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English Version

Eurocode 1 - Actions on structures - Part 1-5: Thermal actions

Eurocode 1 - Actions sur les structures - Partie 1-5 : Actions thermiques

Eurocode 1 - Einwirkungen auf Tragwerke - Teil 1-5: Allgemeine Einwirkungen - Temperatureinwirkungen

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 250.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (prEN 1991-1-5:2023) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 1991-1-5:2005.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

Introduction

0.1 Introduction to the Eurocodes

The structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990, *Eurocode: Basis of structural and geotechnical design*
- EN 1991, *Eurocode 1: Actions on structures*
- EN 1992, *Eurocode 2: Design of concrete structures*
- EN 1993, *Eurocode 3: Design of steel structures*
- EN 1994, *Eurocode 4: Design of composite steel and concrete structure*
- EN 1995, *Eurocode 5: Design of timber structures*
- EN 1996, *Eurocode 6: Design of masonry structures*
- EN 1997, *Eurocode 7: Geotechnical design*
- EN 1998, *Eurocode 8: Design of structures for earthquake resistance*
- EN 1999, *Eurocode 9: Design of aluminium structures*
- < New parts >

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to EN 1991

(1) EN 1991 provides the actions to be considered for the structural design of buildings, bridges and other civil engineering works, or parts thereof, including temporary structures, in conjunction with EN 1990 and the other Eurocodes.

(2) The actions on structures, including in some cases geotechnical structures in conjunction with EN 1997 as appropriate, provided in EN 1991 are intended to be applied in conjunction with the other Eurocodes for the verification of safety, serviceability and durability, as well as robustness of structures, including the execution phase.

(3) The application of this document for the verifications mentioned in (2) follows the limit state principle and is based on the partial factor method, unless explicitly prescribed differently.

(4) EN 1991 does not cover actions for structures in seismic regions, unless explicitly prescribed by EN 1998. Provisions related to such requirements are given in EN 1998, which complements and is consistent with EN 1991.

(5) EN 1991 is also applicable to existing structures for their:

- structural assessment,
- retrofitting (strengthening, repair) design,
- assessment for changes of use.

NOTE In this case additional or amended provisions can be necessary.

(6) EN 1991 is applicable to the design of structures where materials or actions outside the scope of the other Eurocodes are involved.

NOTE In this case additional or amended provisions can be necessary.

0.3 Introduction to EN 1991-1-5

EN 1991-1-5 gives design guidance for thermal actions arising from climatic and operational conditions on buildings and civil engineering structures.

Information on thermal actions induced by fire is given in EN 1991-1-2.

EN 1991-1-5 is intended for clients, designers, contractors and relevant authorities.

EN 1991-1-5 is intended to be used with EN 1990, the other Parts of EN 1991 and EN 1992 to 1999 for the design of structures.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National Annex for EN 1991-1-5

National choice is allowed in this standard where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1991-1-5 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this standard is to be used.

When no national choice is made and no default is given in this standard, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in EN 1991-1-5 through notes to the following clauses:

7.3 (1) NOTE 1
7.3 (2) NOTE 1
7.3 (3) NOTE
7.3 (5) NOTE
7.3 (6) NOTE
8.1.1 (1) NOTE 2
8.1.3.1 (2) NOTE
8.1.3.2 (1) NOTE
8.1.3.2 (5) NOTE
8.1.3.3 (2) NOTE
8.1.3.3 (3) NOTE
8.1.3.3 (5) NOTE
8.1.4 (2) NOTE
8.1.4 (3) NOTE
8.1.4.2 (2) NOTE 1
8.1.4.2 (2) NOTE 2
8.1.4.3 (2) NOTE 1
8.1.4.3 (2) NOTE 3
8.1.4.4 (2) NOTE
8.1.4.5 (1) NOTE
8.1.5 (1) NOTE
8.1.5 (2) NOTE
8.1.6 (1) NOTE
8.2 (3) NOTE
8.2 (4) NOTE
8.2 (5) NOTE
9.3 (2) NOTE
9.3 (3) NOTE
9.3 (4) NOTE
A.2 (2) NOTE 1
A.2 (2) NOTE 3
B.2 (1) NOTE 1

National choice is allowed in EN 1991-1-5 on the application of the following informative annex:

- Annex C (informative) Temperature profiles in buildings and other construction works

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1991-1-5

(1) EN 1991-1-5 gives principles and rules for calculating thermal actions on buildings, bridges and other structures including their structural members. Principles needed for cladding and other attachments of buildings are also provided.

(2) This Part describes the changes in the temperature of structural members. Characteristic values of thermal actions are presented for use in the design of structures which are exposed to daily and seasonal climatic changes.

(3) This Part also gives principles for changes in the temperature of structural members due to the paving of hot asphalt on bridge decks.

(4) This Part also provides principles and rules for thermal actions acting in structures which are mainly a function of their use (e.g. cooling towers, silos, tanks, warm and cold storage facilities, hot and cold services, etc.).

NOTE Supplementary guidance for thermal actions on chimneys is provided in EN 13084-1.

1.2 Assumptions

The assumptions given in FprEN 1990:2022, 1.2 apply to EN 1991-1-5.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. in “should” clauses), permissions (“may” clauses), possibilities (“can” clauses), and in notes.

FprEN 1990:2022, *Eurocode — Basis of structural and geotechnical design*

ISO 2394, *General principles on reliability for structures*

ISO 3898:2013, *Bases for design of structures — Names and symbols of physical quantities and generic quantities*

ISO 8930, *General principles on reliability for structures — Vocabulary*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this European Standard, the definitions given in FprEN 1990:2022, ISO 2394, ISO 3898:2013 and ISO 8930 and the following apply.

3.1.1

thermal actions
those actions on a structure or a structural member that arise from the changes of temperature fields

3.1.2

shade air temperature

temperature measured by thermometers placed in a “Stevenson screen” (an instrument shelter which is ventilated and protected from the solar radiation)

3.1.3

maximum shade air temperature

$T_{\max}$

value of maximum shade air temperature with an annual probability of exceedance of 0,02 (equivalent to a mean return period of 50 years), based on the maximum hourly values recorded

3.1.4

minimum shade air temperature

$T_{\min}$

value of minimum shade air temperature with an annual probability of exceedance of 0,02 (equivalent to a mean return period of 50 years), based on the minimum hourly values recorded

3.1.5

initial temperature

T_0

temperature of a structural member at the relevant stage of its restraint (completion) which should be taken into account during the design to consider movements and /or restraining effects

3.1.6

cladding

parts of the building with protective and/or architectural function which are added after the main structure is complete

3.1.7

uniform temperature component

temperature, constant over the cross section, which governs the expansion or contraction of a member or structure

3.1.8

temperature difference component

part of a temperature profile in a structural member representing the temperature difference between the outer face of the member and any in-depth point

3.2 Symbols and abbreviations

(1) For the purposes of this Part of Eurocode 1, the following symbols, specific to this Part, apply, together with the general notations given in FprEN 1990:2022.

NOTE The notation used is based on ISO 3898:2013.

(2) A basic list of notations is provided in FprEN 1990:2022, and the additional notations below are specific to this Part.

3.2.1 Latin upper-case letters

R	thermal resistance of structural member
R_{in}	thermal resistance at the inner surface
R_{out}	thermal resistance at the outer surface
T_{max}	maximum shade air temperature with an annual probability of exceedance of 0,02 (equivalent to a mean return period of 50 years)
T_{min}	minimum shade air temperature with an annual probability of exceedance of 0,02 (equivalent to a mean return period of 50 years)
$T_{\mathrm{max},p}$	maximum shade air temperature with an annual probability of exceedance p (equivalent to a mean return period of $1/p$)
$T_{\mathrm{min},p}$	minimum shade air temperature with an annual probability of exceedance p (equivalent to a mean return period of $1/p$)
T_N	uniform temperature
$T_{N.\mathrm{max}}$	maximum uniform temperature
$T_{N.\mathrm{min}}$	minimum uniform temperature
$T_{N.\mathrm{night}}$	uniform night cooling temperature
T_0	initial temperature when a structural member is restrained
$T_{0,\mathrm{inf}}$	the minimum initial bridge temperature from which expansion is considered
$T_{0,\mathrm{sup}}$	the maximum initial bridge temperature from which contraction is considered
T_{in}	air temperature of the inner environment
T_{out}	air temperature of the outer environment
ΔT_0	range of initial bridge temperature
ΔT_i	heating (cooling) temperature differences
ΔT_N	range of uniform temperature component
$\Delta T_{N,\mathrm{exp}}$	maximum expansion range of uniform bridge temperature component
$\Delta T_{N,\mathrm{con}}$	maximum contraction range of uniform bridge temperature component
ΔT_M	linear temperature difference component
$\Delta T_{M,\mathrm{heat}}$	linear temperature difference component (heating)
$\Delta T_{M,\mathrm{cool}}$	linear temperature difference component (cooling)
ΔT_{E}	nonlinear part of the temperature difference component
ΔT	sum of linear temperature difference component and nonlinear part of the temperature difference component
ΔT_{p}	difference in the coincident value of uniform temperature between different structural members within a structure

3.2.2 Latin lower case letters

h	height of the cross-section
k	coefficient for calculation of maximum (minimum) shade air temperature with an annual probability of exceedance, p, other than 0,02
k_{sur}	surfacing factor for linear temperature difference component
p	annual probability of maximum (minimum) shade air temperature being exceeded (equivalent to a mean return period of $1/p$ years)
u, c	mode and scale parameters of annual maximum (minimum) shade air temperature distribution

3.2.3 Greek lower-case letters

λ	thermal conductivity
ω_N	reduction factor of uniform temperature component for combination with temperature difference component
ω_M	reduction factor of temperature difference component for combination with uniform temperature component

4 Design situations

(1) Thermal actions shall be determined for the relevant design situation identified in accordance with FprEN 1990:2022.

