



# Designing with Laminated Glass

Presented by: Kamal Niazy



# Best Practice

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# Learning Objectives

- Learn about the types of interlayers used in laminated glass
- Identify the added benefits of each interlayer
- Identify architectural uses for laminated glass
- Testing and standards
- Compatibility issues

# Program topics

- What is laminated glass?
- Types of laminated glass interlayers
- Interlayer comparison
- Architectural uses of laminated glass
- Testing and standards related to laminated glass
- Compatibility of coatings, sealants, and frits

What is laminated  
glass?

# Laminated Glass

- Two or more lites of glass and one or more interlayers
- Glass retention if breakage occurs
- Types of laminated glass
  - Polyvinyl butyral (PVB)
  - Ionoplast



# Typical Laminating Line





# Polyvinyl Butyral (PVB)

- Polyvinyl butyral interlayer developed over 70 years ago for automotive windshields
- UV filtration up to 99%
- Noise reduction due to “damping” properties of interlayer
- Variety of thicknesses and colors
- Meets safety glazing standards
- Many decorative options

# PVB Examples



# Ionoplast Interlayers

- Initially developed for improved performance in windborne debris regions
- Up to 100x stiffer than PVB, 5x more tear resistant
- Variety of thicknesses
- Clear and translucent white
- Exposed edge durability
- Enhanced post-glass breakage performance

# Ionoplast Laminates



*Chemical Heritage  
Museum glass  
walkway*

*Cleveland Clinic*

*Marina Bay Sands  
Resort*

# PVB and Ionoplast Interlayer Comparison

# Interlayer Comparison

<b>Attribute</b>	<b>PVB</b>	<b>Ionoplast</b>
<b>Clarity</b>	<b>Slight yellowish tint</b>	<b>Ultraclear</b>
<b>Color options</b>	<b>Many</b>	<b>Clear or Translucent White</b>
<b>Edge performance</b>	<b>Good when captured; may develop edge blush when exposed</b>	<b>Excellent in open edge applications</b>
<b>Hurricane impact resistance</b>	<b>Small and large missile</b>	<b>Better performance at higher pressures; more tear resistant</b>
<b>Post-glass breakage</b>	<b>Glass retention</b>	<b>Better performance with minimally-supported glazing</b>

# Interlayer Comparison

Attribute	PVB	Ionoplast
<b>Sealant compatibility</b>	<b>Can develop bubbles on glass edge</b>	<b>Not likely to develop edge effects from sealants</b>
<b>Security</b>	<b>1.52mm good for low level blast &amp; intrusion resistance</b>	<b>.89mm for low level blast, 1.52mm for intrusion resistance</b>
<b>Sizes</b>	<b>Maximum width 321cm in .38mm, .76mm and 1.52mm thicknesses</b>	<b>Sheet: Maximum width 248cm Roll widths (.89mm: 121cm, 152cm, 182cm)</b>
<b>Strength</b>	<b>Approximately the same as monolithic at ambient temperature</b>	<b>More strength &amp; less deflection in minimally-supported systems</b>
<b>UV Resistance</b>	<b>Yes</b>	<b>Yes</b>

# Architectural Uses for Laminated Glass



# Safety Glazing

- Hazardous locations including doors, glazed panels, glazing in and bath enclosures shower
- Laminated glass tested to Consumer Product Safety Commission standard 16CFR 1201
- 542 N/m impact test



# Hurricane Impact Resistance



- Resists penetration from windborne debris
- Used in large and small missile impact systems
- Protects people and property
- 24/7 performance

# Typical projects

*Condominiums, hotels, homes, office buildings, hospitals, emergency facilities, schools and universities, retail, airports, courthouses, municipal buildings, libraries*



# Intrusion Resistance



- Resists physical attack
- Deters smash & grab criminals
- Protects valuable merchandise
- Maintains transparency

# UV Resistance



- Additive in interlayer blocks up to 99% harmful UV rays
- Helps to reduce fading of fabrics and other interior furnishings

*Hospital lobby, Tavares, FL*

*Toronto shopping mall skylight*

# High UV option

- When UV is required, 1.52mm ionoplast interlayers can be ordered without UV filter
- Especially critical for plants, some animals, and insects



*Botanical garden skylight in Madrid*

# Sound reduction



- PVB laminates reduce sound transmission over monolithic glass
- Insulating glass units with laminated glass provide superior sound attenuation



*Acoustical testing at ATI Laboratories, USA*

# Structural Glass

- Facades
- Skylights
- Glass roofs
- Stair treads
- Glass bridges
- Canopies
- Railings



