Test principles

for granting general technical test certificates
for reusable pressure-filled movement-joint p-seals, types I and II,
where the base structure is concrete and/or steel and where the seal is against
non-pressing water, railway ballast stones and fire

PG-FMPB-1

Part 1: Family test principles
- General information -

1st Edition (09.2020)

fibre optics
Fibre Optics CT GmbH Consulting & Testing

Testing laboratory for
cable, connector, sensor
and sealing technology
Roland Wolf
www.fibreoptics.de

Contents

Page

0 Preliminary remarks

The Building Rules List, published by the DIBt (German Institute for Construction Engineering) in agreement with the highest supervision authorities of the federal states, does not contain any mention of the construction product "sealing materials for location between structural components made of concrete in waterproofing buildings". In the document it is stated that a general building authority test certificate - abP - is required for these construction products, as proof of usability. Proof of conformity is provided by a "declaration of conformity issued by the manufacturer after previous testing of the construction product by a recognised testing centre". Federal building regulations decree that in Germany such sealing materials may only be employed if they have this certification and are marked with an "Ü-Zeichen" (a national standard which is equivalent to and replaced by CE marking in Europe). An abP may only be issued by a testing lab that is officially recognised for the task by the highest supervision authority of the applicable federal state.

In the absence of standards for this area of application, the test principles (PG-FMPB) presented here in draft form have been developed, tested and optimised to the best of the knowledge and belief of the author and on the basis of familiar standards. They are intended to serve as a basis for testing and assessing sealing materials intended for location between structural elements made of concrete and/or steel for protection against-non-pressing water run-off, with a view to obtaining general building-inspection test certificates.

In the event of new findings, the PG-FMPB principles may be modified - with certain reservations - in cooperation with working groups of inspecting authorities such as DB-Systemtechnik, BASt, DIN, DIBt etc.

Similar PG-ÜBB test principles, (test principles for transitions) were agreed upon by the centres listed below in a working group on the theme of "general building-inspection test certificates for joint-sealing in concrete structural elements with good water-penetration resistance", chaired by Dr.-Ing. U. Hornig, MFPA Leipzig, with the participation of members of the DAfStb subcommittee for "waterproof structural elements made of concrete": and the following testing centres:

- TU München, MPA BAU, München
- MPA Nordrhein-Westfalen, Dortmund
- MPA für das Bauwesen, Braunschweig
- KIWA Bautest Dresden GmbH, Dresden
- MFPA Leipzig GmbH, Leipzig

1 Scope of application

The PG-FMPB test principles apply to non-regulated, pressure-filled, reusable p-joint-seals - also in combination with flaton-flex A, a material in tape or brush form that builds an insulating layer, ballast-stone protection tape or a joint-chamber injection tube, in accordance with DIN 18195-8: 2011 [7] – used against non-pressing water, penetration by ballast stones, smoke and fire. The pressure-filled, reusable p-joint-seals must provide an effective seal for movement joints in bridges, cut-and-cover tunnelling, or transitions or passageways between smooth or subsequently milled-out component joints. It is assumed that in use these joints can open up to a max. width of 150 mm.

Once on-site installation is completed and the reusable p-joint-sealing element is connected to the concrete or metal structural element, it can function as an approved seal against penetration by smoke or fire, for protection against ballast stones, or as a water-drainage channel and/or an injection microtube. To insert the sealing cushion into the joint from above or below, a special temporary holding device can be used.

Compression of the reusable p-joint-seal between the structural elements is achieved by means of pressure-filling (p) at 20 °C ± 3 °C.
Pressure regulation required during operation, due to changes in temperature and/or joint width, is usually carried out by a fully automatic pressure equalising system for negative changes in joint width
bF (joint width) = 0 ≥ to 5 mm.

Example: Without a monitoring system and pressure equaliser, the changes in joint width bF would lead to an increase of lateral pressure:

Change in joint width	bF = 0 to 10 mm	Rise in pressure +0.6 bar (600 g/cm²)
	bF = 0 to 3 mm	Rise in pressure +0.2 bar (200 mbar)

2 Usability and conformity certification

2.1 Usability certification

When testing pressure-filled reusable p-joint-seals, the manufacturer/applicant must provide the testing centre with all necessary information. In addition to a description of the product, details must also be given of the desired water pressure head of the seals to be installed as well as structural details of the connection, including requirements concerning the substrate condition and details of corners and butt joints. The instructions for processing and installation should also be presented.

