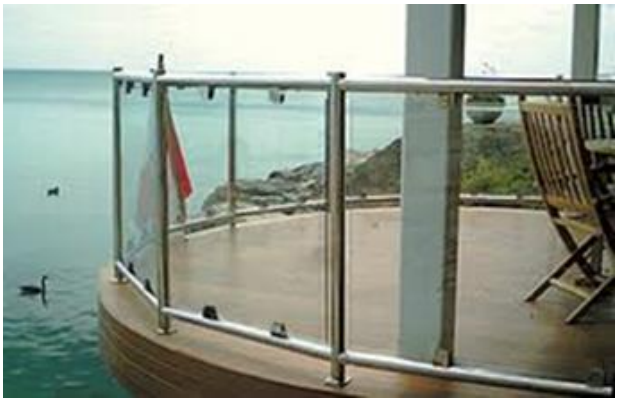
NATIONAL GLASS ASSOCIATION with GANA

Glass Technical Paper **FB33-11 (2023)**

Glass Use in Guardrails



Introduction

Glass railing systems are used in a variety of residential and commercial settings for safety, unobstructed views and the beauty glass adds to a structure. The 2021 International Building Code (IBC) makes specific reference to glass railings in Section 2407 of the code and refers to them as "guards". The code requires the use of fully tempered or heat strengthened laminated glass that complies with Cat. II of CPSC 16 CFR 1201 or Class B of ANSI Z97.1 with very few exceptions.

Fully tempered, laminated glass is the ideal glazing material for these applications and offers a variety of design options. The fully tempered glass is strong, and the interlayer can be clear, tinted, or custom printed. The glass can be clear, tinted or decorative; flat or curved; fully supported on 1, 2, 3, or 4 edges; or minimally supported with bolts and/or clamps. Laminated glass offers a benefit over monolithic fully tempered or heat-strengthened glass when used in railings; if breakage occurs, glass particles tend to adhere to the laminate interlayer increasing the likelihood of glass retention in the system.

Interior glass "guards" create an open feeling on the inside of a large space and enhance visibility and daylighting. These guard systems may be used in spaces such as, but not limited to, shopping centers, hotels, office buildings, restaurants, and hospitals. These glass guard systems can also be installed in exterior applications, such as balconies in apartments, hotels, and condominiums. Laminating the glass provides improved resistance to glass fallout in the event of breakage. If the laminate edges are not covered, additional consideration should be given to the interlayer type and glazing system design. Consult with laminated glass suppliers for additional information on interlayer type for specific applications.

Laminated glass guard systems provide a clear barrier in many sports venues around the world. While a handrail or top rail may still be required by code, in many instances they may be eliminated to afford spectators an unobstructed view onto the playing field so long as the installation complies with IBC Section 2407.1.2. This is discussed in further detail in the Building Code Requirements section below with regards to code adherence.

Definitions

Handrail: According to the 2021 IBC, a horizontal or sloping rail intended for grasping by the hand for guidance or support.

Guardrail system: According to ASTM E1481 *Standard Terminology of Railing Systems and Rails for Buildings* Section 3.1, a railing system, providing protection for building users against accidental fall and injury, located at or near the outer edge of a stair, ramp, landing, platform, deck, balcony, hatchway, manhole, floor opening, porch, or accessible roof; at the perimeter of an opening or accessible surface, such as the opening of a stair; or at a location at which an operating condition requires access limitation to a designated area.

Guard: According to the 2021 IBC, a building component or system of building components located at or near the open sides of elevated walking surfaces that minimizes the possibility of a fall from the walking surface to a lower level.

Baluster: a vertical support piece, such as a lite of glass. The code requires baluster installations to include a top rail which must be attached to at least three glass balusters (unless the laminated baluster has been tested to remain in place as a barrier after impact or breakage according to ASTM E2353).

Balustrade: a railing supported by balusters.

Infill Panel: a non-load-bearing material, such as a lite of glass, that occupies the space between supporting structural members of the system. The code does not require a top (or cap) rail on the glass when used as an infill panel.

Glass Selection

ASTM C1172 *Standard Specification for Laminated Architectural Flat Glass* is the industry specification for laminated glass. ASTM C1048 *Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass* is the industry specification for heat-strengthened and tempered glass. ASTM C1048 also contains vital information about the fabrication of holes and/or notches.

