

WOLF Newsletter

Pilot project: Joint-sealing in the Johannesgraben tunnel in Stuttgart

Extract from a local newspaper:

Tunnel closed for renovation work

Stuttgart: Drivers using the motorway junction in the Stuttgart or Böblingen/Sindelfingen direction next Saturday must expect delays due to work on overhead expansion joints in the Johannesgraben Tunnel, Bundesstraße 14 in Stuttgart-Vaihingen. The tunnel will be closed in both directions from 3 pm on Saturday, 14th October till 7 am on Sunday, 15th October.



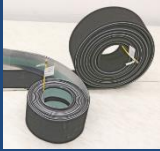
The Johannesgraben tunnel is a six-lane tunnel at the beginning of the 831 motorway in Stuttgart-Vaihingen. It is 220 Meter long and was constructed in 1979.

There have been considerable problems for years with black ice and icicles, due to leaking joints. Various attempts at retro-sealing the joints in the past proved to be unsuccessful.

Stone Engineering was commissioned by Stuttgart Regional Council (RPS) to find out what was causing the leakage, investigate the state of selected joints and test the suitability of sealing technology developed in 2011 by the Stuttgart company, Wolf GmbH as a solution for the problem.

The joint-sealing system

WOIF® GmbH



Wolf GmbH

Supplier of the patented joint-sealing valve system

The inflatable sealing cushions can be installed independently of weather conditions (in dry or rainy weather, or even in standing water),

Ms Gabriele Henrich

On-site support provided by a team of experts



StoNe Engineering

Over 40 years' experience in construction practice.

Planning, project management and coordination of civil and structural engineering sealing projects

Project management, implementation and monitoring of the work involved in preparing and installing the joint seals.

Mr Jörg Neumann Mr Roland Stoll

with a six-man installation team

ibf Ingenieurbüro Prof. Flohrer
Sachverständigenbüro für Bauwesen
Beratung ■ Gutachten ■ Qualitätssicherung
Werkstoffe ■ Instandsetzung ■ Prüfverfahren

Practice-oriented, neutral specialist for concrete structures

Honorary member of the German Concrete and Construction Engineering Association (Deutscher Beton- und Bautechnik-Verein, DBV).

Prof. Claus Flohrer, engineer

fibre optics
CT Consulting & Testing GmbH



Fibre Optics CT GmbH

Testing lab for cable and sealing systems

Development and function testing of the patented joint-sealing system.

Mr Roland Wolf, Mr Martin Wolf

The assignment

In the past, it was not possible to seal the tunnel adequately.

Several sealing products, representing the state of technology at the time, had already been tried out without success, as the sealing was not reliable. In frosty weather icicles and black ice had to be removed regularly by the motorway maintenance staff.

Stuttgart Regional Council commissioned Stone Engineering with the sealing of a pilot joint, using the economical Wolf joint-sealing (valve) system.

Since 2011, Wolf GmbH air-inflatable sealing cushions (valve) had been used to successfully seal 37 bridges for the German Rail company, DB-Netz AG and 8 bridges for the Austrian Rail company, ÖBB. A total of 1305 joint-sealing cushions were installed in joints with widths from 3 to 12 cm.

The Johannesgraben tunnel project was the first opportunity for Wolf GmbH and the Fibre Optics CT GmbH test and research lab to install sealing cushions in a tunnel built with the open construction method, for protection against the periodic entry of water under pressure.

1. Analysis: Leakage in the overhead joints

- The state of the construction had to be assessed, and if necessary, provisional sealing with Wolf GmbH inflatable (valve) sealing cushions for longitudinal movement joints installed
- The reasons for water penetration had to be investigated, with subsequent sealing of the outer wall support element.

2. Finding an economical overall solution

3. Testing the feasibility of a sealing solution on a Fibre Optics CT functional model

4. Training session for the installation team using the Fibre Optics CT functional model

5. Analysis: Assessment of leakage in the overhead joints, segment 4/5 and between the outer wall supports and ceiling element (lengths 19 m and 15 m)

- Analysis of the existing leak points in the joints (ceiling and supports) after removal of previously-installed joint-sealing material (with standard sealing materials). Provisional sealing with the Wolf GmbH inflatable sealing system.

