A Review of Glazing Materials and its Prospects in Buildings of Kathmandu Valley

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Abstract: Windows plays an important role in building energy interaction and consumption patterns. The proper knowledge about the windows system and parameters that affect the energy transition seems necessary and important in present context. With the growing trend of high rise buildings in Kathmandu Valley, proper selection of window is crucial for overall building energy consumption and efforts toward energy efficiency. This review paper discusses the various parameters affecting the energy transformation in glazing system and different types of glazing panes available. This paper thus can be further explored for proper selection of glazing systems for the new and old projects. Furthermore, this paper can be helpful in further exploring the concept of glazing systems for specific locations and projects.

Keywords: Fenestration; Glazing; SHGC; Transmittance; Tinted; Double Glazing

1. Introduction

Fenestration is an architectural term that refers to the arrangement, proportion, and design of window, skylight, and door systems in a building. Fenestration affects building energy use through four basic mechanisms: thermal heat transfer, solar heat gain, air leakage, and daylighting. The energy effects of fenestration can be minimized by

- Using daylight to offset lighting requirements
- Using glazing and shading strategies to control solar heat gain to supplement heating through passive solar gain and minimize cooling requirements
- Using glazing to minimize conductive heat loss
- Specifying low-air-leakage fenestration products, and
- Integrating fenestration into natural ventilation strategies that can reduce energy use for cooling and fresh air requirements.

Fenestration components include glazing material, either glass or plastic; framing, mullions, muntin bars, dividers, and opaque door slabs; and shading devices such as louvered blinds, drapes, roller shades, and awnings.(ASHRAE, 2009)

2. Glazing

Glazing can be considered as the most important part of fenestration products. The glazed area of a building's envelope generally represents the most dynamic connections that a building has to its environment. Glass has been increasingly used and is today a key material in facade technology. When employing glazings in modern buildings, numerous physical and physiological aspects need to be considered such as visual contact between interior and exterior, use of daylight, optimizing and controlling solar energy gains, minimizing thermal losses, optimizing thermal comfort, minimizing glare, noise protection, air and driving rain tightness, and fire safety(Heinrich Manz, 2011)

A glazing unit may consist of a single glazing or multiple glazings. Units with multiple glazing layers, sometimes called **insulating glazing units (IGUs)**, are hermetically sealed, multiple-pane assemblies consisting of two or more glazing layers held and bonded at their perimeter by a spacer bar typically containing a desiccant material. The desiccated spacer is surrounded on at least two sides by a sealant that adheres the glass to the spacer.(ASHRAE, 2009)

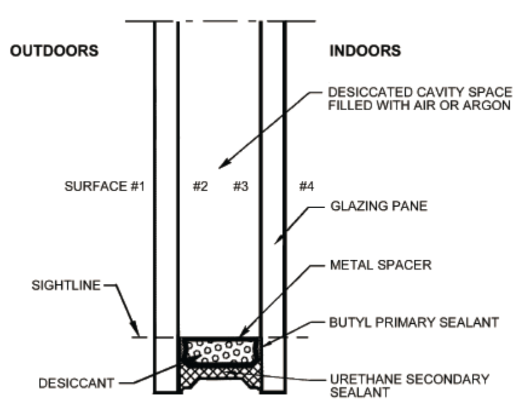

Figure 1: Double Glazing Unit Construction Detail (ASHRAE, 2009)

2.1. A Glazing Pane

A Glazing Pane is the sheet of glass and comprise of main component of the glazing system.

2.2. Spacer

The spacer separates the panes of glass and provides the surface for primary and secondary sealant adhesion.

2.3. Sealant(s)

The primary seal minimizes moisture and hydrocarbon transmission. In dual-seal construction, the secondary seal provides structural integrity between the glazing units. A secondary seal ensures long-term adhesion and greater resistance to solvents, oils, and short-term water immersion.

2.4. Gas Fill

The hermetically sealed space between glass panes is most often filled with air. In some cases, argon and krypton gas are used instead, to further reduce energy transfer. (ASHRAE, 2009)

3. Solar Radiation

The solar radiation at the earth's surface is roughly located between 300nm and 3000nm (0.3 µm and 3 µm, respectively), where the visible (VIS) radiation (light) lies between 380nm and 780 nm. Ultraviolet (UV) and near infrared (NIR) radiation are located below and above the VIS region, respectively(Petter Jelle, 2013)