(2) The effects of thermal actions shall be allowed for in the design of load bearing members of structures, either by providing movement joints or by including the effects in design verifications.

5 Classification of actions

(1) Thermal actions shall be classified as variable and indirect actions, as defined within FprEN 1990:2022.

(2) All values of thermal actions given in this Part are characteristic values, see FprEN 1990:2022.

(3) For design situations where the annual probability of exceedance is other than 0,02 the values of thermal actions should be derived using the calculation method given in Annex A.

6 Representation of actions

(1) The temperature distribution within an individual structural member should be resolved into the following four basic components, as illustrated in Figure 6.1:

a) A uniform temperature component, ΔT_{N} ;

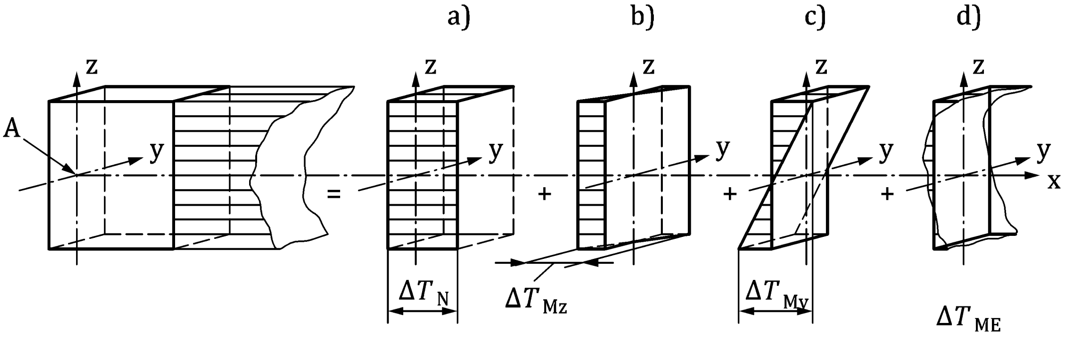
b) A linearly varying temperature difference component about the *z-z* axis, ΔT_{MZ};

c) A linearly varying temperature difference component about the *y-y* axis, ΔT_{MY};

d) A nonlinear temperature difference component, ΔT_{E}. This results in a system of self-equilibrated stresses which produce no net load effect on the member.

NOTE 1 Daily and seasonal changes in shade air temperature, solar radiation, re-radiation, etc. result in variations of the temperature fields within individual members of a structure.

NOTE 2 The magnitude of the thermal actions depends on local climatic conditions, the orientation of the structure, its overall mass, effects of finishes (e.g. cladding in buildings), and in the case of building structures, heating and ventilation regimes and thermal insulation.



Key

A Centroid of section

Figure 6.1 — Diagrammatic representation of components of a temperature profile

(2) When materials with different coefficients of linear expansion are used compositely, their combined thermal response should be taken into account.

NOTE The thermal strains and any thermal stresses resulting from constraint or associated movements depend on the geometry and boundary conditions of the member being considered and on the physical properties of the material used.

(3) For the purpose of deriving thermal actions, the relevant material coefficient of linear expansion should be used.

(4) Values for the coefficient of linear expansion should be obtained from the relevant material specific Eurocode parts where available.

(5) Where not available in material specific Eurocode parts, values for the coefficient of linear expansion may be as specified by the relevant authority or, where not specified, as agreed for the specific project by the relevant parties using reliable published data or verified by tests or more detailed studies.

7 Thermal actions on buildings

7.1 General

(1) Thermal actions on buildings due to environmental and operational temperatures shall be considered in the design of buildings where there is a possibility of the ultimate or serviceability limit states being exceeded due to thermal movements and/or stresses generated as a result of restraint.

NOTE Volume changes and/or stresses due to temperature changes can also be influenced by e.g.:

a) shading from adjacent buildings, effects of orientation (e.g. NE-SW, NW-SE);

b) use of different materials with different thermal expansion coefficients and heat transfer characteristics;

c) use of different cross-sectional shapes with different uniform temperature.

(2) In a multi-skin cladding system, the relative movement of the adjacent layers of the envelope should be considered when specifying brackets, fasteners and other components of the system.

NOTE Where sandwich panels are used as wall or roof cladding, the temperature difference between the inner and outer metal sheets can be significant giving rise to bending effects in the panels. Further information is given in EN 14509.

7.2 Determination of temperatures

(1) Thermal actions on buildings due to environmental changes shall be determined by considering the variation of shade air temperature and solar radiation. Operational effects (due to heating, technological or industrial processes) shall also be considered where appropriate.

NOTE The location of the building and the structural detailing can also affect the determination of thermal actions.

(2) Climatic and operational thermal actions on a structural member shall be specified using the following basic temperature components:

a) A uniform temperature component ΔT_{N} is expressed as a uniform difference in temperature

$$\Delta T_{\mathrm{N}} = T_{\mathrm{N}} - T_0 \tag{7.1}$$

where

T_{N} is a uniform temperature over the full area of a structural member due to climatic temperatures in winter or summer season and/or due to operational temperatures;

T_0 is an initial temperature when a structural member is restrained to be taken into account for consideration of thermal effects in the design of movements and/or restraining effects.

b) A linearly varying temperature component given by the difference ΔT_M between the temperatures on the outer and inner surfaces of a cross section, or on the surfaces of individual layers.

c) A temperature difference ΔT_p of different members within a structure given by the difference in uniform temperature components of these parts.

(3) The components ΔT_{N}, ΔT_M, ΔT_{p}, T_{N} and T_0 should be determined in accordance with the principles provided in 7.3 using regional temperature data relating to the minimum and maximum shade air temperatures (T_{min} and T_{max}).

(4) Values of ΔT_M and ΔT_{p} should take into account the particular operation requirements of the structure and may be as specified by the relevant authority or, where not specified, as agreed for the specific project by the relevant parties.

(5) In addition to ΔT_N, ΔT_M and ΔT_p, the local effects of thermal actions should be considered where relevant.

NOTE Local effects of thermal actions can be of significance for example at supports or fixings of structural and cladding elements.

7.3 Determination of temperature profiles

(1) The uniform temperature T_N in Formula (7.1) may be assumed to be the average temperature of a structural member. In the case of a composite (or sandwich member), T_N might be considered as the average temperature across a particular layer.

NOTE 1 The uniform temperature T_N can be set by the National Annex.

NOTE 2 A method for determination of the temperature fields within structural members using the thermal transmission theory is provided in Annex C.

NOTE 3 When elements of one layer are considered and when the environmental conditions on both sides are similar, T_N can be approximately determined as the average of the coexistent temperatures T_{in} and T_{out} of inner and outer environment.

(2) The temperatures of the inner environment, T_{in} and T_{out} should be determined.

NOTE 1 The values of temperatures T_{in} and T_{out} for rooms with a control of a normal temperature are given in Table 7.1 (NDP) unless the National Annex gives different values for use in a country. The values of temperatures in Table 7.1 are based on data for regions between latitudes 45°N and 55°N.

NOTE 2 The temperatures T_{out} for the summer season depend on the surface absorptivity and its orientation

— the maximum temperature is usually developed for surfaces facing the West, South-West or for horizontal surfaces,

— the minimum temperature is usually developed for surfaces facing the North (typically half of the maximum).

