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Performance category 219

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219

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ZTV-W

Additional technical terms of contract – hydraulic engineering

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Preliminary remark

Products from other European Union Member States or from Turkey, as well as goods originating from an EFTA member state which is a party to the Agreement on the European Economic Area, which do not conform to these Additional Technical Terms of Contract, shall be deemed compliant, including the tests, inspections and certifications conducted in the country of manufacture, if the required level of protection (in terms of health, safety and fitness for purpose) is achieved in a similarly permanent manner.

Basic principles

All parts of ZTV-W LB 219 and the specification of works must always be observed together when planning, designing and executing concrete repair measures.

0 Planning information

0.1 Purpose

The overarching goals of repair measures under ZTV-W LB 219 are the maintenance or restoration of the load-bearing capacity or the fitness for purpose of concrete building components for a certain period of time, stipulating principles that can be implemented using different procedures. Measures aimed at a planned increase in load-bearing capacity are not the subject of ZTV-W LB 219.

0.2 Structural condition, repair concept, repair plan, maintenance plan

The necessary prerequisites for carrying out repair measures in accordance with ZTV-W LB 219 are a comprehensive condition analysis of the component in question and detailed planning of the measures by a qualified planner[1]. The state of the structure (actual condition) must be recorded and the causes of any defects and damage must be determined. The further development of the condition of the structure during the anticipated remaining useful life must be estimated. The target condition is to be determined by the client. The need for repair must be determined based on the comparison between the actual condition and the target condition, taking the anticipated remaining useful life into account, and the objectives of the repairs must be defined. On this basis, a maintenance concept with multiple maintenance variants may have to be created.

The qualified planner must develop a repair plan for the chosen repair variant in accordance with TR-IH Part 1 which takes into account the principles for repair of the concrete, the principles for corrosion protection of the reinforcement, the requirements for the building materials and building material systems, the requirements for execution and any special issues if necessary. A repair plan is to include the following in particular:

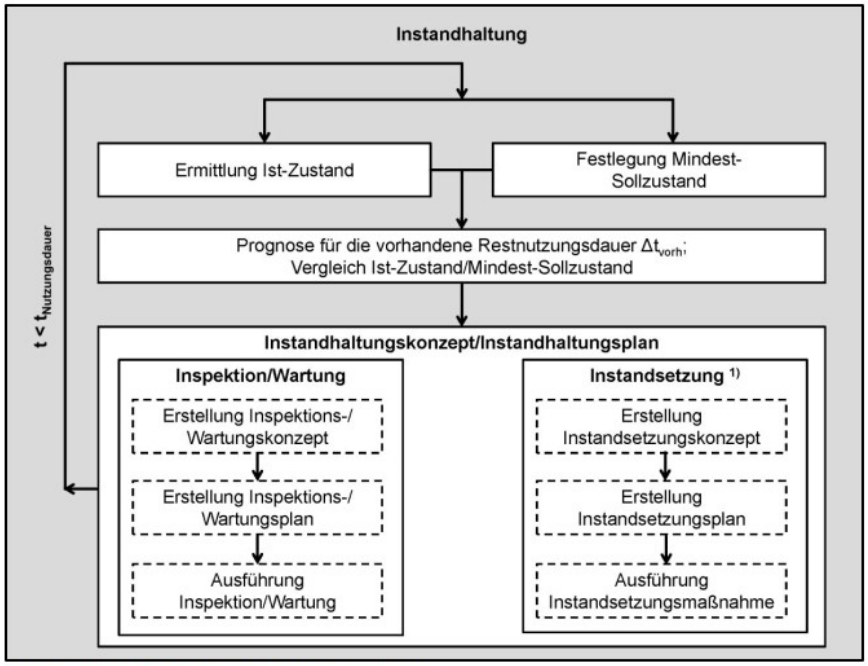
- Details on the actual condition;
- the repair principles to be implemented;
- construction methods to be used (removal, reprofiling, injection, etc.);
- substances to be used and proof of the required project-specific performance characteristics;
- means of ensuring stability during execution;
- fire safety;
- specific requirements for execution;

[1] *Unless arranged otherwise on a project-specific basis, this proof of knowledge can be certified by various organisations on the basis of uniform regulations and content for the training and further education of qualified planners, which are determined by the 'qualified planner (QP)' training advisory board at Deutsches Institut für Prüfung und Überwachung e.V. (German Institute for Testing and Monitoring – DPÜ). Proof of knowledge may also be certified by documents of another Member State certifying that the requirements have been met.*

- scheduling for execution;
- quality assurance (internal and external monitoring), documentation;
- requirements for companies and personnel;
- work safety, health and environmental protection, information on disposal.

Together with the repair plan, the qualified planner must prepare a maintenance plan for the chosen means of execution which must contain details of scheduled inspections, maintenance and repair measures. The qualified maintenance planning must ensure that the actual condition does not fall below the minimum target condition at any time during the period of use.

The basic procedure for planning and executing maintenance measures is shown in the figure below (TR-IH Part 1). The regulations in ZTV-W LB 219 focus on the field of repair.



Instandhaltung	Repair
t < t Nutzungsdauer	t < t useful life
Ermittlung Ist-Zustand	Determination of the actual condition
Festlegung Mindest-Sollzustand	Definition of minimum target condition
Prognose für die vorhandene Restnutzungsdauer Δt_{vorth1}	Forecast of the remaining useful life availableΔt_{vorth1}
Vergleich Ist-Zustand/Mindest-Sollzustand	Comparison of actual condition/minimum target condition
Instandhaltungskonzept/Instandhaltungsplan	Maintenance concept/maintenance plan
Inspektion/Wartung	Inspection/upkeep
Erstellung Inspektions-/Wartungskonzept	Preparation of inspection/upkeep concept
Erstellung Inspektions-/Wartungsplan	Preparation of inspection/upkeep plan
Ausführung Inspektion/Wartung	Execution inspection/upkeep
Instandsetzung[1)]	Repair[1)]
Erstellung Instandsetzungskonzept	Preparation of repair concept
Erstellung Instandsetzungsplan	Preparation of repair plan
Ausführung Instandsetzungsmaßnahme	Execution of repair measure

Figure 0.1: Basic procedure for planning and executing maintenance measures (TR-IH Part 1)

0.3 Planning Principles

In the planning, selection of building materials and execution of maintenance measures on hydraulic structures, the following principles must be followed, taking into account the planned useful life of the repair measure and the given effects from the environment and the concrete substrate:

- Ensuring the durability of the repair system against the anticipated effects over the planned useful life

- Ensuring the durability of the bond between the repair system and the subsoil via adhesion and/or anchoring
- Achievement of the repair targets (including with regard to the corrosion protection of concrete and reinforcement).

Table 0.1: Principles and procedures applicable under ZTV-W LB 219 under TR-IH Part 1

Principle	procedures governed by TR-IH Part 1 which are based on the principles	Applicability as per ZTV-W LB 219
1	2	3
Protection or repair of damage in concrete		
1. Protection from substance penetration:	1.1 Hydrophobic impregnation [1)]	Section 0.6.6
	1.3 Coating [2)]	
	1.5 Filling of cracks and voids	Section 0.6.7
2. Regulating the water balance in the concrete	2.1 Hydrophobic impregnation [1)]	Section 0.6.6
	2.3 Coating [2, 3)]	
	2.6 Filling of cracks and voids [4)]	Section 0.6.7
3. Reprofiling or cross-sectional addition	3.1 Small-area manual application	Section 0.6.5
	3.2 Concreting or casting	Section 0.6.2 [5)]
	3.3 Spray application	Section 0.6.3 Section 0.6.4
	3.4 Replacement of components	[6)]
4. Reinforcement of the concrete structure [7)]	4.1 Addition and replacement of embedded reinforcement bars	-
	4.4 Cross-section supplementation with mortar or concrete	-
	4.5 Filling of cracks [8)] or voids	Section 0.6.7
5. Increase in physical resistance	5.3 Application of mortar or concrete	Section 0.6.2 Section 0.6.3 Section 0.6.4 Section 0.6.5
Reinforcement corrosion protection or repair		
7. Maintenance or restoration of passive protection	7.1 Increase or partial replacement of the concrete cover with additional mortar or concrete	Section 0.6.2 Section 0.6.3
	7.2 Replacement of chloride-containing or carbonated concrete	Section 0.6.4
	7.4 Re-alkalisation of carbonated concrete by diffusion	Section 0.6.5
	7.6 Filling of cracks or voids [4) 9) 10)]	Section 0.6.7

1) The effectiveness, performance and durability of hydrophobic impregnation depend on the depth-dependent active ingredient content based on the concrete and the penetration depth. The penetration depth of hydrophobic impregnations is largely determined by the moisture content and the porosity of the concrete.
2) Coatings restricted in accordance with Section 0.6.6.
3) For the repair of concrete components that have been damaged by an alkali-silica reaction, OS 5 systems with an air layer thickness equivalent to water vapour diffusion sD ≤ 2.5 m must be used.
4) New procedure introduced compared to DIN EN 1504-9.
5) The casting process is not regulated in ZTV-W LB 219.
6) Procedure in accordance with ZTV-W LB 215.
7) Also to increase the load-bearing capacity compared to the actual condition.
8) Usually to increase component rigidity.
9) The procedure is not permissible in the case of chloride exposure and expected crack width changes.
10) Instead of the impregnation, the filling type casting (V) of cracks is regulated.

The application boundary conditions of the Table 0 .1 applicable repair principles and procedures are regulated in TR-IH Part 1. Beyond that, the following aspects must be taken into account in particular:

- If repair systems are applied over a wide area, water saturation in the old concrete under or behind the repair system may increase over its useful life due to factors such as rearward moisture penetration or different water vapour diffusion behaviour of the old concrete and the repair system.
- Wide-area application of repair systems whose bonding effect with the concrete substrate is based on adhesion is only permitted if their strength and deformation properties are compatible with those of the old concrete and increased degrees of water saturation in the old concrete in conjunction with frost effects do not lead to an impairment of the bond or to structural breakdowns in the old concrete.
- Cracks already existing in the old concrete cannot be bridged reliably by applying an unreinforced concrete replacement system. Special solutions may have to be developed in such cases.
- The repair objective ‘minimising water penetration through the component to be repaired’ can generally only be achieved by facing formwork with concrete reinforcement arranged on both sides in accordance with Section 3 or shotcrete in accordance with Section 4.
- The minimum concrete cover c_{min} is 40 mm and the tolerance allowance Δc is 10 mm. For components with exposure classes XD and XS, the minimum concrete cover c is$_{min}$ 50 mm and the tolerance allowance Δc is 10 mm. The minimum concrete cover c_{min} may be lowered to 40 mm if adequate proof of durability is provided for the anticipated remaining useful life. In the case of sprayed mortar/shotcrete in accordance with Section 4 and 5 leaving the surface sprayed, the minimum concrete cover c_{min} is to be increased by 5 mm. This rule does not apply to sprayed mortar.
- With regard to compliance with the above-mentioned minimum concrete coverings, remaining old concrete coverings may be taken into account, as long as the boundary conditions concerning carbonation or chloride content described in the procedures in BAW-MDCC are complied with for the old concrete.
- If there are residual chloride contents in the old concrete, and in particular in the case of small-scale repair measures, Procedure 7.2 (replacement of concrete containing chloride) can only be used if it is ensured that the redistribution of the chloride already present in the old concrete under the influence of the chloride penetrating after the repair cannot lead to depassivation of the reinforcement over the remaining useful life.
- Durability assessments with regard to securing, manufacturing or restoring the corrosion protection of the reinforcement must be based on the following procedures described in TR-IH, Part 1:
  - Increase in or partial replacement of concrete cover (Procedure 7.1)
  - Replacement of chloride-containing or carbonated concrete (Procedure 7.2)
  - Re-alkalisation of carbonated concrete by diffusion (Procedure 7.4).
- The qualified planner’s assessment of durability with regard to chloride-induced reinforcing steel corrosion in accordance with BAW-MDCC must yield a solution which is practical in construction practice. The basis for determining the design-relevant input parameters must be presented in detail and justified. The surface chloride content $C_{S,\Delta x}$ is to be determined in accordance with BAW-MDCC. The target value of the reliability index β_0 must be selected depending on the availability requirement and the reparability of the component. The determined surface chloride content, the chosen reliability index and the planned useful life are to be defined in the specification of works.

  Note 1: For components of exposure classes XD2 and XD3, a reliability index of $\beta_0 = 1.5$ (i.e. approx. 93% certainty) should generally be used. For components with acceptable availability and good accessibility for future repairs, a target reliability index of $\beta_0 = 0.5$ (i.e. approx. 70% certainty) may be chosen.

Note 2: For components of exposure classes XS2 and XS3, the target reliability index β_0 must be selected in accordance with BAW-MBM specifications, depending on the component category.

Note 3: The reliability index chosen must be taken into account in the maintenance plan.

- For concrete replacement systems as per Section 3 and 4 as well as for concrete replacement systems with known composition as per Section 5 (see Table 0 .7, line 1) and Section 6 (see Table 0 .8, line 1), a durability assessment is not required for anticipated further useful lives of up to 100 years for exposure classes XC1 to XC4, provided that the aforementioned minimum requirements for concrete cover are already met with the concrete replacement system alone.
- For concrete replacement systems as per Section 3 and 4 as well as for concrete replacement systems with known composition as per Section 5 (see Table 0 .7, line 1) and as per Section 6 (see Table 0 .8, line 1), a durability assessment according to BAW-MDCC is to be carried out for exposure classes XD2 and XD3. A BAW-MDCC assessment can be dispensed with in cases of an anticipated further useful life of up to 50 years, components under the influence of road structures as well as for subgrade areas, in which cases the special rules under (193) and (355) must be taken into account with respect to the concrete composition. For exposure classes XD1 and XS1, the requirements of the reference standards are sufficient for anticipated further useful lives of up to 100 years and compliance with the above-mentioned minimum concrete cover requirements.
- The BAW-MBM must also be observed for concrete replacement systems in accordance with Sections 3 and 4 in areas exposed to seawater and coastal areas as well as estuaries in exposure classes XS2 and XS3.
- For concrete replacement systems of unknown composition as per Section 5 (see Table 0 .7, line 2) and Section 6 (see Table 0 .8, line 2), a durability assessment according to BAW-MDCC is to be carried out for exposure classes XC1 to XC4. In the case of an anticipated further useful life of up to 50 years, a simpler alternative procedure can be applied in accordance with the BAW-MDCC.
- For concrete replacement systems of unknown composition as per Section 5 (see Table 0 .7, line 2) and Section 6 (see Table 0 .8, line 2), a durability assessment according to BAW-MDCC is to be carried out for exposure classes XD2, XD3, XS2 and XS3. For exposure classes XD1 and XS1, the qualified planner must determine whether further requirements are necessary in addition to compliance with the minimum concrete cover.
- For components of exposure class XS3 with existing reinforcement made of normal reinforcing steel, concrete replacement systems may only be used with a surface chloride load ≥ 2 M.-%/z_{eq} in accordance with Section 5 and Section 6 if the risk of corrosion and damage in the old concrete is classified as acceptable, limited availability is acceptable and there is good accessibility for future repairs.
- Surface protection systems (OS) should not be used for components under water or in the hydraulic area and for components where the water balance changes adversely with regard to durability and bonding after application of the surface protection system.
- Due to the comparatively lower durability of surface protection systems, these are not to be considered equivalent to a sufficiently dense and thick concrete cover.
- If there is moisture penetration from the rear of the component to be repaired (exposure classes XBW1, XBW2), measures to reduce water penetration or water leakage must be taken before a repair system is applied.
- Special requirements for colouring, surface quality and evenness tolerance of concrete replacement or surface protection systems and the creation of sample surfaces must be agreed upon in the specification of works.
- Cement-bound fillers should preferably be used to fill cracks and local voids in accordance with Section 8.

- The anchoring of inset and edge bollards to be installed must be adapted to the static and structural conditions.

When planning repair measures on structural components of minor importance for stability, durability and traffic safety, alternatives to the regulations of ZTV-W LB 219 may be selected with the client's consent, provided doing so is technically necessary and appropriate in justified individual cases.

0.4 Exposure and moisture classes

The qualified planner must describe the effects on the structure or component to be repaired using exposure classes in accordance with Table 0.2 where possible, or otherwise verbally. The exposure and moisture classes must be specified in the specification of works. In addition to DIN 1045-2, Table 1, examples for the exposure and moisture classes which are specific to hydraulic engineering are listed in the following Table 0.2.

Table 0.2: Effects from the concrete substrate and the environment

Class designation		Description of the environment	Examples of hydraulic engineering [1)] (informative)
1		2	3
1. Effects arising from the environment			
XALL		Impact on the structure or building component with repercussions on the repair system and its adhesion to the building component to be repaired which are not depicted by the exposure classes below; substances from the repair system which promote corrosion of the reinforcement *Note: The exposure class must always be estimated.*	All building components
Exposure DIN 1045-2	X0	For non-reinforced concrete or embedded metal: all environmental conditions, with the exception of freeze-thaw attacks, wear and tear or chemical attack	Unreinforced core concrete for zoned construction
Exposure classes as per DIN 1045-2	**Corrosion of the reinforcement, triggered by carbonation**		
	XC1	Dry or constantly wet	Floors of lock chambers, economising basins or weirs; lock chamber walls below tailwater; hydraulic filling and emptying systems
	XC2	Wet, rarely dry	Lock chamber walls in the area between tailwater and headwater (i.e. economising basin walls)
	XC3	Moderate humidity	Surfaces not exposed to the elements (outdoor air, protected from precipitation)
	XC4	Alternating wet and dry	Freeboard of lock chamber or economising basin walls; weir piers above lowest water

Class designation		Description of the environment	Examples of hydraulic engineering [1] (informative)
1		2	3
			level; outer surfaces exposed to the elements; quays
	Corrosion of the reinforcement caused by chlorides, excluding chlorides in seawater		
	XD1	Moderate humidity	Weir piers in the spray zone of road bridges
	XD2[2]	Wet, rarely dry	Waters with chloride contamination (e.g. from industrial discharge)
	XD3[2]	Alternating wet and dry	Subgrade of locks, traffic areas (e.g. transhipment berths of inland ports), stairs on weirs
	Corrosion of the reinforcement, caused by chlorides in seawater		
	XS1	Salty air, but not in direct contact with seawater	External components in coastal vicinity
	XS2	Below water	Bottoms of lock chambers, economising basins or weirs; lock chamber walls below tailwater (e.g. mean low tide); hydraulic filling and emptying systems
	XS3	Tide areas, splash water and spray zone	Quays, piers and walls above lowest known low tide and lock chamber walls in the area between tailwater -1.0 m and headwater +1.0 m (e.g. between mean low tide and mean high tide)
	Freeze-thaw attack with or without de-icing agents/seawater		
	XF1	Moderate water saturation with fresh water without de-icing agents	Freeboard of savings basin walls; weir pillars above high tide
	XF2	Moderate water saturation with seawater and/or de-icing agent	Vertical components in the splash water zone and components in the direct spray zone of seawater
Exposure classes as per DIN 1045-2	XF3	High water saturation with fresh water without de-icing agents	Lock chamber walls in the area between tailwater -1.0 m and headwater +1.0 m (economising basin walls); inlet and outlet areas of culverts between low tide and high tide; weir piers between low tide and high tide
	XF4	High water saturation with seawater and/or de-icing agent	Vertical surfaces of seawater structures such as foundation piles, quays and piers in the hydraulic area; horizontal surfaces exposed to seawater; platforms of locks; traffic areas (e.g. harbour areas); stairs on weir piers
	Concrete corrosion as a result of chemical attack		
	XA1	Slightly aggressive chemical	

Class designation		Description of the environment	Examples of hydraulic engineering [1)] (informative)
1		2	3
		environment	
	XA2	Moderately aggressive chemical environment	Concrete components in contact with seawater (underwater and hydraulic area, spray water area)
	XA3	Highly aggressive environment	
	Concrete corrosion through abrasion		
	XM1	Moderate abrasion[3)]	Surfaces exposed to ship friction (e.g. lock chamber walls above tailwater-1.0 m); components for energy conversion exposed only to fine-grained bed load (e.g. due to design measures such as upstream installation of a bed load trap), ice drift
	XM2	Heavy abrasion	Weir backs and components for energy conversion (stilling basins, obstructions) with exposure to coarse-grained bed load including the adjoining rising components up to a height of 1 m
	XM3	Very heavy abrasion	Components in mountain streams or bed load diversion tunnels
	Moisture classes		
	W0	Concrete that does not remain damp for long after curing and remains largely dry after drying out during use.	In general: Only for non-solid components (dimension ≤ 0.80 m). Internal components of hydraulic structures that are not constantly exposed to a relative humidity higher than 80% (e.g. interiors of control stations).
Exposure classes as per DIN 1045-2	WF	Concrete that is frequently damp during use or for a long period of time.	In general: Always for solid components (dimension > 0.80 m) regardless of moisture ingress. Concrete components of hydraulic structures with free weathering or with temporary or permanent exposure to water in inland areas (e.g. lock chamber walls); Internal components of hydraulic structures in which the relative moisture is predominantly higher than 80%.
	WA	Concrete that is exposed to frequent or long-term external alkali supply in addition to the class WF exposure.	Concrete components of hydraulic structures that come into contact with seawater (tailwater and hydraulic area, splash water zone). Concrete components of hydraulic structures exposed to de-icing salt (e.g. subgrade areas

Class designation	Description of the environment	Examples of hydraulic engineering [1] (informative)
1	2	3
		of lock chamber walls).
XW1	Permanent exposure to water in the form of fresh water or seawater	Sluice compartment or water-saving chamber walls below tailwater
XW2	Alternately wet and dry due to fresh or seawater contamination	Sluice compartment or water-saving chamber walls between tailwater and headwater
2. Effects from the concrete substrate		
XSTAT (static)	Statically active	Reprofiling of pressure-loaded components; positive filling of cracks and voids
XBW1 (backfacing water)	Rear penetration of moisture (no perfusion) or increased residual humidity	Building components under stress as a result of water pressure
XBW2 (backfacing water)	Rear penetration of moisture with perfusion (extensive)	Building components under stress as a result of water pressure
XCR (cracks)	Cracks	
W (width)	with crack width w [4] in mm	
Δw LFR HFR CON	with crack width change Δw in mm - cyclically low frequency, e.g. temperature, water level variation (LFR: low frequent) - cyclically high frequency e.g. from transport (HFR: high frequent) - continuous crack width variation, e.g. due to shrinkage or settling (CON: continuous)	 WU building component; Bridge base plate; cracking due to subsidence of supports
DY (dry)	where the moisture condition is ‘dry’: ingress of water not possible. Impact of water on the crack/void area cannot be ascertained or excluded for a sufficiently lengthy period of time.	Internal component
DP (damp)	where the moisture condition is ‘damp’: change in colouring in the crack or void area caused by water but with no water leak, -Indications of a water leak in the immediate recent past (e.g. sintering deposits, efflorescence). - Crack or void discernibly damp or slightly damp (assessed on dry drilling cores).	freely weathered components; components in contact with the ground
WT (wet)	where the moisture condition is ‘wet	

Class designation	Description of the environment	Examples of hydraulic engineering [1] (informative)
1	2	3
	(filled unpressurised)': water discernible in the crack area in the form of fine droplets, water fizzes from the crack,	
WF (water flow)	where the moisture state is 'flowing water (channelling water under pressure)': contiguous water flow issues from the crack,	WU building component;
XDYN	Dynamic load during application	Bridge carrying traffic

1) These examples apply to the predominant load state over the useful life.
2) Also applies to impacts from rivers, dam-regulated waters or groundwater with a chloride content > 2,000 mg/l.
3) Lock chamber floors and walls which are constantly underwater, as well as filling systems without exposure to bed load are generally not subject to concrete corrosion due to hydroabrasion.
4) Included and evaluated according to DBV-Riss [Cracks].

0.5 Old concrete classes

The concrete components or sections to be repaired must be categorised into old concrete classes according to Table 0 .3 based on their properties at the time of repair. The decisive factor for the classification is the least favourable substrate characteristic (compressive strength or breaking strength). Parts of components to be repaired with local characteristic deviations are to be narrowed down by means of appropriate examinations.

Table 0.3: Classification of old concrete in the area to be repaired

1	2	3	4
Cured concrete class	Compressive strength [1]	Breaking strength [2]	
		Mean value	Smallest single value
	N/mm²	N/mm²	N/mm²
A1	≤ 10	< 0.8	< 0.5
A2	> 10	≥ 0.8 and < 1.2	≥ 0.5
A3	> 20	≥ 1.2 and < 1.5	≥ 0.8
A4	> 30	≥ 1.5 and < 2.5	≥ 1.0
A5	> 75	≥ 2.5	≥ 2.0

1) Mean value for compressive strength (determined in accordance with DIN EN 12504-1).
2) Smallest single value/mean value (determined in accordance with DIN EN 1542)

0.6 Repair systems

0.6.1 Scope of application

Without separate verification, only certain types of repair systems are permitted, depending on the class of the old concrete. A overview of this can be found in Table 0.4.

Table 0.4: Scope of application of the repair systems according to ZTV-W LB 219

1	2	3	4	5	6	7
Old concrete class	Concrete (Section 3)	Shotcrete (Section 4)	Sprayed mortar / shotcrete (Section 5)	Manual application of concrete replacement (Section 6)	Surface protection systems (Section 7)	Filling of cracks and local voids [5] (Section 8)
	$d \geq 90$ mm[1]	$d \geq 90$ mm[1]	$20 \leq d \leq 60$ mm	$10 \leq d \leq 60$ mm		
	anchored, reinforced [4]		unanchored, unreinforced			
A1	X	X	---	---	---	X[6]
A2	X	X	X	---	---	X
A3	X	X	X	---	X[3]	X
A4	X	X	X	X[2]	X	X
A5	X	X	X	X[2]	X	X

1) For facing formwork for lock chamber walls and comparable components, see Sections 3.3.2 and 4.3.2.
2) Not for wide-area application overhead or on vertical surfaces.
3) Only for concrete substrates where the mean breaking strength is at least 1.3 N/mm².
4) Only applies to concrete for wide-area application.
5) DWA Code of Practice 506 applies to the injection of hydraulic binders in hydraulic structures made of mass concrete to reduce directional permeability.
6) Usability must be assessed on a case-by-case basis.

0.6.2 Concrete as per Section 3

This section applies to repair measures with concrete in accordance with DIN 1045-2 and the supplementary requirements of these detailed technical specifications (Table 0 .5), which is applied in layer thicknesses between 90 and 800 mm. In order to ensure load-bearing capacity and suitability for use, the concrete must be reinforced for wide-area application and connected to the concrete base by anchoring elements. Exceptions to the above-mentioned requirements can be made in special cases.

If the breaking strength of the concrete substrate meets the requirements under Table 2 .11, line 1, individual damaged areas in horizontal surfaces may be executed without anchoring and reinforcement if suitable verification is provided in prior consultation with the client.

Repair measures with concrete are to be assigned to planning class PK-S, concrete class BK-S and execution class AK-S and thus to concrete construction quality class BBQ-S as per DIN 1045-1000. All requirements of planning class PK-E, concrete class BK-E and execution class AK-E, and thus the concrete construction quality class BBQ-E, must be complied with.

The BBQ coordinator is to be appointed by the client. The requirements for planning, concrete and execution for small-scale measures are to be defined on a project-specific basis.

In the case of repair measures with concrete, the preliminary concrete construction concept must be developed based on the repair plan in accordance with DIN 1045-1000.

When realising the repair objective ‘minimising water penetration through the component to be repaired’, facing formwork must be formed with reinforcement on both sides in accordance with the planning principles in Section 0.3. In this case, metal or elastomer waterstops should be used as sealing elements in construction joints within the facing formwork. If the component geometry does not allow the arrangement of joint metal or elastomer waterstops, injection hoses can be used as sealing elements in accordance with the DBV-Injektionsschlauch [Injection Hoses]. Cement suspension should generally be used as a filling material in accordance with Section 8.

Table 0.5: Products/systems for repair measures as per Section 3

No	Procedure	Old concrete class	Products	ZTV-W LB 219
1	3.2, 5.3 7.1, 7.2, 7.4	A1, A2, A3, A4, A5	Concrete as per DIN 1045-2	Section 3

0.6.3 Shotcrete (anchored, reinforced) as per Section 4

This section applies to repair measures with shotcrete in accordance with DIN EN 14487-1 and DIN EN 14487-2 in conjunction with DIN 18551 and the supplementary requirements of these detailed technical specifications (Table 0 .6), which is applied in layer thicknesses of 90 mm or more. In order to ensure load-bearing capacity and suitability for use, the shotcrete must be reinforced and connected to the concrete base by anchoring elements.

When realising the repair objective ‘minimising water penetration through the component to be repaired’, facing formwork must be formed with reinforcement on both sides in accordance with the planning principles in Section 0.3. In this case, injection hoses to be subsequently injected into construction joints within the facing formwork as per DBV-Injektionsschlauch must be rendered as a sealing element. Cement suspension should generally be used as a filling material in accordance with Section 8.

Table 0.6: Products/systems for repair measures as per Section 4

No	Procedure	Old concrete class	Products	ZTV-W LB 219
1	3.3, 5.3, 7.1, 7.2, 7.4	A1, A2, A3, A4, A5	Shotcrete as per DIN EN 14487-1 and DIN EN 14487-2 in conjunction with DIN 18551	Section 4

0.6.4 Sprayed mortar/shotcrete (unanchored, unreinforced) as per Section 5

This section applies to sprayed mortar/shotcrete made of cement-bound concrete substitute with or without polymer modification, which is applied in thin layers (20 to 60 mm) without additional anchoring and reinforcement by spraying on concrete substrates of the old concrete class A2, A3, A4 or A5. If any existing, exposed reinforcement is injected, the layer thickness of 60 mm can also be exceeded at specific locations. The bond between the sprayed mortar/shotcrete and the substrate is made by adhesion.

The strength and deformation behaviour of the sprayed mortar/shotcrete must be adapted to the specific old concrete in question. In addition, the possible occurrence of increased water saturation levels in the old concrete behind the sprayed mortar/shotcrete must be taken into account when planning repair measures, for old concrete classes A2 and A3 in particular. With this in mind, the qualified planner must check whether wide-area application is permissible.

Products with additional characteristics based on DIN EN 14487 in conjunction with DIN 18551 or products of unknown composition can be used as sprayed mortar/shotcrete (Table 0.7).

