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Translation of the Federal Waterways Engineering and Research Institute (BAW) leaflet

Surface repair of hydraulic structures with textile-reinforced mortar and concrete layers (MITEX)

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"Surface repair of hydraulic structures with textile-reinforced mortar and concrete layers (MITEX)"
was approved by the Federal Waterways Engineering and Research Institute

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Preliminary remark

The basis of this information sheet is the /ZTV-W LB 219/, unless otherwise specified in this information sheet. Section 0 (planning instructions), sections 1 and 2 (basic sections) and section 5 (system-specific section) of the /ZTV-W LB 219/ apply. The sprayed textile-reinforced layers in this information sheet represent an additional method to the repair methods listed in section 0.5 of the /ZTV-W LB 219/ for the extensive repair of hydraulic structures, which takes into account changes in the crack width in the subsoil.

At present, only textile reinforcements made of carbon fibers can be used. The future use of other materials is conceivable.

The regulations in this information sheet currently only apply to layers made of sprayed mortars and sprayed concrete in accordance with section 5 of the /ZTV-W LB 219/. An extension of the information sheet to the use of other repair materials is conceivable.

The scope of application of this information sheet is currently limited to the repair of components exposed to the weather without water stress on the front or back. An extension of the information sheet for use in other areas is conceivable.

If this information sheet is a binding part of the contract, the use of materials other than those mentioned above or in areas other than those mentioned above is only possible with the consent of the client.

Goods that are lawfully placed on the market in another member state of the European Union or in Turkey or that originate in an EFTA state that is a party to the Agreement on the European Economic Area and are lawfully placed on the market there are deemed to be compatible with this measure. The application of this measure is subject to Regulation (EC) No 764/2008 of the European Parliament and of the Council of 9 July 2008 laying down procedures relating to the application of certain national technical rules to products lawfully placed on the market in another Member State and repealing Decision No 3052/95/EC (OJ L 218 of 13 August 2008, p. 21).

1 References to standards, literature and other technical regulations

/BAW recommendation 2019/ BAW recommendation: Repair products - Information for the expert planner on building-related product features and test methods. Federal Institute for Waterways Engineering and Research, 2019.

/Büttner 2012/ Büttner, T.; Raupach, M.: The building's new clothes. Functional principles and possible uses of textile-reinforced concrete layers for the protection of buildings. In: Bauen im Bestand 35, No. 6, pp. 70-75, 2012.

/DIN EN 12192-1/ DIN EN 12192-1: Products and systems for the protection and repair of concrete structures - Grain size distribution - Part 1: Test methods, 2002.

/DIN EN 1062-7/ DIN EN 1062-7: Coating materials and coating systems for mineral substrates and concrete for exterior use; Part 7: Determination of crack-bridging properties, 2004.

/DIN EN 10204/ DIN EN 10204: Metallic products - Types of inspection certificates, 2005.

/DIN EN 1504-1/ DIN EN 1504-1: Products and systems for the protection and repair of concrete structures: Definitions, requirements, quality control and evaluation of conformity; Part 1: Definitions, 2005.

/DIN EN 14487-1/ DIN EN 14487-1: Shotcrete - Part 1: Terms, specifications and conformity, 2005.

/DIN EN 14487-2/ DIN EN 14487-2: Shotcrete - Part 2: Execution, 2006.

/DIN 18551/ DIN 18551: Shotcrete - National application rules for the DIN EN 14487 series and rules for the design of shotcrete structures, 2014.

/DIN EN ISO 4618/ DIN EN ISO 4618: Coating materials - Terms, 2015.

/DIN EN 12390-3/ DIN EN 12390-3: Testing of hardened concrete - Part 3: Compressive strength of test specimens, 2017.

/DIN EN 1766/ DIN EN 1766: Products and systems for the protection and repair of concrete structures - Test methods - Reference concretes for testing, 2017.

/DIN 18200/ DIN 18200: Proof of conformity for construction products - Factory production control, external monitoring and certification, 2018.

/DIN EN 12127/ DIN EN 12127: Textile fabrics - Determination of mass per unit area using small samples, 1997.

/DIN EN 1542/ DIN EN 1542: Products and systems for the protection and repair of concrete structures - Test methods - Measurement of adhesion strength in the pull-off test, 1999.

/ISO 10406-1/ ISO 10406-1: Fibre-reinforced polymer (FRP) reinforcement of concrete - Test Methods - Part 1: FRP bars and grids, 2015.

/Morales Cruz 2019/ Morales Cruz, Cynthia: Crack-Bridging Carbon Textile Reinforced Concrete Protection Layers. Dissertation in progress, publication expected in 2020, Faculty of Civil Engineering at RWTH Aachen University, 2019.

/ZTV-W LB 219/ ZTV-W LB 219: Additional technical contract conditions - hydraulic engineering (ZTV-W) for the repair of concrete components of hydraulic structures (performance area 219). Federal Ministry of Transport and Digital Infrastructure (BMVI), 2017.

2 Scope of application

This information sheet applies to the extensive repair of cracked hydraulic structures made of concrete or reinforced concrete using textile-reinforced spray mortar/sprayed concrete made of cement-bound concrete substitute with or without polymer modification in accordance with /ZTV-W LB 219/, Section 5, with a maximum grain size of ≤ 6 mm, which is applied in thin layers (30 to 40 mm) without additional anchoring using the spraying method on concrete substrates of old concrete class A2, A3, A4 or A5 in accordance with /ZTV-W LB 219/. The repair layer must not be exposed to any hydrostatic water pressure from the back (crack water and pore water pressure) or from the front during the application and use phase (see Table 2). The application is only permitted in the case of changes in the width of the cracks in the concrete substrate, which mainly result from seasonal temperature changes. The change in crack width in the concrete substrate may generally not exceed 0.6 mm. The bond between the concrete substrate and the textile-reinforced sprayed mortar/shotcrete layer is created exclusively through adhesion. The sprayed mortar/shotcrete must be adapted to the respective old concrete in terms of its strength and deformation behavior. Products in accordance with /ZTV-W LB 219/ based on /DIN EN 14487-1/ in conjunction with /DIN 18551/ with additional features or products of unknown composition can be used as sprayed mortar/shotcrete (see Table 1)

The repair system can be installed on vertical and steeply inclined surfaces as well as overhead.

Table 1: Usable spray mortars/spray concretes according to /ZTV-W LB 219/, Section 0.5, Table 0.4

Nr.	Product
1	Sprayed mortar/sprayed concrete S-A2, S-A3, S-A4 and S-A5 based on /DIN EN 14487-1/ and /DIN EN 14487-2/ in conjunction with /DIN 18551/ with additional features
2	Sprayed mortar SRM-A2, SRM-A3 and SRM-A4 and SRM-A5 or sprayed concrete SRC-A2, SRC-A3, SRC-A4 and SRC-A5 (unknown composition)

In the remainder of this leaflet, for the sake of simplicity, we will refer to sprayed mortar and sprayed concrete.

3 Terms, symbols and abbreviations

3.1 Terms

The following terms apply to the application of this information sheet.

Pull-off test
Determination of the surface tensile strength of the concrete substrate (the concrete base) or the adhesive tensile strength of applied sprayed mortar or sprayed concrete layers by tensile stress normal to the surface

Adhesion
Adhesion of two phases at an interface (wettability), e.g. adhesion of water to the walls of the capillary pores in concrete due to electrostatic forces (van der Waals secondary valence forces)

Old concrete
Concrete that was already present before a repair measure and serves as a base for the repair products and systems to be applied

Equivalent diameter
Measure of the size of an irregularly shaped sand grain particle, calculated by comparing a property of the irregular particle with a property of a regularly shaped particle

Construction joint
Attachment point in the concrete, concrete replacement or surface protection system as a result of a work interruption

Sanding
Uniform application of dried mineral substances to a fresh coating, whereby the grain is firmly embedded in the surface

Coating
Continuous layer that is created by applying a coating material to a substrate once or several times, for example the already soaked textile reinforcement /DIN EN ISO 4618/

Concrete replacement
Cement or plastic-bound mortar or concrete and leveling layer or scratch coat (applied by hand or spraying). The following are considered concrete replacements according to this information sheet:
- Sprayed mortar and sprayed concrete according to /DIN EN 14487-1/ and /DIN 18551/ with additional features
- Concrete replacement using the spraying process (SRM and SRC)

Concrete substrate
Surface and near-surface layer of a concrete component under the concrete replacement to be produced

Batch
Production unit of a component of a repair material from continuous production or a single production batch

Debonding material
Material that prevents the bond between the substrate and the sprayed mortar/sprayed concrete and thus leads to an increase in the free expansion length of the textile-reinforced sprayed mortar/sprayed concrete
Examples: Adhesive tape, epoxy resin, cementitious layer

Hardening
Transition of a binding agent from the liquid to the solid state through chemical or physical reactions

Adhesive tensile strength
See tear-off test

Cavity/hollow spot
Defect or structural disturbance in the concrete component caused by inadequate compaction, segregation (coarse grain enrichments, gravel nests) or leaching

Injection
Introduction of crack fillers using an injection device under controlled pressure via packers with and without damming

Injection pressure
Nominal value of the delivery pressure with which the crack filler is delivered to the packer. A distinction is made between the injection pressure on the injection device and that on the packer

Repair system
Material combination to achieve a specific repair goal "Repair system" here means a protective layer made of textile-reinforced sprayed mortar/sprayed concrete layer and debonding material

Current condition
The condition of a component or structure at a specific point in time resulting from the existing influences and corresponding resistances

Location
Part of a mortar or concrete produced in one operation; One or more layers of the same composition form a layer

Surface tensile strength
See tear-off test

Packer
Transition piece between injection device and component, attached to the component surface (adhesive packer) or in drill holes (drill packer), usually equipped with a valve

Roughness
Average deviation of the surface of a defined measuring area from an imaginary plane

Roughness depth
Characteristic value for the roughness of a surface in millimeters, determined according to the sand surface method according to /DIN EN 1766/

Reaction resin
Polymer mixture that hardens through a chemical reaction

Crack, types of cracks
Separation in the concrete structure, also in the area of dummy joints or construction joints. A distinction is made between surface cracks, near-surface cracks, bending cracks and separation cracks:

- surface cracks, net-like or directional, are a few millimeters deep,

- shrinkage cracks arise as a result of shrinkage, where the deformations are hindered, usually run through the entire thickness of the component
- bending cracks affect significant parts of the cross-section, leaving an uncracked concrete compression zone,
- shear cracks, which form from bending cracks, often run diagonally to the bar axis
- separation cracks run through the entire cross-section
- split cracks run parallel to the main compressive stresses

Crack width
The width of the crack in millimeters measured on the non-mechanically processed surface of the concrete as the distance between the crack edges