Table 7.1 — (NDP) Indicative temperatures for structural members in buildings

Area		$T_{N,max}$ **(C°) (Summer)**		$T_{N,min}$ **(C°) (Winter)**
Temperatures T_{in} of inner environment		$T_1 = 20$		$T_2 = 25$
Temperatures T_{out} for buildings above the ground level [a]	North-East facing members	Bright light surfaces	$T_{max} + 0$	T_{min}
		Light coloured surfaces	$T_{max} + 2$	
		Dark surfaces	$T_{max} + 4$	
	South-West facing members	Bright light surfaces	$T_{max} + 18$	
		Light coloured surfaces	$T_{max} + 30$	
		Dark surfaces	$T_{max} + 42$	
Temperatures T_{out} for underground parts of buildings		6		−4

[a] For intermediate member orientation, the value may be determined by interpolating the angular direction.

(3) For rooms for which the temperature control is not provided, a range of operating temperatures representing realistic upper and lower bound of service conditions should be considered and agreed with the relevant authority for the specific project.

NOTE The values $T_1 = 35°$ C (summer) and $T_2 = 0°$ C (winter) can be applied unless the National Annex gives different values for use in a country·

(4) For rooms with special temperature conditions (e.g. chilling rooms), the temperature should be as agreed for a specific project by the relevant parties.

(5) For structural members with a low thermal inertia, the nightly cooling temperature $T_{N,\text{night}}$ should be considered.

NOTE When no data are available, the value of $T_{N,\text{night}} = 8°$ C, unless the National Annex gives a different value.

(6) For parts of buildings which lay below the level of the surrounding ground, other values may to be determined.

NOTE The temperatures can be set by the National Annex.

(7) Additional project-specific values for parts of buildings which lay below the level of the surrounding ground may be as specified by the relevant authority or, where not specified, agreed for a specific project by the relevant parties.

8 Thermal actions on bridges

8.1 Bridge decks

8.1.1 Bridge deck types

(1) Bridge decks should be classified into one of the following types:

Type 1	Steel deck:	– steel box girder – steel truss or plate girder
Type 2	Composite deck	– steel girder and concrete slab
Type 3	Concrete deck	– concrete slab – concrete beam – concrete box girder

NOTE 1 The “composite decks” considered here are those where the steel members are fully exposed below the concrete deck soffit.

NOTE 2 The National Annex can specify values of the uniform temperature component and the temperature difference component for other types or materials of bridges (e.g. aluminium, timber, polymer composites, etc.).

(2) For filler beam decks (see EN 1994-2), the thermal actions defined for concrete decks (Type 3) may be applied.

(3) Thermal actions for temporary bridges and other reference periods or probabilities of exceedance (e.g. transient design situations) shall be obtained using the procedure provided in Annex A.

8.1.2 Consideration of thermal actions

(1) Representative values of thermal actions should be assessed by taking into account the uniform temperature component (see 8.1.3) and the relevant temperature difference components (see 8.1.4).

(2) The following effects should be taken into account where relevant:

— Restraint of associated expansion or contraction due to the type of construction (e.g. portal frame, arch, elastomeric bearings);

- Friction at roller or sliding bearings;
- Nonlinear geometric effects (2nd order effects);
- For railway bridges, the effects of interaction between the track and the bridge due to the variation of the temperature of the deck and of the rails which may induce supplementary horizontal forces in the rails and bearings.

NOTE For more information, see EN 1991-2.

8.1.3 Uniform temperature component

8.1.3.1 General

(1) The minimum shade air temperature (T_{min}) and the maximum shade air temperature (T_{max}) for the site shall be derived in accordance with 8.1.3.2.

NOTE The uniform temperature component depends on the minimum and maximum temperature which a bridge could achieve. This results in a range of uniform temperature changes which, in an unrestrained structure would result in a change in member length.

(2) The minimum and maximum uniform bridge temperatures $T_{N\text{.min}}$ and $T_{N\text{.max}}$ should be determined for the relevant bridge deck type.

NOTE The minimum and maximum uniform bridge temperatures $T_{N\text{.min}}$ and $T_{N\text{.max}}$ are given in Table 8.1 (NDP) unless the National Annex gives different values. Table 8.1 (NDP) is based on typical daily shade air temperature ranges of 10 °C.

Table 8.1 — (NDP) Maximum and minimum uniform bridge temperature $T_{N,\text{max}}$ and $T_{N,\text{min}}$

Bridge deck type	$T_{N,max}$	$T_{N,min}$
1	$T_{\text{max}} + 16$	$T_{\text{min}} - 3$
2	$T_{\text{max}} + 4$	$T_{\text{min}} + 4$
3	$T_{\text{max}} + 2$	$T_{\text{min}} + 8$

(3) For steel truss and plate girders, the maximum values given for Type 1 may be reduced by 3 °C.

8.1.3.2 Shade air temperature

(1) Characteristic values of minimum and maximum shade air temperatures for the site location shall be obtained.

NOTE Information on minimum and maximum shade air temperatures (e.g. maps of isotherms or tabulated values) can be found in the National Annex.

(2) Where an annual probability of being exceeded of 0,02 is deemed inappropriate, the minimum shade air temperatures and the maximum shade air temperatures should be modified in accordance with Annex A.

(3) Alternative means of determining the minimum and maximum shade air temperatures (e.g. site-specific analysis or using local meteorological data) may be as specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties to allow for local conditions.

NOTE Examples of local conditions are locations where the minimum values diverge from the values given, such as frost pockets and sheltered low lying areas where the minimum might be substantially lower, or in large conurbations and coastal sites, where the minimum might be higher than that indicated in the relevant figures.

(4) The characteristic values of shade air temperature should be periodically statistically re-evaluated to allow for the potential effects of climate change.

(5) Climate change effects may be considered by means of the change factor ΔT_{cc} in terms of differences obtained from the analysis of future climate projections. Considering the current characteristic values of shade air temperatures $T_{\text{Max,k}}$ / $T_{\text{Min,k}}$ based on past observations, the updated values $T'_{\text{Max},k}$ / $T'_{\text{Max},k}$ covering climate change impacts can be obtained as follows

$$T'_{\text{Max},k} = T_{\text{Max},k} + \max\left(\Delta T_{\text{Max,cc}}\right) \tag{8.1}$$

$$T'_{\text{Min},k} = T_{\text{Min},k} + \min\left(\Delta T_{\text{Min,cc}}\right) \tag{8.2}$$

NOTE The framework for the re-evaluation of the characteristic values of shade air temperature, as well the change factors reflecting the climate change effects can be specified in the National Annex.

8.1.3.3 Uniform bridge temperature component

(1) The values of the minimum ($\Delta T_{N,\text{min}}$) and maximum ($\Delta T_{N,\text{max}}$) uniform bridge temperature components for determination of movements and restraining forces shall be derived from the minimum (T_{min}) and maximum (T_{max}) shade air temperatures, see 8.1.3.1 (3).

(2) The initial bridge temperature T_0 should be taken as the temperature of a structural member at the relevant stage of its restraint (completion).

NOTE In the absence of site specific data, the value of initial bridge temperature T_0 can be given by the mean value of minimum/maximum shade air temperature (T_{min} and T_{max}) unless the National Annex gives a different value.

(3) The effects of both contraction over the range from $T_{0,\text{sup}}$ down to $T_{N,\text{min}}$ and expansion over the range from $T_{0,\text{inf}}$ up to $T_{N,\text{max}}$ should be considered. Upper and lower bound values of the initial bridge temperature ($T_{0,\text{sup}}$ and $T_{0,\text{inf}}$) should be used given as:

$$T_{0,\text{sup}} = T_0 + \Delta T_0 \tag{8.3}$$

$$T_{0,\text{inf}} = T_0 - \Delta T_0 \tag{8.4}$$

ΔT_0 is a range of initial bridge temperature.

NOTE The value of ΔT_0 can be set by the National Annex.

(4) As an alternative, upper and lower bound values of the initial bridge temperature ($T_{0,\text{sup}}$ and $T_{0,\text{inf}}$) may be as specified by the relevant authority or, where not specified, agreed for a specific project by the relevant parties.

