DEVELOPMENT OF WINDOW FRAMES WITH IMPROVED THERMAL INSULATION PROPERTIES

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ABSTRACT

Since the wall insulation of buildings and the quality of glazing improve more and more, the window frame becomes the weak point in the facade from a thermal perspective. This paper discusses a new frameless window construction. Results in this paper show that the best position of the glass is in the middle of the insulation. This new junction has an almost 40 % lower energy loss compared to a traditional junction. Computer simulations as well as experimental measurements of a full-scale prototype have proven this.

1. INTRODUCTION

During the seventies and eighties in the Netherlands as well as in many other European countries, the thermal performance of the building envelope has significantly improved. The thickness of applied insulation materials in non-transparent parts of the building envelope has strongly increased. Single glazing has almost everywhere been replaced with double glazing. Advanced window systems with high thermal insulation values are about to enter the market.

Energy losses through the entire window opening will in general be affected by the thermal insulation properties of the applied window frame. In case of combined use of an advanced glazing system and a window frame with poor thermal insulation properties, the negative impact of the window frame on the total energy losses can be unacceptable. This means that in case of combined use of highly insulating transparent and non-transparent facade elements, the window frame will be the weak spot.

The Super Insulation project is one of the ongoing research projects in our group, the Building Physics Group of the Faculty of Architecture at the Delft University of Technology. This project is done in co-operation with the Netherlands Energy Research Foundation (ECN) and aims at the development of thin and transparent facade elements with high thermal insulation properties. Part of the project focuses on development of junctions between transparent and non-transparent facade elements with improved thermal insulation properties. The paper will discuss this specific part of the project.

2. METHOD

2.1 Schematic Variants

The development of a window frame with improved thermal insulation properties has been performed in three parts. At first, highly schematised window-frame junctions have been simulated using the computerprogramm Kobru86 which is capable of calculating the 2-dimensional energy loss per square meter through the window and the frame.

Nearly a hundred schematised window-frame junctions are simulated. Three wall constructions are investigated: a standard wall with inner insulation, a standard wall with outer insulation and a wall consisting of only insulation. These three wall constructions have been simulated with different frame materials. Some examples are shown in figure 1. In addition, a frameless variant is investigated for the three wall-types. Besides the wall type and the frame materials, the position of the window frame with respect to the glass is also investigated. For the frameless variant, the thermal improvement of the depth of the glass inside the wall material is also investigated.

