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**Building components and building
elements—Thermal resistance and
thermal transmittance—
Calculation method**

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Land, Infrastructure and Transport through deliberations at the Japanese Industrial Standards Committee, as the result of proposal for revision of Japanese Industrial Standard submitted by the Architectural Institute of Japan (AIJ)/the Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14. This Standard has been made based on **ISO 6946 : 1996** *Building components and building elements—Thermal resistance and thermal transmittance—Calculation method* for the purposes of making it easy to compare this Standard with International Standard; to prepare Japanese Industrial Standard conforming with International Standard; and to propose a draft of International Standard which is based on Japanese Industrial Standard.

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Building components and building elements—Thermal resistance and thermal transmittance— Calculation method

Introduction The thermal transmittance calculated according to this Standard is suitable for determining heat flow through building components that are within the scope of this Standard.

This Japanese Industrial Standard has been prepared based on the first edition of **ISO 6946** *Building components and building elements—Thermal resistance and thermal transmittance—Calculation method* published in 1996 and Draft Amendment 1 (1999) modifying the technical contents. For the amendment, it is combined by editing.

In addition, the portions with dotted underlines in this Standard are matters which are specified by altering the original International Standard. A list of modifications with their explanation is shown in Annex 1.

1 Scope This Standard specifies the method of calculation of the thermal resistance and thermal transmittance of building components and building elements, excluding doors, windows and other glazed units, components which involve heat transfer to the ground, and components through which air is designed to permeate.

The calculation method is based on the appropriate design thermal conductivities or design thermal resistances of the materials and products involved.

The method applies to components and elements consisting of thermally homogeneous layers (which can include air layers). This Standard also gives an approximate method that can be used for heterogeneous layers, except cases where an insulating layer is bridged by metal.

Remarks : The International Standard corresponding to this Standard is as follows.

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21**.

ISO 6946 : 1996 *Building components and building elements—Thermal resistance and thermal transmittance—Calculation method* (MOD)

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. If the indication of the year of publication is given to these referred standards, only the edition of indicated year constitutes the provision of this Standard but the revision and amendment made thereafter are not applied. The normative references without the indication of the year of coming into effect apply limiting only to the most recent edition (including amendments).

JIS A 0202 *Thermal insulation—Vocabulary*

Remarks : **ISO 7345** : 1987 *Thermal insulation—Physical quantities and definitions* is equivalent to the said standard.

ISO 10456 : 1999 *Building materials and products—Procedures for determining declared and design thermal values*

ISO 13789 : 1999 *Thermal performance of buildings—Transmission heat loss coefficient—Calculation method*

ISO 13370 : 1998 *Thermal performance of buildings—Heat transfer via the ground—Calculation methods*

ISO 10211-1 : 1995 *Thermal bridges in building construction—Heat flows and surface temperatures—Part 1 : General calculation methods*

3 Definitions and symbols

3.1 Definitions For the purposes of this Standard, the following definitions and those given in **JIS A 0202** apply.

3.1.1 building element Major part of a building such as a wall, floor or roof.

3.1.2 building component Building element or a part of it.

Remarks : In this Standard the word “component” is used to indicate both element and component.

3.1.3 design thermal value Design thermal conductivity or design thermal resistance.

Remarks : A given product can have more than one design value, for different applications or environmental conditions.

3.1.4 design thermal conductivity Value of thermal conductivity of a building material or product under specific external and internal conditions which can be considered as typical of the performance of that material or product when incorporated in a building component.

3.1.5 design thermal resistance Value of thermal resistance of a building product under specific external and internal conditions which can be considered as typical of the performance of that product when incorporated in a building component.

3.1.6 thermally homogeneous layer Layer of constant thickness having thermal properties which are uniform or which may be regarded as being uniform.

3.2 Symbols and units

Symbol	Quantity	Unit
A	area	m^2
R	design thermal resistance	$\text{m}^2 \cdot \text{K}/\text{W}$
R_g	thermal resistance of airspace	$\text{m}^2 \cdot \text{K}/\text{W}$
R_{se}	external surface resistance	$\text{m}^2 \cdot \text{K}/\text{W}$
R_{si}	internal surface resistance	$\text{m}^2 \cdot \text{K}/\text{W}$
R_T	total thermal resistance (environment to environment)	$\text{m}^2 \cdot \text{K}/\text{W}$
R'_T	upper limit of total thermal resistance	$\text{m}^2 \cdot \text{K}/\text{W}$
R''_T	lower limit of total thermal resistance	$\text{m}^2 \cdot \text{K}/\text{W}$
R_u	thermal resistance of unheated space	$\text{m}^2 \cdot \text{K}/\text{W}$
U	thermal transmittance	$\text{W}/(\text{m}^2 \cdot \text{K})$
d	thickness	m
h	heat transfer coefficient	$\text{W}/(\text{m}^2 \cdot \text{K})$
λ	design thermal conductivity	$\text{W}/(\text{m} \cdot \text{K})$

4 Principles The principle of the calculation method is to:

- obtain the thermal resistance of each thermally homogeneous part of the component;
- combine these individual resistances obtained in a) so as to obtain the total thermal resistance of the component, including (where appropriate) the effect of surface resistances.