Table 0.7: Products/systems for repair measures as per Section 5

No	Procedure	Old concrete class	Products	ZTV-W LB 219
1	3.3, 5.3, 7.1, 7.2, 7.4	A2, A3, A4, A5	Sprayed mortar/shotcrete S-A2, S-A3, S-A4 and S-A5 based on DIN EN 14487 and DIN 18551 with additional characteristics	Section 5
2			Sprayed mortar SRM-A2, SRM-A3, SRM-A4 and SRM-A5 or shotcrete SRC-A2, SRC-A3, SRC-A4 and SRC-A5 (unknown composition)	

0.6.5 Concrete replacement via manual application (unanchored, unreinforced) as per Section 6

This section applies to concrete replacement via manual application of cement-bound concrete replacement with or without polymer modification and usually the bonding layer and the fine levelling compound if necessary. Concrete replacement may only be applied manually for small-scale repairs. With manually applied concrete replacement, repair measures may only be carried out on components of old concrete classes A4 and A5. The layer thickness is usually 10 to 60 mm, and up to 100 mm in special cases (such as deep cavities). The bond between the concrete replacement in the manual application and the substrate is made by adhesion. The strength and deformation behaviour of the manually applied concrete replacement must be adapted to the old concrete.

Products based on the dry concrete guideline RL Trockenbeton [Dry Concrete] with additional characteristics or products of unknown composition can be used as concrete replacement for manual application (Table 0.8).

Table 0.8: Products/systems for repair measures as per Section 6

No	Procedure	Old concrete class	Products	ZTV-W LB 219
1	3.1, 5.3, 7.1, 7.2, 7.4	A4, A5	Concrete replacement M-A4 and M-A5 based on the DAfStb Guideline ‘Production and use of dry concrete and dry mortar’ (RL Trockenbeton) with additional characteristics	Section 6
2			Concrete replacement RM-A4 and RM-A5 or RC-A4 and RC-A5 (unknown composition)	

0.6.6 Surface protection systems as per Section 7

This section applies to repair measures with surface protection systems, which can be composed of individual products to form a system. With surface protection systems, repair measures may only be carried out on components of old concrete classes A3 (mean breaking strength of at least 1.3 N/mm²) A4 and A5. The minimum breaking strengths of the concrete substrate as per Table 2 .11 required by the surface protection system must be taken into account.

As a general rule, surface protection systems may only be used for the following exposure classes: XC1 (dry), XC3, XC4, XD1, XS1, XF1, XF2. The use of surface protection systems for exposure classes XBW1 and XBW2 is not permitted. Section 0.3 must be observed.

The various types of surface protection systems can be used to pursue the repair objectives listed in Table 0 .9:

Table 0.9: Products/systems for repair measures as per Section 7

No	Procedure	Old concrete class	Repair objectives	Surface protection systems	ZTV-W LB 219
1	1.1, 2.1	A3, A4, A5	Hydrophobisation to reduce capillary water absorption in vertical and inclined concrete components exposed to the elements, e.g. retaining walls (crack widths in concrete substrate ≤ 0.1 mm)	OS 1 (OS A)	Section 7
2	1.3, 2.3	A3[1)], A4, A5	Coating with limited water vapour permeability and increased impermeability for inaccessible areas (with scratch coat or levelling filler) to reduce water absorption, the penetration of substances that attack concrete and steel and carbon dioxide diffusion and to improve resistance to frost and de-icing salt	OS 4 (OS C)	
3		A3, A4, A5	Coating with limited water vapour permeability and low crack-bridging capacity for cracks near the surface for inaccessible areas (with scratch coat or levelling compound) for exposed concrete components with cracks near the surface, also in the spray area of de-icing salts to reduce water absorption, the penetration of substances that attack concrete and steel and carbon dioxide diffusion and to improve resistance to frost and de-icing salt	OS 5 (OS D)	

1) Only for concrete substrates where the mean breaking strength is at least 1.3 N/mm².

For concretes ≥ C35/45, moisture content lower than the manufacturer's binding 'design specifications' may be required. If moisture content is too high, additional measures may be required for surface protection systems according to the qualified planner's specifications (e.g. an additional primer). The manufacturer's other specifications for the design must be observed in all other respects.

0.6.7 Filling of cracks and local voids as per Section 8

This section applies to repair measures using polymeric or cement-bound injection products. These repair measures include closing (or limiting the crack width by means of filling), sealing cracks and joining crack flanks. Table 0 .10 contains the allocation of filling objectives and permissible injection products for closing (or limiting the crack width by means of filling), for sealing cracks and for joining crack flanks.

Table 0.10: Products/systems for repair measures as per Section 8

No	Procedure	Cured concrete class	Filling objective	Fill type	Possible injection products[1)]	ZTV-W LB 219
1a	1.5, 2.6, 4.5 7.6 [3)]	A1[2)], A2, A3, A4, A5[2)]	Closure (limitation of the crack width by means of filling)	by means of injection	F-I (P) F-I (H) D-I (P)	Section 8
1b				by means of casting	F-V (P) F-V (H)	
2a			Sealing	by means of injection	F-I (P) F-I (H) D-I (P)	
2b				by means of casting	F-V (P) F-V (H)	
3a			Force transmitting joining	by means of injection	F-I (P) F-I (H)	
3b				by means of casting	F-V (P)	
4			Limited ductility joining	by means of injection	D-I (P)	

1) F: Injection product for force transmitting filling of cracks, produced with reactive polymer binder (P) (e.g. epoxy resin (EP)), produced with hydraulic binder (H) (e.g. cement paste (ZL) or cement suspension (ZS))
D: Injection product for limited ductility filling of cracks, produced with reactive polymer binder (P) (e.g. polyurethane (PUR); possibly with associated rapid-foaming polyurethane (SPUR))
I: Injection
V: Casting
2) Usability must be assessed on a case-by-case basis.
3) Only with cement-bound filler (H).

Boundary conditions for using the various injection products can be found in TR-IH Part 1, Table 14. The qualified planner must asses the usability of method 7.6 on an object-specific basis with regard to the condition of the crack flanks (soiling of the cracks, depth of carbonation in the crack area, sintering in the crack area, etc.). Repassivation when cement-bound fillers are used can only be done in the area of the crack.

Injection into locally limited voids can also be done with cement-bound fillers as per Section 8. The basis for injection with hydraulic binders in hydraulic structures made of mass concrete to reduce directional permeability is DWA Code of Practice 506.

0.7 Project-specific definition of requirements for repair systems, proof of usability

The requirements for the repair systems referred to in Section 3 to 8 and the associated quality assurance procedures are to be defined by the qualified planner on a project-specific basis, taking into account the planning principles set out in Section 0.3 (see also 1.6.1.2).

For concrete replacement systems under Sections 3 and 4, the requirements in the aforementioned sections must be taken as a basis for planning and tendering.

For concrete replacement systems under Sections 5 and 6, surface protection systems under Section 7 and crack injection under Section 8, the qualified planner must determine which project-specific requirements for building materials and repair systems are to be imposed against in consideration of the respective effects on the structures and components to be repaired and with regard to the achievement of the respective repair objectives. For this purpose, the qualified planner must ensure the following project-specific definitions in the specification of works:

- What characteristics, associated test methods and requirements are required to demonstrate usability[2].
- Which of the following procedures the contractor has to use to demonstrate usability.
- The minimum scope of the manufacturer's binding 'execution instructions'.

Methods for demonstrating usability include:

– Method 1: Proof of the characteristics and requirements stipulated in the construction contract by the contractor on the basis of project-specific proof.
Alternatively, proof of the characteristics and requirements stipulated in the construction contract can be provided on the basis of a verifiable certificate from a qualified body[3] as per Article 40 of the Construction Products Regulation (CPR), provided that it fully guarantees the required characteristics and requirements.

– Method 2: Proof of the characteristics and requirements stipulated in the construction contract by the contractor on the basis of the manufacturer's declaration in accordance with DIN 18200, Annex A, on the basis of DIN 18200, verification procedure system B.
Alternatively, proof of the characteristics and requirements stipulated in the construction contract can be provided on the basis of a verifiable certificate from a qualified body[3] as per Article 40 of the Construction Products Regulation (CPR), provided that it fully guarantees the required characteristics and requirements.

Note:
When determining the procedure, factors such as the following should be taken into consideration: Importance of the structure in the transport network, the scope of the planned repair measure, possible repeatability in the event of failure (especially with regard to service life and accessibility) and the resulting costs.

When providing proof of usability as per Method 1, the qualified planner must specify for the specification of works which product characteristics, associated test methods and requirements are necessary with regard to the proof of conformity and in which form the proof of these product characteristics must be provided by the construction company.

When providing proof of usability as per Method 2, inspection tests may be carried out at the client's request during construction, depending on the importance and scope of the construction project, in order to check some or all of the project-specific characteristics required. The

[2] *Information on characteristics depending on the actions and on the scope of inspection can be found in works such as the BAW recommendation 'Repair products – Information for the qualified planner on building-related product characteristics and test methods'.*
[3] *The qualified body for Germany as per Art. 40 CPR is the German Institute for Structural Engineering (DIBt).*

qualified planner must determine a possible project-specific scope of the inspection tests in consideration of the importance of the repair measure and any potential experience from previous inspection tests on the product in question[2].

All verifications beyond the scope specified in the relevant reference standards are to be tendered and remunerated separately.

0.8 Stability, fulfilment of building inspectorate requirements

For repair measures under ZTV-W LB 219, the client must specify who is responsible for assessing stability issues for each phase of planning and execution and who plans and implements the necessary measures. ZTV-W LB 219 does not contain any rules for the proof of stability and suitability for use.

ZTV-W LB 219 assumes that any repair is relevant to stability. If the qualified planner can demonstrate in writing that the stability of the components or the structure will not be impaired within the planned useful life, exceptions to the requirements of ZTV-W LB 219 can be made regarding the planning, execution and monitoring of repair measures (see 1.6.1.3) with the client's consent.

The introductory decree of the Federal Ministry of Digital and Transport (BMDV) on this issue of ZTV-W LB 219 must be observed (see Technical Regulations – Waterways (TR-W)) with regard to compliance with building inspectorate requirements for repair measures relevant to stability.

1 General

1.1 Scope of application

(1) ZTV-W LB 219 applies to repair measures to maintain or restore the load-bearing capacity or suitability for use of unreinforced and reinforced concrete water structures, including their ancillary installations, e.g. locks, dams, barriers, pumps, nozzles, passageways, port structures, bank walls, unless otherwise agreed upon in the specification of works. They do not apply to road bridges, railway bridges and tunnels (cf. ZTV-ING).

(2) BAW-MBM also applies to concrete replacement systems in accordance with Sections 3 and 4 for the repair of the structures listed in (1) in the impact area of seawater and coastal areas as well as estuaries in exposure classes XS2 and XS3.

(3) Measures aimed at a planned increase in load-bearing capacity are not the subject of ZTV-W LB 219.

(4) ZTV-W LB 219 only applies to components or component areas that are not exposed to water during construction.

(5) DWA-M 506 applies to the injection of hydraulic binders in hydraulic structures made of mass concrete to reduce directional permeability.

(6) In the case of second stage concrete, the requirements of BAW-MBB must also be complied with for planning, building materials and construction.

(7) The provisions of ZTV-W LB 219 take precedence over the 'General technical specifications in construction contracts (ATV)'. If the planner makes technical specifications that differ from the ATV on a project-specific basis, he/she must specify them in the specification of works.

1.2 Basic principles

1.2.1 Systematics of ZTV-W LB 219

(8) Sections 1 and 2 (general sections) always apply, while Sections 3 to 8 (specific sections) contain specific conditions for the repair systems in question. Sections 1 and 2, together with one of the subsequent sections, form the self-contained Additional Technical Terms of Contract for the repair systems in question.

1.2.2 Repair plan

(9) The basis for executing repair measures in accordance with ZTV-W LB 219 is the repair plan drawn up by the client is based on the repair concept, which is attached to the specification of works or contained in full therein.

(10) Any deviation from the repair plan requires the prior written agreement of the client.

1.2.3 Repair of concrete components

(11) The principles and procedures in accordance with Table 0 .1 must be applied when repairing concrete components.

1.2.4 Stability

(12) In any case, the stability of the affected components or structure must be taken into consideration when planning, executing and monitoring repair measures in accordance with ZTV-W LB 219.

(13) Execution of the measures for repairing concrete components may only be commenced once (a) there is a written assessment of stability for all phases of the construction project to be prepared by the client within the framework of the repair plan, and (b) the client has appointed a person who will responsibly and competently assess stability issues on the contractor’s side during construction and initiate the necessary measures.

1.2.5 Further provisions

(14) The DIN/EN safety data sheets must be kept accessible on the construction site at all times.

(15) Any unused construction and auxiliary materials as well as the rebound from spraying work remain the property of the contractor and must be disposed of properly by the contractor.

(16) The limits and tolerances set out in ZTV-W LB 219 include both scatter in sampling and the confidence areas of the test methods and the work-related irregularities, unless otherwise specified in the specification of works.

1.2.6 Definitions

(17) Breaking strength

Tensile strength within the concrete substrate, concrete replacement system or surface protection system or bond strength between concrete substrate and concrete replacement

system or between concrete substrate or concrete replacement system and surface protection system, as determined in a pull-off test.

(18) Adhesion fracture

Fracture between two layers.

(19) Anchor systems

Standardised anchor systems or ones with building inspectorate approval (expansion anchors, undercut anchors, bonded anchors) or bar anchors to be dimensioned on the basis of suitability tests.

(20) Construction joints

The surface created by a work interruption in the component concrete or in the concrete replacement or surface protection system.

(21) Concrete replacement

Replacement of missing or damaged concrete or concrete addition with cement-bound mortar or concrete.

(22) Concrete replacement system

Made up of the building materials of the concrete replacement and any bonding layer, corrosion protection and fine filler present.

(23) Individual damaged area

Damaged area with an area of $\leq$ 1 m² which is not part of a wide-area repair measure.

(24) Bonding layer

Intermediate layer to improve the adhesion of the concrete replacement.

(25) Cohesion fracture

Fracture within a single layer.

(26) Course

Part of a layer (see (34)) that is produced in a single work operation.

(27) Minimum layer thickness

Layer thickness of the hardened concrete replacement system, which must be maintained at each point (see identification note(35)).

(28) Subgrade concrete

Flat, wide-area anchored reinforced concrete component to ensure the durability of the levelling areas of lock chamber walls, quays and similar components.

(29) Crack width

The width of the crack w in [mm], measured along the non-mechanically processed surface of the concrete as the gap to the edges of the cracks.

(30) Crack width variation

Variation in the crack width over time and dependent on the actions affecting the structure.
A distinction is drawn between three types of crack width variations Δw [mm], cf. Table 0 .2:
- low-frequency cycle, e.g. made up of temperature, water level variation: Δw LFR
- high-frequency cycle, e.g. made up of traffic: Δw HFR
- continuous change, e.g. from shrinkage, settlements: Δw CON.

(31) Crack flanks

Concrete boundary surfaces of the crack.

(32) Injection product

Product and system for filling cracks, voids and defective spots in concrete components so that the static load-bearing behaviour and/or the durability of the supporting structure are preserved or restored. Injection products may be classified into three categories in accordance with the intended purpose:
- Injection products for rigid filling of cracks, voids and defective spots in concrete (F)
  Injection products which are capable of forming a bond with the crack flank and of transmitting compressive, tensile and sheer forces which have strength properties irrespective of the injection product (force transmitting): F)
- Injection product for the limited ductility filling of cracks, voids and defective spots in concrete (D)
  ductile injection product which, after filling, is capable of forming a bond with the concrete edge and accommodating crack width variations (ductile): D)
- Injection product for the swellable filling of cracks, voids and defective spots in concrete (S)
  Injection product that is able to swell repeatedly through water adsorption, during which the water molecules are physically bound to the molecules of the injection product (swelling: S)
  Note: The use of swellable injection products is not addressed in these detailed technical specifications.

Other material-related designations:
P: produced with reactive polymer binder, e.g. epoxy resin (EP), polyurethane (PUR); potentially with associated fast-foaming polyurethane (SPUR)
H: produced with hydraulic binder, e.g. cement paste (ZL) / cement suspension (ZS).

(33) Crack boundary

The intersection between a component surface and a crack edge.

(34) Layer
Made up of one or more courses of the same composition.

(35) Layer thickness of the concrete replacement system
Thickness of the hardened concrete replacement system consisting of one or more courses. For rough substrate and/or concrete replacement system surfaces, the layer thickness is defined as the mean distance between the ‘crest’ of the substrate and the ‘valley’ of the concrete replacement system surface.

(36) Bar anchors with bond
Anchoring without expansion pressure in which external loads are transferred into the old concrete via bond stresses between the anchor bar, backfill material and wall of the borehole.

(37) Substrate preparation

Comprises all measures for preparing the concrete substrate and the reinforcement, including cleaning the surface, removing foreign layers, removing concrete, exposing the reinforcement, derusting the reinforcement, creating an edge, removing the reinforcement and applying an anti-corrosion coating.

(38) Substrate pre-treatment

Comprises all additional measures connected with the preparation of the substrate, with the help of substances for creating a substrate required for the application of the repair system.

(39) Bonded anchors

Standardised or building-authority-approved fastenings/anchors made of bar anchors free of expansion pressure in combination with a filler.

(40) Bond strength

Tensile strength within the concrete substrate, concrete replacement system or surface protection system or bond strength between concrete substrate and concrete replacement system or between concrete substrate or concrete replacement system and surface protection system, as determined in a pull-off or tensile test as per Annex 1.

(41) Facing formwork

Flat, wide-area self-supporting reinforced concrete element which, beyond its task as a repair system, can perform additional reinforcement functions for concrete components by means of its slab and disc load-bearing effect.

(42) Water-retaining post-treatment measures
These include:
- Leave in formwork
- Maintain a relative humidity of at least 95% in the air adjacent to the surface by covering with foil with sufficiently high resistance to water vapour diffusion while preventing air exchange between adjacent air and outside air.

(43) Water-feeding post-treatment measures
These include:
- Application of a water-retaining cover and water supply with sufficient evaporation protection
- Spraying with water to maintain a film of water on the surface
- Flooding with water

Note:
For further definitions, see TR-IH, Part 1, Section 10and reference standards in the system-specific sections 3 to 8.

1.3 Construction principles

1.3.1 General

(44) Before applying a concrete replacement or surface protection system, the surface of the relevant component is to be prepared in accordance with Section 2.

(45) If repair work is to be carried out on components to which a concrete replacement and/or surface protection system has already been applied, Section 2 applies accordingly.

(46) Existing joints in the component are to be kept as-is. The function of expansion joints must not be impaired by any repair measures.

(47) Unless otherwise specified in the specification of works, if an external density layer is to be placed in the expansion joint in a concrete or shotcrete prefabrication, it must be constructed with edge protection, elastomer waterstop, clamp construction and cover sheet (if any).

(48) Ladders in concrete or shotcrete facing formwork must be constructed with vertical edge protection.

(49) If there are any built-in parts remaining in the component, corrosion protection must be ensured.

(50) The full-surface embedding of built-in parts and anchoring elements must be ensured. In order to achieve sufficient embedding and tightness, injection hoses to be subsequently grouted in accordance with DBV-Injektionsschlauch must be installed if necessary. The injection hoses must be compressed with cement suspension in accordance with Section 8 unless otherwise specified in the specification of works.

(51) Construction joint should be horizontal or vertical. Construction joints must be made impermeable to water. In hydraulic areas, horizontal construction joints are not permitted in areas with water levels pending over a prolonged periods of time (for locks in the area of the upper water level + 0.5/-1.0 m and the underwater level ± 1.0 m).

(52) Concrete replacement or surface protection systems must meet the following requirements:
- Strength and deformation behaviour adapted to the concrete base
- Sufficient bonding with the concrete base or the individual layers among themselves
- No impairment of the usability and durability of the component to be protected or repaired
- Sufficient frost resistance
- Protecting the reinforcement from corrosion (only applies to concrete replacement systems)
- Sufficient aging, volume and alkali resistance
- Water resistance under the respective stresses
- Compatibility of the building materials used with one another
- Practical processing time, applicability in broad climate range
- Workability suitable for the construction site, even in case of work in difficult situations
- Easy to rework
- Low susceptibility to soiling.

1.3.2 Concrete cover

(53) The minimum concrete cover c_{min} is 40 mm, the tolerance allowance Δc is 10 mm.

(54) Unless otherwise specified in the specification of works the minimum concrete cover for components with exposure classes XD and XS is c_{min} 50 mm and the tolerance allowance Δc is 10 mm.

(55) If the surface is left sprayed rough in accordance with Sections 4 and 5, the minimum concrete cover c_{min} is increased by 5 mm. This rule does not apply to sprayed mortar.

(56) In order not to impair the effectiveness of any reinforcement additionally inserted, the concrete cover ($c_{min} + \Delta c$) specified in the repair plan must not be exceeded by more than 20 mm, even by individual values (5% quantile with 90% probability of acceptance in a statistical evaluation).

1.4 Building materials and building material systems

(57) The contractor must demonstrate compliance with the project-specific requirements for building materials, building material systems and components in accordance with the requirements of ZTV-W LB 219 (see Sections 1.4, 1.6 and 3 to 8, among others) and the specification of works.

(58) For the assessment and use of aggregates that contain harmful quantities of alkali-soluble silica or in cases in which these cannot be ruled out with certainty, as well as for any preventive measures to be taken, the current version of the associated decree of the Federal Ministry of Digital and Transport Affairs must be observed in addition to the Alkali Guideline RL AKR (see TR-W).

(59) If the use of cement with a low effective alkali content (NA cement) is chosen as a preventive measure against damaging alkali reaction, this cement property must be demonstrated on a project-specific basis. The requirements for NA cements according to DIN 1164-10 must be met for the Na_2O-equivalent of the cement. This requirement also applies to cements used as injection products or fillers for injection hose systems or for concrete, shotcrete, sprayed mortar, concrete replacement systems, surface protection systems or fillers for anchor systems when repairing concrete components containing alkali sensitive aggregates.

(60) The mixing water must comply with DIN EN 1008.

(61) For raw materials for concrete according to DIN 1045-2 and shotcrete according to DIN EN 14487 in conjunction with DIN 18551, which are covered by harmonised European standards, all performance characteristics mentioned therein must be explained.

(62) With regard to the usability of products and systems referred to in Sections 5, 6, 7 and 8, complete binding ‘execution specifications’ must be established by the manufacturer. This information is intended to ensure that, under the boundary conditions described, the characteristics of the repair products or systems declared by the manufacturer are safely achieved on the structure. Proper and expert planning and processing is assumed in this regard.

1.5 Construction work

1.5.1 General

(63) The contractor is to draw up a quality assurance plan that includes all measures to ensure the quality of the execution. This must be submitted to the client for consultation in sufficient time before performance to allow significant influence to be exerted.

(64) The contractor must check the suitability of the methods and materials he /she intends to use with regard to the structural conditions encountered; unsuitable methods and materials are to be avoided.

(65) In interpretation of the provisions under VOB/B § 4(3), the contractor must inform the client immediately in writing if the structural conditions or the planned type of execution do not allow the intended effectiveness and durability of the planned repair measures to be achieved.

1.5.2 Requirements for executing companies and personnel

(66) The contractor and all subcontractors it makes use of must comply with the provisions of RL SIB [Guideline on the protection and repair of concrete structural elements] Part 3, Section 1 with regard to personnel and equipment requirements.

(67) When working with plastics or plastic-modified building materials, the crew leader must present the certificate of the ‘Protection and repair of concrete structures’ training advisory board of the Beton- und Bautechnik-Verein E.V. [German Concrete and Construction Technology Association] (known as an ‘SIVV certificate’) or an equivalent proof of qualification before starting work.

(68) The foreman must be present at the place of work at all times during the execution of the work.

1.5.3 Execution instructions

(69) The repairs referred to in Sections 56, 7 and 8 must be carried out in accordance with the manufacturer’s binding ‘execution specifications’.

1.5.4 External conditions

(70) If repair work has to be carried out in unfavourable weather conditions, effective protective equipment must be provided in accordance with Annex 9.

(71) Repair measures may only be carried out if the respective material and processing-related limit values are complied with.

(72) In the application of concrete replacement and surface protection systems and in the use of injection products and for a reasonable period thereafter, the following boundary conditions must be observed for the temperature of the subsoil and the immediately superimposed air layer, provided that no further requirements are imposed in the manufacturer’s binding ‘execution specifications’ or comparable execution instructions:

- Cement-bound materials (including with plastic additive):Minimum value 5 °C / maximum value 30 °C
- Plastic-bound substances, hydrophobic impregnations:Minimum value 8 °C / maximum value 30 °C

These requirements also apply to individual operations for the production of parts of the concrete replacement and surface protection systems as well as when injection products are used. Reaction heat-related temperature increases are not to be taken into account here.

1.5.5 Post-treatment and protection

1.5.5.1 General

(73) Unless otherwise specified for the individual concrete replacement and surface protection systems and injection products in the respective sections of ZTV-W LB 219, the manufacturer's binding ‘execution specifications’ apply.

1.5.5.2 Concrete replacement

<u>Post-treatment</u>

(74) In the case of water-feeding post-treatment measures, rapid cooling of the surfaces exposed to water must be avoided. The temperature difference between the surface of the concrete replacement and the water fed in must not exceed 15 K, or 10 K for floods.

Protection

(75) The concrete replacement must be protected from damaging effects such as flowing water, pressurised water or impacts until it has hardened sufficiently.

(76) The temperature in the concrete replacement as per Sections 3 to 6 must remain above 5 °C until the compressive strength of the concrete replacement is at least 5 N/mm². If frost is to be expected, the concrete replacement must be protected from water access, water-feeding measures for post-treatment are not permitted in this case.

1.6 Quality assurance

1.6.1 Quality assurance by the contractor

1.6.1.1 Basic principles

(77) Compliance with the contractual requirements for the production, properties and processing of building materials, building material systems and components and to the finished performance is to be ensured by quality assurance, consisting of:

- quality assurance of building materials, building material systems and components,
- quality assurance of execution

.

(78) The contractor is responsible for proper implementation of quality assurance and ensures that only products that are demonstrably subject to such quality assurance are used.

(79) The type and scope of quality assurance and the requirements for the quality and project-specific characteristics of the building materials, building material systems and components are defined in the specifications, the respective technical specifications (e.g. DIN standards) and the building material-specific Sections 3 to 8.

(80) The contractor must agree with the client on the details of the inspections due under the contract and the documentation of the inspections results in the scope of quality assurance.

(81) Testing and monitoring bodies must be accredited for their respective fields of activity.

1.6.1.2 Quality assurance of building materials, building materials systems and components

1.6.1.2.1 Proof of usability

(82) The usability of the building materials, building material systems and components for the field of traffic hydraulics must be verified in good time before the start of construction. Additional requirements set out in the specification of works and in the specific Sections 2 to 8 must be taken into account. The specific requirements of traffic water engineering must be taken into account in an appropriate manner in all proofs of usability.

(83) The usability of building materials, building material systems, construction methods and components in accordance with Sections 3 and 4 for the intended use under the boundary conditions of the construction site in accordance with the contractual requirements must be demonstrated by the contractor by means of an initial or suitability test.

(84) The applicability of building materials and building material systems as specified in Sections 5, 6, 7 and 8 for the intended use shall be demonstrated by the contractor in accordance with the relevant provisions of the specification of works in accordance with Method 1 or 2 as specified in Section 0.7. With both methods, proof of the characteristics and requirements stipulated in the construction contract can alternatively be provided on the basis of a verifiable certificate from a qualified body[4] as per Article 40 of the Construction Products Regulation (CPR), provided that it fully guarantees the required characteristics and requirements.

[4] *The qualified body for Germany as per Art. 40 CPR is the German Institute for Structural Engineering (DIBt).*

1.6.1.2.2 Proof of conformity, certificate of conformity

(85) Under Method 1, proof of conformity of the building materials and building material systems intended for use in accordance with Sections 5, 6, 7 and 8 with the building materials and building material systems examined and assessed in the roof of usability must be ensured by the contractor before and during construction by means of proof of conformity in accordance with the specification of works and documented by means of suitable certificates of conformity. If proof of the characteristics and requirements stipulated in the construction contract is provided on the basis of a verifiable certificate from a body qualified in accordance with Article 40 of the CPR[4], proof of conformity is thereby rendered.

1.6.1.2.3 Execution instructions

(86) In the case of factory-manufactured building materials and building material systems, the contractor must provide binding ‘execution specifications’ from the manufacturer, which must meet the requirements of the specification of works in terms of structure and content. The ‘execution instructions’ in the verifiable certificate issued by a body qualified as per Article 40 of the CPR are generally recognised as being an equivalent alternative provided they fully meet the requirements of the specification of works.

1.6.1.3 Execution and testing of the finished service

1.6.1.3.1 General

(87) The execution of repair measures under ZTV-W LB 219 must be subject to monitoring. In any case, this consists of monitoring by the executing company (RL SIB Part 3, Section 2.2) and monitoring by a recognised monitoring body (RL SIB Part 3, Section 2.3).

(88) The client reserves the right to take part in the inspections. The client must be given a timely opportunity to take part in the inspection.

(89) The contractor must inform the monitoring body in good time of the execution times and provide proof of this to the client.

(90) The results of the monitoring of the execution must be documented, submitted to the client without delay and also handed over to the client, unless the client waives the handover in whole or in part. If deviations from the contractual requirements are detected, the client must be informed immediately. The causes must be rectified immediately after prior consultation with the client.

(91) Examinations of the finished service are to include the following as needed:
- sample collection and labelling,
- sealing the sampling points,
- storage of the samples,
- ready-to-ship packaging of the samples,
- transport of the samples to the laboratory,
- provision of test equipment, including accessories and tools,
- performance of field maintenance
- drafting of the test report;
- storage of the reserve samples,
- environmentally sound disposal of the sample material.

(92) Destructive tests on the structure or on components require the prior approval of the client.

(93) The test sites and the sampling points of samples at the structure are to be documented in terms of location and height, specifying the sample number and the date of collection.

(94) In the case of concrete replacement systems, the layer thickness on the lateral surface of a drill core shall be determined as an average of at least 4 individual values, unless otherwise specified in the specification of works.

(95) The records and evaluations from the monitoring must be retained at least until the limitation period for claims for defects elapses and also handed over to the client, unless the client waives the handover in whole or in part.

1.6.1.3.2 Monitoring by the executing company

(96) The nature, scope and frequency of the tests are regulated in Sections 2 to 8 and summarised in table form in Annex 8.

(97) The records and evaluations must be kept on the construction site during construction. They must be submitted to the client without delay. The forms provided for this purpose in the relevant technical specifications are to be used.

1.6.1.3.3 Monitoring by a recognised monitoring body

(98) The contractor shall conclude a monitoring contract with a recognised monitoring body. In so doing, the client's right to view or obtain information regarding all the documents shall be guaranteed. The monitoring agreement must be presented to the client.

(99) The confirmation of the site notification by the approved monitoring body shall be submitted to the client without delay after the order has been placed.

(100) Each construction site must be monitored at least once on site during construction and, as a general rule, without prior notice. In the case of longer-term construction sites, further on-the-spot checks shall be carried out at reasonable intervals.

