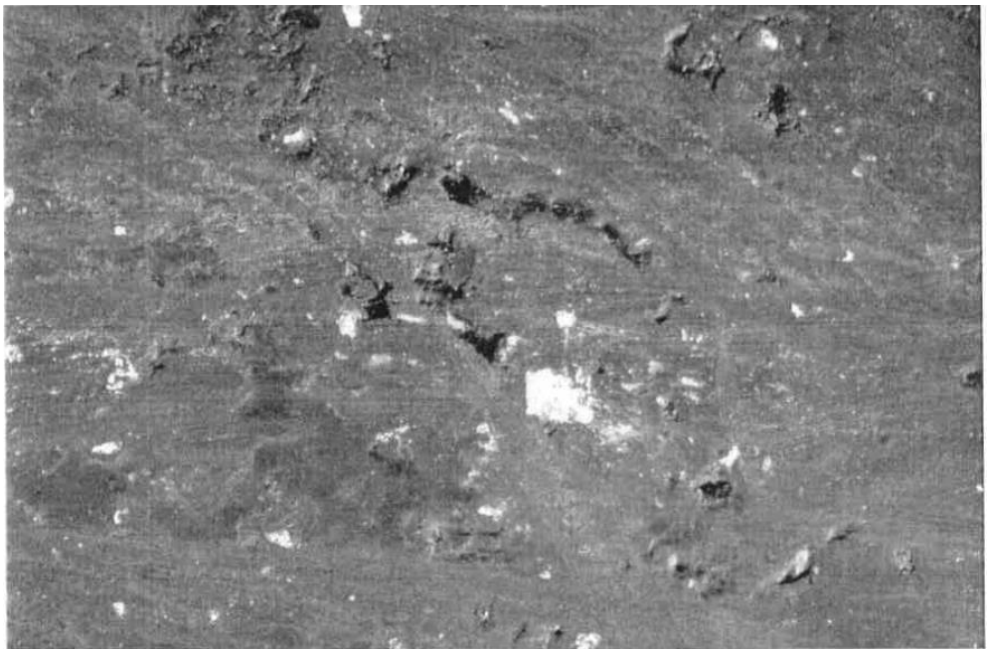

Fig. 1: Pores in the mastic asphalt surface at time of installation (July 2000)

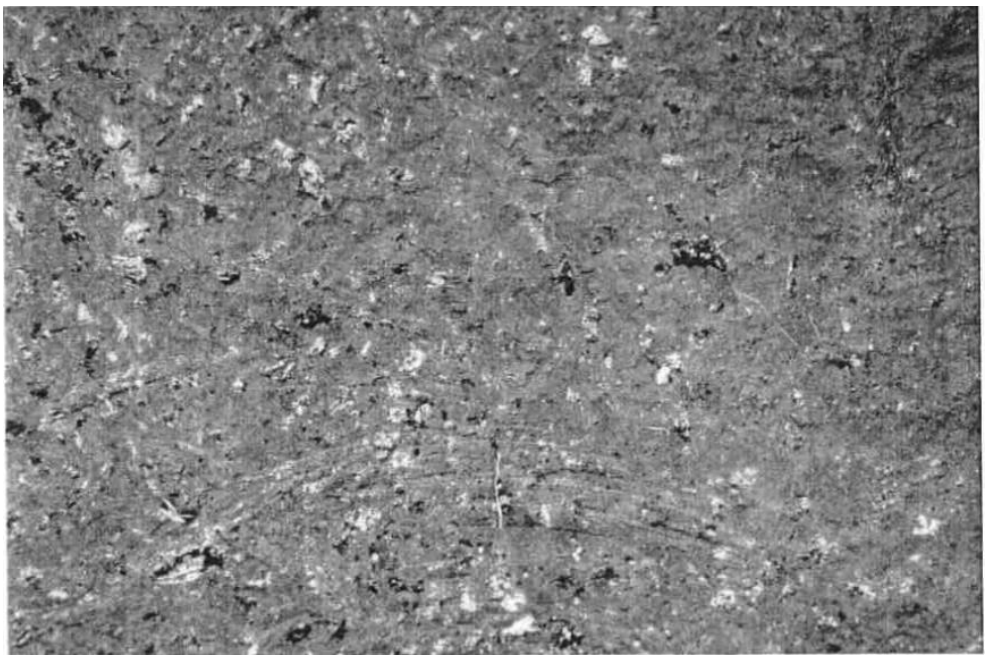

Fig. 2: Pores in the mastic asphalt surface at time of removal (July 2002)

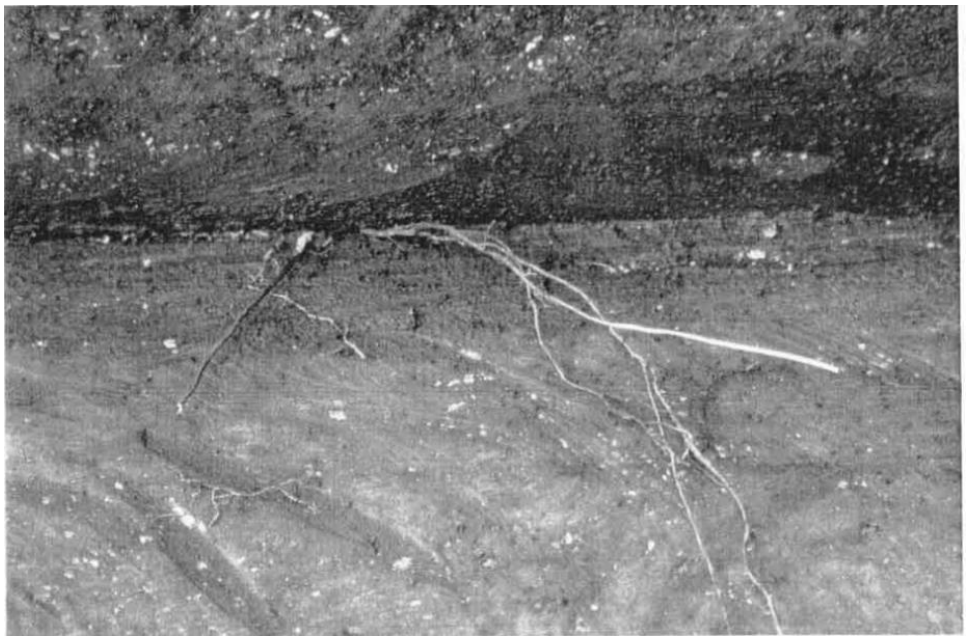

Fig. 3: Pores in the angle area showing root ingress (July 2002)

