NATIONAL GLASS ASSOCIATION with GANA

Glass Technical Paper **FB59-18**

Heat-Treated Laminated Glass Exposed Edges

Introduction/Background

The architectural glass industry has seen a growing interest in minimally-supported glass applications, including facades, skylights, interior partitions and glass balustrades. Whether the glass is glazed top and bottom, point-supported or cantilevered, the trend is for less metal around the edges of the glass. Laminated glass is being used for its ability to provide post-breakage glass retention.

With the shift to laminated glass due to code changes (see International Building Code section), and the trend toward minimal supports resulting in exposed glass edges, questions around laminated glass edge quality and fabrication have arisen. These questions focus on alignment of the glass plies, edge polishing before and after fabrication, and interlayer appearance. Designer and customer requirements for the same high quality finished edge they can consistently receive with monolithic glass are driving the industry to develop guidelines to accommodate these evolving needs. No such guidelines currently exist.

Exposed Edge Applications

One objective of the fabricator is to produce a heat-treated (heat-strengthened or fully tempered) laminate consisting of two or more lites of glass bonded together with an interlayer material having one or more exposed edges that ultimately meets the aesthetic requirements for the intended application. Covered laminated glass edges are not visible and, therefore, not an aesthetic concern after installation. However, when the edges are exposed, the alignment of glass plies and overall appearance of the laminate edge are likely to be critical to the designer and building occupant in most applications. Note: It is also important to advise the customer that laminate edges, when viewed from the edge, have a layered appearance (glass + interlayer + glass), and will not look like a monolithic lite of glass.

According to ASTM C1048, heat-treated exposed-edge glass shall be polished prior to heat-treating. If the specification calls for monolithic tempered glass, the polished edge will not look any different after the heat-treating process. If the glass is to be heat-treated and assembled into a laminate consisting of glass and an interlayer material, alignment issues leading to aesthetic concerns may arise. Due to cutting tolerances, glass slippage during the laminating process, actual handling, and indexing of the lites in the laminate, all of the edges may not align to an acceptable condition after the laminating process. The challenge for the fabricator is to minimize mismatch (imperfect alignment) and trim the interlayer material so that the laminate edge looks aesthetically pleasing.

The industry currently has no generally accepted exposed-edge tolerances to offer as guidelines beyond what appears in ASTM C1036, C1048, and C1172. A consultation with the fabricator may enable the specifier to order heat-treated laminated glass with tighter tolerances than those provided in the ASTM C1172 standard.

Fabrication Techniques for Laminated Glass for Exposed Edge Applications that Comply with Current ASTM Standards

In order to meet customer requirements on alignment of exposed edges in a laminate, some fabricators have developed fabrication techniques to produce laminates with alignment tolerances tighter than those listed in ASTM C1172. The fabrication techniques include edging glass prior to heat treating to minimize dimensional tolerance associated with the cutting process. In addition, during the lamination process, techniques are used to ensure tighter edge alignment on multiple edges. The result of these techniques is to produce laminates with edge alignment intended to meet the customer's expectations without the need for post-fabrication processing which is known to weaken the glass. Consult the supplier to determine their capabilities.

Post-Fabrication Finishing Heat-Treated Laminated Glass for Exposed Edge Applications

Post-fabrication finishing of the edge(s), such as polishing, grinding or other techniques, may minimize or even eliminate the mismatch of the heat-treated glass lites in the laminate. This results in a smoother polished finish and the desired aesthetic result. However, post-fabrication finishing processes do not comply with the current industry standards, ASTM C1048 and C1172. Post-fabrication is likely not supported by these standards because it can weaken the glass.

NGA supports these industry standards, ASTM C1036, C1048, and C1172. Currently, none of these standards expressly permits post-fabrication finishing of the edges of heat-treated lites of laminated glass, even when undertaken to mitigate mismatched lites. ASTM C1048 and C1172 state that no "modification" of the glass should occur after heat-treating "except as recommended by the fabricator" and that "no modification shall be made that will affect its structural characteristics or integrity". Accordingly, companies considering post-fabrication work should first consult with their fabricator-suppliers and consider the issues that follow.

NGA does not endorse post fabrication finishing. The rationale for this position not to endorse post-fabrication finishing of heat-treated glass edges is generally set forth in its Glass Technical Paper, The Importance of Fabrication Prior to Heat-Treatment, FB13-07 (2018). The associations' agreement with these ASTM standards on this point stems from concerns associated with one or more of the potential effects of undertaking this post-fabrication procedure. Some of those effects are listed below:

1. Reduction in edge compression of the tempered glass lites. Note: The edge compression can be reduced, even below the listed 9,700 psi minimum edge compression per ASTM C1048, and the glass can still meet the requirements for tempered glass as long as the surface compression is 10,000 psi or more, or the glass meets ANSI Z97.1 or CPSC 16 CFR 1201.

2. Reduction in the depth of the edge compression layer and thus, in edge strength of the heat-treated (heat-strengthened or tempered) edges.

3. The effects of heat, liquid coolants, and polishing compounds from the post-fabrication finishing process- es upon interlayer material.

4. Reduction in glass strength due to the post-fabrication finishing process may not be in compliance with the strength references in the ASTM E1300 standard or specific project specifications.

