International Standard 6946/2

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Thermal insulation — Calculation methods — Part 2: Thermal bridges of rectangular sections in plane structures

Isolation thermique — Règles de calcul — Partie 2: Ponts thermiques en forme de poutre rectangulaire en partie courante des structures

First edition — 1986-11-15

UDC 699.86.001.24 **Ref. No. ISO 6946/2-1986 (E)**

Descriptors : buildings, thermal insulation, rules of calculation

Price based on 10 pages

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 6946/2 was prepared by Technical Committee ISO/TC 163, *Thermal insulation.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Thermal insulation — Calculation methods — Part 2: Thermal bridges of rectangular sections in plane structures

0 Introduction

The presence of a thermal bridge in a plane building structure, in winter and under steady state conditions, causes two phenomena which are linked to one another:

a) the temperature of the internal surface at the location of the thermal bridge is lower than the internal surface temperature at other locations;

b) the areal density of the heat transfer rate at the location of the thermal bridge is higher than that at other locations.

To judge the practical consequences of these two phenomena (risks of condensation and extra heat losses), a quantitative analysis is necessary. This can be done by analytical or numerical methods with the aid of a computer. However, in the early "sketching" stages of structural design, this method has the disadvantage that, in many cases, the designer has neither the time nor the skill to use computer programs.

This part of ISO 6946 presents simple, basic formulae which can be used to determine in the sketching stage whether or not the performance of a given building structure will meet given requirements. In these formulae, quantities are introduced that are characteristic of the thermal bridge concerned. For the numerical determination of these quantities, different methods are possible.

A simple, approximate method of calculation is given in annex A. This method is based on the results of numerous computer calculations.

Some numerical examples are given in annex B.

1 Scope and field of application

This part of ISO 6946 gives basic formulae for the calculation of

a) the zone of influence of a thermal bridge, i.e. the area in which the heat flow has a noticeable component parallel to the surfaces of the structure;

b) the lowest internal surface temperature at the location of a thermal bridge under steady state winter conditions and under given internal and external ambient temperatures;

c) the value of the areal thermal transmittance of a building structure containing a thermal bridge.

It is applicable only to thermal bridges with rectangular sections in plane structures.

2 Reference

ISO 7345, *Thermal insulation — Physical quantities and definitions.*

3 Definitions and symbols

For the purposes of this part of ISO 6946, the definitions and symbols given in ISO 7345, together with the following, apply.

thermal bridge (in a plane building structure) (part of a building envelope): Location at which the composition differs from that of the adjacent surroundings and at which, in winter and under steady state conditions, the internal surface temperature is lower than that on the adjacent surfaces.

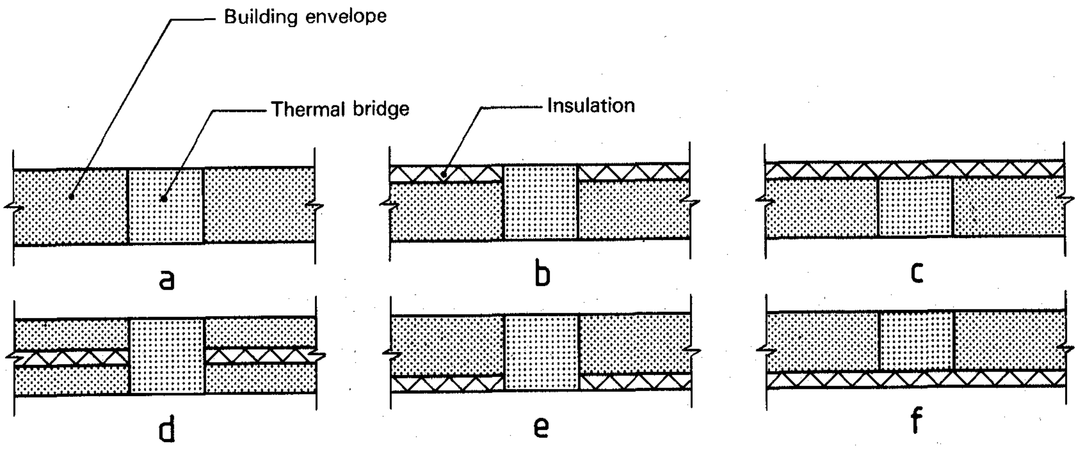


Figure 1 — Cross-sections of basic types of thermal bridge[1]

4 Types of thermal bridge

With the limitations mentioned in clause 1, six basic types of thermal bridge are distinguished, as shown in figure 1.