(101) The contractor must ensure that the recognised monitoring body delivers all monitoring reports (including all interim reports) to him/her within good time of the performance of monitoring. The contractor must forward a copy of all reports to the client without delay.

(102) The construction site must be marked in accordance with RL SIB Part 3, Section 2.3.5.

1.6.2 Inspection tests by the client

(103) Inspection tests are initiated and carried out by the client to determine whether the quality characteristics of the building materials, building material systems and finished performance meet the contractual requirements. The results of the control tests are to be taken as a basis for acceptance.

(104) Sampling and testing carried out at the site must be carried out in the presence of the contractor. They shall also take place in the absence of the contractor if he/she does not meet the date announced in due time.

(105) The client may take reserve samples.

(106) The costs of the control checks are to be borne by the client.

1.6.3 Additional inspection tests

(107) The contractor may require additional inspection tests if he/she suspects that the result of an inspection test carried out by the client is not characteristic of the assigned service. The locations for the collection and the partial works to be assigned, are determined jointly by the contractor and the client.

(108) The right of the client to carry out further inspections at his/her own discretion and own expense remains unaffected.

1.6.4 Monitoring and access rights

(109) The monitoring and access rights of the client pursuant to VOB/B § 4(1)(2) also extend to the premises of the subcontractors and to the manufacturing or supply plants of components, concrete and shotcrete. The contractor must ensure this.

(110) The contractor must ensure that the client's right to inspect documents in accordance with VOB/B § 4(1)(2) can also be effectively exercised in relation to subcontractors, manufacturers and suppliers.

1.7 Determination of condition, coordination, acceptance

(111) Before carrying out work steps whereby parts of the performance are withdrawn from the inspection and determination, the client are to be given the opportunity in good time and in text form to request the joint determination of the condition in accordance with VOB/B § 4(10).

(112) This determination of condition does not constitute acceptance as per VOB/B § 12. It does not release the contractor from his/her inspection and notification obligation under VOB/B § 4(3).

(113) The contractor must ensure accessibility for the inspection and determination of completed partial services and the overall service by the client. There is no separate remuneration for the services required for this purpose.

(114) Coordination with the client, e.g. on the use of certain processes or building materials, does not limit the contractor's responsibility for rendering defect-free work.

(115) Before accepting the construction project in accordance with VOB/B § 12, the contractor must hand over the following documents to the client:
- the records and evaluations of the monitoring by the executing company
- the delivery notes
- the final report of the recognised monitoring body (including all interim reports);
- the compilation and statistical evaluation of the test results to demonstrate the conformity of the building materials and building material systems.

2 Substrate preparation

2.1 General

(116) The substrate preparation must include all necessary measures to achieve a concrete substrate suitable for the planned repair operation and a suitable reinforcement condition.

(117) Among other things, substrate preparation includes:
- cleaning of surfaces
- removal of external layers
- concrete removal specified in the repair plan and, if applicable, the required additional concrete removal due to the found component condition
- uncovering and derusting of reinforcement depending on the chosen repair procedure in accordance with TR-IH Part 1
- establishment of edges to delimit repair areas;
- removal of reinforcement in accordance with the repair plan.

(118) The contractor is to select suitable procedures and equipment within the scope of the contractual requirements to ensure that the substrate preparation does not adversely affect the properties and quality of the concrete substrate and reinforcement as well as their functionality.

(119) Deviations from the repair plan concerning the location and extent of the removal areas and the removal depth require the prior consent of the client. Wide-area concrete removal over an area larger than that contractually agreed upon is not permitted.

2.2 Construction principles

2.2.1 General

(120) Adverse changes to the concrete substrate and the exposed reinforcement in the time between completion of the substrate preparation and application of the concrete replacement or surface protection system must be prevented or rectified.

(121) Unless otherwise agreed upon in the specification of works, the areas to be repaired must be delimited with straight edges. The edges of the excavation must be approximately perpendicular to the component surface to a depth of approx. 10 mm and then bevelled at an angle of approx. 45°.

(122) The prepared areas must have a suitable shape that allows proper installation as well as adequate compaction and ventilation.

(123) In the event of unplanned construction or component conditions (e.g. excessive concrete erosion or damage to the reinforcement, unexpected defects or cracks in the concrete, unexpected corrosion of the reinforcement, unplanned concrete cover, unexpected occurrence of e.g. galvanised or plastic-coated reinforcing steel reinforcement or prestressing steel reinforcement), the client must be informed immediately and the further course of action must be agreed upon.

2.2.2 Concrete substrate

(124) The concrete substrate shall be prepared so as to achieve a solid and durable bond between the concrete replacement or surface protection system to be applied and the concrete

substrate. For this purpose, the concrete substrate after completion of substrate preparation measures must:

- be free of loose and low-strength parts,
- be free of cracks or detached parts which run approximately parallel to the surface or bowl-shaped cracks or detached parts near the surface,
- be free of voids,
- be free of sharp formwork edges and burrs,
- be free of composite-reducing materials such as old coatings, release agents, rubber abrasion, efflorescence, oil or vegetation,
- have roughness adapted to the concrete replacement or surface protection system to be applied and
- have sufficient breaking strength for the concrete replacement or surface protection system to be applied.

(125) Any voids or cavities in the concrete must be sufficiently opened and filled.

(126) The roughness depth class required in accordance with the specification of works for the respective repair measure in accordance with TR-IH Part 1 must be complied with. Unless otherwise agreed upon in the specification of works, in the case of concrete subsoil for concrete substitution, near-surface, firmly embedded aggregate with a diameter > 4 mm must be exposed in a dome-like manner after substrate preparation has been completed.

2.2.3 Existing reinforcement

(127) After substrate preparation has been completed, loose corrosion products must be removed on exposed reinforcement and, if necessary, on exposed installation parts.

(128) Steel surfaces are to be treated in such a way that at least a surface preparation level Sa 2 according to DIN EN ISO 8501-1 or Wa 2 according to DIN EN ISO 8501-4 is achieved in the entire exposed area, even if this does not match the optical image in the photographic comparative samples in DIN EN ISO 8501. DIN EN ISO 12944-4 must be observed accordingly in the process.

Note: For small areas, surface preparation by hand and mechanical surface preparation according to St 2 is permitted.

(129) Reinforcement may only be removed upon prior consultation with the client.

(130) In the case of chloride-induced reinforcement corrosion to de-rust the reinforcement, only high-pressure water jets (HDW) are permitted, unless otherwise agreed upon in the specification of works.

2.3 Construction work

2.3.1 General

(131) Unless otherwise agreed upon in the specification of works, an execution plan must be submitted to the client for agreement no later than 4 weeks before the beginning of substrate preparation and no later than 3 work days prior to the start of work. The execution concept and execution plan become parts of the quality assurance plan in accordance with Section 1.5.1.

(132) The execution concept must contain at least the following information:
- Intended substrate preparation procedures and equipment
- Component list with the aim of substrate preparation
- Measures to comply with the required or permissible removal depths
- Measures for protecting persons and the environment
- Conveying and disposing of demolition material, treatment of the water resulting from the demolition process, neutralisation if necessary
- Demolition instructions in accordance with the accident prevention regulations of the employers' liability insurance association.

(133) The execution plan must contain at least the following information:
- Execution schedule
- Component plan indicating the objective of the substrate preparation (further detail of the execution concept, equipment information, component list)
- Personnel plan
- Measures for protecting pre-treated surfaces until the application of the concrete replacement or surface protection system
- Plan of measures to be taken in case unplanned structural or component conditions are found or occur.

(134) The contractor must visually examine the surfaces to be treated for cracks, faults, reinforcement corrosion, water leakage and other abnormalities in the presence of the client before and after completion of the preparation of the substrate. The surfaces to be repaired must be cleaned of any dirt or adhering substances before the inspection. If the condition of the component found differs from the assumptions on the condition of the component which the repair plan was based on, the client shall decide on the further course of action.

2.3.2 Substrate preparation procedure

(135) The client must be informed immediately if any abnormalities regarding the suitability of the selected preparation procedure are detected during execution.

(136) For all substrate preparation methods that can lead to structural disturbances in the area near the surface of the remaining old concrete, such as chiselling, tapping, milling or similar, the treated surfaces must be reworked using suitable methods (blasting with solid blasting agents, high-pressure water jets).

(137) If compressed air is used as a process or part of a substrate preparation process, the residual oil content must be ≤ 0.01 ppm.

(138) Flame blasting as a method for substrate preparation is not permitted.

(139) Preparation of the concrete substrate using chemical methods is not permitted.

2.3.3 Coating of the reinforcement

(140) If repair principle 7 'Preservation or restoration of passivity' as per TR-IH Part 1 is applied, no additional corrosion protection coating of the reinforcement is provided.

2.3.4 Cleaning the application surface

(141) The application surfaces must be cleaned of water, salt deposits, dust, loose particles and similar impurities immediately before a subsequent layer or coat is applied.

2.3.5 Breaking strength:

(142) Unless otherwise agreed upon in the specification of works, the breaking strength of the concrete substrate after completion of the substrate preparation must comply with the values of Table 2 .11.

Table 2.11: Requirements for the breaking strength of the concrete substrate after completion of substrate preparation

	1	2		3	4
	System			Mean value	Smallest single value
				N/mm²	N/mm²
1	Concrete (Section 3)	unreinforced		≥ 1.5	≥ 1.0
2		anchored, reinforced		No requirement	No requirement
3	Shotcrete (Section 4)	anchored, reinforced		No requirement	No requirement
4	Sprayed mortar/ Shotcrete (Section 5)	unanchored, unreinforced	S-A2, SRM-A2, SRC-A2	≥ 0.8	≥ 0.5
5			S-A3, SRM-A3, SRC-A3	≥ 1.2	≥ 0.8
6			S-A4, SRM-A4, SRC-A4	≥ 1.5	≥ 1.0
7			S-A5, SRM-A5, SRC-A5	≥ 2.5	≥ 2.0
8	Concrete replacement in manual application (Section6)	unanchored, unreinforced	M-A4, RM-A4, RC-A4	≥ 1.5	≥ 1.0
9			M-A5, RM-A5, RC-A5	≥ 2.5	≥ 2.0
10	Surface protection (Section 7)	OS 1 (OS A)		No requirement	No requirement
11		OS 4 (OS C)		≥ 1.3	≥ 0.8
12		OS 5 (OS D)	without fine filler	≥ 1.0	≥ 0.6
13			with fine filler	≥ 1.3	≥ 0.8

(143) If the values of Table 2 .11 are not achieved over the entire area or in partial areas, the client decides on the further course of action.

2.4 Quality assurance

(144) The breaking strength of the concrete substrate after completion of substrate preparation shall be determined and assessed for each 250 m² of installation area or portion thereof, albeit at least once per component, using a set of 5 individual tests distributed evenly over the area to be assessed in accordance with Annex 1, Section A1.3.2. The test must be carried out in the presence of the client. The test reports are to be submitted to the client without delay.

(145) If a single value is found to be below the smallest permissible single value in accordance with Table 2 .11, at least 2 individual tests in close proximity (at a distance of up to approx. 1 m) shall be carried out to determine whether it is an outlier. If the additional values determined

are sufficient, the value initially found shall be discarded. If the value initially found is confirmed, a suitable surface grid is to be used to delimit the area with lower breaking strengths.

2.5 Determination of condition, coordination, acceptance

(146) In addition to (111), the application of the intended concrete replacement or surface protection system may only be started after the condition has been determined in accordance with VOB/B § 4(10) by the client.

3 Concrete

3.1 General

(147) This section applies to repair work with concrete with layer thicknesses between 90 and 800 mm, unless otherwise agreed upon in the specification of works. Deviations are permitted in the case of individual damaged areas.

(148) The requirements of this section apply accordingly to prefabricated parts.

(149) DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA and DIN 1045-1, DIN 1045-2 (implementation of DIN EN 206-1 in Germany) and DIN 1045-3 (implementation of DIN EN 13670 in Germany) shall apply, unless ZTV-W LB 219 contains provisions which diverge from them.

(150) Repair measures with concrete are to be assigned to planning class PK-S, concrete class BK-S and execution class AK-S and thus to concrete construction quality class BBQ-S as per DIN 1045-1000. All requirements of planning class PK-E, concrete class BK-E and execution class AK-E, and thus the concrete construction quality class BBQ-E, must be complied with.

(151) The preliminary concrete construction concept according to DIN 1045-1000 is part of the specification of works. Unless otherwise agreed upon in the specification of works, the contractor must continue the provisional concrete construction plan under his/her responsibility and must agree on the concrete construction plan with the client. Changes to the provisional concrete construction concept must be presented transparently and must be agreed upon. Effects on individual contractual services must be described (e.g. interactions on the quantity of reinforcement, ready-mixed concrete, construction joints).

(152) The DAfStb guideline ‘Hardened concrete structural elements’ (RL MB) may be applied accordingly to layer thicknesses $\geq$ 300 mm if constraint and residual stresses are to be taken into account in a special manner (e.g. in the case of surface-compressed components such as facing formwork).

3.2 Scope of application

(153) Repair measures may be carried out with concrete, provided the concrete is suitable for the exposure classes assigned to the component and the assigned old concrete class.

3.3 Construction principles

3.3.1 General

(154) Unless otherwise agreed upon in the specification of works, the concrete must be reinforced and connected to the concrete substrate via anchoring elements when applied over a wide area to ensure load-bearing capacity and suitability for use.

(155) If the breaking strength of the concrete substrate meets the requirements under Table 2 .11, line 1, individual damaged areas in horizontal surfaces may be executed without anchoring and reinforcement if suitable verification is provided in prior consultation with the client.

3.3.2 Facing formwork for lock chamber walls and similar components

(156) According to DIN EN 1992-1-1, adhesion bonding between the repair system and the old concrete may not be applied to wide-area structural elements with loading that is not predominantly static as per DIN 19702.

(157) Unless otherwise agreed upon in the specification of works, the maximum possible internal water pressure (crack and pore water pressure) in accordance with DIN 19702 must be applied between the concrete substrate and the repair system for components where water pressure can appear behind the repair system.

(158) In the case of facing formwork with loading that is not predominantly static (156), or where an internal water pressure between the concrete substrate and the facing formwork is to be applied(157), the reinforcement is to be arranged on both sides.

(159) The thickness of the facing formwork must be chosen so that sufficient space is available for the introduction and compaction of the fresh concrete. The minimum thickness of the facing formwork with reinforcement on both sides is 300 mm.

(160) If additional waterstops have to be installed in the facing formwork, they must be enclosed with an adapted reinforcement.

(161) The facing formwork must be dimensioned as a directly loaded component and as part of the overall structure for all relevant effects. Included in this is proof of the anchoring, the dimensioning of the reinforcement in the facing formwork and, where necessary, proof of the transfer of shearing force in the construction joint between the concrete and the concrete substrate, as well as proof of limitation of the crack width. In order to be able to use each anchor as a test anchor, it must be taken into account that the anchor rods must be able to withstand at least $F_{Prüf}$ in accordance with Annex 2.

(162) A minimum reinforcement shall be installed in the facing formwork to limit cracking due to pressure from temperature, shrinkage and other influences. Unless otherwise agreed upon in the specification of works, the permissible characteristic crack width is w_k = 0.25 mm. In the absence of more detailed examinations, the minimum reinforcement for centric constraint is to be determined in accordance with DIN EN 1992-1-1/DIN EN 1992-1-1/NA, Section 7.3.2. If the reinforcement is arranged on both sides, two thirds of the reinforcement determined this way is to be arranged on the front side of the shell and one third on the rear side of the shell facing the concrete substrate.

(163) If the strength properties of the concrete substrate can be assigned to at least one strength class C12/15 according to DIN 1045-2 at the time of repair, the anchor system for anchoring the facing formwork can be selected freely, provided that the absorption of the anchor forces can be mathematically verified. If the concrete substrate has lower strengths, only bar anchors with composite or bonded anchors may be used. All anchor systems must be demonstrably durable under exposure to water.

(164) The binding depths and anchor lengths must be checked or determined before the start of drilling and anchoring work on the basis of pull-out tests on site in accordance with Annex 2 (suitability test). The number of tests depends on the size of the construction project, the potential risk of anchor failure during operation and the strength conditions in the old concrete. Unless otherwise agreed upon in the specification of works, at least 5 test anchors are to be executed.

(165) In order to check the quality of execution, the contractor must carry out the tests under Annex 2 in the presence of the client. The selection of the anchors to be tested must be representative of the component and be determined after completion of the anchor work in prior agreement between the client and contractor. Unless otherwise agreed upon in the specification of works, 2% of all required anchors, albeit no fewer than 5 units per component, must be tested in accordance with Annex 2. If there is a general building inspectorate approval or a European Technical Assessment for the chosen anchor system containing test requirements that are stricter, these must also be met. The sampled test anchors can be used as structural anchors after successful anchor testing.

(166) The moisture condition in the borehole must be taken into account when selecting the filling material for the anchors.

(167) The anchor boreholes must be cleaned and cleared of loose parts before the anchors are placed. When filling with cement mortar, the borehole axis should be horizontally inclined by at least 15° so that the borehole can be safely filled with mortar.

3.3.3 Subgrade areas of lock chamber walls, chimneys and similar structural elements

(168) The following regulations apply to the repair of lock chamber walls, heads, buoys and similar components with subgrade concrete:

- The layer thickness of the subgrade concrete must be at least 0.2 m. Layer thicknesses greater than 0.4 m are to be avoided in light of the stress from constraint.
- The pre-mixed concrete must be provided with reinforcement on the top and connected to the old concrete via anchors.
- At minimum, the effects of early constraint must be taken into account when dimensioning anchoring and reinforcement.

3.4 Building materials and building material systems

3.4.1 General

(169) The backfill material for anchor systems must be suitable for the given effects and permanently water-resistant. It may consist of:

- cement mortar (mortar according to the RL Trockenbeton [Dry Concrete] guideline or grouting mortar according to the RL Vergussbeton [Grouting Concrete] guideline),
- mortar systems with building inspectorate certificate of usability for post-installed reinforcement connections.

(170) Anchor bars for anchor systems shall consist of:

- reinforcing steel as per DIN 488,
- standardised threaded rods or ones with building inspectorate approval, or
- standardised structural steel or structural steel with building inspectorate approval.

(171) The profile of requirements applicable to the concrete is based on DIN 1045-2 and the RL MB guideline (where applicable) as well as the additional requirements below. The requirements for all exposure classes assigned to the component in accordance with Table 0 .2 must be complied with.

3.4.2 Concrete constituents

(172) Unless otherwise specified, only starting materials that are listed as being generally suitable or suitable in accordance with DIN 1045-2 may be used.

(173) For non-standardised constituent materials, general building inspectorate approvals or European technical approvals must be submitted to the client. The use of such substances requires the client's prior written consent.

(174) Unless otherwise agreed upon in the specification of works, the following cements may be used in accordance with DIN EN 197-1 and DIN 1164-10 in accordance with the specifications of DIN 1045-2, Tables F.3 and F.4:

- CEM I
- CEM II/A-S, CEM II/B-S
- CEM II/A-D
- CEM II/A-P, CEM II/B-P
- CEM II/A-V, CEM II/B-V
- CEM II/A-T, CEM II/B-T
- CEM II/A-LL
- CEM II/A-M (S-D), CEM II/A-M (S-T), CEM II/A-M (S-LL), CEM II/A-M (D-T), CEM II/A-M (D-LL), CEM II/A-M (T-LL)
- CEM II/A-M (S-V), CEM II/A-M (V-T), CEM II/A-M (V-LL)
- CEM II/A-M (S-P), CEM II/A-M (S-Q), CEM II/A-M (D-P)
- CEM II/A-M (D-V), CEM II/A-M (D-Q), CEM II/A-M (P-V)
- CEM II/A-M (P-T), CEM II/A-M (P-Q), CEM II/A-M (P-LL), CEM II/A-M (Q-V), CEM II/A-M (Q-T)
- CEM II/A-M (Q-LL)
- CEM II/B-M (S-D), CEM II/B-M (S-T), CEM II/B-M (D-T)
- CEM II/B-M (S-LL)[5], CEM II/B-M (V-LL)[6], CEM II/B-M (T-LL)[6]
- CEM III/A, CEM III/B.

(175) Only industrially produced aggregates in accordance with DIN 1045-2, 5.1.3 (2) may be used; for components in exposure classes XM, XF3 and XF4, the use of industrially produced aggregates is not permitted.

(176) The use of industrially produced light aggregate, recycled coated and recovered crushed aggregate is not permitted.

(177) Recycled type 1 aggregate may be used for the production and processing of concrete up to compressive strength class C30/37. A maximum of 25% of the coarse aggregate by volume (based on the total aggregate) may be replaced. Type 2 recycled aggregate and fine recycled aggregate are not permitted. The use of recycled rock granules in exposure classes XF3, XF4, XA2, XA3, XD3, XS3 and XM, as well as for prestressed concrete and light concrete is not permitted. Recycled aggregate may only be used for components with predominantly static loads in accordance with DIN 19702, 5.3.2.4, for components which are not sensitive to deformation or for components with which creep behaviour can be neglected. In the case of components with moisture class WA, recycled aggregates are only permitted if they are

[5] *For the cements CEM II/B-M, the permissible limestone content is limited to 20% mass (DIN 1045-2, Table F.4, footnote e)).*

classified in the alkali sensitivity class E I-S in accordance with Annex B.3 of the DAfStb guideline ‘Alkali Reaction in Concrete’ (RL AKR).

(178) For the use of aggregates in concrete, the following requirements must be complied with in addition to those of DIN 1045-2, Annex E.2, Table E.1:

- Naturally composed (unprepared) aggregate in accordance with DIN EN 12620 may not be used.
- The grain composition of the coarse aggregate must be narrowly graded.
- The grain shape of coarse aggregates must at least correspond to category FI35 or SI40 for crushed grain.
- The resistance to crushing of aggregates from crushed rock must be at least category LA50 or category SZ32.
- The proportion of lightweight organic impurities may not exceed 0.25% by mass for fine aggregates and 0.05% by mass for coarse aggregates.
- Mixtures of grain may not be used unless otherwise agreed upon in the specification of works.

(179) The harmlessness of fine particles of fine aggregate must be demonstrated in accordance with DIN EN 12620, Annex D, Lit. (a), (b) or (c).

(180) Unless otherwise agreed upon in the specification of works, the proof of frost resistance or resistance to frost and de-icing salt of the aggregates in accordance with DIN EN 12620, 5.7.1, may not be older than 6 months at any time during the construction process.

(181) The use of additional water other than drinking water, groundwater or residual water from reprocessing plants for concrete production is not permitted.

(182) Residual water from reprocessing plants in concrete production may not be used for the production of air-entrained concrete.

(183) Unless otherwise agreed upon in the specification of works, the following additional materials may be used in accordance with DIN EN 934-2:

- Concrete plasticisers
- Superplasticisers
- Stabilisers
- Air-entraining agents/hollow microspheres
- Delayer
- Sealant
- Delayer/concrete plasticiser
- Delayer/superplasticiser
- Viscosity modifier

The use of other additional resources requires prior coordination with the client.

3.4.3 Concrete composition

(184) Concrete for water structures may not exceed a w/c ratio of 0.65.

(185) If aggregates larger than 8 mm are used, at least three separate particle groups must be added.

(186) The use of multiple types of cements in a single type of concrete is not permitted.

(187) Unless otherwise agreed upon in the specification of works, the simultaneous use of additives of different manufacturers within a concrete is not permitted.

(188) Unless otherwise agreed upon in the specification of works, the quasi-adiabatic temperature increase of the concrete _xD835__xDEE5_T_{qadiab} may not exceed a value of 45 K after 7 days for facing formwork under Section 3.3.2 with a minimum thickness ≥ 300 mm.

For this purpose, the adiabatic temperature rise _xD835__xDEE5_$T_{adiab,7d}$ must be determined by calculation or technical trial during initial testing in accordance with BAW-MATB. If the adiabatic temperature rise of the concrete is determined by technical trial, the heat of hydration of the cement batch used must be determined in accordance with DIN EN 196-8 or DIN EN 196-11. Based on the cement manufacturer's factory production control (FPC), the production-related fluctuations in the heat of hydration of the cement must be classified by mathematical estimate in accordance with BAW-MATB, Section 5. If cements without FPC data are used, a safety margin of 30 J/g must be added to the tested heat of hydration of the batch for the calculation under BAW-MATB, Section 5.

Note: To comply with the quasi-adiabatic temperature increase in the concrete, it is usually necessary to use cements with low hydration heat development (LH cements according to DIN EN 197-1).

(189) In deviation from RL MB, concrete with frost resistance ensured by the addition of air-entraining agents and in which CEM I, CEM II/A, CEM II/B-S or CEM III/A cement is used may be used for facing formwork under Section 3.3.2 with minimum thickness ≥ 300 mm in the interior, in which exposure class XF3 in conjunction with XC2 or XC4 and XM1 (if applicable) predominates:

- The minimum compressive strength class is set at C20/25 (detection age 56 days), unless higher strengths are required for structural reasons or due to other exposure classes.
- The minimum cement content in accordance with RL MB, Table F.2.2, line 3, is set at 270 kg/m³. At least the difference between the actual cement content and the minimum cement content of 300 kg/m³ in accordance with RL MB must be compensated for by adding powdered grain from concrete admixtures of type I or type II.

This rule may also be applied to the area between the upper water level and the lower edge of subgrade concrete.

(190) In the case of subgrade concrete with exposure classes XC4, XD3 and XF4 (in conjunction with XM1 where applicable), for which classification in exposure classes XD3 and XF4 is primarily based on the use of dew agents to ensure road safety for pedestrians and rare vehicle traffic, the following rules shall apply:

- The maximum permissible w/c ratio (taking the inclusion of fly ash into account) is 0.50.
- The minimum cement content is 300 kg/m³; the cement content may be reduced to 270 kg/m³ if fly ash is taken into account.
- To reduce shrinkage, the total water content in the fresh concrete must be limited to 160 dm³/m³ for 32 mm maximum particle size and 165 dm³/m³ for 16 mm maximum particle size.
- The minimum strength class is C25/30 (detection age 28 days or 56 days), unless higher strengths are required for structural reasons or for other exposure classes.
- Proof of sufficient frost resistance by means of a frost test in accordance with (207) must still be provided for exposure class XF4.

(191) Only aggregates of category F1 according to DIN EN 12620 may be used for concrete of exposure class XF3.

(192) Unless otherwise agreed upon in the specification of works, only the variant with a minimum air content as per DIN 1045-2, 5.4.3 is permitted for exposure class XF3. Alternatively, hollow microspheres may be used under the boundary conditions specified in the general building inspectorate approvals (including compressive strength requirements, fresh concrete tests).

(193) For components with exposure classes XD2 and XD3, a durability assessment of concrete must be carried out in accordance with BAW-MDCC (e.g. for transhipment quays in inland ports; components with a chloride load from flowing water, regulated water bodies or groundwater with a chloride content over 2,000 mg/l).
A BAW-MDCC assessment may be dispensed with in the following cases:

- For components with a scheduled useful life of up to 50 years, provided that the following binders are used:
  - CEM I and CEM II cements after (174) in combination with fly ash as a concrete additive, in which the attributable fly ash content must be at least 20% by weight of (c+f).
  - CEM I and CEM II cements after (174) in combination with silica dust as a concrete additive, in which the attributable silica dust content must be at least 8% by weight of (c+s).
  - CEM III/A in combination with fly ash as a concrete additive, in which the attributable fly ash content must be at least 10% by weight of (c+f).
  - CEM III/B.
- In the case of components areas affected by road structures (e.g. lock heads, subgrade areas or weir piers under road bridges) regardless of the useful life, provided that the aforementioned binders are used.
- For subgrade area of locks and weirs on the interior outside of areas affected by road structures, regardless of the useful life.

(194) The BAW-MBM also applies to components in the area of influence of seawater and coastal areas as well as estuaries with exposure classes XS2 and XS3.

(195) Unless otherwise specified in the specification of works, only the variant with a maximum permissible w/c ratio ≤ 0.45 according to DIN 1045-2, Table F.2, or RL MB, Table F.2.2, is permitted for components assigned to exposure class XM2 as a result of hydroabrasion and aggregates with a quartzite content of at least 70% or alternatively aggregates with a resistance to wear (micro-deval coefficient M_{DE} according to DIN EN 1097-1) of category $M_{DE}10$ according to DIN EN 12620 are to be used.

(196) Bonding layers must be made of water and equal parts by weight of cement and sand (maximum particle size 2 mm). The ready-to-use mixture must produce a viscous cement mortar. The w/c ratio may not exceed 0.55.

3.4.4 Requirements for the fresh concrete

(197) The fresh concrete temperature $T_{Concrete}$ at the transfer point must be set so as not to exceed the (273) maximum permissible fresh concrete temperature of + 28 °C at the installation point.

(198) The consistency of concrete (other than self-compacting concrete) must be determined by the target flow spread value. Only concrete with a target flow spread value of max. 480 mm may be used. For air-entrained concrete, the target value may not exceed 450 mm. Other target values are only permitted for concrete for narrowly reinforced areas and second stage concrete in accordance with the BAW-MZB in coordination with the client. In deviation from DIN 1045-2, Table 26, the permissible tolerance of the target value is ± 30 mm.

(199) If plasticising admixtures are added, the concrete must not have set so much that the actual consistency falls below that measured on site before the initial dosing. Once the consistency has been adjusted on site by means of plasticising admixtures, only a single additional dose is permitted.

(200) Concrete of consistency classes ≥ F4 must be produced with plasticising admixtures, in which the consistency must be ≤ F2 before the admixtures are added (initial concrete).

(201) Delay times of more than 12 hours must be agreed upon with the client in advance.

(202) Unless otherwise agreed upon in the specification of works, for the determination of the w/c ratio at the fresh concrete by testing:

- the water content must be determined in accordance with DBV-Frischbeton [Fresh Concrete] Section 3 and the effective water content must be derived from this, taking the core moisture content (water absorption in accordance with DIN EN 1097-6) of the aggregate into account,
- the cement and admixture content must be taken from the specifications on the current condition listed in the delivery note.

Permissible tolerances based on DIN 1045-2, Table 25.

(203) In the case of concomitant use of plasticising admixtures and air-entraining agents, and in the case of air-entrained concretes with a soft consistency (C3 or ≥ F3), the specified minimum air content (DIN 1045-2, Table F.2, or RL-MB) must be increased by 1% by volume.

(204) Possible changes in the fresh concrete consistency and the air content in the fresh concrete as a result of the conveying process on the construction site from the delivery point to the installation site must be taken into account in order to maintain the fresh concrete properties at the installation site. Corresponding specifications for the target value of the consistency and the target value of the air content at the transfer point must be determined during the initial inspection and regularly adjusted during the construction process.

3.4.5 Requirements for the hardened concrete

(205) Proof of the compressive strength class of the concrete shall be carried out at the age of 28 days. If RL MB is applied in accordance with Section 3.1, proof may also be rendered at the age of 56 days. An age of over 56 days upon proof is only permissible if agreed upon in the specification of works.

