BAWInformation sheet

Determination of the adiabatic temperature increase of concrete (MATB)

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Note:

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Preliminary remark

The adiabatic temperature increase of concrete is a concrete property, which has an impact on early coercion and the formation of self-stresses in concrete components and can influence the risk of secondary ettringite formation in concrete components.

The adiabatic temperature increase of concrete is an input parameter for the determination of the forced reinforcement due to early compulsion according to BAW-MRZ.

The BAW-MATB describes methods that make it possible to determine or estimate the adiabatic increase in the temperature of concrete.

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1 References to standards, literature and other technical regulations

BAW-MRZ	Federal Institute of Hydraulic Engineering [Ed.] (2025) BAWMerkblatt Rissbreitenberenzung für Zwang in massive Wasserbauwerke (MRZ) [BAW leaflet on crack width limitation for constraint in massive hydraulic structures]. Karlsruhe: Federal Institute for Hydraulic Engineering (BAW leaflets, recommendations and guidelines).
DIN EN 196-8	DIN EN 196-8:2010-07 Test methods for cement - Part 8: Hydration heat – Solution method; German version EN 196-8:2010
DIN EN 196-9	DIN EN 196-9:2010-07 Test methods for cement - Part 9: Hydration heat – Part-adiabatic method; German version EN 196-9:2010
DIN EN 196-11	DIN EN 196-11:2019-03 Test methods for cement - Part 11: Hydration heat – Isotherm heat flux calorimetry method; German version EN 196-11:2018
DIN EN 12390-15	DIN EN 12390-15:2019-10 Testing of solid concrete – Part 15: Adiabatic method for the determination of the heat released during the hardening process of concrete; German version EN 12390-15:2019.
ZTV-W LB 215	Federal Ministry of Digital and Transport [ed.] (2025) ZTV-W LB 215: Additional technical terms of contract - hydraulic engineering (ZTV-W), concerned with concrete and reinforced concrete hydraulic structures (service area 215).

2 Scope

(1) The BAW-MATB describes two test methods as well as a calculation method for determining or estimating the adiabatic temperature increase of concrete.

(2) Information on the test procedures and calculation methods can be found in Annex 1.

3 Adiabatic temperature increase according to DIN EN 12390-15 (reference method)

(1) The adiabatic temperature increase of the concrete is determined in accordance with DIN EN 12390-15. The test period is 7 days.

(2) Of the cement batch used in the experiment, the hydration heat shall be determined in accordance with DIN EN 196-8 or DIN EN 196-11 and a reserve sample shall be handed over to the contracting authority.

(3) The tests shall be documented in a test report containing the information in accordance with DIN EN 12390-15, 8, (a) to (t). The following additional information shall be included in the test report:

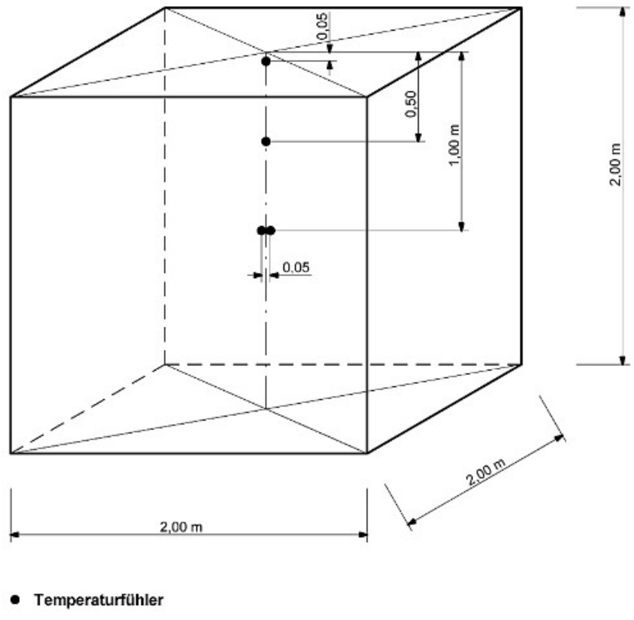
- Fresh concrete temperature after concrete production in °C.
- the ratio C_{Cal}/C_{Con} and comparison with Norman requirement.
- Hydration heat according to DIN EN 196-8 or DIN EN 196-11 of the cement batch used in J/g.
- Date and protocol of the last calibration of the calorimeter according to DIN 12390-15, Annex A.
- Indication of the temperature ranges in which the determined values of deviation from adiabasia (α) are used to determine $T_c^*(t)$.
- the temperatures $T_{con}(t)$, $T_{cal}(t)$, $T_c^*(t)$, q(t) in tabular and graphical form.

