BAW Factsheet

Construction and refurbishment of large-scale marine water structures (MBM)

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Preliminary remark

The provisions of this leaflet supplement the provisions of ZTV-W LB 215 and ZTV-W LB 219 in the area of action of seawater in coastal areas as well as estuaries of exposure classes XS2, XS3 and XF4.

Seawater structures are exposed to intensive environmental conditions. Requirements are placed on particularly exposed areas (e.g. water change zone of the sea lock chamber) with regard to reinforced concrete corrosion, frost-dew salt resistance, limitation of the maximum component temperature and limitation of cracks due to early and late coercion. In addition, cracks in the presence of chloride can pose a general risk of corrosion to the reinforcement (from very low to very high depending on the exposure and boundary conditions), largely independent of the width of the crack. Therefore, specific cases and building areas require tailor-made regulations and, where appropriate, additional preventive measures, such as the choice of specific construction methods and materials.

The BAW Factsheet on the construction and refurbishment of large-scale marine water structures (MBM) contains supplementary regulations to the ZTV-W LB 215 and ZTV-W LB 219 in order to meet the aforementioned simultaneous requirements.

Goods lawfully marketed in another Member State of the European Union or in Turkey or originating and lawfully marketed in an EFTA State that is a contracting party to the Agreement on the European Economic Area are deemed to be compatible with this measure. The application of this measure is subject to Regulation (EC) No 764/2008 of the European Parliament and of the Council of 9 July 2008 laying down procedures relating to the application of certain national technical rules to products lawfully marketed in another Member State and repealing Decision No 3052/95/EC (OJ L 218, 13.8.2008, p. 21).

1 Scope of application

(1) In addition to the ZTV-W LB 215, the BAW-MBM lays down requirements for ensuring the durability of reinforced concrete traffic water structures with regard to reinforced concrete corrosion in the area of action of seawater in coastal areas as well as estuaries in exposure classes XS2 and XS3.

(2) In addition to ZTV-W LB 219, sections 3 and 4, the BAW-MBM lays down requirements for ensuring the durability of repairs with concrete replacement in reinforced concrete and reinforced concrete overlays with regard to reinforced concrete corrosion in the area of seawater in coastal areas and estuaries in exposure classes XS2 and XS3.

(3) The BAW-MBM lays down additional rules to the ZTV-W LB 215 and ZTV-W LB 219 for the adiabatic temperature increase of concrete in the area of action of seawater in coastal areas as well as estuaries in exposure class XF4.

(4) Annex 1 (informative) provides guidance for planners on the application of the BAW-MBM.

(5) Annex 2 (informative) shows an example of a possible design variant of a lock chamber wall with the component categories M1 to M3 for new construction.

(6) Annex 3 (informative) provides an overview of further measures to ensure the durability of reinforced concrete structures with regard to chloride-induced reinforced concrete corrosion.

2 References to standards, literature and other regulations

BAW-MATB Bundesanstalt für Wasserbau [Federal Waterways Engineering and Research Institute] (ed.): Factsheet on the determination of the adiabatic temperature increase of concrete (MATB). Karlsruhe: Bundesanstalt für Wasserbau (BAW Factsheets, recommendations and guidelines).

BAW-MDCC Bundesanstalt für Wasserbau (ed.): Factsheet on durability assessment and evaluation of reinforced concrete structures with carbonation and chloride exposure (MDCC) . Karlsruhe: Bundesanstalt für Wasserbau (BAW Factsheets, recommendations and guidelines).

BAW-MRZ Bundesanstalt für Wasserbau (ed.): Factsheet on limiting crack openings for stress in large-scale hydraulic structures (MRZ) Karlsruhe: Bundesanstalt für Wasserbau (BAW Factsheets, recommendations and guidelines).

DAfStb-RL MB Deutscher Ausschuss für Stahlbeton [German Committee for Reinforced Concrete]. Guideline “Hardened concrete structural elements”

DBV Crack Factsheet Riss Deutscher Beton- und Bautechnik-Verein E. V. [German Concrete and Construction Technology Association] (ed.): DBV Factsheet “Limiting crack formation in reinforced concrete and prestressed concrete construction”

DIN 488-1 Reinforced steel – Part 1: Steel grades, properties, marking.