(5) The characteristic value of the maximum contraction range of the uniform bridge temperature component, $\Delta T_{\text{N,con}}$ (see Figure 8.1) should be taken as:

$$\Delta T_{\text{N,con}} = T_{0,\text{sup}} - T_{\text{N,min}} \tag{8.5}$$

and the characteristic value of the maximum expansion range of the uniform bridge temperature component, $\Delta T_{\text{N,exp}}$ (see Figure 8.1) should be taken as:

$$\Delta T_{\text{N,exp}} = T_{\text{N,max}} - T_{0,\text{inf}} \tag{8.6}$$

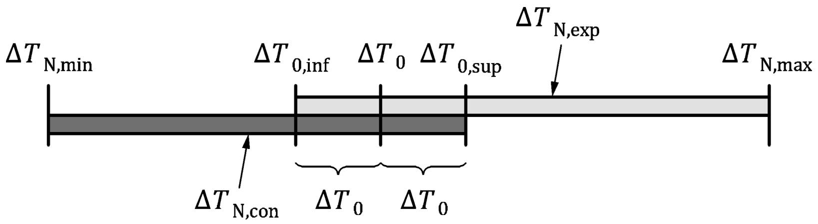


Figure 8.1 — Characteristic value of the maximum contraction ($\Delta T_{N,\text{con}}$) and expansion ($\Delta T_{N,\text{exp}}$) range of the uniform bridge temperature component

NOTE The maximum expansion range, and the maximum contraction range of the uniform bridge temperature component can be set by the National Annex.

8.1.4 Temperature difference components

8.1.4.1 General

(1) The thermal actions that result from a vertical temperature differences through the depth of a bridge deck shall be taken into account.

NOTE Over a prescribed time period heating and cooling of a bridge deck's upper surface will result in a maximum heating (top surface warmer) and a maximum cooling (bottom surface warmer) temperature variation.

(2) In the case of balanced cantilever construction, the influence of the temperature gradient on the free rotation of the cantilever ends at the time of forming the closure joint between adjacent sections should be taken into account.

NOTE Values of the initial temperature difference can be set by the National Annex.

(3) The vertical temperature difference component should generally include a nonlinear component. Either Approach 1 (see 8.1.4.2) or Approach 2 (see 8.1.4.3) should be used.

NOTE The approach to be used can be found in the National Annex.

(4) Where a horizontal temperature difference needs to be considered, a linear temperature difference component may be assumed in the absence of other information (see 8.1.4.4).

8.1.4.2 Vertical linear component (Approach 1)

(1) The effect of vertical temperature differences should be considered by using an equivalent linear temperature difference component with $\Delta T_{M,\text{heat}}$ and $\Delta T_{M,\text{cool}}$. The values $\Delta T_{M,\text{heat}}$ and $\Delta T_{M,\text{cool}}$ should be applied between the top and the bottom of the bridge deck.

(2) The vertical linear component should be defined taking into account different types of bridge decks and the surfacing thickness.

NOTE 1 For 50 mm surfacing thickness, the values of $\Delta T_{M,\text{heat}}$ and $\Delta T_{M,\text{cool}}$ are given in Table 8.2 (NDP) unless the National Annex gives different values.

NOTE 2 For other thicknesses of surfacing, a factor k_{sur} is applied. The values of factor k_{sur} are given in Table 8.3 (NDP) unless the National Annex gives different values.

Table 8.2 — (NDP) Values of linear temperature difference component for different types of bridge decks for road, pedestrian and railway bridges

Type of deck	Top warmer than bottom	Bottom warmer than top
	$\Delta T_{M,heat}$ (°C)	$\Delta T_{M,\mathrm{cool}}$ (°C)
Type 1: Steel deck	18	13
Type 2: Composite deck	15	18
Type 3: Concrete deck: - concrete box girder - concrete beam - concrete slab	 10 15 15	 5 8 8
NOTE The values given in the table could be considered as an upper bound values of the linearly varying temperature difference component for representative sample of bridge geometries.		

Table 8.3 — (NDP) Values of k_{sur} to account for different surfacing thickness

Road, pedestrian and railway bridges						
Surfacing thickness	Type 1		Type 2		Type 3	
	Top warmer than bottom	Bottom warmer than top	Top warmer than bottom	Bottom warmer than top	Top warmer than bottom	Bottom warmer than top
[mm]	k_{sur}	k_{sur}	k_{sur}	k_{sur}	k_{sur}	k_{sur}
0	0,7	0,9	0,9	1,0	0,8	1,1
waterproofed [a)]	1,6	0,6	1,1	0,9	1,5	1,0
50	1,0	1,0	1,0	1,0	1,0	1,0
100	0,7	1,2	1,0	1,0	0,7	1,0
150	0,7	1,2	1,0	1,0	0,5	1,0
ballast	0,6	1,4	0,8	1,2	0,6	1,0
[a)] These values could be considered as upper bound values for dark colour.						

8.1.4.3 Vertical temperature components with nonlinear effects (Approach 2)

(1) The effect of the vertical temperature differences should be considered by including a nonlinear temperature difference component.

(2) The vertical temperature differences should be defined taking into account different types of bridge decks and the surfacing thickness.

NOTE 1 Values of vertical temperature differences for bridge decks are given in Tables 8.4 (NDP) to 8.7 (NDP) for 40 mm surfacing thickness in the case of deck type 1 and 100 mm for deck types 2 and 3, unless the National Annex gives different values. Temperature profiles are illustrated in Figures 8.2 to 8.4.

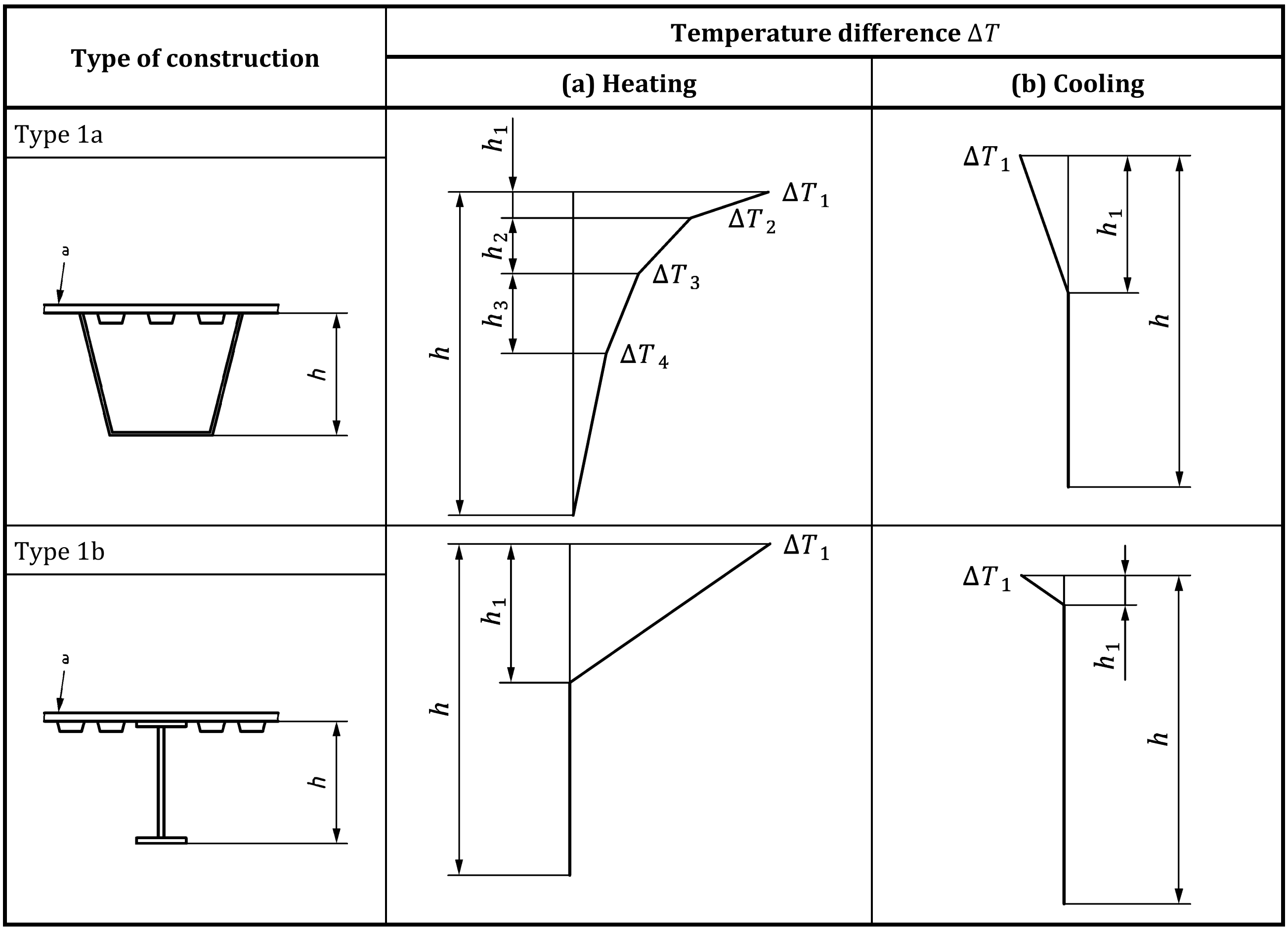
NOTE 2 In Tables 8.4 to 8.6 “heating” refers to conditions such that solar radiation and other effects cause a gain in heat through the top surface of the bridge deck. Conversely, “cooling” refers to conditions such that heat is lost from the top surface of the bridge deck as a result of re-radiation and other effects.

