BUILDING ENCLOSURE COUNCIL

2014 Lecture Series
Glass Enclosure Design

“GLAZED ALUMINUM CURTAIN WALLS: SPECIFYING & TROUBLESHOOTING INSIGHT”
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Glazed aluminum curtain walls: Specifying and Troubleshooting Insight

Wei Lam, PE

WJE Capabilities and Services

• Building Enclosure Consulting, Peer Review, and Cx
• Repair and Rehab
• Roofing and Waterproofing
• Bridge Engineering
• Earthquake Engineering
• Facade Assessment
• Failure and Disaster Response
• Historic Preservation
• Litigation Support
• Materials Evaluation and Research
• Structural Evaluation
• Testing and Instrumentation
Learning objectives

• Classify Typical Curtain Wall Systems
• Recognize new and innovative components related to glazed aluminum curtain wall assemblies
• Describe key design and performance considerations in specifications for glazed aluminum curtain wall
• Understand, through troubleshooting case studies, how some of these criteria can impact performance

Agenda

• Classifying Curtain Wall
• Current Trends and Innovations
• Specifying for Performance
• Case Studies
What is curtain wall?

- Functionally
  - Does not Support Floor or Roof Loads
  - Durable
  - Separates interior and exterior environments (heat/air/moisture)
- Aesthetically
  - Metal and Glass
  - Stone, wood, ETFE???
- System
  - Engineered
  - Mass produced

Classifying Curtain Wall Systems

**Standard**
- Regular ‘Kit-of-Parts’
- Design Flexibility
- Pre-Engineered & Laboratory Tested
- Field Testing
- Generally Less $$$

**Custom**
- Project Designed/Custom Extrusions and Components
- Specialized Assemblies, Extrusions, Fittings
- Increased Design Flexibility
- Increased Engineering Analysis / Mock-ups
- Laboratory and Field Testing
- Generally More $$$
Classifying Curtain Walls: Standard vs. Custom

- Classifications per AAMA
  - Stick
  - Unitized
  - Unit and Mullion (Cassette)
  - Panel
  - Column Cover and Spandrel
- Other

Classifying Curtain Walls: Assembly

**Stick/Site Built**
- Oldest system
- Field assembled and installed
- Glazing Gaskets – wet vs. dry
- Joint between vertical Mullion
- Pressure Plates and Aluminum Snap Caps

**Unitized / Panel**
- Pre-Fabricated: Framing and Glazing
- Improved Quality (??)
- Field Labor Requirements
- Construction Site Speed / Efficiency
- More joints
- Stack Joint
Classifying Curtain Walls: Assembly

Stick/Site Built

Unitized / Panel

Unitized Stack Joints
Classifying Curtain Walls: Moisture Management Strategy

- Face Sealed
- Water Managed
- Pressure Equalized Rain Screen (PERS)
Classifying Curtain Walls: Moisture Management Strategy

Water Managed

Pressure Equalized Rain Screen
Current trends and innovations

Development

Energy

Efficiency
Current trends and innovations

Glass and IGU
- Spectrally Selective Coatings
- Warm Edge Spacers
- Suspended Films
- Chromatic Glass
- Vacuum Glazing
- Vacuum Insulated Panels
- Aerogels

Spectrally Selective Coatings
- SOLAR ENERGY
  - ULTRA-VIOLET
  - VISIBLE LIGHT
  - SHORT-WAVE INFRA-RED (SOLAR HEAT)
- LONG-WAVE INFRA-RED (RADIANT HEAT)
Spectrally selective coatings

“TRIPLE SILVER” COATINGS

- LATEST GENERATION OF COATINGS
- LOW SHGC ~ 0.27
- HIGH VISIBLE LIGHT TRANSMISSION ~ 65%
- LIGHT TO SOLAR GAIN (LSG) RATIO OVER 2.0

Warm edge spacers

- Stainless steel
- Plastic with and without metal backing
- Butyl-matrix
- Thermoset structural foam
Suspended films

- Fiberglass frame
- Insulated frame
- Less weight than triple-glazed

Chromatic Glass

- Reduces heat gain
- Improve energy efficiency
- Optimize daylighting
- Visual privacy

- Passive
  - Photochromic
  - Thermochromic
- Electrochromic
Electrochromic Glass

Vacuum Insulated Panels

- Eliminates convective heat transfer
- R-value COP = 22 @ 1” thickness
- 30-yr life, 20% loss
- Constructability
- Cost
Aerogels

- Developed 1931
- Hydrophobic treatment
- R-value 105 for 3.5”
- Opaque panel applications with U-0.05
- IGUs with Aerogel

Advanced framing

- Advanced thermal breaks and struts
Advanced framing

- Stick fabricated
- Fiberglass pressure plate
- Thermally improved vinyl gasket
- 27% U-Factor improvement
Performance Criteria

Glazed Aluminum Curtain Wall Performance Criteria

• Division 08
  – Glazed Aluminum Curtain Wall
  – Glazing
  – Louvers and Vents
  – Structural-Sealant-Glazed Curtain Walls
  – Sloped Glazing Assemblies