DIN 1045-2 Concrete, reinforced and prestressed concrete structures – Part 2: Concrete.

DIN EN 197-1 Cement – Part 1: Composition, specifications and conformity criteria for common cements.

DIN EN 1992-1-1, Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings.

DIN EN 1992-1-2/NA:2010-12 National Annex – Nationally determined parameters – Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings.

E DIN EN 10370 Steel for the reinforcement of concrete – stainless steel.

Rahimi and Westendarp (2024) Rahimi, A., Westendarp, A. (2024) Dauerhafter und nachhaltiger Korrosionsschutz des Betonstahls in Verkehrswasserbauwerken [Permanent and sustainable corrosion protection of reinforced steel in traffic water structures]. In: Beton- und Stahlbetonbau 119 [Concrete and reinforced concrete construction 119]. https://doi.org/10.1002/best.202400024.

ZTV-W LB 215 Bundesministerium für Verkehr (ed.): ZTV-W LB 215 Additional technical terms of contract – hydraulic engineering (ZTV-W), concerned with concrete and reinforced concrete hydraulic structures (service area 215).

ZTV-W LB 219	Bundesministerium für Verkehr (ed.): ZTV-W LB 219 Additional technical terms of contract – hydraulic engineering (ZTV-W) for the repair of the concrete components of hydraulic structures (performance range 219).

3 Supplementary regulations to the ZTV-W LB 215 and ZTV-W LB 219

3.1 Allocation of components to component categories

(1) Components within the scope of ZTV-W LB 215 are to be classified in component categories M1 to M3 in accordance with Table 1. Table 1 supplements the structures in accordance with ZTV-W LB 215, Part 1000, Table 1, Lines 6a and 6b, on the basis of criterion 2 listed therein. Only the requirements for a period of use of 100 years shall apply.

Table 1: Component categories for new construction and repair for exposure classes XS2 and XS3

Component category	Criterion 2 according to ZTV-W LB 215, Part 1000, Table 1	Description of the environment with regard to corrosion risk of the reinforcement	Examples	Assignment in the scope	
				ZTV-W LB 215	ZTV-W LB 219
0	1	2	3	4	5
M1	high availability requirement or difficult or impossible to access for repairs	Chloride contamination with $C_{S,,x} \geq 2.0$ M.-%/z_{eq} and variable water conditioning (XS3)	Component areas with forced loads such as lock chamber walls in jointless and joint-bearing construction; Fire structures; Facing formwork	Structures and components classified under ZTV-W LB 215, Part 1000, Table 1, row 6a	Concrete replacement systems according to Sections 3 and 4 [1)]
M2		Chloride contamination with $C_{S,,x} \geq 2.0$ M.-%/z_{eq} and constantly submerged (XS2)			
		Chloride contamination with $C_{S,\Delta x} < 2.0$ M.-%/z_{eq} independent of water loading (XS2/XS3)			
M3	limited availability acceptable and easy to access for repairs and reparability	regardless of the Chloride load $C_{S,\Delta x}$ independent of water loading (XS2/XS3)	small, redundant stretchers; solid shore walls; shore walls with reinforced concrete head beams; temporarily lockable anchors and culverts; redundantly designed water-contaminated ancillary systems (pump shaft, lifting system, ladles); formation	Structures and components classified under ZTV-W LB 215, Part 1000, Table 1, row 6b	

$C_{S,\Delta x}$ Chloride load on the component surface (surface chloride content) according to BAW-MDCC

[1)] Concrete replacement systems in accordance with sections 5 and 6 of ZTV-W LB 219 may be assigned *mutatis mutandis* if necessary.

(2) For the scope of application of ZTV-W LB 219, Table 1 applies analogously based on the availability requirement and the accessibility of the components during the use of the component as well as their reparability. The provisions of this leaflet shall also apply for planned periods of use shorter than 100 years.

3.2 General supplementary regulations for components of component categories M1 to M3

(1) Unless otherwise agreed in the specification, for components of component category M1 and M2 in exposure class XS3 for vertical switched component surfaces and for inclined component surfaces with counter formwork, water-repellent formwork membranes (CPF) shall be used.

