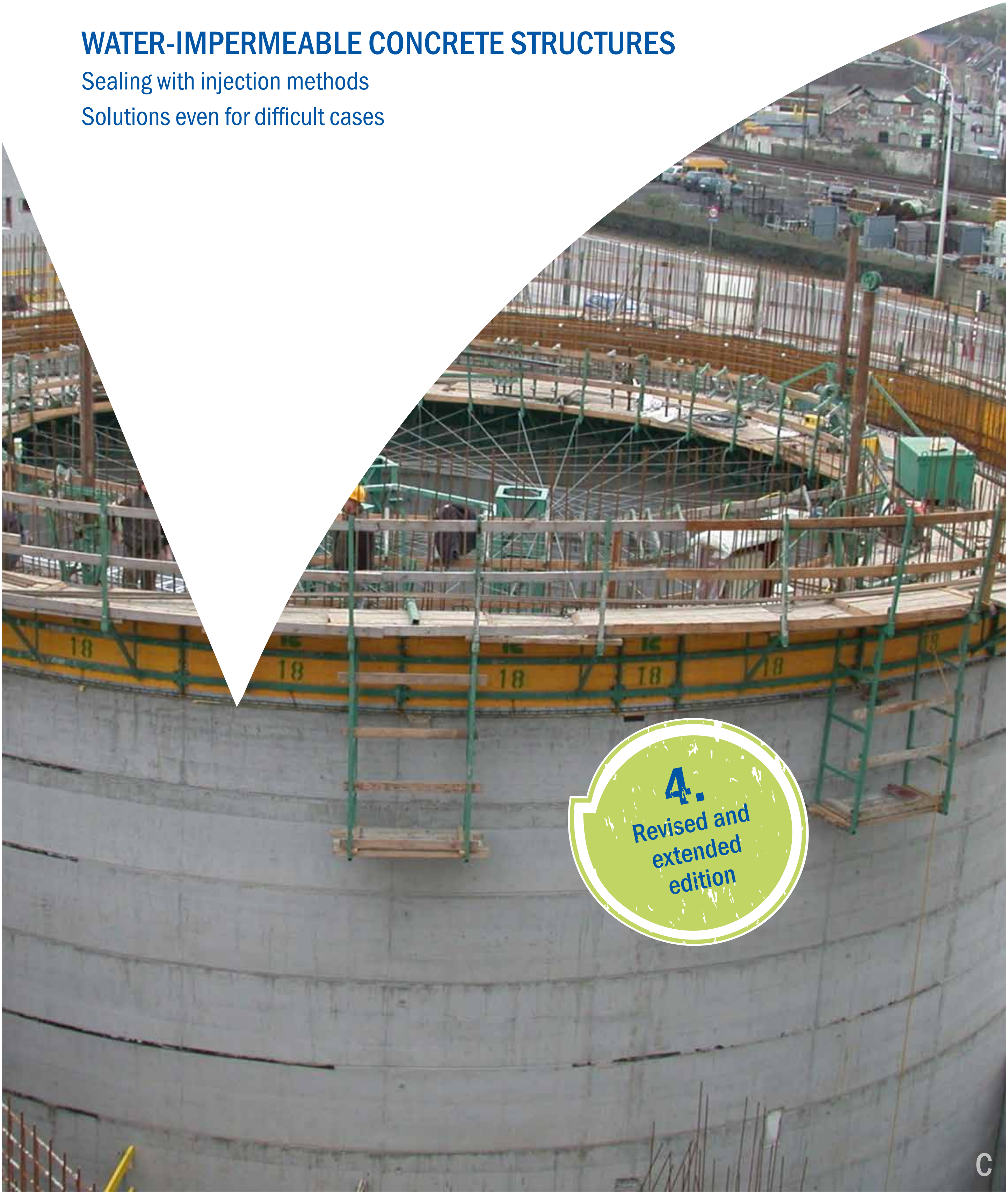
WATER-IMPERMEABLE CONCRETE STRUCTURES

Sealing with injection methods

Solutions even for difficult cases



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BASICS OF THE RENOVATION CONCEPT
INVENTORY AND BUILDING DIAGNOSTICS

1 INTRODUCTION

A large number of structures in civil engineering, building construction, industrial construction, hydraulic engineering and structural engineering are built as water-impermeable structures made of concrete.

Typical examples include

- Basements in residential and industrial buildings
- Basements and garages
- Drinking water tanks, rainwater retention basins and swimming pools
- Basins and containers in sewage treatment plants
- Locks and dams
- Transport structures
- Tunnels

As a rule, these structures have to prevent water from penetrating or escaping, or both.

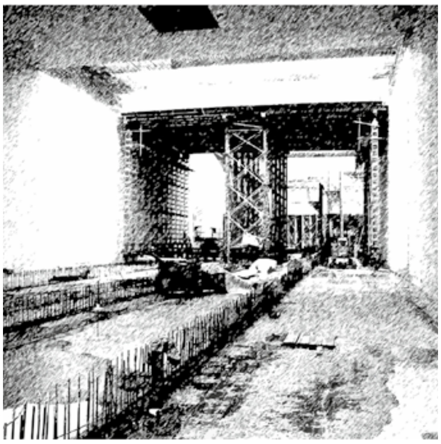
Unfortunately, mistakes that lead to leaks are often made both during planning and during its execution. Water-bearing cracks, surface moisture and leaky joints are not uncommon. They must be sealed professionally and permanently.

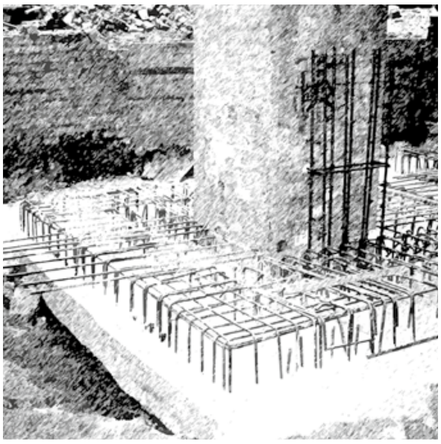
The subsequent sealing of cracks and leaking joints is not “assembly from the bar” but an object-specific customisation, which, among other things, must be adapted to the specific conditions of the object, the structure and location of the component, the type of joint, the cause of damage, the stress and the accessibility of the construction.

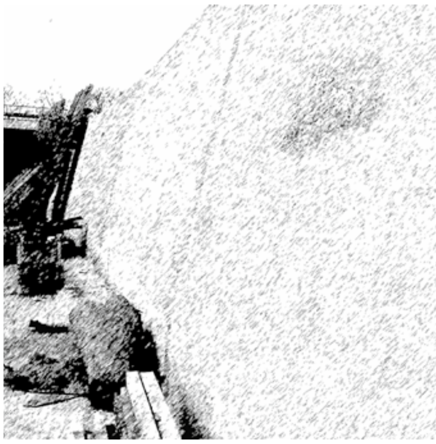
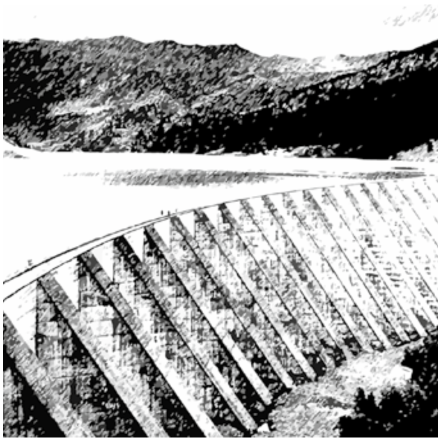
In many cases, injection technology offers a way to seal the construction safely and permanently afterwards, see list of references [1 – 3, 5 – 12].

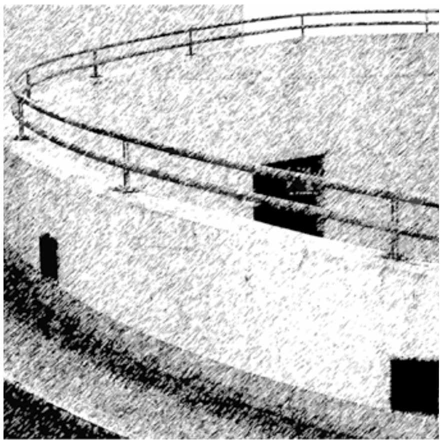
This brochure provides an overview of the different measures for the subsequent sealing of cracks and leaking joints in concrete structures using injection technology.

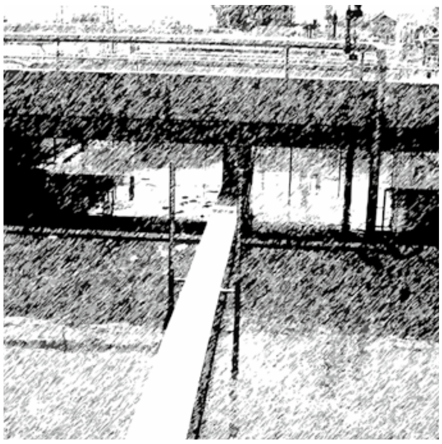
BASICS OF THE RENOVATION CONCEPT
INVENTORY AND BUILDING DIAGNOSTICS





Images: Prof. Dr.-Ing. Rainer Hohmann DESOI GMBH

2 INVENTORY AND BUILDING DIAGNOSTICS – NECESSARY BASICS OF THE RENOVATION CONCEPT

Planning the subsequent waterproofing of a building is a complex and demanding task that requires in-depth specialist knowledge as well as experience and care from both the planner and the contractor (competent specialist planners SKP). For the preparation of the renovation concept, precise knowledge of the construction and the object-specific boundary conditions are required, see also [4]. The renovation concept to be drawn up by the specialist planner should include a description of the actual structural condition, the repair objective, the waterproofing method to be used and the injection material to be used for the injection. The essential injection technology parameters, any accompanying measures required, as well as the quality assurance requirements should also be described or specified. Notes that the renovation concept should contain are given in Table 1.

Table 1: What information should the renovation concept include?