Crack width change
Change in the crack width depending on time and the effects on the structure

Crack bridging
Ability of the coating or coating system to absorb the expansion that results from the movement of the crack flanks /DIN EN 1062-7/

Roving
Bundle, strand or multifilament yarn made of parallel filaments that are used to produce textile reinforcements

Layer thickness
Height of a layer consisting of one or more layers in the case of concrete replacement

Predetermined breaking point
Point in the substrate where crack formation is specifically encouraged /DIN EN 1062-7/

Shotcrete
Shotcrete is concrete according to /DIN EN 14487-1/ in conjunction with /DIN 18551/ with aggregate for concrete with a maximum grain diameter > 4 mm, which is conveyed to the installation site in a closed hose or pipe and is applied and compacted there by spraying (see also sprayed mortar)

Sprayed mortar
Cement mortar (factory-mixed dry mix) with aggregate for concrete ≤ 4 mm, which is produced, monitored and processed like sprayed concrete in accordance with /DIN EN 14487-1/ in conjunction with /DIN 18551/ (see also sprayed concrete)

System
One or more products that are used simultaneously or one after the other to carry out repair or protective measures for concrete structures /DIN EN 1504-1/

Textile reinforcement
Flat, non-metallic reinforcement. A distinction is made between various textile structures:

- Lay-up,
- Fabric,
- Fleece,

- Knitted fabric,
- Weave

Lay-up and fabric are often used in construction in combination with mortar or concrete. The yarns in the longitudinal direction of the fabric/lay are called warp rovings, the yarns in the transverse direction are called weft rovings. The starting materials used in construction are usually carbon fibers or alkali-resistant glass fibers.

Impregnation

Impregnation is the process following textile production in which a liquid mixture is pressed into the interior of the textile reinforcement via squeezing and/or stripping rollers. Curing usually takes place under the influence of temperature. After impregnation, the textile reinforcement can be additionally coated. Cured impregnated textile reinforcements usually have higher tensile strengths than unimpregnated textile reinforcements, as the inner filaments are involved in load transfer. Polymers based on epoxy resin and polyester resins as well as acrylate-based dispersions are currently used to impregnate textile reinforcements.

Impregnation material

Mixture (usually polymer-based) with which the textile reinforcement is penetrated following textile production.

Dry layer thickness

Thickness of a coating after drying or hardening

Substrate

Surface to which a repair layer is to be applied or has been applied. /DIN EN 1062-7/

Substrate preparation

Includes all measures to achieve a suitable concrete substrate and to achieve a suitable reinforcement condition Examples: removal of foreign layers, cleaning of the surface, concrete removal to create a load-bearing concrete substrate

Bond strength

See tear-off test

Insulation

Temporary sealing on the component surface in the crack and cavity area, which prevents the crack filler from escaping during filling

3.2 Formula symbols and abbreviations

A	area of the sample	[m²]
Abes	Proportion of the sanded textile surface in relation to AGes	[%]
Ages	test area for the sanding proportion	[mm²]
AR	fiber cross-sectional area of the roving	[mm²]
Ar	fiber cross-sectional area of the textile reinforcement	[mm²]

B	Width	[mm]
D	Maximum grain diameter	[mm]
d_c	Clearance between the concrete substrate surface and the adjacent textile reinforcement layer or clearance between the adjacent textile reinforcement layers or clearance between the sprayed mortar/shotcrete surface and the adjacent textile reinforcement layer	[mm]
DIBt	German Institute for Building Technology	[-]
$d_{min,S}$	system-specific minimum layer thickness	[mm]
d_{tr}	Thickness of the disc for determining the dry bulk density of the sprayed mortar/shotcrete	[mm]
$\Delta\varepsilon_R$	change in elongation of the roving	[-]
E_R	modulus of elasticity of the roving	[N/mm²]
$\varepsilon_{R,max}$	elongation at break of the roving	[-]
ε_T	elongation of the textile reinforcement	[-]
F	tensile force	[N]
$F_{R,max}$	roving breaking force	[N]
FÜ	external monitoring	[-]
γ	partial safety factor	[-]
H	height	[mm]
L	length	[mm]
ΔL	relative change in length, Mean value of the displacement sensors	[mm]
l_E	Delamination width	[mm]
LM	Clearance between two rovings (see Figure 6)	[mm]
l_o	Initial length	[mm]
m	Mass of a conditioned sample	[g]
M	Mean value of the basis weight	[g/m²]
MaW	Mesh size of the textile reinforcement (see Figure 6)	[mm]
n	Number of cracks and rovings	[-]
RÜ	Crack bridging body	[-]
RÜK	Crack bridging class	[-]

SRC	Concrete replacement in spray application (Sprayable Repair Concrete), Maximum grain diameter (D) > 4 mm	[-]
SRM	Concrete replacement in spray application (Sprayable Repair Mortar), Maximum grain diameter (D) ≤ 4 mm	[-]
$\Delta\sigma_R$	Stress change of the roving	[N/mm²]
$\sigma_{R,\text{max}}$	Maximum tensile strength of the roving	[N/mm²]
σ_T	Textile tensile stress	[N/mm²]
T_E	Degree of embedding of a grain in the coating on the textile reinforcement	[%]
ÜV	Monitoring contract	[-]
w_i	Single crack width	[mm]
Δw_{op}	Maximum crack width change of the crack to be bridged on the structure	[mm]
WPK	Factory production control	[-]
$w_{\text{min,lab}}$	Minimum crack widening for the system test	[mm]
ZL	Cement paste as crack filler	[-]
ZS	Cement suspension as crack filler	[-]

4 Structure, functionality, planning and dimensioning

4.1 Structure and functionality of the repair system

The repair system consists of a sprayed mortar/shotcrete adapted to the concrete substrate in accordance with /ZTV-W LB 219/, Section 5, a textile reinforcement and a release material. In the area of the crack on the surface of the substrate that is to be bridged, the release material prevents the bond between the substrate and the sprayed mortar/shotcrete and thus leads to an increase in the free expansion length of the textile-reinforced sprayed mortar/shotcrete. The textile reinforcement embedded in the sprayed mortar/shotcrete enables the realization of thin reinforced layers and ensures that the crack width change Δw_{op} in the textile-reinforced sprayed mortar/shotcrete is distributed over the debonding area to several cracks with crack widths w_i < 0.1 mm, see Figure 1.

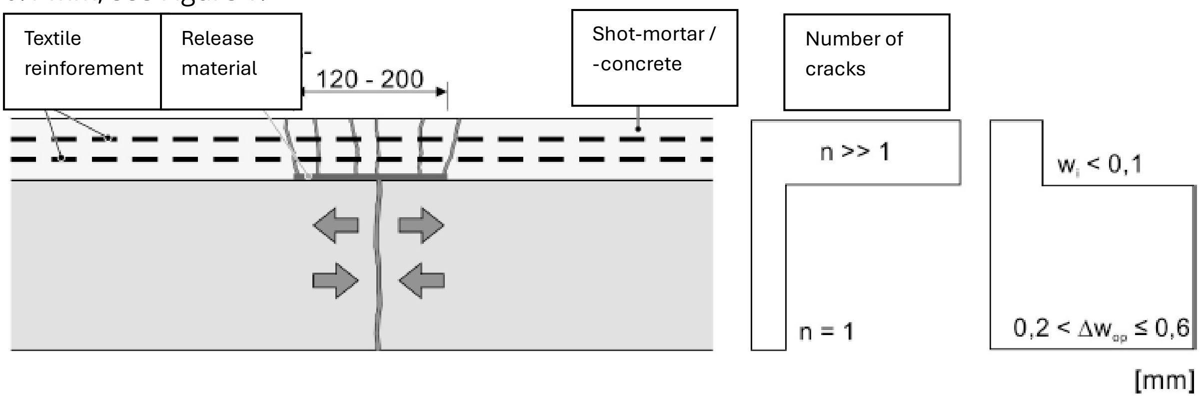


Image 1: Structure and functionality of the repair system (based on /Büttner 2012/)

4.2 Planning and dimensioning

4.2.1 Examination of the structure before repair

According to /ZTV-W LB 219/, Section 0.1, a comprehensive condition analysis of the relevant component must be carried out and documented by the expert planner before a repair measure is implemented.

The actual and minimum target condition of the structure must be determined or specified and documented in accordance with /ZTV-W LB 219/. In addition, the components to be repaired must be assigned to the load scenarios in accordance with Table 2.

Table 2: Load scenarios for surface repair

1	2	3	4	5	6	7
Load	Variant 1		Variant 2		Variant 3	
	a	b	a	b	a	B
Outdoor repair area	yes					
Cyclically moving, possibly water-bearing cracks in the sub-base concrete	yes					
Sufficient bond between repair layer and sub-base concrete	yes		no		no	
Crack water and pore water pressure	no		no		yes	
Hydrostatic water load on the surface	no	yes	no	yes	no	Yes

The maximum seasonal changes in crack width must be determined as a basis for planning. This can be done, for example, by measuring for a sufficiently long period of time. Based on this, the relevant crack bridging class must be determined and documented according to Table 3, Column 2.

Table 3: Crack bridging classes and test conditions within the system test

1	2	3
Maximum crack width change of the crack to be bridged on the structure Δw_{op}	Crack bridging class (RÜK)	Minimum crack expansion for system testing $w_{min.lab}$
mm	-	mm
≤ 0,20	1	*
≤ 0,30	2	0,45
≤ 0,40	3	0,60
≤ 0,60	4	0,90**
> 0,60	5	***
Intermediate values are not to be interpolated * The use of the repair system is not generally intended. The expert planner decides whether the repair system is used and how it is tested if necessary ** Implementation with a sub-base concrete ≥ A4 *** Not permitted		

4.2.2 Planning principles

Based on the classification of the component in accordance with section 4.2.1, the planning of the repair measures and the creation of a maintenance plan must be carried out by a qualified planner.

The repair system described in this leaflet may be used under the following conditions:

- Load scenario variant 1a according to Table 2,
- Crack width change mainly due to seasonal temperature changes,
- Maximum crack width change of the crack to be bridged on the structure Δw_{op} according to Table 3,
- Exposure classes XALL, XBW1, XCR, Δ_w LFR, XC1(dry), XC3, XC4, XS1, XD1, XF1 and XF2.

For the load scenarios variant 1b and variants 2 and 3, additional tests and requirements for the materials and the design must be specified on a project-specific basis and separate evidence must be provided.

The durability of the steel reinforcement in the old concrete in the event of chloride ingress and carbonation must be guaranteed. The system-specific minimum layer thickness $d_{min,S}$ (30 mm) of the textile-reinforced repair system may be taken into account in the durability assessment.