(2) In exposure class XF4, by way of derogation from ZTV-W LB 215, Part 2, 5.2.2 (2), the requirement regarding the use of normal cements with low hydration heat development (LH cements in accordance with DIN EN 197-1) may also be waived for hardened components (smallest component dimension ≥ 0.8 m).

(3) For hardened walls and beams with exposure class XF4, the adiabatic temperature increase of the concrete may exceed the limit value according to ZTV-W LB 215, Part 1 a), 7.3.2 (2), and Part 2, 5.2.9 (5), of 43 K and not exceed 55 K. If the adiabatic temperature increase in the concrete is in the range between 43 K and 55 K, the following additional measures a) to c) must be met.

In this case, all components are grouped as beams in which the maximum temperature in the component is significantly influenced by the heat outflow both over the cross-section width *b* and over the height *h*. Pragmatically, all components with cross-sectional widths of $h/3<b<3\cdot h$ can be considered as beams. The cross-section width is always calculated for the basic cross-section without recesses.

Walls are defined as all components in which the maximum temperature in the component is only influenced by the heat dissipation over the cross-section width *b* ($b\leq h/3$).

a) Proof of compliance with the maximum permissible component temperature of 68 °C to exclude secondary ettringite formation:

The maximum permissible component temperature must be verified both mathematically in the planning process and metrologically in the initial test as well as by means of in situ measurements in the production phase on the structure.

– For the calculation of the maximum component temperature, the heat dissipation can be taken into account with the following equation:

$$max\,T_{BT}=T_{FB}+k_{T_{BT}}\cdot\Delta T_{adiab,7\,d}$$

$\Delta T_{adiab,7\,d}$	Adiabatic temperature increase in the concrete after seven days
T_{FB}	Fresh concrete temperature at the installation site (usually 25 °C according to ZTV-W LB 215)
$k_{T_{BT}}$	factor for component thickness influence,

for walls with cross-section width b_W [m]: $k_{T_{BT}} = 1.1 - 0.3 / b_W^{0.7}$ for beams with the cross-section width b_H [m] and cross-section height h_H [m] and the geometry factor $d_H = min\{b_H ; h_H\} \cdot h_H$: $k_{T_{BT}} = 1.1 - 0.45 / d_H^{0.35}$

- The adiabatic temperature increase of the concrete assumed for the planning must be demonstrated as part of the initial test in accordance with BAW-MATB, Section 3.
- The maximum component temperature in the manufacturing phase shall be demonstrated by *in-situ* measurements.

b) Taking into account the assumed adiabatic increase in the temperature of the concrete when determining the minimum reinforcement in accordance with the BAW-MRZ of walls:

In addition, due to the higher permitted temperatures, the required number of secondary crack pairs due to early coercion must be limited with $n \leq 2{,}5$. If the limit value of the number of secondary crack pairs cannot be met, the concreting section height or length shall be adjusted or the maximum permissible adiabatic temperature increase shall be limited.

c) Consideration of the obstruction situation of beams:

For beams, there are two typical design variants and resulting obstruction situations.

In the case of a compact beam concreted directly onto a sheet wall, the beam is subject to a low degree of obstruction, which means that the geometrically induced primary crack per the BAW-MRZ cannot be generally assumed. In this case, the minimum reinforcement is to be measured as a result of compulsion in accordance with DIN EN 1992-1-1 and DIN EN 1992-1-1/NA.

The concreting of the beam on a shielding panel and sheet wall or on a previously constructed solid concrete component causes a higher degree of obstruction for the beam. In this case, the minimum reinforcement due to force shall be measured in accordance with the BAW-MRZ. The procedure is the same as for walls, see (3) b).

Note: For components with the smallest component dimension ≫ 0,8 m, a zoned design with an attachment shell (see Appendix 2) can be a practical solution.

(4) Hardened flooring slabs of exposure class XF4 (e.g. flooring slab of a water fall basin) shall be constructed “fresh atop fresh” in a zoned construction with a layer thickness of 0,3-0,5 m in the exposed near-surface area. An adiabatic temperature increase of up to 55 K is permitted for the concrete in this area. The underlying concrete (core concrete) must comply with the adiabatic temperature increase according to ZTV-W LB 215, Part 1 a), 7.3.2 (2), and Part 2, 5.2.9 (5), of 36 K. The adiabatic temperature increases of the concretes assumed for the planning must be demonstrated during the initial assessment in accordance with Section 3 of the BAW-MATB. The design of the minimum reinforcement as a result of coercion is to be determined according to the BAW-MRZ with the material input sizes of the core concrete.