International Building Code

The 2015 International Building Code (IBC) was a major impetus for change around glass railing design. Previously, both monolithic tempered, and laminated glass (with heat-strengthened and fully tempered glass plies) were acceptable for use. The 2015 IBC requires fully tempered or heat-strengthened laminated glass that meets CPSC 16 CFR 1201 Cat. II or ANSI Z97.1 Class A. impact requirements. Monolithic tempered glass meeting Cat. II or Class A is allowed only where there is no walkway under the glass, or if the walking surface is permanently protected from the risk of falling glass. For all glass types, the minimum nominal thickness shall be ¼" (6.4 mm).

The 2015 IBC does not allow glass balusters without an attached handrail or guard. However, there is **one exception**: A top rail is not required when: (a) the glass balustrades are laminated glass with two or more plies of glass of the same thickness and type, (b) the panels are designed to withstand the loads specified in IBC 1607.8 (Loads on handrails, guards, etc.) using a design factor of four, and (c) the installation is specifically approved by the building official (*authority having jurisdiction -AHJ*).

The 2018 IBC makes a number of changes to the code provisions governing glass balusters. While the code still requires guards with structural glass baluster panels to be installed with an attached top rail, the exception to that rule no longer requires specific approval by the building official. However, it requires that panels without an attached top rail be tested to remain in place as a barrier following impact or glass breakage in accordance with ASTM E2353-14 - *Standard Test Methods for Performance of Glazing in Permanent Railing Systems, Guards, and Balustrades.* All of the other requirements of Section 2407 still apply, including the requirement that they be designed to withstand the loads specified in IBC 1607.8 using a factor of safety of four.

ASTM International Standards

Three ASTM standards, ASTM C1036, ASTM C1048 and ASTM C1172, offer guidance on laminates made with heat-strengthened or tempered glass.

ASTM C1036, *Standard Specification for Flat Glass,* provides the cut size tolerance for each ply of glass in the laminated construction. ASTM C1036 Table 4, Dimensional Tolerances for Rectangular Shapes of Type 1-Transparent Flat glass, provides the length/width and out of square tolerances based on the glass thickness. For example, based on Table 4, the length/width cut tolerance of any lite of glass with a nominal thickness of 1/4 (6 mm) or less is ± 1/16" (1.6 mm), and the out of square tolerance (difference between the 2 diagonal dimensions) is 5/64" (2 mm).

ASTM C1048, *Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass,* provides guidance that fabrication techniques that alter the glass surface, thickness or edge shall be performed prior to heat treating to avoid a reduction in glass strength.

ASTM C1172, *Standard Specification for Laminated Architectural Flat Glass,* provides a similar statement about fabrication techniques needing to be done prior to heat-treating. There is an additional statement, "After the glass has been strengthened or tempered, it shall not be modified except as recommended by the fabricator." While this last statement may appear to open the door for post-processing of heat-treated glass, it was likely intended to allow only minor alterations, such as coating edge deletion or logo application, of the lite for processes as discussed in the ASTM C1048 section above.

In addition, Table 3 in ASTM C1172 presents size tolerances, including mismatch (imperfect alignment), for laminates made with heat-treated glass. That information is shown in the following chart along with the three footnotes included with that table.

Laminate Thickness Designation, *t* in. (mm)	Heat-Strengthened and Tempered Glass Size Tolerance including Mismatch in. (mm)
t < ¼ (*t* < 6.4)	+7/32, - 3/32 (+5.6, -2.4)
¼ < *t* < ½ (6.4 < *t* < 12.7)	+1/4, -1/8 (+6.4, -3.2)
½ < t < 1 (12.7 < t < 25.4)	+5/16, -1/8 (+7.9, -3.2)

Footnotes

A: *For other than 2-ply laminated glass, or laminates larger than 75 ft2, contact the laminator for size tolerances.*

B: *Size includes cutting and fabrication tolerances as well as mismatch.*

C: *For exposed edge applications, consult the supplier to determine their capabilities.*

While this table is intended to limit the length and width dimensions of laminated glass, including mismatch between glass plies, it could be interpreted to mean that the maximum mismatch for laminates ¼", ½" and 1" thick could be 7/32", ¼", and 5/16", respectively. These large mismatch values may not be acceptable to the customer or designer in exposed edge applications. That is why, in addition to footnote C, ASTM C1172 states in section 8.5.3: "For some laminated applications, such as, point supported glass and balustrades, where the edges of the laminate are exposed, tighter length and width tolerances may be requested by the customer. Consult the supplier to determine their capabilities."

Summary

Laminated glass is being required by the building codes in more applications because of its post-breakage (glass retention) properties. The exposed edges of heat-treated laminated glass will have a different appearance than that of monolithic glass. Until the industry establishes acceptance guidelines or criteria (mismatch tolerances, interlayer appearance, etc.) for heat-treated laminated glass used in exposed edge applications, the glazing contractor and glass specifier should continue to discuss the project needs with the glass fabricator on a case by case basis. They should first consult with their fabricator-suppliers to discuss the best methods to meet exposed glass edge aesthetic requirements. NGA supports the applicable ASTM industry standards for heat-treated and laminated glass and do not endorse any post fabrication finishing of heat-treated glass edges.