*Curved laminated glass railing at movie theater in Italy*



*Interior skylight in Phoenix Courthouse*



*Glass walkway in Chattanooga, Tennessee*



# Facades



- Traditional & minimally supported façade systems
- Missile impact facades and storefront systems



*High rise building in China*

*Las Vegas Speedway, Planar/SentryGlas® System*

*Factory in Japan, Sears Tower in Chicago*

# Skylights

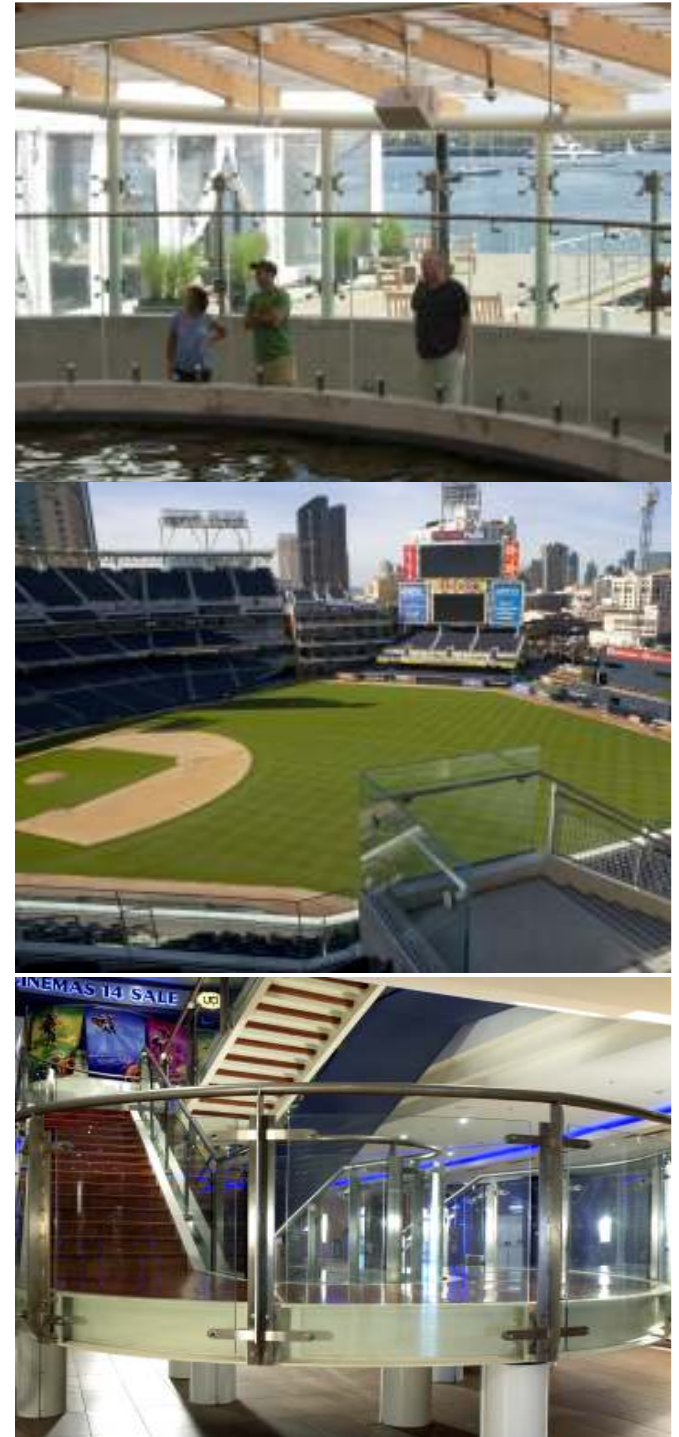
- IBC requires laminated glass with a minimum .76mm PVB interlayer (or equivalent) to prevent glass fall out
- Skylights provide natural light



# Railings

- Heat-strengthened and tempered laminates
- Laminated glass provides glass retention after breakage
- Laminated glass required in windborne debris areas

*New England Aquarium, Boston, Padres Stadium in San Diego, curved railing in Genoa, Italy*



# Canopies



- Laminated glass provides safety from falling glass
- Translucent, colored, and decorative laminated interlayers and glass, provide variety of design choices

*Canopy at subway entrance and rail station*

# Glass Walkways



*Grand Canyon Skywalk, Arizona*

# Stair treads



*Laminated glass, stair treads and bridge at  
Apple Store, New York*



# Testing & Standards

# Blast



**EWRP-7 September 17, 2002  
External High Speed Video**

**PHANTOM High Speed Camera  
1000 PPS**

- Shock tube and arena testing to ASTM F1642 Test Method
- Testing program 41kPa, 282 kPa-msec