Note: For hardened sole plates of exposure class XF4, a detection guide with an increased adiabatic temperature increase is generally not expedient, since in this case the unfavourable interaction of bending force and edge tensile stresses due to residual stresses can be controlled primarily only via the temperature limitation.

(5) In the case of a version with component internal cooling, the provisions of paragraphs (3) and (4) are omitted. Project-specific rules must be laid down.

(6) For facing shells with a maximum thickness of 0.8 m with exposure class XF4, the adiabatic temperature increase of the concrete may exceed the limit value according to ZTV-W LB 219, paragraph (188), of 45 K and not exceed 55 K. The adiabatic temperature increase of the concrete assumed for the planning must be demonstrated as part of the initial test in accordance with BAW-MATB, Section 3. The rules on the determination of the minimum reinforcement in accordance with ZTV-W LB 219, Section 3.3.2 or 4.3.2, must be observed.

3.3 Supplementary regulations for components of component category M1

(1) Unless otherwise agreed in the tender specifications, the durability of the component with regard to chloride-induced reinforced concrete corrosion shall be ensured by the use of reinforcing steel with increased corrosion resistance (stainless reinforcing steel) in the reinforcement planes and connections located in the exposed area.

(2) The use of concrete steels with different corrosion resistances (combination of stainless and conventional, non-alloy concrete steel according to DIN 488-1; mixed reinforcement) within a component is permitted.

Note: Non-rusting concrete steels with different corrosion resistances may also be used as mixed reinforcement.

(3) In the case of faceplates, the reinforcement levels in the exposed area and anchorages to the rear concrete must be made of stainless steel. The execution of the transition zone to adjacent components of a smaller category of components is defined in the tender specifications.

(4) Proof of the corrosion resistance of the stainless reinforced steel shall be carried out with the corrosion test procedure in accordance with Annex D of the draft standard E DIN EN 10370 (Steel for the reinforcement of concrete – stainless steel). The required corrosion resistance according to this laboratory test procedure is defined in the specifications with the characteristic value Cl_{test} (mass fraction of the mixed chlorides in relation to the content of the binding agent) defined therein.

Note: The corrosion resistance Cl_{test} required for each project is to be determined by the client depending on the level of chloride exposure, the degree of separation cracking, the risk of corrosion, the consequences of possible reinforcement corrosion and the desired level of safety. If necessary, the BAW must be consulted.

(5) Unless otherwise agreed in the specifications, the requirements for concrete composition for exposure class XS3 are governed by the provisions of DIN 1045-2, Table F.1, or DAfStb-RL MB, Table F.2.1.

(6) Specific requirements for sealing elements for sealing the working joints are set out in the specifications.

(7) Requirements for the storage of reinforcing steel on the construction site are set out in the specifications.

3.4 Supplementary regulations for components of component category M2

(1) Unless otherwise agreed in the specifications, the durability with regard to chloride-induced reinforced concrete corrosion shall be measured in accordance with BAW-MDCC for target useful lives of more than 50 years. Unless otherwise agreed in the tender specifications, a target value of the reliability index of β_0 = 1.5 (i.e. approximately 93 % collateral) shall be used for the BAW- MDCC measurement. The measurement-relevant input parameters of the chloride-induced reinforced concrete corrosion are laid down in the tender specifications.

Note 1: For the design of the components according to BAW-MDCC, the project-specific surface chloride content $C_{S,\Delta x}$ shall be used, but at least 1.0 M.-%/z_{eq}.

Note 2: The planner's assessment of durability with regard to chloride-induced reinforced concrete corrosion in accordance with BAW-MDCC shall result in a solution which is practical and realisable in construction practice. The basis for determination shall be set out in detail and shall be substantiated. Depending on the result of this evaluation, for example, a specific specification for the use of certain binding agents or a procedure according to component category M1 may be necessary.

