

First Canadian Place

Renewal From The Outside In

16th Annual Symposium
on Building Science
July 30, 2012



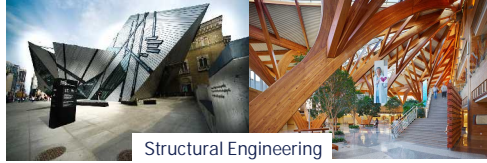
Halsall (A Parsons Brinckerhoff Company)



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Services



Structural Engineering



Restoration Engineering



Green Planning & Design



Cladding Engineering



Property Condition Assessment

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Outline

- Background
- Marble Management
- Building Renewal Vision
- Existing Construction Evaluation
- Re-Cladding Design
- Energy Retrofits



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First Canadian Place

72

STOREYS

3M

SQ-FT

8,500

OCCUPANTS



1975 Construction 978 ft - Tallest in Canada



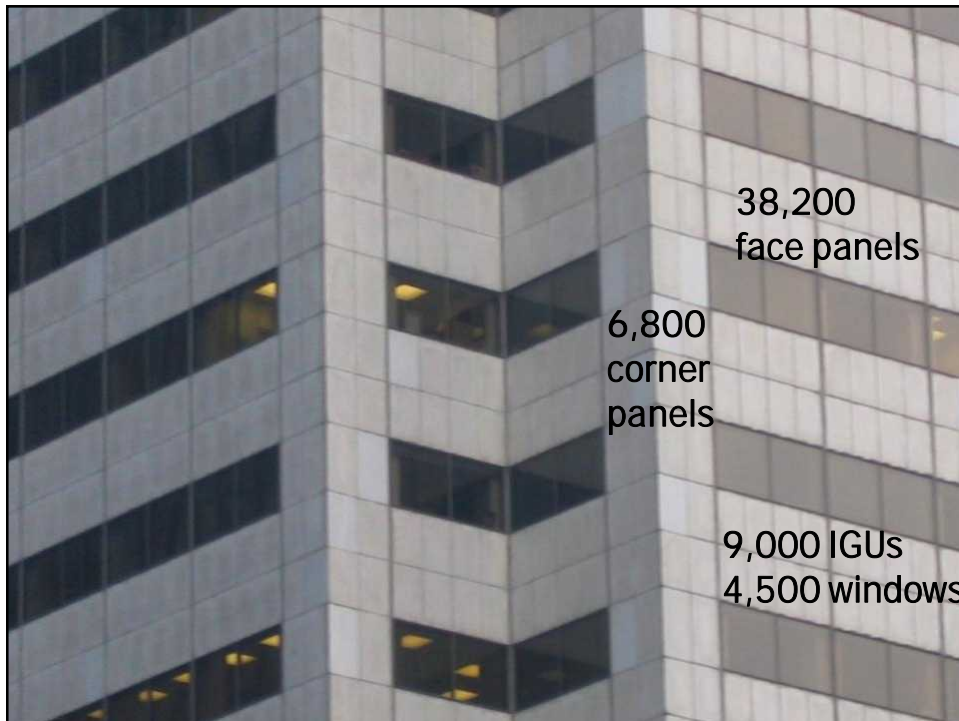
Photo by Clifford Restoration



Photo by Brookfield Properties

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Team

Brookfield et.al
Halsall
MdeAs
B+H
BLWTL/RWDI
Ellis Don
Sota/Clifford
Viracon/PPG
TMP/Aquila
BSC



Timelines



- Marble Management (2005-2010)
- Re-Cladding Design (2007-2009)
- Energy retrofits (2008-2012)
- Re-Cladding Construction (2010-2012)

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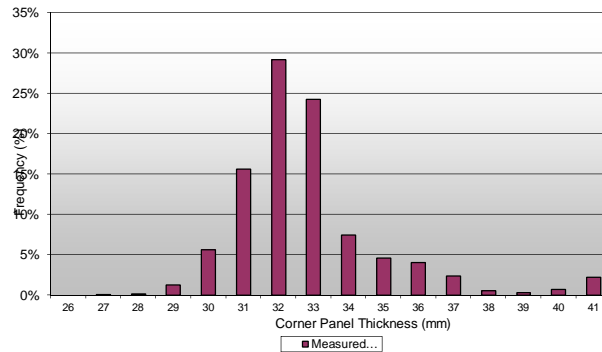
Staining from Silicone Sealant



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Cracks & Panel Thickness Variations



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Thermal Hysteresis & Strength Loss



- Anisotropic behavior with thin marble & heat/moisture
- Volumetric expansion and bowing
- Reduced density and strength loss
- Cracking

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Sister Buildings by Edward Durell Stone Architect