• Division 07
  – Joint Sealants
  – Air Barrier Membranes

• Division 05
  – Architectural Sheet Metal and Trim

• Division 03
  – Architectural Precast
Curtain Wall Performance Criteria

- Structural Loads and Tolerances
- Air Leakage
- Water Penetration
- Thermal Performance
  - U-Value
  - SHGC
  - Condensation Resistance
- Seismic Performance
- Windborne Debris, Human, and Blast Impact Resistance
- Thermal Movement
- Sound Control

Building structure

Movement
- Inter-story drift, maximum:
- Inter-story drift, serviceability
- Live load deflection at slab-edge, worst case
- Long Term Creep
- Column Shortening

Tolerances
- Slab-edges and perimeter beams, in/out: +1”, -2” from design location
- Slabs, beams, columns, left/right & up/down: ±1” from design location
Building structure

• Anchorage
  – Connection at slabs and columns
• Define gap between system and structure

Air infiltration

• For fixed areas: 0.06 CFM/SF @ 6.24 psf (AAMA standard).
• For operable windows, : 0.10 CFM/LF of perimeter @ 6.24 (AAMA standard).
• For sliding doors: 0.30 CFM/SF @ 6.24 psf (AAMA standard).
Water penetration

Internal Drainage System
- Primary and Secondary Defense
- Internal flashings and gutters

Pressure-Equalized Rainscreen Curtain Wall System
- AAMA CWRS1, The Rain Screen Principle and Pressure Equalized Wall Design
- Compartmentalization
  - CMHC’s Rain Penetration Control: Applying Current Knowledge, Chapter 9
  - Sealed Metal Back Pan
- Unitized Gasket vs Sealants

4/30/2014

Water penetration

- Static pressure at 12 psf for 15 minutes per ASTM E331: No water penetration
- Dynamic pressure at 12 psf for 15 minutes per AAMA 501.1: No water penetration
- Sliding Glass Doors and Terrace Doors: Static pressure at 10 psf for 15 min per ASTM E331: No water penetration

4/30/2014
Condensation resistance

Define Performance
- CRF – AAMA 1503-98
  - Weighted Frame Average / Straight Glass Average
  - May not provide sufficient information to confidently specify condensation resistance
- Specify Specific interior and exterior design conditions
- Temp index = \( \frac{(T_{\text{surface}} - T_{\text{out}})}{(T_{\text{in}} - T_{\text{out}})} \)
- Computer Simulation / Laboratory Validation

Factors Affecting Actual Performance
- Diurnal Environmental Changes
- Adjacent Wall Construction and Materials
- Interior Finishes
- Building Operating Practices
- Location of Heat Sources
- Wind Speeds
- Terrain and Adjacent Building Locations
- Variations in Building Height and Elevation
- Size, Shape and Finish of Fenestration
- Air Leakage

Energy Transmission

Thermal Performance
- Driving force:
  - Temperature difference
- Resistance:
  - Thermal Resistance (R-value)
- Basic requirements
  - U-Factor – Primary measure of heat loss
  - SHGC – How well a product blocks heat

Insulation (U-value)
- Vision glazing
- Spandrel glazing
- Shadow boxes
- Other opaque/spandrel conditions
Sound Transmission

• AAMA 1801 Voluntary Specification for the Acoustical Rating of Exterior Windows, Doors, Skylights and Glazed Wall Sections
• AAMA TIR A1-02 Sound Control for Fenestration Products

Acoustical Rating Methods
• ASTM E 90-04 Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions
• ASTM E 413-10 Classification for Rating Sound Insulation (Sound Transmission Class - STC)
• ASTM E1332-10 Standard Classification for Rating Outdoor-Indoor Sound Attenuation (Outdoor-Indoor Transmission Class - OITC)

Shading Devices

• Structural design
• Ice and Snow Accumulation
• Motorized control sequence
• Maintenance Access and Glass Replacement
• Thermal Bridging of Supports
Spandrels, Shadow Boxes and Backpans

- Sealed
- Vented
- Pressure Equalized

Glass

- STRUCTURAL STRENGTH  WIND, DEAD LOAD, IMPACT, THERMAL
- SURFACE PROPERTIES  FLATNESS, SPECULARITY, TEXTURE
- OPTICAL PROPERTIES  COLOR, CLARITY, DISTORTION
- ENERGY TRANSMISSION  LIGHT/HEAT
- THERMAL PROPERTIES  INSULATION
- ACOUSTICAL PROPERTIES  SOUND ATTENUATION
- DURABILITY  SCRATCHING, STAINING, ETCHING
- FIRE-RESISTANCE  FIRE-RATED ASSEMBLIES
- SAFETY  IMPACT, FALL, BLAST
- INSTALLATION  GANA, IGMA