Work stages in detail:

- Clearing (scraping) out of existing sealing material in the joint cavity to a height of ~ 50 cm and a length of ~ 40 m; inspection of the state of the joint edges
- Inspection of the condition of both outer wall supports and the ceiling element to a length of at least 8 m. Removal of concrete debris, nails etc.
- Depending on the state of the joint edges, provisional sealing of the ceiling element and outer wall supports Wolf (valve) sealing cushions
- Writing up a report

Testing the chosen sealing solution on a functional model

Training of the installation team

The team of experts from Stone Engineering and Wolf GmbH were confronted with the challenge of sealing leaking support and ceiling elements with Wolf joint-sealing cushions under extremely difficult conditions. A model trial was carried out in advance, to test the functionality of the joint-sealing cushions, which were specially developed by Fibre Optics CT GmbH (FO) for this area of application, and their installation in accordance with the supply and installation specifications laid down in WO08 Part 4. To avoid delays and installation errors, training with the functional model was also provided for the Stone Engineering installation team.

On-site installation situation

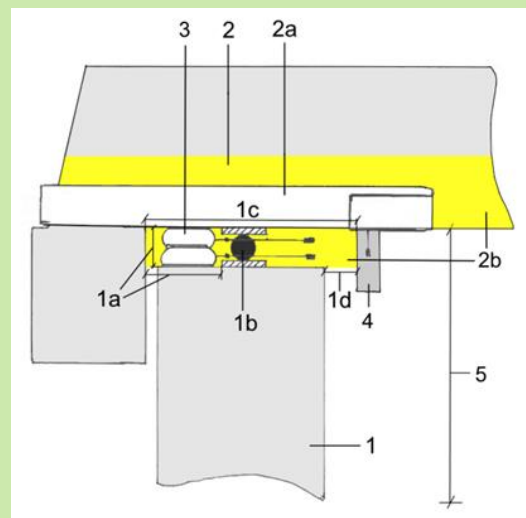
Winter



Summer



Example: Outer wall supports



1 Outer wall

1a Seal (valve) for the outer support
Sealing area of the ceiling element
B = 15 - 30 cm
H = 12 cm

1b Distance between supports

1c Work space ~120 cm for inspection, preparation, repair work and sealing-cushion installation

1d Access to sealing area for inner supports
B = 30 cm

2 Ceiling joint of a segment ~ 46 m

2a Sealing cushion (valve) in the ceiling joint

2b Joint cavity sealing area for ceiling element and supports

3 Sealing cushions (valve) for supports

4 Cable channel and spotlight

5 Height of work space ~ 6 m



Photo: Training of the installation team

1a: Surface covered in gravel, grain size 3 - 8 mm

.../ Testing the chosen sealing solution on the functional model

Sealing the outer wall supports

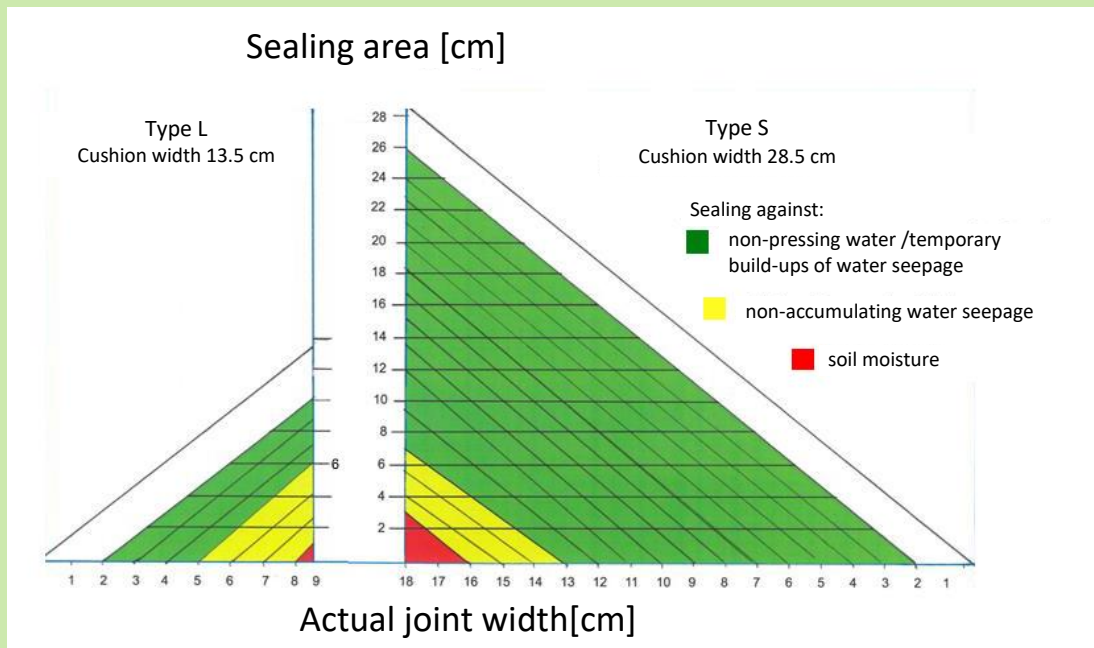
On-site conditions (sealing dimension specification): Installation dimensions