NOTE 3 In Table 8.5 for composite bridges the simplified procedure can be used giving upper bound of thermal effects. Values for ΔT in this procedure are indicative and can be used, unless the National Annex gives different values.

(3) For other surfacing thicknesses, Annex B shall be used.

Table 8.4 — (NDP) Values of temperature differences ΔT_i for steel deck considering depth h

Type 1a – steel deck on steel box girders	**(a) heating**		**(b) cooling**	
	Depth h_i	Temperature differences ΔT_i	Depth h_i	Temperature differences ΔT_1
		$\Delta T_1 = 24$ °C		$\Delta T_1 = -6$ °C
	$h_1 = 0,1$ m	$\Delta T_2 = 14$ °C	$h_1 = 0,5$ m	
	$h_2 = 0,2$ m	$\Delta T_3 = 8$ °C		
	$h_3 = 0,3$ m	$\Delta T_4 = 4$ °C		
1b – steel deck on steel truss or plate girders	$h_1 = 0,5$ m	$\Delta T_1 = 21$ °C	$h_1 = 0,1$ m	$\Delta T_1 = -5$ °C



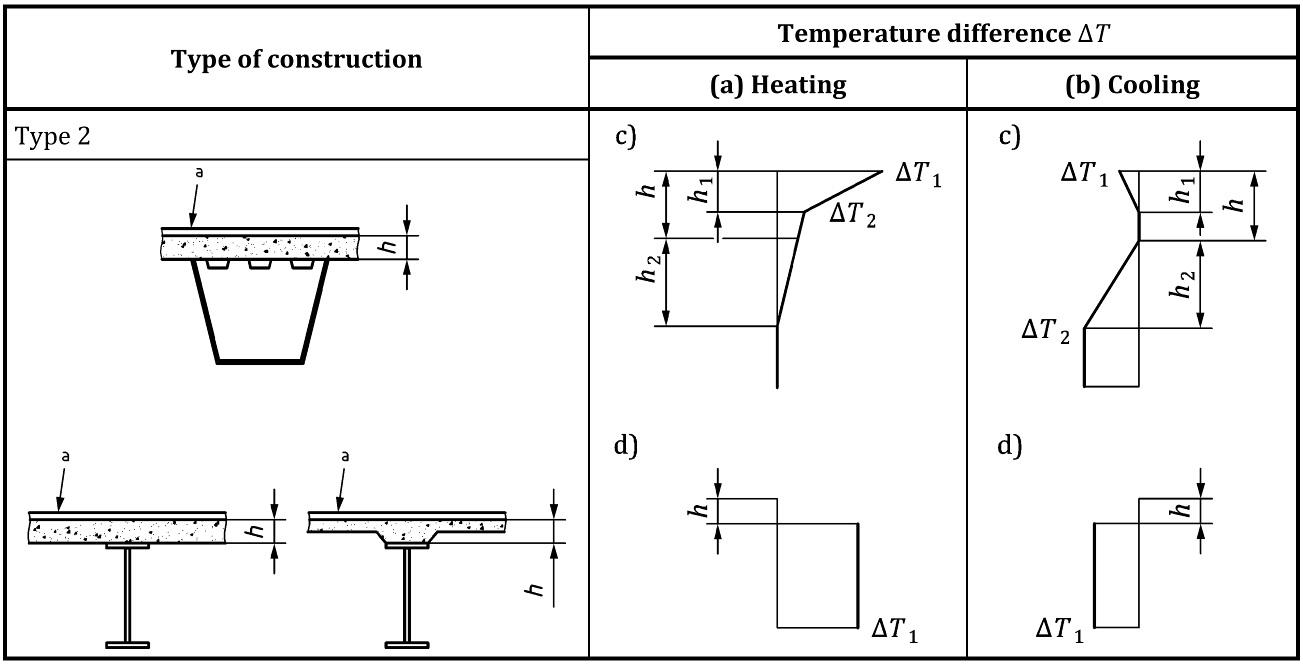
Key

Type 1a	Steel deck on steel box girders
Type 1b	Steel deck on steel truss or plate girders
a	40 mm surfacing

Figure 8.2 — Temperature differences for bridge decks — Type 1: Steel decks

Table 8.5 — (NDP) Temperature differences for bridge decks — Type 2: Composite decks

2 – Composite decks, depth h_i	**(a) heating**		**(b) cooling**	
c) Normal procedure				
$h = 0,2$ m $h_1 = 0,6\ h$ $h_2 = 0,4$ m	$\Delta T_1 = 13$ °C	$\Delta T_2 = 4$ °C	$\Delta T_1 = -3,5$ °C	$\Delta T_2 = -8$ °C
$h = 0,3$ m $h_1 = 0,6\ h$ $h_2 = 0,4$ m	$\Delta T_1 = 16$ °C	$\Delta T_2 = 4$ °C	$\Delta T_1 = -5$ °C	$\Delta T_2 = -8$ °C
d) Simplified procedure				
	$\Delta T_1 = 18$ °C		$\Delta T_1 = -10$ °C	



Key

Type 2	Concrete deck on steel box, truss or plate girders
a	100 mm surfacing
c)	normal procedure
d)	simplified procedure

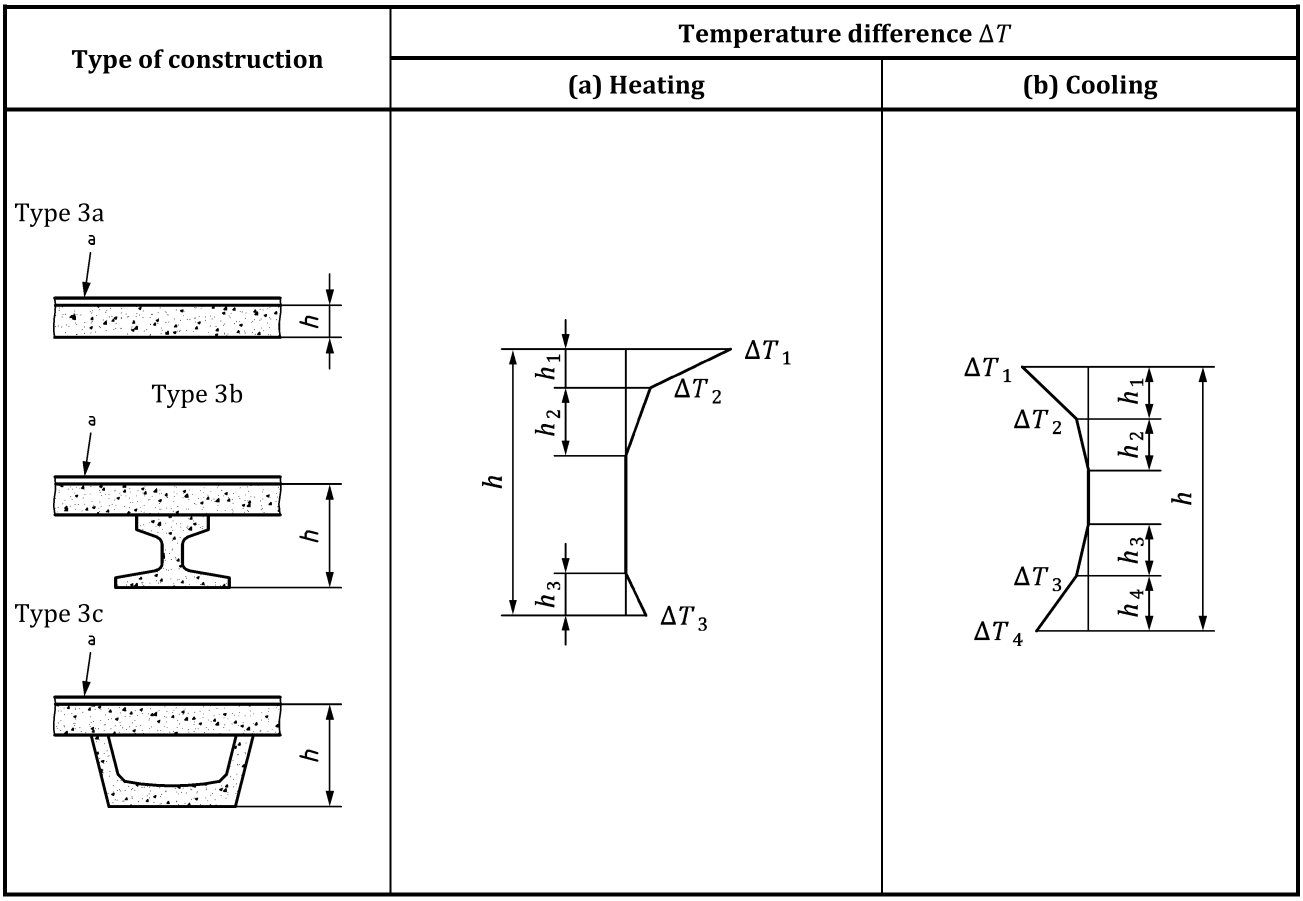
Figure 8.3 — Temperature difference for bridge decks — Type 2: Composite decks

