HI-SMART

HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #2

STANDARD GLAZING SYSTEMS USED IN nZEB

Co-funded by the Erasmus+ Programme of the European Union

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1.1 INTRODUCTION

The accompanying presentation deals with the importance of low-emissivity glazing layers to improve energy balance and in maintaining the interior visual comfort. It describes the physical nature of radiation and the associated surface emissivity and the effects of changes in surface emissivity of glass, depending on the position of low-emissivity layer. It also discusses principles, advantages and disadvantages of the most common combinations of glass and low-emissivity layer - the so-called “high performance” glass and the so-called “low-e” glass.

1.2 SOLAR RADIATION

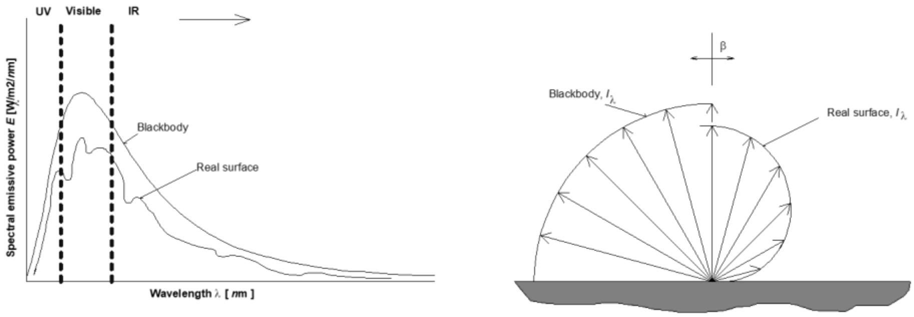
Solar radiation is one of the most exciting, but at the same time the most sophisticated ways of heat transfer. It is electromagnetic waves of different wavelengths in different directions. Depending on what interests us the most, we are talking about the spectral (according to wavelength), directional or integrated (total) radiation. In terms of the direction of radiation two extreme cases are usually distinguished - direct and diffuse radiation. From the spectral point of view we talk often about the visible (light) and invisible (X-rays, UV, IR) part of the solar radiation. When hitting the Earth’s surface the radiation in dependence of its wavelength and direction, and also the nature of the material, to which it is incident, gets reflected, transmitted, or absorbed by it. In semitransparent materials (e.g. glass pane, water) all three phenomena occur, i.e.,

$$\rho \text{ (reflection)} + \tau \text{ (transmission)} + \alpha \text{ (absorption)} = 1 \quad (1)$$

In opaque materials the transmission drops out and applies that

$$\rho \text{ (reflection)} + \alpha \text{ (absorption)} = 1 \quad (2)$$

The absorbed radiation raises the temperature of the material (mass), which in turn removes the excess heat energy by emission. The amount of emitted energy is dependent on the emissivity (surface radiation), ε, which is one of the characteristics of materials. The emissivity is defined as the ratio of the radiation emitted by the surface of the material to the radiation emitted by a black body at the same temperature (Fig. 1) (Incropera & DeWitt, 1996). Black body is a perfect absorber and issuer of radiation, whereas the spectral distribution of the intensity of solar radiation along the wavelengths is approaching the spectral distribution of the intensity of blackbody radiation at a temperature of 5800 K.



(a) **(b)**

Figure 1 - Comparison of blackbody and real surface emissions. (a) Spectral distribution, (b) Directional distribution (I_λ = radiation intensity, β = radiation angle) (Incropera & DeWitt, 1996)

The intensity of blackbody radiation is defined by the emissivity at a given wavelength. According to Stefan-Boltzmann's law, the radiation wavelength, and thus the emissivity of a black body depends on its temperature, whereas applies (Incropera & DeWitt, 1996) that

$$I_b = E_b / \pi = \sigma T^4 / \pi \quad (3)$$

where I_b is the intensity of blackbody radiation in dependence on its emissivity (W/m^2), E_b power as a result of emissivity (W/m^2), π is the number pi, σ is Stefan-Boltzmann's constant (σ = 5,670 x 10^{-8} W/(m^{2}K^4)) and T temperature in Kelvin. Then, in a very simplified way, the emissivity of the surface of a particular material is as follows