4 Determination of the quasi-adiabatic temperature increase on the large-format concrete block in a practical test

(1) One large-format concrete block (2.0 m x 2.0 m x 2.0 m) must be produced per concrete in accordance with the specifications (Figure 1). In doing so, the following boundary conditions shall be taken into account:

- Of the cement batch used in the concrete, the hydration heat shall be determined in accordance with DIN EN 196-8 or DIN EN 196-11 and a reserve sample shall be handed over to the contracting authority.
- The block shall be provided with thermal insulation on all sides (d ≥ 360 mm; thermal conductivity group 040 or lower; sufficient compressive strength).
- Anchoring through is not permitted.
- The fresh concrete temperature during installation may be 15 °C, the temperature of the surrounding air during the test run (measurement time: 168 hours) do not fall below 5 °C.

- Two temperature sensors (distance 5 cm) shall be arranged in the centre of the block. Two additional temperature sensors shall be placed on an imaginary line between the centre of the block and the centre of a side surface or the centre of the top surface at a distance of 5 cm and 50 cm from the surface (see Figure Figure 1).
- Resistance sensors with a permissible deviation of ± 1 K shall be used as temperature sensors. The measuring chain (temperature sensor, data logger, power supply) must have an accuracy of ± 1 K for temperature range recording.
- The temperature profile in the concrete block and the temperature of the surrounding air shall be recorded continuously at a frequency of 30 minutes over a period of at least 168 hours (7 days).
- The tests shall be documented in a test report with the following information:
  - Hydration heat according to DIN EN 196-8 or DIN EN 196-11 of the cement batch used in J/g.
  - Type, designation and measurement accuracy of the sensors and measurement chain
  - Documentation of the measuring chain (data sheets, configuration of the data logger, data preparation)
  - Fresh concrete temperature $T_{Concrete}$ at the time of installation in °C
  - Measured temperature $T_{Concrete}(t)$ in tabular and graphical form in °C
  - $T_{qadiab}(t)$ in tabular and graphic form in K



Temperaturfühler Temperature sensor

Figure 1: Concrete block with arrangement of temperature sensors

5 Computational estimation of adiabatic temperature increase of concrete

(1) A mathematical estimation of the adiabatic temperature increase of the concrete is carried out according to formula (1).

(2) The calculation shall be based on the hydration heat of the cement provided in the concrete on the basis of a current test value $Q_{iso.}$

$$\Delta T_{ad,7d,cal} = \frac{Q_{iso} \cdot z}{\frac{Q_{iso}}{Q_{adiab.}} \cdot (c_c * z + c_{ad} * f + c_o * g + c_w * w) \cdot} \quad (1)$$

$\Delta T_{ad,7d,cal}$ Calculated adiabatic temperature increase of the concrete in K

Q_{iso} Hydration heat of the cement according to DIN EN 196-8 (reference) or DIN EN 196-11 in J/g. Alternatively, the hydration heat determined in accordance with DIN EN 196-9 can be used. The value for Q_{Iso} is then 80 % of the result according to DIN EN 196-9 after 168 hours of measurement.

Q_{adiab} Hydration heat of the cement under adiabatic conditions in J/g

$Q_{iso}/Q_{adiab.}$: Ratio of hydration heat isothermal Q_{iso} at 20 °C to adiabatic hydration heat Q_{adiab} after 7 days:

Without determining the actual ratio, the following values can be used when using

CEM III LH: 0.75

CEM II/A, CEM II/B, CEM III: 0.80

CEM I: 0.90

c_c, c_{ad}, c_a Specific heat of the cement, the additive and the rock grain. Unless separate information is available: 0.84 J/(g*K)

c_w Specific heat of the water contained in the sample. Unless separate information is available: 3.76 J/(g*K) according to DIN EN 12390-15

z, f, g Cement content, additive content, rock grain content in kg/m^3

w Water content in kg/m^3

(3) The tests shall be documented in a test report specifying the parameters used.