Objective and method	• Determination of the repair objective • Selection of the sealing method to be used
Description of the actual construction state	• Type and structure of the construction, condition of the components, rated water level, joint and crack movements, previous sealing measures, in case of veil gelation also information on the subsoil (see chapter 3.5) • Evaluation of the findings from a current subsoil survey
Information on injection technology	• Selection of the injection material to be used or its physical properties • 1 or 2-component injection technology • Planning, execution and evaluation of a sample injection • Number, location and spacing of the holes / injection packers, diameter of the holes, depth of the hole, drilling angle • Information on the injection process, possibly also on the pre-injection and the reaction time, max. injection pressure • Time of the injection (especially with time-dependent component behaviour, which leads to cracking and joint movement, weather conditions, including air temperature, component temperature during the planned injection • under certain circumstances, the time of the post-pressing
Other information	• Description of flanking measures (e. g., pre-injection, protective measures, possible removal of root growth) • Observing building regulations and permits, any necessary permits (e. g., for injections into the ground) and any required test certificates • Requirements for quality assurance and documentation

Some questions that are important for the planning of the renovation are given below

- How is the construction constructed and what component thickness does it have?
- Have the component movements already been completed or which ones are still to be expected?
- What maximum water pressure (rated water level) affects the construction?
- What does the overall planning system of the joint seal look like?
- Which joint seals were installed?
- For which movements / water pressure was the existing seal measured?
- How were the connection points and joints carried out?
- What is the nature of the adjoining soil in the case of remedial measures? (soil type and composition, grain size distribution, pore content, storage density, water content, soil permeability, ...)
- Are the constructions to be sealed free and accessible for a renovation without time restrictions or only at certain times, e. g., in the case of metro operation?
- Have any injections been performed? What injection material was used?
- What injection measures and / or accompanying measures are still planned?

In the case of cracks , it's important to know the cause of the crack, crack width, change in crack width (short-term, daily, long-term), the crack condition (moistu-re, contamination), crack progression, location of the reinforcement, component temperature, air temperature and sunlight at the time of the injection.

3 INJECTION METHOD FOR SUBSEQUENT SEALING OF LEAKY CONSTRUCTIONS

For planning the renovation, the question is, what is the appropriate method?
In principle, the following injection options are available:

- Filling the passages (cracks, defects, cavities, joints) with a filling* (crack or masonry injection, joint gelation)
- Preventing water from accessing the construction or joint by forming a closed injection veil before construction (veil injection) or by filling component or building interstices (masonry injection).

Which method is ultimately used depends on a large number of parameters. Decisive parameters for the selection of the method are e. g.

- Building
- Type and structure of the components
- Damage pattern and cause
- Joint type
- Stress (water pressure, deformation)
- Possibly other specific conditions of the structure
- Accessibility
- Economics
- Ideas, specifications and the safety needs of the client

The choice of the renovation method is property- and damage-specific, and is "tailor-made". An overview of the various methods for subsequent sealing by injection and their field of application is given in Table 2.

** In the ABI leaflet [10], 4th Edition 09 / 2022, the term "injection material" is used, in the TR maintenance [1], edition 05 / 2020 and in the ZTV-ING [3] the term "crack injection material" is used (Only available in German).*

Table 2: Injection method for subsequent sealing of leaky constructions

		Water permeability in							
						Expansion joints			
Method		**cracks**	**Cavities and structural disturbances**	**Working joints**	**Desired crack joint**	**Rotation of the sealing part**	**Damage to the expansion part**	**Joint in tubbing tunnelling**	**Penetrations** *(e. g., pipe penetrations, formwork spreading, foundation earth electrodes)*
Partial injection via injection packer		✔		✔	✔	✔			✔
Partial injection via adhesive packer		✔							
Partial masonry injection in the component			✔	✔					
Gelling of the joint *(on the ground side)*	Injection via injection packer					✔	✔		
Partial injection of the joint *(air side, in combination with insulation)*	Injection via injection packer					✔	✔		
	Injection via the injection profile B-PROFILE®						✔		
	Injection via the flexible hose profile B-JOINT®						✔		
	Injection via the injection formwork DESOI Quick Seal						✔		
	Injection via the B-STING® joint injection needle						✔	✔	
Partial masonry injection on the outside of the component *(curtain injection)*						✔	✔		
Masonry injection into component or building interstices			✔						
Post-compression via an injection hose system installed in the working joint				✔		✔			

CRACK COMPRESSION VIA INJECTION PACKER

ARRANGEMENT OF THE INJECTION PACKERS

Crack injection, polymer

Crack injection, mineral

3.1 Crack compression via injection packer

Depending on the boundary conditions, the grouting of cracks, i.e. the filling of cracks under pressure, can be carried out using injection or adhesive packers with a suitable injection material adapted to the object-specific boundary conditions. In this process, the packers are fitted with a tapered or flat-head nipple only immediately before they are pressed. During the injection, the material flow is controlled via the filling material outlet from the adjacent "open" packers (packer contact). The displaced air can then also escape through these. In the case of vertical cracks, the injection is carried out from bottom to top, starting at the lowest injection pack. Within the processing time specified for the crack injection material by the manufacturer, a post-injection must be carried out for all packers. After the packers have been injected and the crack injection material has hardened, the packers are dismantled or removed; drilled holes are closed with a low-shrinkage mortar.

After appropriate agreement with the builders, stainless clamping parts of injection packers (1-day packers and impact packers made of plastic) can remain in the component.

Which crack fillers (injection materials) are suitable for the sealing crack injection? The WU guideline [4] restricts the use to those crack fillers that meet the requirements of the DAfStb guideline "Protection and repair of concrete components“ [2]. In the ZTV-ING, Part 3 Massive Construction, Section 5 – Filling cracks and cavities in concrete structures [2], the DAfStb guideline "Protection and repair of concrete components“ [2] as well as in the Technical Regulations "Maintenance of concrete structures (TR Maintenance) of the DIBt“ [1] are identified as crack fillers:

1. Crack fillers for the non-positive filling of cracks [1],e. g. epoxy resin (EP), cement glue (ZL) and cement suspension (ZS).
2. Crack fillers for the elastic filling of cracks, e. g. polyurethane resin (PUR).

The performance characteristics of the fillers and rules for their application are described in the Technical Regulations "Maintenance of concrete structures" (TR Maintenance) Part 2 [1]. DIN EN 1504-5 [5] also lists acrylate gels / hydrostructure gels (AY) whose sealing effect is achieved via sources.

The polyurethane-based injection resins are solvent-free, low-viscosity, elastic, pore-forming fillers (PUR-I) which achieve their sealing effect via side adhesion. In justified exceptional cases, polyurethane foams (SPUR-I) can be pre-injected in order to reduce the water supply in the case of strongly pressing water. Under water supply, these form a fine-cell, open-pore foam which temporarily reduces the water supply, but has no permanent sealing effect.

The injection with polyurethane resin (PUR-I) should be carried out immediately afterwards via additional injection packers. In addition to the polyurethane resin, cement glue and cement suspension are also used. These are suitable for high-cavity concrete and larger cavities for cost-effective preinjection. Occasionally, special hydrostructure gels with a general building authority approval (abZ) from the German Institute of Civil Engineering DiBt are used for crack pressing.

3.1.1 Crack compression via injection packer (drill packer)

If water-carrying cracks occur in water-impermeable concrete components, they can be sealed by injecting a suitable crack injection material via injection packers. For this purpose, drilling channels are introduced into the component, which as a rule cross the crack at an angle of 45°. After the drilling channels have been blown out or sucked out, the injection packers are inserted into the drilling channels and braced. Depending on the crack injection material, the drilling channel must be prepared if necessary, e. g. pre-wetted. The cracks are then pressed via the injection packers with a suitable crack injection material.
The spacing of the injection packers depends, among other things, on the object-specific boundary conditions (component thickness, crack width) and the properties of the crack injection material (processing time, viscosity). As a rule, the distance between the injection packers is d/2, where d denotes the thickness of the component. Due to the reciprocal arrangement of the injection packers shown in Figs. 1 and 2, cracks that are offset in the component are also detected.

Recommendation: In order to achieve the crack filling level of 80 % required in the ZTV-ING [3] and to increase the execution reliability, it is recommended to seal the cracks before injection.

As a rule of thumb:
max. injection pressure ≈ ⅓ of the nominal compressive strength of the concrete*

Example:
In-situ concrete construction, concrete C 20 / 25
max. injection pressure $\frac{25}{3} \cdot 10 = 83$ bar

* *Nominal compressive strength: term from concrete technology, denotes the strength of a concrete sample cube after 28 days*

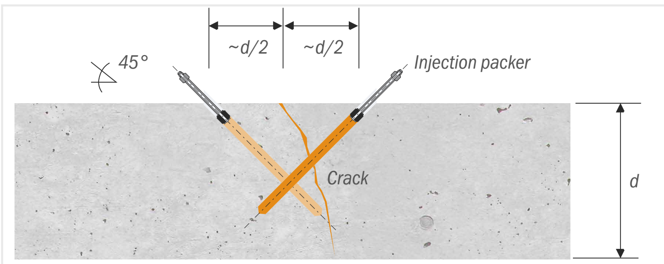


Figure 1: Crack compression via injection packer

CRACK COMPRESSION VIA INJECTION PACKER

ARRANGEMENT OF THE INJECTION PACKERS

The viscosity of the crack injection material is decisive for the success of the injection. The narrower the crack, the smaller (less viscous) the viscosity must be and the longer the processing time of the crack injection material must be in order to achieve good crack filling. During the injection, the material flow is controlled via the filling material outlet from the adjacent open injection packers. When filling the cracks, ensure that water and / or air can escape during the injection. In the case of vertical cracks, the injection is carried out from bottom to top, starting at the lowest injection pack. In order to avoid damage to the concrete structure, the maximum injection pressure should normally be limited to ⅓ of the nominal concrete compressive strength. For element walls, the maximum injection pressure should be significantly lower to avoid damage to the construction. After the injection is completed, the injection packers are removed, and the openings are closed with a low-shrinkage mortar.