According to /ZTV-W LB 219/, for exposure class XBW1, measures to reduce water penetration or water leakage may need to be taken before a repair system is applied. Cement-bound fillers are preferably used for this purpose.

The concrete substrate is to be classified into an old concrete class in accordance with /ZTV-W LB 219/, Section 0.4. If necessary, component areas to be repaired with locally deviating properties must be identified by appropriate investigations.

If reinforcement is exposed locally or there are large uneven areas in the area to be repaired, the substrate must be prepared and leveled in a suitable manner before the textile-reinforced repair layer is applied so that the layer thickness is approximately the same over the entire area.

For cracks with a crack width change of Δw_{op} > 0.2 mm and for those for which this is considered necessary by the expert planner, a release area must be provided. The distance between the edges of adjacent release areas must be at least 400 mm, otherwise the bond between the repair layer and the substrate must be demonstrated separately. This must be taken into account in the repair plan.

The repair plan must specify which cracks are to be provided with a release strip.

The width of the delamination area l_E across the crack path must be determined by the expert planner, depending on the RÜK (see Table 3), according to equation (1). The delamination width should be as narrow as possible and should not exceed the limits given in equation (1). For RÜK 2, RÜK 3 and RÜK 4, the delamination width l_E can be taken from Table 4.

$$120\,mm \leq l_E = \left(\frac{w_{min,lab}}{0{,}1}\right) * \gamma * MaW \leq 200\,mm \qquad (1)$$

With:

Y=1,5

If the width of the release area differs, the functionality of the system on the structure must be demonstrated. This must be taken into account in the repair plan. Widths greater than 200 mm require proof of the secure connection between the repair system and the component to be repaired by a structural engineer.

As a basis for the execution, the expert planner must prepare a reinforcement plan for the textile reinforcement, including information on minimum overlap lengths, as part of the repair plan.

Carbon is to be used as the fiber material for the textile reinforcement in order to achieve a long service life.

Due to the different crack patterns of the components to be repaired, textile reinforcements with the same mesh sizes in the warp and weft directions and the same fineness in both load-bearing directions must be used. At least two layers of textile reinforcement must be provided.

The minimum layer thickness of the repair system is 30 mm when applied over the surface, the maximum layer thickness is 40 mm.

The distances

- between the concrete substrate surface and the center plane of the adjacent textile,
- between the center planes of two adjacent textile layers and
- between the sprayed mortar/sprayed concrete surface and the center plane of the adjacent textile must be the same.

Regarding the thickness d_c (see section 3.2), the following requirements (see equation (2a) and equations (2b)) apply:

- $d_c \geq 5$ mm (2a)
- $d_c \geq$ maximum grain diameter (2b)

The standard structure for the application of textile-reinforced sprayed mortar or concrete (using the example of two layers of textile reinforcement) is as follows:

- Apply the sprayed mortar or sprayed concrete layer,
- Lay the first textile layer,
- Apply the sprayed mortar or sprayed concrete,
- Lay the second textile layer,
- Apply the top layer of sprayed mortar/sprayed concrete.

Each subsequent layer of sprayed mortar/sprayed concrete must be applied to the still fresh (not hardened) previous layer of sprayed mortar/sprayed concrete. The maximum waiting time between the individual steps must be observed in accordance with the instructions of the sprayed mortar or sprayed concrete manufacturer.

The maximum grain diameter of the sprayed mortar/sprayed concrete should be as large as possible (but ≤ 6 mm) and should also be adapted to the textile used.

Unless otherwise specified, the surface must be left rough after spraying (see /ZTV-W LB 219/).

5 Requirements for the repair system

5.1 Proof of the usability of the individual components

5.1.1 Sprayed mortar/sprayed concrete

The sprayed mortar/sprayed concrete must have a maximum grain size of ≤ 6 mm. The sprayed mortar/sprayed concrete may be applied using the dry or wet spraying method.

The sprayed mortar/sprayed concrete must meet the requirements according to /BAW Recommendation 2019/, Tables 2 and 5, for the exposure classes XALL, XBW1, XC1 (dry), XC3, XC4, XS1, XD1, XF1 and XF2, taking into account the old concrete classes for which the repair system is to be used. Tests relating to the durability of the steel reinforcement do not need to be carried out.

5.1.2 Textile reinforcement

The manufacturer must provide the following information on the materials used: type and fineness of the carbon fiber, impregnation material (type, glass transition temperature), if applicable, surface modification consisting of coating material (type, glass transition temperature) and sanding (particle type and grading curve according to /DIN EN 12192-1/).

The textile reinforcement must be designed in such a way that the rovings are aligned longitudinally and transversely without waviness and are completely impregnated with the impregnation material. The impregnation material must be hardened.

The mesh shape of the textile reinforcement must be square. The clear dimension between two rovings must be at least three times the maximum grain diameter of the sprayed mortar or sprayed concrete.

The fiber cross-section of the roving A_R must be the same in the warp and weft directions and is determined according to equation (3):

$$A_R = \frac{Feinheit}{Dichte}\left[\frac{g/_{km}}{g/_{cm^3}}\right] * 10^{-3} \quad (3)$$

The basis weight of the impregnated and, if applicable, surface-modified (coated and sanded) textile (final state) is to be determined according to Appendix 2, A 2.1.

The glass transition temperature of the impregnation material and, if applicable, the coating is to be determined on three samples each based on /BAW Recommendation 2019/, Table 27, line 16. Two runs, each consisting of a heating and cooling curve, are to be carried out for each sample in order to compensate for the thermal history of the sample. The glass transition temperature is determined using the second heating curve.

The chemical compounds of the liquid component of the impregnation material and, if applicable, the coating material are to be characterized using a reference spectrum (infrared spectroscopy) in accordance with /BAW Recommendation 2019/, Table 28, line 5. Two individual measurements are to be carried out for each material.

The tensile strength of the warp and weft rovings shall be determined in accordance with Annex 2, A 2.2, on samples prepared from the ready-to-use textile.

For surface-modified (coated and sanded) textile reinforcements, the following parameters must be determined in accordance with Annex 3:

- Proportion of particles present on the textile surface (see Annex 3, A 3.1),
- Size of particles present in the coating material (see Annex 3, A 3.2),
- Quality of particle integration (see Annex 3, A 3.3) and
- Degree of embedding of particles present in the coating material (see Annex 3, A 3.4).

The requirements are contained in Table 5.

5.1.3 Release material

The following information about the release material to be used must be provided: type, manufacturer's name, layer thickness, application details.

The release material must adhere well to dry and/or damp substrates. On the other hand, there must be no significant bond between the sprayed mortar/sprayed concrete and the release material.

To ensure the decoupling effect of the release material, it is recommended that the adhesive tensile strength be established and tested as follows before the system test (see section 5.2) in accordance with /DIN EN 1542/ with 2 base plates 300 x 300 x 100 (L x W x H) mm in accordance with /BAW Recommendation 2019/, Appendix A1.4.

1. Base body with delamination material,

2. Base body with delamination material and sprayed mortar/shotcrete (while maintaining the minimum layer thickness); to simplify the process, the concrete replacement can be applied by hand.

Depending on the delamination material, the surface of the base body may need to be matt and damp before it is applied.

The tensile adhesive strength of the delamination material on the base body should be ≥ 0.2 N/mm²; the tensile adhesive strength of the sprayed mortar/shotcrete on the delamination material should be ≤ 0.05 N/mm² (see also Table 5).

5.2 Proof of the usability of the repair system – system test

5.2.1 General

The tests described below, referred to here as system testing, are carried out on the composite system consisting of:

- Base concrete (cracked),
- Debonding material,
- Textile-reinforced sprayed mortar or sprayed concrete layer.

The system test includes four consecutive tests (see Figure 2):

- Applicability,
- Tensile bond strength,
- Crack distribution,
- Tensile bond strength after crack widening

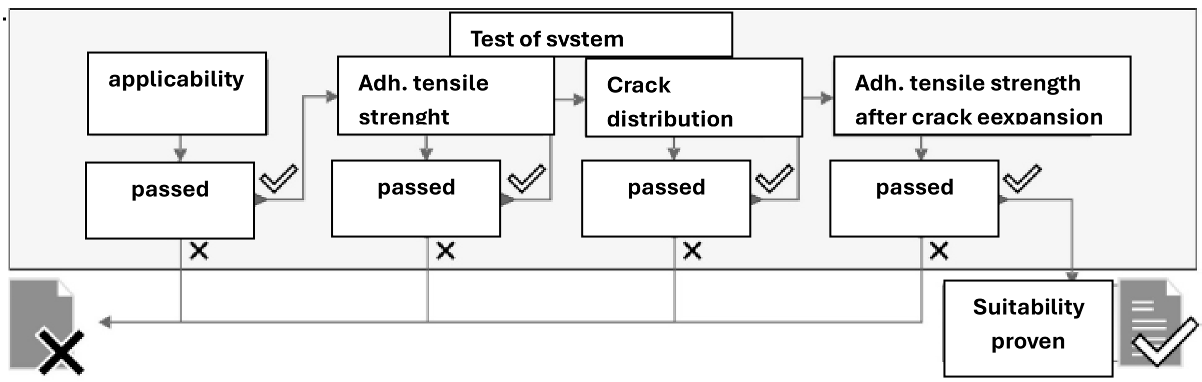


Image 2: Schematic procedure for proving usability – "System test"

If all four tests are passed, proof of the usability of the repair system is provided. The results must be stated in the test report in accordance with Section 7.1.

In order to ensure the suitability of the repair system with a maximum change in the crack width of the crack to be bridged on the structure Δw_{op} of, for example, max. 0.4 mm (RÜK 3), the system test when proving usability must be carried out with a crack widening of at least $w_{min,lab}$ = 0.6 mm (see Table 3). The delamination width l_E is to be selected according to the mesh size of the textile reinforcement (see equation (1) and table 4). The system test is carried out on the safe side with the smallest width of the delamination strip.

5.2.2 Base body concrete

The concrete of the base body must correspond to the old concrete class according to /ZTV-W LB 219/ for which the repair system is to be used. The requirements for the base body concrete are contained in Annex A1.4 of the /BAW Recommendation 2019/ and in /DIN EN 1766/.

Non-absorbent formwork material must be used. The base bodies remain in the formwork covered with plastic film until they are two days old and are then stored at 23 ± 2 °C and 50 ± 5% relative humidity.

When they are at least 21 days old, the formwork side of the base body concrete must be prepared in accordance with Appendix A1.4 of the /BAW Recommendation 2019/, preferably by blasting. The roughness depth must not exceed a value of 1.0 mm.

At least four test specimens with dimensions of at least 700 x 500 x 60 (L x W x H) mm must be produced in accordance with Figure 4.