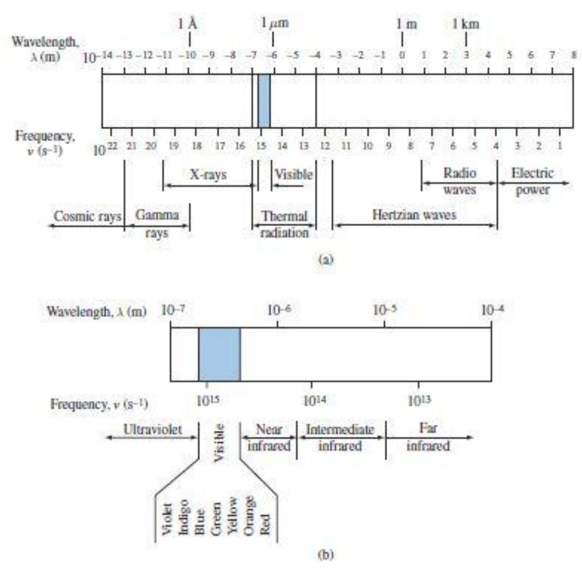

Figure 2 (a) Electromagnetic Spectrum (b) Thermal Radiation Portion of Electromagnetic Spectrum(Frank Krieth, 2011)

When radiation is incident on a surface at rate G, a portion of the total irradiation is absorbed in the material, a portion is reflected from the surface, and the remainder is transmitted through the body. The absorptivity, reflectivity, and transmissivity describe how the total irradiation is distributed. The absorptivity α of a surface is the fraction of the total irradiation absorbed by the body. The reflectivity ρ of a surface is defined as the fraction of the irradiation that is reflected from the surface. The transmissivity τ of a body is the fraction of the incident radiation that is transmitted.

$$\alpha G + \rho G + \tau G = G$$

It is apparent that the sum of the absorptivity, reflectivity, and transmissivity must equal unity i.e.

$$\alpha + \rho + \tau = 1$$

Another important total radiation property of real surfaces is the emissivity. The emissivity of a surface, ϵ, is defined as the total radiation emitted divided by the total radiation that would be emitted by a blackbody at the same temperature, or

$$\epsilon = \frac{E(T)}{E_b(T)} = \frac{E(T)}{\sigma T^4}$$

From Kirchhoff's law of monochromatic emissions at any wavelength λ at temperature T, $\epsilon_\lambda = \alpha_\lambda$ both of which are surface properties that depend solely on the condition of the surface and its temperature.(Frank Krieth, 2011)

Heat flows through a window assembly in three ways: conduction, convection, and radiation. Conduction is heat traveling through a solid, liquid or gas. Convection is the transfer of heat by the movement of gases or liquids, like warm air rising from a candle flame. Radiation is the movement of energy through space without relying on conduction through the air or by movement of the air, the way you feel the heat of a fire.

4. Glazing Performance Parameters

4.1. Transmittance

Transmittance can be defined for different types of light or energy i.e. **Visible Transmittance**, **UV Transmittance** or **Total Solar Energy Transmittance**. Transmission of visible light determines the effectiveness of a type glass in providing daylight and a clear view through the window. For example, tinted glass has a lower visible transmittance than clear glass. While the human eye is sensitive to light at wavelengths from about 0.4 µm to 0.7 µm, its peak sensitivity is at 0.55, with lower sensitivity at the red and blue ends of the spectrum. This is referred to as the photopic sensitivity of the eye.

More than half of the sun’s energy is invisible to the eye. Most reaches us as near-infrared with a few percent in the (UV) spectrum. Thus, total solar energy transmittance describes how the glazing responds to a much broader part of the spectrum and is more useful in characterizing the quantity of total solar energy transmitted by the glazing.

4.2. Reflectance

The reflectivity of various glass types becomes especially apparent during low light conditions. The surface on the brighter side acts like a mirror because the amount of light passing through the window from the darker side is less than the amount of light being reflected from the lighter side. This effect can be noticed from the outside during the day and from the inside during the night. For special applications when these surface reflections are undesirable (i.e. viewing merchandise through a store window on a bright day), special coatings can virtually eliminate this reflective effect.

4.3. Absorptance

Energy that is not transmitted through the glass or reflected off its surface is absorbed. Once glass has absorbed any radiant energy, the energy is transformed into heat, raising the glass temperature.

The Absorptance of glass is increased by glass additives that absorb solar energy. If they absorb visible light, the glass appears dark. If they absorb ultraviolet radiation or near-infrared, there will be little or no change in visual appearance. Clear glass absorbs very little visible light, while dark-tinted glass absorbs a considerable amount. Tints are generally gray, bronze, or blue-green and were traditionally used to lower the solar heat gain coefficient and to control glare. Since they block some of the sun’s energy, they reduce the cooling load placed on the building and its air-conditioning equipment. All glass and most plastics, however, are generally very absorptive of long-wave infrared energy. The property is best illustrated in the use of clear glass for greenhouse, where it allows the transmission of intense solar energy but blocks the retransmission of the low-temperature heat energy generated inside the greenhouse and radiated back to the glass.