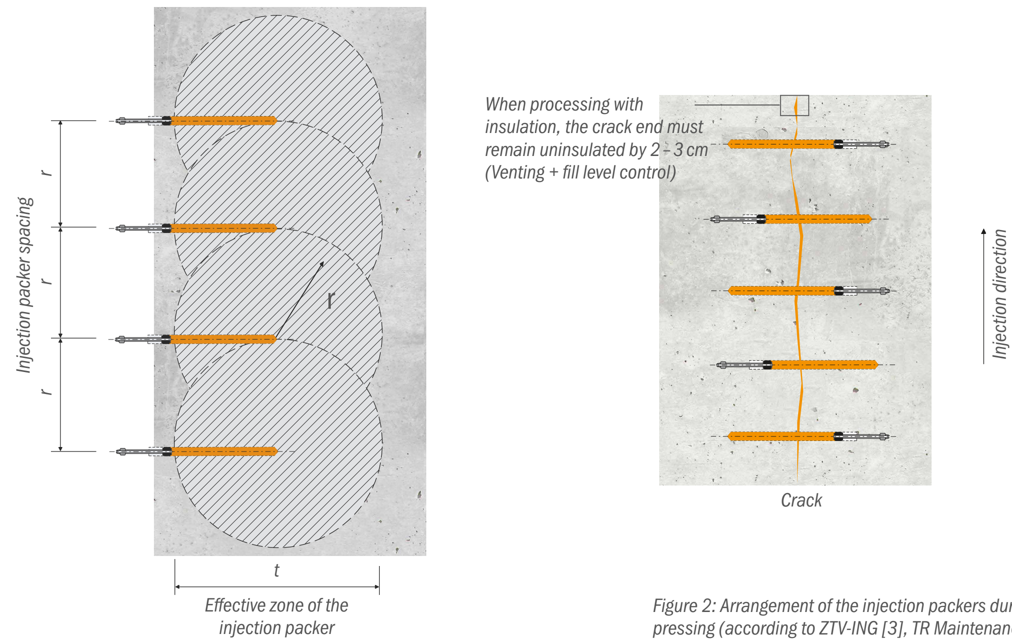


Figure 2: Arrangement of the injection packers during crack pressing (according to ZTV-ING [3], TR Maintenance [1])

3.1.2 Crack compression via adhesive packer

Adhesive packers are glued directly to the crack. Therefore, their use is limited to cases with dry component surfaces in the crack area, very fine cracks and with tight reinforcement, in which it is not possible or permitted to drill. The mutual spacing of the adhesive packers generally corresponds approximately to the component thickness (d). The adhesive bond between the adhesive packer and the component surface is decisive for the functionality. Before setting the adhesive packer, the component surface must therefore be roughened by blasting or grinding 5 cm on both sides of the crack and cleaned of loose parts, dust, etc. In order to avoid closure of the injection channel of the adhesive packer by the adhesive (sealing material), a greased steel pin is first driven into the crack by about 2 – 3 mm, onto which the adhesive packer is placed after application of the adhesive. The steel pin is removed later before the injection. The crack between the individual adhesive packers is sealsed with the adhesive. The injection takes place via a cone nipple, which is screwed onto the packer just before the injection. The maximum injection pressure in adhesive packers depends substantially on the adhesive tensile strength of the component surface and the adhesive properties of the adhesive. As a rule, an injection pressure of < 30 bar is recommended.

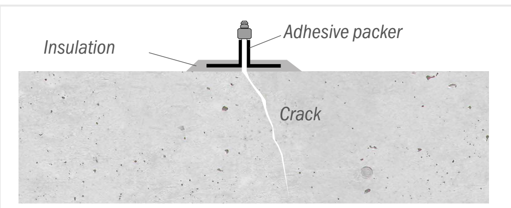


Figure 3: Crack compression via adhesive packer

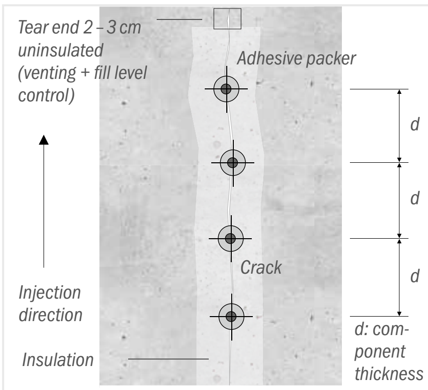


Figure 4: Arrangement of the adhesive packers during crack pressing (according to ZTV-ING [3], TR Maintenance [1])

3.2 Masonry injection into components

In the case of planar structural disturbances and moisture penetration of floor panels and walls, the subsequent sealing can be effected by means of a planar injection into the component. For this purpose, in the region of the damaged area, drill channels are introduced in a grid-like manner into the component (see Fig. 5), via which capillaries, pores and cavities are filled with a suitable injection material and sealed by means of injection packers. In contrast to the curtain injection (see Chapter 3.5), the component is not completely drilled in holes for grid or cavity injection. The grid dimension and the borehole depth must be adapted to the object-specific boundary conditions. The masonry injection enhances the component itself as a sealing element. The choice of injection material depends, among other things, on the permeability of the component (concrete structure). The best possible distribution of the injection material in the component is achieved by the use of fillers having a low viscosity, that is to say fillers which are as thin as possible. Polyurethane foams (SPUR-I) are excluded from injections into cavities, but also into component or building intermediate layers, since, as a rule, a space-filling, sealing injection, e. g., with a polyurethane resin (PUR-I) or acrylate gel is no longer possible after their application.

As a rule of thumb:
Hole spacing = ½ · component thickness
Drill hole depth = ¾ · component thickness

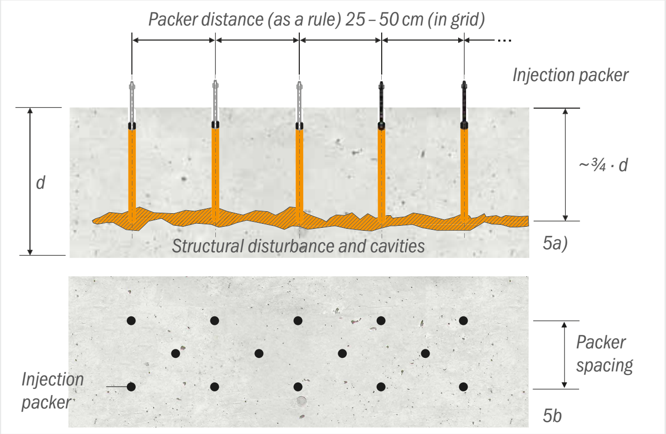


Figure 5: Masonry injection in the component, (5a section, 5b view)

3.3 Renovation of leaking working joints

3.3.1 Injection via injection packer (drill packer)

A leaking working joint can be sealed by injecting a suitable injection material, similar to crack pressing. For this purpose, drilling channels are introduced into the component, which as a rule cross the working joint at an angle of 45°. Figure 6 demonstrates this using the example of the connection point between the base plate and the wall. The injection material is injected via injection packers, which are inserted into the bore channels after the bore channels have been blown out and clamped. As a rule, the maximum distance between the injection packers should be d/2. As in the case of crack compression, the material flow during the injection is controlled via the filling material outlet from the adjacent open injection packers. In the case of vertical joints, the pressing takes place from bottom to top. After the injection is completed, the injection packers are removed, and the openings are closed with a low-shrinkage mortar.

3.3.2 Compression via an injection hose system

If, as shown in Fig. 7, the working joint contains a system of injection hoses which has been installed as planned and which has not yet been compressed, the working joint can be pressed with a suitable injection material via this system. The prerequisite for this is that the injection hose system has been installed professionally, is not yet finally pressed and the pressing ends are still accessible.
In the case of injection hose systems which can be compressed once and have already been injected, or if the compressors are no longer accessible, the injection must be made via injection packers, see section 3.3.1. The same applies to cases in which the compression of the injection hose system has not led to the desired sealing success.

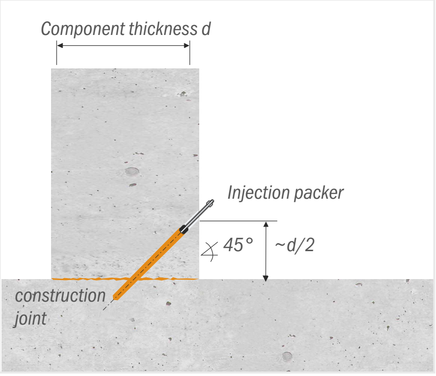


Figure 6: Compression of a working joint between floor plate and wall [8]

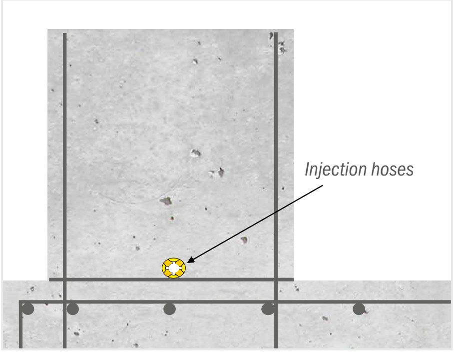


Figure 7: Injection hose in the working joint between base plate and wall (example) [7]

3.4 Repair of leaking movement joints

The sealing of leaky movement joints is more difficult and demanding than the sealing of water-bearing cracks and leaky working joints. This applies both to the repair planning and to the implementation of the measure.

3.4.1 Sealing of the sealing part by partial injection via injection packers (drill packers)

In case of water circulation of the waterstop, cavities and defects in the area of the sealing part can be sealed by injecting a suitable injection material, e. g. PUR, via injection packers. For this purpose, drilling or, as the case may be, drilling through is first carried out in the affected area, as shown schematically in Fig. 8, at a distance of 30 – 50 cm. Care must be taken to ensure that only the sealing part, but not the expansion part of the joint band, is hit during the drilling. The distance between the bores and the movement joint must be matched to the joint band so that the expansion part is not injured. After cleaning the drilling channels of drilling dust and the installation of injection packers, the compression with the injection material takes place via the injection packers. During the pressing process, the material flow at the adjacent open injection packers is controlled. The displaced air can also escape this way.