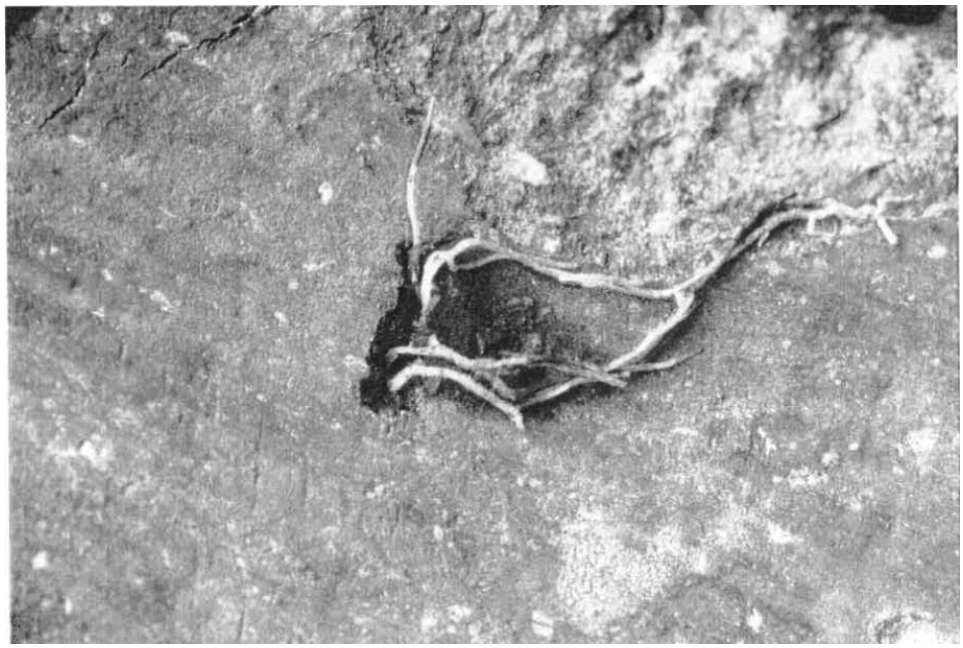

Fig. 4: Pores showing root ingress (July 2002)

Appendix 2

Data on plant growth

Tab. 1: Height and diameter of orange charmer in the 3 control pots

Pot no.	Plant no.	January 2001		July 2001		January 2002		July 2002	
		⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm
C 1	1	1.3	200	1.8	235	2.0	255	2.4	330
	2	1.3	175	1.7	175	1.8	240	2.0	285
	3	1.4	180	1.6	185	2.0	240	2.3	285
	4	1.1	165	1.4	195	1.7	200	2.1	285
C 2	1	1.3	210	1.7	180	2.1	260	2.4	310
	2	1.3	190	1.8	230	1.9	240	2.1	260
	3	1.1	200	1.3	175	1.6	295	2.0	300
	4	1.4	180	1.7	195	2.1	220	2.3	245
C 3	1	1.4	190	1.8	220	2.2	245	2.4	295
	2	1.2	175	1.5	205	1.9	220	2.2	255
	3	1.3	200	1.6	210	1.8	210	2.1	240
	4	1.0	160	1.4	195	1.7	200	2.0	225

[1)] Diameter, measured 20 cm above the substrate surface

Tab. 2: Average height and diameter of orange charmer in the 3 control pots

Pot no.	Plant no.	January 2001		July 2001		January 2002		July 2002	
		⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm
C 1 – C3	1-4	1.26	185.4	1.61	200.0	1.90	235.4	2.19	276.3

[1)] Average diameter, measured 20 cm above the substrate surface

Tab. 1: Height and diameter of orange charmer in the 8 test pots

Pot no.	Plant no.	January 2001		July 2001		January 2002		July 2002	
		⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm
T 1	1	1.3	175	1.6	205	1.9	220	2.3	330
	2	1.1	200	1.6	235	1.8	250	2.4	280
	3	1.2	200	1.4	210	1.6	220	2.0	290
	4	1.2	215	1.5	200	1.7	215	2.1	310
T 2	1	1.3	195	1.6	255	1.8	180	2.0	300
	2	1.3	220	1.5	215	1.9	210	2.2	285
	3	1.2	185	1.5	200	1.7	245	1.9	260
	4	1.3	170	1.6	195	1.8	215	2.1	275
T 3	1	1.1	195	1.3	185	1.6	200	2.0	250
	2	1.4	210	1.6	225	1.8	185	2.2	350
	3	1.2	180	1.5	235	1.8	215	2.1	275
	4	1.1	210	1.4	180	1.6	250	1.9	320
T 4	1	1.2	180	1.3	245	1.6	220	2.0	270
	2	1.4	210	1.6	180	1.9	200	2.3	235
	3	1.2	195	1.5	200	1.7	210	1.9	225
	4	1.3	220	1.5	210	1.8	250	2.0	310
T 5	1	1.4	230	1.6	195	1.9	240	2.4	335
	2	1.1	185	1.3	225	1.7	265	2.1	300
	3	1.2	175	1.4	260	1.6	205	1.8	255
	4	1.1	170	1.3	190	1.6	235	2.1	225
T 6	1	1.0	210	1.2	200	1.5	245	2.1	245
	2	1.3	175	1.4	185	1.8	240	2.2	255
	3	1.1	180	1.3	195	1.7	200	2.0	310
	4	1.4	170	1.6	220	1.7	255	1.8	330
T 7	1	1.3	210	1.4	210	1.8	270	2.2	265
	2	1.4	175	1.7	180	2.0	215	2.3	215
	3	1.0	245	1.4	240	1.6	270	1.8	285
	4	1.3	210	1.7	210	1.8	240	2.0	275
T 8	1	1.0	150	1.2	195	1.5	230	2.0	300
	2	1.3	170	1.6	200	1.8	215	2.1	280
	3	1.2	150	1.4	220	1.8	200	2.2	275
	4	1.3	200	1.6	245	1.7	245	1.9	280

