The next generation windows a new source of energy (reduction)

Sealants and Adhesives have been in use for thousands of years. In biblical times the Tower of Babel was reportedly built with mortar and tar or pitch as a sealant, and naturally occurring bitumen and asphalt materials have been widely accepted as sealants for many centuries. Prior to the 1900s most sealants and adhesives were derived from vegetable, animal, or mineral substances, but the rise of the polymer industry in the early 1930s led to the development of modern polymeric sealants and adhesives and revolutionised the construction and insulation of buildings.

Today sealants and adhesives are used for a wide variety of commercial and residential applications. Common sealants include silicone, acrylic, vinyl acetate, urethane, butyl and other polymeric types. Formulations have been developed over the years to meet the performance specifications established by industry standards and the particular requirements of the end user.

Thanks to modern window technology, for example, city centres that were once 'concrete jungles' now have huge expanses of glass that reflect the sky and provide a lighter environment. Structural glazing attaches glass to a building under high wind and stress loads, yet the adhesives and sealants that strengthen the structure remain largely unseen.

The use of sealants and adhesives allows for greater innovation in building design, along with increased durability of structures, the preservation of the building's environment and a reduction in material consumption for the construction of the façade and windows.

In recent years the increasing demand for energy efficiency has influenced the technical development of façades and windows. Modern market requirements have led to innovative solutions that are technically superior, more cost effective and facilitate 'greener' buildings with a low carbon footprint.

Buildings consume more than 40% of energy in Europe[1]. Windows are one of the most important factors when considering the overall energy efficiency of a building. Insulating glass units are at the heart of every façade and window. For long life and good performance, such windows and façades need specialised sealants that are both durable and compatible with all the other components with which they come into contact.

Air leakages can represent up to 50% of the energy losses in buildings. Sealants and foams play a key role in improving air tightness in those buildings by appropriately sealing gaps between windows and walls or walls and roof.

The steady progress in window profile technology has created windows with better insulation properties that reduce energy losses to a minimum. Sealants and adhesives are critical in their design – for sealing and bonding the glass in the window frame; for sealing the whole window in the building envelope; and for sealing and bonding the glass panes in the insulating windows. Only through the use of the appropriate sealants and adhesives for each application will the overall performance of the window system be dramatically improved.

The solutions provided by sealants and adhesives translate directly into higher energy efficiency. For example, argon gas can be used in insulating windows as a filling between the glass panes. It has better insulation properties than a conventional filling with air. The use of the specialised sealants keeps the loss of argon gas from the windows during the service life to a minimum and the overall energy thermal efficiency of the window is increased.

Glass can be bonded directly to the window frame using adhesives. This technology removes the need for steel reinforcements in plastic windows, producing a thinner frame design. This leads to an increased glass surface, greater energy savings, improved material efficiency and a brighter room ambience.

One of the earliest adhesive chemistries used in structural window glazing is silicone, which now has a 40-year track record of success. The silicone allows for differential thermal expansion between substrates of differing thermal expansion coefficients. Another key requirement is the long-term adhesion durability to glass under the temperature extremes and movements found on the exterior of a commercial building.

Today the world's tallest buildings use this technology, confident of the performance and durability demonstrated over past decades. An example of the remarkable advances in façade and window design can be seen in Burj Khalifa – the world's tallest building – in Dubai. At a height of 828 metres, it is constructed of giant glass façades and aluminium around a central core. The tower resists even the most unpredictable weather conditions thanks in large part to the special silicone-based adhesives and sealants.

A variety of other technologies are widely used in window glazing and weather sealing too, including polyurethane reactive adhesives, acrylics, hot melt urethanes, synthetic rubber membrane systems and, more recently, tapes. Each offers a particular set of performance characteristics and will bond glass to metal, stone, tile, ceramic, wood and composites.

Sealants remain the number one choice for glazing because they deliver high performance and long durability as well as being aesthetically preferable, if not invisible. Glazing adhesives provide insulating properties, lower labour costs, faster installation times, corrosion resistance, and are lighter in weight than old-fashioned mechanical fasteners. In terms of safety, glazing adhesives are flexible, more forgiving and absorb shock better than mechanical fixation systems.