**width of sealing surface 15-20 cm,
height of sealing surface for supports
and ceiling elements 12 cm**

This joint cannot be sealed with the standard sealing cushions:

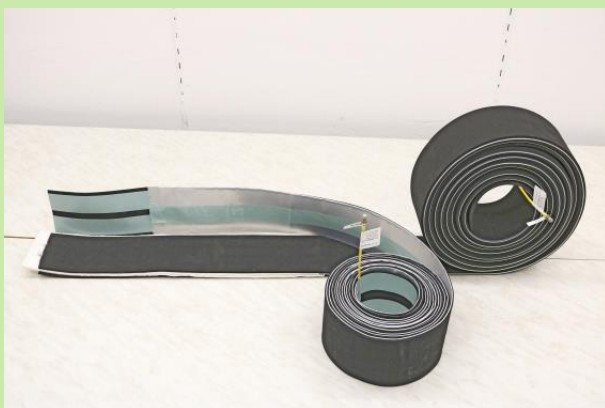
Type L (cushion width 13.5 cm) is for a max. height of 6 cm

Type S (cushion width 28.5 cm) is too wide.



Solution:

Two joint-sealing cushions of type L, width 13.5 cm, are placed on top of each other on-site and glued together. The sealing cushions are suitable for sealing heights of up to 12 cm.



The Wolf GmbH reusable joint-sealing system

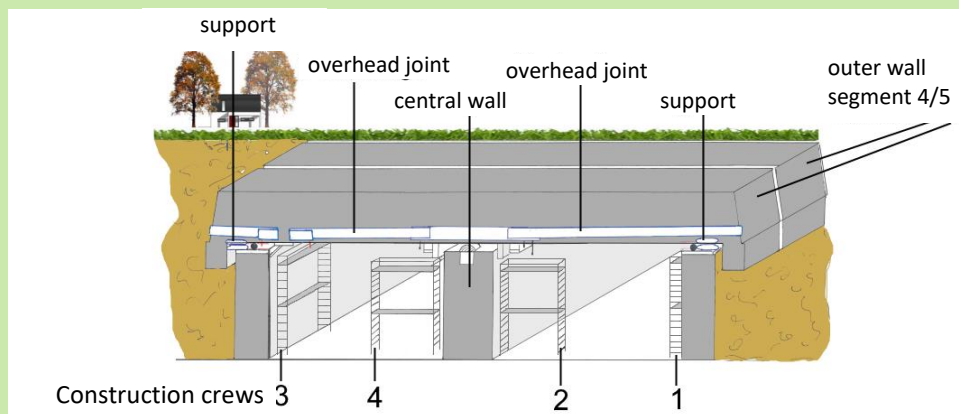
The Wolf joint-sealing system can be removed non-destructively for routine inspections and inflated 4 times (i.e. it can be reused 3 times). In order to be reused after it has been non-destructively removed, it must be wound without kinking round a mandrel ≥ 150 mm and sent to Fibre Optics CT GmbH. Fibre Optics CT will carry out a 2-3 day tightness check and, if necessary, replace the coating.

Stone Engineering

Planning & implementation: sealing of the overhead joints, supports and ceiling element

In practice: Mr Neumann used a camera to analyse the state of the overhead joint cavities. Unfortunately, they were so damaged by previous gel sealing material that extra repairs on the joint edges were necessary after provisional sealing with Wolf sealing cushions.