$$\varepsilon(T) = I(T) / I_b(T), \quad (4)$$

resp. $\varepsilon(T) = E(T)/E_b(T)$ (Incropera & DeWitt, 1996) (5)

where $\varepsilon(T)$ is emissivity of the material surface at a given temperature (-), $I(T)$ intensity of the material surface radiation at a given temperature in W/m^2 and $E(T)$ power as a result of the material surface emissivity at a given temperature in W/m^2. The above shows that the emissivity of a given material depends on the temperature of its surface and the wavelength of the emitted radiation. But also depends on the direction of the radiation (see Fig. 1). The emissivity deviations for radiation angles other than perpendicular to the surface plane (so-called normal ones (ε_n)) are negligible. Therefore for the normal use applies (Incropera & DeWitt, 1996) that

$$\varepsilon \approx \varepsilon_n \quad (6)$$

Tables of surface emissivity values of individual materials published in the standards or professional literature respectively, mainly refer to values at a temperature of 300 K (26.85 °C) or for the most frequent situation of the use or occurrence (e.g., for ice at 0 °C). In the case of metals, values for several temperatures are referred to, because the emissivity as a function of temperature, and the related chemical processes, can vary substantially. According to Kirchhoff’s law for most materials at normal temperatures is true that

$$\alpha = \varepsilon \tag{7}$$

In case of some materials, e.g., in the case of metals, the relation (7) must not necessarily be 100 per cent true (Incropera & DeWitt, 1996).

1.3 GLASS

The glass is without doubt one of the most attractive building materials. It allows visual link between building’s internal and external environment, as well as the use of daylight and solar heat. It has interesting properties (Encyclopedic Technology, 1963) - in addition to the transparency it is formable over flame and resistant to acids, which is of particular importance in the chemical industry. It is made of silica sand with addition (potassium carbonate, limestone, soda, or lead tetraoxide) by heating to a high temperature (approx. 1,600 ° C), formation and cooling. After cooling it hardens, but retains transparency. Method of cooling the molten glass decides on a number of crucial properties of the glass, especially on its strength. Flat glass is produced by casting, blowing, pressing, rolling or by drawing (Encyclopedic Technology, 1963). In the past, the largest share had drawn glass (Encyclopedic Technology, 1963): “Glass in the liquid state is sufficiently coherent to hang like a curtain on the window. There are several methods for drawing glass, but it always begins in that an iron frame, to which the glass is clamped, is immersed in the tub with enamel. When the frame is being pulled up, a wide (up to 300 cm) endless belt of flat glass is being created that passes through the rollers and coolers and is cut to the panes. The glass thickness can be controlled by changing the temperature and drawing speed. The thus prepared plate glass is not perfectly smooth and uniformly thick. It is therefore necessary to grind it. Another option is to pour melted glass on the surface of a liquid tin bath. In the liquid state the tin is perfectly flat and smooth and the glass is spilling on it into absolutely flat plate.”

Another big advantage of the glass is its, almost, 100% recyclability. The process of treatment of the used glass is about the same as in the manufacture of new glass. According to Vetropack the most important limitation of glass recycling is its color. For the production of white glass only shards of white glass can be used. Hence, the share of the used glass in the production strongly depends on the color of glass produced (Vetropack).

1.4 BUILDING PHYSICAL PROPERTIES OF GLAZING

Unlike non-transparent structures, mainly characterized by thermal conductivity factor, λ, in the case of glazing are important also properties that are attributable to the transmittance of solar radiation. There are two main types of these properties - solar and optical. The solar properties refer to, more or less, the entire spectrum of sunlight as the integrated radiation involving both spectral and directional radiation, the optical ones only to the visible part - the light and the direction of its impact and rebound.

"The Betrayal" is that the symbols of both, the solar and optical characteristics, i.e. transmissivity (direct transmittance), τ, reflectivity, ρ, and absorptivity, α, are the same. It is good to add lower indices to them, like "sol" or "opt" respectively, in order to avoid misunderstandings. In addition to the characteristics listed above a global characteristic of the solar properties in form of the total solar energy transmittance coefficient, so-called solar factor, or the *g*-value is introduced.