Thermal resistances of individual parts are obtained according to 5.1.

The values of surface resistance given in 5.2 are appropriate in most cases. Annex A gives detailed procedures for low-emissivity surfaces, specific external wind speeds, and non-planar surfaces.

Air layers may be regarded as thermally homogeneous for the purposes of this Standard. Values of the thermal resistance of large air layers with high-emissivity surfaces are given in 5.3, and Annex B gives procedures for other cases.

The resistances of the layers are combined as follows:

- for components consisting of thermally homogeneous layers, obtain the total thermal resistance according to 6.1 and the thermal transmittance according to clause 7;
- for components having one or more thermally heterogeneous layers, obtain the total thermal resistance according to 6.2 and the thermal transmittance according to clause 7;
- for components containing a tapered layer, obtain the thermal transmittance and/or the total thermal resistance according to Annex C.

Finally, corrections can be applied to the thermal transmittance if appropriate according to Annex D, to allow for the effects of air gaps in insulation, mechanical fasteners penetrating an insulation layer, and precipitation on inverted roofs.

The thermal transmittance so calculated applies between the environments on either side of the component concerned. For example, it applies between internal and external environments in the case of being adjacent to the outside air, between internal environments in the case of an internal partition, between internal environment and an unheated space in the case of being adjacent to an unheated space. Simplified procedures are given in 5.4 for treating an unheated space as a thermal resistance.

5 Thermal resistances

5.1 Thermal resistance of homogeneous layers Design thermal values can be given as either design thermal conductivity or design thermal resistance. If thermal conductivity is given, obtain the thermal resistance of the layer from:

$$R = \frac{d}{\lambda} \dots\dots\dots (1)$$

where

- d is the thickness of the material layer in the component;
- λ is the design thermal conductivity of the material, either calculated according to **ISO 10456** : 1999 or obtained from tabulated values.

Remarks 1 The thickness d may be different from the nominal thickness (e.g. when a compressible product is installed in a compressed state, d is less than the nominal thickness). If relevant, d should also make appropriate allowance for thickness tolerances (e.g. when they are negative).

2 For the design thermal conductivity λ , values measured by a public institution may be used.

Thermal resistance values used in intermediate calculations shall be calculated to at least 3 decimal places.

5.2 Surface resistances Use the values in Table 1 for plane surfaces in the absence of specific information on the boundary conditions. The values under “horizontal” apply to heat flow directions $\pm 30^\circ$ from the horizontal plane. For non-planar surfaces or for specific boundary conditions use the procedures in Annex A.

Table 1 Surface resistances (in $\text{m}^2 \cdot \text{K/W}$)

	Direction of heat flow		
	Upwards	Horizontal	Downwards
R_{si}	0.10	0.13	0.17
R_{se}	0.04	0.04	0.04

Remarks : The values in Table 1 are design values. For the purposes of declaration of the thermal transmittance of components and other cases where values independent of heat flow direction are required, it is recommended that the values for horizontal heat flow are used.

5.3 Thermal resistance of air layers The values given in this subclause apply to an air layer which:

- is bounded by two faces which are effectively parallel and perpendicular to the direction of heat flow and which have emissivities not less than 0.8;
- has a thickness (in the direction of heat flow) of less than 0.1 times each one of the other two dimensions of the surrounding air layers, and not greater than 0.3 m;

Remarks : A single thermal transmittance should not be calculated for components containing air layers thicker than 0.3 m. Rather, heat flows should be calculated by performing a heat balance (see **ISO 13789 : 1999**).

- has no air interchange with the internal environment.

If the above conditions do not apply, use the procedures in Annex B.

5.3.1 Unventilated air layer An unventilated air layer is one in which there is no express provision for air flow through it. Design values of thermal resistance are given in Table 2. The values under “horizontal” apply to heat flow directions $\pm 30^\circ$ from the horizontal plane.

Table 2 Thermal resistance (in $\text{m}^2 \cdot \text{K/W}$) of unventilated air layers high emissivity surfaces

Thickness of air layer mm	Direction of heat flow		
	Upwards	Horizontal	Downwards
0	0.00	0.00	0.00
5	0.11	0.11	0.11
7	0.13	0.13	0.13
10	0.15	0.15	0.15
15	0.16	0.17	0.17
25	0.16	0.18	0.19
50	0.16	0.18	0.21
100	0.16	0.18	0.22
300	0.16	0.18	0.23

Remarks : Intermediate values may be obtained by linear interpolation.

An air layer having no insulation layer between it and the external environment but with small openings to the external environment shall also be considered as an unventilated air layer, if these openings are not arranged so as to permit air flow through the layer and they do not exceed:

- 500 mm^2 per m length for vertical air layers
- 500 mm^2 per m^2 of surface area for horizontal air layers⁽¹⁾

Remarks : Drain openings (weep holes) in the form of open vertical joints in the outer leaf of a masonry cavity wall are not regarded as ventilation openings.