4.4. Emittance

When solar energy is absorbed by glass, it is either convected away by moving air or reradiated by the glass surface. This ability of a material to radiate energy is called its emissivity. Window glass, along with all other objects, typically emit, or radiate, heat in the form of long-wave far- infrared energy. The wavelength of the long-wave far-infrared energy varies with the temperature of the surface. This emission of radiant heat is one of the important heat transfer pathways for a window. Thus, reducing the window’s emission of heat can greatly improve its insulating properties.

Standard clear glass has an emittance of 0.84 over the long-wave infrared portion of the spectrum, meaning that it emits 84% of the energy possible for an object at room temperature. It also means that for long-wave radiation striking the surface of the glass, 84% is absorbed and only 16% is reflected. By comparison, low E-glass coatings have an emittance as low as 0.04. This glazing would emit only 4% of the energy possible at its temperature, and thus reflect 96 % of the incident long-wave infrared radiation(Regents of the University of Minnesota, Twin Cities Campus, College of Design, Center for Sustainable Building Research, 2011)(Bjørn PetterJelle, 2012)(Leftheriotis, 2012)

5. Windows Properties for Energy Performance

5.1. U-FACTOR (Thermal Transmittance)

The glazing unit’s heat transfer paths are subdivided into center-of-glass, edge-of glass, and frame contributions (denoted by subscripts cg, eg, and f, respectively).

$$U_o = \frac{U_{cg}A_{cg} + U_{eg}A_{eg} + U_f A_f}{A_{pf}}$$

Values for U_{cg} at standard indoor and outdoor conditions depend on glazing construction features such as the number of glazing lights, gas space dimensions, orientation relative to vertical, emissivity of each surface, and composition of fill gas.

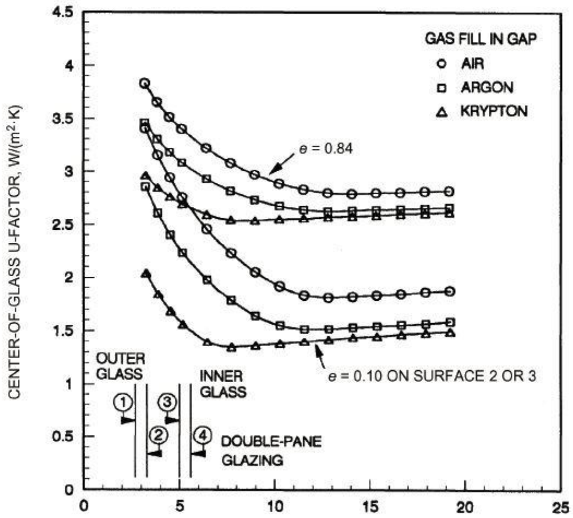

Figure 3: Center-of-Glass U-Factor for Vertical Double Pane Glazing Windows(ASHRAE, 2009)

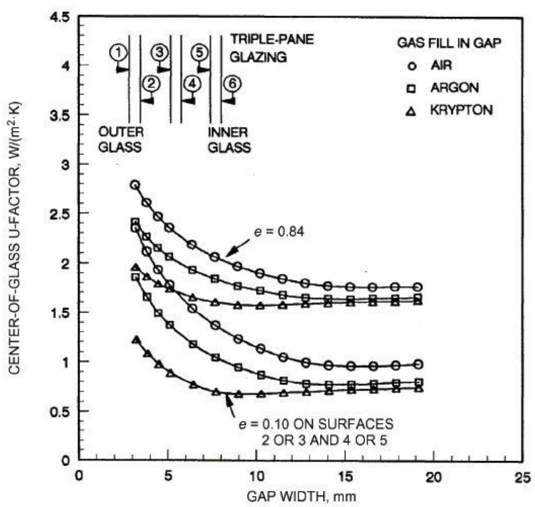

Figure 4: Center-of-Glass U-Factor for Vertical Triple Pane Glazing Windows(ASHRAE, 2009)

The optimum gas space width is 12.7 mm for air and argon, and 8 mm for krypton. Greater widths have no significant effect on U_{cg}. Greater glazing unit thicknesses decrease U_o because the length of the shortest heat flow path through the frame increases.(ASHRAE, 2009)

5.2. Visible Transmittance

Visible transmittance is the solar radiation transmitted through fenestration weighted with respect to the photopic response of the human eye. It physically represents the perceived clearness of the fenestration, and is likely different from the solar transmittance of the same fenestration.

