Thermal bridges in sheet metal construction

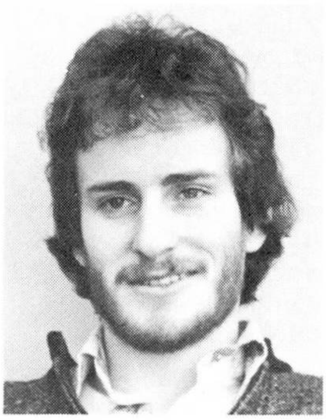
Thermal Bridges in Sheet Metal Construction

Ponts thermiques dans la construction en tôle métallique

Wärmebrücken in Blechkonstruktionen

Gudni JOHANNESSON
Dr. Eng.
Reykjavik, Iceland

Hans A. VINBERG
Tekn. lic.
Korrugal AB
Finspång, Sweden



Gudni Johannesson M.Sc. in physical engineering 1976. Dr. Eng. in building technology 1980. Thesis: «Active Heat Capacity – Models and parameters for the thermal performance of buildings». 1975 to 84 at the Division of Building Technlogy, Lund Institute of Technology. Now active as a consultant in Iceland.

Hans Vinberg, born 1925, civil engineer 1949 at KTH, Stockholm, and tekn. lic. 1951, is responsible for technical development at Korrugal, a producer of building sheet of aluminium.

SUMMARY

Purlins or spacers often give fatal thermal bridges. These can cause extra heat loss and low temperatures. A method to calculate the effect of thermal bridges is described. The thermal flows are treated as electrical flow, the insulations in different parts as electrical resistances. The effect on different constructions is described.

RÉSUMÉ

Les pannes et entretoises constituent souvent des ponts thermiques, entraînant des déperditions de chaleur supplémentaires et un abaissement de la température. L'article décrit une méthode permettant de calculer l'effet des ponts thermiques. Les flux thermiques sont traités par analogie avec les courants électriques, les isolations étant considérées comme des résistances. Les effets des ponts thermiques sont décrits pour différents types de constructions.

ZUSAMMENFASSUNG

Pfetten und Abstandhalter bilden häufig Wärmebrücken. Diese können zusätzliche Wärmeverluste verursachen. Eine Methode zur Berechnung der Auswirkung von Wärmebrücken wird beschrieben. Der Wärmefluss wird als elektrischer Strom, die Isolierung als elektrischer Widerstand behandelt. Die Auswirkung verschiedener Konstruktionen wird beschrieben.

1. INTRODUCTION

The effect of thermal bridges can be calculated by the Johannesson-Åberg method which now is Swedish standard [1].

In order to accomplish simplified calculation methods a research project, sponsored equally by Swedisol and the Swedish Building Research Council, was accomplished at the Division of Building Technology, Lund University. The result was a calculation method which is published in [2].

2. THE PROBLEM

The heat flow problems can be illustrated by means of a construction, consisting of two parallell corrugated sheet metal layers, connected by a sheet metal purlin and with insulation in between. The thermal conductivity for steel is about 1500 times as high as the thermal conductivity for mineral wool. Consequently, if the surfaces of the construction were isothermal, the heat flow per meter through a purlin of thickness 2 mm would equal the heat flow per meter through 3 m of insulation. If we on the other hand assume that no lateral heat flow takes place and the U-value for the construction can be calculated by weighing together by areas the one-dimensional U-value for different sections, the resulting U-value will differ only slightly from the one without a thermal bridge since the lateral heat transfer is neither zero nor infinite and the real thermal bridge effect lies somewhere in between the results of the two different observations described above. The key to a simplified formula is to model the lateral heat flow in different parts of the construction and to provide a suitable coupling to the transversal heat flow.

3. THE DEVELOPMENT OF A NEW CALCULATION METHOD

The solution methodology presented below assumes that one proceeds in three steps. The first step is to divide the construction into a number of separate heat flow paths. In the second step the resistance of each heat flow path is calculated. In the third step the different resistances are coupled to form a network for which the resistance can be calculated analogously to electrical resistance theory.