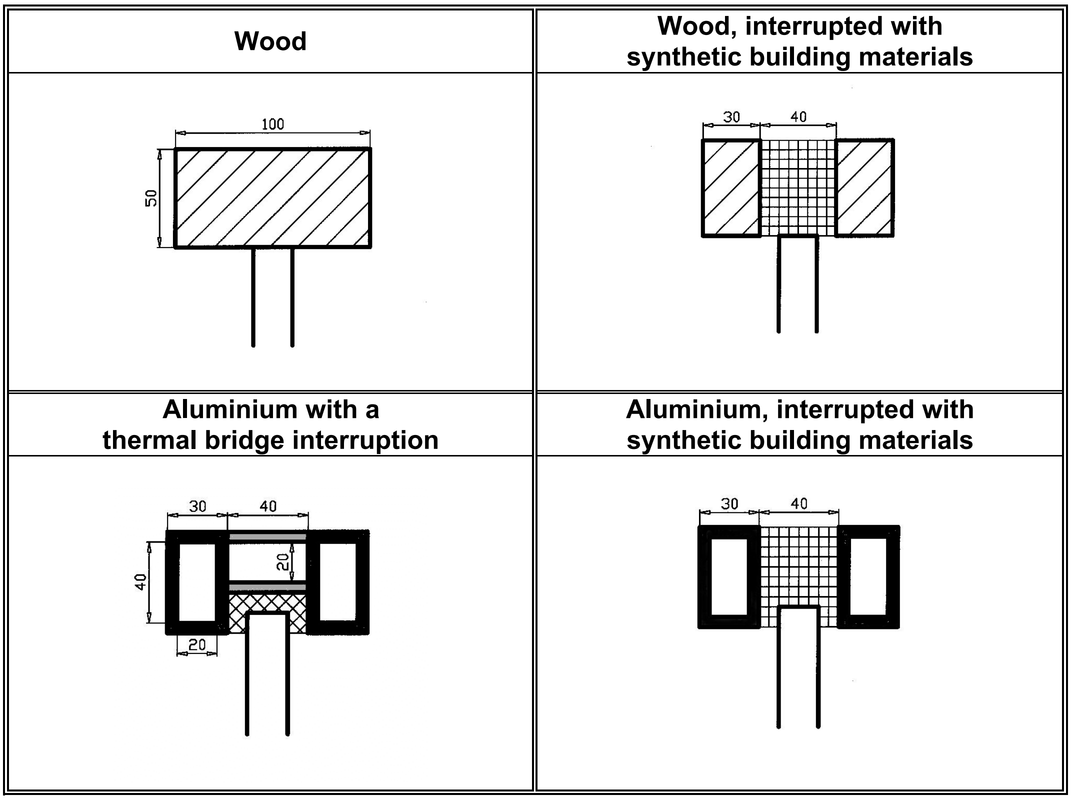

Figure 1: Four examples of the investigated junctions.

2.2 Selected Variants

As a second step, the best variants with the lowest energy loss from the around 100 schematised variants are selected. These best variants are then worked out in more detail with respect to the detailing of the junction and its building-physical properties (thermal and hygric qualities). All variants are graded using the following two criteria: total energy loss and the possibility of the occurrence of condensation problems. All variants are compared with a Dutch standard window frame whose geometry is similar to the new variants. The same very good insulating glazing (triple glazing with a U-value of 0.4 W/mK) is applied while calculating the energy loss for the different frame junctions. For all calculations the Dutch standard heat transfer coefficients (0.13 m^2K/W and 0.04 m^2K/W) are applied. The same wall-insulation is used for all variants and the size of the daylight opening is also kept constant.

2.3. The prototype

As a last step, the variant with the highest thermal improvement is built as a full-scale prototype and the experimental data is compared with the results of the 3-dimensional variant of the computer programm Kobru86 (Trisco). This prototype is experimentally investigated at TNO-bouw in Delft. The measurements are executed according to the ISO/FDIS 12567 (1999) standard based on the NEN-EN_ISO 8990 norm. A photo of the prototype is given in figure 2. Measured are the total energy loss of the facade by the Quarted hot box method. The surface temperatures are measured using thermocouples. The triple glazing with a U-value of 0.4 W/m^2K, used for the calculations, could not (yet) be obtained for the measurements. Triple glazing with a U-value of 0.7 W/m^2K was therefore used in the prototype.

Figure 2 The prototype in the measuring box

2.4 3-Dimensional calculations

The experimental data of the full-scale prototype is compared with the results of the 3-dimensional computer program Trisco. This computer program calculates the total energy loss as well as the surface temperatures of the facade, thus allowing a comparison between the experimental data and the simulated data. A crucial point in the comparison between experimental and simulated data are the heat transfer coefficients between the surfaces and the surrounding air.

3 RESULTS

3.1 Simulation Results

The first analysis of the schematised junctions showed that the frameless junction in which the glass directly joins the wall material in the middle of the insulation material has the lowest energy loss (see figure 3). Of the three options given in figure 3, the sandwich type (junction C) has the lowest total energy loss. Even lower is the energy loss for the junction in which the glass in embedded in the insulation of the wall. This type has therefore been used as a model for the detailed variant. The detailed variant is constructed in such a way that it is also windproof, rainproof and can easily be produced.