(206) Concretes for hydraulic structures must have high resistance to water penetration. For concrete with a w/c ratio > 0.55, the water penetration resistance must be determined on the basis of the water penetration depth in accordance with DIN EN 12390-8 and may not exceed 30 mm.

(207) Unless otherwise agreed upon in the specification of works, frost tests must be carried out in hardened concrete for concretes of exposure classes XF3 and XF4. BAW-MFB is decisive for the performance of the test and the associated acceptance criteria.

(208) Unless otherwise agreed upon in the specification of works, all other properties of hardened concrete (e.g. water penetration depth, frost resistance [for XF3] and resistance to frost and de-icing salt [for XF4]) may, instead of 28 days, be demonstrated at the same time as the compressive strength for the proof of the compressive strength class.

3.4.6 Definition of concrete

(209) Unless otherwise agreed upon in the specification of works, concrete refers to use according to the characteristics specified in DIN 1045-2.

(210) Prior to construction, the contractor is to arrange for initial tests to be carried out, taking into account the boundary conditions specific to the construction site and structure, to demonstrate that the concrete can be reliably processed with the planned constituent materials

and the intended consistency under the conditions of the construction site in question (climatic boundary conditions, transport, conveying, processing, post-treatment, etc.) and that the required properties can be reliably achieved. The initial test includes the tests corresponding to the initial test as per DIN 1045-2 as well as the additional tests specified in ZTV-W LB 219. The initial test may not be have been performed more than 12 months prior to the start of concrete installation.

(211) The contractor must determine whether the compressive strength is to be verified by cylinder or cube testing in consultation with the client during the initial tests. The defined test specimen shapes and storage conditions must be maintained consistently.

(212) For each type of concrete, the proofs for the fresh concrete before the addition of admixtures (initial concrete) and, if planned, after the addition of one or more admixtures must be provided during the initial tests. If multiple admixtures are used, proof of compatibility must be provided taking into account the climate conditions on the construction site and the concrete temperature. The stability of the air content in concrete with artificially introduced air voids must be verified up to the point of installation (at the end of the pump hose if concrete pumps are used).

(213) Unless otherwise agreed upon in the specification of works, the contractor must submit the following information to the client and agree with it at least 2 weeks prior to the start of the initial test:

- Concrete production concept (on-site mixed concrete or ready-mixed concrete)
- in the case of ready-mixed concrete, information on the location of the ready-mixed concrete mixing plant(s), including substitute mixing plant(s), as well as the distance and travel time between the mixing plant(s) and the construction site
- Information on the nature, characteristics, origin and availability of concrete constituents
- Concrete formulations and, if applicable, their compatibility when used together (within one component or in adjacent components)
- planned execution of construction.

(214) Unless otherwise specified in the specifications, the expanded initial test on concrete must include at least the tests listed in Section 3.6.1 in addition to DIN 1045-2, 9.5 (1b).

(215) The client must be informed of the start of the initial tests in good time so that he/she can arrange to take part in the contractor’s initial tests.

(216) The results of the initial tests must be available to the client sufficiently in advance of the initial installation of the concrete in question to allow him/her sufficient time (at least the same time as for carrying out the initial tests plus 3 weeks, unless otherwise specified in the specification of works) to carry out control tests to verify the initial tests. The contractor shall provide the necessary constituent materials for the control tests at the client’s test site in accordance with the specifications in the specification of works.

(217) Execution of concrete work may only commence after successful completion of the initial inspection and after prior consultation with the client.

(218) For all concretes, only the same constituent materials (type, manufacturer, place of extraction) as those with which the initial test was carried out may be used.

(219) The contractor is obliged to carry out new initial tests if the concrete constituents (type, manufacturer, place of extraction) or the conditions on the construction site are to be changed.

3.4.7 Concrete production and delivery of fresh concrete

(220) The strength ratio $f_{cm,2}$ / $f_{cm,x}$ (x = 28, 56, 91) required for determining the minimum duration of the post-treatment to designate the strength development must be determined based on the corresponding strength values of the initial test.

(221) For the manufacture of concretes with more than one additive, the mixing plant must have the facilities for separate dosing and addition of the additives.

(222) The concrete must be mixed in accordance with the concrete and installation-specific minimum mixing times and the mixing regime chosen there. For concretes without air-entraining agents, this is achieved if no further significant change in consistency occurs as a result of further mixing. For air-entrained concrete, the concrete and plant-specific minimum mixing time is reached if no further significant change in consistency and air content occurs as a result of further mixing.

(223) Before unloading the concrete, the manufacturer must allow the user to view the delivery note for each load of concrete. After the concrete has been unloaded, the manufacturer must provide the user with a delivery note for each concrete load. The delivery note for ready-mixed concrete must contain at least the information listed in Table 3 .12 in unencrypted form and, if required there, be printed out automatically. The delivery note must contain a comparison of the target weight (target specification of the ready-mixed concrete manufacturer for concrete production based on the composition according to the initial test, taking into account the variations permitted for modulating the properties of the fresh and hardened concrete in accordance with ZTV-W LB 219) and the actual weight, stating the differences. The surface moisture content of the aggregate (separated according to the individual grain fractions) must be listed in a verifiable manner. Copies of delivery notes must be handed over to the client upon delivery.

Table 3.12: Information on delivery note for ready-mixed concrete

Seq. no.	Information on the delivery note	Automatic printout	Form / handwritten entries
1	Name, address and telephone number of the ready-mixed concrete plant		X
2	Delivery note number	X	
3	Date and time of loading	X	
4	Transport vehicle licence plate number	X	
5	Name of buyer	X	
6	Designation and location of the construction site	X	
7	Details or references to the specification, e.g. Type number, order number	X	
8	Declaration of conformity with reference to the specification and DIN EN 206	X	
9	Mark of conformity indicating DIN 1045-2 and ZTV-W LB 219		X
10	Name or mark of the certification body		X
11	Time of the concrete’s arrival at the construction site		X
12	Time of start of unloading		X
13	Time of end of unloading		X
14	Indication of concrete class BK-N, BK-E or BK-S	X	
15	Information on the proportion of recycled aggregate in relation to the total aggregate	X	

Seq. no.	Information on the delivery note	Automatic printout	Form / handwritten entries
16	Compressive strength class (verification age of the compressive strength class if not 28 days)	X	
17	Exposure class(es) and moisture class	X	
18	Strength development	X	
19	Type of use of concrete (unreinforced concrete, reinforced concrete, prestressed concrete)	X	
20	Target consistency value	X	
21	Origin, type and strength class of cement	X	
22	Origin, activity group (type designation) and name of the additives, origin and type of additives, origin and type of aggregates	X	X[1)]
23	Specific characteristics, e.g. extended processing time	X	
24	Maximum particle size of aggregate D_{max}	X	
25	Bulk density class for light concrete; or Target bulk density value for heavy concrete	X	
26	Actual weight of aggregate per grain fraction	X	
27	Actual weight of cement	X	
28	Actual weight of additive	X	
29	Actual weight per additive	X	X[1)]
30	Actual weight of mixing water	X	
31	Surface moisture of aggregate (separately for each fraction)	X	
32	Total water (mixing water + surface moisture + water from admixture at > 3 l/m³ concrete) and w/c ratio	X	
33	Target weight of all concrete constituents according to lines 26 to 30 and 32	X	
34	Difference between target and actual weight for all concrete constituents	X	
35	Quantity of concrete in m³	X	
36	Minimum mixing time specific to concrete and machine[2)]	X	X
37	Actual mixing time[2)]	X	X

1) When dosing superplasticiser on the construction site. The time of the solvent addition and the estimated residual quantity in the mixer drum before the addition must be specified.
2) If the machine is not yet equipped accordingly, the entry must be made by hand or by collective printout for several delivery notes.

(224) The information required for ready-mixed concrete in accordance with (223) is also relevant for on-site mixed concrete and must be made available to the client accordingly.

(225) The consistency may only be brought to the specified value on delivery using superplasticisers.

(226) Subsequent addition of water is not permitted, even in special cases.

3.4.8 Compliance control and conformity criteria

(227) If any non-conformity with the specification is confirmed, the contractor must inform the client of it without delay.

3.4.9 Production control

(228) In accordance with VOB/B § 4(1)(2), the contractor must ensure that the client can check the performance and reliability of the concrete manufacturer at any time by consulting the production control documents and the monitoring body's reports and by visiting the production sites.

(229) In accordance with VOB/B § 4(1)(2), the contractor must ensure that the client has the right to take retention samples of the constituent materials used from the concrete manufacturer.

(230) In the case of a new concrete composition, it is not permitted to dispense with an initial test under Section 3.4.6, even if there is long-term experience on hand for a similar concrete or concrete family.

3.5 Construction work

3.5.1 General

(231) Unless otherwise agreed upon in the specification of works, the contractor must submit a concreting concept to the client at least 4 weeks prior to the initial concrete installation and a concreting plan at least 3 work days prior to each concreting operation for coordination. Concreting concept and concreting plan are parts of the quality assurance plan as per Section 1.5.1 and the concrete construction concept as per DIN 1045-1000.

(232) The concreting concept must contain at least the following specifications:
- List of concrete (sorted by components/use)
- Concrete production (ready-mixed concrete, on-site mixed concrete); in the case of ready-mixed concrete: intended suppliers, distance, transport routes; in the case of on-site mixed concrete: delivery and storage of the constituent materials, construction site equipment
- List of components (type of components, requirements according to structural analysis, exposure classes and construction sequence, concrete installation quantities and times, type of concrete installation and compaction, concreting sections, reinforcement density, requirements for the concrete surfaces, type of formwork, use of formwork inserts, use of prefabricated or partially prefabricated parts)
- Control of constituent materials (reports from recognised monitoring bodies, in the case of aggregates: factory production control documents as well)
- Preparation of construction joints (accessibility, procedure, timing, removal of water and debris, protection from recontamination, etc.)
- Sealing elements (type, number, installation site, positional stability, protection during the construction process, joint formations, etc.)
- Measures for maintaining the fresh concrete temperature
- Post-treatment concept
- Formation of the concrete surface
- Monitoring of concrete production and concrete installation, concrete testing.

(233) The delivery note must contain at least the following information:
- Schedule (duration of concreting, interruptions)
- Component plan (further detailing of the information in accordance with the concreting concept/component list)
- Concretes (requirements, fresh and hardened concrete properties)
- Consideration of weather conditions (cooling, heating), weather-related protective measures
- Personnel plan per concreting layer
- Supply plants (for ready-mixed concrete)

- Concrete installation (installation quantities, installation times, installation positions, installation systems, work instructions for conveying, installation, compaction and post-treatment)
- Requirements for concrete surfaces
- Monitoring of concrete production (type and scope of fresh concrete and quality tests, hardening tests if applicable)
- Production of construction joints
- Production of joint seals
- Post-treatment plan (type, duration, time and date, documentation)
- Type and time of construction joint processing
- Measures in case of incidents (failure of supply plants, conveying equipment, etc.).

(234) The fresh concrete at the installation site and the hardened concrete in the component must have the characteristics specified in the specification of works and initial test.

(235) Unless otherwise agreed upon in the specification of works, the following requirements shall apply to the flatness tolerances:
- The flatness deviation of horizontal surfaces must conform to DIN 18202, Table 3, line 3.
- The flatness deviation of vertical surfaces and undersides of ceilings must conform to DIN 18202, Table 3, line 6.

(236) The colour and surface structure of the repair areas must be adapted to the surrounding concrete surfaces. The concrete surfaces must be closed and low-porosity. The following applies to the porosity requirements: Pores or flaws with a diameter ≥ 30 mm and/or a depth ≥ 10 mm are not permitted. (235), (246) and (258) apply to displacement and evenness requirements. Fine mortar leakages must be removed.

(237) If there are special requirements for the appearance of concrete surfaces, these are defined in the specifications on the basis of DBV-Sichtbeton [Exposed Concrete]

(238) The hardened concrete surface must have a surface tensile strength of at least 1.5 N/mm².

(239) Concrete for protection and repair measures on hydraulic structures are to be classified in monitoring class 2 as per DIN 1045-3, Table 2.

3.5.2 Scaffolding, formwork, installation parts

3.5.2.1 General

(240) The maximum calculated deflection of the formwork and the supporting structure may not exceed a total of 5 mm, taking any planned protrusions into account. A corresponding mathematical verification must be submitted to the client together with the concreting concept.

(241) Formwork anchors must be arranged in a regular grid on visible concrete surfaces. Their number should be limited as far as possible by a suitable formation of the formwork.

(242) Formwork anchors that leave continuous voids may not be used in case of pressurised water. Anchoring holes must always be completely closed so that the required component properties are also present in these areas. On visible concrete surfaces, the colour and surface structure of the backfilling must match those of the building component. Remaining anchor parts must end at least 50 mm below the surface of the concrete. The planned execution must be agreed upon with the client.

(243) The arrangement and design of the formwork for visible concrete surfaces (e.g. direction of the formwork slabs, joints, joint seals, formwork flaps and openings) must be depicted in a diagram and submitted to the client for approval together with the concreting concept.

(244) The correct position of the formwork must be documented by the contractor. The documentation must be submitted to the client before concreting.

(245) Unless otherwise agreed upon in the specification of works, an absorbent or weakly absorbent formwork in accordance with DBV-Sichtbeton shall be used to achieve a closed concrete surface. The formwork must be clean and free of excess release agent.

(246) The displacement of the joints of formwork elements and between the first and second-stage concrete surface may not exceed 5 mm. The height of the remaining grates in the concrete surface may not exceed 5 mm.

3.5.2.2 Water-repellent formwork liners

(247) Unless otherwise agreed upon in the specification of works, water-repellent formwork liners (CPF) are to be used for formwork surfaces of components 3.3.2 in contact with water in accordance with the section in exposure classes XF3, XF4, XM2 and XA2 and for inclined surfaces with ‘batten cladding’.

(248) Water-repellent formwork liners may be used no more than three times provided that the criteria set out in (236) are met.

(249) Water-repellent formwork liners may not be treated with release agents.

(250) Contamination of the formwork liner above the concreting level must be avoided during concrete installation.

(251) If internal vibrators are used, a minimum distance of 10 cm to the formwork skin must be maintained.

3.5.2.3 Release agents

(252) Release agents for water-covered surfaces and surfaces in contact with the ground must be readily biodegradable in accordance with DE-ZU 178. Biodegradable release agents for dry interiors are not permitted during use in order to prevent the formation of fungi and mould.

3.5.2.4 Installation parts

(253) At the edges of built-in parts, precautions must be taken to ensure sufficient sealing of the formwork and to prevent damage to the corrosion protection.

(254) If any installation components are installed by third parties before concreting, the contractor is responsible for maintaining the position during formwork and concreting. The contractor must ensure that the installation components are properly secured prior to concreting.

(255) Recessed areas for built-in parts must be roughened by means of suitable inserts or mechanical processing. The procedure must be agreed upon with the client.

(256) The recesses for built-in parts must be filled with second stage concrete in accordance with BAW-MZB, in which a water-impermeable bond must be created between the first and

second stage concrete. The second stage concrete must meet all the requirements for the hardened concrete laid down for the first stage concrete.

(257) For the prevention of rust streaks on the concrete surfaces, untreated steel installation parts must be protected until conserved by suitable means.

(258) Displacement of more than 3 mm between the concrete surface and the installation part is not permitted.

3.5.3 Reinforcement

(259) The contractor must provide proof of the origin and quality of the reinforcing steel in good time prior to installation.

(260) Welding of reinforced steel is permitted in exceptional and justified cases and requires prior coordination with the client. In such case, evidence must be provided in accordance with DIN EN ISO 17660.

(261) With the exception of multi-layer reinforcement and overlapping joints, the horizontal and vertical clear bar spacing may not be less than 3 d_g (d_g = maximum particle diameter) as a general rule.

(262) Spacers to adjacent surfaces (e.g. formwork, under-concrete, pit construction) must be made of cement-bound mortar or concrete. Their characteristics must be at least equivalent to those of the surrounding concrete.

(263) Spacers must be arranged in sufficient numbers (at least 4 units per m^2) and selected so that they do not press into the formwork and allow the concrete to be properly installed and compacted. Rod-shaped concrete spacers must be installed vertically on vertical concrete surfaces.

(264) Minimum dimension c_{min} and nominal dimension c_{nom} of the concrete cover are to be selected in accordance with Section 1.3.2.

(265) For additional reinforcement, a minimum c_{min} of the concrete cover of 20 mm relative to the concrete substrate must be maintained.

3.5.4 Concreting

3.5.4.1 General

(266) Concrete whose consistency is outside the range defined by the target value and class limits, concrete with a non-standard air entrainment content and concrete with fresh concrete temperatures above 28°C may not be accepted.

(267) Steel waste, formwork residues, etc. must be completely removed from the formwork before concrete installation.

(268) Formwork, reinforcement, connection surfaces and fittings must be inspected by the contractor for each concreting section. A record must be made of the result. The record is to be handed over to the client.

(269) A bonding layer must be applied to horizontal concrete substrates, provided that the design of the reinforcement so permits.

(270) The concrete substrate must be sufficiently pre-wetted (at least 24 hours in advance for the first time) before the concrete is installed (if a bonding layer is used before its application). During concrete installation (when using a bonding layer prior to its application), the concrete substrate must have dried out sufficiently that there is no water film and the concrete substrate appears matte damp.

(271) When using a bonding layer, the concrete must be installed on the bonding layer while it is still fresh.

3.5.4.2 Transportation of concrete

(272) Truck mixers or vehicles with agitators must be completely unloaded within no more than 90 minutes; vehicles without mixers or agitators for the transport of concrete with a stiff consistency must be completely unloaded within no more than 45 minutes after water is first added to the cement.

3.5.4.3 Temperature of the concrete at the installation site

(273) The fresh concrete temperature $T_{concrete}$ at the installation point may not exceed + 28 °C.

3.5.4.4 Construction joints

(274) The arrangement of the construction joints (including all sealing elements) is to be presented in plans and submitted to the client with the concreting concept for prior coordination. The construction of the construction joints (post-treatment, preparation, type and number of sealing elements, impact formation of sealing elements, cleaning options, accessibility) must be described in detail in the concreting concept and in the execution plans.

(275) Construction joints must be made impermeable to water.

(276) The use of surface delayers in construction joints is not permitted.

(277) The coarse grain structure of the concrete must be exposed in the connection surfaces in order to achieve sufficient bonding. Roughness and surface quality

- of non-formed construction joints must fulfil the requirements of the ‘interlocked’ category as per DIN EN 1992-1-1, Section 6.2.5, in the entire construction joint area, including the subsequent concrete cover immediately before the concrete is installed. Assignment to the category ‘interlocked’ requires an average roughness depth according to the Kaufmann sand patch test $R_t \geq 3.0$ mm or a maximum profile height $R_p \geq 2.2$ mm or at least 6 mm exposure of the aggregate when using a aggregate with $d_g \geq 16$ mm.
- of formed construction joints must meet the requirements of category ‘rough’ as per DIN EN 1992-1-1, Section 6.2.5, in the entire construction joint area, including the subsequent concrete cover immediately before the concrete is installed. Assignment to the ‘rough’ category requires an average roughness depth according to the Kaufmann sand patch test $R_t \geq 1.5$ mm or a maximum profile crest height $R_p \geq 1.1$ mm or at least 3 mm exposure of the aggregates.

(278) The concrete in the area of the construction joints must be compacted with particular care. After completion of the compaction or surface treatment of the concrete, the surface must be immediately treated in accordance with Section 3.5.4.6.

(279) If expanded metal is used, it must be completely removed from the construction joint before the concrete for the next concreting section is installed. The construction joint shall then be pre-treated so that it meets the requirements of (277) for non-formed construction joints.

(280) Unless the specification of works provides otherwise, sealing elements (metal waterstops or elastomer waterstops) must be used in facing formwork in accordance with Section 3.3.2 to ensure the watertightness of construction joints in addition to the design in accordance with (277) to (279).

(281) Joint sheets and waterstops must each integrate into the concrete at half width on both sides of the construction joint. Construction joint waterstops and sheets must be joined watertight by welding at the intersections with each other and, if necessary, with expansion joint waterstops and at joints. Joints of elastomer waterstops may only be joined by means of vulcanisation. Overlaps in the joint area of metal waterstops must be sealed watertight all the way around. Metal waterstops must be made of sheet metal at least 2 mm thick. The width of the metal waterstops must be at least 300 mm. Elastomer waterstops in accordance with DIN 7865 with steel straps should be used as construction joint waterstops.

(282) If injection hoses are used, DBV-Injektionsschlauch applies. The injection hoses must be compressed with cement suspension in accordance with Section 8 unless otherwise specified in the specification of works. Acrylate gels are not permitted as fillers. The time of grouting must be agreed upon with the client. The installation areas for the injection hoses are to be made with a width of approx. 5 cm, preferably with a smooth surface (average roughness depth R_t < 1.5 mm). The installation areas must be protected if the construction joints are prepared to produce higher roughness.

(283) The surface of the previous concreting section must be clean and free of standing water prior to concrete installation. Sections 2.2.2 and 3.5.4.1 apply accordingly to the preparation of joints.

(284) In addition to (111), concreting of connecting sections may only begin after the collective determination of condition in accordance with VOB/B § 4(10).

(285) If connecting mixes are used for concreting connection sections for horizontal construction joints in wall or disc-type components, the respective largest particle group must be left out of the ongoing mix. In this case, an additional initial test for the connecting mix is not required. If a maximum particle size of more than 16 mm is used, a connecting mix must be provided.

3.5.4.5 Insertion, compaction, surface treatment

(286) The concrete must be placed fresh in freshly in equally thick horizontal layers, and the thickness of each layer may not exceed 0.5 m as a general rule.

(287) The fresh concrete is usually to be compacted with internal vibrators. The use of external smelters is permitted only after prior consultation with the client.

(288) Distributing the concrete with internal vibrators or by vibrating the formwork is not permitted.

(289) The concrete may need to be recompacted, especially in the case of soft concrete, delayed concrete, rapid concreting progress and densely reinforced, high components.

(290) If surface treatment is provided, the concrete must be recompressed beforehand.

(291) In the case of larger time intervals between the individual concreting layers, temporary post-treatment measures must be carried out in accordance with Section 3.5.4.6.

(292) Unless the specification of works provides otherwise, a representative of the contractor with proven extensive training in concrete technology (known as an ‘E-certificate’) must be present on the construction site during the concreting work and must assume responsibility in supervising the concrete installation process.

3.5.4.6 Post-treatment and protection

(293) Post-treatment methods other than those in DIN 1045-3, Section 9.6, are only permitted if agreed upon in the specification of works.

(294) The application of post-treatment products must be agreed upon with the client in good time prior to use. The suitability of the post-treatment agents and their compatibility with the substrate (release agents) must be demonstrated.

The post-treatment agent must be applied in two coats (two layers) in a criss-cross pattern. Application must be carried out on predominantly vertical surfaces by rolling. Post-treatment agents are not permitted in construction joints and indoor spaces.

(295) Determination of the duration of post-treatment in accordance with DIN 1045-3, Section 9.6, is not permitted. Table 3 .13 is used to determine the duration of post-treatment:

Table 3.13: Minimum duration of post-treatment of concrete

Strength development of concrete [c] $r = f_{cm2} / f_{cmx}$ (x = 28, 56, 91) [d]			
$r \geq 0.50$ (quick)	$r \geq 0.30$ (medium)	$r \geq 0.15$ (slow)	$r < 0.15$ (very slow)
Minimum duration of total post-treatment in days [a], [b], [e]			
4	10	14	21
Of which minimum duration of retention in the formwork for formed concrete surfaces [b]			
2	5	7	10

a) If processing time exceeds 5 hours, the post-treatment period must be extended appropriately.
b) At temperatures below 5 °C, the post-treatment period is to be extended by the time during which the temperature was below 5 °C.
c) The strength development of the concrete is described by the ratio of the mean values of the compressive strengths f_{cm2} / f_{cmx} (x = 28, 56, 91) determined in the initial test.
d) Interim values for the post-treatment period may be shuttered.
e) For concrete surfaces subject to wear according to exposure classes XM2 and XM3, the minimum duration of the overall post-treatment process must be doubled. The maximum value of the minimum duration is 30 days.

If water-repellent formwork liners are used, the minimum duration of the total post-treatment may be reduced to the minimum duration of retention in the formwork.

(296) The measures for the post-treatment and protection of the concrete may only be started when the concrete has hardened sufficiently that its surface can no longer be adversely altered. However, a change in brightness of the concrete surface in question from dark to light as a result of drying out must not occur at any time.

(297) For layer thicknesses < 150 mm, water-feeding post-treatment measures must be carried out on exposed surfaces that are not shuttered for at least the first 3 days.

(298) For subgrade concrete, thermal insulation of the component surfaces may not be carried out for the ‘fresh-on-hardened’ design variant, provided that the risk of the concrete freezing through can be ruled out. In both execution variants, the top surface of the subgrade concrete must be protected from evaporation immediately after concreting has been completed. In order to reduce the warming due to solar radiation, the surface of the subgrade concrete must be covered with a light or reflective film.

3.5.5 Expansion joints

(299) Samples of expansion joint tapes, including the factory joint if applicable, test certificates (acceptance test certificate as per DIN 7865-5 with tests as per DIN 7865-2, Table 1, 6.2 to 6.8, and 6.9 to 6.12 on an object-specific basis where applicable) and information on the material composition with details of the base polymer as per DIN 7865-3 must be submitted to the client for a control test 6 weeks prior to installation and coordinated with him/her. An excess length of 0.4 m must be planned for the inspection test for each type of joint tape used in accordance with DIN 7865-1. Sampling for control tests must be carried out in the presence of the client and must be documented by the contractor. DIN 18197 applies to the connection of waterstops.

Site documentation as per DIN 18197, Annex B, proof of qualification as per DIN 18197, Annex C and testing records as per DIN 18197, Annex E, must be submitted to the client. BAW-MAB must be taken into account for the planning and execution of expansion joints.

3.6 Quality assurance

3.6.1 Building materials and building material systems

(300) The contractor must provide the client with the results of the monitoring of the raw materials by the approved inspection bodies without delay, including the results of factory production control in the case of aggregate.

(301) The contractor must provide the following tests and proofs as part of initial testing. The provisions in (205) apply to the time of proof.
For all concretes:

- Visual assessment of the characteristics of the fresh concrete (water separation, cohesion, flow behaviour, settling behaviour, etc.)
- Fresh concrete temperature
- Fresh concrete consistency
- Fresh concrete bulk density as per DIN EN 12350-6 (for the production of test specimens hardened concrete tests)
- Compressive strength (including strength development r as per DIN EN 13670, 8.5) at the ages of 2, 7 and 28 days (if the compressive strength class is verified at a greater age, then additionally at this age as well) on 3 specimens each as per DIN EN 12390-3
- Water penetration resistance at the age of 28 days.

In addition for the following concretes and exposure classes:

- for delayed concrete: Stiffening behaviour for air-entrained concrete: Air content in fresh concrete under boundary conditions comparable to those at the installation site
- for facing formwork with thicknesses $\geq$ 300 mm: adiabatic temperature rise of the concrete as per BAW-MATB in accordance with (188)
- for XS2 and XS3: Chloride penetration resistance as per BAW-MDCC if required by BAW-MBM
- for XD2 and XD3: Chloride penetration resistance as per BAW-MDCC if required by (193)
- for XF3: Frost resistance as per BAW-MFB
- for XF4: Resistance to frost and de-icing salt as per BAW-MFB.

3.6.2 Execution and testing of the finished service

(302) The quality of execution is to be ensured in accordance with Section 1.6.1.3 in conjunction with DIN 1045-3. Unless otherwise specified in the specification of works, repairs with concrete must be classified in execution class AK-S. All requirements of execution class

AK-E must be complied with. In addition to DIN 1045-3, Section 5, the services specified in (303) to (316) are to be provided by the executing company.

(303) The decisive factor for the proof of the contractually agreed concrete properties is that the fresh concrete at the installation point and the hardened concrete in the component have the properties agreed upon.

(304) The principle of the concrete families under the conditions set out in DIN 1045-3, Annex B.1 (3) may not be applied.

(305) The tests required by ZTV-W LB 219 for the monitoring of concrete must be carried out on each concrete.

(306) In addition to DIN 1045-3, Table B.1, the following minimum test frequencies apply when the concrete is handed over from the ready-mixed concrete manufacturer to the contractor per supplier:

- The consistency is to be checked for each vehicle.
- The w/c ratio is to be checked for the first two vehicles and then for every tenth vehicle thereafter, as well as in case of doubt. For this purpose, the effective water content is to be determined in accordance with Annex 3. The cement and additive content must be taken from the actual specifications on the delivery note. The air porosity measuring pot is to be used to determine the bulk density of fresh concrete. If the core moisture content of the aggregate (water absorption in accordance with DIN EN 1097-6) is to be taken into account, its size must be demonstrated during the initial assessment by means of a valid test certificate from the aggregate supplier.
- In the case of concrete with minimum air content requirements, the consistency and air content of the concrete of each vehicle must be checked.

(307) The following tests must be carried out at the installation site, documented and provided to the client:

- In the case of concrete with minimum air content requirements, the consistency and air content of the fresh concrete must also be checked directly at the installation site in order to demonstrate the processing properties and the stability of the air pores. For this purpose, the concrete of the first 10 delivery vehicles and then the concrete of every tenth delivery vehicle (albeit at least once per day of concreting) must be tested for each concreting section.
- Unless otherwise agreed upon in the specification of works, a minimum of 3 test blocks shall be manufactured and tested for a maximum of 50 m^3 each or per day of concreting, depending on the requirement giving the largest number of samples, unless otherwise agreed upon in the specification of works. DIN 1045-3, Annex B, Table B.1, must be observed for sampling. Compressive strength testing is to be performed in accordance with DIN EN 12390-3.
- For testing the water penetration depth (testing only at w/c ratio > 0.55), at least 1 test specimen must be manufactured and tested for a maximum of 50 m^3 each or each day of concreting, whichever requirement results in the largest number of samples, unless otherwise agreed upon in the specification of works. DIN 1045-3, Annex B must be observed for sampling.
- For concrete with requirements for resistance to frost and de-icing salt XF4, the test according to BAW-MFB must be carried out at least once during the construction period, in prior consultation with the client, unless otherwise agreed upon in the specification of works. The samples must be taken directly at the installation site.

(308) For the fresh concrete properties at the transfer point, the contractor must define retention dimensions that factor in changes in the fresh concrete properties between the transfer point and the installation point.

(309) If the above-mentioned tests on fresh concrete do not produce sufficient values, the concrete of this delivery must be rejected or may not be installed.

