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SANS 10160-7: BASIS OF STRUCTURAL DESIGN AND ACTIONS FOR BUILDINGS AND INDUSTRIAL STRUCTURES — PART 7: THERMAL ACTIONS

Remarks:

PLEASE NOTE:

- **The technical committee, SABS SC 59I responsible for the preparation of this standard has reached consensus that the attached document should become a South African standard. It is now made available by way of public enquiry to all interested and affected parties for public comment, and to the technical committee members for record purposes. Any comments should be sent by the indicated closing date, either by mail, or by fax, or by e-mail to**

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Basis of structural design and actions for buildings and industrial structures

Part 7: Thermal actions

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Table of changes

Change No.	Date	Scope

Foreword

This South African standard was approved by National Committee SABS SC 59I, *Construction standards – Bases for the design of structures* in accordance with procedures of the SABS Standards Division, in compliance with annex 3 of the WTO/TBT agreement.

This document supersedes SABS 0160:1989 (edition 2).

This document was published in xxxx 2009.

The SANS 10160 series consists of the following eight parts, under the general title *Basis of structural design and actions for buildings and industrial structures*:

Part-1, *Basis of structural design.*

Part-2, *Self-weight and imposed loads.*

Part-3, *Wind actions.*

Part-4, *Seismic actions and general requirements for buildings.*

Part-5, *Basis of geotechnical design and actions.*

Part-6, *Actions induced by cranes and machinery.*

Part-7, *Thermal actions.*

Part-8, *Actions during execution.*

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Basis of structural design and actions for buildings and industrial structures

Part-7:
Thermal actions

1 Scope

1.1 This part of the SANS 10160 Series falls within the general scope of application as given in SANS 10160-1 clause 1.1.

1.2 The requirements specified in SANS 10160-2 shall be applied in conjunction with the requirements specified in the following parts of the SANS 10160 Series :

Part-1, *Basis of structural design*

Part 2: *Self-weight and imposed loads*

Part-3, *Wind actions*

Part-4, *Seismic actions and general requirements for buildings*

Part-5, *Basis of geotechnical design and actions*

Part 6 : *Actions induced by cranes and machinery*

Part-8, *Actions during execution*

1.3 This standard gives principles and rules for determining thermal actions on buildings and industrial structures including their structural elements as well as principles needed for determining thermal actions for cladding and other appendages of buildings are also provided.

1.4 It describes the changes in the temperature of structural elements. Characteristic values of thermal actions are presented for use in the design of structures which are exposed to daily and seasonal climatic changes. Structures not so exposed may not need to be considered for thermal actions.

1.5 Actions due to other sources of expansion or contraction of materials, for example due to changes in moisture content in masonry or timber or structural components and machinery adjacent to furnace tapping facilities, are not defined in this Part, but have to be considered.

2 Normative references

The following referenced documents are indispensable for the application 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. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

SANS 10100-1 *The structural use of concrete Part 1: Design*

SANS 10137 *The installation of glazing in buildings*

SANS 10160-1 *Basis of structural design and actions for buildings and industrial structures Basis of structural design*

SANS 10160-2 *Basis of structural design and actions for buildings and industrial structures* – Part 2: Self-weight and imposed loads

SANS 10160-3 *Basis of structural design and actions for buildings and industrial structures- Part 3: Wind actions*

SANS 10160-4 *Basis of structural design and actions for buildings and industrial structures – Part 4: Seismic actions and general requirements for buildings*

SANS 10160-5 *Basis of structural design and actions for buildings and industrial structures – Part 5: Basis for geotechnical design and actions*

SANS 10160-6, *Basis of structural design and actions for buildings and industrial structures –* Part-6, *Actions induced by cranes and machinery*

SANS 10160-8 *Basis of structural design and actions for buildings and industrial structures – Part 8: Actions during execution*

SANS 10162-1 *The structural use of steel Part 1: Limit-state design of hot-rolled steelwork*

SANS 10162-2 *The structural use of steel Part 2: Limit-states design of cold-formed steelwork*

SANS 10162-4 *Structural use of steel Part 4: The design of cold-formed stainless steel structural members*

SANS 10163-1 *The structural use of timber Part 1: Limit-states design*

SANS 10164-2 *The structural use of masonry Part 2: Structural design and requirements for reinforced and pre-stressed masonry*

3 Definitions and symbols

For the purpose of this document the definitions and symbols given in SANS 10160-1 and the following apply :

3.1 Definitions

3.1.1
thermal actions
those actions that arise from the changes of temperature fields within a specified time interval

3.1.2
shade air temperature
temperature measured by thermometers placed in a white painted louvred wooden box known as a "Stevenson screen"

3.1.3
maximum shade air temperature
maximum shade air temperature with an annual probability of being exceeded 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
minimum shade air temperature with an annual probability of being exceeded of 0,02 (equivalent to a mean return period of 50 years), based on the minimum hourly values recorded

3.1.5
initial temperature
temperature of a structural element at the relevant stage of its restraint (completion)

3.1.6
cladding
part of the building which provides a weatherproof membrane.