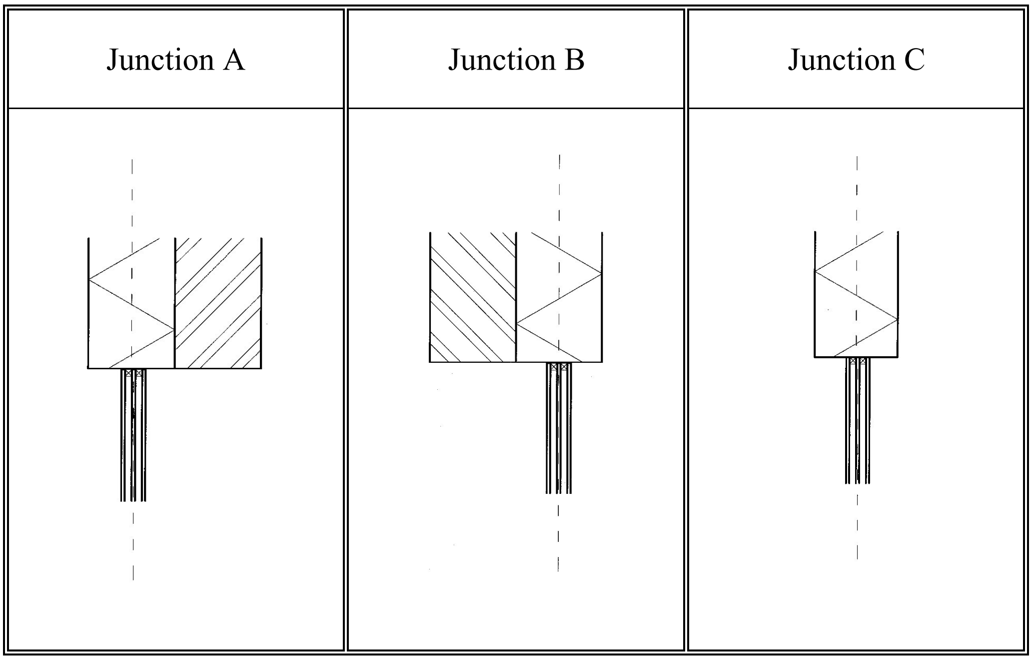

Figure 3: The thermal ideal junction of the glass and the wall.

Figure 4 shows the so developed lower detail of the most ideal junction between the glass and the surrounding construction. This ideal junction can be made from different materials: wood, synthetic building materials or aluminium. In figure 5 the computer simulation results are shown for the three different materials and the reference variant.

All three new variants have a similar energy loss, see figure 5. The highest surface temperatures are found for the aluminium variant. This is not surprising as aluminium has a higher heat transfer coefficient, thus conducting more energy to the ousted, resulting in a higher surface temperature.

All new variants meet the Dutch norm which requires a surface temperature of at least 13 ºC. The reference variant has a lower surface temperature of 10.3 ºC. Condensation problems are therefore likely. The reference variant has an almost 40 % higher energy loss (15.38 W/m vs. 10.99 W/m). This is surprising as the only difference between the reference model and the new variants is the material and the geometry of the junction.

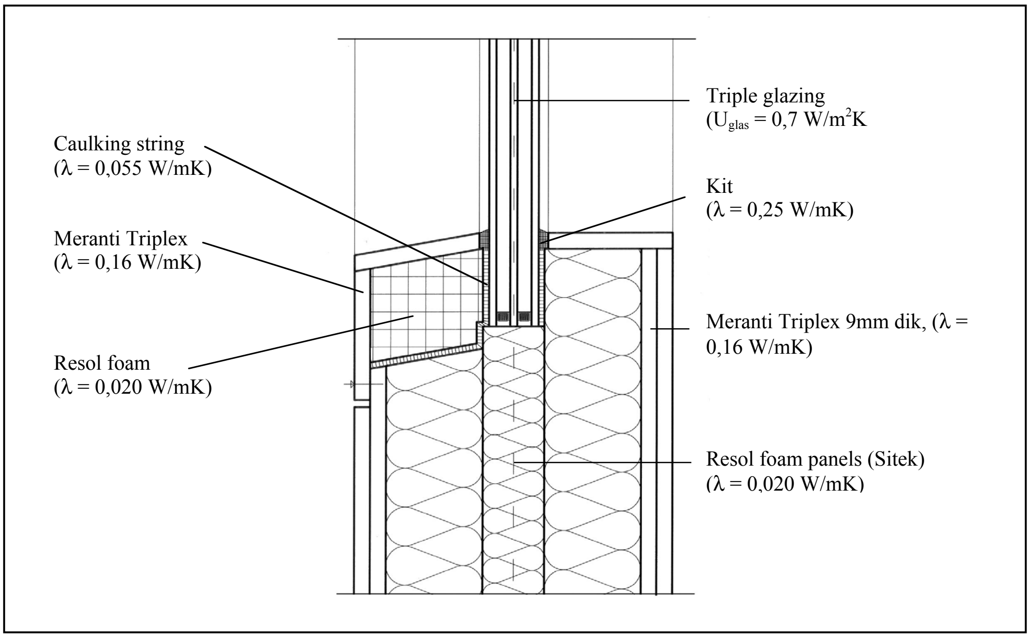

Figure 4: The lower detail of the best variant of the prototype. The wall material is wood.

