Indicators of Insulation Quality: U-value and R-value

Setting the content

In order to describe the thermal performance of building elements professionals use R-values and U-values in the same context. Depending on the geographical location and governmental guidelines one or the other term is more popular. This article sums up the main similarities and differences.

Comparison of U- and R-value

According to ASTM C168 (*Standard Terminology Relating to Thermal Insulation*) the **R-value** is the **thermal resistance**, which is the quantity determined by the temperature difference (ΔT), at steady state, between two defined surfaces of a material or construction that induces a unit heat flow through a unit area (q).

$$R = \frac{\Delta T_{surface}}{q} \quad \left[\frac{m^2K}{W}\right]$$

$$1\left[\frac{m^2K}{\mathrm{W}}\right] = 5.68\left[\frac{\mathrm{ft^2 * h * K}}{\mathrm{btu}}\right] \text{ and } \left[\frac{\mathrm{ft^2 * h * K}}{\mathrm{btu}}\right] = 0.18\left[\frac{m^2K}{\mathrm{W}}\right]$$

In addition, ASTM C168 states that the **U-value** is the **thermal transmittance**. More precisely, it is the heat transmission in unit time ($[W] = \left[\frac{J}{s}\right]$) through unit area of a material construction and the boundary air films, induced by unit temperature difference between the environments on each side.

$$U = \frac{q}{\Delta T_{environment}} \quad \left[\frac{W}{m^2K}\right]$$

$$1\left[\frac{W}{m^2K}\right] = 0.18\left[\frac{\mathrm{btu}}{\mathrm{ft^2 * h * K}}\right] \text{ and } \left[\frac{\mathrm{btu}}{\mathrm{ft^2 * h * K}}\right] = 5.68\left[\frac{W}{m^2K}\right]$$

In the case of materials with high insulation values, it can be approximated, that the environmental and corresponding surface temperature are equal ($\Delta T_{environment} \sim \Delta T_{surface}$). In that case, the R-value is the mathematical reciprocal of the U-value, which is also stated in ASTM 1363 (*Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*):

$$U = \frac{1}{R}$$

As the thermal resistance (R) goes up, the thermal transmittance (U) goes down and vice versa. Consequently, from a mathematical point of view, the two indicators describe the same effect in a different representation.

In some cases, there is a difference in what is taken into account by the reseller for the stated U- and R-values. For example the National Fenestration Rating Council (NFRC) in the US mentions that the U-value of a window is a prorated summation of the U-values of the different components (glass, frame, etc.). Furthermore, K.Haglund, a senior researcher with the Center for Sustainable Research, University of Minnesota, states in the DWM Magazine that most building materials that use an R-value rating are made up of a single material component (such as insulation, roofing materials, etc.). This for example could mean that the stated R-value of a window could only refer to one component of it e.g. the glass. As a consequence, these examples show that one should be careful when reading U- or R-values as sometimes the publisher might indicate only one component of the building element.

Summary

Mathematically, both the U- and the R-value describe the thermal performance of a building element. They are just reciprocal. The lower the U-value, the higher the R-value and the better the thermal performance of the assessed element. It might be easier for customers to understand that an R-value of $R_1 = 8$ is better than an R-value of $R_2 = 4$ instead of dealing with the corresponding U-values, which are below one: $U_1 = 0.125$ and $U_2 = 0.25$. The customer should always be aware of the composition of the stated R- or U-value as they sometimes indicate only one component of the element.

References

DWM Magazine. (2010). Industry Discusses U-Factor Versus R-Value for Window Performance. *Door and Window Manufacturer*, 21.

National Fenestration Rating Council (NFRC). (2010). *Procedure for Determining U-factors*. Greenbelt.

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