NOTE Generally cladding will only carry self-weight and/or wind actions

3.1.7
uniform temperature component
temperature that which governs the expansion or contraction of an element or structure and constant over the cross section

3.1.8
temperature difference component
part of a temperature profile in a structural element representing the temperature difference between the outer face of a element and any in-depth point

3.2 Symbols

NOTE The notation used is based on ISO 3898.

3.2.1 Latin upper case letters

R thermal resistance of structural element

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 being exceeded of 0,02 (equivalent to a mean return period of 50 years)

T_{min} minimum shade air temperature with an annual probability of being exceeded of 0,02 (equivalent to a mean return period of 50 years)

$T_{max,p}$ maximum shade air temperature with an annual probability of being exceeded p (equivalent to a mean return period of $1/p$)

$T_{min,p}$ minimum shade air temperature with an annual probability of being exceeded p (equivalent to a mean return period of $1/p$)

T_0 initial temperature when structural element is restraint

T_{in} air temperature of the inner environment

T_{out} temperature of the outer environment

ΔT_u uniform temperature component

ΔT_M linear temperature difference component

ΔT_E non-linear part of the temperature difference component

ΔT sum of linear temperature difference component and non-linear part of the temperature difference component

3.2.2 Latin lower case letters

h height of the cross section

$k_1 k_2$ coefficients for the calculation of maximum (minimum) shade air temperature

$k_3 k_4$ with an annual probability of being exceeded, p, other than 0,02

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 parameter of annual maximum (minimum) shade air temperature distribution

3.2.3 Greek lower case letters

α_T coefficient of linear expansion (1/ºC)

λ thermal conductivity

4 Classification of actions

4.1 Thermal actions shall be classified as variable and indirect actions (see SANS 10160-1).

4.2 All values of thermal actions given are characteristic values unless it is stated otherwise.

4.3 Characteristic values of thermal actions as given are 50-year return values, unless stated otherwise, for example, transient design situations. The values of both annual minimum and annual maximum shade air temperature represent values with an annual probability of being exceeded of 0,02. The annual maximum shade air temperature is shown in figure 1, the annual minimum shade air temperature is shown in figure 2, normalised for sea level in both cases.

These values should be adjusted for height above sea level. If no information is available, the values of shade air temperature may be adjusted for height above sea level by subtracting 0,5 ºC/100 m height for minimum shade air temperatures and 1,0 ºC/100 m height for maximum shade air temperatures.