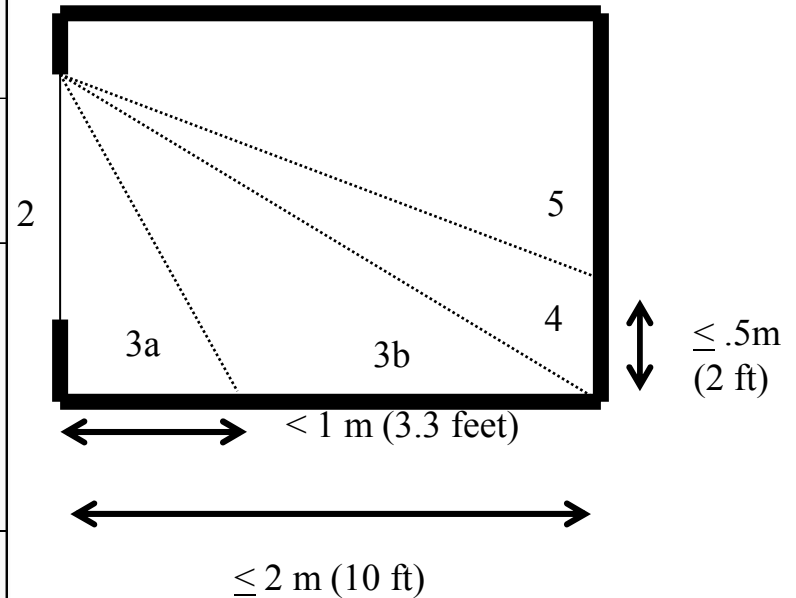


# USA General Services Administration (GSA)

## Minimize hazard from flying glass shards – hazard/protection rating

Condition	Protection Level	Hazard Level	Description of Glazing Response
1	Safe	None	Glass does not break
2	Very High	None	Glass cracks but retained in frame
3a	High	Very Low	Glass cracks. Fragments land on floor no further than 3.3 feet.
3b	High	Low	Glass cracks. Fragments land on floor no further than 10 feet.
4	Medium	Medium	Glass cracks. Fragments land on floor no further than 10 or height no greater than 2 feet above floor at witness 10 feet away.
5	Low	High	Glass cracks and catastrophic failure

Side view into test chamber  
Look at location of glass fragments



# Test Results

## IGU constructions

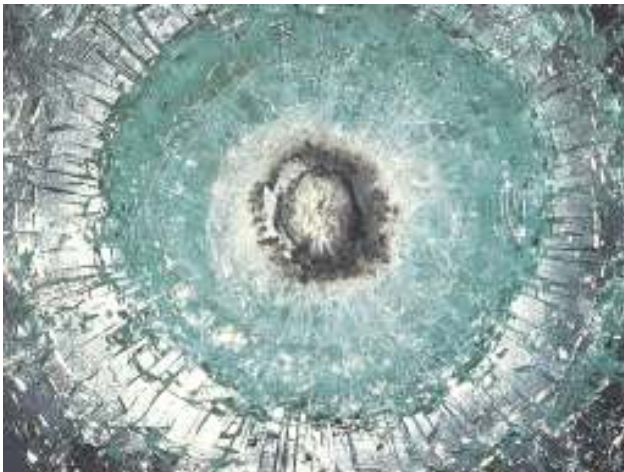
## GSA Rating

- 3mm FT | 12mm AS | 3mm AN | 0.89mm ionoplast | 3mm AN 2
- 3mm FT | 12mm AS | 3mm8 AN | 0.89mm ionoplast | 3mm AN 2
- 3mm FT | 12mm AS | 3mm AN | 0.76mm PVB | 3mm AN 3a
- 3mm FT | 12mm AS | 3mm AN | 1.52mm PVB | 3mm AN 3b
- 6mm FT | 12mm AS | 6mm AN | 0.89mm ionoplast | 6mm AN 2