(310) If there are any doubts as to the uniformity of the concrete structure in accordance with DIN 1045-3, 9.5 (8), appropriate tests on cores from the component under consideration are to be carried out at an early stage during construction, in accordance with BAW-MESB Section 4.3. The number and sampling points of the cores are to be determined by the client on a project-specific basis. The contractor must be involved in the selection of sampling points in order to avoid damage caused by core sampling. The cores must be removed by the contractor in the presence of the client, marked and examined on behalf of the contractor by a laboratory to be agreed upon with the client. The boreholes must be sealed by the contractor in accordance with best practice. The samples must be retained for any subsequent inspections until the facts have been finally clarified.

(311) The functional check of the technical equipment in accordance with DIN 1045-3, Table B.1, lines 9 and 10, must be carried out at least every fifth day of concreting and must be documented.

(312) For on-site mixed concrete transported by ready-mixed concrete vehicles, the regulations for ready-mixed concrete apply analogously. In the case of transportable concrete and on-site mixed concrete transported by other means, rules ensuring a comparable level of quality must be drawn up and agreed upon with the client.

(313) In addition to DIN 1045-3, B.2, the following applies: Concretes with the same constituent materials, the same w/c ratio but other maximum particle size are not considered to be a concrete.

(314) In addition to DIN 1045-3, B.2 (7), the following applies: If proof as per DIN 1045-3, B.2 (7) cannot be provided, the client must be informed without delay. The use of non-destructive testing methods (e.g. rebound hammer) is not permitted.

(315) In addition to DIN 1045-3, Annex C: A compilation and evaluation, including statistics, of the tests carried out must be submitted to the client in good time upon completion of the concrete works of the concrete section in question or upon special request.

(316) In addition to DIN 1045-3, C.2, the following applies: All documents (e.g. concreting log, overview of results) must be kept separately for each concrete.

4 Shotcrete (anchored, reinforced)

4.1 General

(317) This section applies to repair measures with shotcrete applied in thicknesses of 90 mm or more.

(318) DIN EN 14487-1 and DIN EN 14487-2 in conjunction with DIN 18551 shall apply, unless otherwise specified in ZTV-W LB 219.

4.2 Scope of application

(319) Repairs may be carried out with shotcrete, provided that the shotcrete is suitable for the exposure classes assigned to the component.

4.3 Construction principles

4.3.1 General

(320) The concrete replacement must be reinforced and connected to the concrete substrate by anchoring elements in order to ensure the bond.

(321) The layer thicknesses specified in the specification of works are minimum layer thicknesses.

(322) Unless otherwise agreed upon in the specification of works, the specified layer thicknesses (with the exception of deeper local cavities and unevenness caused by removal) may not be exceeded by more than 20 mm.

(323) The maximum particle diameter of the shotcrete
- must lie within the range of 8 to 16 mm
- may not exceed one third of the thickness of the respective spraying layer
- must be selected to be as large as possible
- may not exceed 8 mm in the courses in which the reinforcement is enclosed
- may also be 4 mm in the final spraying layer, as long as its thickness does not exceed an average of 20 mm.

(324) Rebound may not be reused in the production of shotcrete under any circumstances.

(325) The surface of the shotcrete shall be left sprayed rough. If a smooth or specially structured surface is required in the specification of works, a sprayed mortar in accordance with DIN EN 14487/DIN 18551 or Section 5 is to be applied in a separate operation after hardening the shotcrete and processed accordingly. This additional layer applied must meet the same durability requirements as the shotcrete layer and may be taken into account in the overall layer thickness.

4.3.2 Facing formwork for lock chamber walls and similar components

(326) According to DIN EN 1992-1-1, adhesion bonding between the repair system and the old concrete may not be applied to wide-area structural elements with loading that is not predominantly static as per DIN 19702.

(327) Unless otherwise agreed upon in the specification of works, for components for which a water pressure can be set behind the repair system, the maximum possible internal water pressure (crack and pore water pressure) must be set between the concrete substrate and the repair system in accordance with DIN 19702.

(328) In the case of facing formwork with loading that is not predominantly static (326), or where an internal water pressure between the concrete substrate and the facing formwork is to be applied (327), the reinforcement is to be arranged on both sides.

(329) The minimum thickness of the facing formwork with reinforcement on both sides is 160 mm.

(330) The shotcrete facing formwork must be dimensioned as a directly loaded component and as part of the overall structure for all relevant effects. This includes the verification of the

anchoring, the dimensioning of the reinforcement in the shotcrete layer and, if necessary, verification of the shearing force transmission in the joint between the shotcrete and the concrete substrate, as well as verification of the crack width limitation. In order to be able to use each anchor as a test anchor, it must be taken into account that the anchor rods must be able to withstand at least $F_{Prüf}$ in accordance with Annex 2.

(331) A minimum reinforcement must be installed in the shotcrete facing formwork to limit cracking due to pressure from temperature, shrinkage and other influences. Unless otherwise agreed upon in the specification of works, the permissible characteristic crack width is w_k = 0.25 mm. In the absence of more detailed examinations, the minimum reinforcement for centric constraint is to be determined in accordance with DIN EN 1992-1-1/DIN EN 1992-1-1/NA, Section 7.3.2. If the reinforcement is arranged on both sides, two thirds of the reinforcement determined this way is to be arranged on the front side of the shell and one third on the rear side of the shell facing the concrete substrate.

(332) If the strength properties of the concrete substrate can be assigned to at least one strength class C12/15 according to DIN 1045-2 at the time of repair, the anchor system for anchoring the shotcrete layer can be selected freely, provided that the absorption of the anchor forces can be mathematically verified. If the concrete substrate has lower strengths, only bar anchors with composite or bonded anchors may be used. All anchor systems must be demonstrably durable under exposure to water.

(333) The moisture condition in the borehole must be taken into account when selecting the filling material for the anchors.

(334) The anchor boreholes must be cleaned and cleared of loose parts before the anchors are placed. When filling with cement mortar, the borehole axis should be horizontally inclined by at least 15° so that the borehole can be safely filled with mortar.

4.4 Building materials and building material systems

4.4.1 General

(335) The backfill material for anchor systems must be suitable for the given effects and permanently water-resistant. It may consist of:

- Cement mortar (mortar according to the RL Trockenbeton [Dry Concrete] guideline or grouting mortar according to the RL Vergussbeton [Grouting Concrete] guideline),
- Mortar systems with building inspectorate certificate of usability for post-installed reinforcement connections.

(336) Anchor bars for anchor systems shall consist of:

- reinforcing steel as per DIN 488,
- standardised threaded rods or ones with building inspectorate approval, or
- standardised structural steel or structural steel with building inspectorate approval.

(337) The requirements profile applicable to the shotcrete is derived from DIN EN 14487/DIN 18551 in conjunction with DIN 1045-2 and the additional requirements below. The requirements for all exposure classes assigned to the component in accordance with Table 0 .2 must be complied with.

4.4.2 Concrete constituents and composition

(338) For non-standardised constituents, general building inspectorate approvals or European technical assessments must be submitted to the client. The use of such materials requires the client's written consent.

(339) Unless agreed upon otherwise in the specification of works, the following cements may be used in accordance with DIN EN 197-1, DIN 1164-10 and DIN 1164-11 in accordance with the specifications of DIN 1045-2, Tables F.3 and F.4:

- CEM I
- CEM II/A-S, CEM II/B-S
- CEM II/A-D
- CEM II/A-P, CEM II/B-P
- CEM II/A-V, CEM II/B-V
- CEM II/A-T, CEM II/B-T
- CEM II/A-LL
- CEM II/A-M (S-D), CEM II/A-M (S-T), CEM II/A-M (S-LL), CEM II/A-M (D-T), CEM II/A-M (D-LL), CEM II/A-M (T-LL)
- CEM II/A-M (S-V), CEM II/A-M (V-T), CEM II/A-M (V-LL)
- CEM II/A-M (S-P), CEM II/A-M (S-Q), CEM II/A-M (D-P)
- CEM II/A-M (D-V), CEM II/A-M (D-Q), CEM II/A-M (P-V)
- CEM II/A-M (P-T), CEM II/A-M (P-Q), CEM II/A-M (P-LL), CEM II/A-M (Q-V), CEM II/A-M (Q-T), CEM II/A-M (Q-LL)
- CEM II/B-M (S-D), CEM II/B-M (S-T), CEM II/B-M (D-T)
- CEM II/B-M (S-LL)[6], CEM II/B-M (V-LL)[7], CEM II/B-M (T-LL)[7]
- CEM III/A, CEM III/B.

(340) If fast-setting cements as per DIN 1164-11 are used, a separate proof of suitability must be provided to determine suitability for spraying in accordance with RL SIB Part 4, Section 3.6.4.11. The total flaw length may not exceed 120 mm.

(341) Only industrially produced aggregates in accordance with DIN 1045-2, 5.1.3 (2) may be used; for components in exposure classes XM, XF3 and XF4, the use of industrially produced aggregates is not permitted.

(342) The use of industrially produced light aggregate, recycled coated and recovered crushed aggregate is not permitted.

(343) Recycled type 1 aggregate may be used for the production and processing of concrete up to compressive strength class C30/37. A maximum of 25% of the coarse aggregate by volume (based on the total aggregate) may be replaced. Type 2 recycled aggregate and fine recycled aggregate are not permitted. The use of recycled aggregate in exposure classes XF3, XF4, XA2, XA3, XD3, XS3 and XM is not permitted. Recycled aggregate may only be used for components with predominantly static loads in accordance with DIN 19702, 5.3.2.4, for components which are not sensitive to deformation or for components with which creep behaviour can be neglected. In the case of components with moisture class WA, recycled aggregates are only permitted if they are classified in the alkali sensitivity class E I-S in accordance with Annex B.3 of the DAfStb guideline 'Alkali Reaction in Concrete' (RL AKR).

(344) For the use of aggregates in concrete, the following requirements must be complied with in addition to those of DIN 1045-2, Annex E.2, Table E.1:

- Naturally composed (unprepared) aggregate in accordance with DIN EN 12620 may not be used.

[6] *For CEM II/B-M cements, the permitted limestone content is limited to 20% by weight (DIN 1045-2, Table F.4, footnote [e])*

- The grain composition of the coarse aggregate must be narrowly graded.
- The grain shape of coarse aggregates must at least correspond to category FI35 or SI40 for crushed grain.
- The resistance to crushing of aggregates from crushed rock must be at least category LA50 or category SZ32.
- The proportion of lightweight organic impurities may not exceed 0.25% by mass for fine aggregates and 0.05% by mass for coarse aggregates.
- Mixtures of grain may not be used unless otherwise agreed upon in the specification of works.

(345) Unless provided for otherwise in the specification of works, the proof of frost resistance or resistance to frost and de-icing salt of the aggregates in accordance with DIN 1045-2, Annex E.2, Table E.1, may not be older than 6 months at any time during the construction process.

(346) Only aggregates of category F1 according to DIN EN 12620 may be used for exposure class XF3.

(347) The grading curve of the aggregate in the base mix should be in range 3 according to DIN 1045-2, Annex Q, Fig. Q.1 or Q.2.

(348) In the case of a maximum particle size $D \leq 8$ mm, the requirements for the minimum cement content in accordance with DIN 1045-2 must be increased by 30 kg/m³.

(349) The use of concrete additives and concrete admixtures requires prior coordination with the client.

(350) Unless agreed upon otherwise in the specification of works, the contractor must submit all necessary test certificates, test reports and evidence to the client for approval at least 2 weeks prior to the start of the suitability test.

4.4.3 Requirements for the hardened concrete

(351) Unless otherwise agreed upon in the specification of works, all hardened concrete properties (e.g. compressive strength class, water penetration depth, resistance to frost and de-icing salt) must be demonstrated at the age of 28 days.

(352) To assess the tendency of the shotcrete to crack, the impeded shrinkage must be tested in accordance with Annex 4. The test is deemed to have been passed if there are no large-scale detachments from the substrate after 28 days and the crack width does not exceed 0.1 mm.

(353) For shotcretes of exposure classes XF3 and XF4, the resistance to frost and de-icing salt is to be demonstrated in accordance with BAW-MFB. The acceptance criteria according to BAW-MFB must be complied with.

(354) The shotcrete must have a high water penetration resistance according to DIN 1045-2. When tested in accordance with DIN EN 12390-8, the water penetration depth may not exceed 30 mm.

(355) For shotcretes of exposure classes XD2 and XD3, a durability assessment must be carried out in accordance with BAW-MDCC (e.g. for transshipment quays in inland ports, components with a chloride load from flowing waters, dam-regulated waters or groundwater with a chloride content of over 2,000 mg/l).
A BAW-MDCC assessment may be dispensed with in the following cases:
- For components with a scheduled useful life of up to 50 years, provided that the following binders are used:

- CEM I and CEM II cements after (339) in combination with fly ash as a concrete additive, in which the attributable fly ash content must be at least 20% by weight of (c+f).
- CEM I and CEM II cements after (339) in combination with silica dust as a concrete additive, in which the attributable silica dust content must be at least 8% by weight of (c+s).
- CEM III/A in combination with fly ash as a concrete additive, in which the attributable fly ash content must be at least 10% by weight of (c+f).
- CEM III/B.

– In the case of components in the area of influence of road structures (e.g. lock cabins or weir piers under road bridges) regardless of the useful life, provided that the aforementioned binders are used.

(356) The BAW-MBM also applies to components in the area of influence of seawater and coastal areas as well as estuaries with exposure classes XS2 and XS3.

4.4.4 Definition of concrete

(357) The contractor must carry out a suitability test in accordance with DIN EN 14487-1 / DIN 18551, Section 7.3, prior to the start of construction work. The additional characteristics required in Sections 4.4 and 4.6 and in the specification of works (if applicable) must also be demonstrated in this suitability test. The proofs must be submitted to the client.

(358) All influences relevant to the concrete (climatic boundary conditions, transport, conveying, processing, post-treatment, etc.) must be taken into account when carrying out the suitability test.

(359) It is not permitted to dispense with such a suitability test, even if there is long-term experience on hand for similar shotcrete equipment and the same personnel. The suitability test may not be have been performed more than 12 months prior to the start of concrete installation.

(360) In addition to DIN 14487-1 / DIN 18851, the contractor is obliged to carry out new suitability tests if the constituent materials of the shotcrete (type, manufacturer, place of extraction), composition, spraying equipment or the conditions on the construction site are to be changed.

(361) The client must be informed of the start of the suitability tests in good time. The client reserves the right to take part in the contractor’s suitability tests.

(362) The execution of the shotcrete work may only commence after a successful suitability test has been passed and upon prior coordination with the client.

4.5 Construction work

4.5.1 General

(363) Unless otherwise agreed upon in the specification of works, a concreting concept must be submitted to the client for approval at least 4 weeks prior to initial shotcrete installation and a concreting plan at least 3 work days prior to each shotcrete installation. Concreting concept and concreting plan are parts of the quality assurance plan as per Section 1.5.1.

(364) The concreting concept must contain at least the following specifications:

- Results of the suitability test (compressive strength, obstructed shrinkage, water penetration resistance, chloride penetration resistance, resistance to frost and de-icing salt)
- Composition of the base mixture and details of the delivery form (ready-mixed concrete or factory-mixed fresh mortar, factory-mixed dry products, on-site mixed concrete)
- Control of constituent materials (reports from recognised monitoring bodies, in the case of aggregates: factory production control documents as well)
- Spraying method
- Spraying equipment, machines and equipment
- List of components (type of components, exposure classes, structural and construction requirements)
- Anchoring, arrangement and fastening of reinforcement to be installed
- Measures required in the area of built-in parts
- Sealing elements (type, number, installation site, positional stability, protection during the construction process, joint formations, etc.)
- Formation of edges and boundaries (formwork, etc.)
- Number, thickness, time sequence and post-treatment of the individual spraying layers

- Measures to maintain the planned layer thicknesses
- Formation of the concrete replacement system surface
- Disposal of rebound
- Monitoring concrete production and shotcrete processing, concrete tests.

(365) The delivery note must contain at least the following information:
- Component plan (further detailing of the information in accordance with the concreting concept/component list)
- Installation quantities, installation times
- Suppliers (ready-mixed concrete or factory-mixed fresh mortar, factory-mixed dry products)
- Personnel plan, nozzle operator
- Monitoring of concrete production (test plan to demonstrate conformity of the base mixture, fresh concrete and hardened shotcrete with indication of the scope and frequency of testing)
- Production of construction joints for subsequent concreting sections
- Production of edges and boundaries (formwork, etc.)
- Preparation of the application surfaces (concrete substrate, hardened spraying layers)
- Type and time of construction joint processing
- Requirements for concrete surfaces, surface treatment
- Production of joint seals
- Post-treatment plan (type, duration, time and date, documentation)
- Protective measures for adjacent work sections and components
- Consideration of weathering influences, weather-related protective measures
- Measures in case of incidents (e.g. failure of supply plants, spraying equipment, dosing equipment).

4.5.2 Personnel

(366) Only nozzle operators who have successfully passed an examination[7] recognised by the client may be used. The certificate must be submitted before the start of execution.

4.5.3 Substrate preparation

(367) Suitable measures must be taken to ensure that pre-prepared surfaces and installed reinforcement are not re-contaminated before the shotcrete is applied. This applies with regard to influences from spraying work in adjacent work sections in particular.

(368) The surfaces of hardened spraying layers (not fresh in fresh) must be prepared in accordance with Section 2.2.2 before another spraying layer is applied.

4.5.4 Construction joints

(369) Construction joints must be made impermeable to water.

(370) (368) applies with regard to the preparation of construction joints.

(371) For facing formwork reinforced on both sides as per Section 4.3.2, additional injections may be required to ensure water impermeability around the construction joints. These injections should be carried out using packers, since there is a risk of damage to injection hoses during injection. Unless otherwise specified in the specification of works, the injection must be carried

[7] *Proof of the nozzle operator's qualification may be rendered by a certificate of the 'Protection and repair of concrete structures' training advisory board issued by Beton- und Bautechnik-Verein E.V. [German Concrete and Construction Technology Association] (known as a 'nozzle operator licence') or equivalent certificates of qualification.*

out with cement suspension in accordance with Section 8. Acrylate gels are not permitted as fillers. The injections must be agreed upon with the client.

4.5.5 Reinforcement

(372) The installation of any planned anchoring elements and reinforcement may only commence once the results of the pull-off tests have been submitted in accordance with Table 2 .11 and after prior consultation with the client.

(373) For additionally reinforcement laid, the minimum distance to the concrete substrate must be 20 mm.

(374) Minimum dimension c_{min} and nominal dimension c_{nom} of the concrete cover are to be selected in accordance with Section 1.3.2.

4.5.6 Layer thickness

(375) Suitable aids or constructions must be used to maintain the specified layer thicknesses.

(376) If setting jigs are anchored in the application surfaces to maintain the coating thickness, they must be removed after the spraying work has been completed. Defects and recesses must be completely closed fresh in fresh using the same shotcrete so that the required properties are also present in these areas. Remaining steel or concrete parts must end at least 50 mm below the shotcrete surface.

4.5.7 Shotcrete application

(377) The application areas must be pre-moistened sufficiently (at least 24 hours in advance) before the shotcrete is applied. However, the application surfaces must have dried sufficiently by the beginning of the spraying work that they appear matte damp.

(378) The application of the shotcrete may only be commenced once the contractor has checked the application areas and after prior consultation with the client.

(379) The temperature of the base mixture (dry mixture) and the fresh concrete temperature (wet mixture) when applied at the installation site may not exceed a maximum of + 28 ˚C.

(380) If there will be long intervals between the individual spraying layers, temporary post-treatment measures must be carried out in accordance with Section 4.5.8.

4.5.8 Post-treatment and protection

(381) The measures for the post-treatment and protection of the shotcrete may only be commenced after the last spraying layer of a work section has been applied until the shotcrete has hardened sufficiently that its surface can no longer be adversely altered. However, a change in brightness of the shotcrete surface in question from dark to light as a result of drying out must not occur at any time.

(382) The post-treatment period is at least 7 days, in which water-feeding post-treatment measures must be carried out during the first 3 days.

4.5.9 Expansion joints

(383) Samples of expansion joint tapes, including the factory joint if applicable, test certificates (acceptance test certificate as per DIN 7865-5 with tests as per DIN 7865-2, Table 1, 6.2 to 6.8, and 6.9 to 6.12 on an object-specific basis where applicable) and information on the material composition with details of the base polymer as per DIN 7865-3 must be submitted to the client for a control test 6 weeks prior to installation and coordinated with him/her.

An excess length of 0.4 m must be planned for the inspection test for each type of joint tape used in accordance with DIN 7865-1. Sampling for control tests must be carried out in the presence of the client and must be documented by the contractor. DIN 18197 applies to the connection of waterstops. Site documentation in accordance with DIN 18197, Annex B, proof of qualification in accordance with DIN 18197, Annex C, and testing records in accordance with DIN 18197, Annex E, must be submitted to the client. BAW-MAB must be taken into account for the planning and execution of expansion joints.

4.6 Quality assurance

4.6.1 Building materials and building material systems

(384) The contractor must provide the client with the results of the monitoring of the raw materials by the approved inspection bodies without delay, including the results of factory production control in the case of aggregate.

(385) The contractor must provide the following tests and evidence as part of the suitability test. The test standards of the DIN EN 14488 series in addition to the specifications in Section 4.4.3 must be observed for the tests on shotcrete. The provisions in (351) apply to the time of proof.

Base mixture:
- Fresh concrete temperature
- Consistency (for wet shotcrete only).

Fresh shotcrete:
- Density
- Water content
- Fibre content (for fibre-reinforced shotcrete only).

Hardened shotcrete (all exposure classes):
- Density at 20°C and 65% RH.
- Compressive strength
- Static modulus of elasticity
- Water penetration resistance
- Inhibited shrinkage.

Hardened shotcrete (concretes and exposure classes listed below):
- for fibre-reinforced shotcrete: Initial tensile strength, flexural tensile strength, residual strength or energy absorption capacity
- for XS2 and XS3: Chloride penetration resistance as per BAW-MDCC if required in BAW-MBM
- for XD2 and XD3: Chloride intrusion resistance as per BAW-MDCC if required in (355)
- for XF3: Frost resistance as per BAW-MFB
- for XF4: Resistance to frost and de-icing salt as per BAW-MFB.

(386) When using factory-manufactured base mixtures, the contractor must ensure, in accordance with VOB/B § 4(1)(2), that the client is able to obtain information from the manufacturer at any time by submitting documents on the factory production control, the composition of the base mixture and the control by a recognised monitoring body, and is able to

convince himself/herself of the performance and reliability of the manufacturer by visiting the production facilities, as well as to extract materials for additional control tests by the client.

4.6.2 Execution and testing of the work performed

(387) The quality of execution and work performed shall be ensured in accordance with Section 1.6.1.3 in conjunction with DIN EN 14487-2/DIN 18551. Monitoring category 3 applies. In addition, the contractor is to render the services under (388) to (395).

Quality of anchoring

(388) The binding depths and anchor lengths must be checked or determined before the start of drilling and anchoring work on the basis of pull-out tests on site in accordance with Annex 2 (suitability test). The number of tests depends on the size of the construction project, the potential risk of anchor failure during operation and the strength conditions in the old concrete. Unless otherwise agreed upon in the specification of works, at least 5 test anchors are to be executed.

(389) The contractor must carry out tests in accordance with Annex 2 in the presence of the client in order to check the performance quality of the anchor installation. The selection of the anchors to be tested must be representative of the component and be determined after completion of the anchor work in prior agreement between the client and contractor. Unless otherwise agreed upon in the specification of works, 2% of all required anchors, albeit no fewer than 5 units per component, must be tested in accordance with Annex 2. If there are general building inspectorate or European technical approvals for the chosen anchor system containing test requirements that are stricter, these must also be met. The sampled test anchors can be used as structural anchors after successful anchor testing.

Shotcrete quality

(390) DIN EN 14487-1 / DIN 18551, Section 7 shall apply for the scope and frequency of the tests to be carried out as part of the conformity and production control, unless agreed upon otherwise in (391) to (395). Monitoring category 3 applies.

(391) Unless otherwise agreed upon in the specification of works, specimens are t be taken from separately manufactured slabs in accordance with DIN EN 14488-1 for the verification of compressive strength, resistance to frost and de-icing salt and water penetration resistance. Only one specimen may be taken from each plate per test objective.

(392) The compressive strength test as per DIN EN 12390-3 is carried out on series of at least 5 test specimens per 250 m² of installation area.

(393) Unless otherwise agreed upon in the specification of works, tests to verify the resistance to frost and de-icing salt per 500 m² of installation area are to be carried out on a series of at least 5 test specimens in accordance with BAW-MFB.

(394) Tests to verify the water penetration resistance are to be carried out on a series of at least 5 specimens per 250 m² of installation area in accordance with DIN EN 12390-8.

Bond quality

(395) After sufficient hardening time, the finished surfaces must be inspected by tapping in the presence of the client in order to detect voids. No voids may be present at any point.

5 Sprayed mortar/shotcrete (unanchored, unreinforced)

5.1 General

(396) This section applies to repair measures with cement-bound concrete replacement made of sprayed mortar/shotcrete with or without polymer modification, which is applied in thin layers (up to 60 mm) without additional anchoring and reinforcement by spraying on concrete substrates of old concrete class A2, A3, A4 or A5.

(397) The minimum layer thickness for wide-area application is 20 mm.

(398) If any existing, exposed reinforcement is injected, the layer thickness of 60 mm can also be exceeded at specific locations.

5.2 Scope of application

(399) Repair measures may be carried out with sprayed mortar/shotcrete, provided that these are suitable for the effects of the actions assigned to the component and the assigned old concrete class.

5.3 Construction principles

(400) The layer thicknesses specified in the specification of works are minimum layer thicknesses.

(401) Unless otherwise agreed upon in the specification of works, the specified layer thicknesses (with the exception of deeper local cavities and unevenness caused by removal) may not be exceeded by more than 10 mm.

(402) The maximum particle diameter
- may not exceed one third of the thickness of the respective spraying layer
- must be selected to be as large as possible

(403) Rebound may not be reused in the production of sprayed mortar/shotcrete under any circumstances.

(404) The surface of the sprayed mortar/shotcrete is to be left sprayed rough. If a smooth or specially structured surface is required, proceed as follows:
- For single-layer application, a sprayed mortar compatible with the sprayed mortar/shotcrete must be applied in a separate work step after the sprayed mortar/shotcrete has hardened and processed accordingly. It must meet the same requirements as the sprayed mortar/shotcrete. It may be counted against the required sprayed mortar/shotcrete layer thickness, provided that the layer thickness of the hardened sprayed mortar/shotcrete is $\geq$ 20 mm.
- If multiple layers are applied, the last spray layer may be processed accordingly if the total thickness of the previous layers is spraying layer $\geq$ 20 mm.

5.4 Construction materials

(405) Only those sprayed mortars/shotcretes for which proof of usability has been provided in accordance with the relevant requirements of the specification of works in accordance with

Method 1 or 2 as per Section 0.7 may be used. If Method 1 is specified, compliance with the sprayed mortar/shotcrete examined and assessed in the proof of usability must be demonstrated in accordance with the corresponding specifications of the specification of works (see Sections 1.4, 1.6.1 and 5.6).

(406) The sprayed mortars/shotcretes must be adapted to the strength and deformation behaviour of the concrete substrate.

(407) For sprayed mortar/shotcrete with known composition in Table 0 .7, line 1, the requirements in (339) apply accordingly.

(408) The sprayed mortars/shotcretes may only be processed with the spraying systems used to prove their usability and maximum hose lengths. The same applies to dosing and mixing systems for injection mortar/shotcrete components that are mixed on the construction site. Silos require a substance-specific inspection in light of the tendency to separate.

(409) In the case of factory-mixed sprayed mortars/shotcretes, the permissible storage period must not be exceeded.

(410) When processing factory-manufactured mortar/concrete dry components, only whole containers of the dry component may be used. If the liquid component is not added in whole containers, sufficient homogenisation and a suitable dosing device must be ensured. The mixing instructions must be clearly displayed on the mixing machine.

5.5 Construction work

5.5.1 General

(411) Before the sprayed mortar/shotcrete is applied, the client must be provided with proof of usability, the manufacturer’s binding ‘execution instructions’ and, if Method 1 is specified, proof of conformity as per Section 5.4 as well.

(412) Section 1.5.4 and the manufacturer’s binding ‘execution instructions’ must be followed with regard to the material and processing-related limit values for the use of the sprayed mortar/shotcrete.

(413) Unless otherwise agreed upon in the specification of works, an execution plan must be submitted to the client for agreement no later than 4 weeks before the first installation of sprayed mortar/shotcrete and no later than three work days prior to the start of work. The execution concept and execution plan become parts of the quality assurance plan as per Section 1.5.1.

(414) The product data sheets and the manufacturer’s binding ‘execution instructions’ must be submitted to the client together with the execution concept.

(415) The execution concept must contain at least the following information:
- Concrete replacement system with spraying method/spraying equipment
- The manufacturer’s binding ‘execution instructions’ (where applicable)
- Results of the proof of usability
- Component list (type of components, exposure classes, requirements according to construction sequence)
- Preparation of the application surfaces (substrate and hardened spraying layers, if work is done in multiple layers) and construction joints
- Measures required in the area of built-in parts

- Formation of edges and boundaries (formwork, etc.)
- Number, thickness, time sequence and post-treatment of the individual spraying layers
- Measures to maintain the planned layer thicknesses
- Formation of the concrete replacement system surface
- Disposal of rebound
- Monitoring of sprayed mortar/shotcrete production and processing, construction material tests.

(416) The execution plan must contain at least the following information:
- Execution schedule, interruptions, sequence of execution
- Component plan (requirements according to the construction process, further detailing of the information according to the execution concept/component list)
- Installation quantities, installation times
- Personnel plan, nozzle operator, foreman (if applicable) as per Section 1.5.2
- Production of the construction and spray joints, specifications on edge formwork
- Type and time of construction joint processing
- Requirements for concrete surfaces, surface treatment
- Post-treatment plan (type, duration, time)
- Protective measures for adjacent work sections and components
- Consideration of weathering influences, weather-related protective measures
- Measures in case of incidents (e.g. failure of supply plants, spraying equipment, dosing equipment).

(417) The application of the sprayed mortar/shotcrete may only begin once the contractor has checked that the degree of cleaning of the reinforcement has been maintained and after prior consultation with the client.

5.5.2 Personnel

(418) Only nozzle operators who have successfully passed an examination[8] recognised by the client may be used. The certificate must be submitted upon request.

5.5.3 Substrate preparation

(419) Suitable measures must be taken to ensure that pre-prepared surfaces and reinforcement are not re-contaminated before the sprayed mortar/shotcrete is applied. This applies with regard to influences from spraying work in adjacent work sections in particular.

(420) The surfaces of hardened spraying layers (not fresh in fresh) must be prepared in accordance with Section 2.2.2 before another spraying layer is applied.

