Test Report

Airtightness test of sealing products for penetrations of the products „pro clima KAFLEX und ROFLEX“

Manufacturer:
pro clima
Moll bauökologische Produkte GmbH

Airtightness system: penetrations

Darmstadt 12.01.2018

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Product:

1. KAFLEX duo: Sealing grommets for 2 cables, suitable for a diameter of 4.8-12mm
2. KAFLEX multi: Multiple cable grommet, for up to 16 cables, suitable for a diameter of 4.8-12mm
3. KAFLEX post: Cable grommets for subsequent installation
4. KAFLEX mono: Sealing grommets for 1 cable, suitable for a diameter of 4.8-12mm
5. ROFLEX 20: Sealing grommets for pipes, suitable for a diameter of 15-30mm
6. ROFLEX 50: Sealing grommets for pipes, suitable for a diameter of 50-90mm
7. ROFLEX 100 Sealing grommets for pipes, suitable for a diameter of 100-120mm
8. ROFLEX 200: Sealing grommets for pipes, suitable for a diameter of 170-220mm
9. TESCON Primer RP: Solvent-free primer

Product name: KAFLEX and ROFLEX
Tested size: Penetrations

1. Introduction

Alongside the airtightness across the surface of a building element, the airtightness of penetrations is a central prerequisite for an effective airtightness concept. A good level of airtightness of the building envelope is an essential aspect of its overall functioning, particularly in energy efficient buildings. This investigation took place under the most realistic possible boundary conditions within the framework of certification as a Passive House component in order to ensure that the tested products function in their installed state. In particular, the connection of the penetrations to typical adjacent materials will be examined in the context of certification. The connections of typical cables and pipes to concrete, hard engineered wooden panels (in this case OSB) and airtight membranes were examined, as well as the attachment methods and associated products.

2. Criteria

The Passive House Institute (PHI) has set specifications for the cables and pipes for which airtight solutions for penetrations shall be manufactured. The examination is carried out by two identical set ups on three different materials of the airtight layer. The airtightness of the penetrations was examined for a membrane, an engineered wooden panel and a concrete surface. The sealing of the penetrations was created by PHI using the products and methods chosen by the manufacturer. The instructions for use were also reviewed for comprehensibility and completeness.

Table 1: Sealed cables and pipes.

#	**Penetrations by**	**Amount**
1.	Cable House Connection, outer diameter 25mm (NYY-J 5x16mm²)	1
2.	Cable, outer diameter 8,3mm (NYM 3 x 1.5)	2
3.	Telephone cables, outer diameter 5,0mm (J-Y(ST)Y 2 x 2 x 0,60mm) together in one penetration	5
4.	Twin cable, outer diameter 2 x 5,0 mm (Twin 2 x WF65 Satellite/Antenna)	1
5.	HT Pipe DN 50 (smooth pipe)	1
6.	HT Pipe DN 110 (smooth pipe)	1
7.	Electro empty conduit (corrugated pipe) 25 mm outer diameter	2
8.	Spiral duct DN 180 (exhaust and outdoor air)	1
	Sum total of penetrations	**14**

The airtightness of 14 penetrations altogether are examined. In a single-family home are typically double the amount of penetrations, therefore 14 penetrations are manufactured and examined twice for each surface sealing material (OSB, concrete, membrane).

The values specified for PH certification of the system “penetrations“ can be taken from Table 2 below:

Table 2: Requirement classes for the certification of the system “penetrations“ according to the Passive House Institute specifications

Class	**Air permeability based on the circumference of the penetrations** @ 50 Pa [m³/(hm)]
ph**A+**	≤ 0.05
ph**A**	≤ 0.30
ph**B**	≤ 0.50
ph**C**	≤ 0.80

These apply for the overall performance of the products specified by the client for the sealing of penetrations.

In addition, a comprehensible processing guideline/instruction must be provided for the installation of the product, on which the test setup will be based. These must be available to all testers.

3. Materials to be tested

The required products to create the airtight penetrations of cables and pipes were chosen by the client and supplied to PHI.

According to manufacturer’s instructions, products of the series **KAFLEX** were used for sealing the cables. The pipes were sealed using products of the series **ROFLEX**. These are composed of elastic rubber grommets (EPDM) with partly self-sticking adhesive; in other cases they can be attached around the circumference with additional adhesive tapes. The use and application of the grommets took place in accordance with the manufacturer’s directions, which are described in the instructions for use.

The following products were delivered by the client on 21.10.2017 and on 17.11.2017 (including the instructions for use):

- KAFLEX mono, multi and post
- ROFLEX 20, 50, 100 and 200
- TESCON Primer RP

4. Setup of the penetrations

Examined were products and methods for the airtight penetration of cables and pipes through the airtight layer. Concrete panels, wooden panels and airtight membranes were utilized as typical construction component surfaces for penetrations. The airtightness of each 14 penetrations were measured together. In the process the tightness of each sealing between the grommets and cables/pipes, as well as the tightness between the grommets and the respective component surface was examined. A single-family home typically has twice as many penetrations, which is why each connection (wooden panel, concrete panel, membrane) was studied twice. In total 84 penetrations were created, sealed, and examined.

In the wooden panels, concrete panels and the membranes, ten recesses for the penetrations were created. The recesses are larger in diameter than the cables/cable bunch/pipes and were arranged equally for each component. The cables and pipes were attached to the bottom of the test apparatus, so they remained fixed during the measurements, when the surface sealing is deformed by the applied pressure. Afterwards followed the installation of all seals of the cables and pipes.

The installation of the grommets to the components took place when these were already mounted in the test apparatus. For sealing, a frame that was identical in construction to the sub-frame of the test apparatus was placed on the apparatus. The frame and counter frame were each equipped with a 5cm wide sealing surface, which served as a support for the airtight membrane. The counter frame was tightened to a defined torque using screws and a torque wrench. Tension-free and uniform installation in the test stand was possible, due to the even pressure of the counter frame.