Below a distinction is made between the thermal resistance R, K/W between two arbitrary configurations in space defined by the equation

$$R_{12} = \frac{\vartheta_1 - \vartheta_2}{Q_{12}} \quad , \ \vartheta = \text{temperature } [K], \ Q = \text{heat flow } [W],$$

and the areal thermal resistance m, m^2K/W between two plane parallell surfaces

$$m_{12} = A \cdot \frac{\vartheta_1 - \vartheta_2}{Q_{12}} \quad , \ A = \text{area } [m^2].$$

3.1 Identification of heat flow paths

To break down a construction into different heat flow paths requires insight in the actual heat flow pattern and can therefore not be done by means of an explicit solution method.

The construction(fig 1) is transformed into a network of resistances. R_u and R_i are outer and inner surface resistances, R_1 and R_5 characterize an effective mean flow path along the surfaces to the purlin, R_2 and R_4 flows through the insulations 2 and 4 and R_3 is the resistance for the purlin. All the resistances are related to some representative area. The remaining thing to do is to describe the different resistances with suitable expressions.

3.2 Resistances for different construction parts

Below resistances are given for some simple configurations that are of use for the continued analysis. The expressions used can be found derived in most text books on heat transfer. See for instance Carslaw and Jaeger [3].

3.2.1 One-dimensional heat flow

The resistance is given by the equation

$$R = \frac{d}{A \cdot \lambda} \quad , \lambda = \text{thermal conductivity } [\text{W/mK}].$$

3.2.2 Heat transfer from a thin layer with high thermal conductivity and surface heat transfer

If heat is generated at a constant temperature ϑ_o and if the heat flow at the edge can be neglected, the resistance is given by the expressions

$$R = \frac{1}{L\sqrt{\alpha\lambda t}\,\tanh\beta b}$$

$$\beta = \sqrt{\frac{\alpha}{\lambda \cdot t}} \quad , \alpha = \text{coefficient of surface heat transfer } [\text{W/m}^2\text{K}] .$$

If $b \geq 2\sqrt{\frac{\lambda \cdot t}{\alpha}}$, b = partial width [m],

then the term $\tanh \beta b$ is approximately equal to 1.0.

As an example the resistance between a purlin joint with temperature ϑ_o and ambient outside air with temperature ϑ_u is calculated. The purlin flange is neglected, the corrugated sheet metal layer is assumed to be planar and a perfect thermal contact between the purlin and the layer is assumed. If the considered length is 1 m then each side gives the resistance

$$R = \frac{1}{1 \cdot \sqrt{20 \cdot 60 \cdot 0.001} \cdot 1} = 0.912 \text{ K/W}$$

and for both sides the resistance becomes

$$R = \frac{0.912}{2} = 0.456 \text{ K/W}$$

The thermal bridge and the homogeneous part of the construction have the surface resistances in common. Since R above contains even the surface resistance this has to be adjusted for. The resistances R_1 and R_5 of fig. 1 would therefore be given by the formula

$$R = \frac{1}{2L\sqrt{\alpha\lambda t}\,\tanh\beta b} - \frac{2}{2bL\alpha}$$

This resistance then characterizes some actual mean heat flow path along the surface layer.

4. A GENERAL CALCULATION MODEL

Based on the solutions given above for simple heat flow paths a general solution method for the usual type of built up sheet metal construction can be established. The construction type together with corresponding resistance network is given in fig 1 where the formulae for the different partial resistances also have been implemented.

Calculation of the resulting U-value for the construction is best carried out in several steps. First the resistance for the thermal bridge R_{TB} is calculated

$$R_{TB} = R_1 + R_2 + R_3 + R_4 + R_5$$

Then the construction resistance R_C is obtained by combining R_h and R_{TB} as two parallell resistances.

$$R_C = \frac{R_{TB} \cdot R_h}{R_{TB} + R_h}$$

Adding the surface resistances R_i and R_u gives the total resistance R_{TOT}.

$$R_{TOT} = R_C + R_i + R_u$$

The total areal resistance m_{TOT} is then given by

$$m_{TOT} = R_T \cdot B \cdot L$$

and finally the U-value is obtained as

$$U = \frac{1}{m_{TOT}}$$

5. THE EFFECT OF THERMAL BRIDGES

What effect do different thermal bridges give? If we use this method and calculate a roof or a wall with three different thicknesses – 50, 100 and 200 mm we find that the extra energy loss is often 40-70%, caused by the thermal bridges.

The following examples are taken with measurements, that are normal in industrial buildings. (The details are given in [4]).

The types are shown in fig. 2, where the values are fro 200 mm thickness.