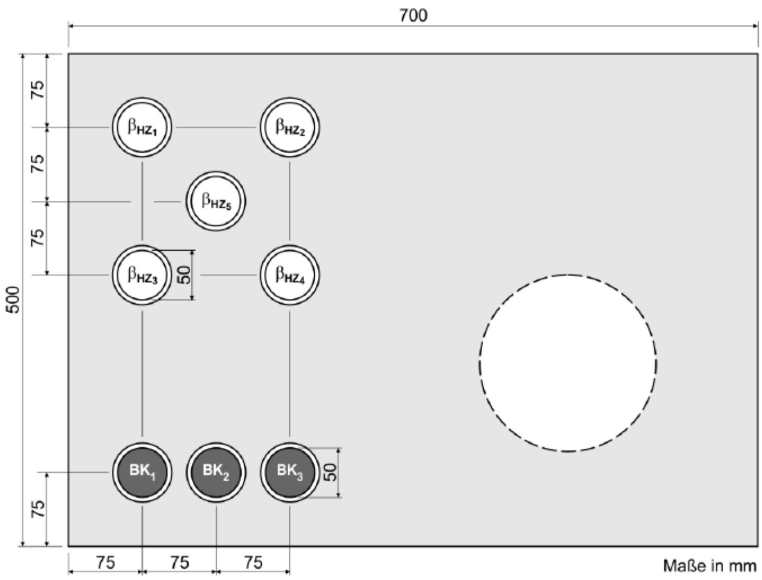
The larger the dimensions of the test specimens, the easier it is to apply the textile-reinforced sprayed mortar or sprayed concrete layer in a practical manner.

To create the predetermined breaking point in the base body, a groove with a depth of 20 mm and a width of 4 ± 1 mm must be cut on the filling side in the middle of the surface, parallel to the narrow sides. The base body must be broken along this saw cut (see Figure 4, detail E).

To avoid cracks in the textile-reinforced sprayed mortar/shotcrete layer (e.g. as a result of sample preparation, transport), three threaded rods (M8 or comparable) are inserted into the base body concrete when it is at least 28 days old and after the crack has been created. These are used to introduce a low compressive stress into the base body (tightening torque approx. 9 Nm) (see Figure 4). To create the channels for the threaded rods, smooth steel rods can be concreted into PVC hoses, for example. The materials shown in Figure 4 have proven to be effective.

To check the uniformity of the base plates, proceed as follows. Three cubes with an edge length of 150 mm are to be produced for each production series. The compressive strength of the cubes is to be determined according to /DIN EN 12390-3/ after 28 days. The roughness, surface tensile strength (at least five test points on the blasted side), dry bulk density and water absorption (at least three test specimens) are to be determined on at least one base body plate for each production series according to Figure 3.

The compaction of the 150 mm cubes must be equivalent to the compaction of the base bodies, i.e. the fresh concrete bulk density of the cubes and the base body must be approximately the same (deviation usually not more than 0.05 kg/dm³).



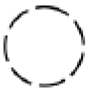
	Surface tensile strength diameter 50 mm x = inspection center number
	Dry bulk density and water absorption x = number of core sample
	Roughness depth

Image 3: Plate base body with arrangement of test points for determining surface tensile strength, dry bulk density, water absorption and roughness depth (based on /Morales Cruz 2019/)

5.2.3 Production of the composite body

To produce the composite body, a non-absorbent formwork as shown in Figure 4 must be used, into which the base body for the application of the sprayed mortar/shotcrete is installed. At least three composite bodies must be produced.

The test specimens for demonstrating the usability of the repair system on vertical and steeply inclined surfaces are produced (almost) vertically. If a repair system is to be used on both vertical and steeply inclined surfaces as well as overhead, it is sufficient to produce the test specimens (almost) vertically.

The concrete surface to be coated must be cleaned (dust-free) and moistened (for at least 24 hours before applying the sprayed mortar/shotcrete).

The debonding material must be applied symmetrically over the crack according to the manufacturer's instructions.

When using cementitious debonding materials, it is important to ensure that their surface is not damp when the sprayed mortar/sprayed concrete is applied.

The warp rovings of the textile reinforcement must run perpendicular to the crack in the base body.

The same number of textile layers must be used as is to be used in the execution.

The system is to be tested with the maximum total layer thickness of the sprayed mortar/sprayed concrete applicable to the structure. Information on the structure of the repair system can be found in Section 4.2.2. The layer thickness to be tested is at least 35 mm and at most 45 mm (planned layer thickness according to Section 4.2.2 increased by 5 mm, corresponds to the permissible layer thickness in the construction according to Section 6).

The composite body is sawn into pieces at an age of at least 21 days in accordance with Figure 5.

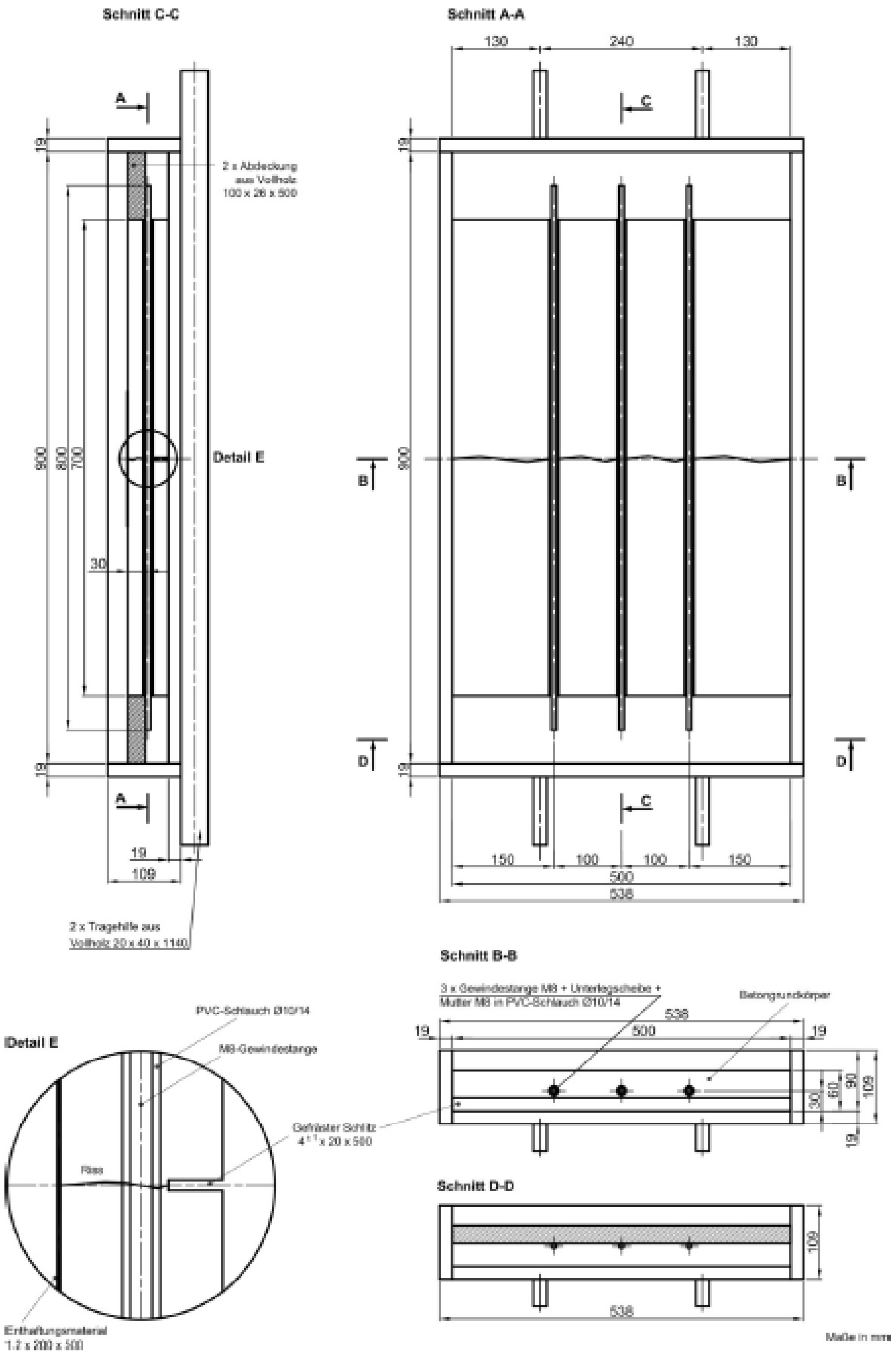


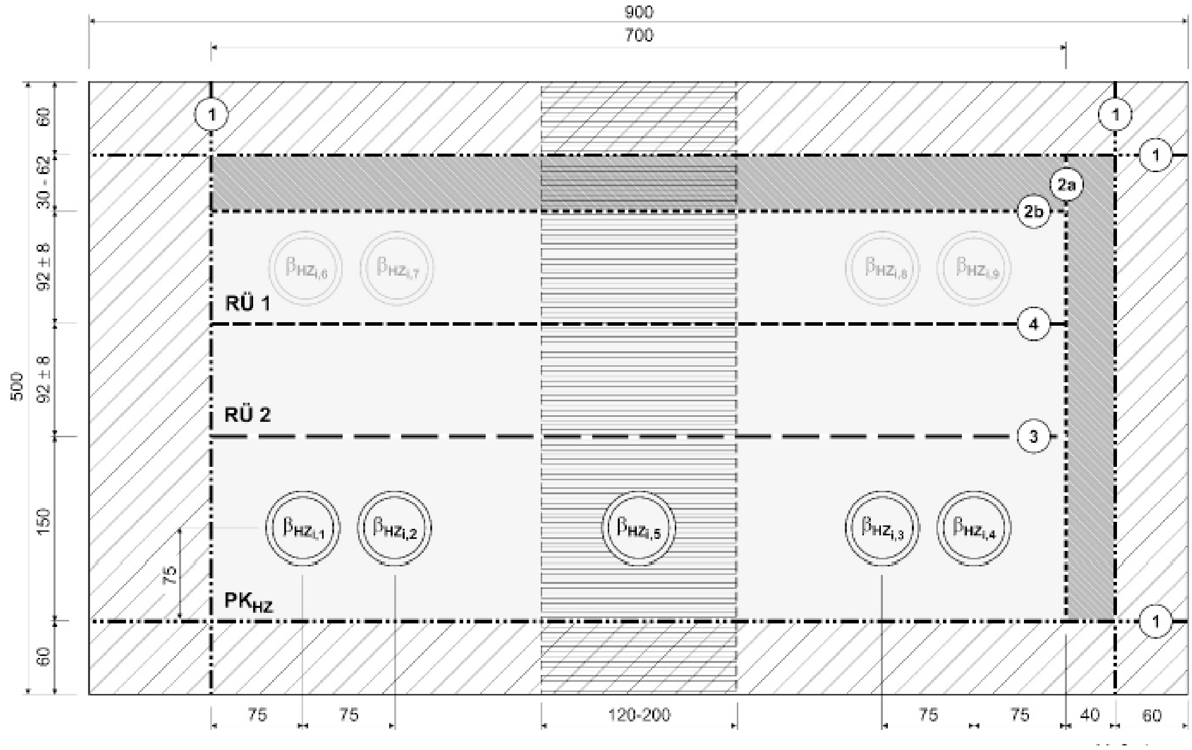
Image 4: Formwork structure for the production of the composite body (based on /Morales Cruz 2019/)