Two papers on shadow box design considerations: www.glassfiles.com (search term: “shadow box")
- C. Keith Boswell, Skidmore, Owings & Merrill; John R. Walker III, Enclos Corporation 2005 "Shadow Boxes“- An Architect and Cladding Designers’ Search for Solutions
- Michel Michno, T.J. Dehghanyar, Kevin Cole 2010 Analysis and Design of Spandrel and shadowbox Panels in Unitized Curtain Walls
Glass

• Construction
  – Glass thicknesses
  – Acceptable products
  – VLT
  – Reflectance
  – U-value (winter)
  – SHGC

• Other Considerations
  – Bent Glass: ASTM C 1464
  – Safety Glazing
  – Roller Distortion: 0.003” peak to valley max.; 0.008” peak to valley max within 10” of leading or trailing edge.
  – Quench pattern
  – Edge deletion

Operable Windows / Doors

• Sightline
• Operation
• Locking hardware
• Motorized control and wiring
• Threshold conditions
Mock-ups

• Visual
• Performance (Laboratory and Field)
• Coordinated

Laboratory Testing

AAMA 501 Methods of Tests for Exterior Walls

Standard Practice
• Air Leakage (ASTM E 283)
• Water Penetration (ASTM E 331)
• Structural Adequacy (ASTM E330)

Optional
• Dynamic Water Resistance (AAMA 501.1)
• Thermal Cycling (AAM 501.5)
• Interstory Lateral Displacement (AAMA 501.4)
• Seismic Performance (AAMA 501.6)
• Thermal Performance (AAMA 507)
• Acoustical Performance (AAMA 1801)
Laboratory Testing

Laboratory Testing Regimen

1. Glass replacement
2. Air Leakage
3. Static Water Resistance
4. Dynamic Water Resistance
5. Structural Performance @ Design Wind Pressure
6. Repeat Air Leakage
8. Interstory Displacement at Elastic Design
9. Perform a Thermal Cycling / Condensation
10. Repeat Air Leakage
11. Repeat Static Water Resistance
12. Repeat Structural Performance @ 1.5 x Design Wind Pressure
13. Repeat Air Leakage
14. Repeat Static Water Resistance
15. Structural Overload to Failure or 2 x Design

ASTM E 2099-00 Standard Practice for the Specification and Evaluation of Preconstruction Lab Mock-Ups of Exterior Wall Systems

Field Testing

Common Practice

• QA & Diagnostic Water Penetration (AAMA 501.2)
• Air and Water for Windows (AAMA 502)
• Air and Water for CW and Slopeded (AAMA 503)
Field Testing

Optional / Diagnostic
• Dynamic Water Resistance Testing (AAMA 501.1)
• Thermal Cycling
• Condensation Risk
• Qualitative Air Leakage
• Light Transmission
• Acoustical Performance

Shop Drawings vs. Fabrication/Erection Drawings

Shop Drawings
Shop Drawings vs. Fabrication/Erection Drawings

Erection Drawings

Plant Fabrication Inspections
Case Study: University of Kentucky Patient Care Facility (UK PCF)

UK PCF: Typical Enclosure

- Architectural Precast Sandwich Panels
- Thin Brick Finish
- Custom Curtain Wall / Punched Openings
- Articulation
Case Study: UK PCF

UK PCF: Challenges

- Location of Primary and Secondary/Weather Seal
- Transition of Primary Seal to Sandwich Panel
- Lab Testing with weather seal only
UK PCF: Challenges

• Location of Primary and Secondary/Weather Seal
• Transition of Primary Seal to Sandwich Panel
• Lab Testing with weather seal only
UK PCF: Field Mock Up

Issues

• Location of primary seal still not defined
• Late shop drawing updates
• Lab testing with weather seal only
• Incomplete or failing sealants on delivered units

Figure 10. Uncured and failing sealant at the head of window unit.
UK PCF: Field Testing

Figure 2: Leak No. 1 at corner of inclined metal back-pan.

Figure 3: Leak No. 2 at north edge of inset metal panel.

Figure 4: Leak No. 3 at south edge of inset metal panel.

UK PCF: Diagnostics / Investigation

Mock Up

As-Built

Figure 5: Sealant condition at glazing pocket of Mock-Up. Arrow points to continuous sealant at vertical.

Figure 6: Sealant condition at glazing pocket of installed window at test location. Note that pencil tip inserted into the vertical joint.
Case Study: Air Leakage and Condensation

- High Rise Residential Condominium – Boston, MA

**Symptoms**

- Water Penetration
- Water Damage
- Condensation and Frost Formation on Windows
- Odor Migration
- Sound
Case Study: Air Leakage and Condensation

Problems Identified
- Joinery Sealant
- Fire and smoke seal
- Building Pressurization, Compartmentalization, Stack Effect

Case Study: What is it?
Case Study: High Rise IGU Failure

- High rise office building
- Unitized CW
- 10-yrs old
- Low-e failure
- Multiple / Progressive Failures
Case Study: High Rise IGU Failure

Findings

- No reports of water intrusion
- Inadequate water management at jambs of IGU