A steel purlin with normal spacing gives about 75% extra heat flow through the construction (type 2). With a breaking layer this goes down to about 25%, but with the support, that is often needed, it gives up to 40% again.

Wood is of course a better insulator than steel. A wood purlin gives around 8% extra loss.

There are some "stepped spacers", with holes in the steel purlins, aimed to reduce the heat flow. They give some 15-30%.

A special spacer, made of compressed mineral wool, held together with stainless steel strips, gives only about 2% extra energy loss (fig.2, Type 7).

Even the mechanical fixings, used in many metal deckings, with bitumen paper as surface, can be calculated, and we find losses of around 10%.

Thus we find that thermal bridges are very important in metal construction. They give extra energy loss.

But they also cause low temperature at local points. This can cause condensation and concentration of dirt etc.

6. REFERENCES

[1] SWEDISH STANDARD SS 02 42 30, Köldbryggor i plåtkonstruktioner-beräkning av värmegenomgångskoefficient (Thermal bridges in sheet-metal constructions - calculation of coefficient of thermal transmittance), Swedish Building Standards Institution. Stockholm, 1983.

[2] JOHANNESSON G, ÅBERG O, Köldbryggor i plåtkonstruktioner. Report TVBH-3006, Lund Institute of Technology, Div. of Building Technology, Lund 1981.

[3] CARSLAW H S, JAEGER J C, Conduction of Heat in Solids. Oxford University Press, 1959.

[4] VINBERG Hans A. The effects of thermal bridges and How to calculate thermal bridge factors, Alurama International, 1-1983, KORRUGAL, Finspong, Sweden.

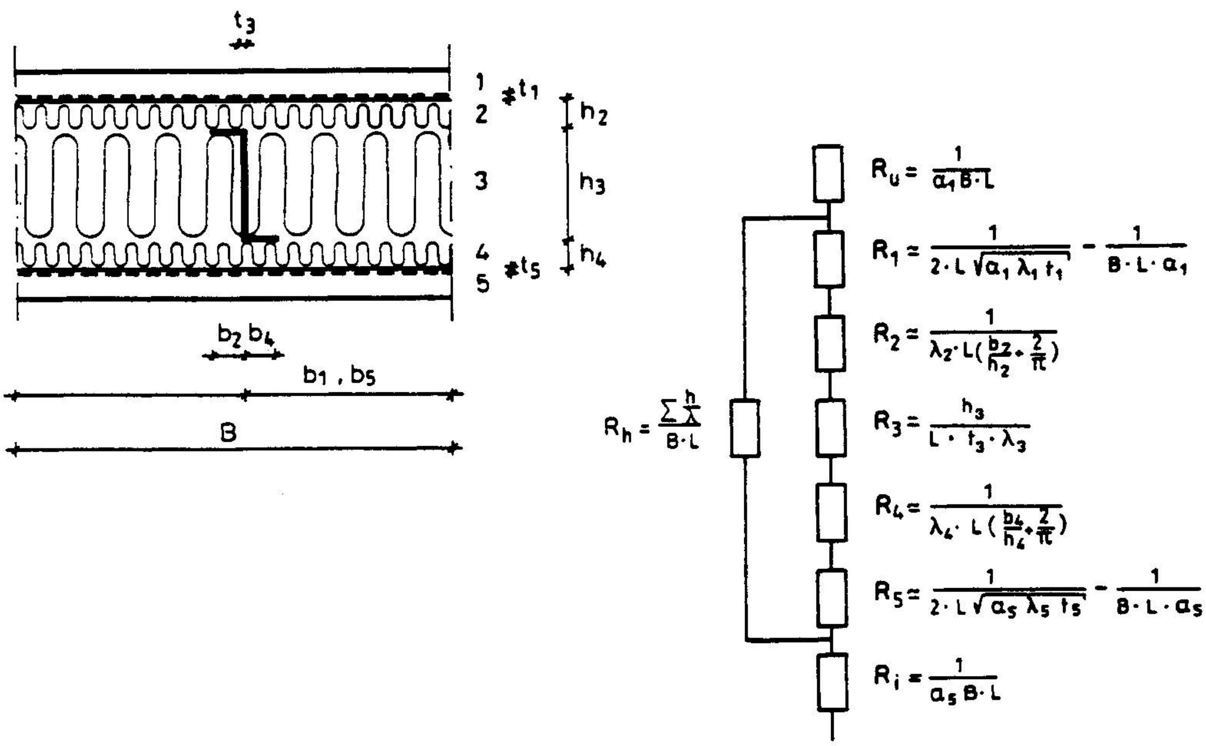
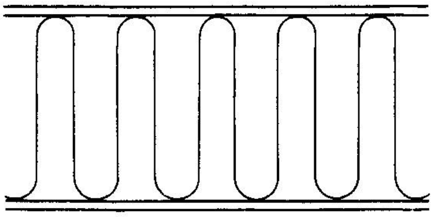
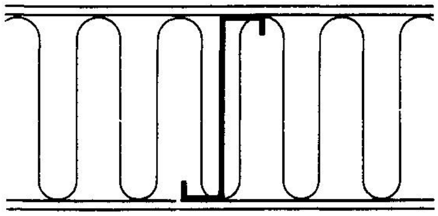