Spectrally selective glazing shows strong changes in its optical properties with variations in wavelength over the spectrum.

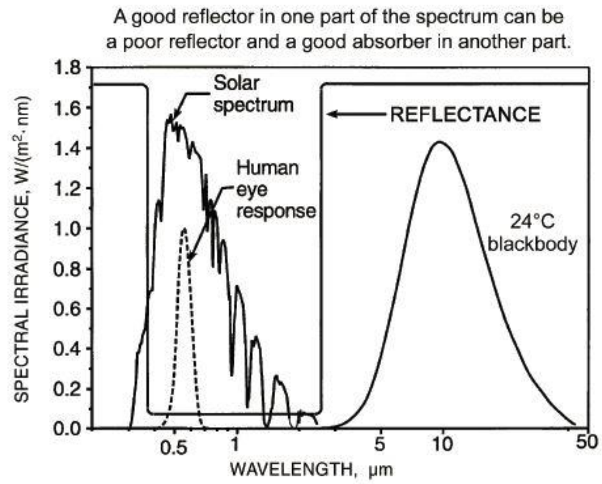

Figure 5: Solar Spectrum, Human Eye Response Spectrum, Scaled Blackbody radiation spectrum, and Idealized Glazing Reflectance Spectrum(ASHRAE, 2009)

The glazing represented in the figure does not appear very reflective. It is also strongly transmitting for solar radiation, including the visible portion. The glazing is, however, nearly opaque to long-wave radiation, demonstrating that visual perception of a material is a poor indicator of its overall spectral characteristics. The glazing system reflectance depicted in Figure 5 is good for admitting solar radiation while preventing the escape of long-wave radiation emitted by surfaces inside the room, a good design for cold sunny days.

Radiation absorbed by surfaces in the room is emitted as long-wavelength radiation, which cannot escape directly through the glass because of its opaqueness to radiation beyond 4.5 μm. Instead, radiation from room surfaces is absorbed and reemitted to both sides as determined by several parameters, such as the inside and outside film heat transfer coefficients, the surface emissivity, and other glazing properties.

Because of the conservation of energy ($T + R + A = 1.0$), high long-wave reflectance means low transmittance and absorptance. Kirchhoff's law shows that low absorptance means low emissivity as well. This is the principle of operation of the high-solar-gain (or cold-climate) low-e coating on window glass. Such a coating has high transmittance over the entire solar spectrum, producing high solar heat gain while being highly reflective to long-wave infrared radiation emitted by the indoor surfaces, reflecting this radiation inward. The term low-e refers to a low emissivity over the long-wavelength portion of the spectrum.

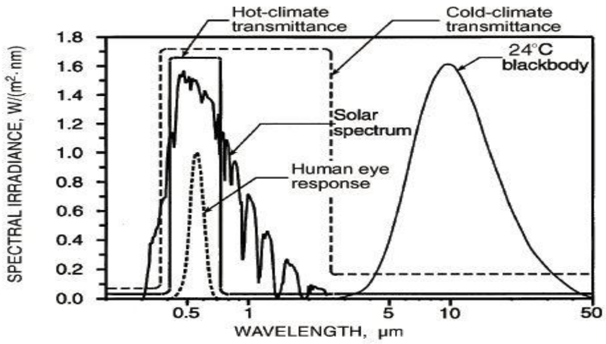

Figure 6: Demonstration of Two Spectrally Selective Glazing Concepts, Showing Ideal Spectral Transmittances for Glazings Intended for Hot and Cold Climates(ASHRAE, 2009)

Figure 6 shows hypothetical glazing systems with performance tuned to specific climates. In this case, the sharp reflectance edge that the ideal high solar gain cold-climate low-e coating exhibits just past the end of the solar spectrum in Figure 5 is shifted closer to the edge of the visible portion of the spectrum, thereby increasing the solar near-infrared (NIR) reflectance of the glazing. This results in a drop in the hot-climate transmittance to the right of the visible portion of the spectrum. The effect is to reflect the near-infrared portion of the solar spectrum outside, reducing solar gain, while still admitting visible light in the wavelength region below about 0.8 μm. This low-solar-gain, hot-climate coating also exhibits low emissivity over the long-wave spectrum, and is therefore also properly termed a low-e coating. To distinguish the cold- from the hot-climate version, a glazing with this type of spectral response is often termed selective low-e. The reduced infrared transmittance for the hot-climate glazing is ideally achieved by high reflectance and low absorptance (meaning also low emissivity). It can also be done with high infrared absorptance, if the flow of absorbed solar radiation to the interior of the building can be reduced, introducing a second approach to the construction of a hot-climate, low-solar-gain glazing system. In this case, the outer pane of a multiple-pane glazing system is made to have good visible transmittance but high absorptance over the solar infrared spectrum. To protect the interior of the building from the heat of this absorbed radiation, additional glazings, gas spaces, and cold-climate or low-solar-gain, low-e coatings are added.(ASHRAE, 2009)