5.5.4 Layer thickness

(421) Suitable auxiliary constructions are to be used to maintain the intended layer thicknesses.

(422) If setting jigs are anchored in the application surfaces to maintain the coating thickness, they must be removed prior to completion of spraying work. The resulting holes and recesses must be completely closed with the sprayed mortar/shotcrete used in such a way that the required properties are also present in these areas.

[8] *Proof of the nozzle operator's qualification may be rendered by a certificate of the 'Protection and repair of concrete structures' training advisory board issued by Beton- und Bautechnik-Verein E.V. [German Concrete and Construction Technology Association] (known as a 'nozzle operator licence') or equivalent certificates of qualification.*

5.5.5 Sprayed mortar/shotcrete application

(423) The application surfaces must be sufficiently pre-wetted (at least 24 hours in advance for the first time) before application of the sprayed mortar/shotcrete. However, the application surfaces must have dried sufficiently by the beginning of the spraying work that they appear matte damp.

(424) When processing factory-manufactured mortar/concrete dry components, only whole containers of the dry component may be used. If the liquid component is not added in whole containers, sufficient homogenisation and a suitable dosing device must be ensured. The mixing instructions must be clearly displayed on the mixing machine.

(425) The temperature of the base mixture (dry mixture) and the fresh concrete/fresh mortar temperature (wet mixture) when applied at the installation site must not exceed + 30 °C, unless lower temperatures are required in the manufacturer's binding 'execution instructions'.

(426) The application of the sprayed mortar/shotcrete may only be commenced once the application areas have been checked and the client has been consulted.

(427) If there will be long intervals between the individual spraying layers, post-treatment measures must be carried out in accordance with Section 5.5.6.

5.5.6 Post-treatment and protection

(428) The measures for the post-treatment and protection of the sprayed mortar/shotcrete may only be commenced after the last spraying layer of a work section has been applied until the sprayed mortar/shotcrete has hardened sufficiently that its surface can no longer be adversely altered. However, a change in brightness of the respective sprayed mortar/shotcrete surface from dark to light as a result of dehydration must not occur at any time.

(429) Unless the manufacturer's binding 'execution instructions' contain further requirements, the minimum post-treatment period is 7 days, in which water-feeding post-treatment measures must be carried out in the first 3 days.

5.6 Quality assurance

5.6.1 Building materials and building material systems

5.6.1.1 Proof of usability

(430) The usability of the sprayed mortar/shotcretes for the intended use under the boundary conditions of the construction site must be demonstrated by the contractor by proof of usability in accordance with the corresponding specifications of the specification of works in accordance with Method 1 or 2 as per Section 0.7.

(431) Product characteristics must be determined and documented in accordance with the requirements in the specification of work as the basis for the proof of conformity as part of the proof of usability in Method 1. The bulk density of the fresh sprayed mortar/shotcrete must be determined as a reference value for execution quality assurance as per Annex 6. The dry bulk density of the sprayed mortar/shotcrete must be determined as a reference value for checking the work carried out in accordance with DIN 52170-1.

5.6.1.2 Proof of conformity, certificate of conformity

(432) The conformity of the spray mortar/shotcrete with the spray mortar/concrete examined and assessed in the proof of its usability per Method 1 shall be ensured and confirmed by the contractor before and during the execution of the works in accordance with the relevant requirements of the specification of works.

5.6.2 Checks during execution

(433) The contractor is to check and ensure the quality of the execution.

(434) The contractor must carry out the following checks on the building materials supplied or on the spraying system prior to installation as part of its own self-monitoring:

- Verification of the expiry date or date of manufacture and of the permissible storage period and storage conditions (factory-manufactured sprayed mortar/shotcrete)
- Verification of the conformity of the spraying system with the spraying system used to demonstrate usability as per Section 5.5.1
- Verification of the functionality of the spraying system including all equipment necessary for the production of the sprayed mortar/shotcrete
- Inspection of the correct device settings in line with the manufacturer's binding 'execution instructions'.

(435) In the case of the wet spraying process, compliance with the mixing ratio chosen in the proof of usability shall be checked when mixing the components of the concrete replacement system. The sufficient homogenisation of the finished mixture and the uniform promotion are to be verified.

(436) In the dry spraying process, the uniform composition and conveyance of the dry mortar/concrete must be checked (visual inspection).

Fresh mortar/fresh concrete

(437) The gross density of the fresh sprayed mortar/shotcrete shall be determined once per 100 m² started per work day in accordance with Annex 6, albeit not less than once per work day. The bulk density of the fresh sprayed mortar/shotcrete may not be less than the reference value from the proof of usability (Method 1 as per Section 0.7) or the value declared by the manufacturer (Method 2 as per Section 0.7) by more than 0.07 kg/dm³.

5.6.3 Inspection of the work performed

(438) The inspection of the work performed must be carried out and documented by the contractor in accordance with Sections 1.6.1.3 and (439) to (441).

(439) After sufficient hardening time, the completed areas must be inspected by tapping in the presence of the client in order to detect voids. No voids may be present at any point.

(440) The bond strength of the sprayed mortar/shotcrete shall be determined for each 250 m² of installation area or part thereof, albeit at least once per component, at an age of at least 7 days in a set of 5 individual tests distributed evenly over the area to be assessed as per Annex 1. The test must be carried out in the presence of the client. Unless otherwise agreed upon in the specification of works, the bond strength of the sprayed mortar/shotcrete shall be at least equal to the corresponding values for breaking strength in Table 2 .11. If a single value lower than the permissible single value is found, at least two individual tests must be carried out in close proximity (at a distance of up to approx. 1 m) to determine whether the test result is an outlier. If the additional values determined are sufficient, the value initially found shall be discarded. If the

value initially found is confirmed, a suitable surface grid must be used to delimit the area with inadequate bond strengths.

(441) The dry bulk density of the sprayed mortar/shotcrete shall be determined in accordance with DIN 52170-1 on all drill cores from the bond strength test. The volume is to be determined by means of immersion weighing. The areas adjacent to the bonding plane and the adhesive layer must be cut off beforehand. The test is only to be carried out if an injection mortar/shotcrete disc of at least 15 mm thickness can be obtained from the drill core. If this is not possible, additional drill cores must be taken. The dry bulk density may not be more than 0.04 kg/dm³ below the reference value from the proof of usability (Method 1 as per Section 0.7) or the manufacturer's declared value (Method 2 as per Section 0.7).

6 Manually applied concrete replacement (unanchored, unreinforced)

6.1 General

(442) This section applies to repairs with cement-bound concrete replacement systems made of mortar or concrete with or without polymer modification applied locally in thin layers without additional anchoring and reinforcement on concrete substrates of the old concrete classes A4 or A5.

(443) The layer thickness is usually 10 to 60 mm, and up to 100 mm in special cases (such as deep cavities). (448) must be observed for determining the minimum layer thickness.

(444) The manually applied concrete replacement consists of the concrete replacement and generally the bonding layer and fine filler (where applicable).

6.2 Scope of application

(445) With manually applied concrete replacement, only small-area repair measures may be carried out, and only on components of old concrete classes A4 and A5. The manually applied concrete replacement must be suitable for the actions assigned to the component.

6.3 Construction principles

(446) The layer thicknesses specified in the specification of works are minimum layer thicknesses.

(447) Unless otherwise agreed upon in the specification of works, the specified layer thicknesses (with the exception of deeper local cavities and unevenness caused by removal) may not be exceeded by more than 10 mm.

(448) The maximum particle diameter
- must be adapted to the required layer thickness
- must be selected to be as large as possible
- may not exceed one third of the thickness of the respective course
- may not exceed 8 mm.

6.4 Building materials and building material systems

(449) Only those concrete replacement may be used in the manual order for which there is proof of usability in accordance with the corresponding specifications of the specification of

works in accordance with Method 1 or 2 as per Section. 0.7 If Method 2 is specified, conformity with the manually applied concrete replacement inspected and assessed in the proof of usability must be demonstrated in accordance with the corresponding specifications in the specification of works (see Sections 1.4, 1.6.1 and 6.6).

(450) The manually applied concrete replacement must be adapted to the strength and deformation behaviour of the concrete substrate.

(451) For manual application of concrete replacement with a known composition according to Table 0 .8, line 1, the requirements according to (174) apply equally.

(452) Only mineral bonding layers are permitted.

(453) The containers of the building materials must be marked and undamaged. The permissible storage period may not be exceeded.

(454) When processing factory-manufactured mortar/concrete dry components, only whole containers of the dry component may be used. If the liquid component is not added in whole containers, sufficient homogenisation and a suitable dosing device must be ensured. The mixing instructions must be clearly displayed on the mixing machine. If silos are used, they require a substance-specific inspection in light of the tendency to separate.

6.5 Construction work

6.5.1 General

(455) Before the manually applied concrete replacement is applied, the client must be provided with proof of usability, the manufacturer's binding 'execution instructions' and, if Method 2 is specified, additional proof of conformity as per Section 6.4.

(456) Section 1.5.4 and the manufacturer's binding 'execution instructions' must be followed with regard to the material and processing-related limit values for the use of the manually applied concrete replacement.

(457) In the case of exposed concrete surfaces, the surface structure of the repair areas must be adapted to the concrete surface surrounding them.

(458) Unless otherwise agreed upon in the specification of works, an execution plan must be submitted to the client for agreement no later than 4 weeks before the first installation of the manually applied concrete replacement and no later than 3 work days prior to the start of work. The execution concept and execution plan become parts of the quality assurance plan as per Section 1.5.1.

(459) The product data sheets and the manufacturer's binding 'execution instructions' must be submitted to the client together with the execution concept.

(460) The execution concept must contain at least the following information:
- Designation of the manually applied concrete replacement to be used
- The manufacturer's binding 'execution instructions' (where applicable)
- Results of the proof of usability
- Component list (type of components, exposure classes, requirements according to construction sequence)
- Preparation of the application surfaces (substrate and hardened layers of manually applied concrete replacement, if work is done in multiple layers) and construction joints

- Measures required in the area of built-in parts
- Formation of edges and boundaries, etc.
- Number, thickness, time sequence and post-treatment of the individual courses
- Measures to maintain the planned layer thicknesses
- Formation of the surface of the manually applied concrete replacement
- Monitoring mortar production and processing, construction material tests.

(461) The execution plan must contain at least the following information:
- Execution schedule, interruptions, sequence of execution, Component plan (requirements according to the construction process, further detailing of the information according to the execution concept/component list)
- Installation quantities, installation times
- Personnel plan, foreman as per Section 1.5.2
- Production of construction joints, specifications on edge formwork
- Type and time of construction joint processing
- Requirements for concrete surfaces, surface treatment
- Post-treatment plan (type, duration, time)
- Protective measures for adjacent work sections and components
- Consideration of weathering influences, weather-related protective measures.

6.5.2 Installation

(462) The installation of the manually applied concrete replacement (when using a bonding layer before its installation) may only be started after the contractor has checked the degree of cleaning of the reinforcement and after prior coordination with the client.

(463) The concrete substrate must be sufficiently pre-wetted (at least 24 hours in advance for the first time) before installing the manually applied concrete replacement (when using a bonding layer before installing it). However, at the start of the installation, the concrete substrate must be dried sufficiently that it appears matte damp. The installation of the manually applied concrete replacement or the bonding layer may only be started after inspection of the application area by the contractor and after prior consultation with the client.

(464) The manually applied concrete replacement must be compressed sufficiently. In the case of horizontal surfaces, mechanical compaction equipment shall be used wherever possible.

(465) In the case of multi-layer installation of the manually applied concrete replacement, it is generally necessary to work fresh in fresh. If this is not possible, the surface of the hardened course of the manually applied concrete replacement must be treated the same way as the concrete substrate.

(466) If there will be long intervals between the individual courses, post-treatment measures must be carried out in accordance with Section 6.5.3.

6.5.3 Post-treatment and protection of the manually applied concrete replacement

(467) The measures for the post-treatment and protection of the manually applied concrete replacement may only be commenced after the installation of the last course or layer of a work section once the manually applied concrete replacement has hardened sufficiently that its surface can no longer be adversely altered. However, a change in brightness of the respective surface of the manually applied concrete replacement or of the fine filler from dark to light as a result of dehydration must not occur at any time.

(468) The post-treatment shall be carried out according to type and duration according to the manufacturer's binding 'execution instructions', taking the relevant environmental conditions into account. The minimum post-treatment period is 5 days, unless the execution specifications contain different requirements.

6.6 Quality assurance

6.6.1 Building materials and building material systems

6.6.1.1 Proof of usability

(469) The usability of the manually applied concrete replacement for the intended use under the boundary conditions of the construction site must be demonstrated by the contractor by proof of usability in accordance with the corresponding specifications of the specification of works in accordance with Method 1 or 2 as per Section 0.7.

(470) Product characteristics must be determined and documented in accordance with the requirements in the specification of work as the basis for the proof of conformity as part of the proof of usability in Method 1. The consistency and air content of the manually applied concrete replacement must be determined in accordance with DIN EN 1015-3 and DIN EN 1015-7 as a reference value for execution quality assurance. The dry bulk density of the manually applied concrete replacement must be determined as a reference value for checking the work carried out in accordance with DIN 52170-1.

6.6.1.2 Proof of conformity, certificate of conformity

(471) If Method 1 is specified, the conformity of the manually applied concrete replacement with the concrete replacement system examined and evaluated in the proof of usability must be ensured and confirmed by the contractor before and during construction in accordance with the corresponding requirements in the specification of works.

6.6.2 Checks during execution

(472) The quality of execution must be checked and ensured by the contractor.

(473) The contractor must carry out the following checks on the building materials supplied as part of monitoring prior to installation:

- Conformity with the order (delivery note with batch number, packaging inscription)
- Verification of the undamaged condition of the packaging
- Verification of proper storage in accordance with regulations
- Verification of the expiry or production date and the permissible storage period.

<u>Consistency, air content</u>

(474) The consistency and air content of the manually applied concrete replacement must be determined once per work day in accordance with DIN EN 1015-3 and DIN EN 1015-7.

(475) The flow spread must not differ by more than 15% from the corresponding reference value in proof of usability (Method 1 as per Section 0.7) or from the manufacturer's declared value (method 2 as per Section 0.7).

(476) The air content may not deviate by more than 2% by volume or 50% in relative terms (the smaller tolerance range is decisive) from the corresponding reference value in the proof of

usability (Method 1 as per Section 0.7) or from the manufacturer's declared value (Method 2 as per Section 0.7).

Temperature of the concrete substrate and the materials used

(477) The temperatures of the concrete substrate and the materials to be used are to be measured before the start of construction. The measurements are to be repeated during execution if the temperatures are close to the limit values specified in Section 1.5.4 or in the manufacturers' binding 'execution instructions'. All measurement results must be documented.

Mixing

(478) When mixing the components of the manually applied concrete replacement, compliance with the mixing ratio must be checked in accordance with the proof of usability.

(479) Adequate homogenisation of the finished mixture must be verified.

6.6.3 Inspection of the work performed

(480) The inspection of the work performed must be carried out and documented by the contractor in accordance with Sections 1.6.1 and (481) to (483).

(481) After sufficient hardening time, the finished surfaces must be inspected by tapping in the presence of the client in order to detect voids. No voids may be present at any point.

(482) Unless agreed upon otherwise, the bond strength of the manually applied concrete replacement is to be determined for each 25 individual areas or part thereof, albeit at least once per component, at an age of at least 7 days in a set of 5 individual tests distributed evenly over the area to be assessed as per Annex 1. The test must be carried out in the presence of the client. Unless otherwise agreed upon in the specification of works, the bond strength of the manually applied concrete replacement must be at least equal to the corresponding values for breaking strength in Table 2 .11. If a single value lower than the permissible single value is found, at least two individual tests must be carried out in close proximity (at a distance of up to approx. 1 m) to determine whether it is an outlier. If the additional values determined are sufficient, the value initially found is to be discarded. If the value initially found is confirmed, a suitable surface grid must be used to delimit the area with inadequate bond strengths.

(483) For target layer thicknesses > 15 mm, the dry bulk density of the manually applied concrete replacement must be determined according to DIN 52170-1 on all drill cores from the bond strength test. The volume is to be determined by means of immersion weighing. The areas adjacent to the bonding plane and the adhesive layer must be cut off beforehand. The test is only to be carried out if a disc of the manually applied concrete replacement at least 15 mm in thickness can be obtained from the drill core. If this is not possible, additional drill cores must be taken. The dry bulk density of the manually applied concrete replacement may not be more than 0.04 kg/dm^3 below the corresponding reference value from the proof of usability (Method 1 as per Section 0.7) or the manufacturer's declared value (Method 2 as per Section 0.7).

7 Surface protection systems (OS)

7.1 General

(484) This section applies to repair measures with surface protection systems on concrete substrates A3 (average breaking strength at least 1.3 N/mm²), A4 and A5.

7.2 Scope of application

(485) Repair measures may be carried out with surface protection systems, provided that the surface protection system is suitable for the effects of the actions assigned to the component and the assigned old concrete class.

7.3 Construction principles

(486) Section 1.3 shall apply.

7.4 Building materials and building material systems

(487) Only those surface protection systems may be used for which there is proof of usability in accordance with the corresponding requirements in the specification of works in accordance with Method 1 or 2 as per Section 0.7. If Method 1 is specified, conformity with the surface protection systems examined and assessed as part of the proof of usability must be demonstrated in accordance with the relevant requirements in the specification of works (see Sections 1.4, 1.6.1 and 7.6).

(488) Unless agreed upon otherwise in the specification of works, the contractor must submit all necessary test certificates, test reports and evidence to the client no later than 2 weeks prior to the start of execution work.

(489) The containers must be marked and undamaged. The permissible storage period may not be exceeded.

(490) As a general rule, only whole containers may be used when processing surface protection systems. If, in exceptional cases, the product is not added in whole containers, sufficient homogenisation and weighing accuracy of the components must be ensured.

7.5 Construction work

7.5.1 General

(491) Before the surface protection system is applied, the client must be provided with proof of usability, the manufacturer’s binding ‘execution instructions’ and, if Method 1 is specified, proof of conformity as per Section 7.4 as well.

(492) Section 1.5.4 and the manufacturer’s binding ‘execution instructions’ must be followed with regard to the material and processing-related limit values for the use of the surface protection systems.

(493) The manufacturer’s binding ‘execution instructions’ must be observed with regard to the permissible substrate moisture content for the use of surface protection systems.

(494) Application of surface protection systems may only commence upon prior coordination with the client.

7.5.2 Application of hydrophobic impregnations

(495) Hydrophobic impregnations in liquid or paste form should be applied by hand or by spraying onto a dry substrate.

7.5.3 Application of coatings

(496) Coatings must be applied so that the dry-layer thicknesses are within the defined product-specific maximum and minimum values.

(497) The product-specific minimum and maximum layer thicknesses can be found in the manufacturer's binding 'execution instructions'.

(498) The manufacturer's binding 'execution instructions' during the revision periods must be complied with.

(499) Before carrying out the coating measures, the contractor must determine and document the required consumption quantities (taking into account, for example, the minimum dry film thickness, roughness and flatness of the substrate, volatile content of the coating material, general processing losses) (see Annex 7).

7.5.4 Implementation concept, execution plan

(500) Unless otherwise agreed upon in the specification of works, an execution plan must be submitted to the client for agreement no later than 4 weeks before the first surface protection application and no later than 3 work days prior to the start of work. The execution concept and execution plan become parts of the quality assurance plan as per Section 1.5.1.

(501) The product data sheets and the manufacturer's binding 'execution instructions' must be submitted to the client together with the execution concept.

(502) The execution concept must contain at least the following information:
- Surface protection system
- Component list (type of components, exposure classes, requirements according to construction sequence)
- Condition of the application surfaces (smooth, rubbed, glued, shot-blasted or similar)
- Preparation of the application surfaces and section transitions
- Measures required in the area of built-in parts
- Number, thickness, time sequence and post-treatment of the individual build-up layers
- Measures to maintain the planned layer thicknesses
- Formation of the surface
- Collection and disposal of residues and containers
- Monitoring of material production and processing, building material testing.

(503) The execution plan must contain at least the following information:
- Execution schedule, interruptions, sequence of execution
- Component plan (requirements according to the construction process, further detailing of the information according to the execution concept/component list)
- Installation quantities, installation times
- Personnel plan, foreman as per Section 1.5.2
- Formation of section transitions
- Specifications on edge taping
- Requirements for surfaces, surface treatment
- Post-treatment plan (type, duration, time)
- Protective measures for adjacent work sections and components
- Consideration of weathering influences, weather-related protective measures.

7.6 Quality assurance

7.6.1 Building materials and building material systems

7.6.1.1 Proof of usability

(504) The applicability of the surface protection system for the intended use under the boundary conditions of the construction site must be demonstrated by the contractor by proof of applicability in accordance with the corresponding requirements in the specification of works as per Method 1 or 2 in accordance with Section 0.7.

(505) Product characteristics must be determined and documented in accordance with the requirements in the specification of work as the basis for the proof of conformity as part of the proof of usability in Method 1.

7.6.1.2 Proof of conformity, certificate of conformity

(506) If Method 1 is specified, the conformity of the surface protection system with the surface protection system examined and assessed as part of the proof of usability must be ensured and confirmed by the contractor before and during construction in accordance with the relevant requirements in the specification of works.

7.6.2 Checks during execution

(507) The quality of execution must be checked and ensured by the contractor.

(508) The contractor must carry out the following checks on the building materials supplied as part of monitoring prior to installation:

- Conformity with the order (delivery note with batch number, packaging inscription)
- Verification of the undamaged condition of the packaging
- Verification of proper storage in accordance with regulations
- Verification of the expiry or production date and the permissible storage period.

7.6.3 Inspection of the work performed

(509) The inspection of the work performed must be carried out and documented by the contractor in accordance with Sections 1.6.1.3 and (510) to (513).

(510) For surface protection systems OS 4 (OS C), the product-specific minimum dry layer thicknesses ($d_{min,P}$) of the surface protection layer (hwO [primary effective surface protection layer]) may be demonstrated in accordance with the manufacturer's binding ‘execution specifications’ on consumption volumes in accordance with Annex 7, Section A7.1.

(511) For OS 5 (OS D) surface protection systems, the product-specific minimum dry film thicknesses shall be demonstrated in accordance with the manufacturer’s binding ‘execution instructions’ and the criteria set out in paragraph (492) (test according to Annex 7, Section A7.2).

(512) Layer thickness criteria

a) Criterion 1: smallest single value of test series $d_{ist,i,min} \geq 0.7 \cdot d_{min,p}$
b) Criterion 2: Mean value of test series $d_{ist,m} \geq d_{min,p}$
c) Criterion 3: Mean value of test series $d_{ist,m} < d_{max,p}$

d) Criterion 4: largest single value of test series $d_{ist,i,max} \leq 1.3 \cdot d_{max,p}$

$d_{max,p}$ product-specific maximum layer thickness
$d_{min,p}$ product-specific minimum layer thickness
$d_{ist,m}$ mean value of the test series
$d_{ist,i,min}$ smallest single value of the test series
$d_{ist,i,max}$ largest single value of the test series

(513) There must not be any bonding disturbances between the surface protection system and the substrate at any point. The bond strength of the surface protection system is to be determined for each 250 m² of installation area or part thereof, albeit at least once per component at an age of at least 7 days, in a set of 3 individual tests distributed evenly over the area to be assessed in accordance with Annex 1. The test must be carried out in the presence of the client. Unless otherwise agreed upon in the specification of works, the bond strength of the surface protection system must be at least equal to the corresponding values for breaking strength in Table 2 .11. If a single value lower than that permissible in Table 2 .11 is found, at least two individual tests must be carried out in close proximity (at a distance of up to approx. 1 m) to determine whether it is an outlier. If the additional values determined are sufficient, the value initially found is to be discarded. If the value initially found is confirmed, a suitable surface grid must be used to delimit the area with inadequate bond strengths.

8 Filling cracks and local voids

8.1 General

(514) This section applies to repair measures using polymeric or cement-bound injection products. These measures include closing (or limiting the crack width by filling), sealing and connecting cracks as well as filling local voids.

(515) Unless local voids are mentioned separately below, the information for crack injections shall apply accordingly.

8.2 Scope of application

(516) Repair measures may be carried out with injection products, provided that the respective injection product is suitable for the effects of the actions assigned to the component and the assigned old concrete class.

8.3 Construction principles

(517) Section 1.3 shall apply.

8.4 Building materials and building material systems

(518) Only injection products for which proof of usability has been provided in accordance with the relevant requirements of the specification of works in accordance with Method 1 or 2 in accordance with Section 0.7 may be used. If Method 1 is specified, conformity with the injection product examined and assessed in the proof of usability must be demonstrated in accordance with the relevant requirements of the specification of works (See Sections 1.4, 1.6.1 and8.6).

(519) Unless agreed upon otherwise in the specification of works, the contractor must submit all necessary test certificates, test reports and evidence to the client no later than 2 weeks prior to the start of execution work.

(520) The containers must be marked and undamaged. The permissible storage period may not be exceeded.

(521) As a general rule, only whole containers may be used when processing polymer injection products. If, in exceptional cases, the product is not added in whole containers, sufficient homogenisation and weighing accuracy of the components must be ensured.

8.5 Construction work

8.5.1 General

(522) Prior to the use of polymeric or cement-bound injection products, proof of usability, the manufacturer's binding 'execution instructions' and, where Method 1 is defined, the proof of conformity in accordance with Section 8.4 must be submitted to the client.

(523) With regard to the material and processing-related limit values for the use of polymer or cement-bound injection products, Section 1.5.4 and the manufacturer's binding 'execution instructions' must be complied with.

8.5.2 Treatment of cracks and local voids

8.5.2.1 General

(524) The actual condition determined by the planner must be visually checked before the start of the execution. Furthermore, attention must be paid to changes in condition from the construction process.

(525) The filling of cracks (injection or grouting) requires minimum crack widths depending on the type of filler and the method used. The cracks should be filled as close as possible to the maximum crack width.

(526) The filling of local voids presupposes the minimum dimensions of accessibility depending on the type of cement-bound filler (ZL, ZS) and the procedure used.

(527) If necessary, local voids in the component must be opened up by drilling holes for filling and venting.

(528) The flanks of cracks and local voids must be free of adhesion-reducing impurities when filled with force and limited stretching.

(529) In order to ensure the complete filling of the cracks and local voids, all-round plugging is required, as far as is practicable.

(530) In the case of crack or void filling, suitable fast-hardening insulation materials must be provided for leakage points.

(531) Mixing and injection equipment must be adapted to and suitable for the filler to be processed.

(532) For mixing cement pastes and cement suspensions, agitators must be used that open up all the constituents in such a way that the required mixing stability is achieved.

(533) When processing with the one-part injection device, only whole containers or precisely measured individual parts in the mixing ratio specified by the manufacturer may be mixed. Mixed container contents may only be used for filling and post-injection within the workability period. Extending the container workability period by cooling is only permissible at high ambient temperatures.

(534) When processing with the two-part injection device, the temperature-dependent individual viscosities of parts A and B must be available in order to adjust the target mixing ratio of the injection product. Compliance with the mixing ratio must be checked by calibration.

(535) Cracks must be filled completely, i.e. at least up to a filling level of 80% of the component cross-section to be filled, unless otherwise specified by the qualified planner, e.g. when casting cracks.

8.5.2.2 Injection of fillers into cracks and local voids

8.5.2.2.1 General

(536) When using drill packers, it must be ensured that the reinforcement required for structural stability is not impaired as a result of the boreholes being created. The position of tendons in particular must be determined before drilling.

(537) The arrangement of the packers for crack injection up to a filling depth of 600 mm should be carried out in accordance with Figure 8.1. The mean distances (r) between the packers as a function of the component thickness (d) listed in Figure 8.1 are to be observed. Different packing arrangements may be defined if this is required by the component dimensions, the crack widths and the reinforcement arrangement. Depending on the accessibility, a one-sided or two-sided arrangement and corresponding packer distances must be selected for adhesive packers. Different requirements may apply to uninterrupted filling low-pressure injection methods.

(538) In the case of filling depths > 600 mm, the qualified planner specifies the execution (e.g. definition of the packer distances, degree/depth of crack filling). In this instance, the drill packers may for instance be mounted in boreholes which traverse the crack plane at various depths (multi-row packer arrangement), calculated from the surface of the component. In the case of building components that are accessible on one side, it is recommended to carry out sample injections in order to test the possible level and depth of filling.

(539) For void injections, the packers must be arranged in a grid corresponding to the type and size of the void.

(540) In the case of boreholes, the continuity of the borehole must be ensured through cleaning measures (e.g. suction).

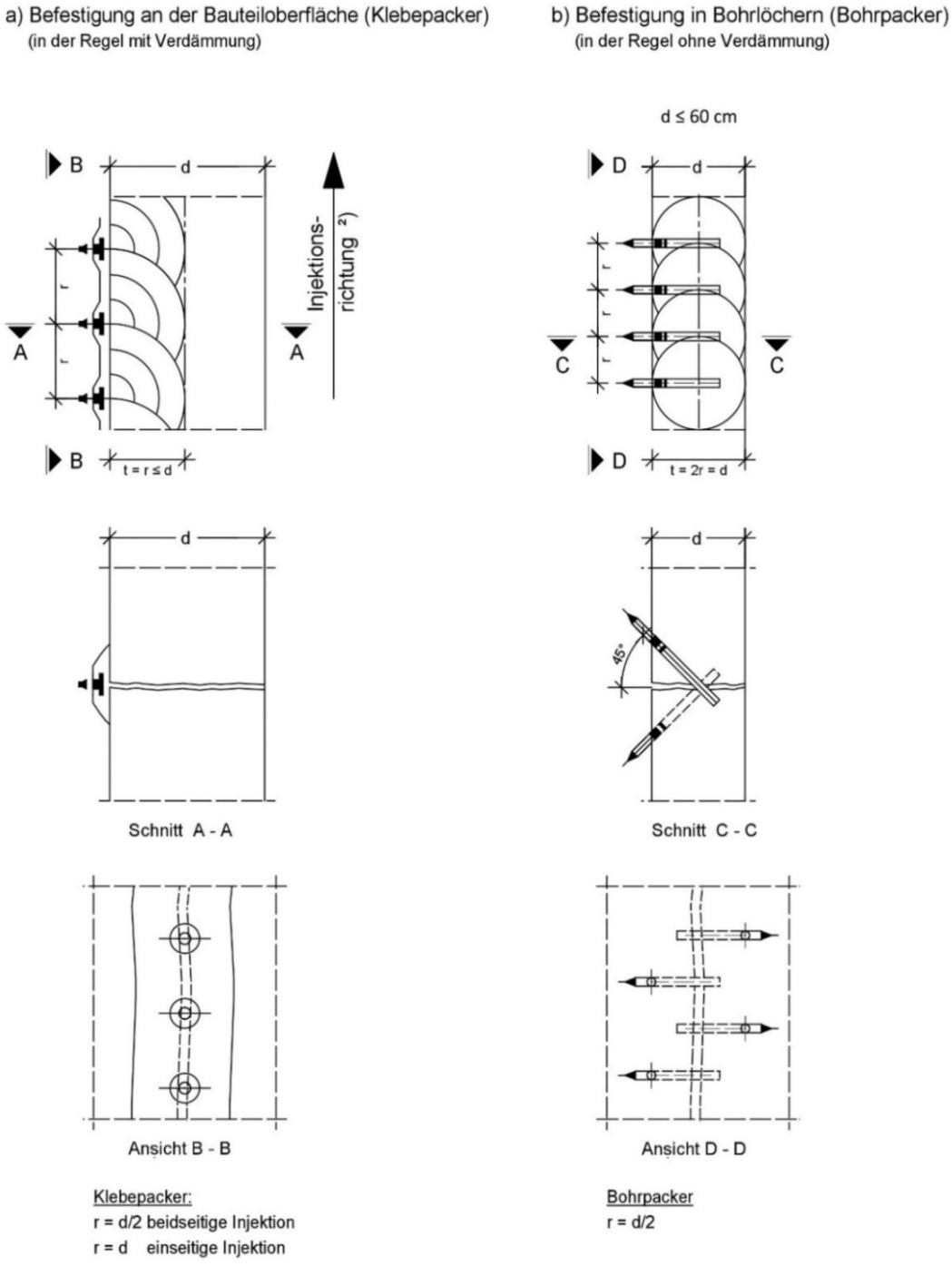
(541) In the case of an injection, sufficient ventilation of the crack or void must be ensured.