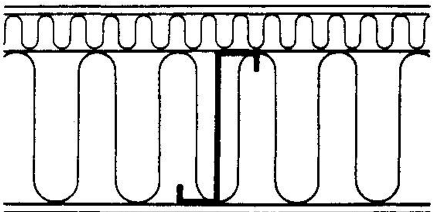
FIG 1. A generalized built-up sheet metal construction together with the corresponding resistance network.



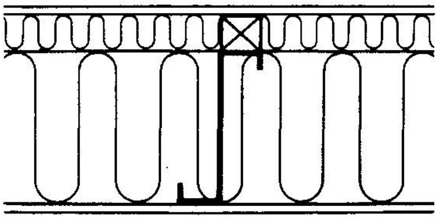
Type 1. The U-value is 0.19 if there is no thermal bridge.



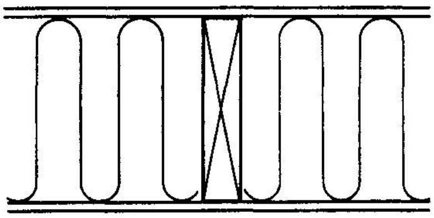
Type 2. The U-value rises to 0.33, an increase of 75%, if a lightweight steel spacer is used.



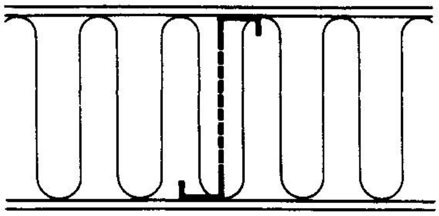
Type 3. The use of a layer to break the thermal bridge reduced the impairment of the U-value to 27%.



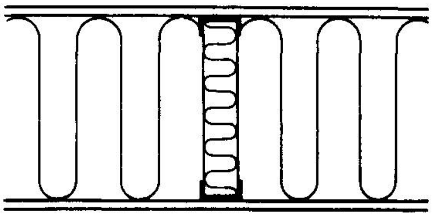
Type 4. A support against the spacer impairs the U-value to 43%.



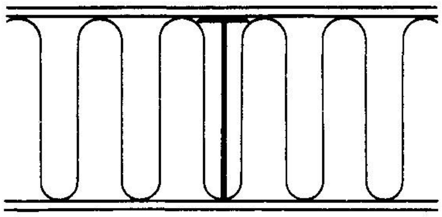
Type 5. A wood spacer impairs the U-value by 7%.



Type 6. A stepped spacer impairs the U-value by 15%.



Type 7. A Korrugal insulation spacer impairs the U-value by no more than 1%.



Type 8. Metal decking with a mechanical fixture impairs the U-value by 13%.

Fig. 2. Examples of different thermal bridges.

Effect of different thicknesses

Type	U-value, W/m²C			Impairment, %		
	200	100	50	200	100	50
1 Without coldbridge	.191	.364	.667	0	0	0
2 Steel spacer, c/c 2 m	.333	.563	.897	75	55	35
2 c/c 2, 1.5, 1 m (also for 3-7)	.333	.630	1.133	75	73	70
3 Breaking layer 30 mm	.242	.434	.762	27	19	14
3 30, 23, 15 mm (also for 4)	.242	.444	.805	27	22	21
4 With support	.271	.503	.922	43	38	38
5 Wood spacer	.203	.394	.736	7	8	10
6 Stepped spacer	.219	.438	.874	15	21	31
7 KORRUGAL spacer	.193	.371	.687	1	2	3
8 Metal decking	.215	.403	.723	13	11	8