5.3. Solar Heat Gain (SHG)

Solar gain (or solar heat gain) (SHG) in general refers to the heat increase of a structure (or object) in a space that results from absorbed solar radiation. Objects intercepting sunlight absorb the radiation and as a result their temperature is increased. Then, of course, part of the heat is reradiated at far-IR wavelengths. If a glass pane (or other material) is placed between the solar irradiation and the objects intercepting it, that is, transparent to the shorter wavelengths and not to the longer, then the solar irradiation has as net result an increase in temperature (solar gain).

Solar heat gain coefficient (SHGC) is the fraction of incident solar irradiation admitted through a window, both directly transmitted and absorbed, and subsequently released inward. SHGC is given as a number between 0 and 1. The lower a window's SHGC, the less solar heat it transmits in the protected space. SHGC is used in the United States.

g-Value is the coefficient commonly used in Europe while shading coefficient (SC) is an older term that is still sometimes used in the United States. The relationship between SHGC and SC is as follows: SHGC = SC x 0.87.

SC values are calculated using the sum of the primary solar transmittance and the secondary transmittance. Primary transmittance is the fraction of solar radiation that directly enters a building through a window compared to the total solar insolation, the amount of radiation that the window receives. The secondary transmittance is the fraction of heat flowing inside the space from the window, compared to the total solar insolation.

Total solar energy rejected (%) is the percent of incident solar energy rejected by a glazing system. It is to the sum of the solar reflectance and the part of solar absorption that is reradiated as thermal energy outward.

Shading coefficient (SC) is the ratio of the SHG through a given glazing system to the SHG under the same conditions for clear, double-glass window. The SC defines the solar control capability of the glazing system and it is useful when discussing the properties of fenestration and shading devices. In other words, the SC gives the solar energy transmittance through windows.(Petter Jelle, 2013)(Leftheriotis, 2012)

5.4. Low Emittance Coatings

Low-e coatings are thin films that exhibit spectral selectivity: they are highly transparent in the visible (VIS) part of the electromagnetic spectrum (from 0.4 to 0.7 μm), highly reflective in the IR (for wavelengths higher than 0.7 μm), and absorbing in the UV (e.g., below 0.4 μm).

Thus, it is possible to decouple the visible light spectrum from that of thermal radiation and to have surfaces with properties being entirely different with regard to thermal and visible radiation .Nowadays, use of low-e glass in architecture is very common, and in many countries it is mandatory by law to increase the energy efficiency of buildings, to promote rational use of energy, and to reduce CO_2 emissions.

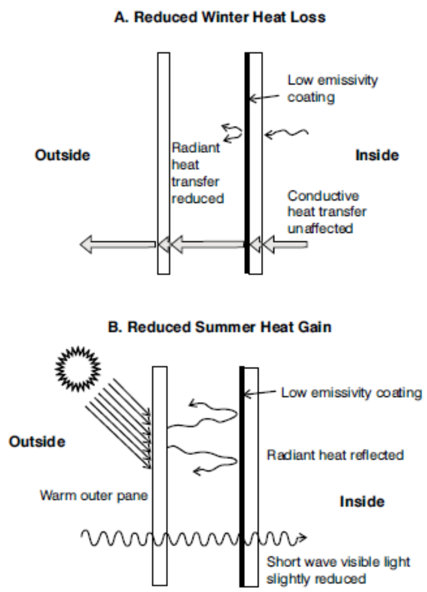

Figure 7: Low E glazing heat transfer phenomenon (Heinrich Manz, 2011)

6. Commercially Available Glazings

6.1. Single Glazed Units

6.1.1. Clear Single Glazing

The simplest type of window consists of a single clear uncoated glass. It provides the highest visible transmittance but exhibits large thermal losses. Furthermore, such a glazing does not provide sufficient sound insulation and suffers from mist condensation. Nowadays, the use of such glazing is limited to low-cost solutions or to retrofitting of windows in historical buildings that do not possess thick enough frames to accommodate double glazing.