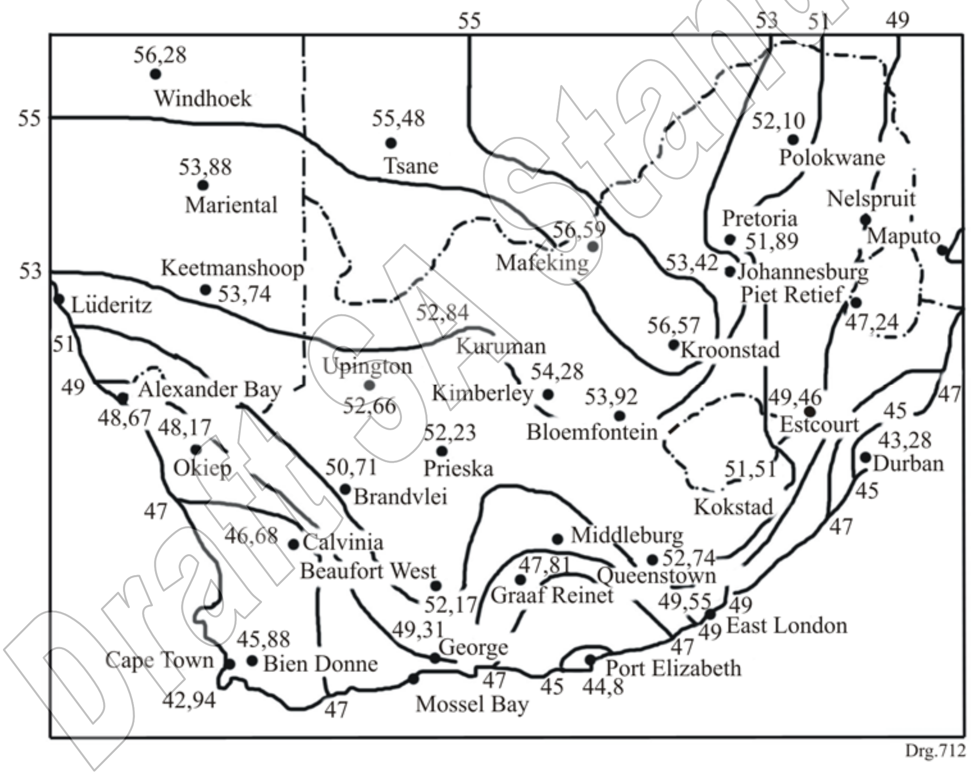

Figure 1 — Isotherms of maximum shade air temperature in ºC for a 50-year return period

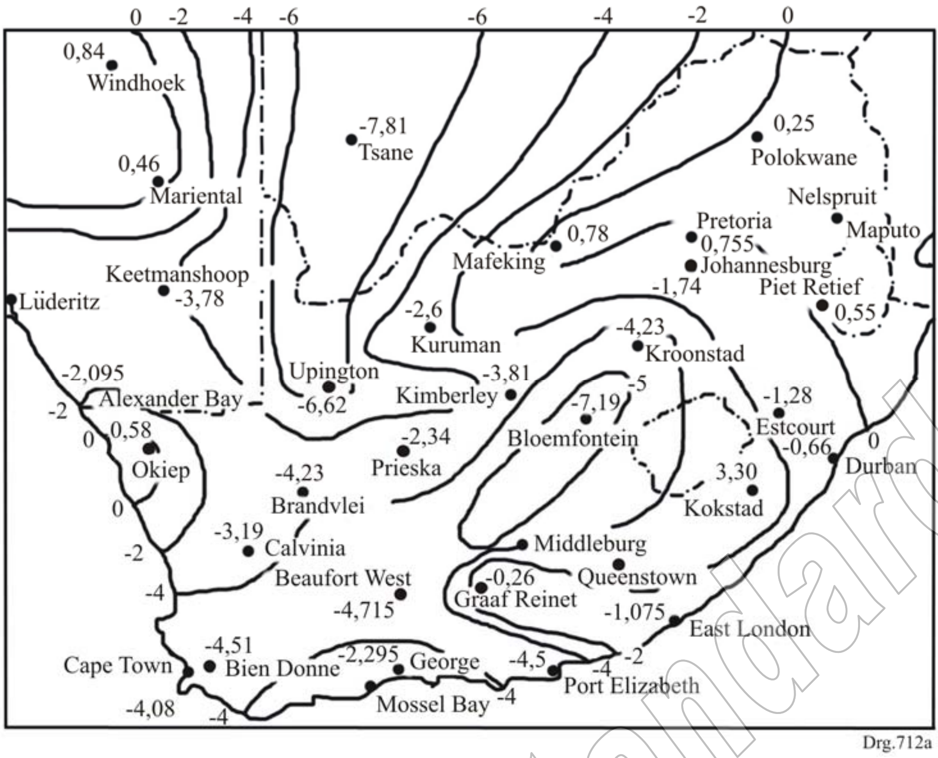

Figure 2 — Isotherms of minimum shade air temperature in °C for a 50-year return period

4.4 The initial temperature T_0 should be taken as the temperature of a structural element at the relevant stage of its restraint (completion). If it is not predictable, the average temperature during the construction period should be taken.

NOTE If no information is available, T_0 may be taken as 10 ^{0}C. Using a possible maximum and minimum T_0 should be considered, whichever has the worst effect.

4.5 At locations where the minimum values diverge from the values given, such as frost pockets and sheltered low lying areas where the minimum may be substantially lower, or in large conurbations and coastal sites, where the minimum may be higher than that indicated in the relevant figures, these divergences should be taken into consideration using local meteorological data.