Table 8.6 — (NDP) Temperature differences for bridge decks — Type 3: Concrete decks, (a) heating

Depth h	ΔT_1	ΔT_2	ΔT_3
≤ 0,2 m	8,5	3,5	0,5
0,4	12	3,0	1,5
0,6	13	3,0	2,0
≥ 0,8	13	3,0	2,5
$h_1 = 0{,}3\ h$, but $h_1 \leq 0{,}15$ m $h_2 = 0{,}3\ h$, but $0{,}10\ \text{m} \leq h_2 \leq 0{,}25$ m $h_3 = 0{,}3\ h$, but $h_3 \leq 0{,}10$ m (+ surfacing depth in metres), for thin slabs h_3 is limited by $h - h_1 - h_2$			

Table 8.7 — (NDP) Temperature differences for bridge decks — Type 3: Concrete decks, (b) cooling

Depth h	ΔT_1	ΔT_2	ΔT_3	ΔT_4
≤ 0,2 m	−2,0	−0,5	−0,5	−1,5
0,4	−4,5	−1,4	−1,0	−3,5
0,6	−6,5	−1,8	−1,5	−5,0
0,8	−7,6	−1,7	−1,5	−6,0
1,0	−8,0	−1,5	−1,5	−6,3
≥ 1,5	−8,4	−0,5	−1,0	−6,5
$h_1 = h_4 = 0{,}20\ h$, but ≤ 0,25 m $h_2 = h_3 = 0{,}25\ h$, but ≤ 0,20 m				



Key

Type 3a	Concrete slab
Type 3b	Concrete beam
Type 3c	Concrete box girder
a	100 mm surfacing

Figure 8.4 — Temperature difference for bridge decks — Type 3: Concrete decks

8.1.4.4 Horizontal components

(1) In general, the temperature difference component should only be considered in the vertical direction.

(2) In particular cases (for example when the orientation or configuration of the bridge results in one side being more highly exposed to sunlight than the other side) a horizontal temperature difference component should be considered.

NOTE The value of temperature difference in the horizontal, transversal direction between the outer edges of the bridge independent of the width of the bridge is 5 °C unless the National Annex gives a different value.

8.1.4.5 Temperature difference components within walls of concrete box girders

(1) Care should be exercised in the design of large concrete box girder bridges where significant temperature differences can occur between the inner and outer web walls of such structures.

NOTE The value for a linear temperature difference within walls of concrete box girders is 15 °C unless the National Annex gives a different value.

8.1.5 Simultaneity of uniform and temperature difference components

(1) If it is necessary to take into account both the temperature difference $\Delta T_{\mathrm{M,heat}}$ (or $\Delta T_{\mathrm{M,cool}}$) and the maximum range of uniform bridge temperature component $\Delta T_{\mathrm{N,exp}}$ (or $\Delta T_{\mathrm{N,con}}$) assuming simultaneity (e.g. in case of frame structures), the most adverse effect from either Formula (8).7) or Formula (8).8) should be chosen when considering Approach 1:

$$\Delta T_{\mathrm{M,heat}} \left(\mathrm{or}\ \Delta T_{\mathrm{M,cool}}\right) + \omega_{\mathrm{N}}\ \Delta T_{\mathrm{N,exp}} \left(\mathrm{or}\ \ \Delta T_{\mathrm{N,con}}\right) \tag{8.7}$$

or

$$\omega_{\mathrm{M}}\ \Delta T_{\mathrm{M,heat}} \left(\mathrm{or}\ \Delta T_{\mathrm{M,cool}}\right) + \Delta T_{\mathrm{N,exp}} \left(\mathrm{or}\ \ \Delta T_{\mathrm{N,con}}\right) \tag{8.8}$$

NOTE The values of reduction factors are ω_N = 0,35 and ω_M = 0,75 unless the National Annex gives different values.

(2) A similar procedure may be applied when considering Approach 2.

NOTE The values of reduction factors ω_N and ω_M can be set in the National Annex

8.1.6 Differences in the uniform temperature component between different structural members

(1) Significant differences in the uniform temperature component between different structural members should be taken into account.

NOTE The difference in the uniform temperature between main structural members (e.g. tie and arch) is 15 °C, and between suspension/stay cables and deck (or tower) 10 °C for light colour, and 20 °C for dark colour unless the National Annex gives a different value.

(2) These effects should be considered in addition to the effects resulting from a uniform temperature component in all members, determined from 8.1.3.

8.2 Bridge piers

(1) Temperature differences between the outer faces of bridge piers, hollow or solid, shall be considered in the design.

NOTE Such temperature differences can lead to restraining forces or movements in the surrounding structures.

(2) Overall temperature effects on piers should be considered, when these can lead to restraining forces or movements in the surrounding structures.

(3) For concrete piers (hollow or solid), the linear temperature differences between opposite outer faces should be taken into account.

NOTE The value for a linear temperature difference for concrete piers is 5 °C unless the National Annex gives a different value.

(4) For concrete walls, the linear temperature differences between the inner and outer faces should be taken into account.

NOTE The value for a linear temperature difference for concrete walls is 15 °C unless the National Annex gives a different value for use in a country.

(5) For steel or composite piers, minimum and maximum values of the linear temperature differences between opposite outer faces should be identified.

NOTE Minimum and maximum values for a linear temperature difference for steel or composite piers can be set in the National Annex.

(6) Additional project-specific values for a linear temperature difference for steel or composite piers may be as specified by the relevant authority or, where not specified, agreed for a specific project by the relevant parties.

8.3 Thermal actions due to hot paving

(1) When relevant, effects due to thermal actions arising during paving of hot asphalt on bridge deck should be considered in the design of the structural members. The actions should be assessed by taking into account a uniform temperature component and vertical and horizontal temperature difference components.

(2) For other effects which should be taken into account where relevant, see 8.1.2 (2).

(3) In general hot paving is a transient design situation of short duration.

(4) The uniform temperature and temperature difference components due to the application of hot paving systems on bridge decks should be specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties, taking into account all relevant factors.

NOTE Factors affecting the thermal actions due to hot paving can be the materials used, the thickness of the surfacing material layer and its extent across the deck, the temperature at which it is placed, the rate of heat transfer into the deck and the degree of restraint provided by adjacent surfacing that remains in place, etc.

9 Thermal actions on industrial chimneys, silos, tanks and cooling towers

9.1 General

(1) Industrial chimneys, silos, tanks and cooling towers shall be designed for

- thermal actions from climatic effects due to the variation of shade air temperature and solar radiation;
- temperature distribution for normal and abnormal process conditions;
- effects arising from interaction between the structure and its contents during thermal changes (e.g. shrinkage of the structure against stiff solid contents or expansion of solid contents during heating or cooling);
- the effect of temperature differences between adjacent members.

(2) Values of maximum and minimum flue gas, liquids and materials with different temperatures should be agreed for a specific project by the relevant parties.

NOTE Containment structures can be subjected to thermally induced changes in shape arising from heating/cooling effects of either the contents or their surrounding external environment.

9.2 Determination of temperature components

(1) The uniform and linearly varying temperature components shall be determined taking into account climatic effects and operating conditions.

(2) The linearly varying temperature difference component in the wall or its layers shall be taken as arising from the difference between the minimum (or maximum) shade air temperature on the outer face and the value of the liquid or gas temperature on the inner face, taking into account insulation effects.

NOTE Guidance on temperature profiles is given in Annex C.

9.3 Values of temperature components

(1) In the absence of any specific information on characteristic values of the temperature components, the following guidance and indicative values may be used.

(2) The maximum and minimum uniform temperature component should be based on the maximum and minimum shade air temperature.

NOTE The National Annex can give values of the maximum and minimum uniform temperature components valid for industrial chimneys, silos, tanks and cooling towers.