6.1.2. Tinted Single Glazing

Tinted glass is a normal float glass containing colorants. Colored glass is an important architectural element for the exterior appearance of facades. Due to its high extinction coefficient, low transmittance, and high absorptance, tinted glass is often called ‘absorptive’. The low visible transmittance reduces the quantity of daylight admitted indoors. Its primary use in windows is therefore to reduce glare and excessive solar transmission. As the reduction in light transmission is effected through absorption, such glazing exhibit high SHGCs: the absorbed radiant energy is initially transformed into heat within the glass, thus raising the glass temperature. A significant amount of it is then reemitted indoors. Tinted glazing allows a greater reduction in visible transmittance (Tvis) than in SHGC due to reemission. In a practical situation, transmittance in the visible and SHGC are required to increase (winter, cold climates) or to decrease (summer, hot climates) simultaneously by a similar degree. Thus, single-tinted glazings are far from achieving optimum performance. To rectify this situation, other, more appropriate solutions have been developed such as spectrally selective coatings with light blue/green tint having higher visible performance and lower SHG (glazing no. 13 in Table 1 is one such example).

6.1.3. Reflective Single Glazing

A reflective coating can be added to glass to increase the reflectivity of its surface, in order to achieve a considerable reduction in solar gains. The reflective coating usually consists of thin metallic or metal oxide layers, and comes in various metallic colors such as bronze, silver, or gold. The SHGC varies with the thickness and reflectivity of the coating, and its location in the glazing system. While some reflective coatings must be protected by sealing in cavity (e.g., those based on noble metals), others are durable and can be added on exposed surfaces. It can be seen in Table 1 that a reflective coating changes very little the U-value of single glazing that is dominated by convection (between glass and the surrounding air) and conduction (through the glass). Similar to that of tinted glass, the visible transmittance of reflective glass declines more than its SHGC. Architects are generally fond of reflective glazing because of its glare control and appealing outside appearance. However, the usage is limited by its sun mirror effect that may cause disturbances on traffic roads and nearby buildings. Also in well-illuminated rooms, the loss of visual privacy and outside views at night can be a concern to the occupants.

6.1.4. Low Emittance Single Glazing

Low-e coatings can be added to float glass to achieve either solar control or thermal insulation. The performance of single low-e-coated glazing depends on the position of the coating (indoors or outdoors). The correct placement of the coating is indoors in order to suppress long-wave radiative heat losses to the environment. In that configuration, the heat emitted from indoors is reflected back into the room. Otherwise (e.g., with the low-e coating facing outdoors), the heat would have been absorbed by the glass, raising its temperature, which would have caused an increase of convective heat losses. The glass thickness also plays a role in the performance of such a glazing, especially in

SHGC (or g-value), as can be seen in Table 1. Low-e-coated glass is very popular in modern architecture over the world, mostly in conjunction with double glazing.

6.2. Multiple Glazed Windows

Multiple panes with air-sealed cavities can be used to improve the glazing thermal insulation properties without undue reduction in transmittance and in heat gains. The fabrication of multiple glazing (double, triple, and quadruple) poses new challenges to the manufacturers: the cavity must be air and moisture proof, thus appropriate sealants (called 'spacers') must be developed. Furthermore, the spacers must be able to accommodate the thermal stress and the differential expansion of the two (or more) glass sheets. They are also required to be thermally insulating, otherwise edge losses may exceed the extra insulation multiple glazing offer. To minimize heat losses through multiple glazing, one needs to reduce not only the peripheral heat losses (e.g., conduction through the spacers) but also the heat transferred through the air gap.

6.2.1. Double Glazing

As can be seen in Table 1, the U-value of a double glazing with two clear panes is 49%lower than that of a similar single pane window. The improvement of the window thermal properties comes at a price of a 12% reduction in SHGC, which is more than acceptable. In situations where further reduction of solar gains is desirable, tinted and reflective glass can offer a decrease in g-value between 30% and 60%. As with single glazing, the U-value of double-glazed windows with tinted or reflective glass is not affected considerably. Low-e coatings, on the other hand, further improve thermal insulation, halving the clear double glazing U-value. Depending on the type of low-e coating, different properties can be obtained (e.g., solar control, with suppressed solar gains, or thermal insulation with high solar gains), each appropriate for a different climate type and application. The placement of low-e coating on the window assembly plays a marginal role on the overall window properties. Usually these coatings are placed within the air gap for protection reasons. The outdoors pane is preferred by glass manufacturers to be the coated one, with the indoors pane being clear glass, as this configuration is more efficient in blocking thermal radiation from the inside (in a similar way as in the case of single glazing but less pronounced). Indeed, as follows by comparison of windows 10 and 15 of Table 1, the use of two low-e coatings instead of one causes a 23% reduction in SHGC and an 11% reduction in U-value, which are small compared to the increase of the window cost, which could be 1.5 times higher or more. Of the double glazing appearing in Table 1,the most effective ones in terms of thermal insulation seem to be those with the solar control coatings.