The type and scope of the tests required for usability certification depend on the type of reusable p-joint-seal and the essential functional properties it should have. Tests are described in sections 4 and 5. An assessment of suitability also includes the aspect of durability, according to the criteria laid down in section 5. Test results must be documented in a test report, on the basis of which a general building-inspection test certificate is issued.

2.2 Conformity certification

The Building Rules List A, Part 2, section 2, No. 2.48 declares that ÜHP* conformity certification procedure should be followed for these products. This means that confirmation must be submitted that the connection between seal and movement joint is in conformity with the regulations governing the general building-inspection test certificate. This applies to each manufacturing plant and requires a declaration of conformity from the manufacturer, based on the initial test carried out by a recognised testing centre and on the manufacturer's own in-house production control (WPK).

* ÜHP is the German abbreviation for a declaration of conformity issued by the manufacturer after previous testing of the product by a recognised testing lab.)

2.2.1 Initial test

The scope of the initial test includes all identifying tests and selected function tests. These must be specified by the inspecting body in the general building-inspection test certificate.

The initial test can be omitted if certification of usability with a validity of at least 24 months can be provided after samples from on-going production have been tested.
This should be in the form of a one-off building-inspection approval for joint-sealing in a bridge and/or tunnel constructed using the cut-and-cover method. The initial test can also be omitted for system components that are in conformity with a standard, or that have already been tested within the scope of a general building-inspection test certificate.
The initial test is required if the above-mentioned cases do not apply, or if the conditions of production have been modified. The test must be carried out by a testing centre that is approved by the construction supervision authorities for the testing of this product group.

2.2.2 In-house production control

The standard DIN 18200:2000-5 [1] obliges the manufacturer/applicant to set up in-house production control with a "tightness" function test for the entire production of the flat, tubular, cushion-shaped p-seal. In this way it can be established that the manufactured products comply with the provisions of general building-inspection test certification.

The scope of in-house production control and the tolerances that must be observed are agreed on with the applicant. They must be defined specifically for the product by the testing centre in the inspection certificate. The results of production control must be archived for at least 5 years and made available on request from the testing centre.

3 Identifying tests

Insofar as there is a lack of directives in the DIBt PG-FBB Teil x [8] or DIN EN 1366-4:2010 [9] standards, only those sealing products may be installed whose usability as a seal in bridges, tunnels, overhead or transit areas has been confirmed by a single building-inspection approval with a validity of 24 months, or that have received a general building-inspection certificate (abP) or European Technical Approval (ETA).

Identifying tests must be carried out on all reusable pressure-filled sealing components. The necessary tests and testing methods are agreed upon by the applicant and the testing centre, on the basis of Table 3.1. Unless otherwise stated, all tests are carried out to evaluate application-specific, mechanical and environmental behaviour under operational conditions, in accordance with DIN EN 60794-1-21 / 2016 [2] and DIN EN 60794-1-22 / 2016 [3].

Table 3.1 contains examples of what certification could cover. Under certain circumstances, further tests or a different type of test might be necessary.

Table 3.1 Identifying tests

	Reusable sealing components	3.1	3.2	3.3	3.3	3.4	3.5	3.4	3.4
	Reusable p-sealing	X	X	X	X	Combi X	Combi X	Combi X	X
	Swelling sealing tape	X	X	X	X	X	X	X	
	Cellular rubber tape	X	X	X	X	X	X	X	
	Ballast stone protection	X	X	X		X	X		
	Water drainage channel	X	X			X	X		
	Injection microtube	X	X			X	X		
	Fire resistance flaton-flex A	X	X			X	X		
	Joint repair and inspections before/after installation of reusable p-joint-seals								

Key:

3.1 Material basis
3.2 Resistance
3.3 Geometry
3.3 Mass per area
3.4 Mechanical properties
3.5 Environmental properties
3.4 Lateral pressure properties
3.4 Leak rate

3.1 Basic materials

The basic materials used must be stated for all components of the system, quoting relevant standards where applicable.