(2) Unless otherwise agreed in the tender specifications, a determination of the durability with regard to chloride-induced reinforced concrete corrosion in accordance with the BAW-MDCC may be waived for target useful life up to 50 years using the following binding agents:

- CEM I and CEM II cements according to ZTV-W LB 219, in combination with fly ash as a concrete additive, where the fly ash content must be at least 20 % by weight of (z+f),
- CEM I and CEM II cements according to ZTV-W LB 219 in combination with silica dust as a concrete additive, whereby the countable silica dust content must be at least 8 M.-% of (z+s),
- CEM III/A in combination with fly ash as a concrete additive, wherein the fly ash content must be at least 10 M.-% of (z+f).
- CEM III/B.

If other binding agents are used, the durability for chloride-induced reinforced concrete corrosion shall be measured in accordance with BAW-MDCC. Unless otherwise agreed in the tender specifications, a target value of the reliability index of β_0 = 1.5 (i.e. approximately 93 % collateral) shall be used for the BAW- MDCC measurement.

Note: The eligibility of additives in accordance with DIN 1045-2, 5.2.5.2 shall be taken into account.

3.5 Supplementary regulations for components in the component category M3

(1) Unless otherwise agreed in the tender specifications, a determination of the durability with regard to chloride-induced reinforced concrete corrosion in accordance with the BAW-MDCC may be waived for target useful life up to 100 years using the following binding agents:

- CEM I and CEM II cements according to ZTV-W LB 215 or ZTV-W LB 219, in conjunction with fly ash as a concrete additive, with a fly ash content of at least 20 M.-% of (z+f).
- CEM I and CEM II cements according to ZTV-W LB 215 or ZTV-W LB 219 in combination with silica dust as a concrete additive, whereby the countable silica dust content must be at least 8 M.-% of (z+s).
- CEM III/A in combination with fly ash as a concrete additive, wherein the fly ash content must be at least 10 M.-% of (z+f).
- CEM III/B.

Note: The eligibility of additives in accordance with DIN 1045-2, 5.2.5.2 shall be taken into account.

(2) If other binding agents are used, the durability for chloride-induced reinforced concrete corrosion shall be measured in accordance with BAW-MDCC. Unless otherwise agreed in the tender specifications, a target value of the reliability index of at least β_0 = 0,5 (i.e. approximately 70 % collateral) shall be used for the BAW-MDCC measurement.

Annex 1 (informational): Instructions for planners on the application of the BAW-MBM

In order to enable differentiated, safe and economical construction in coastal areas and estuaries, the BAW-MBM is classified into component categories in accordance with the ZTV-W LB 215 on the basis of the availability claim of the component during operation, its accessibility for repair and its repairability. This ensures that safety-relevant components – components that must be continuously available, as well as those that are heavy or inaccessible – are carried out in new construction and repair with high requirements for the choice of building materials (component categories M1 and M2). Components not covered by these criteria may be executed with a reduced level of safety regardless of the risk of corrosion (component category M3), as potential damage can normally be repaired due to the low availability requirement.

Due to the usual jointless construction in traffic water engineering, a large number of separation cracks are to be expected, especially in new buildings. Despite the small crack widths, according to the current state of knowledge, it is not possible to assume a reliable self-healing of these cracks, as the prerequisites for this are not met in most cases. In the event of chloride exposure, these cracks constitute a general risk of corrosion for the reinforcement, largely irrespective of the crack width. This means that the intended corrosion protection of the reinforcement with the design principle b) “Rissverteilung” [Crack distribution] according to DBV-Riss cannot be ensured reliably and permanently. (Rahimi and Westendarp 2024)

Even outside cracks, insufficient resistance of the concrete to the penetration of chlorides, e.g. as a result of the absence of certain binding agent components to optimise other concrete properties or due to their unavailability (see the preamble to this leaflet), may require special measures to protect the reinforcement against corrosion.