The geometrical parameters of thermal bridges are shown in figure 2,

where

l is the length of the structure and of the thermal bridge;

b is the width of the thermal bridge;

d is the thickness of the structure;

B is the width of the structure.

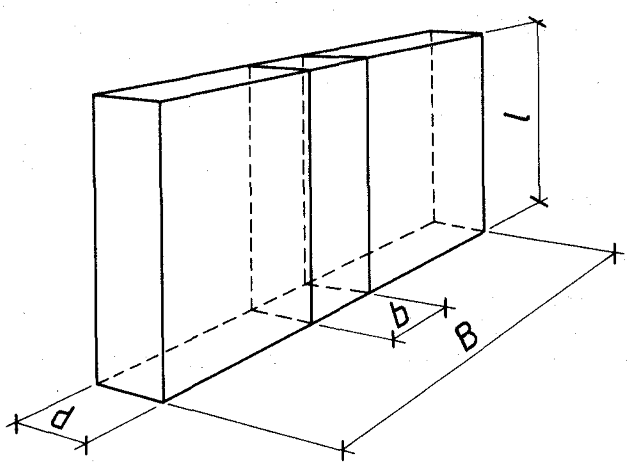


Figure 2 — Geometrical parameters (view)

The total area A is equal to Bl, while the area of the thermal bridge (A_{TB}) is equal to bl.

5 Calculation method

5.1 Auxiliary quantities

In the formulae given in 5.3 and 5.4, the auxiliary quantities U_0, U_{TB} and $\overline{U}$ are used. These are defined by formulae (1), (2) and (3) respectively.

5.1.1 Auxiliary quantity U_0 [W/(m^2·K)]

$$U_0 = [(\Sigma R)_0 + R_i + R_e]^{-1} \quad \ldots(1)$$

where

$(\Sigma R)_0$ is the sum of the thermal resistances, in square metre kelvins per watt, from surface to surface, of the subsequent layers at locations other than the thermal bridge;

R_i is the surface thermal resistance, in square metre kelvins per watt, at the interior surface;

R_e is the surface thermal resistance, in square metre kelvins per watt, at the exterior surface.

5.1.2 Auxiliary quantity U_{TB} [W/(m^2·K)]

$$U_{TB} = [(\Sigma R)_{TB} + R_i + R_e]^{-1} \quad \ldots(2)$$

where

$(\Sigma R)_{TB}$ is the sum of the thermal resistances, in square metre kelvins per watt, from surface to surface, of the subsequent layers at the location of the thermal bridge;

R_i and R_e are as defined in 5.1.1.

1) In this part of ISO 6946, when cross-sections of structures that are part of the building envelope are illustrated, the outdoor climate is always presumed to be on the top (or the left-hand side) and the indoor climate on the bottom (or the right-hand side).

5.1.3 Auxiliary quantity $\overline{U}$ [W/(m²·K)]

$$\overline{U} = \frac{A - A_{TB}}{A} U_0 + \frac{A_{TB}}{A} U_{TB} = \frac{B - b}{B} U_0 + \frac{b}{B} U_{TB} \quad \ldots(3)$$

where

A is the total area, in square metres, of the structure;

A_{TB} is the area, is square metres, of the thermal bridge;

B is the width, in metres, of the structure;

b is the width, in metres, of the thermal bridge.