[1)] Diameter, measured 20 cm above the substrate surface

Tab. 4: Average height and diameter of orange charmer in the 8 test pots

Pot no.	Plant no.	January 2001		July 2001		January 2002		July 2002	
		⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm
T 1 – T 8	1-4	1.23	192.7	1.47	210.8	1.73	226.7	2.08	281.1

[1)] Average diameter, measured 20 cm above the substrate surface

Tab. 5: Average values for orange charmer in the 8 test pots relative to the plants in the 3 control pots (expressed in %, target values: ≥ 80%)

Pot no.	Plant no.	January 2001		July 2001		January 2002		July 2002	
		⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm	⌀, cm[1)]	Height, cm
T 1 – T 8	1-4	98	104	91	105	91	96	95	102

[1)] Diameter, measured 20 cm above the substrate surface

Tab. 6: Plant density rating for couch grass in the 3 control pots

Pot no.	January 2001	July 2001	January 2002	July 2002
	Plant density (in %)	Plant density (in %)	Plant density (in %)	Plant density (in %)
C 1	65	80	85	95
C 2	70	75	80	90
C 3	70	80	80	95

Tab. 7: Average values for plant density of couch grass in the 3 control pots

Pot no.	January 2001	July 2001	January 2002	July 2002
	Plant density (in %)	Plant density (in %)	Plant density (in %)	Plant density (in %)
C 1 – C 3	68.3	78.3	81.7	93.3

Tab. 8: Plant density rating for couch grass in the 8 test pots

Pot no.	January 2001	July 2001	January 2002	July 2002
	Plant density (in %)	Plant density (in %)	Plant density (in %)	Plant density (in %)
T 1	75	80	85	95
T 2	70	75	85	95
T 3	70	80	90	95
T 4	75	80	90	90
T 5	75	80	85	90
T 6	75	85	90	95
T 7	70	85	85	90
T 8	75	80	85	90

Tab. 7: Average values for plant density of couch grass in the 8 test pots (target value: ≥ 40%)

Pot no.	January 2001	July 2001	January 2002	July 2002
	Plant density (in %)	Plant density (in %)	Plant density (in %)	Plant density (in %)
T 1 – T 8	73.1	80.6	86.9	92.5

Appendix 3

Method for Determining the Resistance to Root Damage of Flexible Sheets and Coatings for Roof Plantings

FLL
Forschungsgesellschaft
Landschaftsentwicklung Landschaftsbau e.V.
[Landscape Research, Development & Construction Society]
Colmanstr. 32
53115 Bonn

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Introduction

To prevent vegetation-related damage caused by roof plantings, a “Method for determining the root resistance of products for protection against roots” was developed in 1984 by a working group from the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. [Landscape Research, Development & Construction Society]. The method is based on knowledge and experience gathered over many years of tests carried out at the Institut für Bodenkunde und Pflanzenernährung [Institute for Soil Science and Plant Nutrition], Weihenstephan University of Applied Sciences. These tests were carried out from 1975 to 1980 using a variety of plants and waterproofing sheets.

The FLL method was revised in 1992 and again in 1995.

It enjoys a high level of trust among manufacturers, planners and executing companies; this is evidenced, inter alia, by the high number of tests already completed and in progress.

In 1993, the FLL decided to revise the procedure, which had thus far stipulated a test duration of 4 years. The goal was to reduce the test duration to 2 years without deviating from the stringent standards of the existing method.

Following multiple tests at the Institute for Soil Science and Plant Nutrition (Weihenstephan University of Applied Sciences), researchers finally managed to agree on the the specifications: the 2-year test should take place in a climate-controlled greenhouse, whereby the plant varieties used must have the ability to grow all year round in the temperature and light conditions provided. This achieves an effective growth period of 24 months – the same duration as the 4-year test, once the annual, several-month dormancy period of the vegetation under outdoor conditions is taken into account. Both variants of the test are deemed to have equally validity and are both described in this revised version of the method.

As part of the changes to content, the format of the method has also been revised; this is intended to enable easier comprehension and easier analysis of the results by test institutes.

1 Scope of Application

This method applies for the determination of resistance to root penetration and root ingress by the roots and rhizomes of test plants in the following products:

- root protection sheets/membranes
- roof sheets and waterproofing sheets, and
- coatings applied wet,

and for all forms of roof planting (intensive green roofs, simple intensive green roods, extensive green roofs).

The method covers the testing of products including their associated jointing techniques. As such, it is only permissible for the testing of individual sheets or coatings. It is not suitable for the testing of roof waterproofing systems (roof waterproofing structures comprised of multiple layers).
For technical reasons, when applying a wet coating, it may be necessary to install a separate layer underneath. This is permitted, insofar as the manufacturer clearly states that the root resistance effect is rendered exclusively by the coating on top.
Lamination (that is, a separate layer applied on the sheet or coating to be tested) is expressly not permitted.

Where a result has been obtained for the resistance of a sheet or coating to root penetration or root ingress, the same resistance may not be assumed against plants with strong rhizome growth (e.g. bamboo and Chinese reed varieties). Such plants require special maintenance measures and structural precautions exceeding the experimentally determined level of root resistance.

The method does not assess the environmental sustainability of the tested products.