Note (1) For vertical air layers the range is expressed as the area of openings per metre length. For horizontal air layers it is expressed as the area of openings per square metre area.

5.3.2 Slightly ventilated air layer A slightly ventilated air layer is one in which there is provision for limited air flow through it from the external environment by openings within the following ranges:

- > 500 mm^2 but $\leq 1\,500\, \text{mm}^2$ per m length for vertical air layers
- > 500 mm^2 but $\leq 1\,500\, \text{mm}^2$ per m^2 of surface area for horizontal air layers⁽¹⁾

The design thermal resistance of a slightly ventilated air layer is one half of the corresponding value in Table 2. If, however, the thermal resistance between the air layer and the external environment exceeds $0.15\, \text{m}^2 \cdot \text{K/W}$, it shall be replaced by the value $0.15\, \text{m}^2 \cdot \text{K/W}$.

5.3.3 Well ventilated air layer A well ventilated air layer is one for which the openings between the air layer and the external environment exceed:

- 1 500 mm² per m length for vertical air layers
- 1 500 mm² per m² of surface area for horizontal air layers⁽¹⁾

The total thermal resistance of a building component containing a well-ventilated air layer shall be obtained by disregarding the thermal resistance of the air layer and all other layers between the air layer and external environment, and including an external surface resistance corresponding to still air (i.e. equal to the internal surface resistance of the same component).

5.4 Thermal resistance of unheated spaces When the wall between the unheated space and the internal environment is insulated and the external envelope of the unheated space is not insulated, the following simplified procedures, treating the unheated space as a thermal resistance, may be applied.

Remarks : ISO 13789 : 1999 gives general, and more precise, procedures for the calculation of heat transfer from a building to the external environment via unheated spaces, and should be used when a more accurate result is required. For crawl spaces below suspended floors, see ISO 13370 : 1998.

5.4.1 Roof spaces For a roof structure consisting of a flat, insulated ceiling and a pitched roof, the roof space may be regarded as if it were a thermally homogeneous layer with thermal resistance as given in Table 3. However, if the roof space leads to the outside air, it is treated as 5.3.3.

Table 3 Thermal resistance of roof spaces

Characteristics of roof		R_u m ² · K/W
1	Tiled roof with no felt, boards or similar	0.06
2	Sheeted roof, or tiled roof with felt or boards or similar under the tiles	0.2
3	As 2 but with aluminium cladding or other low emissivity surface at underside of roof	0.3
4	Roof lined with boards and felt	0.3

Remarks : The values in Table 3 include the thermal resistance of the roof space and the (pitched) roof construction. They do not include the external surface resistance (R_{se}).

5.4.2 Other spaces When the building has a small unheated space attached to it, and the wall between the unheated space and the internal environment is insulated, the thermal transmittance between the internal and external environments can be obtained by treating the unheated space together with its external construction components as if it were an additional homogeneous layer with thermal resistance R_u . When the unheated space leads to the outside air, it is treated as 5.3.3. R_u is given by:

$$R_u = 0.09 + 0.4 \frac{A_i}{A_e} \dots\dots\dots (2)$$

subject to $R_u \leq 0.5 \text{ m}^2 \cdot \text{K/W}$,

where

A_i is the total area of all components between the internal environment and the unheated space;

A_e is the total area of all components between the unheated space and the external environment.

Remarks 1 Examples of small unheated spaces include garages, store rooms and conservatories.

2 If there is more than one component between the internal environment and the unheated space, R_u should be included in the calculation of the thermal transmittance of each such component.

6 Total thermal resistance If the total thermal resistance is presented as a final result, it shall be rounded to two decimal places.

6.1 Total thermal resistance of a building component consisting of homogeneous layers The total thermal resistance R_T of a plane building component consisting of thermally homogeneous layers perpendicular to the heat flow shall be calculated by the following expression:

$$R_T = R_{si} + R_1 + R_2 + \dots + R_n + R_{se} \dots\dots\dots (3)$$

where

R_{si} is the internal surface resistance;

$R_1, R_2, \dots R_n$ are the design thermal resistances of each layer;

R_{se} is the external surface resistance.

In the case of calculation of the resistance of internal building components (partitions etc.), or an component between the internal environment and an unheated space, R_{si} applies on both sides.

Remarks : The surface resistances should be omitted in equation (3) when the resistance of a component from surface to surface is required.

6.2 Total thermal resistance of a building component consisting of homogeneous and heterogeneous layers This subclause gives a simplified method to calculate the thermal resistance of building components consisting of thermally homogeneous and heterogeneous layers, except in cases where an insulation layer is bridged by metal.

Remarks 1 A more precise result will be obtained by using a numerical method conforming to **ISO 10211-1 : 1995** or Part 2 (under preparation): *Calculation of linear thermal bridges*.

2 The procedure described in **6.2** is not suitable to compute surface temperatures for the purposes of evaluating the risk of condensation.