Further reductions in U-values are possible with use of a less conductive and more viscous inert gas. Manufacturers use Ar, Kr, Xe, and mixtures of these as filling gases. They are nontoxic, nonreactive, clear, and odorless. As can be seen in Table 1, the effect of filling the gap with an inert gas is a reduction in U-values in the range of 0.1–0.3$Wm^{-2}K^{-1}$ depending on the glazing configuration. Thus, highly insulating windows benefit more from the use of inert gases, as the relative change in U-value is larger. The biggest problem with inert gases is that their retention in the glazing is questionable. As with all gases, they tend to diffuse through the seals and to escape through micro cracks in the sealing materials. Keeping the gas within the window unit depends largely on the quality of the design and construction, materials in use, and assembly, particularly the sealing techniques. As a result of all these improvements, state-of-the-art double glazings with g-values up to 0.49 and U-values down to 1.1$W\ m^{-2}K^{-1}$ have been achieved.

6.2.2. Triple and quadruple glazing for ultrahigh thermal insulation

In heating-dominated climates with extremely low temperatures, the U-values of double glazing are not low enough to ensure acceptable thermal losses of buildings. In these environments, triple and quadruple glazing is used, having U-values down to 0.6$W\ m^{-2}K^{-1}$. The price to be paid is the reduction in solar gains, and increase of the window dimensions, weight, and cost. In high-tech triple and quadruple glazing, Kr or Xe are used as the filling gases to reduce the overall width of the window. These gases allow placement of the glass panes at shorter distances(Leftheriotis, 2012)

6.3. Electro chromic window configuration

In principle, an ECW normally consists of an electro chromic (EC) material or coating, anionic conductor(IC) and a counter electrode (CE) interposed between two glass panes each with a transparent conductor (TC). By applying a voltage over the two transparent conductors, ions will go through the ionic conductor between the electro chromic coating and the counter electrode, and thereby change the color of the electrochromic layer. The counter electrode acts as ion storage, supplying the necessary ions for the electrochromic reaction, which, via the ionic conductor, are injected into or withdrawn from the electrochromic layer depending on the polarity of the applied voltage. The counter electrode may also have electrochromic properties complementary to the electro chromic coating (CE=EC), thus enhancing the color changes(Petter Jelle, 2013)

The windows can change solar factor (SF) and transmittance properties to adjust to outside and indoor conditions, thus reducing energy costs related to heating and cooling. For ECW it is important to achieve as high Tvis as possible in their transparent state in order to obtain as much natural day- lighting as possible. For energy regulation and to be able to shut off as much solar radiation as possible, it is important to have as low Tvis as possible in the coloured state. The total solar radiation regulation is given by Tsol or SF, where it is important to have as high and low values as possible in their transparent and coloured states, respectively. The main advantages smart windows have over multi-layer glazing are their dynamic solar factor and transmittance properties, which enable them by application of an external voltage to control the solar radiation throughout, thus saving energy.(Bjørn PetterJelle, 2012)

7. Glass for Multi-Storied Building in Kathmandu

Kathmandu Valley is in the Warm Temperate Zone (elevation ranging from 1,200–2,300 meters (3,900–7,500 ft), where the climate is fairly temperate, atypical for the region. The city generally has a climate with warm days followed by cool nights and mornings. It is difficult to predict the exact window glazing configuration for the Kathmandu as series of optimization is required to be done with the climatic data of the valley, the orientation of the buildings, nature of the building etc.

If the building is south facing, then the cooling load of the building could increase significantly due to higher solar gain. So for building oriented toward south, the glazing should be solar control glazing with medium SHGC and high Tvis as possible. A double glazing as depicted in above chart of TI-Lowe/Clear with SHGC 0.69 or SC-Lowe/Clear with SHGC 0.49 can be projected as the viable option. They both offer sufficient visible light transmittance of around 70-75 %, with Tsolar value of 55 and 38 respectively.

For building oriented towards other direction, the concern should be provided to low U value with as much as visible and solar transmittance possible. A double glazed clear clear glass both indoors and outdoors with high visible transmittance, solar transmittance of 79 and 64 can be logical choice with g value of 0.72 and U value of 2.9 W/m^2K.

The choice of glass is also governed by the aesthetic aspect and economical aspect as well. Opting for the tinted glasses reduce the visible transmittance significantly so the factor should be optimized so using triple glazed pane but its economical aspect should be considered.

The emerging technology of the electrochromic windows can be practiced for the maximum visible transmittance as well as efficient energy management.