3.2 IR spectrum

IR spectral scans are recorded within the range 4000 cm^{-1} to 500 cm^{-1}, on the basis of DIN EN 1767 [12] and DIN 51451 [11] Details of the type of device used, measurement conditions and sample preparation should be indicated, along with the test results.

3.3 Geometry / dimensions / outer characteristics / mass per area

The geometry and outer characteristics should be described. The materials used must have a smooth outer surface and in cross-section they must be free from pores, homogenous and without cracks, inclusions, creases or defects. The dimensions must be recorded with suitable measuring instruments and in accordance with the relevant standards. Each individual measurement should be taken 10 times, whereby the degree of precision of the measurement is product-specific. Mass per area must also be indicated. In addition to information regarding test standards followed and the conditions of testing, details must be provided of all individual values, averages and standard deviation.

For pressure-filled reusable p-joint-seal constructions that can be used in combination, the following information must also be provided:

- Profile widths and thickness
- Seal contact surface in the case of movement joints, width, installation depth
- Drawings of the reusable p-joint-seal constructions

3.4 Mechanical properties

Determination of mechanical properties (depending on the type of pressure-filled reusable p-joint-seal construction)

3.4.1 Construction

xx reusable p-joint-sealing without outer sealing tapes of swelling material or cellular rubber	leak rate, short-term and long-term burst pressure, tensile strength, stretchability, elastic modulus
QV reusable p-sealing ZK reusable p-sealing in conjunction with outer sealing tapes	Lateral pressure, impact, adhesion, tensile strength

3.4.2 Components

- Ballast-stone protection
- Water drainage channel

} Tearing, lateral pressure, impact

- Injection microtube, lateral pressure, guideline value

- Fire resistance flaton-flex A Tape
- Brush strip

} Tensile strength, fire propagation

- Pressure equalising system for movements of not less than 4 mm

3.5 Environmental properties

Determination of environmental properties (depending on the type of reusable p-joint-seal)

3.5.1 Reusable p-joint-sealing

- Temperature resistance, chemical resistance
- Sealing efficiency against non-pressing water (i.e. pressureless water runoff)

3.5.2 Reusable p-joint-sealing – coated with QV or ZK

- For joints with a straight, rounded, arched or rectangular profile
  Reusable seals overlapped for lengths of up to 24 m or
  superimposed for lengths of up to 100 m
- For vertical and parallel movements up to 150 mm

3.5.3 Reusable p-joint-sealing - BF-BHB or SVS tape or FIJ-MKR microtube

- Sealing efficiency of BF-BHB-(flaton-flex A) for fire resistance
- Sealing efficiency of SVS tape against railway ballast stones
- Sealing efficiency of the MKR injection microtube for treating cracks in the joint chamber

4. Testing of properties crucial for the product function

4.1 Service life of pressure-filled p-joint-sealing

4.1.1 Resistance of pressure-filled p-joint-sealing to continuous pressure

The durability of the reusable seal, derived from a short-term determination of resistance to continuous pressure, can be attested to by GEMTEC or a similar testing-place, who can then provide a statement regarding the total leak rate.

For this purpose and in accordance with the requirements of the Deutsche Telekom TS 0307/96 [4], at least two uncoated test samples are placed circularly in a duct with an inner diameter of ~ 100 mm. They are then filled with a gas medium (air) to 2.0 bar and the total leak rate is determined in a vacuum after 10 min, followed by 24 h resting time.

Minimum requirement	TS 0307/96	
Diffusion	≤ 4.4 x 10^{-6}	mbar / sec
	corresponding to 138 mbar / year	

4.1.2 Long-term determination of the burst pressure of reusable p-joint-sealing

A statement regarding the durability of pressure-filled reusable p-joint-sealing is made possible by in-house production control of 100% of the products, with long-term testing.