2 Definitions

The following definitions apply for the application of the method:

2.1 Experimental Pots

Pots equipped, for the purpose of the test, with either minimal amounts of the sheet or coating to be tested (test pots) or with non-woven material (control pots).

2.2 Moisture Layer

The moisture layer consists of coarse mineral material that is layered under the sheet or coating to be tested. It is kept moist at all times and thus enables the penetrating or ingressing roots or rhizomes to continue growing to the transparent base of the pot. This, in turn, enables the early recognition of penetration.

2.3 Protective Layer

Non-woven material, compatible with the sheet or coating, that is placed directly under the material to be tested on top of the moisture layer to achieve equal pressure distribution.

2.4 Vegetation Base Layer

Uniform culture substrate (mixture of substances) that is available or can be produced in the same manner at all test sites at all times. It is structurally stabilised, has a favourable water/air balance and thus favours optimal root development of the test plants. The vegetation base layer is in direct contact with the sheet to be examined.

2.5 Test Plant Varieties

2.5.1 For the 2-year test

- *Pyracantha coccinea* ‘Orange charmer’, a decorative shrub that shows suitable root growth throughout the entire year under the specified greenhouse conditions, and
- *Agropyron repens*, couch grass, an indigenous grass with fast-growing rhizomes that almost always establishes itself naturally on green roofs and shows sufficient year-round growth under the described test conditions.

2.5.1 For the 4-year test

- *Alnus incana*, grey alder, a wild-growing shrub that shows suitable root growth under the stipulated outdoor conditions during the vegetation period, and
- *Agropyron repens*, couch grass

2.6 Adequate Growth Rate of Test Plants

The shrubs (orange charmer or alder) in the test pots must demonstrate growth that is at least 80% of the average growth (height, diameter) of the plants in the control pots. In this way, any impairment of the test plants by plant-damaging substances released by the sheet or coating can be detected. The spread of the couch grass on the substrate surface is monitored visually (and rated, see point 2.7). From the first periodic evaluation (see 7.1) and throughout the entire duration of the test, the plants in the test pots must achieve at least an average plant density.

2.7 Rating of Couch Grass Density

The visual rating of couch grass density is performed by assigning a number, whereby the following classifications are to be observed:

1 = Almost no couch grass present (around 0-20% of the area covered)
2 = Sparse density (around 20-40% of the area covered)
3 = Medium density (around 40-60% of the area covered)
4 = High density (around 60-80% of the area covered)
5 = Very high couch grass density (around 80-100% of the area covered)

2.8 Equivalent Jointing Techniques

Different jointing techniques may be combined as part of the test, so long as all techniques are aimed at achieving homogeneous joint connections (e.g. solvent welding – with a solvent that evaporates – and hot-gas welding). All joint connections of this nature are deemed equivalent. In contrast, combinations of non-adhesive connections and connections using adhesive cement, or of 2 different adhesive cements, are not deemed equivalent.

2.9 Root Ingress

Root ingress into the surface or joints of the tested sheet or coating, whereby the underground parts of the plant actively create cavities and thus the sheet or coating is damaged.

Not to be classed as root ingress, but to be listed in the test report are:

- Root ingress in pre-existing pores in the surface or in a regular joint/day joint of a sheet or coating (i.e., no new damage). To enable the situation to be assessed clearly, the sheet or coating section must be examined under the microscope.
- Root ingress of ≤ 5 mm in the surface or in a regular joint/day joint of a sheet or coating containing root inhibitors, since this inhibition can only occur after the root ingress has taken place. To enable the situation to be assessed clearly, these sheets or coatings should be clearly labelled as “root-inhibiting” by the manufacturer at the start of the test.
- Root ingress in the surfaces of products composed of multiple layers (e.g. bitumen sheet with copper layer or PVC sheet with polyester cloth layer), whereby the layer that performs the protective function is not damaged in the process. To enable the situation to be assessed clearly, the layer performing the protective function is to be clearly labelled as such by the manufacturer.
- Root ingress in joint sealing (where the joint is not damaged).

2.10 Root Penetration

Root penetration in the surface or joints of a tested sheet or coating, whereby the roots make use of pre-existing pores in the sheet or coating or have actively created cavities.

2.11 Attestation of “Root-Resistant”

A sheet or coating is deemed root-resistant if no root ingress pursuant to section 2.9 or root penetration pursuant to section 2.10 can be identified in any of the test pots following the expiry of the test period. It must also be the case that the shrubs used in the test pots display adequate growth pursuant to 2.6 throughout the entire duration of the test.

2.12 Couch grass rhizomes

Since a differentiation is made between roots and rhizomes as part of the assessment, it is essential that the underground plant organs can be clearly identified.

The following can be used as a guide:

The couch grass rhizomes that spread in the vegetation base layer (underground runners) have a uniform thickness of approx. 2 mm and a low degree of branching. They are divided into individual sections marked by nodes; to these nodes are attached thin roots and inconspicuous leaflets wrapped around the stem. Between the nodes, the couch grass rhizomes are hollow (see Fig. 1).

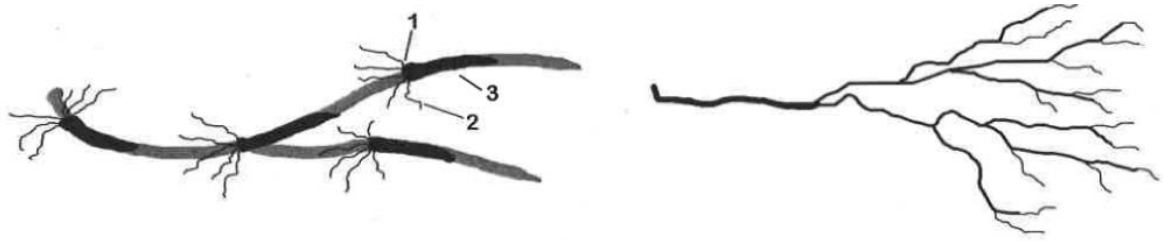

Fig. 1: Schematic representation of a couch grass rhizome (left) with nodes (1), roots (2) and leaflets (3) compared to an orange charmer root

2.13 Assessment of couch grass rhizomes

Root penetration and ingress in the sheet or coating (surface or joint) is identified and listed in the test report, but not evaluated from a root resistance perspective. If no damage to the product can be observed as a result of the rhizomes, this is expressly noted in the test report (see 2.14).