In contrast to the connections to the wooden and concrete panels, the penetrations were sealed to the membrane without a hard base and therefore „suspended in the air“. Consequently pressing the grommets is only possible to a limited extent. This is equivalent to common workmanship, e.g. when installing in the slanting roof between the rafters.

Each test setup (connection to membrane, OSB, and concrete) was created and tested twice in order to minimize any influences by workers.

4.1 Sealing of the penetrations

Each setup was penetrated with 14 different cables and pipes sealed with the products of the manufacturer.

For each penetration of the cables and pipes the manufacturer chose the following products for sealing:

Table 3: Chosen products by the manufacturer for the different penetrations.

Cable / Pipe	Grommet
1 Cable House Connection (outer diameter: 25 mm)	ROFLEX 20
2 Cables (outer diameter: 8.3 mm)	KAFLEX mono
5 Telephone Cables (outer diameter: 5.0 mm)	KAFLEX multi
1 Twin Cable (outer diameter: 2 x 5.0 mm)	KAFLEX post
1 HT Pipe DN 50	ROFLEX 50
1 HT Pipe DN 110	ROFLEX 100
2 Electro Empty Conduit (corrugated pipe; outer diameter: 25 mm)	ROFLEX 20
1 Spiral Duct DN 180	ROFLEX 200

The cables were mostly threaded through the intended recesses separately. Only the five telephone cables were threaded through the recesses in a bundle. All seals were created according to manufacturer’s instructions.

ROFLEX 20 is a sealing grommet for pipes with a diameter of 15-30mm, which is why they are ideal for the sealing of the house connection. The sealing grommet is composed of the actual grommet (ethylene propylene diene monomer rubber, EPDM) and an adhesive sheet made from TESCON VANA for gluing onto the component. Also the two empty conduits (corrugated pipe) with an outer diameter of 25mm were connected with this grommet. In case of the corrugated pipe, make sure the grommet is concise with the smaller diameters (“valley”). The grommet cannot be between the grooves.

Fig. 1: House connection cable sealed with ROFLEX 20 (left) and connection to the empty conduit (corrugated pipe) with ROFLEX 20 (right).

The cables with a diameter of 8.3mm were sealed with the KAFLEX mono grommet. These cable grommets are used for a single cable with a diameter of 4.8-12mm. They also consist of an EPDM area and an adhesive sheet made of TESCON VANA.

Fig. 2: Sealing of a 3x1.5 NYM cable with KAFLEX mono.

Five telephone cables with a diameter of each 5.0mm were threaded together through one opening of the component surface and afterwards the grommet KAFLEX multi was attached. This cable grommet is for up to 16 cables with a diameter of 4.8-12mm. The cable grommet consists of an EPDM-mat, in which holes are punched by a user with a hollow punch as needed. A minimum distance between the holes has to be kept. Before threading the cables through the EPDM-sheet, the cables were bent twice at right angles for separation, in order to allow the flattest possible placement of the grommet on the surface. After pulling through the cables the grommet was attached according to manufacturer’s instructions with TESCON VANA adhesive tapes.

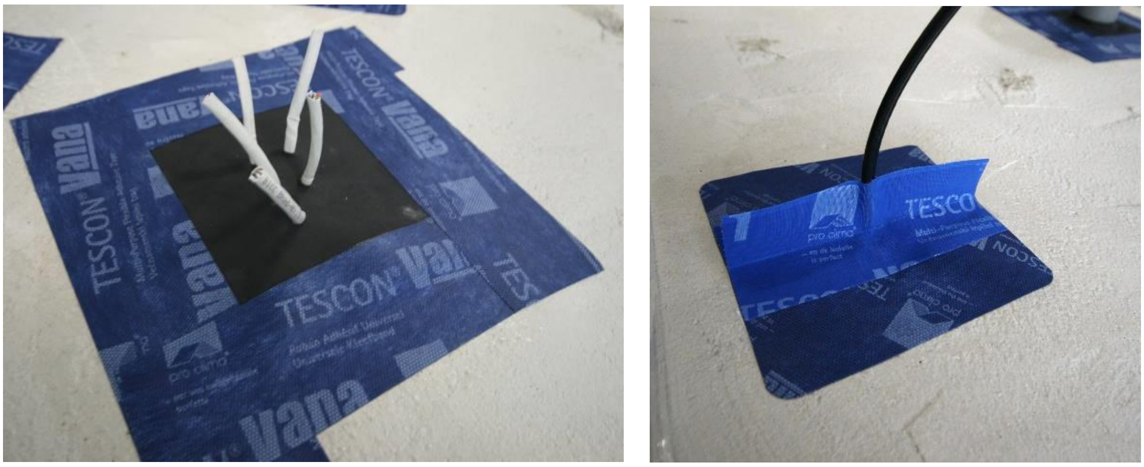

Fig. 3: **Penetration of five telephone cables with the cable grommet KAFLEX multi and the adhesive tape TESCON VANA (left).**
Connection of the twin cable using KAFLEX post (right).

The twin cables (2 x 5mm) were attached using KAFLEX post. This grommet type is used for subsequent installation; the cable does not have to be pulled through a hole. Therefore they are being used for pre-installed cables. KAFLEX post consists of special PP-fleece and a perforated PE-foil.

ROFLEX 50 was used to attach the HT pipe with a diameter of 50mm. These pipe grommets are intended for pipes with an outer diameter of 50-90mm. The sealing grommet is composed of EPDM. The EPDM sheet is subsequently attached to the component surface using the adhesive tape TESCON VANA.

Furthermore an HT pipe with a diameter of 110mm was part of the penetrations using the grommet ROFLEX 100. The sealing grommet is suitable for pipes with a diameter of 100-120mm. It consists as well of EPDM and a succeeding attachment with TESCON VANA.

Fig. 4: Adhesion of HT pipe DN 50 using ROFLEX 50 (left). HT pipe DN 110 attached with pipe grommet ROFLEX 100 (right).

The spiral duct with a diameter of 180mm was attached using ROFLEX 200, a pipe grommet for diameters of 170-220mm. The sealing grommet is made from EPDM and was attached concise around the circumference using TESCON VANA.