In order to do this, reusable p-joint-seals without double-sided coatings of permanently elastic swelling material or cellular rubber and with lengths from 1-24 m are set up linearly and filled with a gas medium (air). The p-joint-seals have the following dimensions: width 13.5 for joint widths of 2-6 cm and width 28.5 for joint widths of 2-15 cm.

For long-term tightness, on-site inflation should be at a pressure that is 100% safe, as shown below:

Installation and delivery recommendations

Width	Pressure filling
135 mm	P 300 - 350 mbar / 20 °C
285 mm	P 150 - 200 mbar / 20 °C

- Pressure filling instructions
- Joints with low inherent stability
- Damage to structural components due to excessive filling pressure = possible lateral pressure overload
- A pressure equalising system is necessary for negative parallel or vertical joint movements > 5 mm

In-house testing instructions

Width	Pressure filling
135 mm	P 900 - 1000 mbar / 20 °C ± 3 %
285 mm	P 500 - 600 mbar / 20 °C ± 3 %

Requirement:

- 100 % of the items should be tested
- Tightness stabilised after min. 36 h / 20 °C ± 3°C
- Fall in pressure ≤ 0.5 %
- Test report
  Pressure recording
  Delivery protocol

4.1.3 Short-term determination of the burst pressure of reusable p-joint-sealing

A statement concerning the durability of reusable p-joint-sealing is made possible by the time-dependent determination of this property in in-house type-approval testing. Durability is affected by environmental conditions such as temperature, joint movement or installation errors.

For testing purposes, p-joint-seals are laid out linearly between metal "small-profiles" simulating an average joint width of 3 cm, or for type L a max. joint width of ~ 8 cm, or for type S 16 cm. The seals are then evenly filled with pressurised air until they burst.

The test report should contain details of testing, type and length of joint seal, pressure-recording and temperature.

4.2 Connection to the movement-joint chamber

These function tests as described in section 5 are carried out on single samples. The samples are installed and then tested according to the method chosen:

- Test setup
- Testing procedure
- Requirements
- Evaluation

The time-dependent single test makes a direct statement about the installed samples possible, corresponding to the test method described.

4.2.1 Long-term adhesive tensile strength and shear strength of the in relation to movements that are parallel and vertical movement to the joint edge

The time-dependent determination of adhesive tensile strength and shear strength after movements of up to 100 mm makes it possible to make a direct statement about the durability of reusable p-joint-seals at reduced pressure (service lifetime - leak rate).

The adhesive tensile strength and shear strength test is carried out on the basis of DIN EN 60794-1-21 / 2016 [2]. Adhesive strength, pressure-filing and movement are presented in a diagram as a function of the leak rate (service lifetime) and ist reduction.

4.2.2 Durability of the lateral pressure resistance of reusable p-joint-seals

- Coating of swelling material or cellular rubber
- Protection against ballast stones
- for movements parallel to the sealing plane

The time-dependent lateral-pressure resistance test carried out on pressure-filled reusable p-joint-seals makes it possible to make a direct statement about changes in sealing-cushion filling pressure and lateral pressure exerted on the joint seal as a function of joint movement.

The setup used for testing the coating on the reuseable seal is equivalent to DIN EN 60794-1-21 (section on lateral pressure):

- a > 30 x 30 cm steel base plate
- a 10 x 30 cm pressure plate
- a DMS load cell and a pneumatic measuring device

For seals with ballast-stone protection, the following are used:

- a > 30 x 30 cm steel base plate
- a ~ 3 x 10 x 30 (H x W x L) container filled with ballast stones (basalt)
- a ballast-protection layer with the laminate side facing the ballast stones
- a DMS load cell and a pneumatic measuring device

The lateral pressure test is carried out on the basis of DIN EN 60794-1-21 / 2016 [2].

4.2.3 Fatigue strength of the sealing combination with ballast-stone protection, against abrasion and water penetration during movements parallel and vertical to the joint edge

The time-dependent determination of the abrasion resistance of ballast-stone protection or surface waterproofing makes it possible to make a direct statement about the durability of the joint-seals against penetration by water or ballast stones.

