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## Glass Railing Systems

Presented by:

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## Learning Objectives

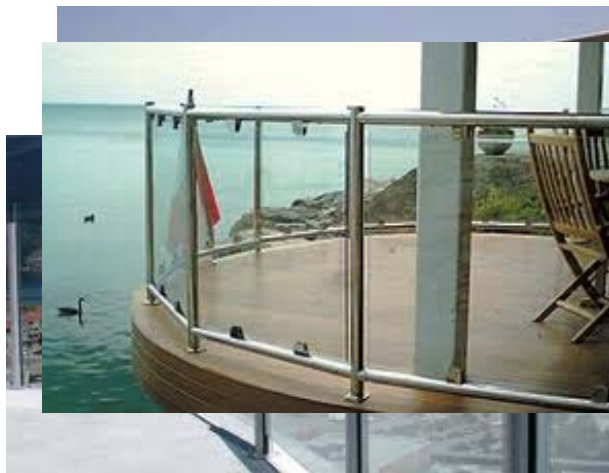
- Updates to ASTM Glass Railing Standard
- Overview of IBC requirements for glass railing systems
- Requirements per other standards

## Examples (Unobstructed Views)



## Additional Examples

- With top rail (guard rail)
- With vertical posts
- With infill panels



## Something to consider



## ASTM E2358

### -Standard Specification for the Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades-

- Scope
  - Based on the health and safety of all potential users.
  - For normal and anticipated building uses, but not for abuses.
- Design Requirements
  - Guardrail Systems (4.1.1)
    - 42" from walking surface
    - At least 48" when adjacent surface is more than 20 ft
      - Public assembly
      - Elementary schools
      - Multi-family buildings

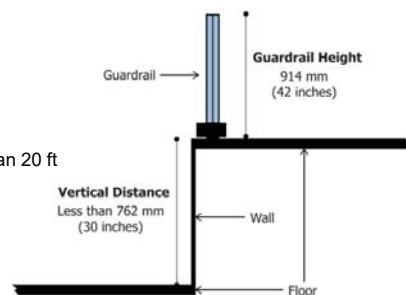


FIG. 1 Guardrail Height for Adjacent Floors

## ASTM E2358

- Handrails (4.1.2)
  - Corridors, ramp, walkways, enclosed stairways
  - Slope of at least 1 in 20.
  - Height not less than 34"
  - Height no more than 38"
- Transfer Rails Systems
- Railing System Penetrations
- Hand-grip

## ASTM E2358

- Performance Requirements  
Deflection (6.2)
  - Load at vertical support
    - $h/12 = 42"/12$
    - 3.5"
  - Horizontal load at rail mid-span
    - $h/24 + l/96 = 42"/24 + 60"/96$
    - 2.375"
  - Vertical load at rail mid-span
    - $l/96 = 60"/96$
    - 0.625"



## ASTM E2358

- Classification (5.1)
  - Type I – VI
  - Level of Performance
    - Level 1 – Basic
    - Level 2 – Safety
    - Level 3 – Enhanced
    - Level 4 – Enhanced

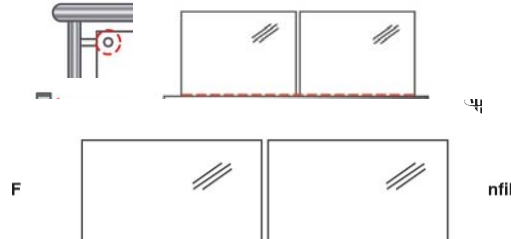


TABLE 1 Performance Requirements

Type (refer to Figs. 3-8)	Structural Performance <sup>a</sup>	Shot Bag Impact Performance <sup>b</sup>	Pendulum Impact Performance <sup>c</sup>	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) <sup>d</sup>	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) <sup>d</sup>	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) <sup>d</sup>	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) <sup>d</sup>	Pass 678 J 500 ft - lb	Pass	Level 4 (Type L4)