Thanks to the good preparation work, the whole team was able to deal with the unexpected problems that arose during the tunnel closure period.



The Stone Engineering installation team were divided into 4 2-man crews.

Crew 1: Outer wall and supports in the Singen direction

Crew 2: Removal of old joint sealing above the lane in the Singen direction

Crew 3: Outer wall and supports in the Singen direction

Crew 4: Removal of old joint sealing above the lane in the Stuttgart direction



Construction crews 3 and 4, Stuttgart direction



Construction crews 1 and 2, Singen direction

Sealing of the supports and ceiling element – the first challenge

Tasks assigned to construction crews 1 + 3 and 2 + 4

- Erection of scaffolding
- Removal of the pigeon guard
- Clearing out of concrete and metal debris rubbish in the supports and ceiling element to a length of 4 m to both sides (accessed from the ceiling joint): photographic documentation of the state of the construction.

This had to be carried out under extremely difficult working conditions, at the back of a recess that was only 12 cm high.

The state of the construction was documented throughout the 12-hour installation period by specialists Professor Flohrer, Mr Neumann, Mr Stoll and Mr Roland Wolf, who worked at a height of 5 m in unfavourable conditions.



Prof. Flohrer's assessment of the debris in the supports raised further difficulties. The poor condition of the surface at the back of the support, segment 4/5, meant that extensive clean-up operations were necessary.



Debris in the support area



Support area



Concrete debris



Concrete debris, formwork timber and nails

Tasks assigned to construction crews 1 + 3 and 2 + 4

Sealing cushions for the support and ceiling element areas were pulled into the back of the ~ 20-cm wide support area over a length of 8 m.



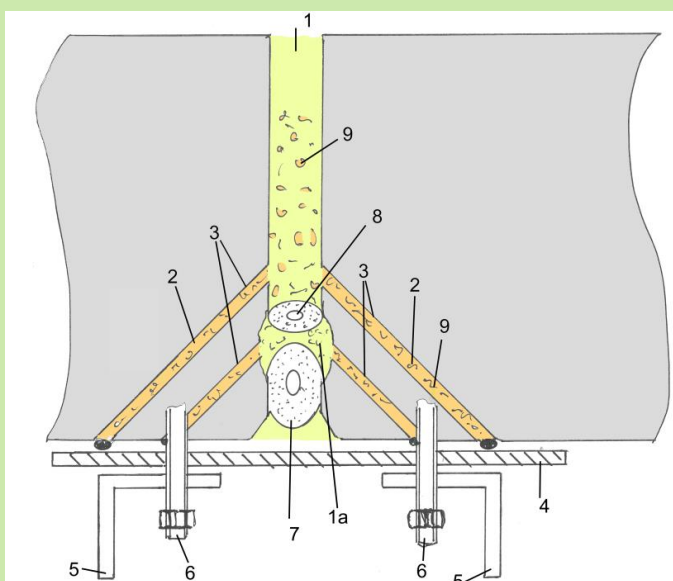
Under supervision, the sealing cushion for the outer wall ceiling element was installed across the previously installed cushion for the support.



Sealing the ceiling joint – the second challenge

Implementation by construction crews 2 + 4

Old material had to be cleared from the joints, lengths 19 m and 15 m, under difficult circumstances (at night, at temperatures between 7 °C and 14 °C). This was overhead work and had to be done manually, to a depth of 40 cm. Damage to the joint edge was inspected in each case by Mr Neumann, Mr Stoll and Prof. Flohrer, and repair methods were discussed.



- 1 Joint cavity
- 1a Areas with chipped concrete
- 2 Injection channels at 50-cm intervals
≥ 80 in the Singen direction
≥ 60 in the Stuttgart direction
- 3 Injection channel
- 4 Sealing strip width 25 cm
- 5 Steel profile 5 x 5 cm
- 6 Screw attachments at 20-cm intervals
≥ 190 in the Singen direction
≥ 150 in the Stuttgart direction
- 7 Sealing profile Ø 45 cm, 30 cm
- 8 Heating tape or sealing tape
- 9 Dried gel material, granulation size ~ 3 - 5 mm

.../ Sealing the ceiling joint

A total of ~ 190 kg backfill material was removed from the joints



Inspection of the ceiling joint cavities during the tunnel closure period



There was continuous discussion regarding the state of the support and ceiling element joints.