It is this remarkable performance of adhesives and sealants that is extending the limits of architectural creativity. Sealants and adhesives allow for new building shapes such as curved glass structures, breaking conventional block construction boundaries. Most importantly, they allow architects to combine cutting-edge design with highly energy-efficient buildings.

ANNEX I

The embodied energy of sealants and adhesives used in windows are put in balance with the energy gain provided in a standard building. For the embodied energies, average values (table 1) were taken from the ICE report[2]. Energy use calculations (table 2) have been carried out using the software EFEN[3] with the following assumptions: a 30mx35m Building with 15 (1.5m x 1.2m) PVC windows per side was used. The analyses were carried out using a UK type climate, comparing the use of single glass panes, double insulated glass, bonded windows and the introduction of air leakage.

Table 1: Embodied energy of sealants/adhesives and window elements

Material	Use	Embodied energy (MJ/kg)	Amount used/ window kg	Embodied energy/window MJ	Embodied energy in building GJ
Sealant	Glazing	100	0.05	5	0.3
Sealant/ adhesive	Insulated Glass	100	0.5	50	3
Sealant	Perimeter	100	0.6	60	3.6
Adhesive	Bonding	100	0.15	15	0.9
Glass	Glass	16	20	320	19.2
Steel	Frame	25	10-20	250-500	15-30
PVC	Frame	80	5-10	400-800	24-48
PVC Window	/	1000-2000	/	1000-2000	60-120

Table 2: Energy used with different window configurations (two different climates)

Type	Type of window	U (W/m2.K)	SHG	Energy (GJ/yr)*	Energy gain (GJ/yr)
1	Single glass pane (6mm glass)	4.4	0.54	1808	/
2	Low E Ar filled insulated glass (4mm glass)	1.6	0.33	1548	260
3	Same as (2) but bonded	1.5	0.36	1541	267
4	Same as (3) with introduction of air leakage of 5.5m3/m2.h	1.5	0.36	1601	215

*Total energy: includes heating, cooling, water heating, electrical equipments

Analysis of table 1 shows that the embodied energy of sealants and adhesives corresponds to about 10% of the embodied energy of the window and provides multiple benefits.

In tables 1 and 2, we can see that 3GJ are needed to produce the sealant/adhesive used to make the insulated glass, leading to an energy gain of 260GJ/yr (type 1 vs 2). Thus the energy needed to produce the sealant/adhesive is recovered in a few days.

Less than 1 GJ (0.9GJ) was needed to produce the adhesive whilst the energy gain is 7GJ/yr. Whilst the embodied energy of the bonded window is already lower compared to the non-bonded window (type 3 vs 2), the sealant/adhesive also allows omission of the steel in the PVC frame, thereby decreasing the frame thickness and increasing the glass area. More daylight enters into the building, which improves the overall energy efficiency of the window (reduced U-value).

These calculations were carried out using a perimeter sealant. The use of a different type of sealant/adhesive would lead to higher air leakage than in the simulation (5.5m3/m2.hr). Therefore, calculations were made assuming bad sealing of the space between the window frame and the building façade. Using this assumption, we can see that the embodied energy of the perimeter sealant although higher than that of other types of sealants (3.6GJ) is much lower than the energy gain (52GJ/yr) through the correct sealing of the building (type 4 vs 3).

References

1: **EU pubblication:** http://ec.europa.eu/energy/intelligent/library/doc/ka_reports/eeproducts08_en.pdf and http://www.energy.eu/publications/saving-energy-2011.pdf

2: Hammond G., Jones C., **Inventory of Carbon and Energy** (ICE), University of Bath (2008).

3: EFEN 1.3.02 from DesignBuilder Software.

About Feica

FEICA, the **Association of the European Adhesive & Sealant Industry** is a multinational association representing the European Adhesive and Sealant Industry. With the support of 14 national associations and several company and affiliated members, FEICA coordinates, represents and advocates the common interests of our industry throughout Europe. In this regard FEICA aims at establishing a constructive dialogue with legislators in order to act as a reliable partner to resolve issues affecting the European Adhesive and Sealant Industry.

Picture 2."**Passiv House**" Image courtesy of Dow Building Solutions and Sto Ltd. Photographer: Samuel Ashfield.

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