Fig. 5: Spiral duct (180 mm) attached using ROFLEX 200. The pipe was sealed with a balloon for the measurement.

4.2 Connection to membrane

The product INTELLO by the manufacturer pro clima was used as an airtight membrane. The membrane roll was cut into two meter pieces and the recesses were cut into the membrane. Afterwards the membrane was clamped into the test apparatus across their full width, so that they extended on all sides. After installing the penetrations, the grommets were installed. As described above. the membrane was “suspended in the air”, so pressing the adhesive tape was only possible with low pressure.

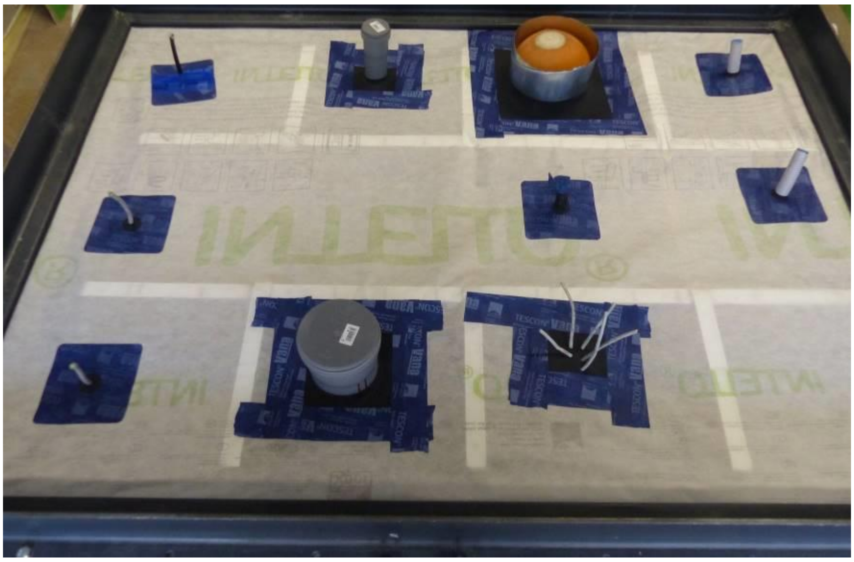

Fig. 6: Installed and attached penetrations on a membrane.

4.3 Connection to concrete

For the investigation of the concrete connection, a concrete slab was produced that fit into the test apparatus. The cables and pipes were threaded through the recesses and were fixed in the test apparatus. Before attaching the grommets, dust was brushed off the concrete slab and the Primer RP was spread thinly on the areas of adhesion. This is a wash primer for the grommets.

Fig. 7: Penetrations through the concrete slab; some of the cables or the EPDM sheet are still not attached.

4.4 Connection to OSB panel

For the connection to the engineered wooden panels, an airtight OSB panel was used (manufacturer SMARTPLY PROPASSIV; air permeability 0.01m³/(hm²) ±0.04). Before clamping the panel into the test apparatus, the cables and pipes were threaded through the recesses and also fixed to the bottom of the test apparatus. Afterwards the cables and pipes were attached using the corresponding grommets.

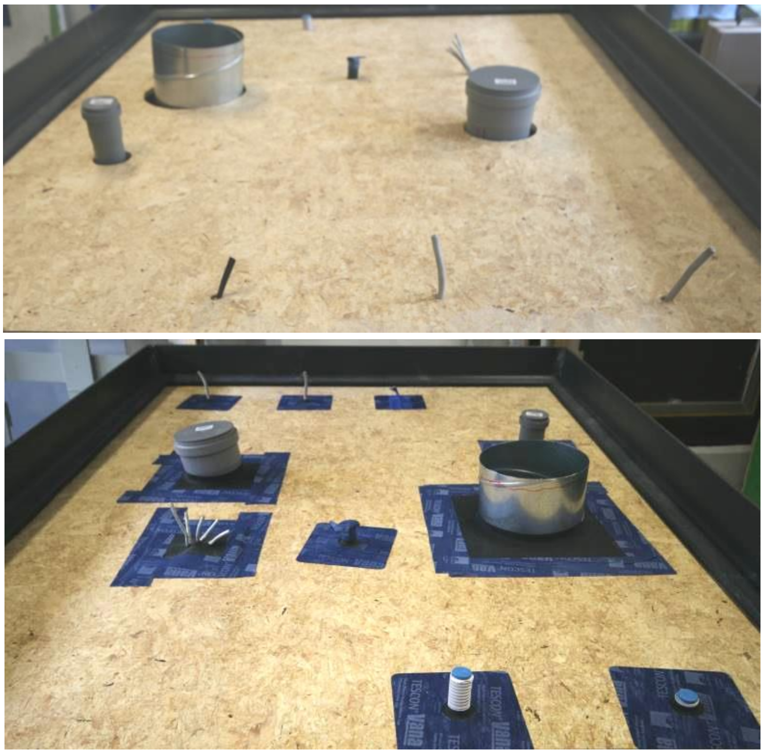

Fig. 8: OSB panel with penetrations without attachments in the test apparatus (top). OSB panel with attached penetrations in the test apparatus (bottom).

5. Test procedure

After setting up in the test stand and attaching the membrane, a measurement was carried out in compliance with DIN EN 12114. For this measurement, the following pressure stages were set for positive and negative pressure: 50, 100, 150, 200, 250, 300, 350 Pa. First the residual leakage of the test stand for all pressure stages was measured and documented for each measurement (reference measurement). For this, the test apparatus was closed using an airtight board. The infiltration air of the test stand determined was thus deducted from the result of the measurement afterwards.

In each measurement, the conveyed volume flow was measured and recorded for each individual pressure difference. With these pairs of measured values, it was possible to calculate the leakage coefficient ***C*** in accordance with DIN EN 12114 Appendix B.

From the two series of reference measurements and the two series of actual measurements, smoothing functions were determined through a regression analysis. After deducting the leakage of the test stand itself (reference measurement), the leakage flow was determined as an average value from the series of positive and negative pressure measurements. The volume flow is related to the total length of the penetrations (circumference of all cables and pipes added), in order to receive the specific leakage flow for each meter of penetration.