## ASTM E2353

### -Standard Test Method for Performance of Glazing in Permanent Railing Systems, Guards, and Balustrades-

- Tests
  - Static Loads
  - Shot Bag Impact Test
  - Pendulum Impactor Test
- Performance after impact

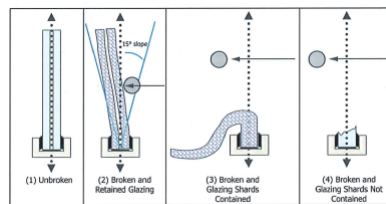


FIG. 15 Graphical Depiction of Glazing Classification

TABLE 2 Post Impact Classification

Classification Number	Description	Requirements
1	Glazing unbroken	Glazing completely retained in system and unbroken
2	Glazing broken and retained	No passage of a 76 mm (3 in.) diameter solid sphere with a horizontal force of 18 N (4 lb)
3	Glazing broken and shards contained	Glazing shards separated from system not greater than 6452 mm <sup>2</sup> (10 in. <sup>2</sup> ) of equivalent weight of original glazing specimen
4	Glazing broken and shards not contained	Glazing shards separated from system are greater than 6452 mm <sup>2</sup> (10 in. <sup>2</sup> ) of equivalent weight of original glazing specimen

## ASTM

- ASTM WK59324
  - Standard Practice/Guide for Design of Glass Railings and Guards and Balustrades

## Code Requirements IBC 2015

- Glass supports (IBC 2403.2)
  - If not firmly supported on all four sides
    - Construction documents
    - Shop drawings
    - Analysis
    - Test data



## Code Requirements IBC 2015

- Glass General Requirements (IBC 2406)
  - Safety Glazing required
  - Hazardous location (IBC 2406.4, 2406.4.4)
    - Structural baluster
    - In-fill panels
    - Regardless of area or height above walking surface.
  - Hazardous locations – Requirements
    - Impact Test – CPSC 16 CFR Part 1201.
  - Permanently marked (IBC 2406.3)
    - Manufacturer
    - Standard with which it complies
  
- Glass in Handrails and Guards (IBC 2407.1)
  - Laminated glass – Category II or CPSC 16 CFR Part 1201 or Glass A of ANSI Z97.1.
  - Minimum 1/4"
    - Monolithic tempered glass is allowed at:
      - No walking surface beneath
      - Walking surface beneath is permanently protected from the risk of falling glass



## Code Requirements IBC 2015

- Loads (IBC 2407.1.1)
  - Design factor of 4 must be used
  - IBC Section 1607.8
    - 50 plf applied at the top
    - 200 lb applied at the top
  - WL on all vertical exterior glass (IBC 2404.1)
  - On all vertical exterior glass
  - From Section 1609 for components and cladding
  
- Support (IBC 2407.1.2)
  - Each guard section to be supported by a minimum of 3 glass balusters
  - Guard to remain in place if one baluster panel fails.
    - Top rail is not required if glass is laminated.
    - Some local codes require a top rail. Therefore this exception would not apply.

\*\*2018 IBC. Panels shall be tested to remain in place as a barrier following impact or glass breakage in accordance with ASTM E2353