Table 4: Width of the debonding material depending on the mesh size of the textile reinforcement and the RÜK as well as width of the RÜ depending on the mesh size of the textile reinforcement

1	2	3	4	5	6
Mesh size of the textile reinforcement MaW	Width of the release material l_E [1]			Width of the RÜ [2]	Number of whole rovings per layer
	RÜK 1	RÜK 3	RÜK 4		
mm					-
7	120	120	120	91	13
8	120	120	120	88	11
9	120	120	122	90	10
10	120	120	135	90	9
11	120	120	149	88	8
12	120	120	162	96	8
13	120	120	176	91	7
14	120	126	189	84	6
15	120	135	-	90	6
16	120	144	-	96	6
17	120	153	-	85	5
18	122	162	-	90	5
19	129	171	-	95	5
20	135	180	-	100	5
21	142	189	-	84	4
22	149	198	-	88	4

1) see equation (1)

2) Maximum deviation ± 0.5 mm



	Waste	1
	Determination of applicability	2
PK_{HZ}; $\beta_{HZi,x}$	Specimen for determining the adh. tens. strength	3
RÜ	Crack-bridging body	4
	Debonding area between the concrete base body and the textile-reinforced sprayed mortar or sprayed concrete layer	

Image 5: Composite body for system testing, cutting pattern (adapted from /Morales Cruz 2019/)

The geometry of the test specimens for determining applicability, adhesive tensile strength and crack bridging ability as well as the position of the test surfaces, saw cuts and the cutting sequence can be found in Figure 5. The sequence of cuts of the composite body is as follows:

1) The composite bodies are cut to a size of 700 x 380 (L x W) mm by sawing perpendicular to the spray-rough surface.

2) To determine applicability, a thin strip is cut off from the short (underside when spraying) and long side of the composite body (see dark gray area in Figure 5), the width of which depends on the width or length of the RÜ.

3) Cutting the PKHZ test specimen with a length of 700 mm and a width of 150 mm to determine the adhesive tensile strength.

4) Cutting two RÜs with a length of 700 mm and a width according to Table 4, column 5. The longitudinal cut should be chosen so that it is in the middle of the mesh. The central axis of the threaded rod in the base concrete must be at least 30 mm from the edge of the RÜ.

5.2.4 Tests on the composite body

5.2.4.1 Applicability

The applicability is assessed for each composite body plate (at least three) on sections 2a and 2b according to Figure 5. The test specimens are to be examined for defects in accordance with /BAW Recommendation 2019/, Appendix A1.7. A distinction is made between surface-like (see Figure 6, top left) and linear (see Figure 6, bottom left) defects that either border the rovings or are located immediately near the rovings. The defect length corresponds to the length of the greatest extent. Examples are shown in Figure 6. The requirements are listed in Table 5.

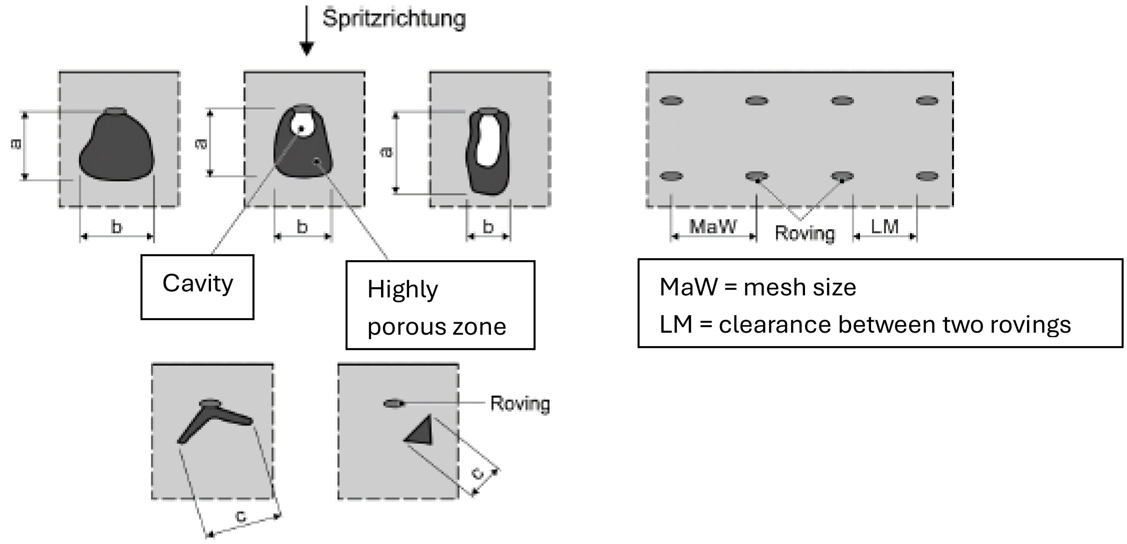


Image 6: Examples of defects in the repair system

5.2.4.2 Adhesive tensile strength

The adhesive tensile strength is assessed for each composite panel (at least three) on a composite PKHZ according to Figure 5. The test is carried out at the ßHZ test points i,1 to i,5 according to Figure 5 and in accordance with /DIN EN 1542/. The ßHZ test points i,1 to i,4 are located outside the delamination area. The requirements are listed in Table 5.

5.2.4.3 Crack distribution

5.2.4.3.1 Conducting the test

The crack distribution is assessed for each composite body plate on RÜ 1 according to Figure 5. RÜ 2 is kept as a reserve sample.

The minimum crack widening in the base body $w_{min.lab}$ during the test depends on the crack bridging class in Table 3.

For the crack distribution test, the RÜ is glued to two carrier plates with the dimensions 350 x 150 x 20 (L x W x H) mm so that the crack in the substrate is located between the carrier plates (see Figure 7). The distance between the carrier plates is 10 ± 0.5 mm. In addition, the underside of the base body must be freed of dust, grease and loose components before gluing to ensure optimal adhesion. To ensure the most even distribution of force during the test, the carrier plates must be attached to the RÜ over the entire surface with the same adhesive thickness and parallel to the edges. To avoid displacement of the carrier plates, the carrier plates must be fixed with tabs screwed on to the sides during gluing.

The test device consists of a rigid base frame that is firmly connected to the table of the testing machine. A slide is attached to the base frame. The lower half of the slide is firmly attached to the base frame, the upper half is mounted so that it can move in the direction of the test. After the RÜ has been attached to the carrier plates, it is screwed to the slide parts.

At least one displacement sensor per side is attached centrally above the crack in the base body and as close as possible to the delamination area parallel to the direction of the load. The nominal measuring travel must be at least 1 mm. The linearity of the displacement transducers must be at least ± 0.01%. The displacement transducer must be mounted in such a way that any influence on the measurement by slight, sometimes unavoidable bending of the RÜ is excluded or compensated. The crack expansion in the base body is calculated from the mean value of the displacement transducers.

The test must be carried out at 23 ± 2 °C.

The tensile force is introduced at the height of the middle plane of the textile reinforcement into a U-shaped head section, which is screwed to the moving part of the slide via the upper support plate, see Figure 7. Before the tensile force is introduced, the threaded rod in the base body, if present, must be relieved of load and the side tabs must be removed.

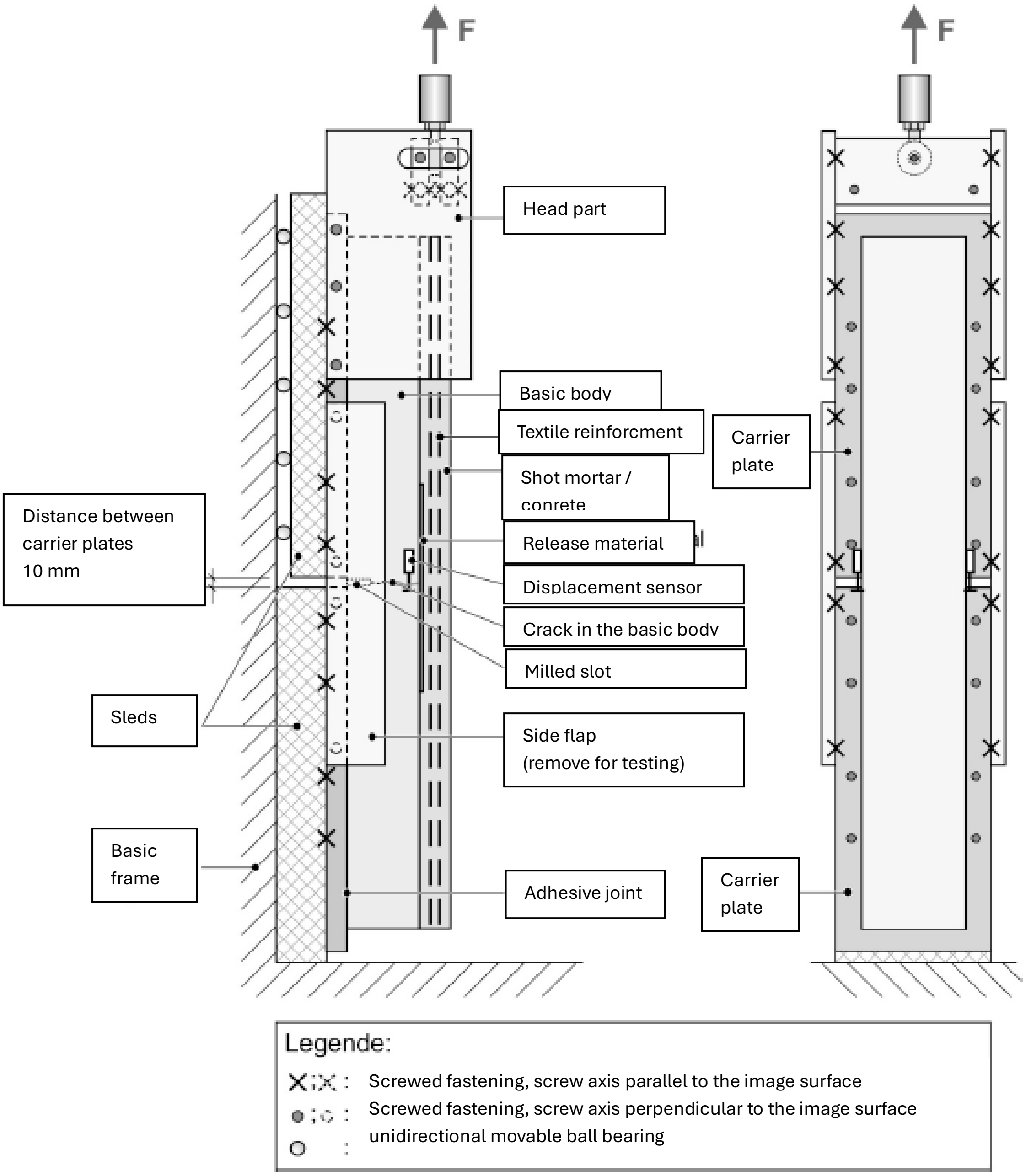


Image 7: Setup for testing crack distribution (side and front view) (adapted from /Morales Cruz 2019/)