2.14 Attestation of “Rhizome-Resistant against Couch Grass”

A sheet or coating is considered to be resistant to couch grass rhizomes if no rhizome ingress or rhizome penetration can be identified in any of the test pots by the expiry of the test period (process analogue to that for root ingress (see 2.9) and root penetration (see 2.10).

In order for the sheet or coating to receive this attestation, the couch grass in the test pots must display adequate growth over the entirety of the test period (see 2.6).

2.15 Criteria for a Premature Termination of the Test

If root or rhizome penetration of the sheet or coating being tested is identified as part of the period evaluations (see p. 71), the client is to be informed. Where the penetration is caused by roots, the test is to be terminated prematurely. If the penetration is caused by rhizomes, the test may be continued in coordination with the client.

If more than 25% of the shrubs die or become diseased during the course of the test, the test is to be started anew – that is, replanting is to be carried out, whereby the vegetation base layer should also be replaced by a new mixture. The start date of the test should be adjusted accordingly.

The same process should be followed insofar as adequate plant growth of the test plants is not achieved during the course of the test (p. 2.6)

3 Summary of the Method

This pot experiment, which is carried out under standardised conditions, investigates the resistance to root penetration of waterproofing roof sheets and coatings offering protection against roots. In the 4-year variant of the test, this occurs under outdoor conditions, with elder and couch grass used as test plants. In the 2-year variant, orange charmer and couch grass are used in a climate-controlled greenhouse.

The sheet or coating to be tested, which should have multiple regular joints or at least one day joint, is installed in 8 test pots. A further 3 pots without the sheet or coating are included in the test. These serve as control pots for the plant growth.

The pots are filled with a thin vegetation base layer. Dense planting, moderate fertilisation and restrained irrigation are used to try and attain the desired high root pressure.

At the end of the test, the vegetation base layer is removed and the sheet or coating is inspected for the ingress and penetration of roots and/or rhizomes. Retain samples of the tested sheet or coating are stored by the test institute.

4 Experimental Setup and Material

4.1 Test site

4.1.1 For the 4-year test

A hall with a transparent roof covering is to be provided; other than this, all sides should be open. This creates near-enough outdoor conditions while preventing precipitation from falling on the pots, which could lead to waterlogging of the non-draining pots.
Also permissible as a test site is an unheated greenhouse, so long as it has sufficient ventilation and does not prevent the effects of frost.

4.1.2 For the 2-year test

A greenhouse with adjustable heating and ventilation is to be provided. The heating is to be adjusted such that the interior temperature is maintained at minimum (18±3)°C during the day and at minimum (22±3)°C at night. The greenhouse is to be ventilated from a temperature of (22±3)°C. Sustained interior temperatures of > 35°C are to be avoided.
Under the stated temperatures, the natural lighting conditions in Central Europe ensure the favourable growth of test plants throughout the year. It is not necessary to provide shade for the plants in summer or artificial lighting in winter.
Taking into account the required minimum distance between pots pursuant to section 6.1, the space requirement per pot (800 x 800 mm) is – depending on how the pots are arranged – around 1.5 to 2 m^2.

4.2 Experimental Pots

The experimental pots must have internal dimensions of 800 x 800 x 250 mm. Depending on the installation requirements, it may be necessary to use larger test pots.
The experimental pots are to be equipped with a transparent base (e.g. acrylic glass) to enable penetrating roots to be identified during the test without disturbing the vegetation. The base is to be obscured (e.g. with non-transparent film) to prevent the growth of algae in the moisture layer.

The transparent base is to be designed as an insert with an upstand of 20 mm, to ensure sufficient water supply to the moisture layer. The water is to be fed into the moisture layer via a filler tube (diameter approx. 35 mm) that ends at the upturn of the base insert and is angled diagonally upwards. The tube should be affixed to the outside of the pots.

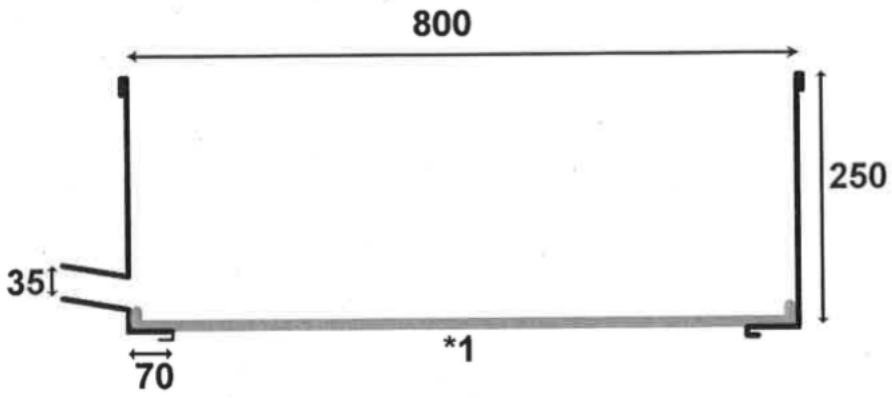

Fig. 2: Structure of the experimental pot (minimum dimensions, size in mm, *1 = transparent base with upstand)

8 test pots are required for each sheet or coating to be tested. 3 control pots (without sheet or coating) are also required per test run, regardless of how many sheets or coatings are to be tested.

4.3 Moisture Layer

This layer consists of expanded shale or expanded clay (grain size 8-16 mm), which must have the qualities listed in Table 1. To avoid the test institute having to carry out any analysis work in this regard, it is recommended only to use products that are subject to ongoing quality control regarding the below-mentioned values and where the manufacturer can guarantee the required properties. For the required layer thickness of (50±5) mm (see 6.1), the material requirement is around 32 l per experimental pot (800 x 800 mm).