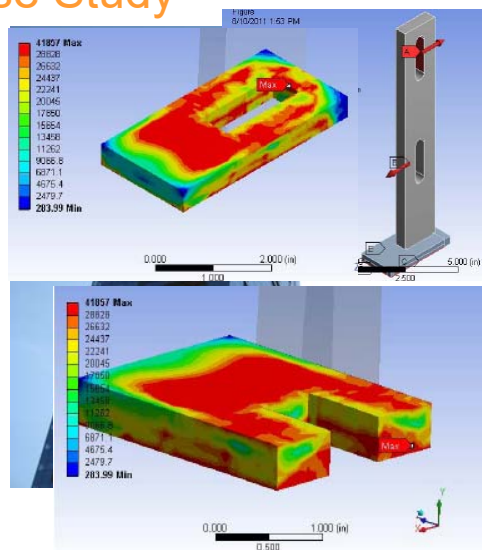


## Case Study



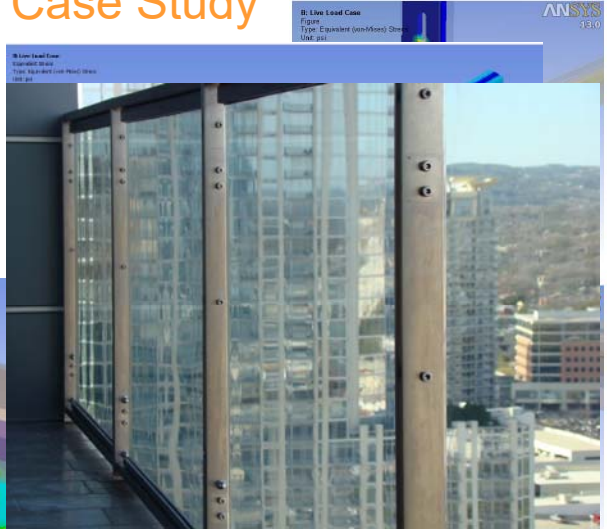
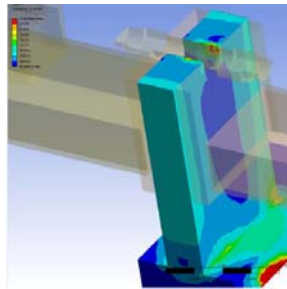
## Case Study

- Glass Failure
- CDC's preliminary investigation
  - Post-tension cable failure
- Additional glass failures
  - Poor design
    - (red indicates beyond yield limits)



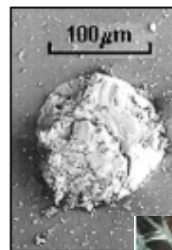
## Case Study

- Solution
  - Glass replacement
  - Stanchion re-design
    - Using FEA
    - Stainless Steel (45 ksi yield strength)



## Glass in Railing Systems

- Tempered glass considerations
  - Nickel Sulfide (NiS)
    - Thermal cycles
    - Sudden explosion
    - Breakage probability (5ft x 3ft panel)
- Heat soaking



Non-heat soaked toughened glass

Glass thickness	m <sup>2</sup> per inclusion	Panes per inclusion
4mm	400	220
6mm	265	145
10mm	160	90
15mm	105	60
19mm	85	45

# Discussion

# Discussion

- Handrail height is from 34" to 38" (code definition)
- Handrails are not guards (based on height definition)
  - Handrails are only required by code at stairs
- In the event of one glass baluster failing, the guard needs to remain in place and needs to resist the specified loads.
  - Simple edge protectors will not meet this requirement.



## Discussion

- Is a Top Rail required or not?



## Discussion

*IBC 2407.1.2. Each handrail or guard section shall be supported by a minimum of 3 glass balusters or shall be supported to remain in place should one baluster panel fail. Glass balusters shall not be installed without an attached handrail or guard.*

- This section protects the public in the event of an individual panel failure. The adjacent panels will hold the railing and prevent people from falling.
- Does this mean that as long as a handrail is installed a guard (top rail) is not required?



## Laminated Glass Examples



## Discussion

- Questions asked to ICC via their “Code Opinion Submission Form”
- *Can a glass rail system be installed without a guard on top of the glass if there is a handrail attached to the glass? In other words... no cap, exposed top edge of glass at 42 inch height with a handrail mounted on the side of the glass and handrail height*
  - ICC response: “No”
- *Whether the system has an attached handrail or not, does the guard (piece on top of the glass) have to meet the loading requirement if one baluster fails.*
  - ICC response: “Yes”

## Conclusion

- Considerations when designing with glass
- ASTM
- Code requirements
- Is a top rail required?
- Additional documents
  - ICC AC 439 – Acceptance Criteria for Glass Railing and Balustrade Systems (2014-2015)
  - ICC AC 273 – Acceptance Criteria for Handrails and Guards

## Thank You For Attending!

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