Additionally, two ASTM standards and one Canadian Standards Association (CSA) standard address testing, specification, and design of glass railings. These are:

- ASTM E2353 *Standard Test Methods for Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades*
- ASTM E2358 *Standard Specification for the Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades*
- *CSA A500 Guard Standard*

Building Code Requirements

The 2021 International Building Code (IBC) makes specific reference to glass guards in Section 2407 of the code. The code requires the use of laminated glass with very few exceptions.

The main points of section 2407 of the 2021 IBC are:

1. Glass Types: Laminated glass must be used in handrails, and guards. Glass types must be fully tempered laminated or heat-strengthened laminated (except where there is no walkway beneath them or the walking surface is permanently protected from the risk of falling glass).

2. Safety Glazing: The laminated glass must comply with CPSC 16 CFR 1201 Cat II or ANSI Z97.1-2015 Class A and be permanently marked as safety glazing.

3. Glass Thickness: Minimum nominal glass thickness must be 1/4 inch (6.4 mm), but most glass infill is supplied at higher thicknesses due to load requirements.

    a Exception for Single Fully Tempered Glass: Single fully tempered glass at least ¼ inch thick that meets safety glazing requirements of CPSC 16 CFR 1201 Cat II or ANSI Z97.1-2015 Class A is permitted where there is no walking surface beneath the system or where the walking surface is permanently protected from the risk of falling glass.

4. Top Rail (Handrail): The code requires an attached top rail (or handrail) for guards with glass balusters. The top rail must be attached to at least three glass balusters, unless is otherwise supported to remain in place, such as a connection to a wall that has been designed to resist the loads specified, should one baluster fail. The requirement for a top rail in baluster installations includes one exception: if the laminated baluster is constructed of two or more glass lites of equal thickness and glass type and has been tested to remain in place as a barrier after impact or breakage according to ASTM E2353.

5. Loads: Glass guards must be designed to meet two separate load requirements as specified by the code: a linear load of 50 pounds per linear foot and a concentrated load of 200 pounds. In addition, glass used in guards must be designed using a factor of safety of four.* The safety factor of four applies only to the glass; not to the non-glass materials in the guard system such as metal structural posts or rails.

6. High Windload: In windborne debris regions, exterior infill glass and glass balusters must be laminated and comply with safety glazing standards. The entire assembly is required to be tested for impact from windborne debris, as required in the code for glazing in hurricane-prone regions. If the glass is supporting a top rail, the top rail must stay in place after impact testing.

7. Deflection Limits: When designing and installing glass guards, consider allowable deflection limits of the glass panels. The IBC limits the deflection of the unsupported edges of two adjacent panels of interior glazing that are installed near a walking surface. The deflection is limited to the thickness of the glass when a horizontal load of 50 pounds per linear foot is applied (to one panel and not the adjacent panel) at any point up to 42 inches from the floor. The purpose of this requirement is to eliminate the possibility of a person's fingers being trapped between adjacent panels of glass if a load, such as a person leaning on the glass, is applied to one panel and not the adjacent panel.

8. Parking Garages: Glazing materials may not be installed as handrails or guards in parking garages except in pedestrian-only areas not exposed to potential impact from vehicles.

**The design factor is used to reduce a material's limiting stress to an allowable stress in design. Compliance with this safety factor can be determined by dividing the traditional glass strength values by four. Traditional glass strength values can be found in NGA Glass Technical Paper FM05-12 Physical and Mechanical Properties of Typical Soda Lime Float Glass.*

The 2015 IBC represented a major change in the use of glass in railing systems. Prior to the 2015 code, the designer could use either monolithic tempered or laminated glass in most railing applications. As states adopted the 2015 and later versions of IBC, the use of monolithic tempered glass was restricted, and is replaced by a laminated heat-strengthened or laminated tempered glass alternative.

In remodeling projects, designers and specifier are advised that all or parts of the structure may have to be brought up to the requirements of current code. They should also consider the risks associated with glass breakage and specify laminated glass to conform to current code requirements and best industry practices.