5.2 Zone of influence of the thermal bridge

The width of the zone of influence on each side of the thermal bridge, a, is defined as the larger of the two values obtained from formulae (4a) and (4b) (see also figure 3):

$$a_i = 2\sqrt{R_i\ d_i\ \lambda_i} \quad \ldots(4a)$$

$$a_e = 2\sqrt{R_e\ d_e\ \lambda_e} \quad \ldots(4b)$$

where

d_i is the thickness of the layer (either building envelope or insulation) adjacent to the interior environment at locations other than the thermal bridge;

λ_i is the thermal conductivity, in watts per metre kelvin, of the material of that layer;

d_e is the thickness of the layer (either building envelope or insulation) adjacent to the exterior environment at locations other than the thermal bridge;

λ_e is the thermal conductivity, in watts per metre kelvin, of the material of that layer;

R_i and R_e are as defined in 5.1.1.

For homogeneous constructions, d_i and d_e are equal to half the thickness of the construction.

In the example shown in figure 3, a equals a_i.

In the case where the width of the structure, B, (or the distance between the axes of symmetry) does not cover the total zone of influence on both sides of the thermal bridge (i.e. in the case where $B < 2a + b$), there is no simple approximate method of calculating either the lowest internal surface temperature or the thermal transmittance.

5.3 Lowest internal surface temperature

The lowest internal surface temperature at the location of the thermal bridge (ϑ_{TB}) under steady state winter conditions is calculated from formula (5):

$$\vartheta_{TB} = \vartheta_i - \zeta\,(\vartheta_i - \vartheta_e) \quad \ldots(5)$$

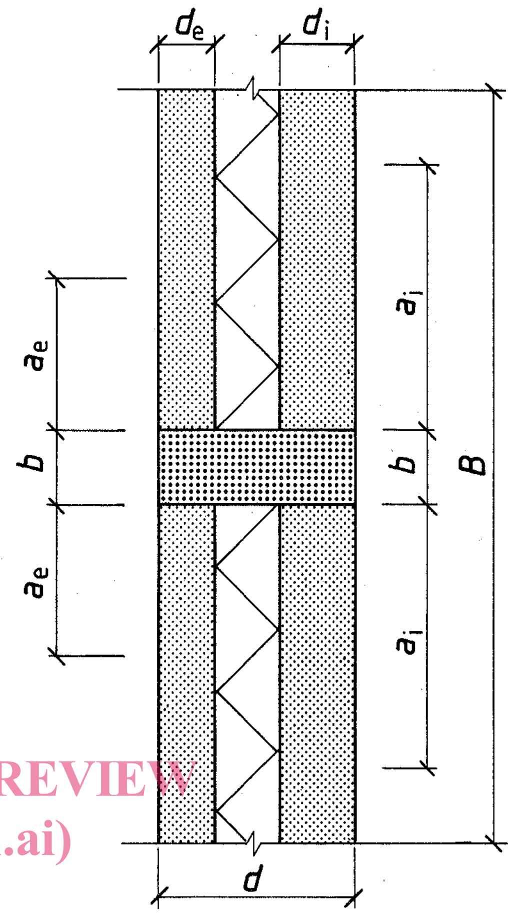


Figure 3 — Geometrical parameters (cross-section)

where

ϑ_i is the internal ambient temperature, in degrees Celsius;

ϑ_e is the external ambient temperature, in degrees Celsius;

and the temperature difference ratio, ζ, explicitly expressed as

$$\zeta = \frac{\vartheta_i - \vartheta_{TB}}{\vartheta_i - \vartheta_e} \quad \ldots(5a)$$

is given by formula (6):

$$\zeta = R_i\,[U_0 + \eta(U_{TB} - U_0)] \quad \ldots(6)$$

where

U_0 and R_i are as defined in 5.1.1;

U_{TB} is as defined in 5.1.2;

η is a factor characteristic of the thermal bridge concerned.

In the case where $B < 2a + b$, the value of η changes with the value of B.

5.4 Thermal transmittance

The thermal transmittance (U) of a building structure containing a thermal bridge shall be calculated from either formula (7) or (9):

$$U = \frac{(A - A_{TB})\, U_0 + l U_l}{A} \qquad \dots(7)$$

where

A is the total area, in square metres, of the structure;

A_{TB} is the area, in square metres, of the thermal bridge;

U_0 is the auxiliary factor defined in 5.1.1;

l is the length, in metres, of the structure and the thermal bridge;

U_l is the linear thermal transmittance, in watts per metre kelvin, of the thermal bridge.