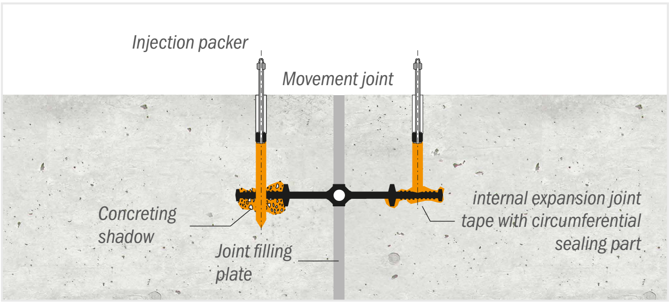


Figure 8: Pressing of cavities on the sealing part with an internal expansion joint tape/with (left) or without (right) drilling of the joint tape [7]

3.4.2 Injection of the movement joint between the joint tape and the water-facing component surface (gelling of the joint)

In the case of a damaged and leaking expansion part of the joint tape, the movement joint can be pressed and sealed with a “flexible” filler, for example, a suitable acrylate gel or polyurethane resin. For this purpose, the movement joint is drilled between the soil and the expansion joint tape, as shown in Fig. 9. The injection of the injection material takes place via injection packers inserted into the drilling channels after blowing out. In this case, the soil and the embedded expansion joint tape serve as abutments for the injection. The control of the material flow takes place during compression via open adjacent injection packers or a vent hole. After the injection is completed, the injection packers are removed, and the openings are closed with a low-shrinkage mortar. When carrying this out, it is important that the physical properties of the injection material (e. g., reaction time, flow properties) are matched to the object-specific conditions. According to [10], the suitability of the PUR injection material to be used must be established. In this case, care must also be taken to ensure compatibility with the joint band. Due to the limited extensibility of the fillers, this method is limited to applications in which the joint movement is completed or no significant joint movement is to be expected.

When using acrylate gels / hydrostructure gels (AY) whose sealing effect is achieved via sources, movement joints can be sealed with limited joint movement. In this instance, the physical properties of the acrylate gel (hydrostructure) gel are decisive. The usability for this application and the limited deformation should be demonstrated.

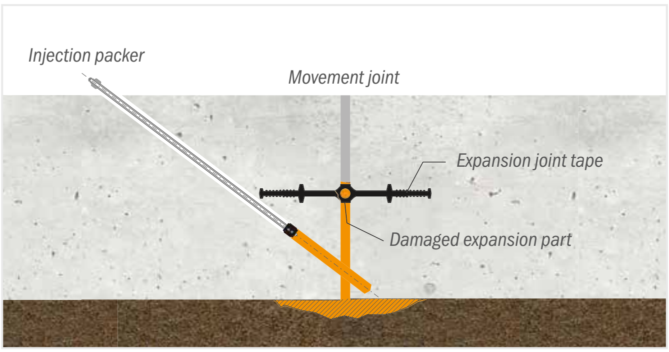


Figure 9: Gelling of the movement joint in the case of a damaged expansion part [7]

REPAIR OF LEAKY MOVEMENT JOINTS

INJECTION OF THE MOVEMENT JOINT BETWEEN THE JOINT STRIP AND THE SURFACE OF THE COMPONENT FACING AWAY FROM WATER

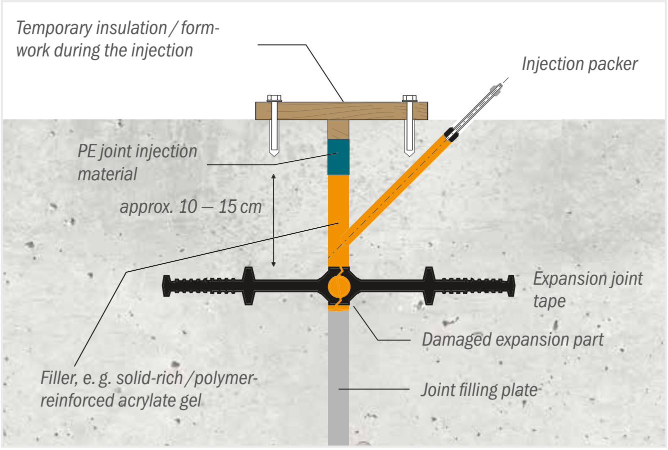


Figure 12: Injection of the intermediate space between the joint tape and the room-side component surface [6, 8]

3.4.3 Injection with injection packer (drill packer)

A leaking movement joint can also be sealed by temporarily switching off the joint on the room-side component side – as shown in Figure 12 – and then pressing the intermediate space between the joint strip and the room-side formwork via injection packer with solid-rich acrylate gel or filled polyurethane resin, see also [10].

In order to prevent the injection material from drying out and shrinking, the joint is closed or covered with a joint filling profile, a compression profile, a permanently elastic joint closure compound, a strip-shaped masking system or a sheet metal cover after the injection and after removal of the formwork.

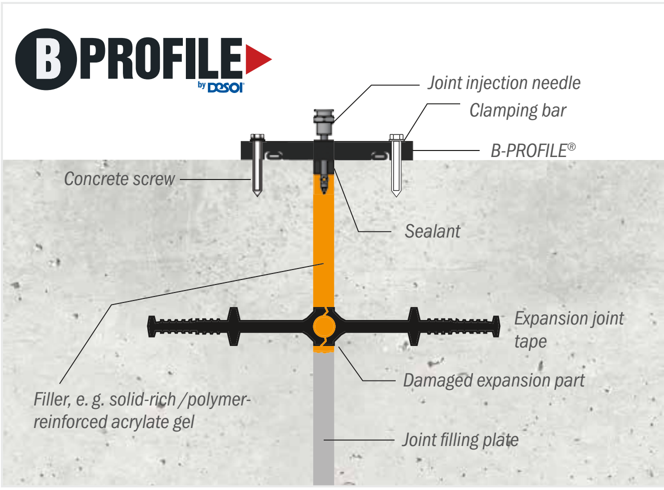


Figure 13: Temporary shuttering of the defective movement joint with B-PROFILE® and injection of the joint via the joint injection needle

3.4.4 Injection via B-PROFILE®

A leaking movement joint can also take place object-related temporarily via an injection formwork B-PROFILE®, see Figures 13 – 15. The prefabricated injection formwork B-PROFILE® eliminates the time-consuming drilling of the drilling channels for the injection packers. The movement joint is injected via low-pressure injection after the B-PROFILE® has been installed and the joint injection needle has been inserted. When the joint injection needle is screwed into the B-PROFILE®, no material is removed; the lateral outlet holes of the joint injection needle remain clean and a free flow of the injection material is ensured. The solid material of the B-PROFILE® spans the joint injection needle; this holds it in place and seals the puncture site at the same time. The integrated sealing lips of the joint rubber ensure an impermeable connection to the component and the rubber adapts exactly to the unevenness. After successful injection and curing of the injection material, the B-PROFILE® is removed again.

In order to prevent the injection material from drying out and shrinking, the joint is closed with a joint filling profile, a compression profile, a permanently elastic joint closure compound or a strip-shaped masking system after the injection material has hardened and B-PROFILE® has been removed. The B-PROFILE® is reusable.

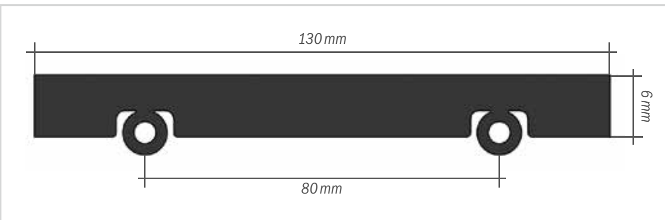


Figure 14: Dimensions of the B-PROFILE®

Figure 15: Joint injection needle (No. 23207), Ø 5 mm x 71 mm, stainless steel, lateral outlet openings Ø 2.5 mm; working length 25 mm, connection pan head nipple with check-valve, AF17

REPAIR OF LEAKY MOVEMENT JOINTS

INJECTION OF THE MOVEMENT JOINT BETWEEN THE JOINT STRIP AND THE SURFACE OF THE COMPONENT FACING AWAY FROM WATER

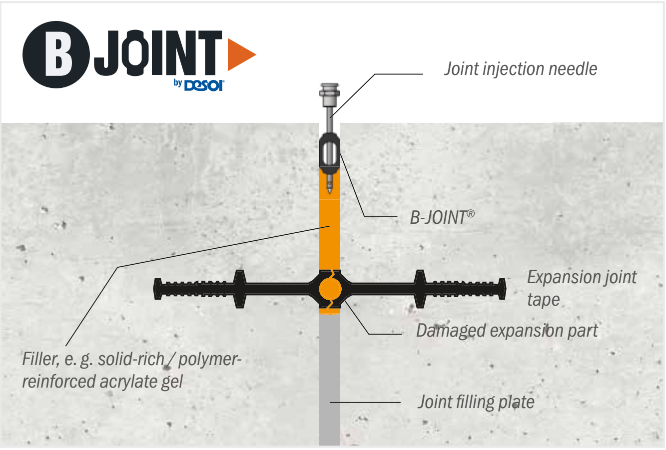


Figure 16: Built-in B-JOINT® in a movement joint

3.4.5 Injection via B-JOINT®

B-JOINT® is a flexible hose profile for sealing leaking movement joints; it can be processed in any length and is used with a joint width of 20 to 30 mm. The subsequent injection takes place via the joint injection needle, which is screwed into the hose profile via low-pressure injection, see Figures 16 and 17. After installing B-JOINT® into the defective expansion joint, the hose profile is clamped over the air-filling needles by applying air. B-JOINT® is flexible, adapts to unevenness, and does not require terminal strips. There's no need to tighten it with nuts.

After the injection material has been injected and hardened, B-JOINT® is removed again and the movement joint is closed with a joint filling profile, a compression profile, a permanently elastic joint closure compound or a strip-shaped masking system in order to prevent the injection material from drying out and shrinking. B-JOINT® can be reused after removal.

