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Standard Practice for Design and Performance of Supported Laminated Glass Walkways¹

This standard is issued under the fixed designation E2751/E2751M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice addresses elements related to load-bearing glass walkways, glass treads, and glass landings constructed with laminated glass. This standard includes performance, design, and safe behavior considerations. It addresses the characteristics unique to glass and laminated glass. Issues that are common to all walkways, such as slip resistance, are addressed in existing referenced standards.

1.2 This practice does not address glass walkways constructed with monolithic glass, glass block, insulating glass units, glass tiles that are directly bonded to a non-glass structural substrate, or glass walkways intended to support vehicular traffic.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

¹ This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.56 on Performance of Railing Systems and Glass for Floors and Stairs.

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2. Referenced Documents

2.1 *ASTM Standards:*²

C1036 Specification for Flat Glass

C1048 Specification for Heat-Strengthened and Fully Tempered Flat Glass

C1172 Specification for Laminated Architectural Flat Glass

E631 Terminology of Building Constructions

E1300 Practice for Determining Load Resistance of Glass in Buildings

F1637 Practice for Safe Walking Surfaces

F2508 Practice for Validation, Calibration, and Certification of Walkway Tribometers Using Reference Surfaces

2.2 *ANSI Standard:*³

A137.1 American National Standard Specification for Ceramic Tile

3. Terminology

3.1 *Definitions*—For definitions of general terms related to building construction used in this practice, refer to Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *duration of load*—the period of continuous application of a given load, or the aggregate of periods of intermittent applications of the same load.

3.2.1.1 *Discussion*—Any load duration longer than one hour shall be considered a permanent load. Uniformly distributed live loads shall have a load duration of at least one hour. Concentrated live loads shall have a load duration of at least ten minutes.

3.2.2 *ethylene vinyl acetate (EVA) interlayer*—co-polymer of ethylene and vinyl acetate used to permanently bond two or more lites of glass.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

3.2.3 *glass-clad polycarbonate laminate*—assembly consisting of two or more lites of glass and one or more sheets of polycarbonate bonded by interlayers.

3.2.4 *ionomer interlayer*—a partially neutralized copolymer of ethylene and acrylic or methacrylic acid, used to permanently bond two or more lites of glass.

3.2.5 *laminated glass*—an assembly consisting of two or more lites of glass bonded by an interlayer.

3.2.6 *liquid resin interlayer*—liquid formulations, generally polyester-, urethane-, or acrylic-based, that react to form solid interlayers after being introduced between two lites of glass.

3.2.7 *polyurethane interlayer*—polymer sheeting based on isocyanates and mostly polyester or acrylic polyols, or both.

3.2.8 *polyvinyl butyral (PVB) interlayer*—polymer sheeting prepared from polyvinyl alcohol by reaction with butyraldehyde used to permanently bond two or more lites of glass.

3.2.9 *post-breakage glass retention*—the ability of the broken glass to remain in place so as to reduce cutting and piercing injuries from the broken shards and to prevent fall through or glass fallout.

3.2.10 *slip resistant*—the provision of adequate slip resistance to reduce the likelihood of slip for pedestrians using reasonable care on the walking surface under expected use conditions.

3.2.11 *supported glass walkway*—any glass walkway with a free spanning section, including continuous or local multiple supports at the edge or any location of the glass.

3.2.12 *walkway surfaces*—interior and exterior walking surfaces constructed and intended for pedestrian use, including but not limited to floors, ramps, sidewalks, and stair treads.

4. Significance and Use

4.1 Glass is a brittle material with different time and temperature-dependent properties than other solid materials used as walkways surfaces. Therefore, the type of glass is an important consideration in the design and construction of glass treads and glass landings constructed with laminated glass.

4.2 Post-breakage glass retention is an important consideration in the design of a glass walkway system as a means of minimizing tripping, cutting/piercing injuries, or fall-through or fallout of the glass.

4.3 The structural design shall be confirmed by calculations by a licensed design professional in accordance with Section 5.

4.4 If testing is required (see 4.4.1 – 4.4.3) to verify post-glass breakage behavior of the glass walkway, the testing shall be in accordance with Section 6.