- Q_{iso} as test value in J/g accompanied by the test report
- the assumed ratio Q_{iso}/Q_{adiab}
- Cement content, additive content, water content, rock grain content of concrete in kg/m^3
- c_c, c_{ad}, c_a, c_w

- $\Delta T_{ad,7d,cal}$ in K

A.1. Notes on the procedure

A.1.1. General

(1) In the following, information is given on the three methods to be taken into account in the evaluation of the results.

(2) The hydration heat of the concrete is mainly influenced by the cement properties and cement content.

(3) In essence, the production fluctuations of the cement properties can lead to different adiabatic temperature increases being determined with the same concrete composition but with a different batch of cement. In order to classify the adiabatic temperature increase in the concrete determined in accordance with Sections 3 and 4, it is therefore absolutely necessary to determine the hydration heat of the cement batch used in the experiment in accordance with DIN EN 196-8 or DIN EN 196-11.

(4) For the concrete composition expected fluctuations of the adiabatic temperature increase of the concrete can be estimated by the knowledge of the production fluctuation of the hydration heat of the cement.

A.1.2. Adiabatic temperature increase in accordance with section 3

(1) The determination of the adiabatic temperature increase in accordance with Section 3 is the reference method for determining the adiabatic temperature increase.

(2) In the laboratory test under defined framework conditions, taking into account the heat losses in the concrete caorimeter, the adiabatic temperature increase of the concrete is determined taking into account all the properties of the concrete tested with the concrete input batches used therein.

(3) It is demonstrated that a certain adiabatic temperature increase of the concrete can be maintained with the investigated concrete composition.

A.1.3. Quasi-adiabatic temperature increase according to section 4

(1) In the construction site test, if the test is carried out correctly, the quasi-adiabatic temperature increase of the concrete is determined taking into account all the properties of the examined concrete with the batches of concrete feedstock used therein.

(2) The quasi-adiabatic temperature increase determined in the construction site test represents a lower estimate of the adiabatic temperature increase in the concrete, as unavoidable heat losses are not taken into account depending on the changing environmental conditions. Larger ranges of the fresh concrete temperature as well as larger fluctuations in the concrete composition expected in the concrete plant due to production compared to the laboratory test can also be expected to result in larger fluctuations in the results.

(3) In addition to the determination of the quasi-adiabatic temperature increase of the concrete, other concrete properties can be investigated during the production of the block, unlike in the laboratory test, such as the pumpability and the air pore stability under practical construction conditions.

(4) It is demonstrated that a certain adiabatic temperature increase of the concrete can be maintained with the investigated concrete composition. The results are less but sufficiently on the safe side than with the adiabatic test referred to in Section 3.

A.1.4. Computational estimation of adiabatic temperature increase according to section 5

(1) Using a computational approach, the adiabatic temperature increase of the concrete is estimated under the assumption of a fresh concrete temperature of 20 °C, taking into account assumptions on parameters from literature references as well as a hydration heat of the cement determined by testing.

(2) The determination of the hydration heat of the cement is possible with three different standardised test methods (DIN EN 196-8, DIN EN 196-9, DIN EN 196-11), the actual purpose of which is to determine the LH property of the cement. The test results of these three procedures are subject to certain fluctuations due to the procedure. The results of two correctly executed tests carried out by two laboratories may differ according to the precision specifications specified in the standards according to DIN EN 196-8 up to 50 J/g, according to DIN EN 196-9 up to 42 J/g and according to DIN EN 196-11 up to 37 J/g.

(3) The deviations referred to in (2) may result in deviations of approximately 5 K of the calculated adiabatic temperature increase of the concrete on the basis of the hydration heat of the cement alone, with otherwise unchanged parameters.

(4) Deviations of 0.05 of the actual ratio Q_{iso}/Q_{ad} from the calculated ratio can represent a difference of about 3 K in the calculated adiabatic temperature increase in the concrete.

(5) When applying the computational approach with the inaccuracies mentioned in (3) and (4), careful consideration must be given to a simple methodology for estimating the adiabatic temperature increase and possible effects on the structure/component under consideration.