The measurement of the penetrations took place in the time period from 20.11.2017 to 12.01.2018.

6. Test results

The test results are shown in the following tables and figures, sorted according to the component material. The requirement classes for the certification of penetrations are additionally entered in the diagrams.

6.1 Penetrations through membrane

Penetrations through	
Membrane	x
OSB	
Concrete	

Table 4: Test results of the two measurements of the penetrations through membrane attached using products of the series KAFLEX and ROFLEX. [1]

Circumference of all penetrations	1,46 m

Pressure stages	Pa	50	100	150	200	250	300	350
Penetrations through membrane #1								
total volume flow	m³/h	0,34	0,58	0,79	0,99	1,18	1,36	1,53
test stand leakage	m³/h	0,05	0,07	0,09	0,11	0,13	0,14	0,16
specific air volume flow	m³/h	0,29	0,50	0,70	0,88	1,05	1,21	1,37
leakage volume flow based on length	m³/(h m)	0,20	0,35	0,48	0,60	0,72	0,83	0,94
Penetrations through membrane #2								
total volume flow	m³/h	0,36	0,60	0,80	0,98	1,15	1,31	--
test stand leakage	m³/h	0,05	0,08	0,10	0,11	0,13	0,14	--
specific air volume flow	m³/h	0,31	0,52	0,70	0,87	1,02	1,17	--
leakage volume flow based on length	m³/(h m)	0,21	0,36	0,48	0,59	0,70	0,80	--

Average

PHI - assessment V_L = **0,21** m³/(h m)

resulting in an airtightness class of **A** according to PHI $V_L \leq 0,3$

[1] In the second measurement, the measured value of the pressure level 350Pa in Table 4 and Figure 10 was not taken into account due to an implausible, deviating value.

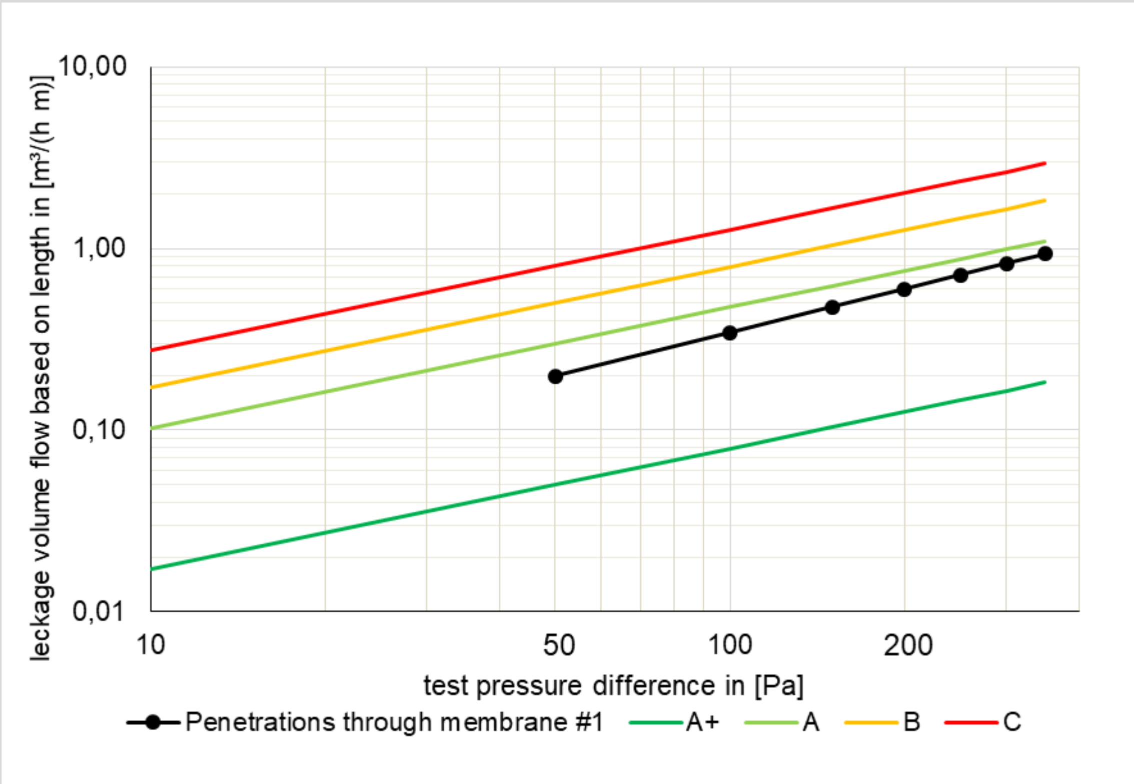

Fig. 9: **Series of measurements for the sample “penetrations through membrane #1“. The Certification Classes A+ to C according to PHI are entered in addition.**

