The Code Corner

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Glass and Glazing

2012 International Building Code

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According to the *Glass Manual*, published by the Glass Association of North America (GANA), glass has been around for more than 4,000 years. Glass allows daylight in and allows building occupants to view the outside world while still maintaining an envelope to separate inside from outside. However, the use of glass in buildings presents issues that must be addressed, such as energy efficiency, fire protection, and life safety. The *International Building Code* (IBC) covers all three of these areas.

The IBC establishes energy efficiency requirements through its reference to the *International Energy Conservation Code* (IECC) in Chapter 13. For fire protection, Chapter 7 covers requirements for glazed openings in exterior walls and interior partitions. Openings are discussed in detail in *The Code Corner* article Nos. 34 and 35, "Openings" Parts 1 and 2. For this article, only the third area, life safety, will be discussed, which is covered in Chapter 24. For glazing in elevator cars and hoistways, see *The Code Corner* No. 38, "Elevators."

The terms *glass* and *glazing* have similar meanings and are frequently used interchangeably, but they do describe different things. *Glass* is the material itself, whereas *glazing*, the noun, refers to any material used as an infill panel, whether it is glass, plastic, or some other material, which is installed in an opening. *Glazing*, the verb, is defined by GANA as the "process of installing an infill material into a prepared opening in windows, door panels, partitions, etc."

The life safety aspect of glass and glazing can be separated into two areas: structural loads and impact loads. Although an impact load is a form of structural load, it is distinguished as a separate category due to its unique application requirements in the IBC. There are two types of impact loads addressed by the IBC: human impact loads and wind-borne debris impact loads. In the IBC, structural loads are used to determine glass thickness. For glazing sloped more than 15 degrees from vertical, the structural loads consist of wind, snow, seismic, and dead loads. For vertical glazing of 15 degrees or less from vertical, the only structural loads considered are the wind and seismic loads. Because the determination of glass thickness is a complex process, it should be accomplished by a registered structural engineer; therefore, this article will only address the basic concepts of glass structural design.

Glass is required to be provided with a manufacturer's mark indicating glass type and thickness. The marking may be omitted if approved by the building official and an affidavit from the glazing contractor is provided indicating that the glass conforms to the construction documents and the requirements of the IBC. Tempered glass[1] must be permanently marked (*e.g.* acid or laser etched, sandblasted, ceramic fired, or embossed), except that tempered spandrel[2] glass, which may be provided with removable paper labels.

The IBC references ASTM E 1300, *Standard Practice for Determining Load Resistance of Glass in Buildings*. This standard uses wind with a duration of 3 seconds as the basis of determining the maximum load resistance of glass. Factors affecting load resistance of glass include the dimensions of the lite, the thickness of the glass, and the number of supported glass edges. This load resistance must equal or exceed the calculated wind load determined per Section 1609 of the IBC.

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[1] *Tempered glass* is defined by GANA as "Flat or bent glass that has been heat-treated to a high surface and/or edge compression to meet the requirements of ASTM C 1048, Kind FT." "FT" means "fully tempered."

[2] *Spandrel* is defined by GANA as "panel(s) of a wall located between vision areas of windows, which conceal structural columns, floors and shear walls."

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Section 2403.2 states that if any edge of a glass pane is unsupported, or if the loads on the glass are unusual, then detailed drawings and analysis or test data are required. A firmly supported edge is one where the framing member prevents the edge from deflecting more than 1/175 of the glass edge or ¾ inch, whichever is less. As mentioned earlier, one of the factors affecting the load resistance of glass is the number of supported edges. ASTM E 1300 provides load charts for glass supported on four sides to one side, which would contribute to the analysis. Butt-glazed joints would be considered as unsupported edges.

While on the subject of butt-glazed units, Section 2403.4 addresses adjacent unsupported glass edges that are near an interior walking surface. The provision requires that if a 50 plf load is applied to any point along one of the edges to a maximum height of 42 inches, the deflection cannot be greater than the thickness of the glass panel (See Figure 1). This eliminates the possibility of someone leaning against one panel, causing it to deflect, and allowing someone to place fingers or other objects within the gap created.

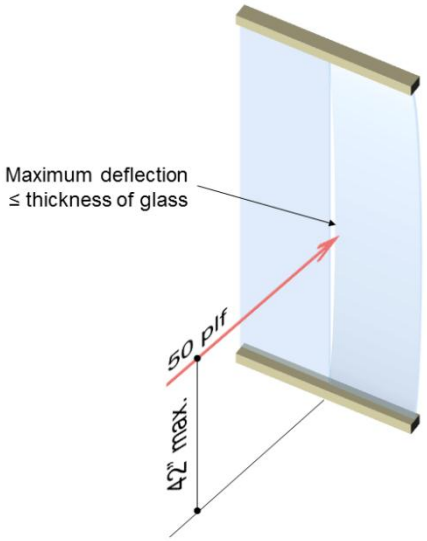

Figure 1 – Deflection of interior butt-glazed panels.