4.4.1 For laminates with two glass plies, verification testing is required.

4.4.2 For laminates with more than two glass plies, verification testing is not required provided that calculations completed in accordance with 4.3 demonstrate that the glass assembly has sufficient strength to sustain the full design load with any one glass ply broken.

4.4.3 When verifying post-breakage behavior by calculation, allowable glass stress for 10 min load duration in accordance with Table 1 shall be used for all load cases.

4.5 The manufacturer or designer of glass walkway systems shall provide installation directions and fabrication and installation tolerances of their systems.

4.6 The structural integrity of the glass walkway system after glass breakage shall be sufficient to support the design loads after any one glass ply is broken. If damage of any kind occurs, the walkway shall be cordoned off and the installation shall be inspected to ensure structural integrity and pedestrian safety of the system.

5. Calculation Procedure

5.1 Use established engineering methods, such as engineering mechanics or finite element analysis, to determine glass assembly stresses and deflections. Such methods shall account for temperature, boundary conditions, loading requirements, load duration, interlayer properties, and glass strength.

5.2 Design Criteria:

5.2.1 Assign nominal load conditions or combinations of load conditions as required by the specifying authority. Additionally, the final design shall include consideration of a concentrated live load of at least 136 kg [300 lb] applied to all glass walking surfaces in a 2600 mm² [4 in.²] area.

5.2.2 Determine maximum allowable material stress.

5.2.2.1 *Glass*—Refer to Table 1 to determine allowable glass stress.

(1) Use minimum glass thickness in accordance with Specification C1036, Table 2, for design purposes.

5.2.2.2 *Interlayer*—Consult the interlayer manufacturer for interlayer material properties, load duration and temperature behavior. Typical interlayers are PVB, ionomer, liquid resin, EVA, and polyurethane.

5.2.2.3 *Other Laminate Materials*—Consult the supplier for properties of other laminate materials, such as polycarbonate.

5.2.3 The structural support system shall provide sufficient strength to support the combined applicable loads.

5.2.4 Deflection of the floor members shall conform to relevant building code requirements.

TABLE 1 Allowable Glass Stresses for Nominal Load Conditions

NOTE 1—An allowable stress reduction factor of 0.5 is recommended for disruptive surface treatments, for example, sandblasting, unless otherwise provided by the manufacturer. A glass stress reduction factor may be required for some acid etched or patterned glasses; consult the manufacturer.

NOTE 2—Values derived from Practice E1300, Table X9.1 (seamed edges), factored for load duration using Practice E1300, Equation X7.1, using $n = 16$ for annealed glass, $n = 32$ for heat strengthened glass, and $n = 48$ for tempered glass.

Glass Type	3-sec MPa [psi]	10-min MPa [psi]	60-min MPa [psi]	Permanent MPa [psi]
Annealed	18.3 [2650]	13.2 [1902]	11.7 [1701]	5.7 [827]
Heat-strengthened	36.5 [5300]	30.9 [4482]	29.2 [4235]	20.3 [2944]
Tempered	73.0 [10 600]	65.3 [9471]	63.0 [9137]	49.4 [7165]

6. Post-breakage Verification Test Methods

6.1 Assign nominal load conditions or combinations of load conditions as required by the specifying authority.

6.2 Test for the dominant load case (uniform load or concentrated load) as determined by calculations in accordance with Section 5.

6.3 Test the glass as a system with frame and attachments.

6.4 For walkways with two supported edges, test a panel with the largest span between supports. For walkways with three or more supported edges, test the sample size that represents the most demanding or highest stress condition.

6.5 Condition glass for at least four hours at the same temperature at which it will be tested.

6.6 Conduct testing at the maximum temperature for the intended use environment. When the intended end use environment is unknown, conduct testing at 50 °C and 0 °C ± 5 °C.

6.7 Concentrated Load Testing:

6.7.1 Break any one glass lite to produce the most unfavorable results. The worst case condition shall be determined by analysis or all combinations of broken glass shall be tested.