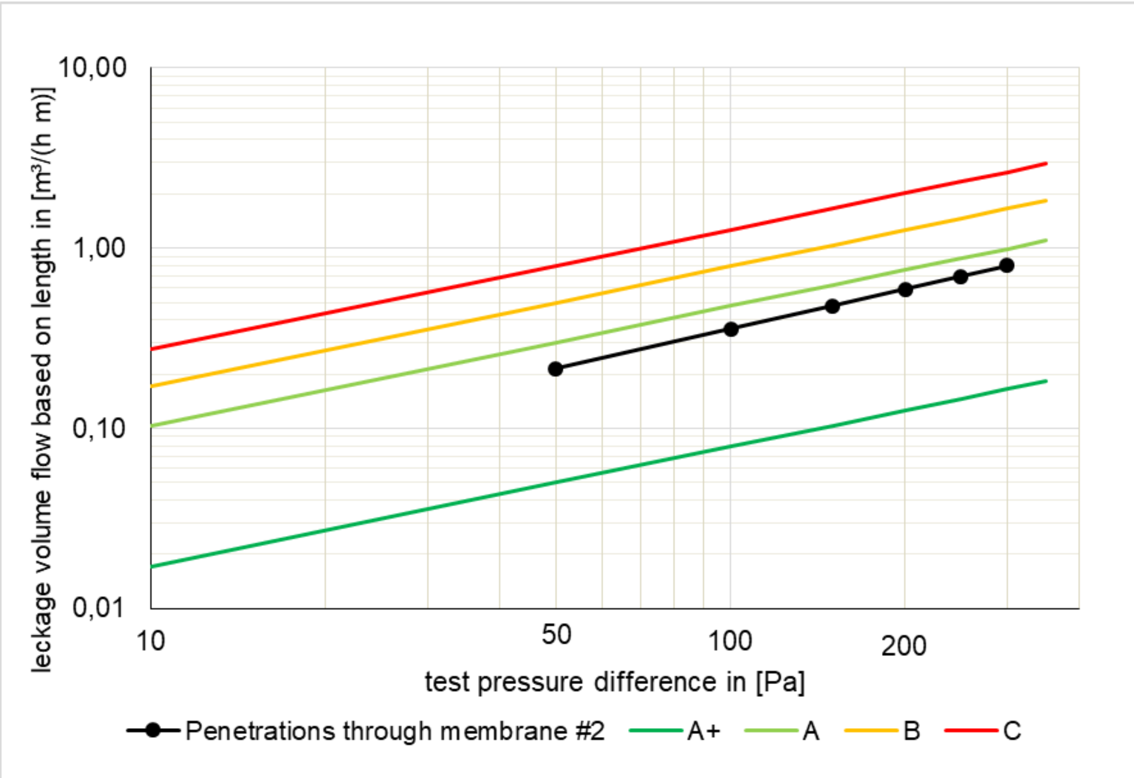

Fig. 10: **Series of measurements for the sample “penetrations through membrane #2“. The Certification Classes A+ to C according to PHI are entered in addition.**

In the investigation of the seals of the grommets to the cables and pipes, or to the component surfaces, small leakages were discovered at the following points:

- Adhesion of the twin cables and adhesion to the membrane (KAFLEX post)
- EPDM rubber to the spiral fold of the 180mm pipe (ROFLEX 200)
- On the cables of the multiple penetrations of the telephone cables, due to the slight tension of the stiff cables (KAFLEX multi)

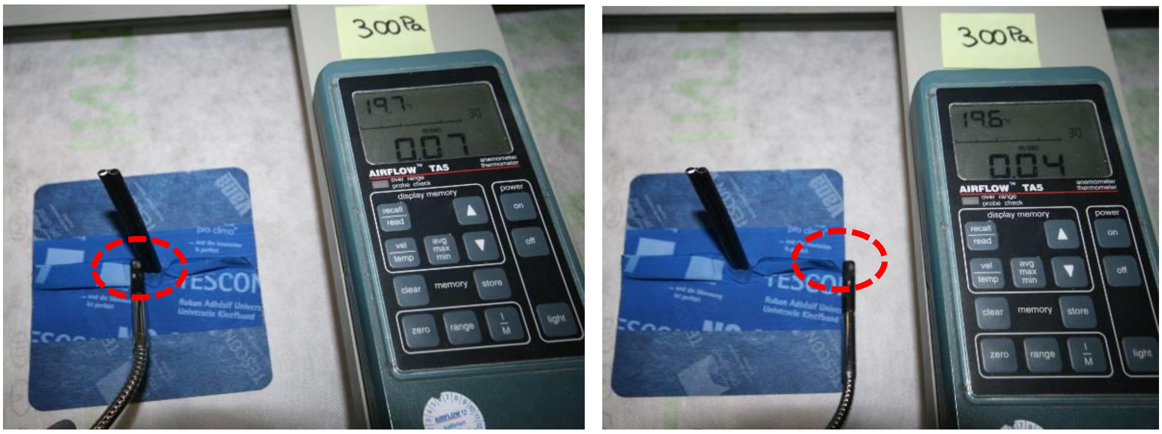

Fig. 11: Small residual leakages at 300Pa negative pressure at KAFLEX post. The air speed is measured using a thermoanemometer.

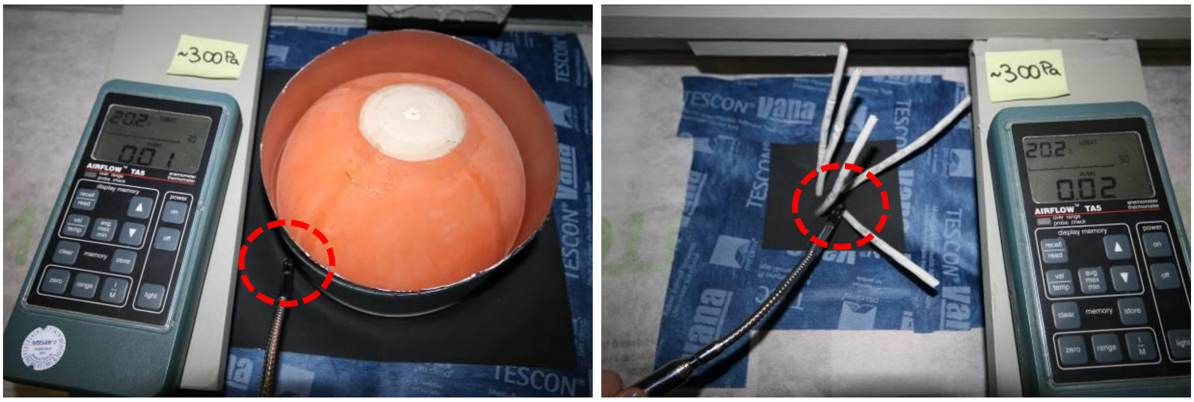

Fig. 12: Small residual leakages at 300Pa negative pressure at the sealing of ROFLEX 200 and the spiral duct (left) and at the sealing of KAFLEX multi and the cables (right). The air speed was measured using the thermoanemometer.

These are small residual leakages, only measureable at a pressure difference of 300Pa. At 50Pa, the value was below the measuring limit of the thermoanemometer and was therefore not detectable.

6.2 Penetrations through OSB

Penetration through	
Membrane	
OSB	x
Concrete	

Table 5: Test results of the two measurements of the penetrations through OSB attached using products of the series KAFLEX and ROFLEX.