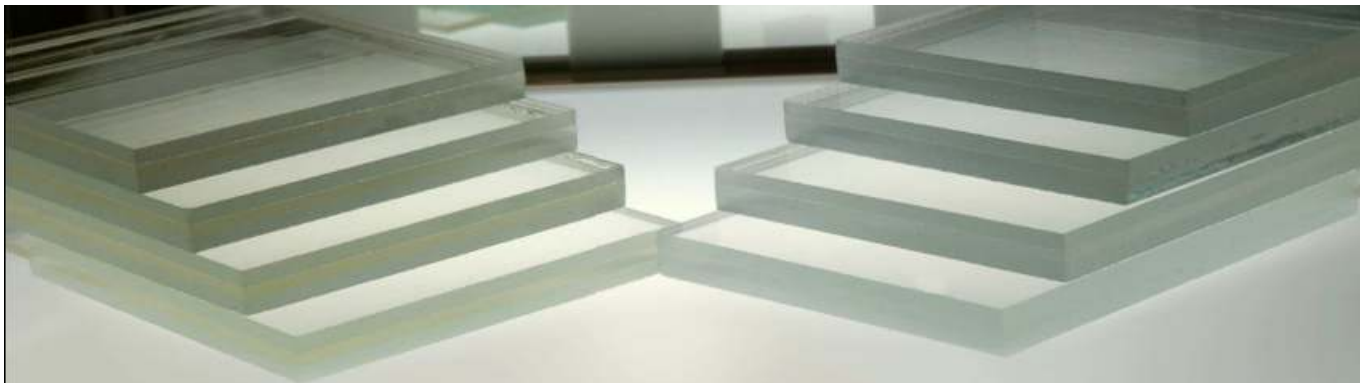
## Monolithic laminate constructions

- 3mm AN | .89mm ionoplast | 3mm 2
- 3mm AN | .76mm PVB | 3mm 3a
- 3mm AN | 1.52mm PVB | 3mm AN 2
- 6mm AN | 0.89mm ionoplast | 6mm AN 2
- 6mm AN | 0.76mm PVB | 6mm AN 2

# Ballistics



- Composite laminates comprised of multiple plies of glass and both PVB and ionoplast interlayers
- Testing done for most levels of UL 752 and NIJ 0108.01



# Ballistics Levels

Ammunition	Bullet Mass (g)	Velocity (mps)
9mm	8	358-394
.357 Magnum	10.2	381-419
.44 Magnum	15.6	411-441
.30-60 Caliber Rifle	11.7	774-852
7.62mm Rifle	9.7	838-922
9mm	8	427-469



*Underwriters Laboratories UL 752*

*Courthouses and automotive vehicles  
may incorporate ballistics laminates for security*

# Missile Impact



- Resists penetration from windborne debris
- Used in large and small missile impact systems
- Protects people and property
- No need for plywood or storm shutters
- Building code compliant

*Demonstration of air cannon test for certification of hurricane system*

# Test Requirements

<b>Missile A</b> <b>&gt; 9.1 meters</b>	<b>Missile D</b> <b>≤ 9.1 meters</b>	<b>Missile E*</b> <b>≤ 9.1 meters</b>
<b>2 gram balls</b> <b>@ 39.62 mps</b> Followed by 9000 pressure cycles	<b>4100 g 2 x 4 @</b> <b>15.25 mps</b> Followed by 9000 pressure cycles	<b>4100 g 2 x 4 @</b> <b>24.38 mps</b> Followed by 9000 pressure cycles

*\* Missile E applications include hospitals, healthcare facilities, police stations, fire rescue stations, emergency shelters, communications centers, jails and detention centers, buildings critical to the national defense*

# Psychiatric Facilities



- Office of Mental Health/State of New York
- 907 kg impact to the framed glazing
- No holes or punctures in the glazing allowed

*Impact testing of security windows at test laboratory in the United States*

# Glass Railing Test Program

1/2 inch Fully Tempered Glass





# Glass floors



*Laminated glass floor in Taiwan beauty salon*

- ASTM E2751 Standard Practice
  - Calculation method
    - Determine glass stresses and deflection
    - Consider concentrated live load of at least 136 kg
  - Testing
    - Before testing, break one ply of glass
    - Evaluate slip resistance

# Compatibility of coatings, sealants, & frits

# Sealant Compatibility

- Many sealants compatible with PVB and ionoplast interlayers
- Sealant compatibility requires testing and verification



# Coating Compatibility

- The following companies manufacture low-E coatings that are compatible with ionoplast interlayers:
  - Cardinal
  - PPG
  - Guardian
  - AGC
  - Viracon

# Frit Compatibility

- Paints and frits require testing to verify compatibility
- Can be placed on the inside of the laminate if testing demonstrates acceptable adhesion



# Conclusions

- Both PVB and ionoplast laminates break safely—the glass does not vacate the frame
- Both PVB and ionoplast interlayers glass offer safety and design versatility
- Laminated glass complies with building code requirements for safety and impact resistance
- Laminated glass provides impact resistance to windborne debris in hurricanes and bomb blasts

# Conclusions

- PVB laminates effectively dampen sound
- PVB laminates can be designed for intrusion, blast, and seismic performance
- Ionoplast interlayers are especially suited for structural designs, including bolted glass façade and railings, laminated glass floors, stair treads, skylights and canopies
- Ionoplast laminates can offer thickness and weight benefits

Thank you.

Questions?

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