Where the joint edges were damaged due to injection channel drillholes, it was almost impossible to install the temporary sealing cushions for the ceiling joints.

Photo right: Injection ports

Photo below: Joint edges damaged by injection; ports and chipped areas in the ceiling joint of the Johannesgraben tunnel



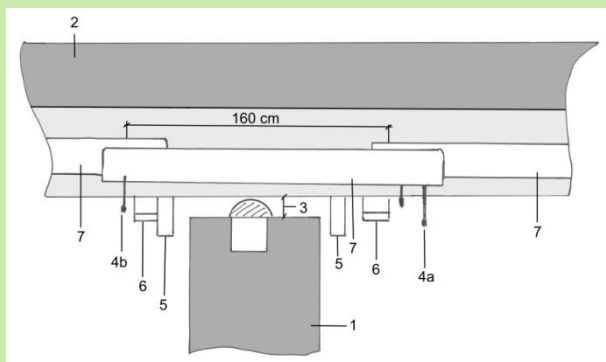
Status 06.02.2020

Sealing the central wall ceiling joint – the third challenge

To seal the ceiling joint in the central wall, four sealing cushions (valve), one pair on top of the other, had to be inserted into the joint cavity under difficult circumstances. Each cushion was 0.7 – 0.8 cm thick.

In the early hours of the morning, the first 15-metre long ceiling sealing cushion (7) was fitted from the outer wall (in the Stuttgart direction) to the central wall (1), and inserted over cable channels (5) and lighting (6), until it overlapped the central wall cushion (4b) by 30 cm. The 19-metre long cushion (7) was then fitted similarly between the central wall cushion and the outer wall (in the Singen direction).

An unexpected problem was caused by the chips in the joint edges and concrete pockets > 0.5 cm, which made it difficult to overlap the sealing cushions in the central area, as the two cushions together had a thickness between 1.4 and 1.6 cm and the joint width varied.



- 1 Central wall width 100 cm
- 2 Sealing area (joint cavity segment 4/5)
- 3 Height of the support/overhead element 12 cm
- 4a Wolf sealing cushion for central wall, QADK/VV (2 valves)
- 4b Valve No. 2
- 5 Cable channels
- 6 Installation of the sealing cushions is hampered by lights at intervals of 160 cm
- 7 Wolf sealing cushions for overhead joints in the Stuttgart and Singen directions, with 30-cm overlaps (4a, 4b) in relation to the central wall cushion



Summary after completion of the installation work done on 14.10.2017

Due to heavy traffic, the six-lane street tunnel could only be closed completely at certain times. As a result, information regarding the exact state of the joint walls could not be obtained prior to installation. This could only be done after the joints had been cleared.

A sealing trial was agreed upon, to facilitate the assessment of the opportunities and limitations of the sealing system for this area of application.

Evaluation of the sealing trial carried out on 14.10.2017

During the sealing cushion installation, cracks, spalling and pockets of rubble were observed at various points along the selected joints. These ageing effects are well-known in practice and have been the subject of detailed discussion in many publications. There was also additional damage to joint edges caused by previous injection-channel drilling.

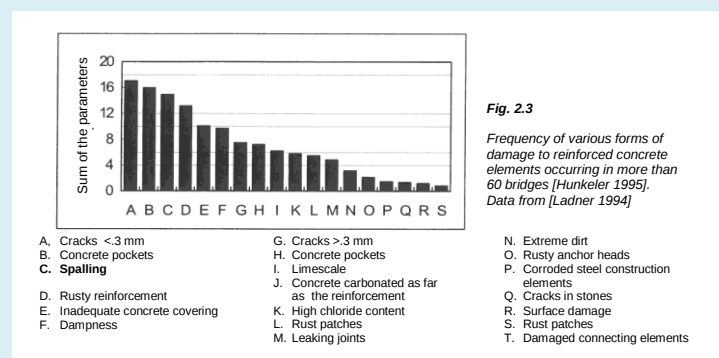
All damaged areas, including over 140 injection boreholes would need to be completely repaired.

Extract from the publication "Risk of concrete spalling due to reinforcement corrosion"

Published by: Swiss Department for Environment, Transport, Energy and Communication, Swiss Federal Roads Authority

Author: TFB, Technik und Forschung im Betonbau, Wildeg (Technology and Research in Concrete Construction)

"A common deficit is, for example, spalling (Fig. 2.3). Cracks in concrete are also very common. They may be the first indication of spalling, or may have other causes (Table 2.1)."