Wind-Borne Debris Resistance

Impact loads created by wind-borne debris are only applicable to structures constructed within *wind-borne debris regions*. Chapter 2 defines wind-borne debris regions as areas within 1 mile of a coastal high water line where the ultimate design wind speed is 130 mph or greater, areas where the ultimate design wind speed is 140 mph or greater, or Hawaii. Design wind speeds are determined per Figures 1609A and 1609B, depending on the risk category of the structure per Table 1604.5. Essentially, most glazing in structures along the Gulf and Atlantic coasts are subject to requirements for wind-borne debris impact.

To qualify for debris impact resistance, glazing must either be impact resistant or include a permanent impact-resistant covering that can protect the glazed opening. The standards to test for impact resistance are ASTM E 1886, *Test Method for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Storm Shutters Impacted by Missiles and Exposed to Cyclic Pressure Differentials*, and ASTM E 1996, *Specification for Performance of Exterior Windows, Glazed Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*. If a glazed opening is within 30 feet of the grade, then the glazing must pass the large-missile test of ASTM E 1996. If the glazed opening is greater than 30 feet above the grade, then the glazing need only pass the small-missile test of ASTM E 1996. The IBC has some exceptions to these requirements, and also provides some substitutions that modify the application of ASTM E 1996.[3]

Human Impact Resistance

Glazing required to resist human impact needs to comply with the provisions of Section 2406, which requires testing in accordance with Consumer Product Safety Commission (CPSC) 16 Code of Federal Regulations (CFR) Part 1201, *Safety Standard for Architectural Glazing Material*. Glazing not located in

[3] For more information about wind-borne debris-resistant design, see "Glazing Design Beyond the Minimum" in the May 2012 issue of *The Construction Specifier*.

doors or in wet areas, such as hot tubs, bathtubs, showers, and saunas, may comply with ANSI Z97.1, *Safety Glazing Materials Used in Buildings—Safety Performance Specifications and Methods of Test*. Both the Federal and ANSI standards use similar impact test stands (See Figure 2).

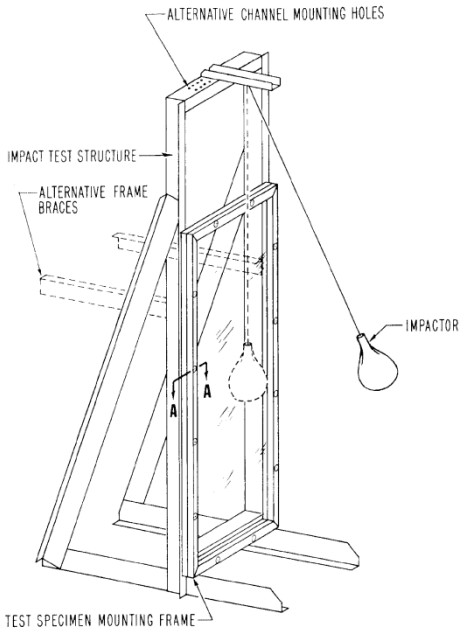

Figure 2 – Impact test stand per CPSC 16 CFR Part 1201.

The basic test involves raising the impactor—a punching bag filled with lead shot weighing 100 pounds. To qualify as safety glazing, the test specimen must not, at a minimum, develop a hole in which a 4-pound 3-inch solid steel sphere could pass. After the test, the specimen is rotated to the horizontal position and the sphere is placed in the opening. If after one second the sphere has not dropped through, the specimen is deemed to have met the impact criteria. Glass with a Category I rating (Class B per ANSI Z97.1) has passed the test when the impactor is raised 18 inches (measured vertically) above the impactor's position at rest. A Category II rating (Class A per ANSI Z97.1) is given to glass when the impactor is dropped from a height of 48 inches.

At a minimum, all safety glass must comply with the criteria for Category II; however, Category I glass is permitted when the exposed surface area of a single pane is 9 sq. ft. or less, except for glazing around wet areas per Section 2406.4.5. Glazing is permitted to be tested by ANSI Z97.1, but must comply with Class A, unless otherwise indicated in Table 2406.2(2) to be Class B. All safety glazing must be identified by a permanent marking that indicates the manufacturer and the safety standard with which it complies, plus the information previously mentioned.