The solar factor (total solar energy transmittance), *g*, is defined by EN 410:1998 as the sum of the direct solar transmittance, τ_{sol}, and the secondary heat transfer factor, q_i, of the glazing towards the inside. The secondary heat transfer factor is caused by convection and long-wave infrared radiation of that part of the incident solar radiation, which has been absorbed by the glazing. The respective equation for the *g*-value is then:

$$g = \tau_{sol} + q_i \tag{8}$$

The solar direct transmittance, τ_{sol}, is a glazing property. It is the portion of incident solar radiation that passes through the glazing and can be described as primary heat gain, g_1, divided by the total incident solar heat flux, φ_e (several standards, e.g. ISO 15099:2003, use the symbol *I* instead of φ_e for the total density of heat flow rate of incident solar radiation). The secondary heat transfer factor, q_i, is dependent on the absorption factors of glazing layers, their emissivities (long-wave infrared radiation), ε, and thermal conductance, Λ, including the cavities and surface heat transfer. It is the absorbed portion of incident solar radiation that is converted into conductive and radiative heat flow towards the inside, and can be described as secondary heat gain, g_2, divided by the total incident solar heat flux, φ_e. Hence, another equation for the *g*-value is:

$$g = \frac{g_1 + g_2}{\varphi_e} \tag{9}$$

The solar factor is one of the most important characteristics of glazing systems because it allows an immediate and reliable assessment of the future performance of the glazing system in terms of solar heat gains. Thus solar as well as optical and thermal characteristics of glazing can be detected using computational procedures set out in international and European standards. A prerequisite, however, are the measured values of the characteristics of specific glasses, i.e. α, τ, ρ, ε and λ. These can be obtained from the glass manufacturers or quality databases, such as WIS (www.windat.org), respectively. The WIS database has the advantage that it also allows the calculation of the solar, optical and thermal characteristics of the glazing systems of any configuration, including spaces filled with air / gas / vacuum, or ventilated spaces respectively, further reflective layers, shading elements and even frames. Values of boundary conditions can be entered freely or normative data may be used (for example ISO 15099: 2003 distinguishes between winter and summer boundary conditions). Results from WIS can be used in software for energy performance of buildings simulation, as well as daylight simulation.

1.5 LOW-EMISSIVITY LAYER

At present the properties of glass can be significantly modified (Encyclopedic Technology, 1963). In construction, two most frequent methods of glass treatment in terms of improving their solar properties are used - application of reflective films and so-called coating or plating. The first method, as the name suggests, is to improve the reflectivity of the visible part of the spectrum (light). It is used where we want to reduce the cooling load of internal spaces. The disadvantage of this method is that it also reduces the transmission of natural light, which can lead to increased use of artificial light and thus, ironically, increase the internal heat gains. The second method is based on reducing the emissivity of the glass by applying an extremely thin layer of metal. It happens either by pyrolytic plating during manufacturing of the glass (on-line process) or by so-called magnetron technology after curing glass (off-line process) (www.glassdbase.unibas.ch). Plating can reduce the glass emissivity from values of about 0.9 to 0.95 (clear glass) to the values of about 0.2. Such glass is called low-emissivity or “low-e” glass, if the coating is on the side of the glass facing the outside world. If it is on the side toward the indoor environment, while it is also low-emissivity glass, is often referred to as the so-called “high performance” glass (in German is used the term “Sonnenschutzglas”) in order to distinguish between the two of them.

Reducing the infrared radiation inwards greatly reduces the thermal load on the cooling system, so the high performance glass is used mainly in the areas that need to be more cooled than heated. Conversely, the low-e glass is used in areas where we want to prevent heat losses and utilize the solar radiation. Nevertheless, its contribution to the reduction of heat loss is not as pronounced as the effect of high performance glass in reducing heat gain from solar radiation.