U_l can be expressed as:

$$U_l = b\, U_{TB} + \xi U' \qquad \dots(8)$$

where

b is the width, in metres, of the thermal bridge;

$U' = 1$ W/(m·K);

ξ is a factor characteristic of the thermal bridge concerned.

Substitution of relation (8) as well as $A = l \cdot B$ and $A_{TB} = l \cdot b$ (see clause 4) in relation (7) and taking into account formula (3) leads to relation (9):

$$U = \overline{U} + \xi \frac{U'}{B} \qquad \dots(9)$$

where

$\overline{U}$ is the auxiliary quantity defined in 5.1.3;

$U' = 1$ W/(m·K);

B is the width, in metres, of the structure;

ξ is a factor characteristic of the thermal bridge concerned.

In the case where $B < 2a + b$, the value of ξ changes with the value of B.

Annex A

Approximate method to calculate the values of factors η and ξ

(This annex does not form part of the Standard.)

A.1 Symbols

In addition to the quantities defined in clauses 4, 5.1 and 5.2, the following symbols are used in this annex:

d_{ins}: thickness, in metres, of the insulation layer

d': 1 m

λ_{ins}: thermal conductivity, in watts per metre kelvin, of the insulating material

λ_c: thermal conductivity, in watts per metre kelvin, of the material constituting the building envelope

λ_{TB}: thermal conductivity, in watts per metre kelvin, of the material constituting the thermal bridge

λ': 1 W/(m·K)

A.2 Formulae

Approximate formulae are given in the table for the calculation values of η and ξ for each type of thermal bridge.

These formulae are based on the results of numerous computer calculations on each type of thermal bridge described in clause 4.

For the parameters b, d, d_{ins}, λ_c, λ_{TB} and λ_{ins}, each combination of the following matrix was considered:

b: 0,05 m — 0,10 m — 0,15 m — 0,20 m — 0,25 m

d: 0,10 m — 0,20 m — 0,30 m — 0,40 m

d_{ins}: $0,2\,d$ — $0,6\,d$

λ_c: 0,2 W/(m·K) — 1,1 W/(m·K) — 2,0 W/(m·K)

λ_{TB}: 1,0 W/(m·K) — 2,0 W/(m·K)

λ_{TB}: $\geqslant \lambda_c$

λ_{ins}: 0,02 W/(m·K) — 0,07 W/(m·K)

Furthermore, the following assumptions were made:

$$B = 1 \text{ m} \quad R_i = 0{,}13 \text{ m}^2\text{·K/W} \quad R_e = 0{,}04 \text{ m}^2\text{·K/W}$$

The formulae given in the table may also be used when other surface thermal resistances have to be taken into account, provided that they do not differ by more than 0,01 m²·K/W from the values of R_i and R_e given above.

The assumption $B = 1$ m has the consequence that the application of the formulae in the table is restricted to those cases in which $2a + b < 1$ m, the quantity a being the width of the zone of influence of the thermal bridge as defined in 5.2.

As far as thermal bridges of type d are concerned, the relevant formulae from the table may be used only if each of the following three conditions is fulfilled (see also figure 3):

a) $d_i \geqslant 0{,}02$ m

b) $d_e \geqslant 0{,}02$ m

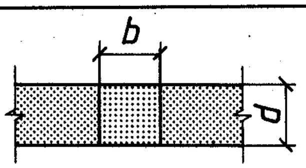
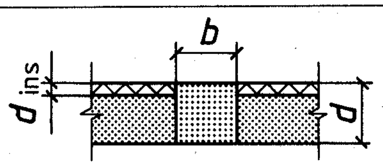
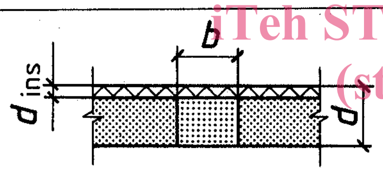
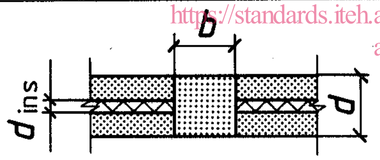
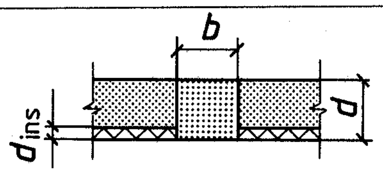
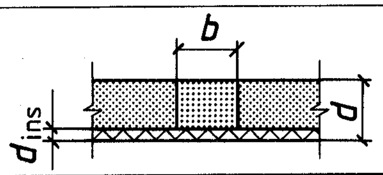
c) $2 > \dfrac{d_i}{d_e} > 0{,}5$