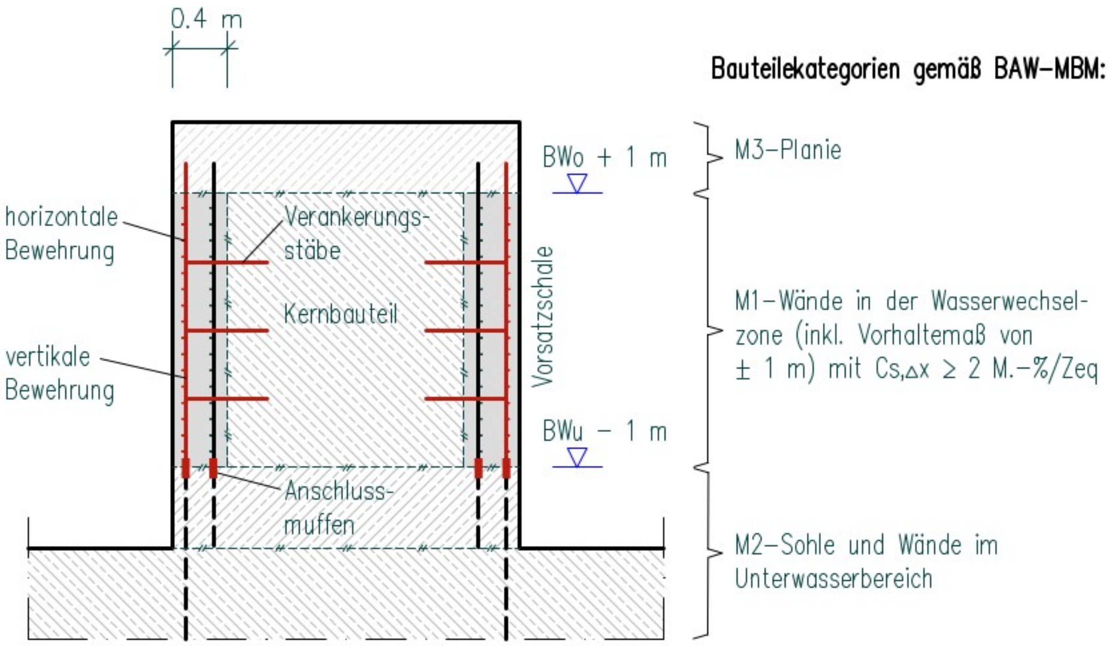
In order to counteract the currently existing uncertainties and challenges with regard to the corrosion risk of the reinforcement, the use of stainless reinforcing steel is encouraged in this leaflet for components of component category M1. Despite the higher effort involved in the construction of the building, this represents an economical and sustainable solution within the framework of a holistic view over the service life.

In the case of components of exposure class XS1, the chloride exposure is significantly lower compared to exposure classes XS2 and XS3 and does not usually constitute a dominant load. For this reason, no additional building material regulations to DIN 1045-2 are provided for components of exposure class XS1 in this leaflet or in the ZTV-W LB 215 and ZTV-W LB 219.

Annex 2 (informational): Use of stainless reinforced steel on the example of a zoned construction by means of overlay in new construction

Below is an example of a possible execution variant of a new central wall of a lock chamber to be constructed. The chamber wall shall be constructed in the area of the water change zone including retention dimension due to the effective chloride load of $C_{S,\Delta x} \geq 2$ M.-%/z_{eq} in component category M1. In order to meet the simultaneous requirements for frost-to-salt resistance and maximum component temperature of the concrete, the area assigned to component category M1 shall be reconstructed in zoned construction from a 40 cm thick overlay and a core component.

Figure 1 shows the schematic representation of the centre wall of the lock chamber with the arrangement of an overlay in the area of component category M1.



Horizontale Bewehrung, vertikale Bewehung, Verankerungsstäbe, Kernbauteil, Anschlussmuffen, Vorsatzschale, Planie, Wände in der Wasserwechselzone (inkl. Vohrtaltemasse von , mit, Sohle und Wände im Unterwasserbereich

Horizontal reinforcement, vertical sweeping, anchoring rods, core component, connecting sleeves, facing shell, formations, walls in the water change zone (including retention mass of/with soles and walls in the submerged area

Figure 1: Schematic cross-section of a new central wall to be erected of a lock chamber in a zoned design with an overlay shell in the area of the water change zone with assignment of the component categories

The design variant shown below with a 40 cm (in the basic cross section without recesses, etc.) thick overlay shell in the area of component category M1 enables targeted measures in the near-surface area to ensure durability in the area of exposure classes XS3/XF4.