Circumference of all penetrations	1,46 m

Pressure stages	**Pa**	**50**	**100**	**150**	**200**	**250**	**300**	**350**
Penetrations through OSB #1								
total volume flow	m³/h	0,38	0,59	0,77	0,92	1,05	1,18	1,30
test stand leakage	m³/h	0,06	0,09	0,12	0,14	0,17	0,19	0,21
specific air volume flow	m³/h	0,33	0,50	0,65	0,77	0,89	0,99	1,09
leakage volume flow based on length	m³/(h m)	0,22	0,34	0,44	0,53	0,61	0,68	0,75
Penetrations through OSB #2								
total volume flow	m³/h	0,32	0,51	0,67	0,81	0,94	1,07	1,19
test stand leakage	m³/h	0,07	0,11	0,14	0,17	0,20	0,23	0,26
specific air volume flow	m³/h	0,25	0,40	0,53	0,64	0,74	0,84	0,93
leakage volume flow based on length	m³/(h m)	0,17	0,27	0,36	0,44	0,51	0,57	0,64

Average

PHI - assessment V_L= **0,20** m³/(h m)

resulting in an airtightness class of **A** according to PHI $V_L \leq 0,3$

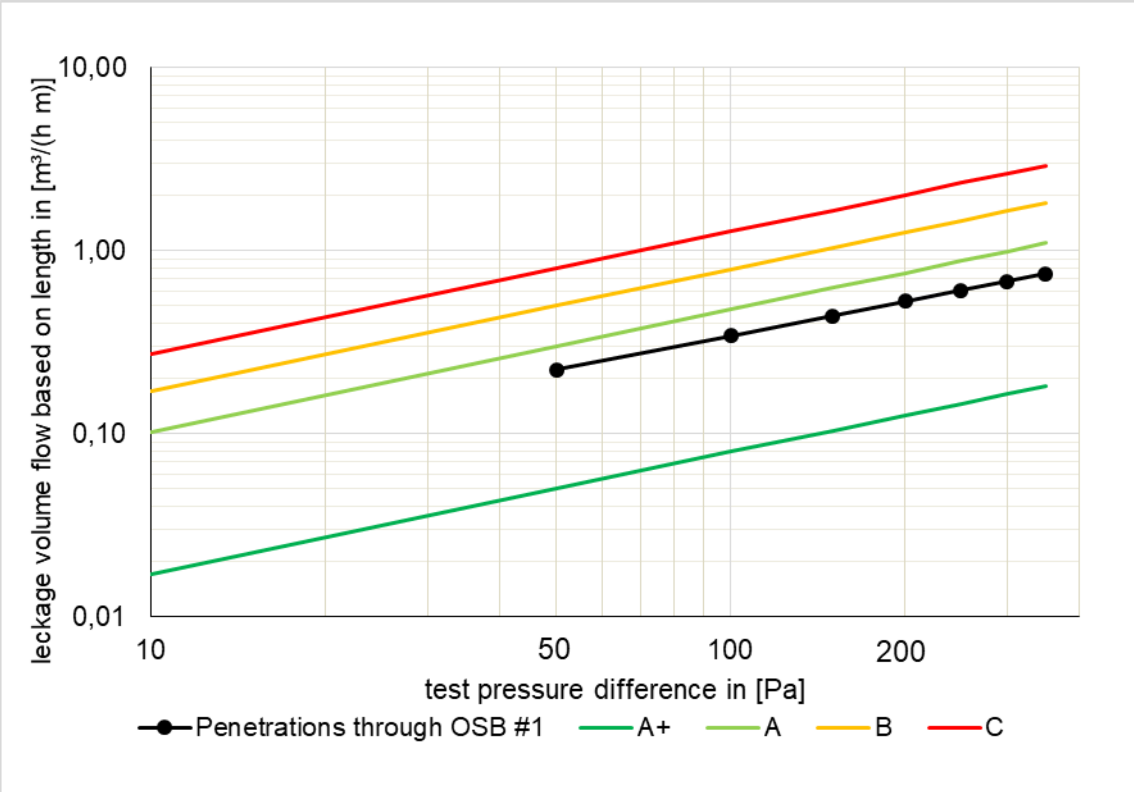

Fig. 13: Series of measurements for the sample "penetrations through OSB #1". The Certification Classes A+ to C according to PHI are entered in addition.