A tensile force is applied to open the crack in the base body to the intended crack expansion $w_{min,lab}$ (see Table 3). The test is carried out in a path-controlled manner (machine path) at a speed of 0.05 ± 0.01 mm/min. During the test, at least the force and the mean value of the displacement sensors must be recorded. Crack expansion is stopped when the mean value of the displacement sensors has reached $w_{min,lab}$. The stress-strain curve must be documented in the test report. The textile tensile stress σ_T is to be calculated based on the fiber cross-sectional area of the textile reinforcement using equation (4):

$$\sigma_T = \frac{F}{A_T} = \frac{F}{(A_R * n)} \qquad (4)$$

The elongation of the textile reinforcement in the debonding area is calculated using the mean value of the displacement sensors relative to the width of the debonding area according to equation (5):

$$\varepsilon_T = \frac{\Delta L}{l_E} \qquad (5)$$

If failure of the base body occurs before the required crack expansion, the reserve sample RÜ 2 must be tested.

The crack widths in the delamination area must be measured to an accuracy of 1 µm on any side of the RÜ in accordance with Figure 8 in planes evenly distributed over the sample height. The auxiliary lines run parallel to the delamination area at the height of each layer of textile reinforcement and halfway up each sprayed mortar/shotcrete layer. The crack width is the sum of the crack widths in all planes divided by the number of planes. All measurement results must be documented in a table that must be attached to the test report. The mean value and the standard deviation per plane and across all planes as well as the maximum individual value in each case must be stated. The sum of the averaged individual crack widths across all planes must then be calculated. The sum of the individual crack widths in the textile-reinforced sprayed mortar or shotcrete layer must correspond to the average crack expansion in the base body, calculated from the mean value of the displacement sensors. The maximum deviation may be ± 10%.

The evaluation of the individual crack widths w_i is carried out either via:

- Optical 3D measuring system (see section 5.2.4.3.2) or
- Microscopy images after fixing the cracks (see section 5.2.4.3.3) or
- Microscopy images with a digital camera (see section 5.2.4.3.4).

The crack distribution test is passed if all three RÜ 1 samples meet the requirements according to Table 5. However, if only two of the three samples meet the requirements, at least three reserve samples (RÜ 2) must be tested. Of these, all three RÜ 2 samples must meet the requirements according to Table 5.

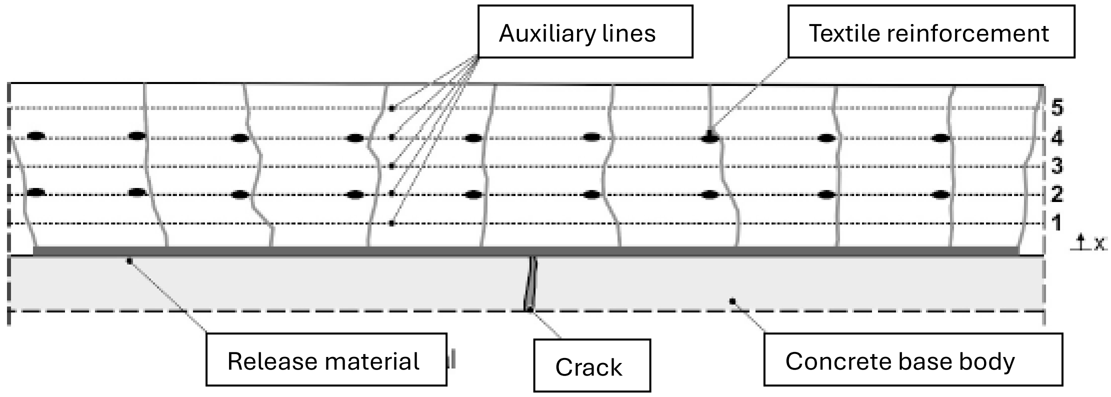


Image 8: Scheme of auxiliary lines for evaluating crack widths (exemplary for two layers of textile reinforcement) (based on /Morales Cruz 2019/)

5.2.4.3.2 Measurements of individual crack widths using an optical 3D measuring system

The optical 3D measuring system records the change in the position of coordinate points over time without contact. The 3D coordinates are calculated using reference points or a stochastic pattern on the sample surface. The system must be calibrated before testing in accordance with the manufacturer's instructions. The calibration deviation must be stated in the test report.

The coordinate accuracy must be in the range of 0.0200 ± 0.0035 mm/m and must be stated in the test report.

The crack widths are recorded and evaluated in accordance with section 5.2.4.3.1. The requirements can be found in Table 5.

5.2.4.3.3 Measurements of individual crack widths using a microscope after fixing the cracks

After the crack in the base body has completely widened, this state is fixed (e.g. using side tabs). The cracks in the textile-reinforced sprayed mortar or sprayed concrete layer are then filled with a low-viscosity reaction resin (e.g. epoxy resin) suitable for the transfer of forces. Alternatively, after the crack in the base body has completely widened, the RÜ can be fixed in this state using tabs screwed on to the side (see Figure 7) and removed. The crack widening of the base body must be documented before and after removal (permissible deviation ± 5%) and stated in the test report.

A custom-made adhesive packer must be used for the injection. The dimensions of the packer must be selected so that it is approx. 20 mm longer than the width of the debonding material and approx. 10 mm narrower than the width of the RÜ.

A cutout approximately 5 mm deep must be milled into the underside of the packer with a distance of approx. 5 mm to all edges. In addition, two holes must be drilled into the packer for the low-pressure nipple required for injection and for venting the adhesive packer.

To prepare for injection, the adhesive packer is glued to the untreated surface of the textile-reinforced sprayed mortar or shotcrete layer using a suitable crack-sealing filler and the crack in the base body is sealed from all sides.

The cracks in the textile-reinforced sprayed mortar or sprayed concrete layer are filled with an injection pressure of a maximum of 7 bar. In order to make cracks visible, the addition of a dark pigment (e.g. cyan blue) to the injection resin has proven to be effective.

After the reaction resin has completely hardened, the area of the RÜ above the delamination area plus one mesh size must be cut out on both sides. The test specimen must then be sawn parallel to the test direction. At least one of the two cut surfaces must be ground and polished. Images must then be taken under a microscope with a calibrated scale.

The crack widths are recorded and evaluated in accordance with Section 5.2.4.3.1. The requirements can be found in Table 5.

5.2.4.3.4 Measurements of individual crack widths with a digital camera

The microscope must be equipped with a digital camera with a resolution of at least 1600 x 1200 pixels.

The test is carried out when the crack is widened. The measurement should be carried out in the testing machine if possible.

Alternatively, after the crack has completely widened in the base body, the crack should be fixed in place using lugs screwed on to the side (see Figure 7) and removed. The crack widening in the base body should be documented before and after removal (permissible deviation ± 5%) and stated in the test report.

Before the measurement, auxiliary lines should be drawn at regular intervals as shown in Figure 8 for later orientation. The microscope with digital camera is placed on each line and moved along it. An image should be taken at each intersection of a crack with the line.

The digital evaluation of the crack widths should be carried out using a calibrated scale.

The recording and evaluation of the crack widths is carried out in accordance with Section 5.2.4.3.1. The requirements can be found in Table 5.

5.2.4.4 Adhesive tensile strength after crack expansion

After testing the crack distribution, the adhesive tensile strength is measured at the $ß_{HZ}$ test points i,6 to i,9 in accordance with Figure 5 and /DIN EN 1542/. The requirements are listed in Table 5.

5.3 Summary of the requirements for the repair system

Table 5 provides an overview of the tests on the individual components (textile reinforcement and debonding material) and on the repair system and their requirements.

For sprayed mortar/sprayed concrete, the exposure-related requirements for the project-specific proof of usability and the requirements for the project-specific proof of conformity are contained in /BAW Recommendation 2019/, Tables 2 and 3 (for products according to Table 1, line 1) and Tables 5 and 6 (for products according to Table 1, line 2).

Table 5: Summary of requirements for the repair system

Nr	Test aspect, characteristic value		fabric/fabric combination/sub-area	Requirement		Frequency		
				usability test (mean value)	WPK, FÜ	WPK		FÜ
					permissible deviation from the target value or from the usability test (mean value)	each batch	every 10th batch	yearly
	1	2	3	4	5	6	7	8
1	**Raw materials of textile reinforcement**							
1.1	infrared spectrum		impregnation material	spectrum documentation	no indication of deviations in composition	-	x	X
1.2	glass transition temperature		impregnation material	⩾ 80 °C; otherwise a separate proof must be provided	± 5 % or ± 10 °C, whichever is smaller	-	x	x
1.3	fiber cross-section		roving	specify value	± 10 %	-	x	x
1.4	grammage		coated textile reinforcement	specify value	± 10 %	x	-	x
2	Surface modification of textile reinforcement							
2.1	infrared spectrum		coating material	spectrum documentation	no indication of deviations in composition	-	x	x
2.2	glass transition temperature		coating material	⩾ 80 °C; otherwise a separate proof must be provided	± 5 % or ± 10 °C, whichever is smaller	-	x	x
2.3	size of particles		coating material	specify grading curve	± 10 M.-%	x	-	x
3	Textile reinforcement (final state)							
3.1	mesh shape (mesh width, clear dimension between two rovings)			determine value; square; LM > 3 times the maximum grain diameter of the sprayed mortar or sprayed concrete	± 10 %	x	-	x
3.2	grammage			specify value	± 10 %	x	-	x
3.3	tensile strength		warp and weft roving	> 2500 N/mm²	± 10 %	-	x	x
3.4	elongation at break		warp and weft roving	> 11,25 ‰	± 10 %	-	x	x
3.5	sand coated part of the textile surface			specify value	± 10 %	x	-	x
3.6	size of existing particles (sanding material) from 0.5 mm in the coating material			specify the number of grains per grain class	± 50 %	x	-	x
3.7	quality of the integration of the particles (sanding material) from tape test: weight loss			< 1 %	< 1 %	x	-	x
3.8	degree of embedding of existing particles (sanding material) from 0.1 mm into the coating material			for at least 70% of the grains of each class, the degree of embedding must be at least 50%	for at least 70% of the grains of each class, the degree of embedding must be at least 50%	x	-	x