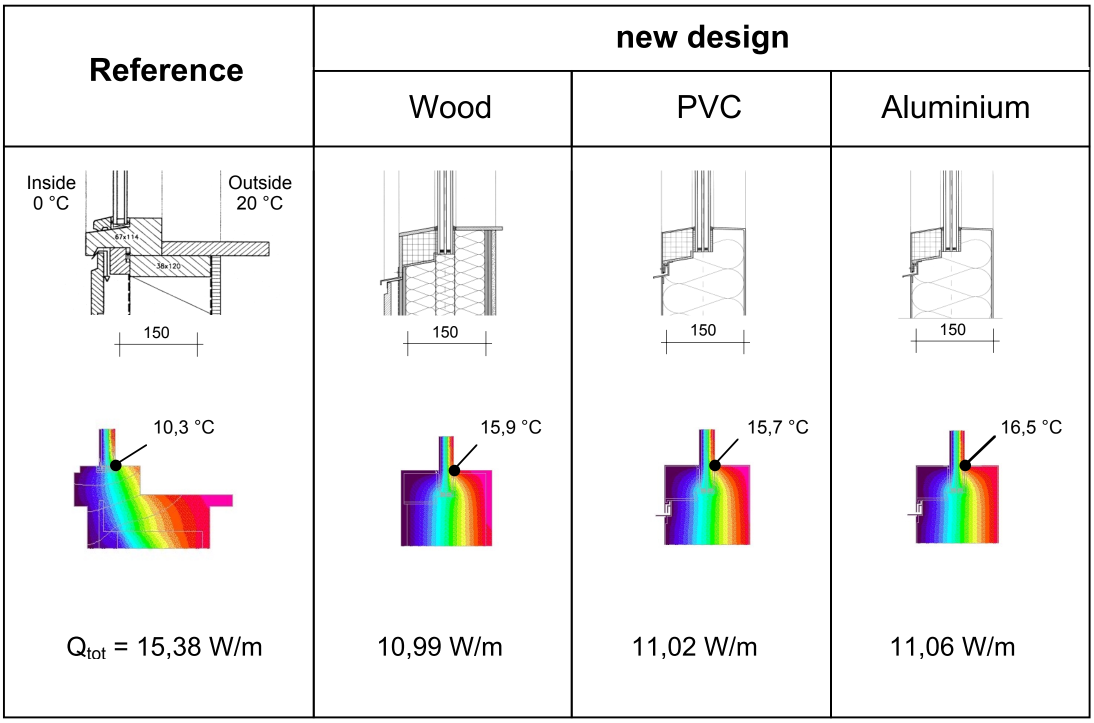

Figure 5 : Energy loss and the lowest surface temperatures of the simulated junctions and the reference junction.

3.2 The prototype

The prototype consists of a wood-sandwich construction, see figure 3.1. The prototype is made of wood as wood is the easiest material to produce a single prototype from. Besides, the simulated differences between wood, aluminium and synthetic building materials were very small so that the influence of the use of the other materials is expected to be small. The wind- and rainproofing has not been incorporated in the prototype as those hardly influence the total energy loss and the surface temperatures.

The simulated and measured surface temperatures are shown in table 1. Two measured temperature values are dubious as the surface temperatures are lower (< 0 ºC) than the actual outside temperature. The simulated total energy loss of the facade (31.4 W for the entire facade of 3.73 m^2) is in agreement with the measured value of 30.9 W for the entire facade. The mean U-value of the prototype is 0.4 W/m^2K (42 % op the prototype surface consists of triple glazing).

	inside		**outside**	
	simulated	measured	simulated	measured
1	18,1	17,4	1,6	1,4
2	16,1	15,6	2,0	1,9
3	14,7	14,5	2,9	-0,4
4	16,2	15,7	2,1	-0,4

Table 1: simulated (3-D Trisco) and measured (full-scale prototype) surface temperatures in ºC for the points 1-4.

4 CONCLUSIONS AND REMARKS

It can be concluded from this research that a frameless window with an embedded junction in the middle of the insulation has a significant thermal improvement over the traditional window frames. This conclusion is supported by measurements with a full-scale prototype as well as with the simulation programmes Kobru86 and Trisco. Both simulation programs predict the measured energy loss to a reasonable accuracy.
There is a small difference between the simulated and calculated surface temperatures. This is most likely due to the theoretical assumption that the inside temperature is constant. In practice, the inside temperature is lower near the floor and higher near the ceiling. Further research is necessary to investigate whether the here developed junctions can also be applied for openable windows. The windproofing is a large point of interest for the openable window.
It would also be interesting to investigate whether it is possible to modify the newly developed junction in such a way that the windowframe can also be applied in the traditional building industry.

5 REFERENCES

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