The IBC identifies seven specific hazardous locations where safety glazing is required:

1. *Glazing in Doors*: Section 2406.4.1 requires that all glass in swinging, sliding, and folding doors, whether the glass is operable or fixed, must be safety glass (See Figure 3). Safety glazing is not required if the glazed opening does not permit the passage of a 3-inch-diameter sphere. Additionally, decorative glass[4], curved glass panels in revolving doors, and glass in commercial refrigerated cabinets are also exempt from the safety glazing requirement.

2. *Glazing Adjacent to Doors*: Section 2406.4.2 requires all glazing, fixed or operable, that is within a 24-inch radius of the vertical edges of the door (hinge and latch edges) in a closed position with a bottom exposed edge of glass that is less than 60 inches above the walking surface be safety glazing (See Figure 3). Exceptions include decorative glass,

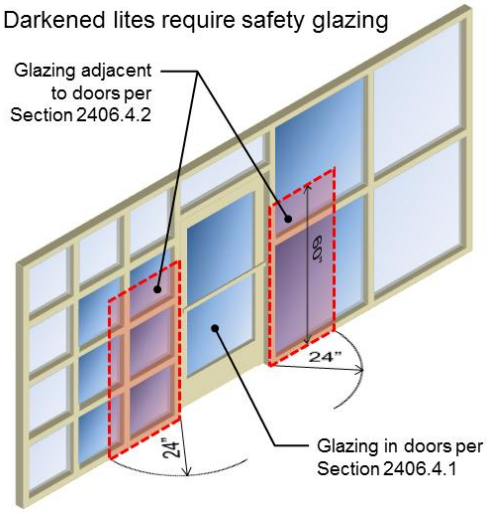

Figure 3 - Safety glazing in doors and adjacent to doors.

[4] *Decorative glass* is defined in the IBC as a "carved, leaded or Dalle glass or glazing material whose purpose is decorative or artistic, not functional; whose coloring, texture or other design qualities or components cannot be removed without destroying the glazing material and whose surface, or assembly into which it is incorporated, is divided into segments." *Dalle glass* is made up of glass pieces "embedded in a cast matrix of concrete or epoxy."

where an intervening wall or permanent barrier is between the door and glazing (See Figure 4), where access through the door is to a closet 3 feet or less in depth, or in walls on the latch side and perpendicular to the door in one- and two-family dwellings and R-2 dwelling units.

3. *Glazing in Windows*: Section 2406.4.3 requires glazing in windows, whether fixed or operable, to be safety glass when all of the following conditions exist:

- The exposed area of glass in a single pane is greater than 9 sq. ft.
- The bottom edge of the glass is less than 18 inches above the floor.
- The top edge of the glass is greater than 36 inches above the floor.
- A walking surface is located within 36 inches of the glass measured perpendicular to the glass surface.

One exception to the requirements is decorative glass. Another exception is when a horizontal rail is installed across the glass at a height of 34 to 38 inches. The horizontal rail must withstand a horizontal load of 50 plf without contacting the glass and must be a minimum of 1½ inches in height (See Figure 5). The last exception applies to insulating glass installed 25 feet above a walking surface, roof, grade, or other surface with a slope within 45 degrees of horizontal. With this exception, the outboard pane is not required to be safety glass.

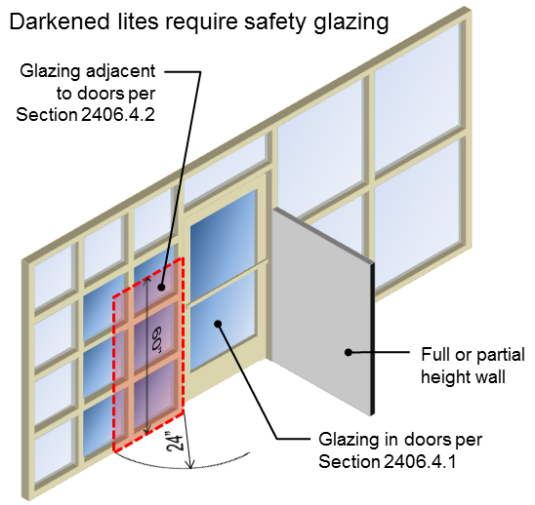

Figure 4 - Exception to requirement for safety glass when partition is between door and adjacent glass.