Nr			Requirement	Frequency

	Test aspect, characteristic value		fabric/fabric combination/sub-area	usability test (mean value)	WPK, FÜ	WPK		FÜ
					permissible deviation from the target value or from the usability test (mean value)	each batch	every 10th batch	yearly
	1	2	3	4	5	6	7	8
4	**Release material**							
4.1	width		-	⩾ 120 mm and ⩽ 200 mm	-	-	-	-
5	Composite body							
5.1	applicability	error length, error length sum	entire sprayed mortar/sprayed concrete cross-section of the cutting surfaces 2a and 2b in Figure 5	Defect length: ⩽ half mesh width or 10 mm, whichever is smaller; total defect length: ⩽ 5% per cut length and textile layer	-	-	-	-
5.2	adhesive tensile strength	medium adhesive tensile strength	between debonding material and sprayed mortar/sprayed concrete	$ß_{HZi,5} \leq 0,05$ $\mathrm{N/mm^2}$	-	-	-	-
5.3			between concrete substrate and sprayed mortar/sprayed concrete	ß$_{HZi}$,1 to ß$_{HZi}$,4: at least adhesive tensile strengths according to /BAW Recommendation 2019/, Table 2, line 5 or Table 5, line 6	-	-	-	-
5.4	crack distribution	crack width	sprayed mortar/sprayed concrete	Individual value w_i < 0.10 mm; if an individual value is ⩾ 0.10 mm, all other widths of the crack in question must be < 0.10 mm	-	-	-	-
5.5		textile tension	roving	⩽ 1500 N/mm^2	-	-	-	-
5.6		textile stretching	roving	< 10 ‰	-	-	-	-
5.7	adhesive tensile strength after crack widening	medium adhesive tensile strength	between concrete substrate and sprayed mortar/sprayed concrete	ß$_{HZi}$,6 to ß$_{HZi}$,9: at least adhesive tensile strengths according to /BAW Recommendation 2019/, 2017, Table 2, line 5 or Table 5, line 6; no decrease in strength compared to line 5.4	-	-	-	-

6 Execution of the repair measure

The execution of repair measures with repair systems in accordance with this information sheet must be carried out on the basis of /ZTV-W LB 219/, sections 1, 2 and 5, the execution instructions associated with the repair system and the repair plan prepared by the expert planner including the reinforcement plan.

Only repair systems with their individual components that are included in the compilation of materials, equipment and processes approved for hydraulic engineering (hydraulic engineering compilations) "Textile-reinforced sprayed mortar/sprayed concrete" may be used. This must be documented by appropriate certificates (delivery notes, etc.).

The application of the debonding material may only be carried out on those cracks for which this is intended according to the repair plan. The debonding areas must be mapped before the sprayed mortar/sprayed concrete is applied. When using cementitious delamination materials, it is important to ensure that their surface is not damp when the sprayed mortar/sprayed concrete is applied. This means that the delamination strips must either be covered before the substrate is pre-wetted or dried after the substrate has been pre-wetted.

The layer thicknesses specified in section 4.2.2 (30 to 40 mm) may be exceeded by a maximum of 5 mm. Information on the structure of the repair system can be found in section 4.2.2. Deviations of the individual textile layers by more than 5 mm from the intended position are not permitted.

No more than two reinforcement layers may be arranged in the area where the textile reinforcement overlaps.

The tests in accordance with sections 7.3 and 7.4 must be carried out during execution.

7 Quality assurance

7.1 Proof of usability

As part of the proof of usability, the tests specified in Section 5 must be carried out on the individual components and on the repair system. Compliance with the requirements specified in Section 5.3 must be demonstrated and documented.

All tests to prove usability must be carried out by a testing center recognized for this purpose by the Federal Institute for Waterways Engineering and Research (BAW). Proof of the usability of the sprayed mortar/sprayed concrete may alternatively be provided by a report from the German Institute for Building Technology (DIBt), provided that compliance with the requirements in accordance with Sections 5.1.1 and 5.3 is thereby fully demonstrated.

The layer thicknesses specified in Section 4.2.2 (30 to 40 mm) may be exceeded by a maximum of 5 mm.

At least one sample with an area of at least 10,000 mm² and with minimum dimensions of 100 x 100 mm must be taken from the batch of textile reinforcement on which proof of usability is provided and kept by the testing center. This sample must be documented photographically.

The test report to prove usability must contain the following information:

- All details that serve to identify or prove the usability of the sprayed mortar/shotcrete for the exposure classes specified in section 5.1.1 in accordance with /BAW Recommendation 2019/ (alternatively: corresponding report from the DIBt),
- All details that serve to identify (including image documentation) or prove the usability of the textile reinforcement (see section 5.1.2),
- All details that serve to identify or prove the usability of the debonding material (see section 5.1.3),
- Documentation of the properties (composition, dimensions, fresh and hardened concrete parameters) of the base concrete (see section 5.2.2),
- Preparation of the base concrete and its roughness depth,
- Method for conditioning the base body before testing and extent of conditioning,
- Method for producing the Crack in the base concrete,
- Procedure for applying the delamination material,
- Dimensions (width and layer thickness) of the delamination material (see section 5.2.3),
- Documentation of the work process and machine technology for sprayed mortar or sprayed concrete application,
- Number of sprayed mortar/sprayed concrete layers and layer thicknesses,
- Application or installation method of the textile reinforcement,
- Specification of the temperature-dependent processing time of the sprayed mortar/sprayed concrete,
- Documentation of the test processes and test conditions,
- Recording of all test data from the system test such as total defect length, adhesive tensile strength, individual crack widths of the repair system (according to section 5.2.4.3.1), crack widening in the base body, crack pattern, load, removal and break points when testing the adhesive tensile strength before and after crack widening and test specimen designation,
- Any deviation from the specified test procedures,
- Test data,
- Tabular documentation of all test and inspection results required to assess usability (see section 5),
- Description of the work process and machine technology when applying the repair system.

7.2 Conformity

The conformity of the sprayed mortar/shotcrete with the sprayed mortar/shotcrete that was examined as part of the proof of usability must be in accordance with /BAW Recommendation 2019/, Table 3 (for products according to Table 1, line 1) or 6 (for products according to Table 1, line 2). Proof of conformity of the sprayed mortar/shotcrete may alternatively be provided by a report from the DIBt.

The conformity of the delamination material with the delamination material that was examined as part of the proof of usability must be confirmed by the relevant manufacturer by means of a delivery note.

The conformity of the textile reinforcement with the textile reinforcement used as part of the proof of usability must be ensured by an in-house production control (FPK) and an external monitoring (FÜ) in accordance with /DIN 18200/ by a body recognized by the BAW for this purpose. The frequency of the tests to be carried out as well as the requirements to be met within the framework of the FPK and the FÜ can be found in Table 5.

7.3 Tests during execution

With regard to the sprayed mortar/sprayed concrete, the procedure must be as per /ZTV-W LB 219/, Section 5.6.2.

With regard to the textile reinforcement and the delamination material, the contractor must carry out the following checks as part of its own monitoring:

- The delamination material must correspond to the material specified in the execution instructions. This must be proven using an acceptance test certificate 3.1 in accordance with /DIN EN 10204/.
- The correct delivery of the textile reinforcement must be checked using the delivery notes.
- If the textile surface is sanded, its quality must be visually checked using the corresponding image in the execution instructions. To do this, the surface must first be brushed using light pressure with a medium-hard brush over an area of 100 x 100 (L x W) mm per 10 running meters. After brushing, there may be a maximum of 20% fewer grains of sand on the surface than in the picture in the implementation instructions. This must be clearly determined and documented photographically.
- The layer thickness and width of the delamination material must be checked for each crack bridged. The layer thickness of a delamination material produced on site must at least correspond to that in the implementation instructions. The width of the delamination material must correspond to the specifications in section 4.2.2.

7.4 Checking the work carried out

The contractor must check the work carried out in accordance with /ZTV-W LB 219/, Section 5.6.3, and document it, with the following restrictions applying.

With regard to hollow areas and bond strength, areas outside the release zones must be examined, which are determined by the client after completion of the work. The release zones must be mapped before the sprayed mortar/shotcrete is applied.

Contrary to /ZTV-W LB 219/, the height of the textile reinforcement must first be determined on the core samples for the bond strength test as follows. The layer thickness of the repair system and the position of the reinforcement on a surface line must be determined on all core samples. The requirements in Section 6 must be met. To determine the dry bulk density, a slice without textile must be taken from each core sample from the bond strength test. The thicknesses of the discs $ddtttt$ must meet the following requirement (see equation (6)):

$$8\,mm \leq d_{tr} \leq 15\,mm \qquad (6)$$

Annexes

Annex 1: Compilation of documents for the inclusion of materials, equipment and processes approved for hydraulic engineering (hydraulic engineering compilations) "Textile-reinforced sprayed mortar/shotcrete"

A 1.0 General

The following sections show the required documents and the procedure for including a repair system made of textile-reinforced sprayed mortar/shotcrete in accordance with this information sheet in the hydraulic engineering compilation "Textile-reinforced sprayed mortar/shotcrete".

A 1.1 Proof of usability

Submission of a test report by a testing center recognized by the BAW for carrying out proof of usability, in which compliance with the requirements according to sections 5 and 7 is documented.

A 1.2 Checking the details of the execution

Submission of details of the execution by the manufacturer taking into account the specifications in Annex 4. The details of the execution must be checked by the testing body that provided proof of usability for the repair system to ensure that they are consistent with the proof of usability. The testing body must confirm that they are consistent.

A 1.3 Proof of conformity

Submission of a monitoring contract (ÜV) by the manufacturer of the textile reinforcement with a monitoring body recognized by the BAW.

Proof of conformity must be provided for the sprayed mortar/sprayed concrete on a project-specific basis (for each individual project) in accordance with /BAW Recommendation 2019/. Alternatively, a DIBt report can be submitted.

A 1.4 Confirmation of usability

Formal confirmation by the testing body which carried out the proof of usability that all requirements of this leaflet with regard to usability, conformity and implementation instructions have been met.

