EXPANDING LAMINATED GLASS PERFORMANCE

By Valerie L. Block, CDT, LEED AP

The capabilities of laminated glass performance have expanded thanks to the introduction of stiff, structural polymer interlayers. This means reduced overall pane thickness and weight, improved durability of exposed laminate edges in exterior applications, and better post-glass breakage performance in minimally supported glazing systems.

Laminated glass is typically made with two plies of heat-treated glass bonded together with a polyvinyl butyral (PVB) or ionoplast interlayer. The glass can be annealed, heat-strengthened, or fully tempered, depending on the application. Annealed glass is the basic product, typically made by floating molten glass over a bath of molten tin, and then slowly cooling under controlled conditions to remove residual stresses in the material. The controlled cooling process is known as 'annealing.'

There are two types of heat-treated glass: heat-strengthened and fully tempered. The former is twice as strong as annealed glass and the latter is four times as strong. The improved strength of these glass types is produced by running regular annealed glass through a furnace, heating it just above its annealing point (about 720°C [1328°F]), and then rapidly cooling it to increase its surface compression.

Standards providing useful information on the acceptable tolerances and quality of architectural glass include:
- ASTM C1036, Standard Specification for Flat Glass;
- ASTM C1048, Standard Specification for Heat-treated Flat Glass, Kind HS, Kind FT Coated and Uncoated Glass; and

Glass thickness considerations
Laminated glass thickness varies based on load requirements and application. Load resistance and deflection of the glass depend on the support conditions, which can range from traditional four-sided continuous framing to minimally supported examples, such as a railings or canopies, and glass point-supported with bolted fittings.
Laminated glass provides safety from falling glass in overhead glazing by virtue of the interlayer's ability to retain fragments after breakage. Flexible interlayers, such as PVB have been used for many years in skylight laminate applications. Stiffer interlayers are now available that not only provide glass retention after breakage, but also result in thinner, and overall lighter, laminated glass construction. For example, in 2005, ionoplast interlayers were used to reduce the thickness over PVB laminates in the design of an 18.3-m (60-ft), barrel-vaulted atrium of laminated glass at Toronto's Yorkdale Shopping Centre.

**Safer glass railings**

Building code requirements for glass railings have typically led architects to tempered or laminated glass made with heat strengthening. While load requirements are typically found in building codes, two ASTM standards are useful in the specification and testing of glass in railing systems. ASTM E2358, Standard Specification for the Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades, addresses the design and performance requirements for glass railings. ASTM E2353, Test Methods for Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades, presents test protocols to assess the static strength, impact performance, and post-breakage retention characteristics of these systems. Over the past few years, numerous occurrences of falling monolithic tempered glass from upper-storey balconies have resulted in increased awareness about the need for laminated glass. Specific incidences with Toronto, Seattle, and New York City high-rises have encouraged the replacement of traditional monolithic tempered glass with its laminated counterpart to prevent falling shards in the event of breakage.

In Toronto, the threat of falling glass prompted building officials to form an expert advisory panel to make recommendations around balconies. The panel suggested prescriptive requirements for glazing used in interior and exterior balcony guards be part of the building code. Additionally, the panel suggested glass located within 50 mm (2 in.) of the edge of the floor of the balcony railing be heat-strengthened laminated glass. The Canadian Standards Association (CSA) has assembled experts to begin developing the requirements for glass balcony railings.

As the demand for laminated glass increases, so will systems designed to incorporate the material. An example already on the market is a dry-glazed railing assembly with laminated glass installed in an aluminum-extruded base shoe serving as a guard for fall protection in structures. This system, and others like it, can be installed in both interior and exterior weather-exposed applications.

Glass railings are often specified to enhance the view—this is especially true in sports stadiums. To afford the best line of sight possible onto the playing field, supports are kept to a minimum. In some cases, the top rail is omitted and the glass is only supported on its bottom edge. In these instances, it is important to consider post-breakage glass behaviour. Stiffer interlayers are more tear-resistant
Decorative colours that have been digitally printed onto polyvinyl butyral (PVB) interlayers create a vibrant curtain wall at Toronto's Centre for Cellular and Biomolecular Research (CCBR).

Laminated glass railings made with ionoplast interlayers protect spectators and provide an unobstructed view onto the Citizens Bank Park playing field in Philadelphia, Pa.

bubbles or whitish blush along the glass edge. In more serious cases, the defects can extend throughout the laminated panel, at which point the interlayer's bonding strength may be compromised. This is called delamination and requires immediate glass replacement. The selection of sealants and grouts used with laminated glass products should be based on compatibility testing of these materials.