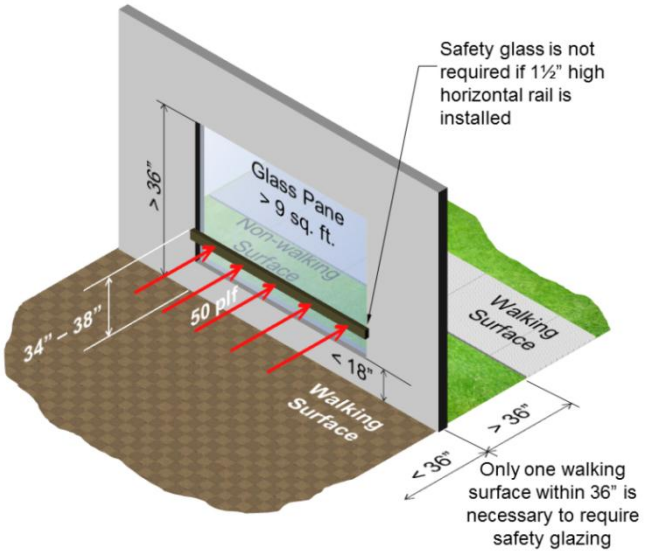

Figure 5 - Glazing in windows adjacent to walking surfaces with Exception 2 shown.

4. *Glazing in Guards and Railings*: Section 2406.4.4 requires safety glass when glass is used as structural balusters or as infill panels within a railing system of a different material. The requirement is applicable regardless of height above a walking surface. Section 2407 has specific provisions for glass in guards and railings, which require tempered glass or laminated glass fabricated with either tempered or heat-strengthened[5] glass. Glass balusters must have an attached handrail or guard, unless the baluster is constructed of laminated glass of equal type and thickness, can withstand the loads for handrails and guards per Section 1607.8, and is approved by the building official. Handrails and guards are required to be supported by a minimum of three glass panels, unless they are designed to be supported by other means.

[5] *Heat-strengthened glass* (Kind HS, per ASTM C 1048) is heat-treated glass similar to fully tempered, but at a compressive strength that is much lower than fully tempered. Heat-strengthened glass is about two times stronger than annealed glass, but is not considered safety glass per CPSC 16 CFR Part 1201 or ANSI Z97.1. Annealed glass is float glass that has been through a controlled cooling process.

5. *Glazing in Wet Areas*: Section 2406.4.5 requires safety glass (for single pane and all panes of multi-glazed units) installed as fences, enclosures, or walls near swimming pools, hot tubs, spas, whirlpools, saunas, steam rooms, bathtubs, and showers when the bottom edge of the glass is within 60 inches vertically above any standing or walking surface. The exception to this is that safety glass is not required if the glass is located more than 60 inches from the edge of the water when measured horizontally from the face of the glass (See Figure 6).

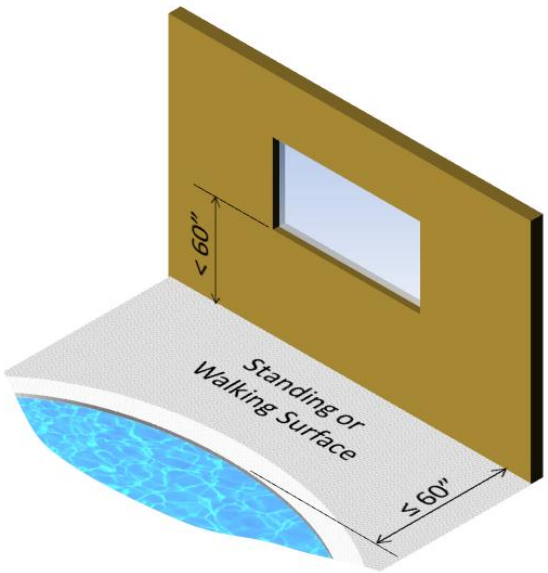

Figure 6 – Criteria for safety glazing adjacent to wet areas.

6. *Glazing Adjacent to Stairs and Ramps*: Section 2406.4.6 requires safety glass when the bottom edge of the glass is less than 60 inches above the plane of the walking surface of stairs, landings between flights of stairs, and ramps. Safety glass is not required if the stairway, landing, or ramp has a guard between the walking surface and the glass, and the glass is more than 18 inches horizontally from the guard. The guard must comply with Section 1013 and shall withstand the loads per Section 1607.8. Another exception to the safety glass requirement is if the glass is 36 inches or more, measured horizontally, from the walking surface.

7. *Glazing Adjacent to the Bottom Stair Landing*: Section 2406.4.7 requires safety glass at the bottom stair landing when the bottom edge of the glass is less than 36 inches above the landing and within 60 inches of the last tread measured horizontally. The only exception is one similar to that for stairs and ramps, when the glass is protected by a guard complying with Sections 1013 and 1607.8 and the glass is more than 18 inches from the guard.