4.6 If the value of maximum (or minimum) shade air temperature, $T_{\max,p}$ $\left(T_{\min,p}\right)$, is based on an annual probability of being exceeded p other than 0,02, the ratio $T_{\max,p} / T_{\max}$ $\left(T_{\min,p} / T_{\min}\right)$ may be determined from figure 3.

NOTE 1 In general $T_{\max,p}$ (or $T_{\min,p}$) may be derived from equations based on a type 1 extreme value distribution. A procedure for determining $T_{\max,p}$ (or $T_{\min,p}$) is given in annex A.

NOTE 2 Figure 3 can only be used if $T_{\min}$ is negative.

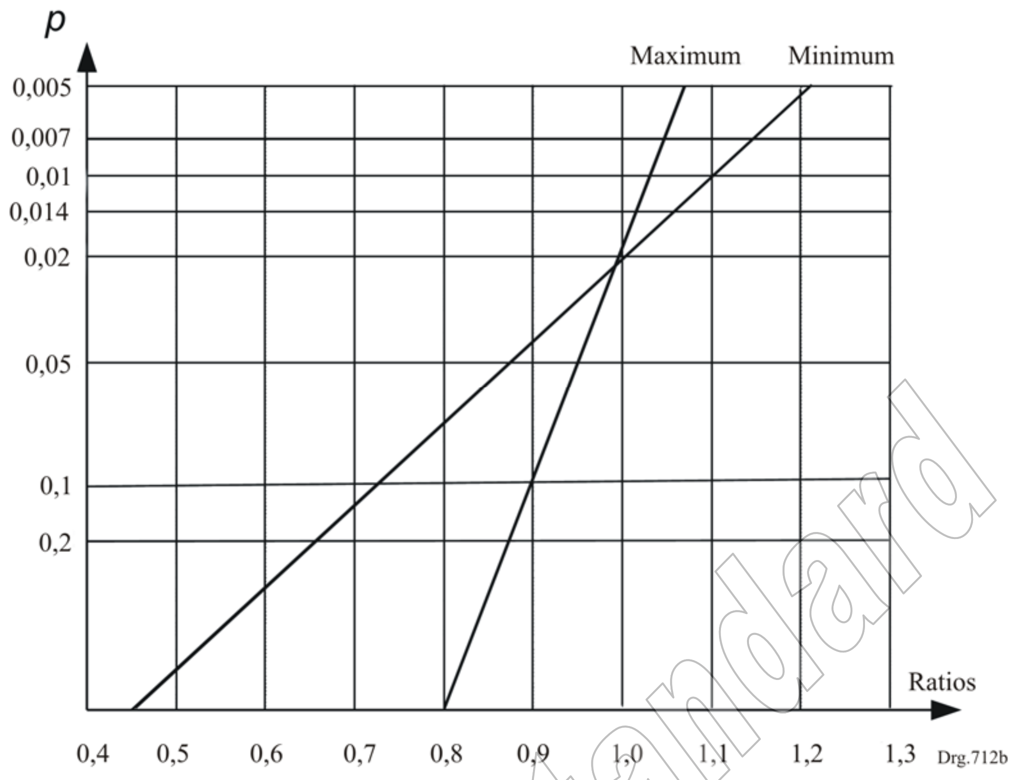

Figure 3 — Probability of exceedance as a function of the ratios $T_{max,p} / T_{max}$, and $T_{min,p} / T_{min}$

5 Design situations

5.1 Thermal actions shall be determined for each relevant design situation identified in accordance with SANS 10160-1.

5.2 The elements of load bearing structures shall be checked to ensure that thermal movement will not cause overstressing of the structure, either by the provision of movement joints or by including these effects in the design.

6 Representation of actions

6.1 Daily and seasonal changes in shade air temperature, solar radiation, re-radiation, etc., will result in variations of the temperature distribution within individual elements of a structure.

6.2 The magnitude of the thermal effects will depend on local climatic conditions, together with the orientation of the structure, its overall mass, finishes (e.g. cladding in buildings), and in the case of building structures, heating and ventilation regimes and thermal insulation.

6.3 The temperature distribution within an individual structural element may be split into the following four essential constituent components in a given direction, as illustrated in figure 4:

a) a uniform temperature component, ΔT_u

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

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

d) a non-linear temperature difference component, ΔT_E . This results in a system of self-equilibrated stresses which produce no net load effect on the element.