4.4 Non-woven Protective Material

A non-woven material made from synthetic fibres with a weight of approx. 200 g/m^2 is to be used. It must be ensured that this material is compatible with the coating or sheet to be tested. The material requirement is 0.64 m^2 per experimental pot (800 x 800 mm).

4.5 Sheet or Coating to be Tested

The sheet or coating is to be installed or applied pursuant to section 6.1. Taking into account the dimensions of each pot (800 x 800 x 250 mm), and after deducting the 50 mm moisture layer, this means an area of around 1.3 m^2 to be covered (without overlapping).

4.6 Vegetation Substrate

The substrate consists of:

- 70% vol.-% bog peat with low decomposition
- 30% vol.-% expanded shale or expanded clay (grain size 8-16 mm), which must satisfy the qualities listed in Table 1. As described in section 4.3, it is prudent to make exclusive use of previously quality-controlled products.

The addition of calcium carbonate should be used to bring the substrate to a pH value ($CaCl_2$) between 5.5 and 6.5 (see 4.7).

The fertilising agents defined in section 4.8 should be mixed homogeneously with the vegetation layer prior to filling.

For a 4-year test, the substrate requirement – taking into account the required layer thickness of (150±10) mm – is around 96 l per experimental pot (800 x 800 mm); for the 2-year test, taking into account the supply of substrate via the root balls of the plants, the requirement is around 88 l per experimental pot.

Table 1: Required quality of expanded shale/ expanded clay. Determination of ground material in the water extract using demineralised water in the ratio 1:10 (weight/vol.)

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 mg
F	< 1.2 mg/100g

4.7 pH Adjustment

For the vegetation base layer, the amount of calcium carbonate needed to adjust the pH value to 5.5 – 6.5 may vary.

The amount required can be determined using the following procedure:

- Remove 5 samples of the well-mixed vegetation layer for every 1 l,
- Moisten the samples with tap water,
- Mix the individual samples with different amounts (4, 5, 6, 7 or 8 g) of calcium carbonate
- Place the samples in a plastic bag, seal and label
- Store the bags at room temperature for 3 days,
- Send the samples to a test laboratory that works according to VDLUFA methods, requesting a pH analysis in $CaCl_2$,
- Extrapolate the amount that result in the desired pH value in the 1 l sample for the volume of the entire vegetation layer.

4.8 Fertiliser

A mixed fertiliser with approx. 15% N, 10% P_2O_5, 15% K_2O, 2% MgO and less than 0.5% Cl is to be used; also to be used is a micronutrient fertiliser with iron (Fe), copper (Cu), molybdenum (Mo), mangan (Mn), boron (B) and zinc (Zn). 30 g of mixed fertiliser is to be applied per experimental pot (800 x 800 mm). The micronutrient fertiliser is to be used in the amount recommended by the manufacturer for the substrate. For subsequent fertilisation, a bagged, slow-acting mixed fertiliser with approx. 15% N, 10% P_2O_5, 15% K_2O and a duration of action of 6-8 months is to be used. The required amount of fertiliser is 30g/pot (800 x 800 mm) at each application.

4.9 Tensiometer

To control the amount of water supplied to the vegetation base layer, a tensiometer with a measuring range of 0 to 600 hPa is to be used for each pot.

4.10 Test Plants

For the 4-year test, the following 2 species are to be used as test plants with the specified characteristics:

- *Alnus incana* – Grey alder, seedling transplanted after 2 years, height 60-100 cm, and
- *Agropyron repens* – Couch grass, seed.

For the 2-year test, the following 2 species are to be used as test plants with the specified characteristics:

- *Pyracantha coccinea* 'Orange charmer' – In a 2-litre container, height 60-80 cm, and
- *Agropyron repens* – Couch grass, seed.

Around 4 shrubs (alder, orange charmer) and 2 g of crouch grass seed are to be used per experimental pot of 800 x 800 mm. This gives a calculated plant density of 6.25 plants/m^2 and 3.13 g of seed/m^3. If larger experimental pots are used, the number of plants and the amount of seed must be increased to achieve the same plant density.

4.11 Irrigation Water

The irrigation water must satisfy the minimum quality criteria in Table 2.
The water quality is to be enquired from the relevant water treatment plant.
if the values in Table 2 are exceeded, the irrigation water is to be blended with fully demineralised water or rainwater accordingly.

Table 2: Minimum quality of irrigation water

Conductivity	< 1000 µS/cm
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 Sampling and Manufacturer's Information

Prior to and after the test, the test institute is to remove a sample from the sheet or coating to be tested
The piece removed must contain at least one example of each type of pre-welded joint or one day joint, and must have an area of at least 0.5 m^2. The retain sample must be stored by the test institute in a dark location at a temperature of minimum 5 C and maximum 25 C.
The duration of storage must correspond to the period of validity of the test report (see 8).
The compatibility of substances is to be taken into account for the storage.
To enable clear identification of the tested product, the following information is to be requested

from the manufacturer at the start of the test: product name, field of application, product name, material standards, thickness (without lamination), composition/structure, delivery form, preparation technique, test certificates, year of production, installation technique at the test site (overlapping, jointing techniques used, joining agent, type of joint sealing, cover strips over joints, special corner and angel connections), addition of biocides (e.g. root inhibitors) with concentrations.
In addition, the test institute is to file a product data sheet for the sheet or coating to be tested.
Furthermore, if a product is composed of multiple layers (e.g. bitumen sheets with copper layers or PVC sheets with polyester layers), the manufacturer must label it clearly at the beginning of the test to indicate which layer provides the root protection.