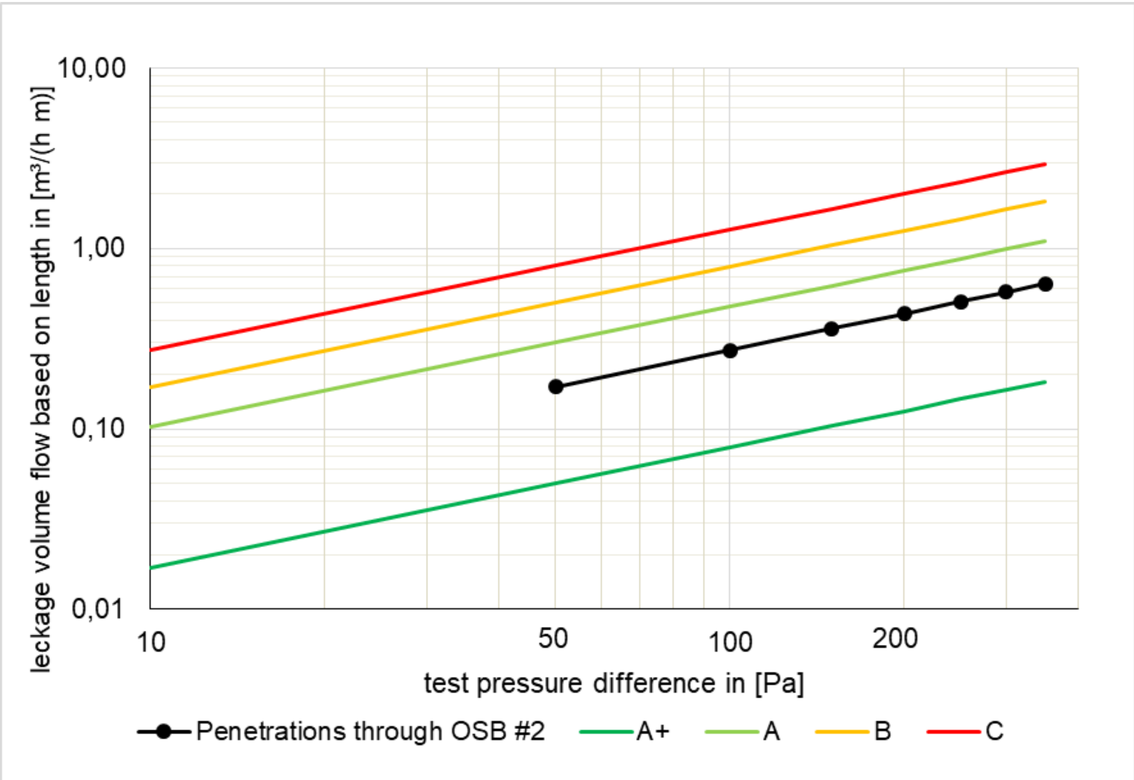

Fig. 14: Series of measurements for the sample "penetrations through OSB #2". The Certification Classes A+ to C according to PHI are entered in addition.

Fig. 15: Small residual leakages at 50Pa negative pressure are only detectable at KAFLEX post (middle) (connection to OSB as well as the cable). On the KAFLEX multi and ROFLEX 200 grommets, no leakages are detectable on the cables (left) or on the spiral duct (right). The air speed was measured using a thermoanemometer.

6.3 Penetrations through concrete

Penetrations through	
Membrane	
OSB	
Concrete	x

Table 6: Test results of the two measurements of the penetrations through concrete attached using products of the series KAFLEX and ROFLEX.

Circumference of all penetrations	1,46 m

Pressure stages	**Pa**	**50**	**100**	**150**	**200**	**250**	**300**	**350**
Penetrations through concrete #1								
total volume flow	m³/h	0,31	0,51	0,68	0,83	0,98	1,11	1,24
test stand leakage	m³/h	0,08	0,12	0,16	0,19	0,22	0,24	0,27
specific air volume flow	m³/h	0,23	0,38	0,52	0,64	0,76	0,87	0,97
leakage volume flow based on length	m³/(h m)	0,16	0,26	0,35	0,44	0,52	0,59	0,67
Penetrations through concrete #2								
total volume flow	m³/h	0,38	0,62	0,82	1,01	1,18	1,34	1,49
test stand leakage	m³/h	0,06	0,10	0,14	0,17	0,20	0,22	0,25
specific air volume flow	m³/h	0,32	0,51	0,68	0,84	0,98	1,12	1,24
leakage volume flow based on length	m³/(h m)	0,22	0,35	0,47	0,57	0,67	0,76	0,85

Average

PHI - assessment V_L= **0,19** m³/(h m)

resulting in an airtightness class of **A** according to PHI $V_L \leq 0,3$

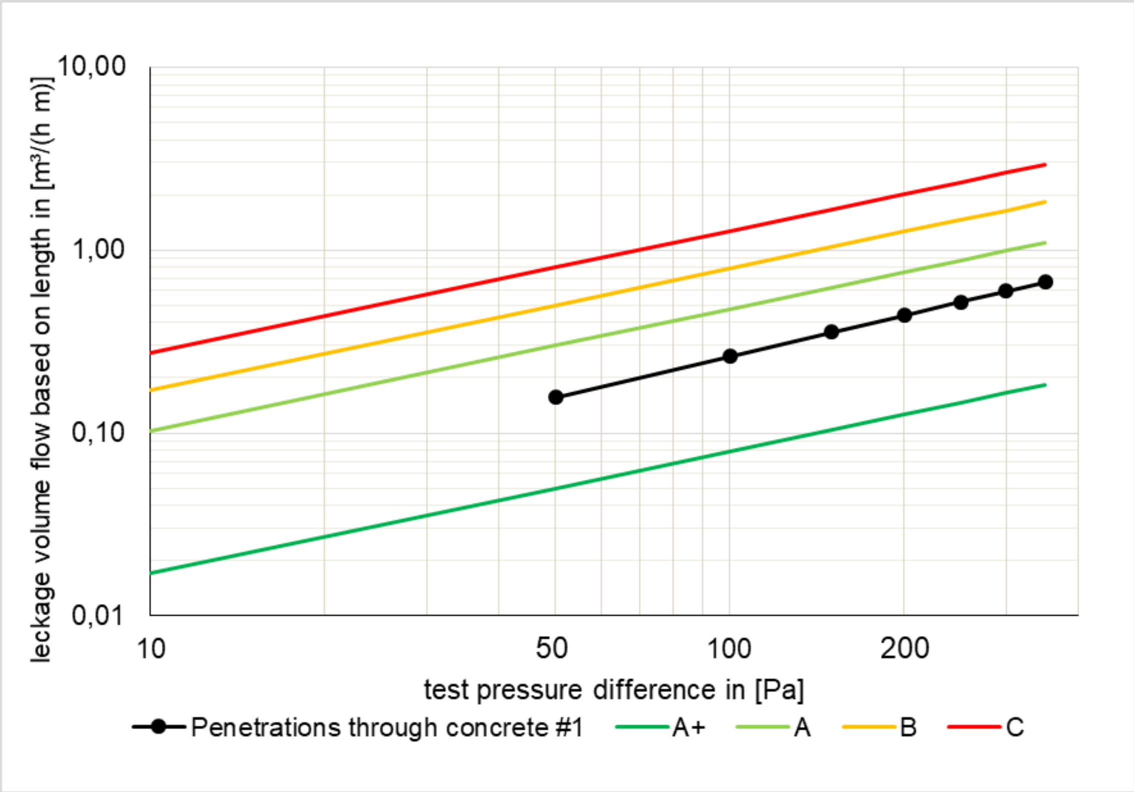

Fig. 16: Series of measurements for the sample "penetrations through concrete #1". The Certification Classes A+ to C according to PHI are entered in addition.