Cause of cracks	Characteristics of cracks	Conductive conditions	Remedies
Hydration heat	Separating and bending cracks	"Massive components"	Cements with low hydration heat, avoidance of rapid cooling, reinforcement to restrict cracking
Shrinkage	Surface cracks (early shrinkage), separating and bending cracks (drying-out shrinkage)	Early/extreme shrinkage	Restriction of drying-out (post-treatment), avoidance of grease in concrete, reinforcement to restrict cracking
Temperature	Separating and bending cracks	Temperature fluctuation	Expansion joints and reinforcement to restrict cracking, application of a pre-load
(Direct) external pressures	Hair, separating, bending and shear cracks	Depending on utilisation	Restriction of cracking through reducing steel tension by means of • low concrete covers • thin steel diameters • high level of reinforcement • good properties of composite steel

Table 2.1: Cause of cracking in concrete construction elements (not taking into account corrosion in reinforcement and concrete) [Nürnberg 1995]

How the state of a joint affects sealing efficiency

Wolf joint-sealing cushions straighten out on inflation. Relatively small isolated unevennesses are filled out by the sealing cushions, but larger ones are not. In the latter case, adequate tightness can unfortunately not be achieved.

Repair of the existing unevenness was not included in the scope of the sealing-trial order. For future sealing cushion installations, surface repairs would be a prior condition if reliable tightness is to be achieved without a joint-smoothing process. Assessment of the sealing efficiency of the cushions used in the trial was carried out a few days later by Stone Engineering and Wolf GmbH. The result was that there were a few leaks in the area of the central wall. An official follow-up inspection for a more exact assessment was set for 25.10.2017.

Result of the follow-up inspection of the overhead joint (Singen direction), 25.10.2017

In order to carry out the inspection of the installation work, some traffic lanes were partially closed on 25.10.2017.

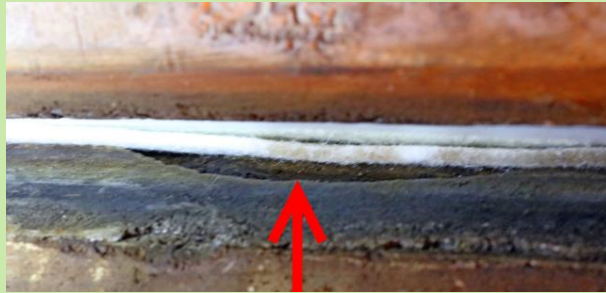
Results:

While the traffic lanes were closed, scaffolding was erected.

The air was then removed from the 19-metre overhead joint-sealing cushion



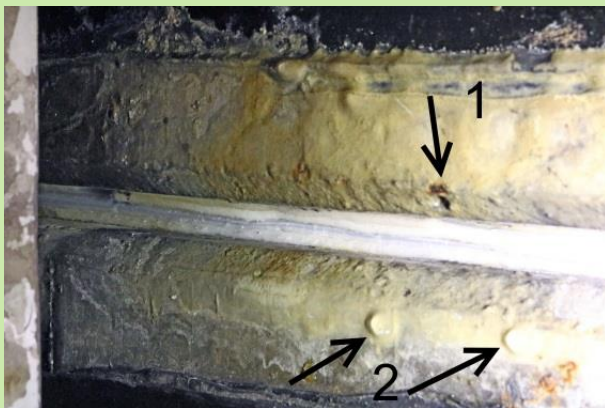
After deflation, the Wolf sealing cushion lay on the joint edge in such a way that the broken edge was clearly visible. (Photo, right)



The concrete had partly flaked off to such an extent that the damaged areas could not be covered by the sealing cushion. (Photo, below)



Due to partial closure of the road, Mr Stoll and Mr Neumann, experts from Stone Engineering, were only able to inspect and assess the edge damage in the central overhead joint over a length of 3 m.



- 1 Hole
- 2 Injection channel drillholes

We consider that reliable joint seals with the sealing cushions can only be achieved if the joints are repaired beforehand.

In order to attain full tightness, for which the manufacturer will give a 4-year product guarantee, the joints surface must be smoothed up to the level of the cushion with a special mortar.