AON CENTER_CHICAGO

Amoco (Aon Centre)
Chicago '73



FIRST CANADIAN PLACE_TORONTO

images by MdeAs



GM BUILDING_NEW YORK

GM Building
New York '68

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Amoco Re-Cladding
Granite Re-clad '89 -'92

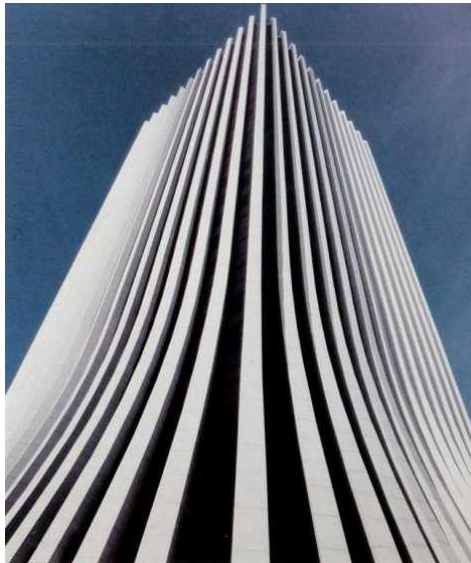


\$80M USD

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Lincoln Bank, Rochester, NY
Constructed 1970 – '80's Aluminum Re-clad



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Finlandia Hall, Helsinki Constructed '71 – Marble Reclad '97-'99



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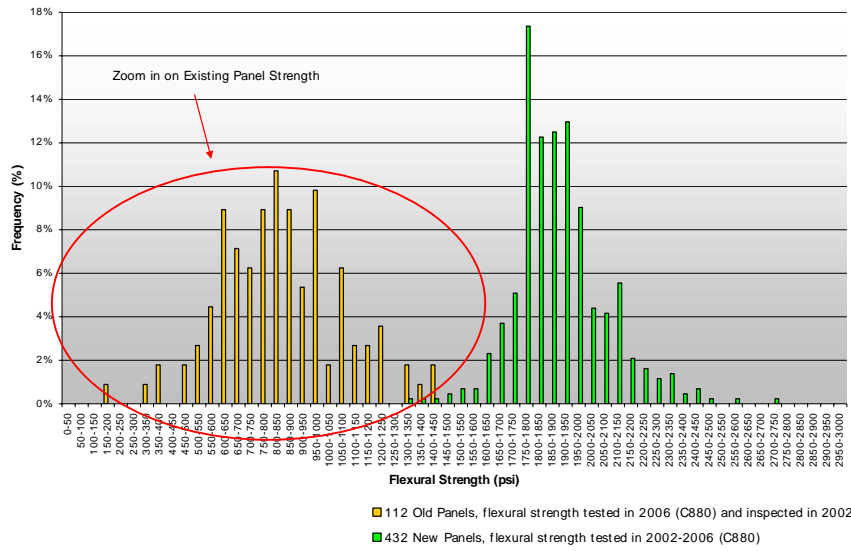
Management Strategy

- Comprehensive review, testing and monitoring program
- Targeted replacement to maintain acceptable safety and progressively renew

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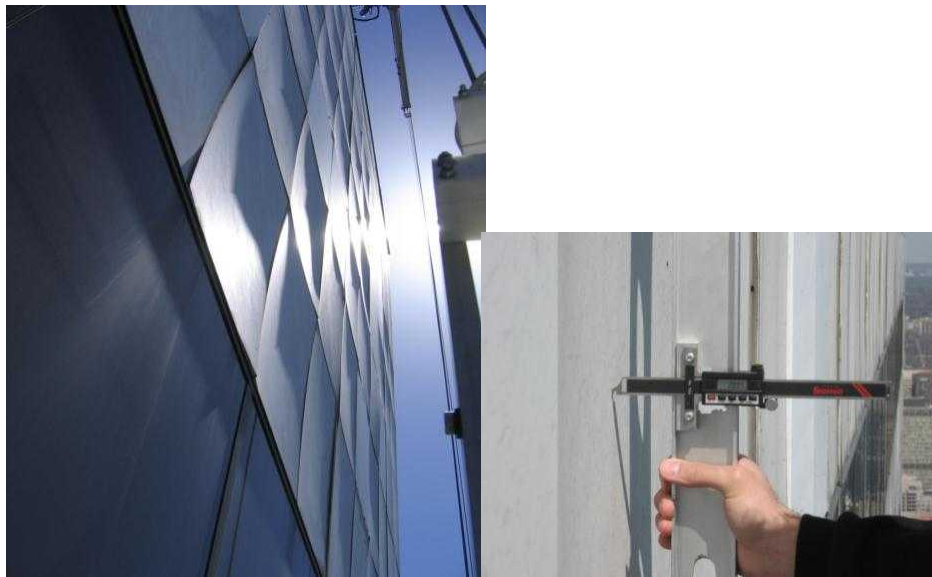
Old vs New Marble Strength