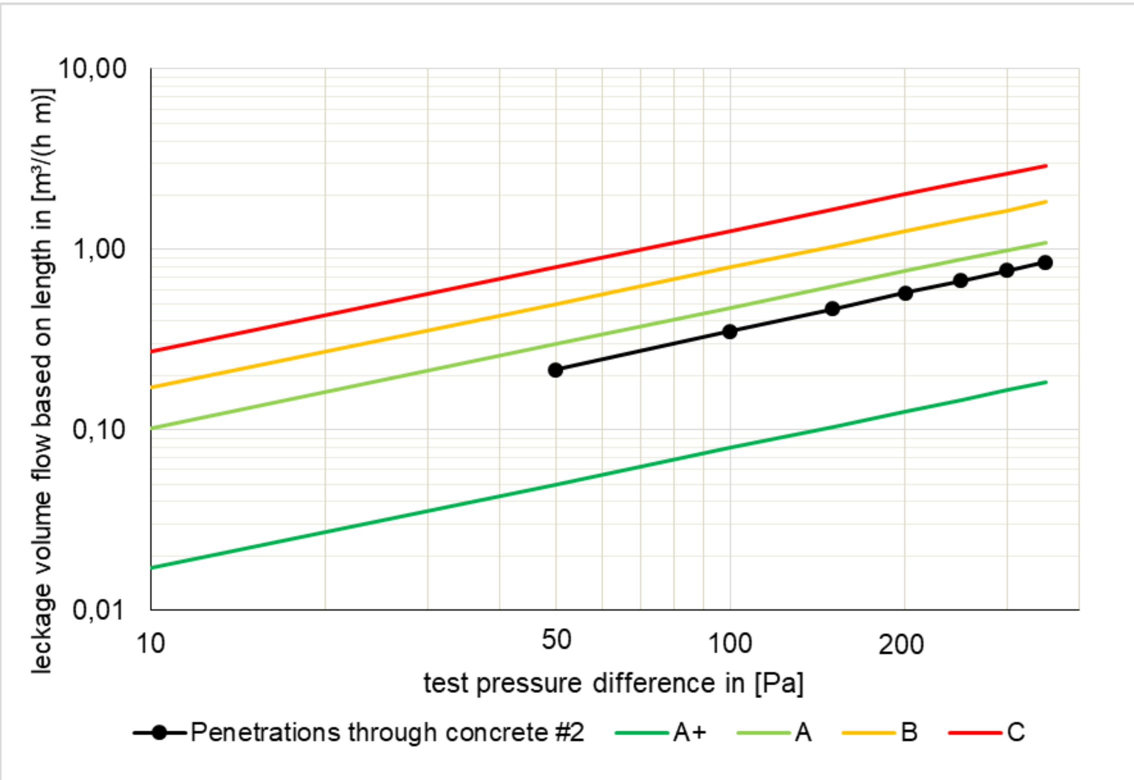

Fig. 17: Series of measurements for the sample "penetrations through concrete #2". The Certification Classes A+ to C according to PHI are entered in addition.

The adhesive tape is 60mm wide, meaning the adhesive sheet on the concrete is around 30mm. It is recommended to increase the adhesive sheet around the EPDM rubber with another layer of adhesive tape when using the larger grommets. The connection would thereby be more secure.

Fig. 18: Residual leakages at 300Pa negative pressure occur at ROFLEX 200 (left) at the spiral fold as well as at KAFLEX post (middle and left). The air speed was measured using a thermoanemometer.

6.4 Assessment of the leakages in all material surfaces

The detected residual leakages at the spiral fold of the 180mm pipes is due to the shape of the elevation of the fold: The EPDM-rubber is not completely tight to the upper and lower part of the fold and therefore residual leakages remain.

In case of the 5 telephone cables, the stiffness of the cables results in a mechanical stress on the sealing points of the EPDM rubber, which leads occasionally to small residual leakages.

The sealing with KAFLEX post regularly caused one or two leakages at the connection to the twin cable. Due to the shape of the cable section, it was not possible to make it completely airtight. Also at the connection to the ground, multiple leakages have been detected in the vertical attachment where the grommet is joined together. In the case of an improper application of the attachment, a tension results, leading to poor adhesion to the surface.

Overall it can be concluded that only smaller residual leakages occurred, which were found only at higher, component-atypical values of 300 Pa.

7. Test conditions

The average indoor climate conditions during the measurements and storage were as follows:

Indoor temperature: 20.5 °C
Indoor air humidity: 41 % r.H.

8. Measurement devices

A laminar flow element by the company TetraTec® Instruments was used for measuring the volumetric flow. The differential pressure was measured using an automated performance testing system (APT) by the manufacturer The Energy Conservatory.

Table 7: Overview of the used measurement devices

Name	Device type	Serial number	Measurement range	Measurement accuracy
LaminarMasterFlow-System	LMF	PH796	0-85 l/min	2% in the range of 8-80 l/min
TEC Automated Performance Testing	APT	0072 4	0-2000 Pa	1 %

9. Results

The results of these measurements were compiled and the overall average value was created according to the type of connection. On average, this resulted in an air permeability of **0.20 (±0.01) m³/(hm)** standardized for a test pressure of 50Pa. The PHI certification class “ph**A**“ was achieved.

Table 8: Overview of the results of the airtightness measurement.

Average value of	m³/(hm) @ 50 Pa
Penetration through membrane	0.21
Penetration through OSB	0.20
Penetration through concrete	0.19
Overall	**0.20** (±0.01)

Table 9: Requirement class achieved by the examined product for certification as an “Airtightness system penetrations“, according to the specifications of the Passive House Institute.

Class	**Air permeability based on length** @ 50 Pa [m³/(h m)]	**Class achieved**
ph**A+**	≤ 0.05	
ph**A**	**≤ 0.30**	✓
ph**B**	≤ 0.50	
ph**C**	≤ 0.80	

Darmstadt, 12.01.2017

Søren Peper

Søren Peper