Sloped Glazing and Skylights

Skylights and sloped glazing, because of their typical condition of being installed over occupied spaces, are subject to special limitations to protect occupants from falling glass. Glazing is considered sloped when the angle at which it is installed is more than 15 degrees from vertical.

The types of glass permitted in skylights and sloped glazing include laminated glass with a 30-mil interlayer (polyvinyl butyral or equivalent), wired glass, light-transmitting plastics per Section 2607, heat-strengthened glass, or fully tempered glass. If the glazing system consists of multiple layers, then each layer can be of any allowed material.

If heat-strengthened and fully tempered glass is used monolithically (*i.e.* not part of a multi-glazed unit) or as the bottom layer of a multi-glazed unit, then screens must be installed within 4 inches directly below the glass to catch the fragments should the glass break. Section 2405.3 provides specific criteria for the screening. Screening is not required as permitted by several exceptions:

- Fully tempered glass is permitted without screening if the glass is located between intervening floors and is sloped 30 degrees or less from vertical. Additionally, the highest point of the glazing must be 10 feet or less above the walking surface.
- Screening is not required for, and annealed glass is permitted in, glazing where the walking surface is permanently protected from falling glass, or the area below the glass is not a walking surface.

- Screening is not required for, and annealed glass is permitted in, sloped glazing of commercial or detached noncombustible greenhouses used only for growing plants and which is not open to the public. The height of the greenhouse ridge is limited to 30 feet.
- Fully tempered glass is permitted without screen in Groups R-2, R-3, and R-4, provided no pane is larger than 16 sq. ft., the highest point is no more than 12 feet above a walking surface or other accessible area, and the glass is 3/16 inch or less in thickness.
- Laminated glass with 15-mil interlayer (polyvinyl butyral or equivalent) is permitted without screening if used within dwelling units in Groups R-2, R-3, and R-4, provided no pane is larger than 16 sq. ft. and the highest point is no more than 12 feet above a walking surface or other accessible area.

Framing of sloped glazing and skylights in Type I and II construction must be noncombustible. The IBC does permit the use of pressure-treated wood or other materials, when approved by the building official, if the environment within the building has a corrosive effect on metal framing. The framing system must be capable of supporting the design loads required by Chapter 16. Skylights must be set on a 4-inch curb if the slope of the skylight unit is at an angle of 45 degrees or less from the horizontal. A curb is not required for Group R-3 if the slope of the roof is a minimum of 14 degrees (3:12 slope).

Glazing in Athletic Facilities

Due to the higher potential for impact against glass in athletic facilities, the IBC has established requirements specific to those uses. In racquetball and squash courts, glass shall be tested per CPSC 16 CFR Part 1201 or ANSI Z97.1 at a drop height of 48 inches. However, the test method is modified to test an actual installation or an identical assembly, with all the required fixtures and fittings, and the impact point is located at a height of 59 inches above the playing surface. To pass the test, the glass must remain intact following the impact, and the deflection at the point of impact cannot exceed 1½ inches. In gymnasiums and basketball courts, the glazing must comply with CPSC 16 CFR Part 1201, Category II, or ANSI Z97.1, Class A.

What Happened to Wired Glass?

Not mentioned directly in the IBC, but addressed via compliance with current safety glazing standards, is the absence of traditional wired glass as safety glass. For decades, wired glass was exempt from the impact requirements of CPSC 16 CFR Part 1201 if used in areas where fire-resistance and safety glass was required. With the introduction of specialty fire-resistive glass that can comply with safety glazing standards, the federal standard and the IBC have removed the exceptions, and traditional wired glass is no longer permitted in areas where safety glass is required.[6] Contrary to popular belief, traditional wired glass is not gone—it has always been permitted where annealed glass is allowed and in fire windows where safety glazing is not required. However, wired glass that does comply with safety glass standards is now available, which typically includes an added film to improve its performance.

The use of glass in building construction will continue to grow as the benefits of daylighting are realized and integrated into building design. Further, glass technology continues to improve allowing greater expanses of glazing with greater energy efficiency. Glass is also being used in more creative applications, generating specialized areas in structural glazing systems. Not addressed by the building code, but applicable based on circumstances, is the availability of security glass. Although safety glass minimizes potential injury from accidental impact, it is not intended to prevent unwanted entry, stop the

[6] See *The Code Corner* No. 5, "How You Can Change a Building Code," for more information on the elimination of the wired glass exemption.

passage of a projectile fired from a weapon, or withstand the pressures created by an explosion. Glass used in these applications is subject to additional testing based on standards that require a minimum performance that far exceeds those for safety glass. Regardless of the varieties of glass types and performance levels that are available in the construction market, the basic requirement for safety still applies.

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