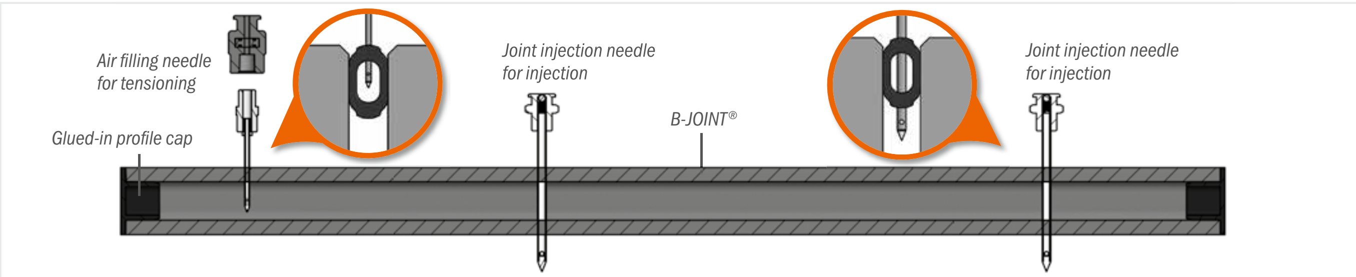


Figure 17: B-JOINT® - Sealing and injection profile for sealing and injecting leaking movement joints

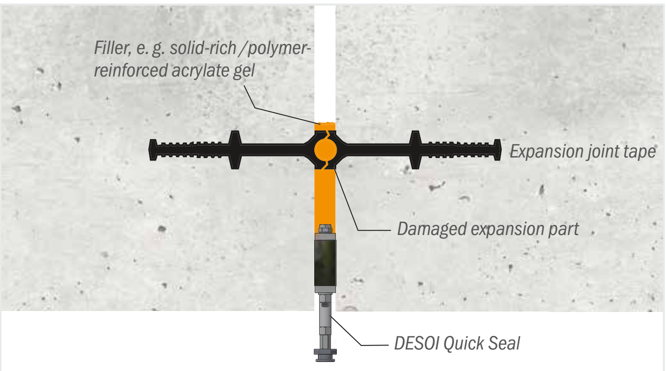


Figure 18: Built-in DESOI Quick Seal in a movement joint

3.4.6 Injection via DESOI Quick Seal

Leaks in damaged movement joints can be sealed by inserting the flexible sealing and injection profile DESOI Quick Seal into the joint (see Figures 18 and 19), fixing it, tensioning it via the tightening nuts in the movement joint and then pressing it back via the injection tubes of the sealing and injection profile Quick Seal , for example with a suitable acrylate gel or polyurethane resin. The sealing and injection profile can be separated and is suitable for joint widths of 18 to 26 mm.

After the injection material has been injected and hardened, DESOI Quick Seal is removed and the movement joint is closed with a joint filling profile, a compression profile, a permanently elastic joint closure compound or a strip-shaped masking system in order to prevent the injection material from drying out and shrinking. If an acrylate gel is used as a injection material, DESOI Quick Seal can then be reused.

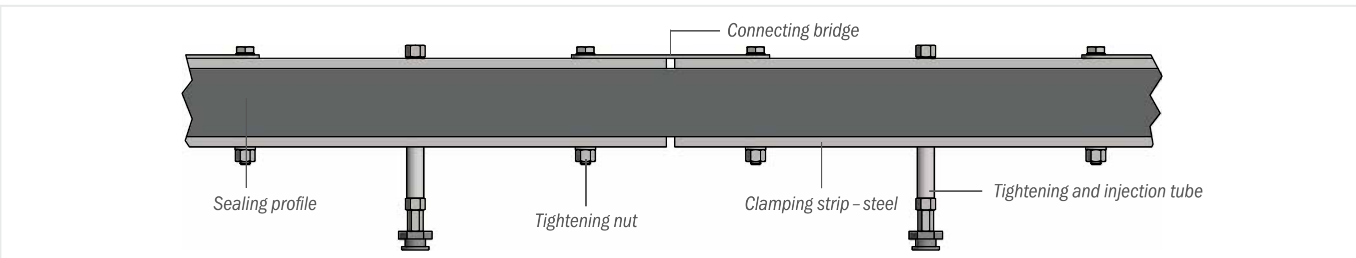


Figure 19: DESOI Quick Seal, sealing and injection profile for sealing and injecting leaking movement joints

REPAIR OF LEAKY MOVEMENT JOINTS

INJECTION OF A MOVEMENT JOINT VIA THE B-STING® JOINT INJECTION NEEDLE

3.4.7 Injection with the B-STING® joint injection needle

The subsequent sealing of leaky expansion joints (Figure 20) in tunnels, in particular if they were created in tubbing construction (Figure 21), can also be carried out object-related via joint injection needle B-STING®. The injection via the joint injection needle is possible without significant joint movement, depending on the object-related boundary conditions in joints. The B-STING® eliminates the otherwise complex drilling work.

3.4.7.1 Sealing leaky expansion joints

With the method, an approximately 5 mm thick B-STING® is screwed into the movement joint by means of a cordless screwdriver and, as shown in Fig. 20, pierces the sealing hose of the joint tape. An acrylate gel/hydrostructure gel is injected into the water-facing side of the joint via a flat-headed gel nipple and the injection tube screwed onto the B-STING®. After the injection process, the injection tube is removed, while the B-STING® remains in the component and closes the borehole permanently and in a pressure-tight manner.

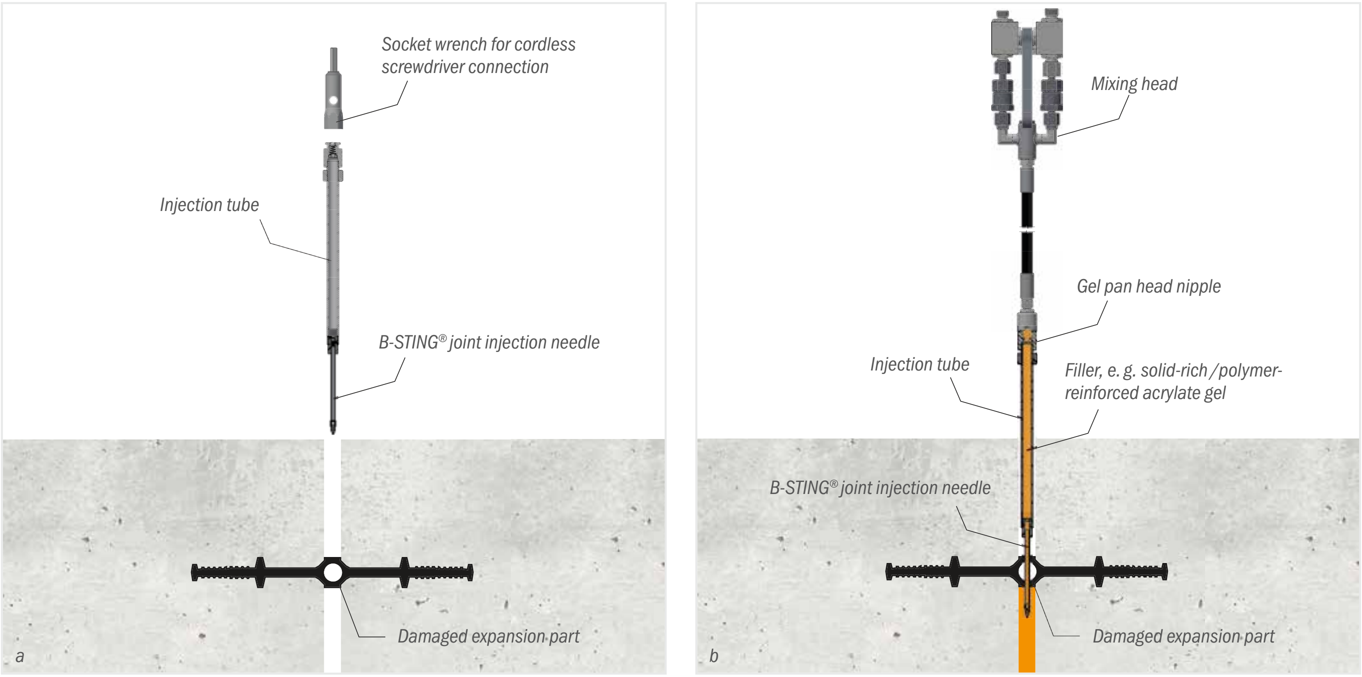


Figure 20: Screwing in the B-STING® joint injection needle through the seal with a cordless screwdriver (a) and subsequent injection of the motion joint (b)

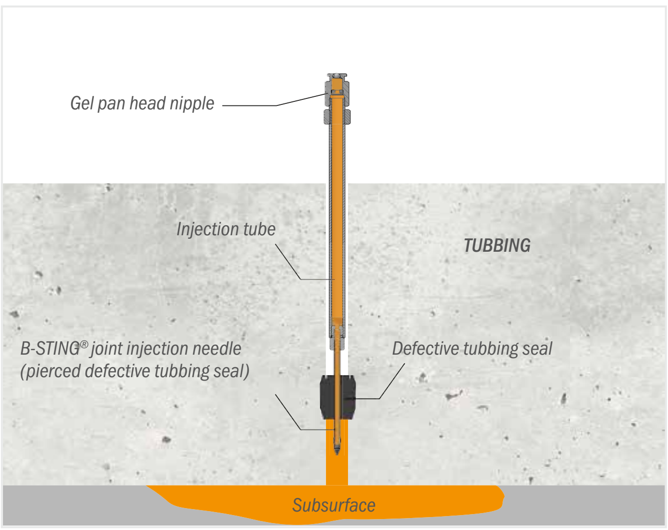


Figure 21: Gelling of the joint in the case of a leaking tubbing joint via a B-STING® joint injection needle

3.4.7.2 Sealing leaky tubbing joints

For the subsequent sealing of tubbings, the procedure is basically identical to the procedure described in Section 3.4.7.1, see also [10]. With the method, an approximately 5 mm thick joint injection needle is screwed into the tubbing seal by means of a cordless screwdriver via the tubbing joint and – as shown in Fig. 21 – pierces the tubbing seal. An acrylate- or polyurethane-based injection material is injected into the tubbing joint via a flat-headed gel nipple and the injection tube screwed onto the B-STING®. However, due to the smaller joint width in tubbings, it is usually necessary to drill open the longitudinal or annular joints of the tubbings to insert the injection tube with the B-STING® joint injection needle into the joint. As a rule, a borehole with a diameter of approx. 15 mm is enough for this. The B-STING® joint injection needle remains in the tubbing seal and permanently seals the bore.

3.5 FOG INJECTION ON THE OUTSIDE OF THE COMPONENT

Leaking constructions can also be sealed by masonry injection on the outside of the component (fog injection), depending on the object. In this case, a gel veil (gel/soil mixture) formed in front of the component prevents water from entering the construction or the movement joint (see also Figure 9, page 7).