The use of suitable glazing for the high rise building of the Kathmandu Valley is being felt with the present growing trend of building high rise buildings in the valley. But the gradual need of different options of glazing materials are felt considering its aesthetic, economic and energy efficient benefits. The glazing that are generally used nowadays are used without or with very little knowledge about all the parameters associated with it. They are imported from the glass manufactures in India like St. Gobain’s Glass, Pilkington Glass etc. The glass manufactures provide the glass with their own nomenclature so it is imperative to understand the actual physics behind the glass and proper selection should be made based on our needs and prevalent conditions.

With the rising number of high buildings with more prospects of use of glazing in such buildings in Kathmandu Valley, the proper knowledge about the same is very necessary if rational choices are to be made. Otherwise, the selection could be made based on certain known parameters only which could have severe implications otherwise.

8. Conclusion

Glazings play very important role in energy transition with outside environment. The energy consumption pattern of the building can be greatly attributed to the performance of a glazing; so its proper selection can play a crucial role in energy saving strategies. So this paper comprehensively presents the various parameters required to be known to properly assess any glazing systems.

This paper could serve as a baseline to path towards the proper knowledge of different types of glazing available in the markets. So a rational choice on proper selection of glazing can be exercised and it may be very crucial factor in whole of the building energy consumption, aesthetics and economics associated with it. Though the subject is in primitive stage, it is expected to grow rapidly with more and more Multi-Storied Building being build in the valley.

Furthermore, a separate research concerning the most suitable glazing for Kathmandu Valley can be carried out considering all the relevant parameters.

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Appendix

Table 1: Mid-pane values of optical and thermal performance indicators for various types of coatings (Leftheriotis, 2012)

		Visible		Solar					Thermal: U-value ($WK^{-1}m^{-2}$)	
No	Type of glazing	T_{vis}	R_{vis}	T_{sol}	R_{sol}	A_{sol}	g-value (SHGC)	SC	Air filled	Gas filled
	Single Glazing									
1	Clear, 6 mm thick	88	8	79	7	14	0.82	0.95	5.7	
2	Tinted, 6 mm thick	50	5	47	5	48	0.60	0.68	5.7	
3	Reflective	31	42	24	47	29	0.38	0.44	5.6	
4	TI Low-e 6 mm thick, indoors	67	25	58	19	23	0.62	0.71	3.8	
5	TI Low-e, 10 mm thick, indoors	65	24	53	17	30	0.58	0.66	3.7	
6	Self-cleaning, 6 mm thick	83	14	79	13	8	0.81	0.93	5.9	
	Double glazing (all panes 6-mm thick) OUTDOORS | INDOORS									
7	Clear | Clear	79	14	64	12	24	0.72	0.82	2.9	2.8
8	Tinted | Clear	44	7	38	7	55	0.48	0.55	2.7	2.6
9	Reflective | Clear	49	39	28	43	29	0.31	0.36	2.7	2.6
10	TI Low-e | Clear	73	17	55	15	30	0.69	0.79	1.7	1.5
11	SC Low-e | Clear	70	10	38	28	34	0.43	0.49	1.4	1.1
12	Self-cleaning/SC Low-e | Clear	67	16	36	32	32	0.40	0.46	1.4	1.1
13	Tinted SC Low-e | Clear	49	39	28	42	30	0.31	0.36	1.4	1.3
14	SC Low-e | TI Low-e	53	22	29	34	37	0.34	0.40	1.3	1.1
15	TI Low-e | TI Low-e	56	31	42	23	35	0.53	0.60	1.5	1.3
	Triple glazing (all panes 6 mm thick)									
16	Clear | Clear | Clear	70	19	52	15	33	0.63	0.73	1.8	1.7
17	TI Low-e | Clear | Clear	55	32	39	24	37	0.50	0.57	1.3	1.2
18	SC Low-e | Clear | Clear	62	14	33	29	38	0.39	0.45	1.0	0.9
19	Self-cleaning/SC Low-e | Clear | TI Low-e	54	20	28	35	37	0.35	0.40	0.8	0.7
	Quadruple glazing (all panes 6 mm thick)									
20	Clear | Clear | Clear | Clear	63	23	43	17	40	0.57	0.65	1.3	1.2
21	TI Low-e | Clear | Clear | Clear	50	35	33	25	42	0.45	0.52	1.0	0.9
22	SC Low-e | Clear | Clear | Clear	56	17	28	31	41	0.36	0.45	0.9	0.7
23	SC Low-e | Clear | Clear | TI Low-e	52	18	26	31	43	0.34	0.39	0.7	0.6

SC, solar control; TI, thermal Insulation.
(|) Symbolizes the gap between glass panes.