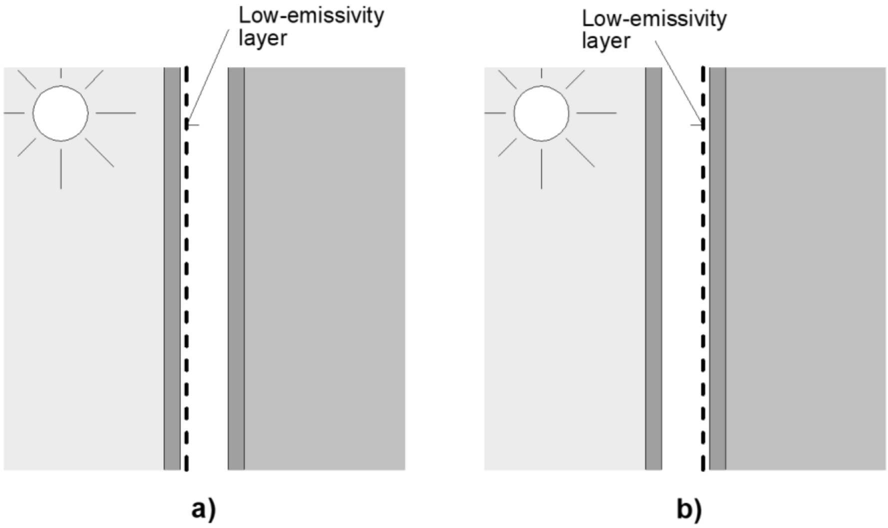


Figure 2 - Typical position of low-emissivity layer in double glazing. (a) High performance system, (b) Low-e system

Given that, in our climatic conditions, it is essential to use glazing systems with at least two panes of glass and closed cavity filled with air or vacuum or inert gases and their mixtures with air, the low-e layer may be placed in different positions. Fig. 2 shows typical positions of the low-emissivity layer within double glazing in the case of the use of low-e and high performance glass respectively.

Of course, the low-emissivity glass is not used alone, but in glazing systems. Hence, their efficiency can be increased, e.g. in the case of low-e glass by closed cavities filled with an inert gas or vacuum, in the case of high performance glass by ventilated air layers or reflective glass on the outer position. It is always good to analyze the planned glazing system, e.g. using appropriate software such as WIS, so that the subsequent daylighting or energy balances of investigated spaces best correspond to their real behavior.

1.6 SELECTIVITY

The selection of suitable glass or glazing system depends primarily on the requirements for indoor comfort of the planned space, and they can be quite contradictory, particularly in summer. For example, in office spaces the best possible daylight is required to be achieved, but we want to prevent them from overheating as well. The use of a low-emissivity layer reduces the light transmission of the glass or glazing system respectively, which is an undesirable side-effect of reducing the solar factor. Hence, in addition to *g*- and *U*-values the glass producers introduce also so-called selectivity of the glass or glazing system in order to demonstrate their suitability for specified conflicting requirements.

Table 1. The properties of typical clear, high performance and low-e glass.

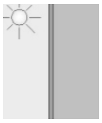
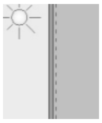
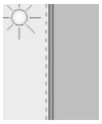
Type of glass		light transmittance (τ_{opt}) [-]	*g*-value [-]	*U*-value [W/(m²K)]	selectivity, *S* [-]
	Clear glass	0,885	0,840	4,69	1,05
	High Performance glass	0,565	0,472	2,54	1,20
	Low-E glass	0,565	0,583	3,96	0,97

Table 2. Values of selectivity that can be achieved by today's technologies (Brandi, 2005)

Type of glass	light transmittance (τ_{opt}) [-]	*g*-value [-]	selectivity, *S* [-]
Low-E (Thermally insulating glass)	0,70	0,60	1,17
High performance glass (colored)	0,25	0,21	1,19
High performance glass (color-neutral)	0,66	0,33	2,00

The selectivity is the ratio of optical transmissivity, τ_{opt}, to *g*-value. The higher, the better suits the glass or glazing system in terms of conflict of requirements for daylight comfort and reduction of summer overheating. Maximum, by current technologies achievable selectivity is about 2.

Table 1 shows the selectivity, *S*, light transmittance, τ_{opt}, and *g*- and *U*-values of the above mentioned clear, high performance and low-e glass. Of course, the specific values of other glasses may vary, depending on the manufacturer and the technology used. Values that can be achieved by today's technologies are shown in Table 2 (Brandi, 2005).

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http://www.glassonweb.com/glassmanual

http://www.glassdbase.unibas.ch

Co-funded by the Erasmus+ Programme of the European Union