(542) In the event of an injection of water-filled cracks or water-saturated concrete structure, it must be ensured that the water escapes during the injection process.

(543) Before injecting cement-bound fillers, dry flanks of cracks and voids must be pre-wetted in accordance with the specifications in the execution concept.

(544) If a change in crack width is to be expected during the execution of the injection, the reduction of the crack width (closure phase) should be accompanied by the strength development of the injection products. If the filling target is the effective connection of the crack

flanks, the temperature-dependent duration of the strength development until 3 N/mm² of the cracking agent is reached must be taken into account.



a) Befestigung and der Bauteiloberfläche (Klebepacker)
(in der Regel mit Verdämmung)
a) Befestigung in Bohrlöchern (Klebepacker)
(in der Regel ohne Verdämmung)
Injektion richtung
Schnitt
Ansicht
Klebepacker:
r = d/2 beidseitige Injektion
r = d einseitige Injektion
Bohrpacker
r = d/2
d: Component thickness

a) Fastening to the component surface (adhesive packer)
(generally with plugging)
a) Fixing in boreholes (adhesive packers)
(generally without plugging)
Injection direction
Cut
View
Adhesive packers:
R = d/2 two-sided injection
r = d one-sided injection
Drill packer
R = d/2

r: Distance between packers [1)]
t: Area of action of a packer

1) The mean distance r may only be exceeded to a negligible extent in both cases.
2) Injection direction: from bottom to top, use of the packers successively after the injection product has leaked from the previous filling process.
3) For uninterrupted filling low-pressure injection methods, different requirements may apply with regard to packer arrangement and filling process.

Figure 8.2: Arrangement of the packers in standard cases at a specified filling depth up to a maximum of 600 mm (DAfStb Volume 638)

(545) A re-injection must always be carried out over all existing packers. This may only be carried out within the workability period proven for the injection product used in accordance with the manufacturer's binding 'execution instructions' (component temperature, if applicable reaction temperature of the filler in the case of voids). Different requirements may apply to uninterrupted filling low-pressure injection methods.

(546) Re-injection of cracks and voids that have become leaky is permitted according to the filler-specific application conditions (see TR-IH Part 1, Table 14). New drilling channels and packers must also be installed for this purpose as a general rule.

(547) Drilled channels must be permanently sealed with a suitable mortar at the end of the work. The residues of drill packers are to be removed to a depth of at least 4 cm.

(548) The injection pressure must be practicably limited depending on the condition and quality of the concrete substrate as well as the specific filler and filler type. Particular care must be taken when filling voids near the surface.

8.5.2.2.2 Requirements for equipment technology

(549) Mechanical injection devices must have a pressure control and an indicator for the injection pressure. Two-part injection systems must have a temperature control device for the individual components. Different requirements may apply to uninterrupted filling low-pressure injection methods.

8.5.2.2.3 Requirements for injection equipment

(550) The injection is carried out via

- adhesive packers that are glued to the component surface in the course of plugging.
- drill packers that are fastened into boreholes.

The packers must be fastened so as to form a connection to the component that can withstand the injection pressure and prevent the filler from escaping once injection is complete. Packing parts remaining close to the surface of the component must be made of non-corroding materials.

(551) The cement or polymer-bound plugging must be such that adhesion adapted to the injection pressure can be ensured. If crack width changes are to be expected during execution work, the plugging must have sufficient flexibility to accommodate the crack width changes without leakage.

8.5.2.3 Unpressurised filling by casting widened cracks, cracks of defined minimum width and local voids with injection products

(552) Accessible crack flanks and local voids must be cleaned by suitable methods (e.g. with compressed air or industrial vacuum cleaners) of loose fine materials before filling without pressure. Wetting and adhesion-preventing impurities should be removed.

(553) The contact surfaces of cracks or local voids must be pre-moistened in advance and only in capillary saturation prior to the installation of cement-bound fillers.

(554) The required filling depth must be determined in advance and checked during execution.

(555) When filling cracks and local voids without pressure, a continuous excess of material must be ensured within the processing period. This can be done when filling cracks without pressure, e.g. by creating a groove in the course of the crack or by arranging temporary barriers on both sides of the crack flanks.

8.6 Quality assurance

8.6.1 Building materials and building material systems

8.6.1.1 Proof of usability

(556) The usability of the injection product for the intended use under the boundary conditions of the construction site must be demonstrated by the contractor by proof of usability in accordance with the corresponding specifications of the specification of works in accordance with Method 1 or 2 as per Section 0.7.

(557) Product characteristics must be determined and documented in accordance with the requirements in the specification of work as the basis for the proof of conformity as part of the proof of usability in Method 1. As a reference value for quality assurance of the design, the outflow time (Marsh funnel) for cement-bound injection products must be determined in accordance with DIN EN 14117.

8.6.1.2 Proof of conformity, certificate of conformity

(558) If Method 1 is specified, the conformity of the injection product with the injection product examined and assessed as part of the proof of usability must be ensured and confirmed by the contractor before and during construction in accordance with the relevant requirements in the specification of works.

8.6.2 Checks during execution

(559) The quality of execution must be checked and ensured by the contractor.

(560) The contractor must carry out the following checks on the building materials supplied as part of monitoring prior to installation:

- Conformity with the order (delivery note with batch number, packaging inscription)
- Verification of the undamaged condition of the packaging
- Verification of proper storage in accordance with regulations
- Verification of the expiry or production date and the permissible storage period.

(561) For cement-bound injection products, the outflow time (Marsh funnel) as per DIN EN 14117 may not deviate from the reference value from the proof of usability (Method 1 as per Section 0.7) or from the manufacturer’s declared value (Method 2 as per Section 0.7) by more than 20%.

8.6.3 Inspection of the work performed

(562) If agreed in the specification of works, the objective of the filling measure specified therein must be checked by removal and examination of drill cores.

(563) With the method of unpressurised filling by casting widened cracks, cracks of defined minimum width and local voids with injection products as per Section 8.5.2.3, the filling depth must be checked.

Annex 1: Technical test requirements – Bond strength of concrete replacement and surface protection systems

A1.1 Purpose and scope of application

The test is used to assess the bond between the concrete substrate and the concrete replacement or surface protection system applied to it, as well as within the concrete replacement on the basis of a tensile or breaking strength value. Depending on the location of the fracture surface, the test value corresponds to the adhesive tensile strength or the tensile strength of the concrete or the concrete replacement or the adhesive tensile strength of the surface protection system. In the case of failure within the concrete or the concrete replacement or the surface protection system, it can be concluded that the adhesive tensile strength corresponds to the at least determined tensile strength.

For concrete replacements in layer thickness greater than 50 mm, the tensile test described in Section A1.3.1 is to be applied. For layer thicknesses up to 50 mm, the pull-off test described in Section A1.3.2 may be used. For surface protection systems, the pull-off test described in Section A1.3.2 is used.

A1.2 Cited standards and regulations

[1] DIN EN 12504-1: Testing concrete in structures - Part 1: Cored specimens; Taking, examining and testing in compression

[2] DAfStb Volume 422: Testing of concrete. Recommendations and notes to supplement DIN 1048. Section 3.3: Tensile strength. Deutscher Ausschuss für Stahlbeton (DAfStb)

[3] RL SIB Part 3: DAfStb Guideline on the protection and repair of concrete structural elements (Repair Guideline), Part 3: Requirements for companies and the supervision of the execution, Annex C

[4] RL SIB Part 4: DAfStb Guideline on the protection and repair of concrete structural elements (Repair Guideline), Part 4: Test procedure

[5] DIN EN 1542: Products and systems for the protection and repair of concrete structures. Test methods - Measurement of bond strength by pull-off

A1.3 Test procedure

A1.3.1 Tensile test

The test shall be carried out on drill cores as defined in [1] with a diameter d equal to at least four times the maximum particle diameter but not less than 50 mm. In the wet cutting process, just enough of the two ends of the drill cores must be cut off in each case so that flat surfaces oriented perpendicular to the drill core axis are created. The remaining height h of the drill cores shall be at least 2 d. The binder between the concrete replacement and the concrete substrate shall lie centrally, albeit at a distance of not less than h/4 from the front surfaces.

In the case of multi-layer application of concrete replacement, in particular shotcrete and SPCC, a separate assessment of the bonding of the individual layers may also be required. This may have to be taken into account when preparing the specimens with regard to the position of the bonding planes.

Load entry plates with a thickness of not less than $3.5 \cdot \sqrt{d}$ are to be glued onto the front surfaces of the cores.

The drill cores or specimens obtained from them must be stored under water at (20 ± 2) °C until tested. The water storage may only be interrupted for sawing out the specimens from the drill cores and attaching the load bearing plates.

The central tensile test according to [2] is to be carried out at a load speed of (0.05 ± 0.01) N/(mm²s). The maximum load achieved yields the tensile strength:

$$f_t = \frac{4 \cdot F}{\pi \cdot d^2} = 1.27 \cdot \frac{F}{d^2}$$

f_t = tensile strength in N/mm²
F = maximum load in N
d = diameter of the specimen in mm

Further information on the removal of the drill cores and the performance of the test can be found in [1] and [2].

A1.3.2 Pull-off test

As a general rule, the pull-off test according to [5] is carried out on test surfaces that are limited by an annular groove with an internal diameter of 50 mm.

For concrete replacement systems and hard coatings (OS 5b (OS DI)), the annular groove must be produced by wet drilling with a force-guided diamond drill bit perpendicular to the surface. The depth should be approximately 5 to 10 mm greater than the layer thickness of the repair system. The test surface should be levelled before free drilling if necessary. A test stamp with a diameter of (50 ± 0.5) mm and a minimum thickness of 25 mm shall be glued to the prepared and cleaned test surface.

For soft coatings (OS 4 (OS C), OS 5a (OS DII)), the test surface must be cut through to the concrete after the test stamp has been affixed. The cut must be flush with the lateral surface of the test stamp. A utensil such as a sharp knife can be used as a cutting device.

For concrete replacement systems and hard coatings, the pull-off test is to be carried out at a loading speed of (100 ± 20) N/s, for soft coatings of (300 ± 20) N/s. The maximum load gives the breaking strength f_h. The breaking strength f_h is to be calculated in the same way as the tensile strength f_t in Section A1.3.1.

Further instructions on carrying out the test can be found in [3] and [4].

A1.4 Evaluation

Individual values, mean values and standard deviations as well as the smallest individual value of a test series are to be rounded to 0.1 N/mm². In addition, for each individual value, the respective area fraction of the failure type must be estimated and reported at 10%. The failure modes are designated in accordance with [5]:

A = cohesion failure in the concrete substrate or in the sublayer
A/B = adhesion failure on the bonding plane of the concrete substrate/concrete replacement
B = cohesion failure in concrete replacement 1st layer
B/C = adhesion failure on bonding plane 1st layer/2nd layer
C = cohesion failure in concrete replacement 2nd layer, etc.
...
Y/Z = Adhesion failure on the bonding plane adhesive/test stamp

Form for the tensile or pull-off test

Sheet

Structure no. | Construction measure: | Construction section: | Component:

Assigned test surface:

Company or institute commissioned with the test:

Test date: _____

Date of completion of test material: _____

Temperature of test material: _____°C

Test device specifications:

Device type no.: _____

Measuring range: _____

Test stamp diameter: 50 mm

Test performance

Drilling depth (pull-off test) (mm) _____

Drill core height in tensile test (mm): _____

Location of the bonding plane (distance from drill core surface) (mm) _____

Core diameter (mm): _____

Adhesive: _____

Load increase rate: 100 N/s[1] ☐ 300N/s[2] ☐

Test material

Unprepared concrete substrate ☐

Prepared concrete substrate ☐

Concrete replacement system ☐

Surface protection system ☐

No	Maximum load F (N)	Breaking strength or bond strength: single value (N/mm²)	Breaking strength or bond strength: Mean value (N/mm²)	Type of failure as % of fractured area: Cohesion failure A	B	C	D	Y	Adhesion failure A/B	B/C	C/D	-/Y Y/Z
Cohesion failure			Adhesion failure						Designation of layer			

Date, signatures:

_____ _____ _____

Tester Contractor Client

_____

1) for hard test material

2) for elastic and thermoplastic test material

A – In concrete or base layer

B - In the first layer of the test material

C - In the second layer of the test material

...

Y - In the adhesive layer

A/B - between concrete (or base) and the first layer of the test material

B/C - between the first and second layers of the test material

...

-/Y - between the last layer of the test material and the adhesive layer

Y/Z - between adhesive layer and stamp

A =

B =

C =

Annex 2: Technical test requirements – Anchor tensile test

A2.1 Purpose and scope of application

The test serves to assess the bond between the steel surface of the anchor rods and the injection or filling mortar as well as between the injection or filling mortar and the concrete substrate. In addition, the tensile strength of the concrete substrate is checked with regard to the transfer of the anchor forces into the overall structure (excavation cone).

A2.2 Cited standards and regulations

[1] DIN EN 1992-1-1 Design of reinforced concrete and prestressed concrete structures, Part 1-1, General design rules and rules for building construction, including National Annex

[2] DIN 19702 Solid structures in hydraulic engineering – bearing capacity, serviceability and durability

A2.3 Test procedure

As a general rule, anchors that are identical to the original anchors in terms of material, design and dimensions are to be arranged or selected as test anchors.

The measured variable of the anchor tensile test is the tensile standard force $F_{Prüf}$ to be applied axially to the anchor rod. The amount of the test force $F_{Prüf}$ results from the product of the anchor force N_{Ed} used in the structural analysis as the design value from the decisive design situation and the partial safety factor of the bearing resistance γ_c of the concrete substrate, see [1] or [2]:

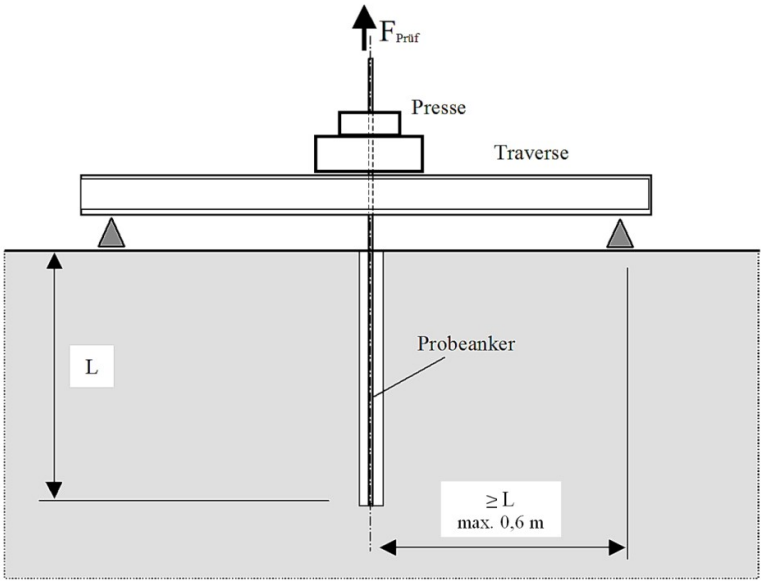
$$F_{Prüf} = \gamma_c \cdot N_{Ed} \leq A \cdot f_{yk}$$

F_{YK} Yield point
A Steel cross section

If more precise specifications are not available, $\gamma_c = 1.5$ is to be set.

The test force must be introduced axially into the respective test anchor. After reaching the final value $F_{Prüf}$, the test force must be kept constant for at least 10 minutes. No plastic deformation of the tie rod or damage to the concrete substrate or backfilling mortar may occur during the tensile test.

If the concrete substrate surrounding the test anchor is used as an abutment for the application of the test load, a tie-bar or similar implement must be used. The distance between the anchor axis and the tracer bearing must be greater than the anchor binding length L, but not more than 0.6 m (see Figure).



Presse	Press
Traverse	Tie-bar
Probeanker	Test anchor

Figure 1: Test arrangement anchor tensile test

A2.4 Evaluation

The results must be documented in a report. It must include at least the following specifications:

- Object, client of the construction measure, executing construction company, tester and client, date of test
- Data of the test anchors (location, borehole and anchor diameter, embedding depth)
- Date of test anchor installation
- Anchor material (steel, mortar)
- Strength development of the anchor mortar
- Test force $F_{Prüf}$
- Test equipment and measurement range
- Description of the test result (apparent absence of damage or details of the type of failure, e.g. pull-out of the anchor rod with or without excavation cone, bond failure of the backfilling or injection mortar or steel failure).

Annex 3: Technical test requirements – Determination of the water content of fresh mortar/fresh concrete by kiln drying

To determine the water content when calculating the w/c ratio of fresh mortar/fresh concrete, proceed as follows:

A sample of at least 5,000 grams of fresh concrete must be weighed into the drying vessel to an accuracy of 1 gram and dried quickly and thoroughly under constant stirring until no more lumps can be observed and no more vapour rises (check with a glass plate). The heat should be applied to as large an area as possible so that the sample is dry within 20 minutes at the latest. The dry and cooled sample is to be weighed. The resulting loss in mass corresponds to the water content of the sample.

Two tests are to be carried out. If the results of both trials differ by more than 20 grams, a third trial will be necessary. The arithmetic mean from the 2 or 3 tests is decisive for the assessment.

The core moisture of the aggregate must be taken into account in prior consultation with the client.

The time between the production of the fresh concrete and the start of the test may not exceed 1 hour.

Annex 4: Technical test requirements – Inhibited shrinkage

A4.1 Purpose and scope of application

The test is used to assess the tendency to tear of sprayed mortar/shotcrete as a result of impeded shrinkage.

A4.2 Cited standards and regulations

[1] DIN EN 10056-1:Structural steel equal and unequal leg angles - Part 1: Dimensions; German version EN 10056-1

[2] DIN 50014:Climates and their technical application; normal climates

A4.3 Test procedure

Depending on the maximum particle diameter of the sprayed mortar/shotcrete to be examined, angled steels with a free length of 1,000 mm are used as shrink gutters in accordance with DIN EN 10056-1 [1] (see Figures 1 and 2):

Maximum particle size $\leq$ 5 mm: L 70 x 7

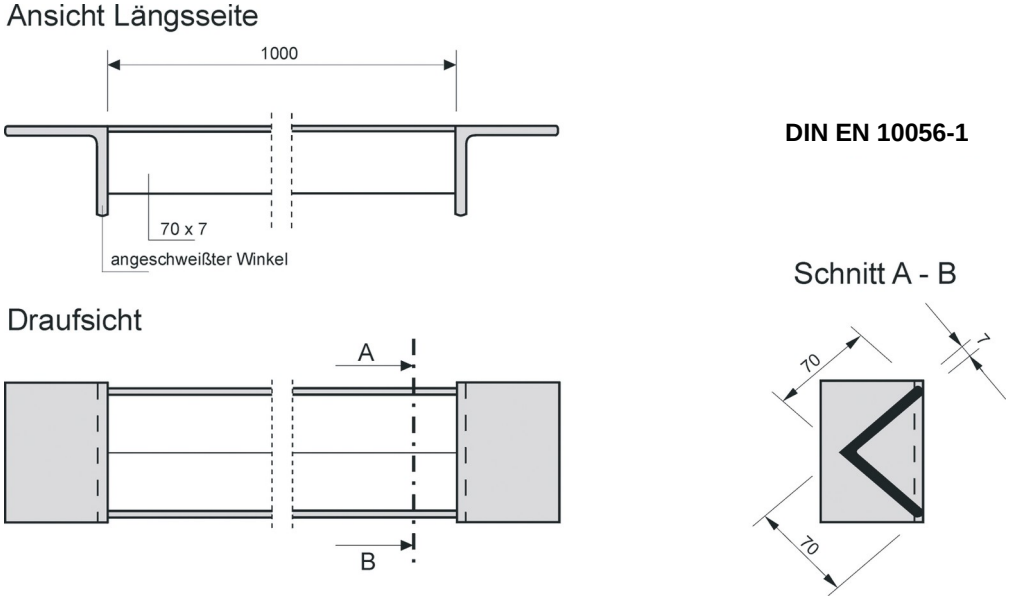
Maximum particle size > 5 mm: L 100 x 8

Two shrinkage channels are required to test a sprayed mortar/shotcrete.

The inner surfaces of the shrinkage channels must be roughened by blasting with a solid blasting agent before the start of the test. For injection of the sprayed mortar/shotcrete, the shrinkage channels with their longitudinal axis in the horizontal is to be arranged so that the surface of the installed sprayed mortar/shotcrete is in the vertical.

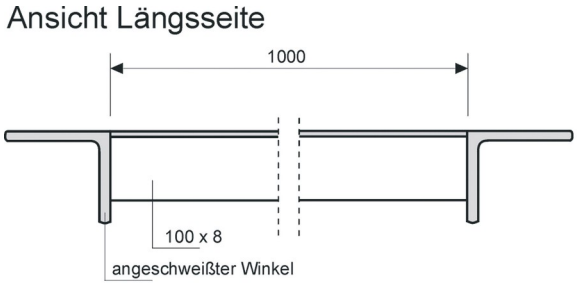
The sprayed mortar/shotcrete is injected horizontally into the shrinkage channels. Immediately after spraying, the sprayed mortar/shotcrete is to be removed flush with the edges of the shrink troughs. The shrink troughs must then be stored horizontally in the normal DIN 50014-23/50-2 [2] climate with the surface of the sprayed mortar/shotcrete facing upwards without covering.

The test specimens must be continuously examined for the formation of cracks and large-scale detachments.

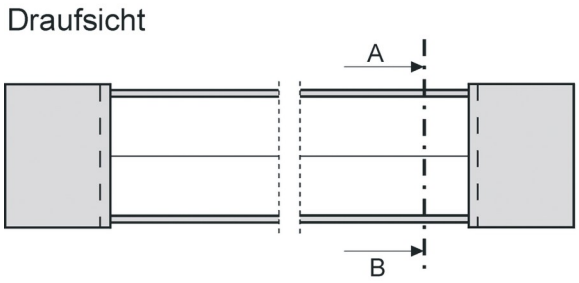


Ansicht Längsseite — View of longitudinal side
Draufsicht — Top view
Schnitt A - B — Section A - B

Figure 1: Shrinkage channel for maximum particle size ≤ 5 mm



DIN EN 10056-1



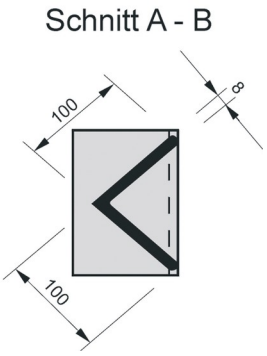
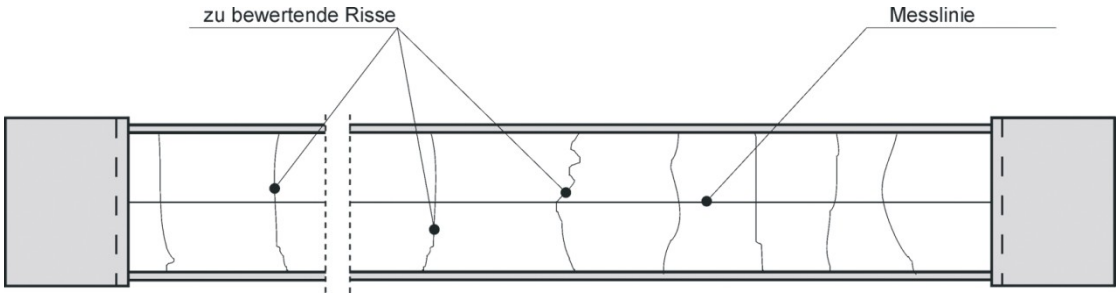


Figure 2: Shrinkage channel for maximum particle size > 5 mm

A4.4 Evaluation, documentation

28 days after application of the sprayed mortar/shotcrete, any cracks that may have appeared must be measured along the centre line of the surface as shown in Fig. 3. Specify the number of cracks, the average and maximum crack width with an accuracy of 0.02 mm and the time of cracking. In addition, the extent and timing of the emergence of any existing replacements must be documented.



zu bewertende Risse — Cracks to be assessed
Messlinie — Measurement line

Figure 3: Example of crack measurement

Annex 5: Technical test requirements – Durability under changes in water stress

A5.1 ZPurpose and scope of application

The test is used to assess the durability of concrete replacement systems in hydraulic areas of freshwater and seawater structures.

A5.2 Cited standards and regulations

[1] RL SIB Part 4:DAfStb Guideline on the protection and repair of concrete structural elements (Repair Guideline), Part 4: Test procedure

[2] DIN 50014:Climates and their technical application; normal climates

[3] DIN 50905 Part 4:Corrosion of metals; Corrosion testing; Performance of chemical corrosion experiments without mechanical stresses in liquids in the laboratory

A5.3 Test procedure

In the case of hand-applied concrete replacement, 4 sets of prisms as for the test of flexural tensile strength according to RL SIB Part 4, Section 2.5 (PCC), in the case of sprayed mortar/shotcrete (unanchored, unreinforced) 4 sets of prisms as for the test according to RL SIB Part 4, Section 3.6 (SPCC, sprayed samples) [1] are produced from a mixture. The prisms for the manually applied concrete replacement are kept moist in the mould for 2 days, the sprayed mortar/shotcrete (unanchored, unreinforced) is kept moist in the spray pan for 2 days and then sawn using the wet-cut method.

At the age of 2 days, 2 sets of prisms are stored under fresh water at 20 ± 3 °C or in a normal climate DIN 50014 - 23/50-2 [2]. Demineralised water is to be used for storage under fresh water.

At the age of 7 days, the seawater exchange storage starts on the two prism sets previously stored in fresh water. A cycle of this storage includes 1 week of storage in seawater of 20 ± 3 °C after [3] and 1 week of storage in normal climate 23/50. The prisms are loaded with 6 cycles in total.

The storage tanks for freshwater and seawater storage shall be designed so as to maintain a prism/liquid volume ratio of 1/3. The prisms are to be stored on round glass or plastic rods. The storage containers must be sealed. The liquid of the seawater storage must be changed after 42 days (3 cycles), whereby the storage containers must be cleaned before filling the fresh liquid. Any deposits on the prisms should only be rinsed under running water when changing the liquid (do not brush).

All four prism sets are tested for bending tensile strength at 91 days of age. At the end of each storage period (wet, wet, dry storage), the prism masses are determined for control purposes.

A5.4 Assessment

The durability of the manually applied concrete replacement or the sprayed mortar/shotcrete (unanchored, unreinforced) is assessed on the basis of the relative flexural tensile strength after alternating seawater storage in relation to the flexural tensile strength after storage in a normal climate 23/50. The individual values and mean values of the bending tensile strength and the quotient from the two mean values are to be indicated in % with an accuracy of 1%.

Annex 6: Technical test requirements – Determination of fresh mortar/fresh concrete

A6.1 Bulk density of fresh sprayed mortar/shotcrete

A6.1.1 Production

(1) Spray pans as shown in Figure 1 are to be used. The inner surfaces of the spray pans must be roughened by blasting with a solid abrasive.

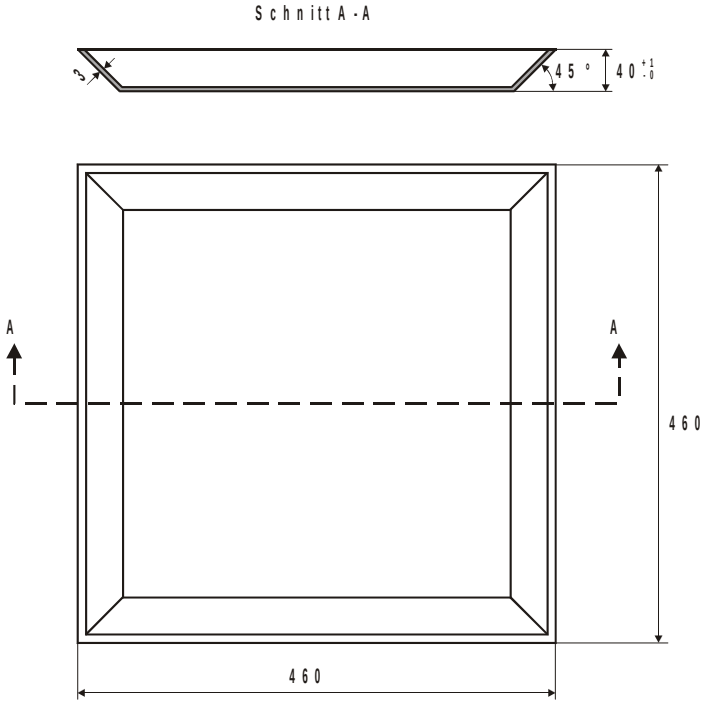


Figure 1: Spray pan made of sheet steel, dimensions without tolerance specifications according to DIN ISO 2768-1 in [mm]

(2) The spray pan must be sprayed in a single work step. Once the spraying process is complete, the spray pan must be removed immediately from the spray booth, and the surface must be removed and smoothed.

A6.1.2 Testing

Bulk density is to be determined by weighing and measuring the volume of the sample sprayed in the spray pan. The test must be carried out immediately after the completion of the spraying process in question.

A6.2 Consistency and air content of the manually applied concrete replacement

A6.2.1 Production

(1) The production of the fresh mortar is carried out in observance of DIN EN 196-1, Sections 4 and 6. The manufacturer's specifications on the mixing of the concrete replacement products should be observed.