Transparency and security
Many commercial buildings, especially storefronts, are taking advantage of the transparency of ultra-clear glass laminates and the security interlayers bring to the overall glazing product. This type of glass has reduced iron content, making it appear highly transparent, even when laminates are constructed with multiple pieces of thick glass.

Burglar-resistant laminates use a 1.52-mm (0.06-in.) interlayer for impact resistance. Underwriters Laboratories (UL) 972, Burglary-resisting Glazing Material, contains a test method for evaluating laminates. UL 752, Bullet-resisting Equipment, provides rating levels, required ammunition, and other information related to testing bullet-resistant products. Multi-ply glass laminates, or those incorporating polycarbonate, are designed to resist bullet penetration and spall (i.e. release of small glass fragments from the back side of the laminate). A UL certification program is available for both burglarly- and bullet-resistant products, and can be a requirement in the contract documents.

Special security applications include zoo enclosures, correctional centres and jails, psychiatric facilities, and data-processing centres. Careful consideration of the threats associated with each project must be undertaken before specifying laminate construction. For instance, new mental health facilities in London and St. Thomas, Ont.,

than flexible ones, and broken minimally supported laminates are more likely to remain upright or attached to bolts. This is also important for taller glass panels installed on rooftops.

Interlayer compatibility
It is significant to note excessive exposure to moisture and using incompatible sealants and grouts can lead to edge defects and, in extreme cases, delamination of laminated glass. Edge defects may consist of a few
operated by St. Joseph's Healthcare, will incorporate impact-resistant laminated glass to elevate the overall security of the buildings.

**Energy performance**

The typical laminate interlayer filters up to 99 per cent of ultraviolet (UV) radiation below 380 nanometers. UV exposure is a major cause of fading fabrics and other interior furnishings. Therefore, the laminate interlayer can help reduce fading, while providing other valuable benefits.

Laminated glass interlayers are available in various tints that can help lower solar heat gain and control glare. Tinted and spectrally selective tinted glass, can be used in laminate construction. Low-emissivity (low-e) coatings are often specified to improve energy performance. These are microscopically thin, virtually invisible, metal or metallic oxide layers deposited on the glass. The coating reduces infrared radiation from a warm pane of glass to a cooler one, lowering the window's U-factor (i.e. heat transfer).

Low-e coatings are designed for high, moderate, or low solar gain. Requirements for U-value and solar heat gain are given in ASHRAE 90.1, Energy Standard for Buildings except Low-rise Residential Buildings, as well as in the applicable building code. These requirements vary by climate zone. Additionally, programs designed to promote sustainability—such as Canada Green Building Council (CaGBC) and U.S. Green Building Council’s (USGBC’s) Leadership in Energy and Environmental Design (LEED) rating system—encourage the use of energy-efficient glass.

In some cases, energy performance is enhanced by materials encapsulated inside the laminate interlayer. One example features an encapsulated solar film between two pieces of interlayer that decreases solar heat gain by up to 34 per cent. The film is neutral in colour with a minimal reduction of visible light.

**Decorative applications**

Digital printing on glass, interlayer, or film encapsulated between interlayers is another way of creating colour and imagery with laminated glass. The printing process allows multiple colours on a single panel and the replication of photography and designs through the use of coloured inks. Graphics encapsulated within glass are safe from any surface abrasions.

Laminated glass has always been a vehicle for decoration by encapsulating materials to create a unique appearance. Natural materials, such as leaves and feathers, have been encapsulated, as well as various fibres that provide texture to the laminate. One type of decorative encapsulation incorporates an open-weave fabric, finely woven from black polyester fibres and coated on one side with a thin layer of metal to give a highly reflective metallicized appearance.

Gold-blue and copper-bronze encapsulated dichroic films between two interlayers are now being marketed as alternatives to dichroic glass. This non-metallic, corrosion-free technology does not interfere with radio frequencies or wireless communication.

**Conclusion**

Laminated glass has been used for safety, including overhead glazing, for many years. Its use in glass railings and floors is expanding as applications continue to grow. While interlayers have traditionally bonded glass plies together and created a safety glazing material, stiff, structural interlayers now enable thinner, lighter construction and improved open-edge durability of the laminate.

Laminated glass products offer designers colour, imagery, and encapsulation options. Additionally, new solar choices expand choices in the energy area. More materials are bound to appear as demand increases in the future.

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