For new project planning, as an alternative:

For joint chambers with existing injection drill holes and their consequential damages

- Clear out the joint chamber to a depth of at least 40 cm.
- Install sealing element (valve) type S technical correct with an installation depth of ~40 cm. Overlap the sealing element approx. 1 m.

Sealing products from Wolf Kabeltechnik GmbH used by for the project

Art. No. 21.1 QADK/V L

Reusable swelling sealing cushion for joints in bridges, tunnels or buildings subject to **longitudinal or circular movement**



Art. No. 21.2 QADK/VV

Reusable swelling sealing cushion, for **central wall expansion joints** (with 2 tyre valve connections)



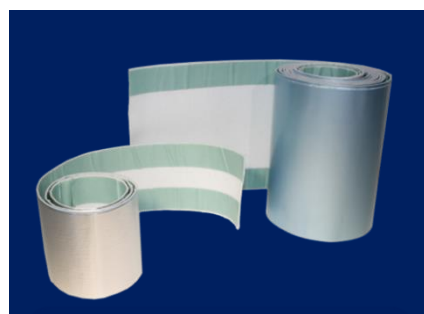
Art. No. 21.95 ZK6-ADK/V

Reusable swelling sealing cushion with cellular rubber for **support benching** (Lengths of sealing cushion that are glued on top of each other)



Art. No. 21.4 WSF

Water-blocking laminate for the overlapping area of two sealing cushions



Art. Nr. 21.1 QADKV S

Bewegungsfugen-Abdichtung (Ventil)

Für Längs- und Querfugen in Brücken. Temporäre Abdichtung gegen Eiszapfen- und Glatteisbildung

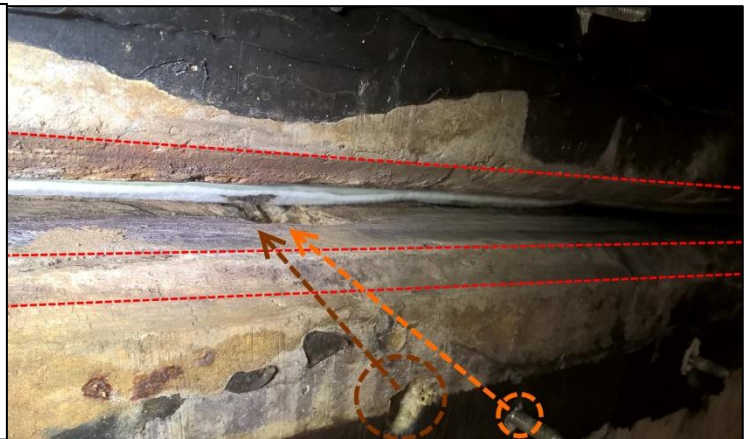


New technology for expansion and movement joint opens up new possibilities!

Gel treatment for cracks in expansion and movement joints without injection channel drilling and follow-on damage



Sketch showing injection



Original photo (problem resulting from injection)

Example taken from provisional joint-cavity injection in expansion and movement joints

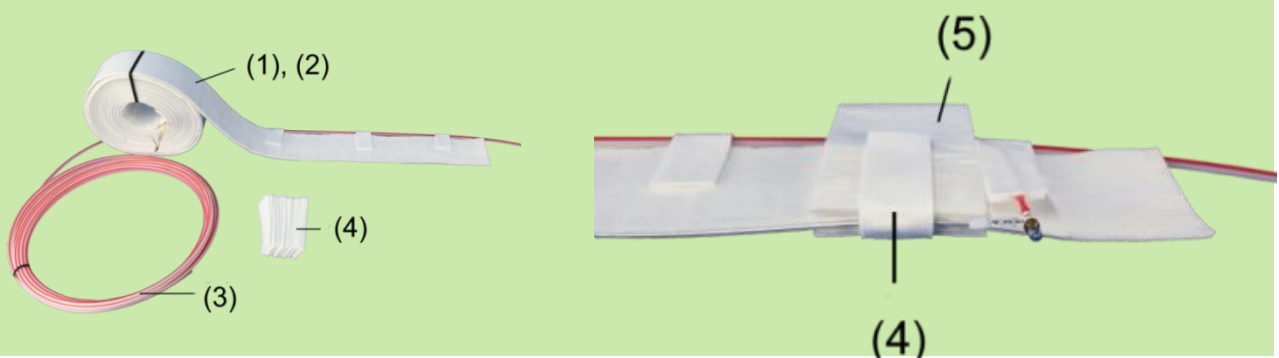
Installing the new technology, (Extract from WO21 Teil 11, Example of installation)

The seal must be carried out in such a way that a sloping water drainage channel is formed by the joint-sealing cushion. At least two (valve) sealing cushions [Art. No. 21.1 QADK/V (1), (2)] must be used to cover the whole joint length l_F .