(3) For concrete structures, the linear temperature difference component between the inner and outer faces of the wall should be considered.

NOTE The value of the linear temperature difference component for concrete walls is 15 °C unless the National Annex gives a different value.

(4) For concrete structures of cylindrical shape a stepped temperature component round the circumference (causing both overall and local thermal effects) should be taken into account on the basis that one quadrant of its circumference has a mean temperature higher than that one of the remainder of the circumference.

NOTE The value of the difference of temperature is 15 °C unless the National Annex gives a different value.

(5) The rules for steel chimneys are given in EN 13084-1.

(6) The rules for temperature difference between the stored solid and the silo structure and/or between the external environment and the silo structure are given in EN 1991-4.

9.4 Simultaneity of temperature components

(1) When considering thermal actions due to climatic effects only, the following components should be assumed to act simultaneously:

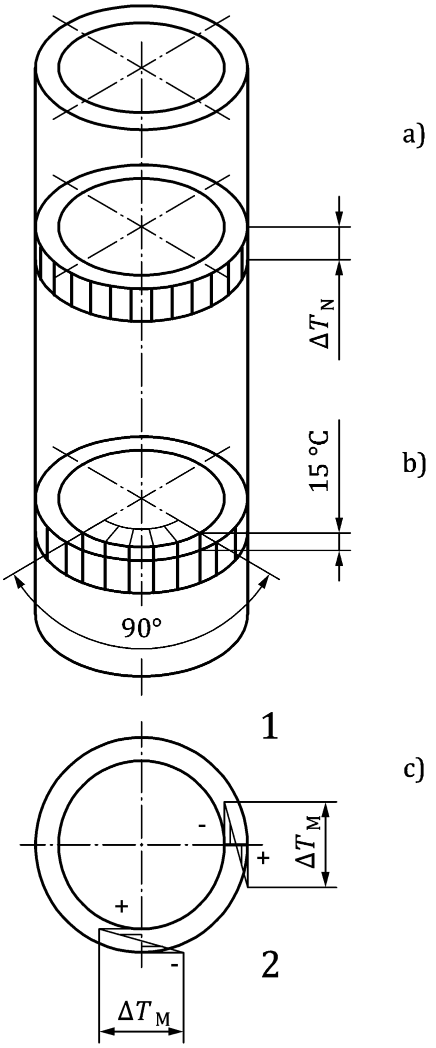
a) uniform temperature component (see Figure 9.1 (a));

b) stepped temperature component (see Figure 9.1 (b));

c) the linear temperature difference component between the inner and the outer faces of the wall (see Figure 9.1 (c)).

(2) When considering a combination of thermal actions due to climatic effects with those due to process effects (heated gas flow, liquids or heated materials) the following components should be combined:

- uniform temperature component;
- linear temperature difference component;
- stepped component.



Key

- a) Uniform temperature component
- b) Stepped temperature component round the circumference
- c) Linear temperature difference component between the inner and the outer faces of the wall
- 1 Outer face warmer
- 2 Inner face warmer

Figure 9.1 — Temperature components for silos, tanks, cooling towers and chimneys

Annex A
(normative)

Adjustment of shade air temperature for an annual probability *p* of being exceeded

A.1 Field of application

(1) This Annex provides adjustment of the shade air temperature for an annual probability *p* of being exceeded.

A.2 Adjustment using extreme value distribution

(1) The extreme value distribution should be used for determination of the values of maximum (or minimum) shade air temperature, $T_{\max,p}$ ($T_{\min,p}$) for an annual probability *p* of being exceeded other than 0,02.

(2) In common cases, the Weibull distribution may be applied, then the value of maximum (or minimum) shade air temperature, $T_{\max,p}$ ($T_{\min,p}$) may be derived from the following formulae based on a type III extreme value distribution:

for maximum: $T_{\max,\mathrm{p}} = T_{\max} \; \{k_1 - k_2 \ln\left[-\ln\left(1-p\right)\right]\}$ (A.1)

for minimum: $T_{\min,\mathrm{p}} = T_{\min} \; \{k_3 + k_4 \ln\left[-\ln\left(1-p\right)\right]\}$ (A.2)

where

$T_{\max}$ ($T_{\min}$) is the value of maximum (minimum) shade air temperature with an annual probability of being exceeded of 0,02

$k_1 = uc / \left(uc + 3{,}902\right)$ (A.3)

$k_2 = 1 / \left(uc + 3{,}902\right)$ (A.4)

where

u, c are the mode and scale parameters of the annual maximum shade air temperature distribution.

$k_3 = uc / \left(uc - 3{,}902\right)$ (A.5)

$k_4 = 1 / \left(uc - 3{,}902\right)$ (A.6)

The parameters *u* and *c* depend on the mean value *m* and the standard deviation *σ* of the Weibull distribution:

for maximum: $u = m - 0{,}57722 / c$ (A.7)

for minimum: $u = m + 0{,}57722 / c$ (A.8)

$c = 1{,}2825 / \sigma$

NOTE 1 The ratios $T_{\max,p}/T_{\max}$ and $T_{\min,p}/T_{\min}$ respectively can then be taken from Figure A.1 based on the coefficients k_1 to k_4:

$k_1 = 0{,}781$;

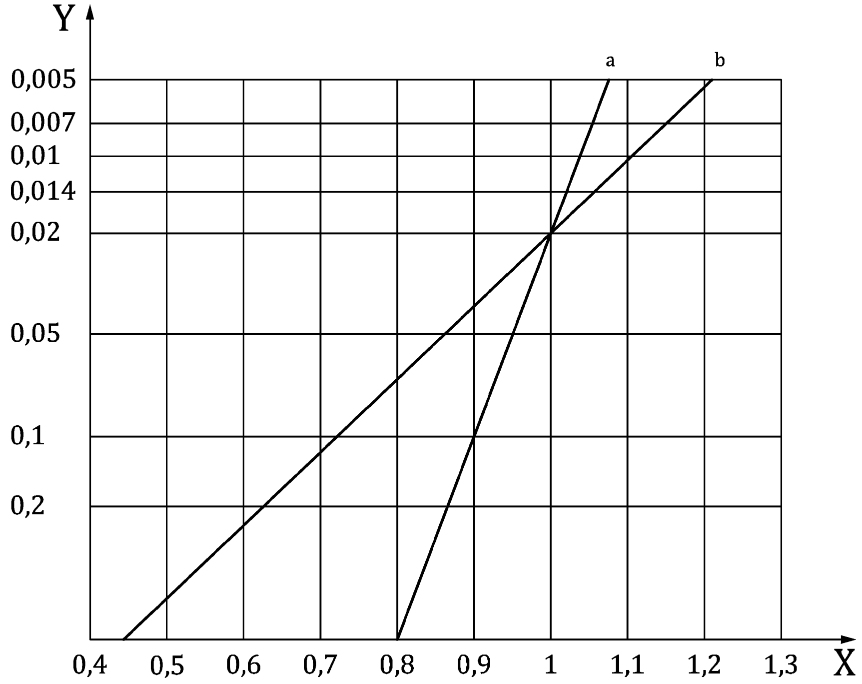
$k_2 = 0{,}056$;

$k_3 = 0{,}393$;

$k_4 = -0{,}156$.

unless the National Annex gives alternative values of coefficients k_1, k_2, k_3 and k_4, depending on climate conditions.

NOTE 2 Formula (A.2) and Figure A.1 can only be used if $T_{\min}$ is negative.



Key

X $T_{\max,p} / T_{\max}$ or $T_{\min,p} / T_{\min}$

Y p

a maximum

b minimum

Figure A.1 — Ratios $T_{max,p} / T_{max}$ or $T_{min,p} / T_{min}$ for probability p

NOTE 3 Another extreme value distribution can be set by the National Annex as appropriate.

Annex B
(normative)

Vertical temperature differences with various surfacing thickness using Approach 2

B.1 Field of application

(1) This Annex applies for determination of vertical temperature differences with various surfacing thickness using Approach 2.

B.2 Vertical temperature differences

(1) Temperature difference profiles for surfacing thicknesses other than 40 mm for deck type 1, and 100 mm for types 2 and 3 should be defined.

NOTE 1 The values of temperature differences are given in Tables B.1 (NDP) to B.3 (NDP) for deck types 1 to 3, unless the National Annex gives different values.

NOTE 2 Ballasted decks are not explicitly covered.