6 Test Conditions

6.1 Preparation and installation of the 8 test vessels

The layers in the pots are structured as follows (from bottom to top): moisture layer, protective layer, sheet or coating to be tested, vegetation base player, plants.
The moisture layer of thickness (50±5) mm is placed directly over the transparent vessel base as the bottom layer.
The protective layer is cut to the right dimensions for the pot area and laid directly on the moisture layer.
The sheet or coating to be tested is inserted as described in section 6.1.1 and 6.1.2.
Following the insertion of the sheet or coating to be tested, the vegetation substrate is filled to a layer thickness of (150±10) mm. For a pot 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).
Per experimental pot of 800 x 800 mm, *Alnus incana* (grey alder) (for the 4-year test) or *Pyracantha coccinea* (orange charmer) (for the 2-year test) are to be planted evenly over the available space (see Figure 3). In addition, for both variants of the test, 2 g of couch grass seed (*Agropyron repens*) is to be distributed evenly over the vegetation layer.

If larger experimental pots are used, the number of plants must be increased so that at least the same plant density is achieved (see 4.10).
The ceramic cell of the tensiometer must be placed directly over the sheet or coating in the vegetation layer such that the measurement can be taken in the lowest part of the root zone. The tensiometer is to be positioned at an equal distance from all surrounding plants (see Fig. 3).
Where possible, the pots are to be placed on racks to enable periodic inspections for root penetration. A minimum interval of 0.4 m between each pot is to be guaranteed on all sides. The pots are to be arranged in a random order.

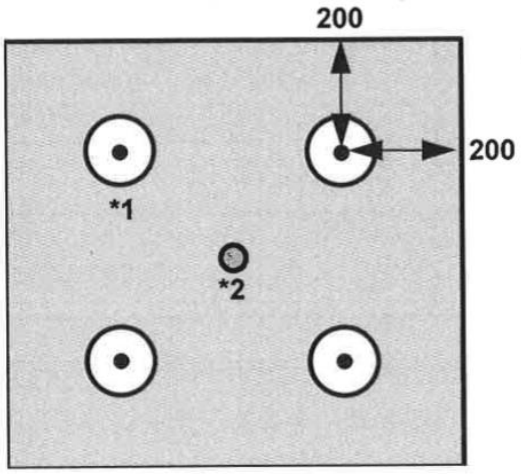

Fig. 3: Arrangement of the shrubs (*1) and tensiometer (*2) in the vegetation base layer for a pot of 800 x 800 mm (dimensions in mm)

6.1.1 Installation of an anti-root or waterproofing sheet for testing

Pieces should be cut from the sheet to be tested and installed in the pots by the client at the test site using appropriate technical methods. As part of this process, 4 wall corner joints, 2 floor corner joints and 1 centrally running T-joint are to be executed (see Fig. 4). A variety of jointing techniques may be used to do this, insofar as these deemed equivalent to one another (see 2.8).
The sheet is to be raised to the edge of the pot.

6.1.2 Application of a wet coating for testing

Wet coatings are likewise to be installed in the pots by the client at the test site using appropriate technical methods. The coating must be installed in 2 work steps, whereby a continuous day joint is to be positioned in the middle of the pot. The time interval between the two work steps must be at least 24 hours.

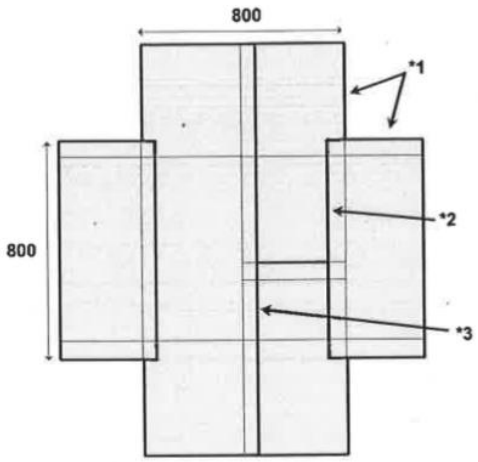

Fig. 4: Arrangement of joints (*1 = wall corner joint, *2 = floor corner joint, *3 = T-joint) in the sheet to be tested (dimensions in mm)

6.2 Preparation and Installation of the 3 Control Pots

The preparation and installation of the 3 control pots should occur as described under section 6.1 however, no sheet or coating is installed, which means that the protective layer lies directly under the vegetation base layer.

6.3 Caring for the Plants during the Growth Period

The substrate moisture is to be adjusted by irrigation from above to the vegetation base layer depending on the plants' needs. The moisture (soil water tension) is to be controlled using the tensiometer.
To ensure good germination of the seed and good plant growth, during the first 8 weeks after planting, watering should be carried out as soon as the soil water tension dips below -100 hPa. Over the further course of the test, watering should only be carried out when the soil water tension sinks to a value

between -300 and -400 hPa. The amounts of water are to be measured such that a soil water tension of close to 0 hPA is achieved in the substrate. It must be ensured the entire vegetation layer (incl. the edges) is equally moistened. A sustained excess of water (waterlogging) in the lower region of the vegetation base layer is to be avoided. To avoid damage to the tensiometer, this is to be removed when the first frost arrives (for the 4-year variant). Watering during the annual dormancy period of the vegetation is to be adjusted to the plants' minimal water needs. Following the last frosts in the spring, the tensiometer is to be put back in place. Watering should then continue as described above.
The moisture layer is to be kept moist at all times via the filler tube attached to the pot.
For the 2-year test, top-up fertilisation is to occur at half-yearly intervals with the fertiliser type and amount described in section 4.8. The first application should occur 3 months after planting. For the 4-year test, top-up fertilisation should occur once yearly in March or April.
Any unplanned growth or dead/diseased shrubs on the surface of the vegetation base layer should be removed. Dead or diseased shrubs (orange charmer/alder) are to be replaced. In order not to disturb root formation among the remaining shrubs, however, this is only permitted during the first 2 months (in the 2-year test) or the first 6 months (in the 4-year test). If, during the course of the test, more than 25% of the shrubs become unviable, the test is to be started afresh (see 2.15).
If the shrubs (grey alder or orange charmer) need to be cut back in height, this is to be done in such a way that a height of (150±10) cm remains The cutting is to be performed on the same day for the test and control pots. Side shoots can be cut back to keep the way between the pots clear.
If the coverage of couch grass is sparse (< 40% of the area covered), a top-up administration of seed is to be carried out up to 2 times in the first 3 months (2-year test) or the first 6 months (4-year test). To avoid the clumping of the couch grass, the stalks are to be cut back to a length of 5 cm once they have reached a length of 20 cm. If many of the plants become unviable or if there is an outbreak of disease, suitable measures are to be taken.