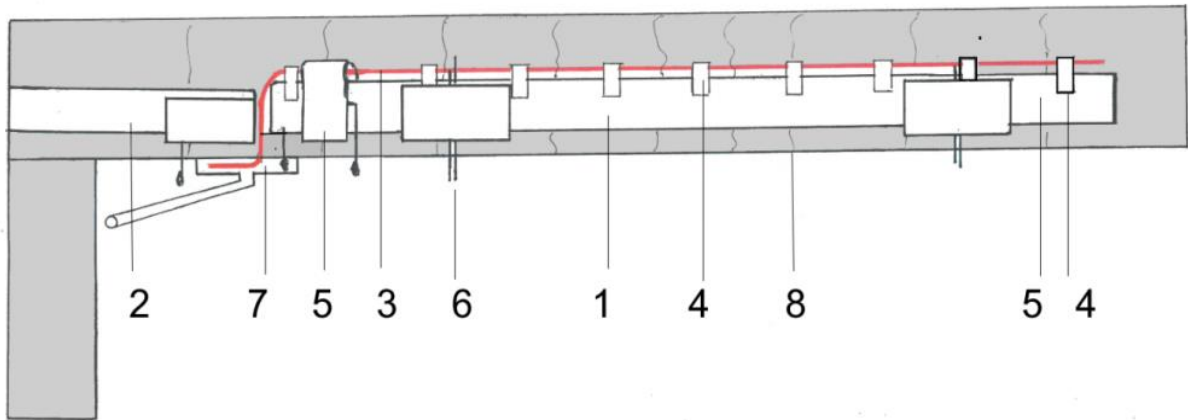
The valve ends must be easily accessible (near a pedestrian walkway, for example).

The sealing cushion QADK/V and injection-microtube [Art. No. 21.15 FIJ-MR (3)] must be positioned relative to each other in such a way that during the installation process the microtube can be fixed in place at intervals of 0.5 m on the side opposite the valve, using MRB microtube fixing strips [Art. No. 21.17 MRB (4)].

Before the sealing cushion (plus microtube) is inserted, the injection agent plugs 1KS-QADK/V [Art. No. 21-18 1KS-QADK/V (5)] are attached flush with the underside of the sealing cushion, using MRB strips (4), as shown below.



Depending on the depth of the joint cavity (insertion depth of the sealing cushion), a valve extension [Art. No. 21.5 MSR-VV] may need to be glued on to the valve ends with screw-sealing adhesive.



- | | |
|---|---|
| 1 Sealing cushion Art. No. 21.1 QADK/V long | 5 Injection agent plugs 21.18 1KS-QADK/V at the lowest or end point |
| 2 Sealing cushion Art. No. 21.1 QADK/V short (drainage chamber) | 6 Joint injection inserts/ fill-level indicator 21.19 FIJF |
| 3 Injection microtube 21.15 FIJ-MR | 7 Drip edge of the forced drainage |
| 4 Microtube fixing strip 21.17 MRB | 8 Cracks in the joint cavity and concrete surface |

To protect sealing cushions installed in overhead areas on transport routes against falling out, they are secured at one-metre intervals with PE rectangular-profile or round-cord foam rubber [Art. No. 21.5 PE or PER] and at 3-metre intervals with a transverse support wire [Art. No. 21.5 Niro 6].

The injection insert [Art. No. 21.19 FIJF] is adapted before installation, depending on the function it will have in (either injection fill-level indicator or retro-injection).

For joint widths of 2 - 3 cm, the injection insert FIJF is fitted between cushion and joint edge, flush with the top of the cushion (see diagram, above)

For joint widths of > 3 cm, the injection insert FIJF is additionally secured to the sealing cushion with fixing strips on the right and left. [Art. No. 21.17 MRB]

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