Table B.1 — (NDP) Values of ΔT for deck type 1

Surfacing thickness	**Temperature difference**				
	Heating				**Cooling**
	ΔT_1	ΔT_2	ΔT_3	ΔT_4	ΔT_1
mm	°C	°C	°C	°C	°C
0	30	16	6	3	8
20	27	15	9	5	6
40	24	14	8	4	6

Table B.2 — (NDP) Values of ΔT for deck type 2

Depth of slab (h)	Surfacing thickness	Temperature difference	
		Heating	Cooling
		ΔT_1	ΔT_1
m	mm	°C	°C
0,2	0	16,5	5,9
	waterproofed [a]	23,0	5,9
	50	18,0	4,4
	100	13,0	3,5
	150	10,5	2,3
	200	8,5	1,6
0,3	0	18,5	9,0
	waterproofed [a]	26,5	9,0
	50	20,5	6,8
	100	16,0	5,0
	150	12,5	3,7
	200	10,0	2,7

[a] These values represent upper bound values for dark colour.

Table B.3 — (NDP) Values of ΔT for deck type 3

Depth of slab (h)	Surfacing thickness	Temperature difference						
		Heating			Cooling			
		ΔT_1	ΔT_2	ΔT_3	ΔT_1	ΔT_2	ΔT_3	ΔT_4
m	mm	°C	°C	°C	°C	°C	°C	°C
0,2	0	12,0	5,0	0,1	4,7	1,7	0,0	0,7
	waterproofed [a]	19,5	8,5	0,0	4,7	1,7	0,0	0,7
	50	13,2	4,9	0,3	3,1	1,0	0,2	1,2
	100	8,5	3,5	0,5	2,0	0,5	0,5	1,5
	150	5,6	2,5	0,2	1,1	0,3	0,7	1,7
	200	3,7	2,0	0,5	0,5	0,2	1,0	1,8
0,4	0	15,2	4,4	1,2	9,0	3,5	0,4	2,9
	waterproofed [a]	23,6	6,5	1,0	9,0	3,5	0,4	2,9
	50	17,2	4,6	1,4	6,4	2,3	0,6	3,2
	100	12,0	3,0	1,5	4,5	1,4	1,0	3,5
	150	8,5	2,0	1,2	3,2	0,9	1,4	3,8
	200	6,2	1,3	1,0	2,2	0,5	1,9	4,0
0,6	0	15,2	4,0	1,4	11,8	4,0	0,9	4,6
	waterproofed [a]	23,6	6,0	1,4	11,8	4,0	0,9	4,6
	50	17,6	4,0	1,8	8,7	2,7	1,2	4,9
	100	13,0	3,0	2,0	6,5	1,8	1,5	5,0
	150	9,7	2,2	1,7	4,9	1,1	1,7	5,1
	200	7,2	1,5	1,5	3,6	0,6	1,9	5,1
0,8	0	15,4	4,0	2,0	12,8	3,3	0,9	5,6
	waterproofed [a]	23,6	5,0	1,4	12,8	3,3	0,9	5,6
	50	17,8	4,0	2,1	9,8	2,4	1,2	5,8
	100	13,5	3,0	2,5	7,6	1,7	1,5	6,0
	150	10,0	2,5	2,0	5,8	1,3	1,7	6,2
	200	7,5	2,1	1,5	4,5	1,0	1,9	6,0
1,0	0	15,4	4,0	2,0	13,4	3,0	0,9	6,4
	waterproofed [a]	23,6	5,0	1,4	13,4	3,0	0,9	6,4
	50	17,8	4,0	2,1	10,3	2,1	1,2	6,3
	100	13,5	3,0	2,5	8,0	1,5	1,5	6,3
	150	10,0	2,5	2,0	6,2	1,1	1,7	6,2
	200	7,5	2,1	1,5	4,3	0,9	1,9	5,8
1,5	0	15,4	4,5	2,0	13,7	1,0	0,6	6,7
	waterproofed [a]	23,6	5,0	1,4	13,7	1,0	0,6	6,7
	50	17,8	4,0	2,1	10,6	0,7	0,8	6,6
	100	13,5	3,0	2,5	8,4	0,5	1,0	6,5
	150	10,0	2,5	2,0	6,5	0,4	1,1	6,2
	200	7,5	2,1	1,5	5,0	0,3	1,2	5,6

[a] These values represent upper bound values for dark colour.

Annex C
(informative)

Temperature profiles in buildings and other construction works

C.1 Use of this Informative Annex

(1) This Informative Annex provides supplementary guidance for the determination of temperature profiles using the thermal transmission theory.

NOTE National choice on the application of this Informative Annex is given in the National Annex. If the National Annex contains no information on the application of this Informative Annex, it can be used.

C.2 Field of application

(1) This Informative Annex applies to buildings and other construction works.

C.3 Thermal transmission theory

(1) In the case of a simple sandwich member (e.g. slab, wall, shell) without local thermal bridges the temperature T(x) at a distance x from the inner surface of the cross section may be determined assuming steady thermal state as

$$T(x) = T_{\text{in}} - \frac{R(x)}{R_{\text{tot}}}\left(T_{\text{in}} - T_{\text{out}}\right) \tag{C.1}$$

where

T_{in} is the air temperature of the inner environment;

T_{out} is the temperature of the outer environment;

R_{tot} is the total thermal resistance of the member including resistance of both surfaces;

$R(x)$ is the thermal resistance at the inner surface and of the member from the inner surface up to the point x (see Figure C.1).

(2) The total thermal resistance R_{tot} and $R(x)$ [$\text{m}^2\text{K/W}$] may be determined using the coefficient of heat transfer and coefficients of thermal conductivity given in EN ISO 6946 and EN ISO 13370:

$$R_{\text{tot}} = R_{\text{in}} + \sum_i \frac{h_i}{\lambda_{\text{i}}} + R_{\text{out}} \tag{C.2}$$

where

R_{in} is the thermal resistance at the inner surface [$\text{m}^2\text{K/W}$];

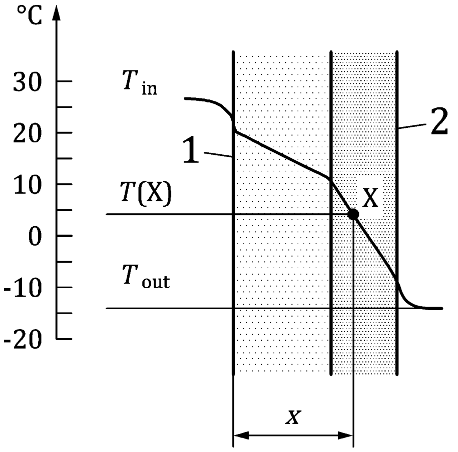
R_{out} is the thermal resistance at the outer surface [$\text{m}^2\text{K/W}$];

λ_i is the thermal conductivity and h_i [m] is the thickness of the layer i [W/(mK)].

$$R(x) = R_{\text{in}} + \sum_i \frac{h_i}{\lambda_i} \tag{C.3}$$

where layers (or part of a layer) from the inner surface up to point x (see Figure C.1) are considered only.

NOTE In buildings the thermal resistance R_{in} = 0,10 to 0,17 [m^{2}K/W] (depending on the orientation of the heat flow), and R_{out} = 0,04 (for all orientations). The thermal conductivity λ_i for concrete (of volume weight from 21 to 25 kN/m^3) varies from λ_i = 1,16 to 1,71 [W/(mK)].



Key

1 Inner surface

2 Outer surface

Figure C.1 — Thermal profile of a two-layer member

Bibliography

References contained in recommendations (i.e. "should" clauses)

The following documents are referred to in the text in such a way that some or all of their content constitutes highly recommended choices or course of action of this document. Subject to national regulation and/or any relevant contractual provisions, alternative documents could be used/adopted where technically justified. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies

None.

References contained in permissions (i.e. "may" clauses)

The following documents are referred to in the text in such a way that some or all of their content expresses a course of action permissible within the limits of the Eurocodes. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies

[1] EN 1994-2, *Eurocode — Design of composite steel and concrete structures — Part 2: General rules and rules for bridges*

[2] EN ISO 6946, Building components and building elements — Thermal resistance and thermal transmittance — Calculation methods *(ISO 6946)*

[3] EN ISO 13370, Thermal performance of buildings — Heat transfer via the ground — Calculation methods *(ISO 13370)*

References contained in permissions (i.e. "can" clauses) and notes

The following documents are cited informatively in the document, for example in "can" clauses and in notes

[4] EN 1991-2, *Eurocode 1: Actions on structures — Part 2: Traffic loads on bridges and other civil engineering works*

[5] EN 1991-4, *Eurocode 1: Actions on structures — Part 4: Silos and tanks*

[6] EN 13084-1, *Free-standing chimneys — Part 1: General requirements*

[7] EN 14509, *Self-supporting double skin metal faced insulating panels — Factory made products — Specifications*