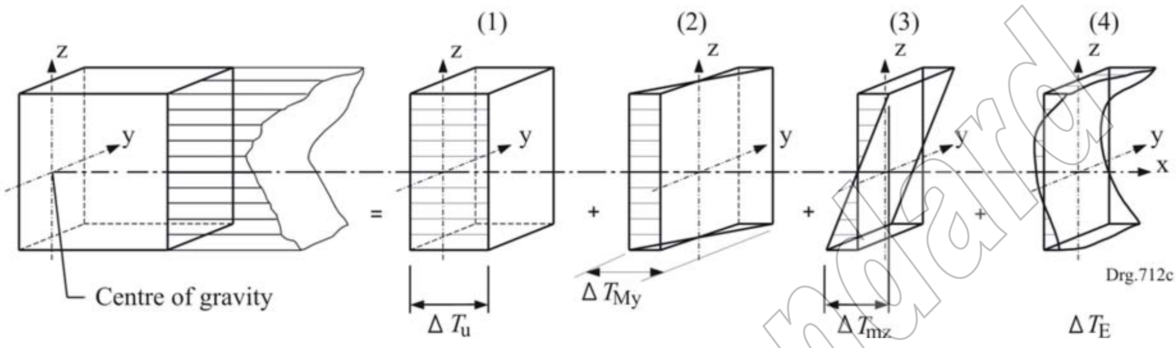

Figure 4 — Diagrammatic representation of constituent components of a temperature profile

6.4 The strains and therefore any resulting stresses are dependent on the geometry and boundary conditions of the element being considered and on the physical properties of the material used. When materials with different coefficients of linear expansion are used compositely the thermal effect should be taken into account.

6.5 For the purpose of deriving thermal effects, the coefficient of linear expansion for a material should be used.

NOTE The coefficient of linear expansion for a selection of commonly used materials is given in annex B.

7 Temperature changes in buildings

7.1 General

Thermal actions on buildings due to climatic and operational temperature changes 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 movement or stresses (or both).

NOTE 1 Volume changes and/or stresses due to temperature changes may also be influenced by :
- shading due to adjacent buildings;
- use of different materials with different thermal expansion coefficients and heat transfer;
- use of different shapes of cross-section with different uniform temperature and
- design and detailing of the building.

NOTE 2 Moisture and other environmental factors may also affect the volume changes of elements.

7.2 Determination of temperatures

7.2.1 Thermal actions on buildings due to climatic and operational temperature changes should be determined in accordance with the principles and rules provided in this part taking into account regional data and experience.

7.2.2 The climatic effects shall be determined by considering the variation of shade air temperature and solar radiation. Operational effects (due to heating, technological or industrial processes) shall be considered in accordance with the particular project.

7.2.3 In accordance with the temperature components given in clause 4, climatic and operational thermal actions on a structural element shall be specified using the following basic quantities:

a) a uniform temperature component ΔT_u given by the difference between the average temperature T of an element and its initial temperature T_0;

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; and

c) a temperature difference ΔT_p of different parts of a structure given by the difference of average temperatures of these parts.

NOTE Values of ΔT_M and ΔT_p may be provided for particular projects.

7.2.4 In addition to ΔT_u, ΔT_M and ΔT_P, local effects of thermal actions should be considered where relevant (for example at supports or fixings of structural and cladding elements). Adequate representation of thermal actions should be defined taking into account the location of the building and structural detailing.

7.2.5 The uniform temperature component of a structural element ΔT_u is defined as:

$$\Delta T = T - T_0 \qquad (1)$$

where

T is an average temperature of a structural element due to climatic temperatures in winter or summer season and due to operational temperatures.

7.2.6 The quantities ΔT_u, ΔT_M, ΔT_P, and T should be determined in accordance with the principles provided in 7.3 using regional data. When regional data is not available, the rules in 7.3 may be applied.

7.3 Determination of temperature profiles

7.3.1 The temperature T in equation 1 should be determined as the average temperature of a structural element in winter or summer using a temperature profile. In the case of a sandwich element, T is the average temperature of a particular layer.

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

7.3.2 The temperature of the inner environment, T_{in} , should be determined in accordance with the particular project.

NOTE When no data are available, the indicative temperature of the inner environment T_{in} may be taken as 20 ºC.

7.3.3 The maximum temperature of the outer environment, $T_{out,max}$, which occurs in summer, consists of the maximum shade air temperature T_{max} , as defined in 2 (c), which is increased by the effect of solar radiation, expressed as temperature T_r . The value of T_r is dependent on the relative absorptivity of the surface and the orientation of the surface as defined in Table 1.