6.7.2 Apply the specified load over a 2600 mm² [4 in.²] area at a rate of 45.4 kg [100 lb] per minute up to the design load and hold for a duration of 10 min.

6.7.3 At the conclusion of testing, no additional glass plies shall have broken.

6.8 Uniform Load Testing:

6.8.1 Break any one glass lite to produce the most unfavorable results. Worst case condition shall be determined by analysis or all combinations of broken glass shall be tested.

6.8.2 Apply the specified uniform load at a rate of 30 psf/min up to the design pressure and hold for a duration of 60 min.

6.8.3 At the conclusion of testing, no additional glass plies shall have broken.

7. Other Considerations

7.1 Slip Resistance:

7.1.1 Walkway slip resistance should be commensurate with intended use, user populations, and foreseeable conditions and contaminants. Non-level walkways, exterior walkways, walkways on which activities other than walking take place (for example, athletic events), and walkways that cater to special populations (for example, nursing homes, rehabilitation centers) may require a higher level of slip resistance than other walkway surfaces. (See Practice F1637.)

7.1.2 Appropriate levels of slip resistance can be accomplished through a variety of glass surface treatments, including sandblasting, acid-etching, ceramic frit, embossing, kiln casting/fusing, and other processes designed to treat the walking surface.

7.1.3 The selection of the slip resistant treatment shall be made according to the intended use and desired durability of the walking surface.

7.1.4 Evaluate and report the slip resistance of manufactured glass walkway products in one of the following ways:

7.1.4.1 In accordance with ANSI A137.1.

7.1.4.2 Testing using tribometers (slip testing devices) demonstrated to be valid in accordance with Practice F2508.

7.1.4.3 Test methods required or accepted by applicable local building codes and safety standards.

7.1.4.4 As specified by the designer.

7.1.5 Certifications of slip resistance shall be conducted by independent testing laboratories or agencies.

7.2 Materials:

7.2.1 *Glass Selection*—Glass selection is based on many factors, including strength, fabrication, durability, aesthetics, cost, and glass post-breakage behavior.

7.2.1.1 *Annealed Glass*—Refer to Specification C1036 for requirements pertaining to flat glass.

7.2.1.2 *Heat-Strengthened Glass*—Refer to Specification C1048 for requirements pertaining to heat-strengthened glass.

7.2.1.3 *Tempered Glass*—Refer to Specification C1048 for requirements pertaining to tempered glass.

7.2.1.4 *Laminated Glass*—Refer to Specification C1172 for requirements pertaining to laminated glass.

7.2.2 *Interlayer Selection*—Interlayer selection is based on many factors, including strength, fabrication, durability, aesthetics, cost, and glass post-breakage behavior.

7.3 Structural Support System:

7.3.1 The glass edge support system shall be sufficiently stiff to limit the deflection of the supported glass edges under the design load to no more than L/500 of their lengths, where L is the supported length of the glass, unless analysis taking into account frame deflection effects on glass stress is carried out in combination with the design loads in accordance with Section 5.

7.3.2 The glass shall be cushioned to prevent direct contact with the glass support system.

7.4 Dynamic Use Considerations:

7.4.1 The licensed design professional shall consider the necessity of a glass floor systems vibration review, and if necessary, perform such review. Considerations may include system continuity, supports, and deflection compatibility with adjacent structures.

7.5 Fire Resistance Requirements:

7.5.1 Glass walkways shall provide a fire rating when required by the authority having jurisdiction.

7.6 Visual Cues:

7.7 Glass walkways present a special challenge in balancing the visual characteristics of glass with considerations of safety. Visual cues of conditions that impair the ability of pedestrians to walk safely shall be incorporated into the glass walkway design.

8. Durability

8.1 The walking surface of the glass shall be designed with suitable durability for the specified application. In cases where use of the walkway eventually reduces its slip resistance, instruction shall be provided to the end user regarding safe maintenance and replacement requirements.



8.2 The use of cleaning and maintenance equipment shall be tested for compatibility with the glass walking surface and walking surface components.

9. Keywords

9.1 annealed glass; glass; glass floor; glass stair treads; glass walkways; heat-strengthened glass; laminated glass; tempered glass

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