Glass Railing Performance Standards

Glass railing system testing is done according to ASTM E2353 *Standard Test Methods for Performance of Glass in Permanent Glass Railing Systems, Guards & Balustrades*. The standard evaluates static strength, impact resistance, and post-break retention. Railing systems are specified according to ASTM E2358 *Standard Specification for the Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades*. These systems include glazing infill, as well as structural glass railing types. The four levels of performance are shown in Table 1. Post-impact classifications per ASTM E2358 are shown below.

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TABLE 1 Performance Requirements

Type (refer to Figs. 3-8)	Structural Performance[A]	Shot Bag Impact Performance[B]	Pendulum Impact Performance[C]	Performance Level Indicator
I – III	Concentrated Load on Rail: 890 N (200 lbf) Uniform Linear Load on Rail: 290 N/m (20 lbf/ft) Infill Horizontal Load: 220 N (50 lbf)[D]	Pass 203 J 150 ft · lb	Not Required	Level 1 (Type L1)
I – IV	Concentrated Load: 890 N (200 lbf) Uniform Load: 730 N/m (50 lbf/ft) Infill Horizontal Load: 220 N (50 lbf)[D]	Pass 542 J 400 ft · lb	Not Required	Level 2 (Type L2)
I – V	Concentrated Load: 1330 N (300 lbf) Uniform Load: 730 N/m (50 lbf/ft) Infill Horizontal Load: 220 N (50 lbf)[D]	Pass 542 J 400 ft · lb	Pass	Level 3 (Type L3)
I – VI	Concentrated Load: 1620 N (365 lbf) Uniform Load: 880 N/m (60 lbf/ft) Infill Horizontal Load: 220 N (50 lbf)[D]	Pass 678 J 500 ft · lb	Pass	Level 4 (Type L4)

[A] Tests performed as outlined in Test Methods E935.
[B] Tests performed as described in ANSI Z97.1 and 13.3 of Test Methods E2353.
[C] Tests performed as described in Test Method E2025 and 13.4 of Test Methods E2353.
[D] Horizontal load applied to glazing infill (Test Method C of Test Methods E935) shall be distributed evenly over a 306 × 306 mm 93.636 mm^2 (12 × 12 in. 144 $in.^2$) area located at the most critical point of the glazing.

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Post-impact classifications of laminated glass railings from ASTM E2353-16 are shown below. A post-impact classification of 1 or 2 must be met to prevent falling glass as well as to increase protection of building occupants above ground level from falling through an unprotected opening.

Post-Impact Classification

1. Glazing unbroken
2. Glazing broken and retained with no opening large enough to pass a 3-inch solid sphere

3. Glazing broken and shards contained. Glazing shards separated from system not greater than 10 square inches of equivalent weight of original system specimen.
4. Glazing broken and shards not contained. Glazing shards separated from system are greater than 10 square inches of equivalent weight of original system specimen.

Laminated Glass Quality

Unlike monolithic tempered glass, edge quality with laminated glass must be clearly specified to the glass fabricator. Issues such as edge misalignment and protruding interlayer may impact the aesthetics and safety of the glass edge.

ASTM C1172 Section 8.5.1 shows standard tolerances for laminated glass including misalignment. Tighter tolerances may be required for exposed edge applications. This concern is addressed in Section 8.5.3 where it states, "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."

Glazing System Considerations

When a system is wet glazed, it is important to verify compatibility of the caulk, grout, blocks, and sealant used in contact with the laminate interlayer. This is especially important in exterior applications where moisture and expansion rates can impact the system. Traditional methods of setting monolithic glass in railings such as cement-based grouts may be incompatible with laminated glass. Polyurethane or epoxy type sealants may be suitable alternatives. Dry-glaze methods have shown to be compatible with laminated glass systems. Bolted or clamped systems must be designed and installed properly to avoid over-stressing the glass around the points of contact. Consult with the fabricator and component suppliers (i.e. interlayer manufacturers, sealant suppliers, etc.) for questions surrounding compatibility.

Additional Resources

For more information on laminated glass, refer to the NGA Laminated Glazing Reference Manual, available at glass.org/store.

Visit www.glass.org/store for a complete list of Glass Technical Papers, as well as other glass building products and glazing industry reference materials.

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