7 Evaluation

7.1 Periodic Evaluations

In both the 2-year test and the 4-year test, the transparent bases of all 8 test pots are to be inspected for visible roots and rhizomes (successful penetration) every 6 months.

If penetration has occurred in the test pots, the client is to be informed. The test may be terminated (see 2.15).

Beyond this, no interim results may be disclosed in writing during the test.

Twice yearly (2-year test) or yearly (4-year test), the growth of the shrubs (orange charmer/alder) in all test and control pots is to be checked by measuring their height and diameter from a height of 20 cm. The spread of couch grass on the substrate surface should also be rated (see 2.7). The average growth of plants in the test pots is to be recorded and the result compared to the control pots. If adequate growth is not achieved pursuant to 2.6, the test is to be started afresh (see 2.15).

If plant damage, leaf deformations or leaf discolouration occur, these are to be recorded separately.

7.2 Evaluations at the End of the Test

The timing of the final evaluation is to be announced to the client to enable them to participate if so desired.

The final plan growth measurement is to be recorded as described in 7.1.

The vegetation base layer should be removed from all test posts at the end of the test and the sheet or base layer inspected for the penetration or ingress of roots or rhizomes. Pursuant to sections 2.9, 2.10 and 2.12, the number of instances of root or rhizome ingress or penetration is to be recorded in absolute terms.

Numbers are also to be recorded separately for the following areas:

- for anti-root and waterproofing roof sheets:
    - the surface, and

- the joints;

- for wet coatings:
  - the surface and, where applicable
  - the day joint, insofar as this can be seen.

If a single pot contains more than 50 instances of root or rhizome ingress in the surface of a sheet or coating, the evaluation shall – by way of deviation from the above – focus solely on a partial segment of the tested material. The evaluation must cover at least 0.2 m^2 (around 20% of the sheet or coating covered with substrate) and must be performed in the area indicated in Figure 5.
For the ingress of roots or rhizomes in the overlap area of joints, the maximum ingress depth is to be determined.
Photographic examples of the ingress and penetration of roots and rhizomes are to be recorded.

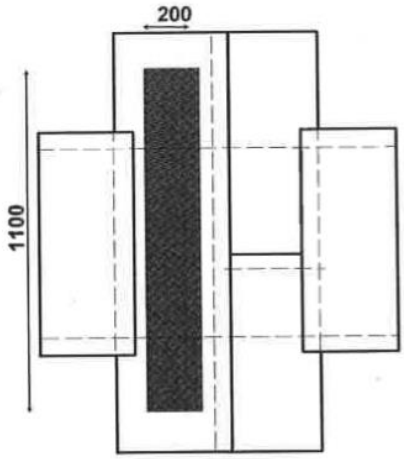

Fig. 5: Evaluation area for root and rhizome ingress in the surface of a tested sheet or coating in the case of > 50 instances of ingress per pot (dimensions in mm).

Retain samples are to be taken from the tested sheet or coating and must roughly reflect the overall result. The samples are to be stored according to section 5.

8 Test Report

No interim results may be disclosed in writing during the test.

After the end of the test, two copies of the complete test report will be drawn up by the test institute (1 copy for the test institute and 1 for the client); however, this only applies if the sheet or coating was proven to be root-resistant pursuant to section 2.11. Companies and products that undertake a test without successful results will not receive a test report, but a written notice stating that the sheet or coating was not proven to be root-resistant according to FLL.

The report may only be used in an unabridged form. It must contain the following:

- Manufacturer's information regarding the tested sheet in accordance with section 5,
- Detailed information about the preparation of the test pots pursuant to section 6 (or a statement that the test was performed according to the FLL guidelines, whereby the guidelines underlying the test are attached as an appendix),
- all results of evaluations pursuant to section 7, and
- a summary evaluation of the tested sheet pursuant to section 2.11 and 2.13.

The report must also contain the following formulations:

- "The test report contains … pages and may only be used in an unabridged form."
- "The test results are subject to the characteristics and material properties of the tested sheet or coating, which are listed in the report in accordance with requirements, as well as to the equivalent jointing techniques applied during the test."
- "Retain samples of the tested sheet or coating are stored by the test institute."
- "The test report was created on …… and has an initial validity period of 10 years. By obtaining the attestation from the test institute, the period of validity can be extended for a further 5 years at a time; however, this only applies if:

- the test specification has not undergone significant changes, and

- the tested product is still part of the applicant's current range."

A sample test report can be ordered from the FLL.

9 Responsibility

The client is responsible for:

- Procuring and installing the protective layer (see 2.3 and 6.1) and the sheet or coating to be tested (see 6.1),
- Provision of a material sample (see 5)
- Providing information regarding the sheet or coating (see 5)

The test institute is responsible for:

- Providing a suitable area for carrying out the test (see 4.1)
- Removing and storing a material sample (see 5)
- Procuring/mixing and installing the moisture layer and vegetation base layer (see 4.3, 4.6, 6.1 and 6.2)
- Procuring and installing the tensiometer (see 4.9, 6.1 and 6.1)
- Procuring the test plants or seed and planting the pots (see 4.10, 6.1 and 6.2)
- Caring for the plants during the growth period (see 6.3),
- Carrying out the evaluation (see 7), and
- Creating the test report (see 8).

The procurement of the experimental pots (see 4.2) can be performed by either the client or the test institute. The various responsibilities are to be defined as part of a contract between the client and the test institute. This contract should also make provisions for the assumption of test-related costs by the client.
A sample contract can be ordered from the FLL.