Typical applications for the curtain injection are the subsequent sealing of

- Tunnels
- Basement walls and floor panels in pressing groundwater that are not accessible from the outside
- Basements and garages

In the case of the fog injection, first of all, as shown in principle in Figs. 22 and 23, grid-like bores must be made which penetrate the entire construction. As a rule, the soil in front of the component is pressed with acrylate gel via gel steel packers installed in the bores.

Ideally, a hemispherical injection body (gel-ground mixture) is thereby formed on the ground side in front of the exit points of the injection material, in which the ground serves as a supporting framework for the acrylate gel. The curtain injection is a sealing injection, which, however, does not effect any reinforcement of the components from a static point of view.

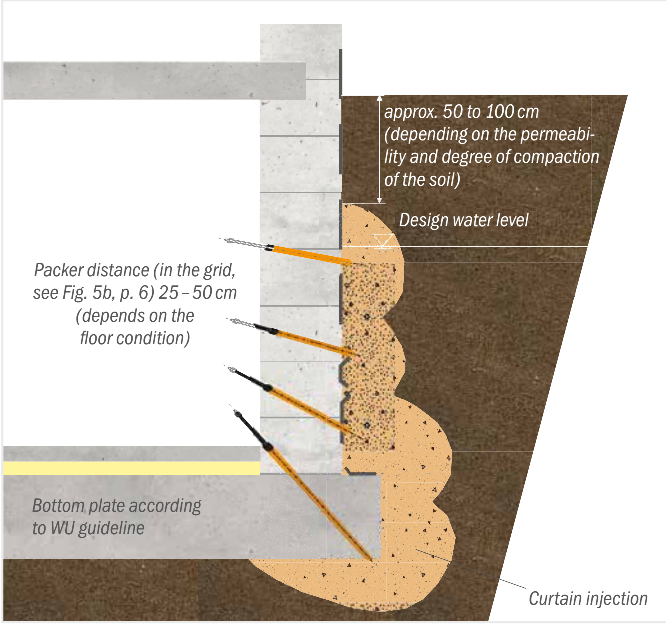


Figure 22: Example of curtain gelling (principle sketch) [8]

Figure 23: Injection curtain exposed [8]

Instructions for the curtain injection procedure

Waterproofing using curtain injection is an alternative for the subsequent waterproofing of engineering and traffic structures, hydraulic structures and structures in building construction. It is always used when other sealing options for the repair of buildings are uneconomical or technically impossible, e. g. when:

- The costs of the accompanying works are disproportionately high (high excavations, complex excavation shoring, bypasses, etc.).
- Traffic conditions do not allow the repair area to be blocked
- Adjacent development or use of the repair area precludes exposure of the seal
- Area to be sealed is no longer accessible or a construction method that is gentle on operations is required

Materials or fillers are increasingly used for repairing structural damage caused by the entry of water and moisture, for whose product descriptions and processes there are currently no regulations. Risks may well arise for the applications for builders, planners and contractors. Working groups of experts in the field of planning, execution, material production, construction supervision and material testing have developed corresponding information sheets [10, 12].

It is recommended that builders be informed accordingly.

CURTAIN INJECTION

The distances of the injection packers should be selected according to [10] in such a way that a gel curtain of at least 10 cm thick of overlapping hemispherical injection bodies (gel/soil mixture) is formed in front of the structure to be sealed. In the case of permeable soils, the distance between the injection packers is usually 25 – 50 cm, in the case of strongly to very strongly permeable soils about 50 – 100 cm. In the case of very weakly permeable soils, as a rule, no coherent gel-ground soil body is formed, but at best only a thin gel curtain along the boundary surface of the building-ground soil.

Recommendation: In the event of unfavourable soil conditions, experience has shown that a trial injection should be prescribed by a competent planner.

The success of the curtain injection depends largely on

- Subsoil
- Injection technology
- Characteristics of the injection material

In order to achieve the desired sealing success, the different influencing variables must be coordinated with one another. Therefore, in the case of a curtain injection, detailed knowledge of the upcoming soil is required, such as:

- Soil type and composition
- Particle-size distribution
- Percentage of porosity
- State of compaction
- Water content
- Soil permeability
- Design water level
- Chemical properties of the water

In addition to these parameters, the spread of the injection material and thus the success of the curtain injection is also dependent on:

- Type of injection (single-stage or two-stage injection)
- Injection pressure
- Speed of the injection
- Injection material response time
- Injection packer spacing (horizontal, vertical)

When choosing the injection material, the chemical properties of the water and the environmental compatibility of the filler must also be taken into account. The success of curtain injection also depends on the skills and experience of the person performing it. Curtain injections should therefore only be carried out by professionals who have the appropriate experience.

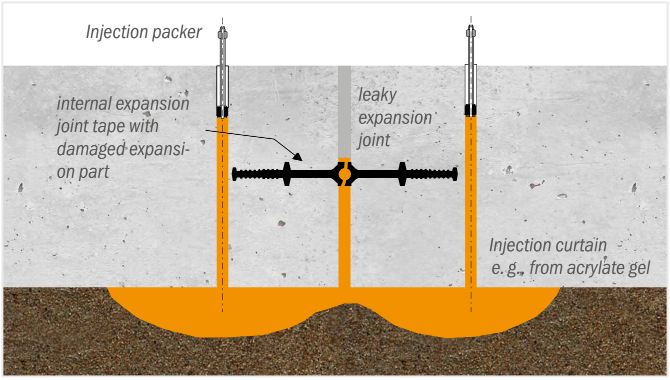


Figure 24: Sealing of leaky movement joints by curtain injection [8]

Note: Injections of the subsoil are subject to approval according to the Water Resources Act (WHG). Therefore, prior to the start of the gelation work, a corresponding permit must be obtained from the competent Lower Water Authority and the Office for Environmental Protection, see [9].

3.6 MASONRY INJECTION IN PART OR BUILDING INTERSTICES

If two-dimensionally injectable interstices between components or structures are present, the subsequent sealing of the construction can also be effected by injecting these interstices with a suitable injection material, see Fig. 25.

The aim of masonry injection is to form a coherent sealing injection curtain in the distribution plane.
Examples of planar distribution planes are, e. g.:

- Structures with a separating surface between the building structure and the sealing membrane (with / without nonwoven insert)
- Intermediate spaces between multi-layer surface sealing systems
- Boundary layer between wall and insulation
- Separating surface between outer and inner shell in tunnel construction

In the case of masonry injection into component or building interstices, the injection parameters such as

- Bore hole spacing
- Hole depth
- Injection technology

must be selected in such a way that a coherent sealing plane is formed in the intermediate space. The bores must be drilled with particular care so that any sealing planes still in operation are not damaged or destroyed.

The suitable injection material is selected as a function of the object-specific boundary conditions, for example with fillers based on acrylate or polyurethane. As in the case of injections into cavities, however, the use of the polyurethane foams (SPUR-I), which seal only temporarily, as a pre-injection is also excluded in the case of injections into component or building intermediate layers, since, as a rule, a space-filling, sealing main injection is no longer possible.

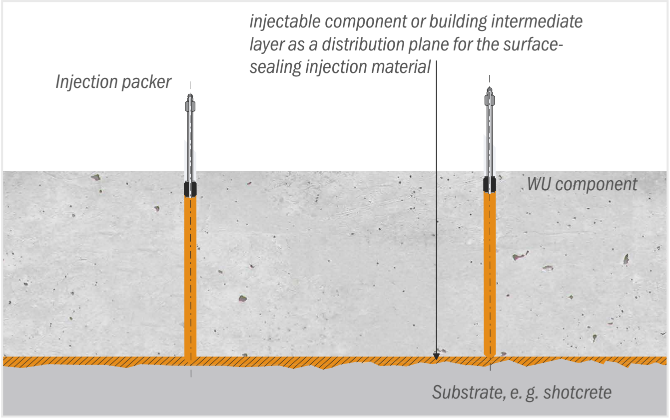


Figure 25: Example of a masonry injection in structural or building interstices [8]

3.7 SUBSEQUENT SEALING OF ELEMENT WALLS

In contrast to in-situ concrete construction, an element wall has a number of special features in the event of leaks due to the large number of possible water pathways, see also [7]. In order to seal the leaky working joint between the base plate and the element wall by injection via injection packers, bore channels are introduced at the connection point between the base plate and the wall, as shown in Fig. 26, which intersect the working joint at an angle of 45° (1). The working joint must be drilled over and the injection material should engulf the joint in part as shown in Fig. 26. In order to seal the boundary layer between the precast slabs and the in-situ concrete and the associated water pathways, it is additionally recommended to inject via horizontally installed injection packers (2) – in Figure 26.

Vertical butt joints in the wall or corner region can also be subsequently sealed by injection of a suitable injection material via injection packers. Figure 27 shows that for an element wall corner in which leaks have occurred in the region of a sealing tube; Figure 28 shows that for an element wall corner in which a predetermined crack joint rail was used. The injection of vertical butt joints in the wall region can optionally be carried out according to the drilling scheme indicated in Figs. 29 and 30. If the installed sealing tubes have not been filled, they must first be filled with cement glue or superfine cement suspension via injection packers. For this purpose, the sealing tube is drilled in the lower and upper region.

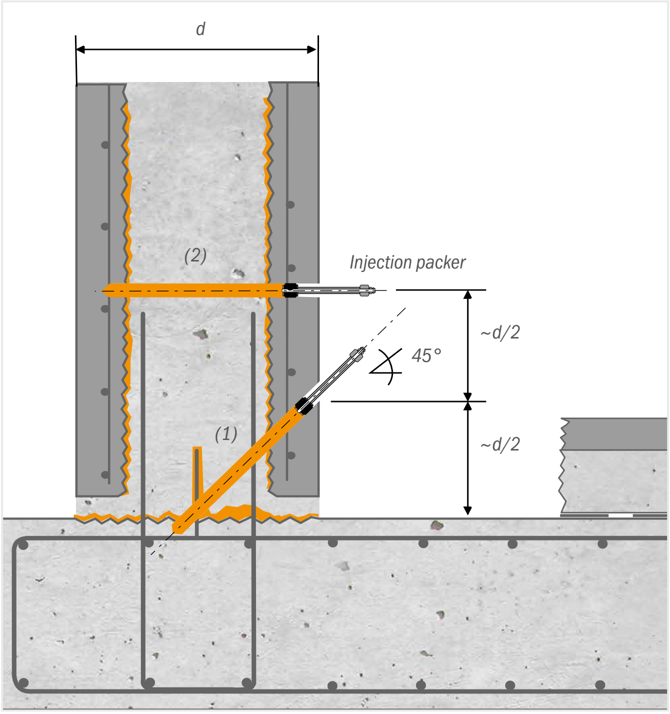


Figure 26: Subsequent sealing of an element wall by injection [7]

SEALING OF ELEMENT WALLS BY INJECTION

The mineral injection material is injected via the lower injection packer, while the upper injection packer is used for venting. After hardening of the mineral filler, the sealing injection can be carried out, for example , according to the drilling pattern with PUR resin shown in Figs. 27 and 30. As a rule, this is the case after seven days at the earliest.