The minimum temperature of the outer environment, $T_{out,min}$, which occurs in winter, consists of the minimum shade air temperature T_{min} , as defined in 2 (c), as indicated in table 1, ignoring solar radiation effects.

NOTE The temperatures T_{out} for the summer season as indicated in table 1 depend on:

- the heat absorption characteristics of the surface;
- the orientation (the maximum is usually reached for horizontal surfaces and for surfaces facing the west or north-west and the minimum (in 0C about half of the maximum) for surfaces facing the south or south-east.

Table 1 — Indicative temperatures T_{out} for structures above ground level

1	2	3	4	5	6
Season	**Surface colour**	**Significance[a] factor**	**Temperature T_{out} °C**		
			Shade air temperature	**Orientation of surfaces**	
				Horizontal, North, West	**South, East**
Summer	bright light surface	0,5	T_{max}	$T_r = 20$	$T_r = 0$
	light coloured surface	0,7	T_{max}	$T_r = 30$	$T_r = 2$
	dark surface	0,9	T_{max}	$T_r = 40$	$T_r = 4$
Winter	N/A	N/A	T_{min}	$T_{max} / 2$	$T_{max} / 2$

[a] Relative absorptivity depending on surface colour.

Annex A
(informative)

Procedure for determining $T_{\max,p}$ (or $T_{\min,p}$)

A.1 Determination of $T_{\max,p}$

In general $T_{\max,p}$ may be derived from the following equation based on a type I extreme value distribution:

$$T_{\max,p} = T_{\max}\left\{k_1 - k_2 \times \ln\left[-\ln\left(1-p\right)\right]\right\} \quad (A.1)$$

where

$T_{\max,p}$ is the value of maximum shade air temperature with an annual probability of being exceeded of 0,02;

$$k_1 = u/\left(u + 3{,}90\right) \quad (A.2)$$

$$k_2 = 1/\left(u + 3{,}90\right) \quad (A.3)$$

The parameters u and c are dependent on the mean value m and the standard deviation σ. of type 1 extreme value distribution:

$$u = m - 0{,}577/c \quad (A.4)$$

$$c = 1{,}238/\sigma \quad (A.5)$$

where

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

NOTE If no other information is available the following values may be used:
$k_1 = 0{,}781$;
$k_2 = 0{,}056$;

A2 Determination of $T_{\min,p}$

In general $T_{\min,p}$ may be derived from the following Equations based on a Type 1 extreme value distribution:]

$$T_{\min,p} = T_{\min}\left\{k_3 - k_4 \times \ln\left[-\ln\left(1-p\right)\right]\right\} \quad (A.6)$$

where

T_{min} is the value of minimum shade air temperature with an annual probability of being exceeded of 0,02;

$$k_3 = u/(u - 3,90) \quad (A.7)$$

$$k_4 = 1/(u - 3,90) \quad (A.8)$$

The parameters u and c are dependent on the mean value m and the standard deviation σ of type 1 extreme value distribution:

$$u = m + 0,577/c \quad (A.9)$$

$$c = 1,283/\sigma \quad (A.10)$$

where

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

NOTE If no other information is available the following values may be used:

$k_3 = 0,393$

$k_4 = -0,156$

Annex B
(informative)

Coefficients of linear expansion

For the determination of action effects due to temperature components, table B.1 gives values of the coefficient of linear expansion for a selection of commonly used materials.

Table B.1 — Coefficients of linear expansion

1	2	3	4
Material	**Base**	**Description**	α_T ($\times 10^{-6}/^\circ C$)
Metals	Aluminium, aluminium alloy		23,0
	Brass		19,0
	Bronze		18,0
	Copper		16,7
	Iron	grey cast	11,0
		wrought	12,0
	Lead		28,7
	Magnesium		28,8
	Nickel		12,6
	Steel	cast	11,3
		stainless	17,8
		structural	11,7
	Zinc	rolled	31,0
Non-metals	Portland cement		13,0
	Concrete	stone	10,0
		lightweight aggregate	7,0
	Glass		7,8
	Granite		8,3
	Limestone		7,9
	Marble		9,0
	Masonry		6,1
	Masonry		6,3
	Plaster		16,0
	Sandstone		11,0
	Slate		10,0
	Timber	along grain	5,4
		across grain	30 to 70

Bibliography

ISO 3898 *Bases for design of structures – Notations – General symbols.*