A.3 Accuracy

Values of the temperature difference ratio (ζ), calculated using the approximate formulae for η given in this annex, normally differ by less than 5 % from values obtained from computer calculations.

Values of the thermal transmittance (U), calculated using the approximate formulae for ξ given in this annex, usually differ by no more than 5 % from values obtained from computer calculations.

Table — Approximate formulae to calculate values of η and ξ

Basic type	Cross-section	Calculation of η	Calculation of ξ
	Top = exterior Bottom = interior	Auxiliary quantities $Z_1 = \frac{(d'-b)\,d}{d'b} \times \left(\frac{\lambda_c}{\lambda_{TB}}\right)^{0,5}$ $Z_2 = \left[\frac{(d'-b)\,d}{d'b}\right]^{-0,75} \times \left(\frac{d}{d_{ins}}\right)^{0,5}$	$\xi = p \times \left(\frac{b}{d'}\right)^q \times \left(\frac{d}{d'}\right)^r \times \left(\frac{d_{ins}}{d'}\right)^s \times$ $\times \left(\frac{\lambda_c}{\lambda'}\right)^t \times \left(\frac{\lambda_{TB}}{\lambda'}\right)^u \times \left(\frac{\lambda_{ins}}{\lambda'}\right)^v$
a		$\eta = \left[1 + 0{,}29\, Z_1\right]^{-1}$	$\xi = 0$
b		$\eta = \left[1 + 0{,}59\, Z_1\right]^{-1}$	$p = 0{,}1$ $q = 0{,}38$ $t = 0{,}65$ $r = 0{,}35$ $u = 0{,}34$ $s = -0{,}33$ $v = -0{,}26$
c		$\eta = 1 + 2{,}4\left[Z_1 + Z_1^{-1}\right]^{-1}$	$\xi = 0$
d		$\eta = \left[1 + 0{,}33\, Z_1\right]^{-1}$	$p = 0{,}1$ $q = 0{,}39$ $t = 0{,}71$ $r = 0{,}37$ $u = 0{,}42$ $s = -0{,}29$ $v = -0{,}24$
e		$\eta = 1 + 0{,}1\, Z_1\, Z_2$	$p = 0{,}04$ $q = 0{,}15$ $t = 0{,}34$ $r = 0{,}16$ $u = 0{,}18$ $s = -0{,}21$ $v = -0{,}14$
f		$\eta = \left[1 + 0{,}67\, Z_1\right]^{-1}$	$\xi = 0$

Annex B

Numerical examples

(This annex does not form part of the Standard.)

B.0 Introduction

In the examples given in this annex, U-values are expressed to three decimal places and ϑ-values to two decimal places. In reality, the third decimal place in a U-value and the second decimal place in a ϑ-value have no significance.

B.1 Example 1

B.1.1 Description of structure (see also figure 4)

Wall structure consisting of columns of dense concrete at distances of 4 m. Width of each column: 0,2 m. Thickness: 0,26 m. Between the columns, elements of lightweight concrete with a thickness of 200 mm and a thermal conductivity of 0,2 W/(m·K). Insulation layer with a thickness of 60 mm on the outside of the lightweight concrete. Thermal conductivity of the insulation: 0,04 W/(m·K). On the external surface of the structure, there is a 4 mm thick rendering of plaster [λ = 1,0 W/(m·K)].