In order to be able to reach and compress as many of the potential water pathways as possible, it may be expedient to additionally drill into the boundary layers between the precast slabs and the in-situ concrete core in order to seal any defects, longitudinal cracks or the like present there by injection of the injection material. Corresponding examples are shown in Figs. 27 and 30. In order to avoid damage to the element wall due to too high an injection pressure, this should be significantly lower than with an in-situ concrete wall, see also Chapter 3.1.1 or [7].

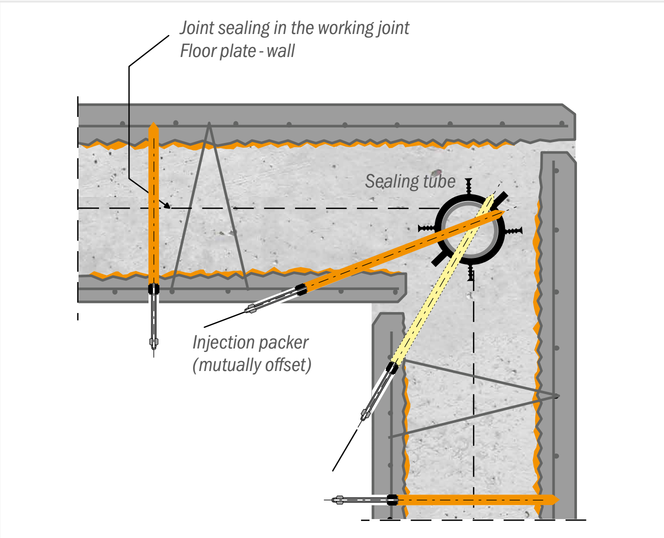


Figure 27: Subsequent sealing of an element wall ceiling with sealing tube by injection [7]

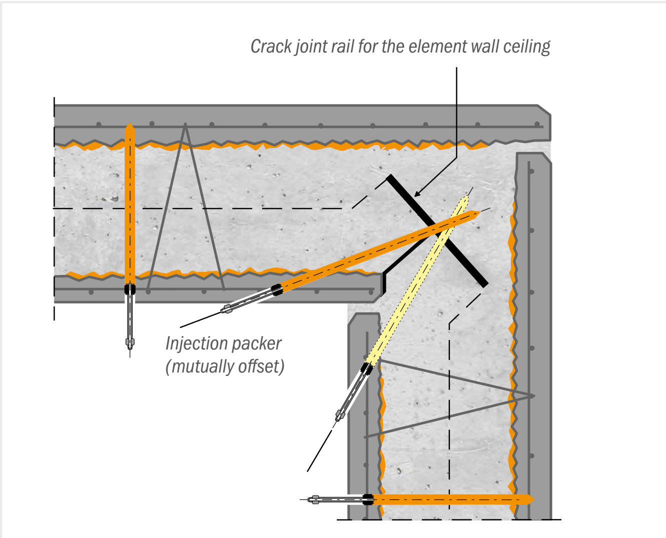


Figure 28: Subsequent sealing of an element wall ceiling with a predetermined crack joint rail [7]

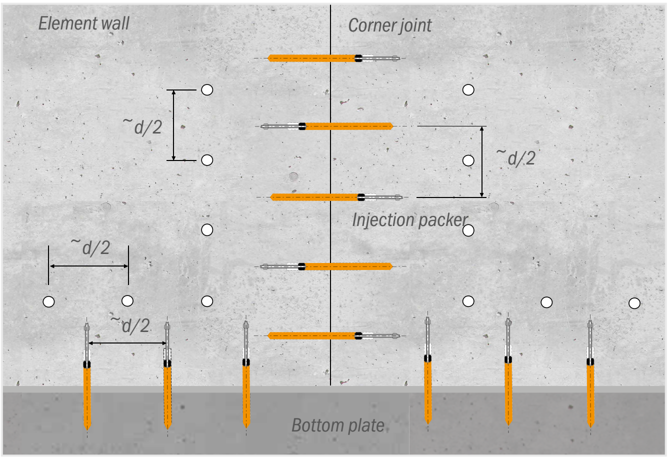


Figure 29: Drilling scheme for sealing an element wall ceiling by injection (example) [7]

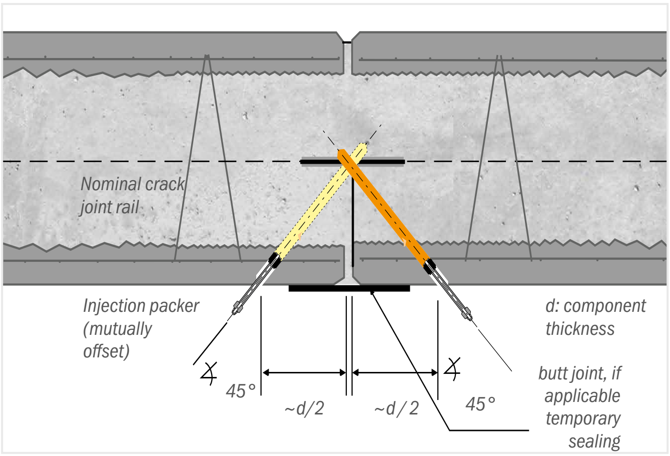


Figure 30: Subsequent sealing of the butt joint of an element wall by injection [7]

4 DOCUMENTATION OF INJECTION WORK

Injection work must be carefully documented. The scope of the documentation must be specified in detail by the specialist planner in the planning phase or tender phase. The documentation is not an ancillary service, but an own item to be advertised. Table 3 indicates which information, among other things, must be documented, see also [10]. The evaluations / injection protocols are part of the documentation.

Table 3: What information should be documented during injection work?

Information on the object and time	• Object and component • Date of pressing
Information on - holes - injection points - injection packers	• Number, location and spacing of the holes / injection packers • Diameter of the holes • Drill hole depth and drilling angle per injection point (injection packer) • Drawing and / or photographic documentation of the drilling grid (with, for example, the drill hole or packer number, the drilling depth and the drilling angle next to each drill hole on the wall) • Specification of any deviations from the planning specifications of the renovation concept
Information, among other things, on injection material / filler* - injection technology - Injection process	• Type, product name and batch number/identification of the filler used • Injection technology used (1- or 2-component injection technology, 1K or 2K pump technology) • Amount of filler used • Temperature of the environment (outside air) and the component • Mixing ratio and reaction time of the filler • Material consumption per injection point (injection packer), stage and phase • Time of pressing and injection duration per injection point (injection packer), stage and phase • Sequence of the injection (packer numbers) • Pressing pressure (p_{min}, p_{max}) per packer • Volume flow (Q_{min}, Q_{max}) per packer • Special features and course of the injection (e. g., packer contacts per packer during the injection, material leaks, stoppers,...) • Information on post-injections (including time, injection duration, pressing pressure, volume flow, quantity,...)
Other information	• Information on the test plan / quality monitoring of the injection measure) • Notes on deviations from the planning specifications • Information on any structural deformations that may occur • Description of flanking measures (e. g., pre-injection, protective measures, possible removal of root growth) • Notes for checking and functional control of the injection technology as well as the devices for dosing and mixing the components of the filler

** In the ABI leaflet [10], 4th Edition 09 / 2022, the term "injection material" is used, in the TR maintenance [1], edition 05 / 2020 and in the ZTV-ING [3] the term "crack injection material" is used (Only available in German).*

4.1 More safety for injection processes

DESOI w.i.l.m.a. stands for wireless injection logging monitoring assistant (Figure 31) and is at the heart of the injection pump. State-of-the-art electronics combined with a tablet form an integrated unit and conveniently manage all relevant recording data of the injection process.

The data logger, which has been successfully used worldwide for several years, is connected directly to the injection pumps and reliably records the pressure, volume, time and deviation of the injection processes.
DESOI w.i.l.m.a. combines a series of innovative injection pumps for various construction processes and documents them securely in accordance with the specifications of quality and construction management.

All collected data for further evaluations is, with an existing mobile connection, directly transferred from the device to a central server on request.

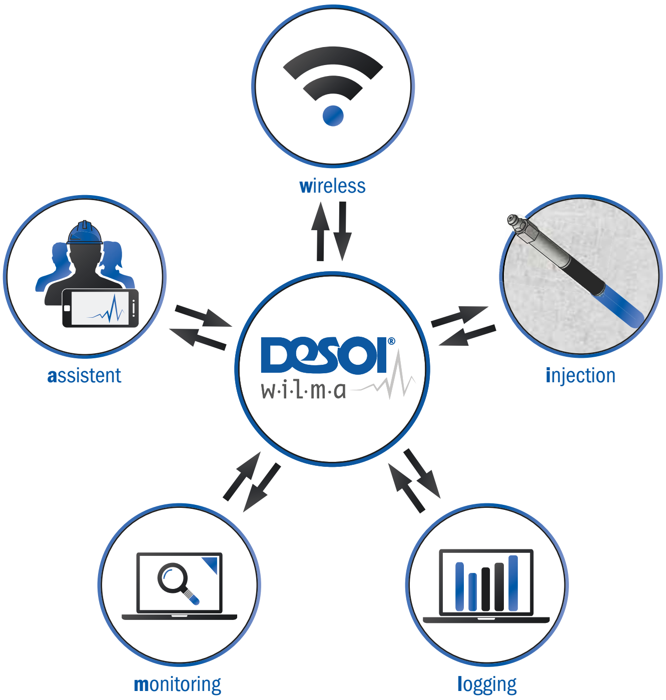


Figure 31: Basic representation of the functions of the data logger w.i.l.m.a.