To do this, two concrete slabs or concrete supports, a container filled with basalt ballast stones and a pulling device are set up as described below:

- Two parallel concrete supports with a 5 cm joint gap (in accordance with the manufacturer's specification) with a height offset of at least 2 cm
- Railway ballast-stone protection or surface waterproofing in accordance with the manufacturer's specification, attached to the concrete support
- Pulling-container for the ballast stones
- Filling: basalt, to a height of at least 50 cm

The abrasion test is equivalent to IEC 60794-1-21 / E 18 [2]

- The pulling direction is parallel to the joint edge, from A to B and back
- Number of cycles: at least 10
- Speed: 10 m / min
  The pulling force and movements are shown in a diagram. Abrasion resistance (resistance to penetration by water) is tested and evaluated visually.

4.3 Durability in relation to environmental factors

4.3.1 The time-dependent determination of the resistance of the joint-sealing to temperature fluctuation and joint movements parallel to the sealing plane makes it possible to make a direct statement about the durability of the joint seal and the lateral pressure exerted by structural elements

To do this, two steel-reinforced concrete slabs are connected to an adjustable joint chamber for joint widths 2-10 cm by means of 4 threaded rods.
Slab dimensions: 6 x 30 x 50 cm

The test setup is positioned correctly, in accordance with the intended sealing application, in a climate chamber IEC 60068-2-14, Abs. 2 Prüfung Nb, based on IEC 60794-1-22 / F1 [3].

A pneumatic pressure-measuring system is then connected to the test setup.

1. Procedure for testing tightness against non-pressing water (pressureless water runoff)

Temperature cycling:	-30 °C (up to +45 °C)
Joint width:	3 cm
	-30 °C (dwell time 6 h)
	+45 °C (dwell time 6 h)
Number of cycles:	30 After 30 cycles, the joint is widened to 6 cm

Temperature and pressure progression are shown in a diagram as a function of time and change in pressure (tightness).

2. Procedure for test of tightness in relation to fire resistance

The test setup, in combination with flaton-flex A [4b], the material which forms the insulating, fire-resistant layer on the seal, is positioned correctly in a climate chamber, in accordance with the intended application, IEC 60068-2-14, Abs. 2 Prüfung Nb [4].

The test setup is then connected to a pressure-measuring system via a pressure-equalising system

Temperature cycling:	-40 °C up to +70 °C
Joint width:	3 cm
	-40 °C (dwell time 6 h)
	+70 °C (dwell time 6 h)
Number of cycles:	20
	After 20 cycles joint movement
	from 3.0 cm to 1.5 cm
	from 1.5 cm to 6.0 cm

4.4 Usability of reusable p-joint-sealing against non-pressing water, for controlled drainage of water runoff, with reference to the state of the substrate

After the joint walls have been smoothed off, it is possible to make direct statement about the time-dependent determination of the watertightness of a reusable p-joint-seal which is subject to the formation of icicles. For this, all areas within the joint chamber are photographed with a telescopic endoscope camera and documented, evaluated and then smoothed and cleaned with a saw-milling machine.

In the case of joint chambers where injection drilling has caused deep cracks or flaking in the concrete, an MR-injection tube is attached above the p-joint-seal. After the seal has been inflated, the tube is used to gel-inject the damaged areas.

4.5 Usability of reusable p-joint-sealing against smoke and fire and for controlled water runoff, with reference to the required flaton-flex A tape coating

With regard to the time-dependent determination of the long-term sealing efficiency of the joint-sealing combination, in which movements before, during and after flame treatment are measured, it is only possible to make a direct statement if a pressure equalising system is used, as prescribed by building regulations.
For the test, a strip of flaton-flex A tape is glued centrally along the length of the reusable p-joint seal, on both sides. The seal is then inserted into the joint chamber, flush with the lower joint edge, and inflated according to the installation and delivery specifications.

For testing sealing for cables/ducting systems, flaton-flex A fringed tape is used. The tape is glued onto the reusable p-joint-seal and is arranged in a circle or lengthwise round the cable/duct configuration.
After inflation of the reusable p-joint-seal, the flaton-flex A fringed tape is attached by wire to the cable or duct bundle.