(2) The mortars are to be mixed with the minimum and maximum amount of liquid added.

(3) The components must be weighed with an accuracy of at least 1 ‰.

(4) The mixing time and mixing sequence are to be specified by the manufacturer. Type of forced mixer, mixing time and mixing sequence are to be specified in the test report.

A6.2.2 Testing

(1) The consistency must be determined immediately after mixing or the maturing time specified by the manufacturer (if any) in accordance with [1].

(2) The air content must be determined immediately after mixing or the maturing time specified by the manufacturer (if any) in accordance with [2].

A6.3 Standards and regulations

[1] DIN EN 1015-3:Methods of test for mortar for masonry - Part 3: Determination of consistence of fresh mortar (by flow table)

[2] DIN EN 1015-7:Methods of test for mortar for masonry - Part 7: Determination of air content of fresh mortar

Annex 7: Determination of consumption quantities and dry layer thicknesses of surface protection systems

A7.1 Dimensioning approach for determining the application quantities for surface protection systems

(1) The following equations are to be used to determine application quantities to achieve the required minimum layer thicknesses of the primary effective surface protection layer (hwO). Relevant layer thickness parameters are shown in Table 1.

At $d_{min,P}$ $$m'' = \frac{\rho_{coat}}{FV} (d_{min,P} + 1{,}64\,\sigma_{x,max})\,(1 + k_v)\,(1 + k_u) \quad [g/m^2] \qquad (1)$$

At $d_{ist,m}$ $$m'' = \frac{\rho_{coat}}{FV} d_{ist,m}\,(1 + k_v)\,(1 + k_u) \quad [g/m^2] \qquad (2)$$

In which:

$d_{min,P}$	product-specific minimum layer thickness	[µm]
$d_{ist,m}$	actual mean layer thickness	[µm]
$m“$	application quantity	[g/m²]
ρ_{coat}	censity of the coating material	[g/cm³]
FV	proportion of solids in the coating material by volume	[-]
$\sigma_{x,max}$	maximum sample standard deviation	[µm]
k_v	Factor for taking processing loss into account	[-]
k_u	factor for consideration of subsurface roughness	[-]
ssa	standard deviation of the sample	[µm]

(2) The parameters $\sigma_{x,max}$ and k_v are predominantly within the responsibility of the executing company and must be specified by it.

Note 1: The values can be reduced to a statistically unavoidable level with appropriate craftsmanship during application.

Note 2:The scattering of layer thickness distributions can be minimised against the technical and economic background using the coefficient of variation (V_x) (Eq. 3). As a rule, the coefficient of variation is 0.15 and should not exceed 0.20.

$$V_x = \frac{ssa}{d_{ist,m}} \quad [-] \qquad (3)$$

(3) After substrate preparation (roughness) or substrate pre-treatment (evenness), a new k_u factor must be determined.

Note: The parameter k_u largely depends on the nature of the substrate to be coated.

Table 1: Example parameters for determining consumption quantity

Surface protection system	Minimum layer thickness $d_{min,S}$ of the primary effective surface protection layer (hwO) [µm]	SSA for V_x 0.15 - 0.20	min. k_v	min. k_u
		[µm]	[-]	[-]
1	2	3	4	5
OS 4 (OS C)	80	24 - 35[a]	0.03	0.10
OS 5a (OS DII)	300	60 - 90	0.03	0.10
OS 5b (OS DI)	2 000	400 - 600	0.03	0.10

[a] Deviation due to surface roughness or processing material and quantity

A7.2 Determination of dry film thicknesses for OS 5 (OS D)

(1) To determine the layer thicknesses using the wedge cut method or differential layer thickness method, at least 30 measured values are determined for every 250 m² or part thereof.

(2) As an alternative to (1), 3 cores (test series) with a diameter of 25 to 50 mm are taken for every 250 m² or part thereof, cut perpendicular to the core axis (fine section) and the cut surface is measured under an optical microscope after entering balance lines.

(3) For the evaluation under Section 7.6.3 ZTV-W LB 219, a relevant layer thickness $d_{ist,i}$ between the respective equalisation lines is determined for each drill core. The following measurement values are to be specified:

a) $d_{ist,m}$: mean value of the test series of three drill cores;
b) $d_{ist,i,min}$: the smallest single value of the test series;
c) $d_{ist,i,max}$: largest single value of the test series.

Annex 8: Monitoring of execution by the executing company

The following table summarises the nature, scope and frequency of audits in the context of the monitoring of execution by the executing company for measures under Sections 1 to 8 of ZTV-W LB 219. For the Sections 3 and 4 of ZTV-W LB 219, the tests according to DIN 1045-3 or DIN EN 14487 / DIN 18551 must also be carried out.

Note: The table should serve as a guide for the user. The requirements in Sections 1 to 8 of ZTV-W LB 219 are decisive for the fulfilment of the contract.

	Test object	**Type of test/size**	**Concrete monitoring classes 2 and 3** [1)]	**Shotcrete reinforced** [2)]	**Shotcrete/ mortar not reinforced** [2)]	**Concrete replacement/ Manually applied unreinforced** [2)]	**Surface protection**	**Injection products**	**Requirements**	**Requirement, frequency, time**
1	**General**									
1.1	Construction contract	Instructions for construction execution	X	X	X	X	X	X	Conformity of the specifications with the construction contract including repair plan and stability assessment in accordance with Section 1.2	Prior to start of work
1.2	Stability	Documents, Designation	X	X	X	X	X	X	Written stability assessment by client as per Section 1.2.4 on hand? Appointment of contractor's responsible person as per Section 1.2.4	Prior to start of work
1.3	Recognised monitoring body	Registration, contract	X	X	X	X	X	X	Monitoring of the measure by a monitoring body recognised for this purpose as per Section 1.6.1.3	Prior to start of work
1.4	Concept, plan	Submission to client	X	X	X	X	X	X	Concept, plan as per Section2.3.1 or 3.5.1 or 4.5.1 or 5.5.1 or 6.5.1 or 7.5.4	Concept 4 weeks prior to execution, plan 3 work days prior to execution
2	**Substrate**									
2.1	Concrete substrate	Visual inspection	X	X	X	X	X	X	Suitability of the concrete substrate for the planned measure as per Section 1.5.1 and 2.3.1; presence of client	Before the start of the subsoil preparation, after the completion of the subsoil preparation or before the application of the concrete replacement / surface protection system
2.2		Surfaces	X	X	X	X	X	X	Quality as per Section 2.3.2 or 4.5.3 and DIN 18551 No 5.2.2	
2.3		Formation of areas to be repaired	X	X	X	X		X	Quality as per Section 3.3 or 4.3 or 5.3 or 6.3	After completion of substrate preparation
2.4		Test areas	X	X	X	X	X	X	Suitability of the procedure for substrate preparation as per Section 2.2	Prior to start of work, in consultation with the client

	Test object	Type of test/size	Concrete monitoring classes 2 and 3 [1]	Shotcrete reinforced [2]	Shotcrete/ mortar not reinforced [2]	Concrete replacement/ Manually applied unreinforced [2]	Surface protection	Injection products	Requirements	Requirement, frequency, time
2.5	Concrete substrate	Roughness depth as per TR-IH Part 1, Table 8 or reference sample					X		Compliance with the manufacturer's binding 'execution instructions'	Before application of surface protection system; 3 measuring points per test area
2.6		Breaking strength after substrate preparation	X	X	X	X	X		Achievement of values in accordance with Table 2 .11	For every 250 m² of installation area or part thereof, 5 individual values from the test area as per Section 2.4
2.7		Comparison of the achievable layer thickness with the construction contract	X	X	X	X			Compliance with the specifications in the construction contract and Sections 3.1 and 3.3.2, 4.1 and 4.3, 5.1 and 5.3, 6.1 and 6.3	Each work section
2.8		Comparison of achievable concrete cover with construction contract	X	X	X	X			According to construction contract and Section 1.3.2	
2.9		Construction joints	X						Professional training as per Section 1.3, 3.3.2, 3.5.4 and 4.5.4	
2.10		Anchor holes	X	X					Compliance with the requirements under Section 3.3.2 or 4.3.2	
2.11		Reinforcement with repair principle R (visual inspection)	X	X	X	X			Surface preparation level St 2 or SA 2 as per Section 2.2.3	
2.12	Substrate	Temperature	X	X	X[3), 7)]	X	X	X	Compliance with the requirements under Section 1.5.4 or the manufacturer's binding 'execution instructions'	Prior to start of work, in the event of changes in temperature/weather

	Test object	Type of test/size	Concrete monitoring classes 2 and 3 [1]	Shotcrete reinforced [2]	Shotcrete/ mortar not reinforced [2]	Concrete replacement/ Manually applied unreinforced [2]	Surface protection	Injection products	Requirements	Requirement, frequency, time
2.13		Humidity	X	X	X	X		X	Compliance with specifications under Section 3.5.4.1 or 4.5.7 or 5.5.5 or 6.5.2	Each layer prior to application
2.14		Moisture and dew point, concrete base and building materials					X		Compliance with the manufacturer's binding 'execution instructions'	Prior to start of work, in the event of changes in temperature/weather
3	**Materials prior to processing**									
3.1	Transfer of substances belonging to the system	Delivery note and packaging label, product name, batch number			X[3]	X	X	X	Product name, packaging label	Every delivery
3.2		Visual inspection			X[3]	X	X	X	No noticeable changes, undamaged containers	
3.3	Storage	Storage conditions, expiration/ production date, permissible storage period			X[3]	X	X	X	According to the manufacturer's binding 'execution instructions'	Prior to application or during storage
3.4	Selection	Scope of application	X						Compliance with specifications under Section 3.2	Prior to start of work
3.5				X					Compliance with specifications under Section 4.2	
3.6					X				Compliance with specifications under Section 5.2	
3.7						X			Compliance with specifications under Section 6.2	
3.8							X		Compliance with specifications under Section 7.2	

	Test object	Type of test/size	Concrete monitoring classes 2 and 3 [1)]	Shotcrete reinforced [2)]	Shotcrete/ mortar not reinforced [2)]	Concrete replacement/ Manually applied unreinforced [2)]	Surface protection	Injection products	Requirements	Requirement, frequency, time
3.9								X	Compliance with specifications under Section 8.2	
3.10		Scope, structure, system-specific minimum layer thickness					X		Compliance with specifications under Section 7.4	
3.11		Maximum particle size	X	X	X	X			Sections 3.4 and DIN 1045-2, 5.2.3	
3.12	Non-standard constituent substances	Visual inspection	X	X					General building inspectorate approvals or European technical assessments	
3.13	Proof of usability	Visual inspection			X[3), 7)]	X	X	X	Conformity with the substance systems to be used, safety data sheets, packaging labels	Prior to start of work
3.14	Mixing instructions	Visual inspection			X[3), 7)]	X	X	X	Conformity with the manufacturer's binding 'execution instructions'	
3.15	Fresh mortar/ concrete or fine levelling compound for surface protection	Mixture composition (visual inspection)		X	X[3), 7)]	X	X	X	Exclusion of gross deviations from the specified properties or from the conditions of the initial test	During the first processing of the building material, then at appropriate intervals thereafter.
3.16		Mixing instructions			X[3), 7)]	X	X	X	Conformity with the manufacturer's binding 'execution instructions'[7)]	
3.17		Added water	X	X	X	X		X	Compliance with specifications under Section 1.4 and 3.4.2	

	Test object	Type of test/size	Concrete monitoring classes 2 and 3 [1)]	Shotcrete reinforced [2)]	Shotcrete/ mortar not reinforced [2)]	Concrete replacement/ Manually applied unreinforced [2)]	Surface protection	Injection products	Requirements	Requirement, frequency, time
3.18		Consistency (visual appearance), sufficient mixing effect, compliance with mixing times (visual inspection)	X	X	X	X	X		Uniform mixing result	Every mixture
3.19		Uniformity (visual test)	X				X		Homogeneous appearance	Each mixture or delivery of ready-mixed concrete
3.20		Flow spread and air content as per DIN EN 1015-3 and DIN EN 1015-7				X			Compliance with specifications under Section 6.6.2	1 test per work day
3.21		Consistency	X						Compliance with specifications under Section 3.4.4 and 3.6.2	Each mixture or delivery of ready-mixed concrete
				X					Compliance with specifications under Section 4.6.1 and DIN EN 14487-1, Table 11	Base mixture at the start of production
3.22	Fresh mortar/ concrete or fine levelling compound for surface protection	Air content of air-entrained concrete	X						Compliance with specifications under Section 3.4.4 and 3.6.2	Upon handover: each vehicle At installation site: first 10, then every 10th vehicle, albeit at least once per day of concreting
3.23		Bulk density of the fresh concrete			X				Compliance with specifications under Section 5.6.2	Per 100 m², at least per work day
3.24		Consistency (for cement paste ZL and cement suspension ZS)						X	Compliance with specifications under Section 8.6.2	Every mixture

	Test object	Type of test/size	Concrete monitoring classes 2 and 3 [1]	Shotcrete reinforced [2]	Shotcrete/ mortar not reinforced [2]	Concrete replacement/ Manually applied unreinforced [2]	Surface protection	Injection products	Requirements	Requirement, frequency, time
3.25		Fresh concrete temperature	X	X	X		X		≤ 28 °C as per Section 3.4.4 and 3.5.4 or 4.5.7 or 5.5.5	Every mixture
4	**Processing**									
4.1	External conditions	Temperature	X	X	X	X	X	X	Compliance with specifications under Section 1.5.4 or manufacturer's binding 'execution instructions'	Continuous as per RL SIB Part 3, 2.2.1 (thermo-hygrograph)
4.2		Relative air humidity					X			
4.3	Component temperature	Component	X					X	Compliance with specifications under Section 1.5.4	During the first 7 days after installation
4.4	Bonding layer	Visual inspection	X			X			Compliance with specifications under Section 3.4.3 and 3.5.4.1 and/or 6.4 and 6.5.2	Each layer
4.5	Concrete cover	Concrete cover thickness	X	X	X	X			Compliance with specifications under Section 1.3.2	Each work section
4.6	Layer thickness	Thickness of individual layers		X	X	X			Compliance with determinations in the specification of works or under Section 4.3, 4.5.6 and DIN EN 14487/DIN 18551 No 9.1 and 10.2 or manufacturer's binding 'execution instructions' or usability assessment	Each course
4.7		Determination of the consumption and installation quantities of the individual layers					X		Compliance with the requirements set out in the manufacturer's binding 'execution instructions' or in the specification of works.	Every stage of work and every shift
4.8	Reinforcement/ formwork	Fastening and position of the reinforcement/ formwork (visual inspection)	X	X[4]	X[4]	X[4]			Sufficient positional stability, cement-bound spacers, tightness, low resilience during spraying; compliance with the specifications under Section 3.5.2 and 3.5.3 and/or 4.5.5 and DIN EN 14487/DIN 18551 No. 6	Each work section

	Test object	Type of test/size	Concrete monitoring classes 2 and 3 [1]	Shotcrete reinforced [2]	Shotcrete/ mortar not reinforced [2]	Concrete replacement/ Manually applied unreinforced [2]	Surface protection	Injection products	Requirements	Requirement, frequency, time
4.9	Post-treatment and protection	Type and duration	X	X	X	X			Compliance with specifications under Section 1.5.5 and/or 3.5.4.6 and/or 4.5.7 4.5.8 5.5.5 and/or5.5.6 6.5.2and/or 6.5.3 in the usability assessment	Each layer
4.10		Type and duration of weather protection					X	X	According to the manufacturer's binding 'execution instructions'	Each layer
5	**Hardened substances**									
5.1	Bond quality	Bond strength		X[5]	X	X	X[8]		Compliance with specifications under Section 5.6.3 or 6.6.3 or 7.6.3; testing in presence of client	5 values (for surface protection 3 values) per started 250 m² installation area or per component
5.2		Voids or bonding disturbances		X	X	X	X	X	Definition of voids/bond disturbances as per Section 4.6.2 or 5.6.3 or 6.6.3 or 7.6.3 or 8.6	All completed surfaces
5.3	Durability	Frost resistance and resistance to frost and de-icing salt	X						Compliance with specifications under Section 3.4.5 and 3.4.6 or 4.4.3 and 4.6.2 or 5.4	1 test series of 5 test specimens as per Sections 3.4.6 and 3.6.2; if necessary, a larger number of test series as per construction contract
5.4				X	X[6]					5 values per started 500 m² installation area or per component
5.5		Water penetration resistance	X						Maximum penetration depth of 30 mm as per Section 3.4.5 at w/c ≥ 0.55	3 specimens per 50 m³ or per day of concreting
5.6				X					Maximum penetration depth of 30 mm as per Section,4.4 and 4.6.2	5 values per started 250 m² installation area or per component
5.7	Strength	Compressive strength	X						Compliance with specifications under Section 3.6.2, taking into account the acceptance criteria as per DIN 1045-3, Annex B	3 specimens per 50 m³ or per day of concreting

	Test object	Type of test/size	Concrete monitoring classes 2 and 3 [1)]	Shotcrete reinforced [2)]	Shotcrete/ mortar not reinforced [2)]	Concrete replacement/ Manually applied unreinforced [2)]	Surface protection	Injection products	Requirements	Requirement, frequency, time
5.8				X					Compliance with specifications under Section 4.6.2, taking into account the acceptance criteria as per DIN EN 14487-1, Table 13	5 values per started 250 m² installation area or per component
5.9	Layer thickness	Thickness of primary effective surface protective layer					X		Compliance with the specification in accordance with the manufacturer's binding 'execution instructions'; test in presence of client	5 values per started 250 m² installation area or per component
5.10	Density	Dry bulk density			X	X			Compliance with specifications under Section 5.6.3 or 6.6.3	On all drill cores of the bond strength test
6	**Technical equipment**									
6.1	Measuring devices	Visual inspection			X	X	X	X	Flawless functioning	At the start of the work, weekly thereafter
6.2	Mixing tools	Functional check			X	X	X	X		At the start of the work, monthly thereafter
6.3	Conveying, spraying and feeding equipment		X	X	X	X	X	X		At the start of the work, weekly thereafter
6.4	Compaction equipment		X			X				
6.5	Measuring, testing and laboratory equipment		X	X	X	X	X	X	Sufficient accuracy of measurements	Upon commissioning, at appropriate intervals thereafter
6.6	Hose	Hose length		X	X			X	Hose length according to suitability test and manufacturer's binding 'execution instructions' in the suitability assessment	Prior to start of work

[1] in addition to DIN 1045-3
[2] in addition to DIN EN 14487/DIN 18551
[3] for factory made shotcrete/sprayed mortar
[4] edge formwork, if applicable
[5] only for layer thicknesses < 150 mm
[6] for shotcrete/mortar not manufactured in the factory
[7] for mixed-site shotcretes/sprayed mortars, see proof of usability
[8] only for OS 4 and OS 5 with fine filler

Annex 9: Protective devices against weathering influences

A9.1 General

Protective devices against the effects of weather are stationary or movable scaffolding fitted with tarpaulins or other covers.

A9.2 Principles of application

Protective devices against atmospheric influences are to be designed so that the processing conditions of the substances and material systems intended for installation can be complied with.

Occupational health and safety regulations must be complied with. The contractor must coordinate all constructions and technical execution measures required for occupational health and safety with the responsible supervisory authorities.

A9.3 Requirements

Protective devices against atmospheric influences must be designed, executed and maintained so that their stability and road safety are guaranteed at all times. The proper condition of passive protective equipment and other additional measures for traffic safety must also be ensured during non-working hours.

Simple and quick installation and realisation must be possible.

DIN EN 16508 must be observed.

Design of safety guards

The type, number and dimensions of the protective devices against weather influences must be adapted to the object, intended design, local and traffic conditions and processing time. These include the following in particular:

- planned daily output,
- temperature-related downtimes, e.g. heating and hardening time,
- total construction time,
- feasibility,
- clear spaces to be kept free from active transport facilities,
- protection distances and safety provisions for work in the area of overhead line systems and other electrical overhead lines.

Loading of existing structures and parts of structures

The permissible loads of affected structures and parts of structures must not be exceeded.

Auxiliary structures for anchoring to the structure must be agreed upon with the client during the planning phase and must be approved in writing.

Damage to structural components must be avoided as far as possible. Any repairs that nevertheless become necessary are to be carried out by the contractor, unless otherwise stipulated in the specification of works. This applies to the dismantling of anchoring elements in particular.

Structural design

The outer skin of the protective device must be tear-resistant and flame retardant.

The protective devices must be designed in so that precipitation, surface and spray water as well as mist are kept away from the surfaces to be worked on.

Water must be drained off without causing damage. The construction under flexible roof skin must be designed so as to prevent water from accumulating.

Drainage of condensation onto the surfaces to be treated must be prevented.

Working conditions

The interior must be illuminated so as to ensure an orderly workflow.

The clear interior dimensions must be adapted to the work to be carried out under or in the protective equipment against the effects of the weather, whereby a minimum clearance height may not be any lower than 2.00 m.

Sufficient ventilation must be ensured. The ventilation must not lead to faulty execution.

A9.4 Execution documents

Structural proofs and implementation plans are required for the weather protection devices. This includes proof that the resulting additional loads do not exceed the permissible stresses of the affected parts of the structure. These documents must be submitted inspected by a test engineer unless otherwise specified in the specification of works.

The documents examined must be available on the construction site during construction.

The contractor must draw up an execution report in which the conformity of the structure of the protective equipment against the effects of weather is certified with the reviewed documents.

Construction work under or in the protective device may only begin after the execution report has been submitted.

Annex 10: List of cited documents

BAW-MATB	Bundesanstalt für Wasserbau [Federal Institute for Hydraulic Engineering], Karlsruhe
Code of Practice ‘Determination of the adiabatic temperature rise of concrete’	
BAW-MAB	Bundesanstalt für Wasserbau, Karlsruhe
Code of practice ‘Sealing of expansion joints’	
BAW-MBM	Bundesanstalt für Wasserbau, Karlsruhe
Code of practice ‘Construction and repair of massive hydraulic structures in seawater area’	
BAW-MDCC	Bundesanstalt für Wasserbau, Karlsruhe
Code of practice ‘Durability assessment and evaluation of reinforced concrete structures with carbonation and chloride exposure’	
BAW-MESB	Bundesanstalt für Wasserbau, Karlsruhe
Code of practice ‘Separation sensitivity of concrete’	
BAW-MFB	Bundesanstalt für Wasserbau, Karlsruhe
Code of practice ‘Frost testing of concrete’	
BAW-MZB	Bundesanstalt für Wasserbau, Karlsruhe
Code of practice ‘Second stage concrete’	
DAfStb Volume 422	Deutscher Ausschuss für Stahlbeton (DAfStb) [German Committee for Reinforced Concrete]
Testing of concrete. Recommendations and notes to supplement DIN 1048	
DAfStb Volume 638	Deutscher Ausschuss für Stahlbeton (DAfStb) Application aid for the DIBt Technical Rules for the Maintenance of Concrete Structures (TR IH) in conjunction with the DAfStb Guideline on Protection and Repair of Concrete Structures (RL SIB)
DBV-Injektionsschlauch [Injection Hoses]	Deutscher Beton- und Bautechnik-Verein E.V. [German Concrete and Construction Engineering Association]
DBV code of practice ‘Injection hose systems and swellable inserts for construction joints’	
DBV-Frischbeton [Fresh Concrete]	Deutscher Beton- und Bautechnik-Verein E.V. DBV code of practice ‘Special procedures for testing fresh concrete’
DBV-Riss [Cracks]	Deutscher Beton- und Bautechnik-Verein E.V.
DBV code of practice ‘Limiting crack formation in reinforced concrete and prestressed concrete construction’	
DBV-Sichtbeton [Exposed Concrete]	Deutscher Beton- und Bautechnik-Verein E.V.
DBV code of practice ‘Exposed concrete’	
DBV-Betonierbarkeit [Concreting Capability]	Deutscher Beton- und Bautechnik-Verein E.V.
DBV code of practice ‘Concreting capability of components made of concrete and reinforced concrete’	
DIN 488	Reinforced steel
DIN 1045-1	Concrete, reinforced concrete and prestressed concrete structures - Part 1: Planning and design
DIN 1045-2	Concrete, reinforced concrete and prestressed concrete structures - Part 2: Concrete – Specification, performance, production and conformity – Application rules for DIN EN 206-1
DIN 1045-3	Concrete, reinforced concrete and prestressed concrete structures - Part 3: Execution of structures – application rules for DIN EN 13670
DIN 1045-1000	Concrete, reinforced concrete and prestressed concrete structures - Part 1000: Basic principles and quality classes of concrete construction (BBQ)
DIN 1055-4	Actions on structures – Part 4: Wind loads
DIN 1055-5	Actions on structures – Part 5: Snowloads and ice loads
DIN 1164-10	Special cement - omposition, requirements, certificate of conformity, Edition 2023-02
DIN 1164-11	Special cement – Part 11: Cement with short setting time - Composition and requirements, Edition 2023-02

DIN 7865-1	Elastomeric-Waterstops for sealing joints in concrete – Part 1: Shapes and dimensions
DIN 7865-2	Elastomeric-Waterstops for sealing joints in concrete – Part 2: Material requirements and testing
DIN 7865-3	Elastomeric-Waterstops for sealing joints in concrete – Part 3: Scope of use
DIN 7865-5	Elastomeric-Waterstops for sealing joints in concrete – Part 5: Conformity assessment
DIN 18197	Sealing of joints in concrete with waterstops
DIN 18200	Assessment of conformity for construction products – factory production control, external surveillance and certification
DIN 18202	Tolerances in building construction – Buildings
DIN 18349	General technical specifications in construction contracts (ATV) – Repair work on concrete structures – DIN 18349
DIN 18551	Sprayed concrete – National rules for series DIN EN 14487 and rules for design of shotcrete constructions
DIN 19702	Solid structures in hydraulic engineering – load-bearing capacity, usability and durability
DIN 50014	Climates and their technical application; standard atmospheres
DIN 50905-4	Corrosion of metals; Corrosion testing; Performance of chemical corrosion experiments without mechanical stresses in liquids in the laboratory
DIN 52170-1	Determination of composition of hardened concrete: general, terms, sampling, dry-bulk density
DIN EN 196-1	Methods of testing cement – Part 1: Determination of strength
DIN EN 196-8	Methods of testing cement – Part 8: Heat of hydration – Solution method
DIN EN 196-11	Methods of testing cement – Part 11: Heat of hydration - Isothermal Conduction Calorimetry method
DIN EN 197-1	Cement - Part 1: Composition, specifications and conformity criteria for common cements.
DIN EN 197-4	Cement - Part 4: Composition, specifications and conformity criteria for low early strength blast furnace cements
DIN EN 206-1	Concrete – Part 1: Specification, properties, construction and performance
DIN EN 450	Fly ash for concrete. Definition, specifications and conformity criteria
DIN EN 934-2	Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures - Definitions and requirements, conformity, marking and labelling
DIN EN 1008	Mixing water for concrete
DIN EN 1015-3	Methods of test for mortar for masonry – Part 3: Determination of consistence of fresh mortar (by flow table)
DIN EN 1015-7	Methods of test for mortar for masonry – Part 7: Determination of air content of fresh mortar
DIN EN 1097-6	Tests for mechanical and physical properties of aggregates – Part 6: Determination of particle density and water absorption
DIN EN 1542	Products and systems for the protection and repair of concrete structures – Test methods – Measurement of bond strength by pull-off test
DIN EN 1766	Products and systems for the protection and repair of concrete structures – Test methods – Reference concretes for testing
DIN EN 1992-1-1	Design of reinforced concrete and prestressed concrete structures, Part 1-1, General design rules and rules for building construction, including National Annex

DIN EN 10056-1	Structural steel equal and unequal leg angles – Part 1: Dimensions
DIN EN 10204	Metallic products – Types of inspection documents;
DIN EN 12350	Testing fresh concrete
DIN EN 12390	Testing hardened concrete
DIN EN 12504-1	Testing concrete in structures – Part 1: Cored specimens; Taking, examining and testing in compression
DIN EN 12620	Aggregates for concrete
DIN EN 13055-1	Lightweight aggregates – Part 1: Lightweight aggregates for concrete, mortar and grout
DIN EN 13670	Execution of concrete structures

DIN EN 14487-1	Sprayed concrete – Part 1: Definitions, specifications and conformity
DIN EN 14487-2	Sprayed concrete – Part 2: Execution
DIN EN 14488	Testing sprayed concrete
DIN EN 16508	Temporary works equipment – Encapsulation constructions – Performance requirements and general design
DIN EN ISO 8501	Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings Part 4: Initial conditions, preparation levels and rust levels in connection with water washing
DIN EN ISO 12944-4	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 4: Types of surface and surface preparation
DIN EN ISO 17660	Welding – Welding of reinforcing steel
DIN ISO 2768-1	General tolerances; tolerances for linear and angular dimensions without individual tolerance indications
DIN V 18026	Surface protection systems for concrete products according to DIN EN 1504-2
DWA-M 506	DWA Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V., Hennef code of practice ‘Injections with hydraulic binders in hydraulic structures made of mass concrete’
RAL-UZ 64	Basic principles for awarding the RAL-UZ 64 eco-label for rapidly biodegradable lubricants and formwork oils, RAL e.V., St. Augustin, Germany
RL AKR	Deutscher Ausschuss für Stahlbeton (DAfStb) Guideline ‘Preventive measures against harmful alkali reaction in concrete (Alkali Guideline)’
RL MB	Deutscher Ausschuss für Stahlbeton (DAfStb) Guideline for hardened concrete structural elements
RL MB	Deutscher Ausschuss für Stahlbeton (DAfStb), October 2001 Guideline for protection and repair of concrete structural components Part 1: General rules and planning principles Part 3: Requirements for companies and the supervision of the execution Part 4: Test procedure
RL Trockenbeton [Dry Concrete Guideline]	Deutscher Ausschuss für Stahlbeton (DAfStb) Guideline ‘Production and use of dry concrete and dry mortar’
RL Vergussbeton [Grouting Concrete Guideline]	Deutscher Ausschuss für Stahlbeton (DAfStb) Guideline ‘Manufacture and use of cement-bound grouting concrete and grouting mortar’
TR-IH	Deutsches Institut für Bautechnik (DIBt) [German Institute for Building Technology] Technical Rule on the maintenance of concrete structures (TR Instandhaltung [TR Maintenance]) Part 1: Field of application and maintenance planning
TR-W	Technical Regulations – Waterways Information Centre for Hydraulic Engineering – WSV (https://izw.baw.de/wsv/planen-bauen/tr-w)
ZTV-ING	Additional technical terms of contract and guidelines for civil engineering structures (ZTV-ING), Federal Ministry for Digital and Transport Affairs
ZTV-W LB 215	Additional technical terms of contract – hydraulic engineering (ZTV-W), concerned with concrete and reinforced concrete hydraulic structures (service area 215). Federal Ministry for Digital and Transport, Department of Waterways and Shipping.