4.1.2 Permanent data recording

Monitoring during injection work: Through the continuous monitoring of injection processes, it is ensured that the planned parameters can be tailored, monitored and documented specifically for the respective building.
In advance, limit values are set, for example, for the mixing ratio, the pressure and the volume (Figure 32).

If these values are undershot or exceeded, for example, the injection process could be stopped and a corresponding message appears on the display. The recorded data is continuously and securely stored on the DESOI w.i.l.m.a. platform and, if there is an existing mobile phone connection, is immediately stored on a secure server in Germany for further processing.

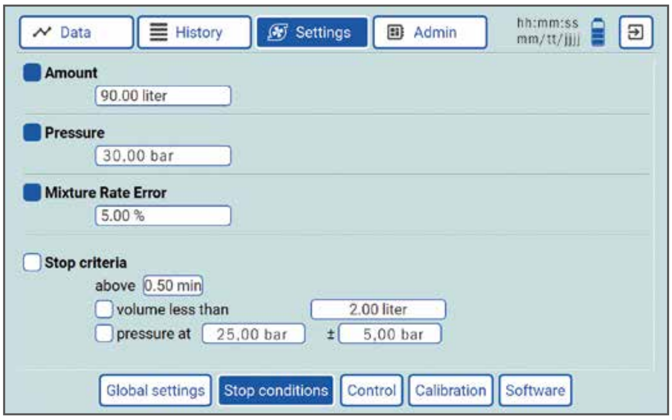


Figure 32: Example of input mask

4.1.3 Worldwide access to web servers

In cooperation with our partner eguana, we form a joint unit to secure all transmitted data on the SCALES platform. Evaluations, analyses and data can be accessed from any browser-enabled device. Three different service tariffs are available to the end user for this service. Irrespective of this, the data can also be read manually by DESOI w.i.l.m.a. (Figure 33).

In principle, communication and transparency are ensured from the time the data is recorded at the construction site. All data is password-protected for the user and is processed and managed exclusively on a server in Germany.

Responsible and efficient data management is ensured, including automatic data reading, remote access to device and diagnostic information, and use via conventional standard browsers – anytime, anywhere.

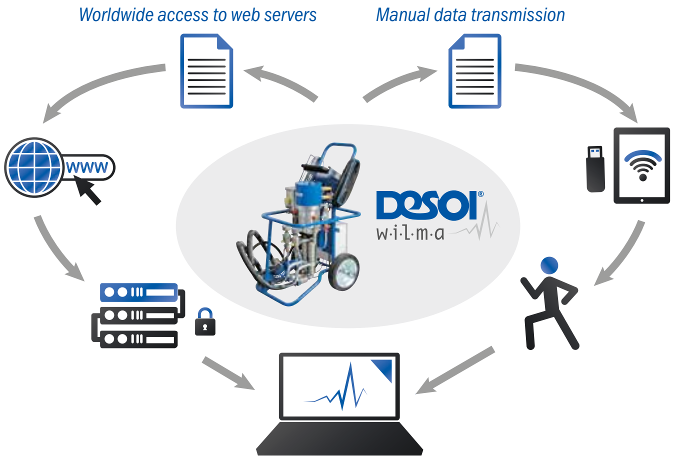


Figure 33: Data transmission options DESOI w.i.l.m.a.

The server is located in Germany in a certified data centre and is subject to automatic version and security updates as well as certified data encryption.

4.1.4 Manual data transmission

- Data download via USB-C or WLAN in CSV format

Manual access to the data is generally possible. However, this way requires more time and effort for the evaluation compared to the automatic method. Furthermore, there is a risk of errors by the operator, which can lead to inaccuracies in the logs. Even a repetition of the same protocols is not 100 % secure if they are created manually.

Manually created protocols can only be partially supported by support mechanisms. In addition, it should be noted that managing data on USB memory and transferring it to other media is potentially error-prone.

4.1.5 Evaluation

Intuitive visualisations, automatic analyses (Figure 34) and customised reports offer a wide range of possibilities for presenting stored data transparently. Of course, you can also subsequently transfer the data to higher-level systems or export it as a CSV file.

Responsible & efficient data management

- Automatic data acquisition
- Intuitive visualisations:Display of current and historical data in tabular and graphical presentation
- Smooth cooperation for all parties involved
- Real-time access
- Logging: audit-proof data backup
- Export for further processing in higher-level programs (PDF, CSV, and many more)

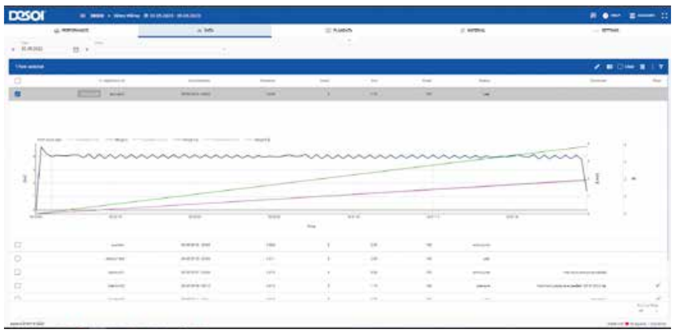


Figure 34: Graphical representation of the evaluation

4.1.6 Versions

DESOI w.i.l.m.a. is available in different versions (Figures 35 – 37) and secures all processes of injection technology.

- 1C + 2C injection resin (PU) / silicate resin
- 2C acrylate gel (AY)
- 1C cement (Z)
- Special solutions on request

Figure 35: DESOI w.i.l.m.a. - AY
DESOI AirPower M35-3C VA

Figure 36: DESOI w.i.l.m.a. - PU
DESOI AirPower L36-2C

Figure 37: DESOI w.i.l.m.a. - Z

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BIBLIOGRAPHY

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Prof. Dr.-Ing. Rainer Hohmann is Professor of Building Physics at the University of Applied Sciences Dortmund. Among other things, he is a Member of the

- Expert Committee "Building and Roof Sealing" of DiBt [1]
- DIN Committee of DIN 18197 "Sealing joints in concrete with joint tapes"
- DIN Committee of DIN 18541 "Joint tapes made of thermoplastic materials for sealing joints in in-situ concrete"
- DAfStb[2] "Water-impermeable concrete structures" subcommittee
- DBV[3] "High-quality use of basements – building physics and indoor climate" working group
- DBV[3] "Injection hose systems and swellable inserts for joints" working group
- DBV[3] "Coated joint sheets" working group

He is the author of numerous specialist publications and lectures on the topic of "Sealing concrete structures".

[1] German Institute of Civil Engineering (DiBt)
[2] German Committee for Reinforced Concrete e.V.
[3] German Concrete and Construction Technology Association e.V.

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ALWAYS HERE TO HELP THROUGH MEDIA

"Progress depends on the exchange of knowledge," said Albert Einstein. And we are happy to pass on our decades of experience in the field of injection and industrial technology to you. You will also find all DESOI media on our homepage, which we can also send to you by post on request. Visit us on our social media channels and follow our news.
You can see what we have to offer here through media at a glance.

VIDEOS

Step by step, we will explain commissioning and maintenance with our injection devices. It's certainly worth a look.

YouTube

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The success of a renovation measure lies in professional planning and implementation.
You can benefit from our performance specifications (recommendations) from various specialist areas with the associated test certificates.
In addition, you will find numerous brochures with useful information about our products.

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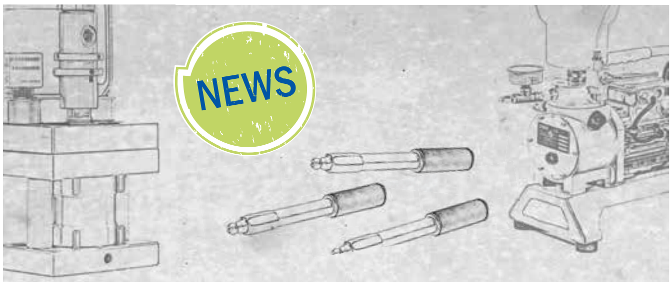

ALWAYS HERE TO HELP THROUGH MEDIA

DESOI INJECTION ABC

Our injection ABC has become a faithful companion for construction specialists. The reference work contains information on the subject of injection.

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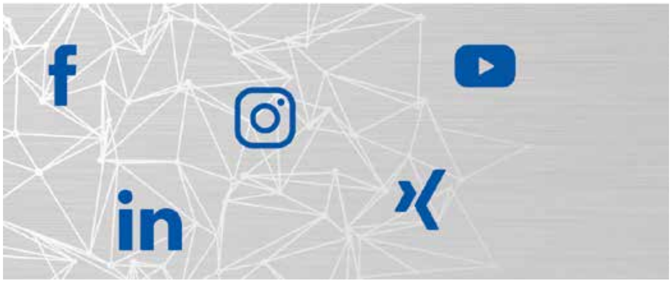

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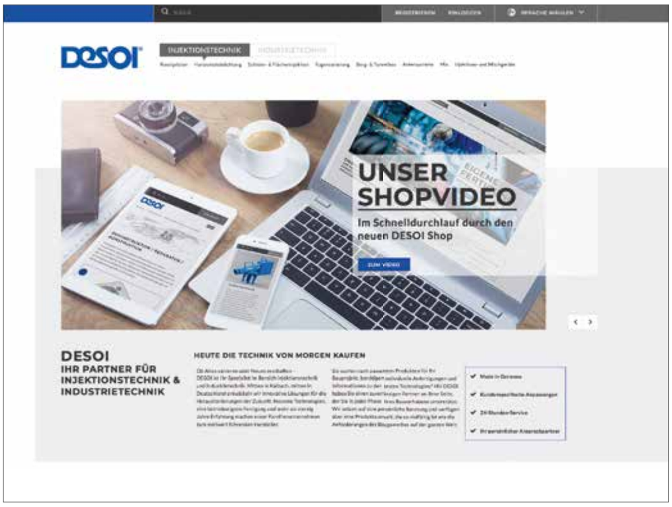

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