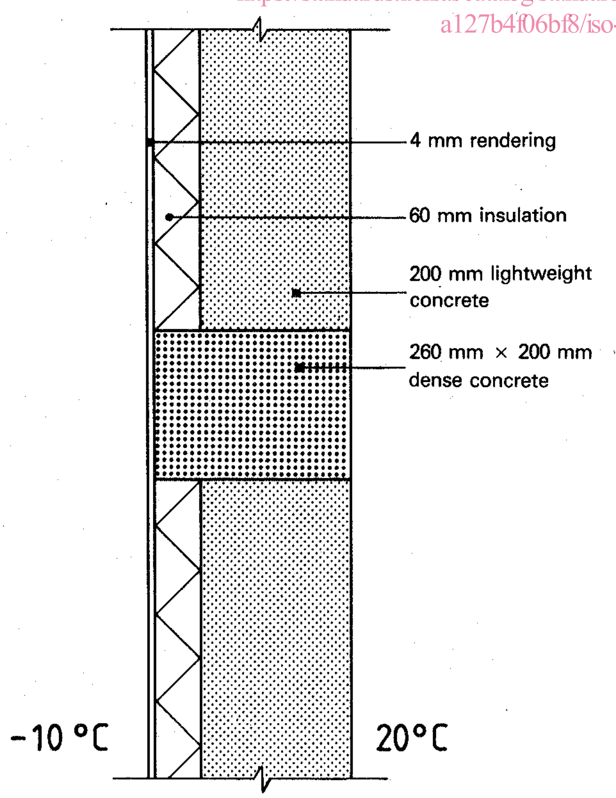


Figure 4 — Structure for example 1

The rendering is such that there is negligible lateral heat flux within it, so that the structure may be regarded as type b. The parameters involved can be summarized as follows:

B = 4 m $\quad d$ = 0,26 m $\quad d_{ins}$ = 0,06 m $\quad b$ = 0,2 m

λ_c = 0,2 W/(m·K) $\quad \lambda_{TB}$ = 2 W/(m·K)

λ_{ins} = 0,04 W/(m·K) $\quad d_i$ = 0,2 m $\quad \lambda_i$ = 0,2 W/(m·K)

d_e = 0,06 m $\quad \lambda_e$ = 0,04 W/(m·K)

$A = 4l\ m^2 \quad A_{TB} = 0,2l\ m^2$

Furthermore, it is assumed that R_i and R_e are 0,13 m²·K/W and 0,4 m²·K/W respectively and that the environmental temperatures are ϑ_i = 20 °C and ϑ_e = −10 °C.

B.1.2 Calculation of auxiliary quantities

$$(\Sigma R)_0 = \frac{0,2}{0,2} + \frac{0,06}{0,04} + \frac{0,004}{1,0} = 2,504\ m^2{\cdot}K/W$$

$$U_0 = (2,504 + 0,17)^{-1} = 0,374\ W/(m^2{\cdot}K)$$

$$(\Sigma R)_{TB} = \frac{0,26}{2,0} + \frac{0,004}{1,0} = 0,134\ m^2{\cdot}K/W$$

$$U_{TB} = (0,134 + 0,17)^{-1} = 3,289\ W/(m^2{\cdot}K)$$

$$\overline{U} = \frac{4,0l - 0,2l}{4,0l} \times 0,374 + \frac{0,2l}{4,0l} \times 3,289 = 0,520\ W/(m^2{\cdot}K)$$

B.1.3 Zone of influence of the thermal bridge

$$a_i = 2\sqrt{0,13 \times 0,2 \times 0,2} = 0,14\ m$$

$$a_e = 2\sqrt{0,04 \times 0,04 \times 0,06} = 0,02\ m$$

$a = a_i$ = 0,14 m; $2a + b$ = 0,48 m < 1 m (therefore, the formulae given in the table may be used)

B.1.4 Approximate calculation of η

$$Z_1 = \frac{(1,0 - 0,2) \times 0,26}{1,0 \times 0,2} \times \left(\frac{0,2}{2}\right)^{0,5} = 0,329$$

$$\eta = [1 + 0,59 \times 0,329]^{-1} = 0,838$$