A 1.5 Application for inclusion in the hydraulic engineering compilation

On the basis of sections A 1.1 to A 1.4, the inclusion of the repair system in the compilation of materials, equipment and processes approved for hydraulic engineering (hydraulic engineering compilations) "Textile-reinforced sprayed mortar/sprayed concrete" can be applied for informally at the BAW. The application can be submitted by the manufacturer of the sprayed mortar/sprayed concrete, the manufacturer of the textile reinforcement, the manufacturer of the debonding material, a distributor of these construction products or the company carrying out the work. The confirmation of usability must be attached to the application.

A 1.6 Inclusion in the compilation of materials, equipment and processes approved for hydraulic engineering (hydraulic engineering compilations)

Checking of the requirements for inclusion in the hydraulic engineering compilations by the BAW on the basis of the confirmation of usability. Inclusion is limited to five years. An extension can be granted after the requirements have been re-examined.

The hydraulic engineering compilations document, among other things, the exposure classes and load scenarios for the extensive repair of hydraulic structures for which the requirements are met.

Appendix 2: Testing of textile reinforcement

A 2.1 Determination of the weight per unit area

(1) The mass per unit area is determined in accordance with /DIN EN 12127/ and is carried out on small samples of impregnated textile reinforcement and, if applicable, surface-modified textile reinforcement. The aim is to determine the mass of a textile fabric in relation to a known area in g/m².

(2) The textile reinforcement must be in an unloaded state before the test and for this purpose is stored for at least 24 hours before the test in a stress-free and horizontal position at a room temperature of 23 ± 2 °C.

(3) Sampling is carried out using a cutting device. Six samples are taken, the area of which consists of a large number of mesh sizes and half mesh sizes at the edges. The area is at least 10,000 mm². No pieces are taken that show signs of damage due to transport or moisture. The samples must be representative of the entire delivery batch.

(4) When taking the sample, three length and three width measurements are taken on each sample to an accuracy of 0.1 mm. The area of the cut is then calculated from the mean values of the length and width and rounded to the nearest 1 mm².

(5) The measurement samples are weighed to an accuracy of 1 mg. The area-related mass M of the individual samples is calculated using equation (7):

$$M = \frac{m}{A} \qquad (7)$$

(6) The average value of the mass per unit area must be calculated from the individual measurements and stated in g/m². The individual and average values of all measurements must be stated. All results must be rounded to three decimal places.

(7) The test pieces must be kept for the tests in accordance with Appendix 3.

(8) If the requirements in Table 5 are not met, six new pieces must be tested after consultation with the textile manufacturer.

A 2.2 Roving tensile strength

(1) The uniaxial tensile test to determine the tensile strength, elongation at break and modulus of elasticity is carried out in accordance with /ISO 10406-1/. A roving with no weakening in cross-section is subjected to central tension in a tensile testing machine. At the same time, the deformation of the roving is measured.

(2) Individual rovings with a length of at least 350 mm must be cut out of a soaked and, if necessary, surface-modified biaxial textile. The free test length is at least 150 mm. It is necessary to take samples of both warp and weft rovings in order to be able to determine the material

properties of the textile reinforcement in both directions. Ten individual tests must be carried out in each direction (warp and weft direction).

(3) The deformation is recorded using an optical measuring system or alternatively with an extensometer.

(4) The transverse pressure when anchoring the rovings in the tensile testing machine must be minimized so that failure of the rovings in the area of load introduction is excluded or, if this occurs, this result is not included in the evaluation. In order to anchor the rovings in the tensile testing machine without direct transverse pressure, they must be cast centrally at both ends in sleeves with an inner diameter adapted to the roving diameter. The height of the sleeves is between 75 and 125 mm and depends on the fiber cross-sectional area. A suitable material, e.g. epoxy resin, must be used to anchor the roving ends force-fit. Suitable wedge clamps can also be used.

(5) The test is carried out at least seven days after the steel sleeves have been cast at a temperature of approx. 23 ± 2 °C. The test is carried out with a constant speed of traverse displacement of 2 mm/min. To compensate for the traverse play, a pre-load of approx. 2% of the maximum breaking force is applied.

(6) The force and deformation values measured during the test must be recorded and stated in the test report. The further calculations and the creation of a stress-strain diagram are carried out using these measured values and with the determined fiber cross-sectional area of the roving AR in mm² and the initial length L_0 in mm.

(7) To determine the roving tensile strength, the following equation (8) shall be used:

$$\sigma_{R,max} = \frac{F_{R,max}}{A_R} \tag{8}$$

(8) To determine the elongation at break of the roving, the following equation (9) shall be used:

$$\varepsilon_{R,max} = \frac{\Delta L}{l_o} \tag{9}$$

(9) To determine the modulus of elasticity, the following equation (10) shall be used:

$$E_R = \frac{\Delta\sigma_R}{\Delta\varepsilon_R} \tag{10}$$

The elastic modulus is determined in the linear range (between 30 and 60% of the maximum breaking stress) of the stress-strain curve.

(10) The individual and average values of all measurements must be given. All results must be expressed to two digits (digits greater than zero).

(11) If the requirements in Table 5 are not met, 10 further tests must be carried out for each test direction after consultation with the textile manufacturer.

Appendix 3: Testing the modified surface of the textile reinforcement

The following tests are carried out on the samples of possibly surface-modified textile reinforcement used to determine the basis weight (Appendix 2, A 2.1).

A 3.1 Proportion of particles present (sanding material) on the textile surface

(1) The proportion of particles present on the textile surface is determined using a microscope or digital camera. When using a digital camera, the resolution of the measuring range should be at least 1500 x 1500 pixels.

(2) For each sample (sample no. 1 to 3 from the test in A 2.1), three roving areas A_{Ges} are measured from an area of 8 x 8 (L x W) mm with a central crossing point of the rovings. The size of the sanded areas A_{Bes} can obviously be estimated to within 10% of A_{Ges}.

(3) The individual values of all areas A_{Ges} are given in mm to two digits indicating the value (digits greater than zero). The individual values of the sanded areas A_{Bes} are given to within 10% and their mean value to within 1%.

A 3.2 Size of particles present (sanding material) in the coating material

(1) The test is carried out for particles of ≥ 0.5 mm or more.

(2) The equivalent diameter is determined using a microscope or digital camera. When using a digital camera, the resolution of the measuring range should be at least 1500 x 1500 pixels.

(3) Three measuring points are examined for each sample (sample numbers 1 to 3 from the test in A 2.1). The equivalent diameters of all grains are determined within the square area to be examined. The areas have their center at the intersection points and a side length of approx. 4 mm.

(4) Depending on the smallest and largest grain, at least 4 grain classes with the same range must be formed. The lower limit of the lowest grain class is the planned smallest grain or 0.5 mm, whichever is greater. The lower limit of the highest grain class is the planned largest grain.

EXAMPLE: With a planned smallest grain size of 0.3 mm and a planned largest grain size of 0.8 mm (see section 5.1.2 for information from the textile manufacturer), 4 grain classes with a range of 0.09 mm can be formed (0.50–0.59; 0.60-0.69; 0.70-0.79; 0.80-0.89).

(5) The individual values of all equivalent diameters in mm must be stated to two decimal places, along with the number of grains per grain class.

A 3.3 Quality of the integration of the particles (sanding material) – tape test

(1) The tape test is used to assess the mechanical resistance of the bond between the particles (sanding material) and the coated textile.

(2) The test requires a scale, a piece of cardboard (at least 140 x 140 mm) and four 120 mm long adhesive strips with an adhesive strength of 10 ± 1 N.

(3) The three samples (sample numbers 1 to 3 from the test in A 2.1) must be weighed immediately before the test.

(4) The prepared adhesive strips must be stuck on a total of four test points so that there is a one-sided overhang of 20 mm. The adhesive strips are then carefully pressed onto the sample using a soft roller. The sand coating must be prevented from breaking off prematurely. Two test points must be selected in the weft direction on the front and two in the warp direction on the back.

(5) The adhesive strips must be pulled off the sample evenly within 0.5 s to 1 s at an angle of approx. 60 around 5 minutes after application and stuck onto the cut cardboard. The cardboard is kept including the adhesive strips and can be used later as evidence.

(6) The sample is then weighed again and the weight loss due to the removal of the sand coating is determined. The weight loss of each sample and the mean of all samples must be expressed in g to three decimal places.

A 3.4 Degree of embedding of existing particles (sanding material) in the coating material

(1) This test detects particles ≥ 0.1 mm.

(2) For the evaluation, photos are preferably taken using a light microscope or digital camera. When using a digital camera, the resolution of the measuring range should be at least 1500 x 1500 pixels.

(3) For each sample (sample no. 4-6 from the test in A 2.1), a roving section is embedded in pigmented epoxy resin. A cross-section is examined for each roving section. The equivalent diameter and degree of embedding of all embedded particles are estimated in this cross-section.

(4) Depending on the smallest and largest grain, at least 3 grain classes with the same range must be formed. The lower limit of the lowest grain class is the planned smallest grain or 0.1 mm, whichever is greater. The upper limit of the highest grain class is the planned largest grain.

EXAMPLE: With a planned smallest grain of 0.3 mm and a planned largest grain of 0.8 mm (see section 5.1.2 for information from the textile manufacturer), 3 grain classes with a range of 0.16 mm can be formed (0.30-0.46; 0.47-0.63; 0.64-0.80).

(5) The equivalent diameter of each grain must be assigned to a grain class in order to be able to classify the degree of embedding of this grain into a grain class. The photos of the cross sections must be documented in the test report. The starting point of the assignment and the direction of the procedure must be marked on the photo.

(6) The degree of embedding T_E is apparently estimated to within 10% (see Figure 9).

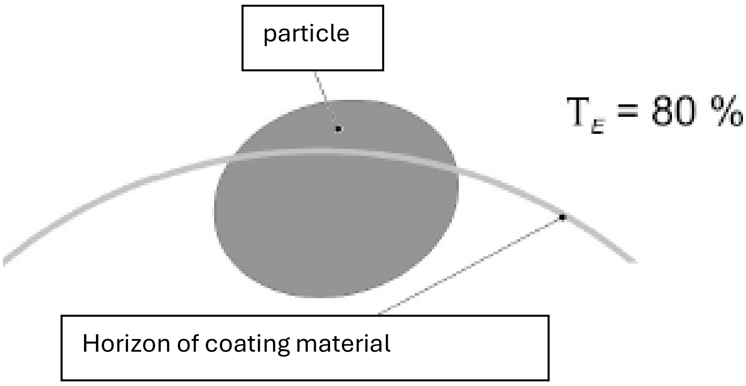


Image 9: Example for estimating the degree of embedding

(7) The individual values of the embedding degrees of all grains and their proportion with an embedding degree ≥ 50 % per grain class must be stated in % to the nearest two digits (digits greater than zero).

Annex 4: Implementation instructions, template

The implementation instructions and templates provided could be find in the original document of the BAW leaflet.

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