In the area of the precast shell, a high number of separation cracks is to be expected, which do not allow for self-healing. With regard to the design of anchorage and reinforcement of the precast shell, the building principles according to ZTV-W LB 219 apply *mutatis mutandis*. An internal water pressure between the core component and the precast shell must be taken into account.

In the area of the precast shell, the two front reinforcement layers, the anchorages in the core component, and the connection to the constantly submerged concrete (component category M2) are made of stainless steel. Where appropriate, the connection to the permanently submerged part of the structure may be made of conventional, non-alloy steel, provided that the anti-corrosion protection is ensured by an adapted concrete in the bottom concrete layer of the overlay. The two rear reinforcement layers of the precast shell can be executed with conventional, unalloyed reinforcing steel. The concrete of the precast shell can be designed according to the requirements of exposure class XS3 of DIN 1045-2, table F.1, or DAfStb-RL MB, table F.2.1. The LH requirement for cement may be waived. However, in order to avoid the risk of secondary ettringite formation, compliance with a maximum component temperature of 68 °C is mandatory. This is to be estimated mathematically as part of the planning. The heat outflow from the component during hydration may be taken into account for the demonstration. During construction, appropriate evidence must be provided of the adiabatic temperature increase of the concrete during the initial test (BAW-MATB, Section 3) and of the maximum component temperature during production (*in-situ* measurements). The design of the crack-width limiting reinforcement by force is carried out for the header shell in accordance with the ZTV-W LB 219.

The hardened core concrete behind the precast shell in this design variant is not subject to any special environmental requirements and can therefore be optimised with regard to limiting the development of hydration heat to prevent secondary ettringite formation. The reinforcement may be carried out with conventional, non-alloyed reinforcing steel. The calculation of the width-limiting reinforcement by force is carried out in accordance with the BAW-MRZ. Where appropriate, the contracting authority may lay down a project-specific crack width criterion for the core component.

Walls and soles with no water change load can be implemented in accordance with component category M2 with the supplementary regulations under section 3.4 of the BAW-MBM. The reinforcement may be carried out with conventional, non-alloyed reinforcing steel. The calculation of the width-limiting reinforcement by force is carried out in accordance with the BAW-MRZ.

If limited availability during the use phase is acceptable and possible repair measures can be carried out, the formation can be assigned to the component category M3. The reinforcement may be carried out with conventional, non-alloyed reinforcing steel. The calculation of the width-limiting reinforcement by force is carried out in accordance with the BAW-MRZ. In the event of a chloride load of $C_{S,\,diex} \geq 2.0$ M%/z_{eq}, in the maintenance plan measures such as the use of monitoring systems or systematic chloride profile determination may support the maintenance of the construction works in order to determine a meaningful intervention time.

Annex 3 (informational): Further measures to ensure durability with regard to chloride-induced reinforced concrete corrosion

The following measures are also aimed at preventive protection of the building (for new construction) against damage caused by reinforcement corrosion, but these are currently considered less suitable for use in transport water construction from a technical and/or economic point of view (Rahimi and Westendarp 2024):

- cathodic reinforcement corrosion protection (preventive or reactive),
- crack-preventing construction methods (use of prestressed concrete, design principle a) according to DBV-Riss),
- construction methods with planned subsequent treatment of a few “acceptable” wide cracks (design principle c) according to DBV-Riss),
- Use of other corrosion carriers (e.g. hot-dip galvanised reinforcing steel) or non-metallic (e.g. carbon reinforcement) reinforcement,
- Use of sealing,
- Application of surface protection systems.

However, depending on the planned remaining service life, the installation of a cathodic corrosion protection system may be useful for the repair of hydraulic structures.

As a further measure, both for new construction and for repair, monitoring using, for example, monitoring systems may be used to support the determination of the timing of a necessary intervention. Particularly for components of component category M3 with a chloride load of $C_{S,\Delta x} \geq 2{,}0$ M.-%/$z_{eq.}$ measures such as the use of monitoring systems or the systematic determination of chloride profiles can provide useful support for building maintenance in the maintenance plan.