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Bow Measurements

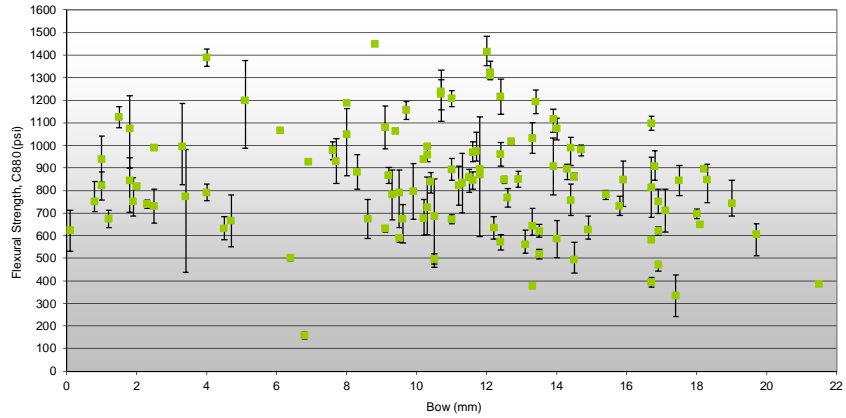


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Bow vs. Strength Analysis

First Canadian Place - Marble Cladding
Bow vs C880 Flexural Strength of Panel Populations Tested in 2005/2006



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Acoustic Testing

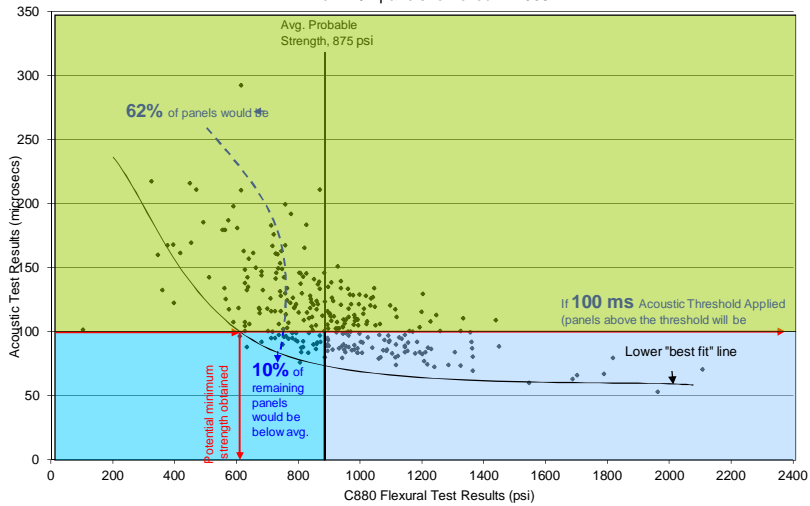


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Acoustic Testing vs Strength

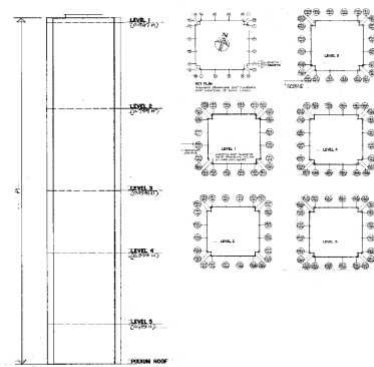
First Canadian Place - 100 King St., Toronto
 100 microsec Acoustic Threshold Applied to Acoustic and Flexural Test Data
 from 291 panels removed in 2005



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1974 Wind Tunnel Testing



ELEVATION
 SECTION THROUGH THE LEVELS
 1. FLOOR TO FLOOR HEIGHT (FFH)
 2. FLOOR TO FLOOR HEIGHT (FFH) INCLUDING SLAB THICKNESS
 3. FLOOR TO FLOOR HEIGHT (FFH) INCLUDING SLAB THICKNESS AND SLAB OVERHANG
 4. FLOOR TO FLOOR HEIGHT (FFH) INCLUDING SLAB THICKNESS AND SLAB OVERHANG AND BALCONY
 5. FLOOR TO FLOOR HEIGHT (FFH) INCLUDING SLAB THICKNESS AND SLAB OVERHANG AND BALCONY AND BALCONY OVERHANG
 6. FLOOR TO FLOOR HEIGHT (FFH) INCLUDING SLAB THICKNESS AND SLAB OVERHANG AND BALCONY OVERHANG AND BALCONY OVERHANG AND BALCONY OVERHANG
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 PODIUM ROOF
 ROOF

Max -50 / +30 psf

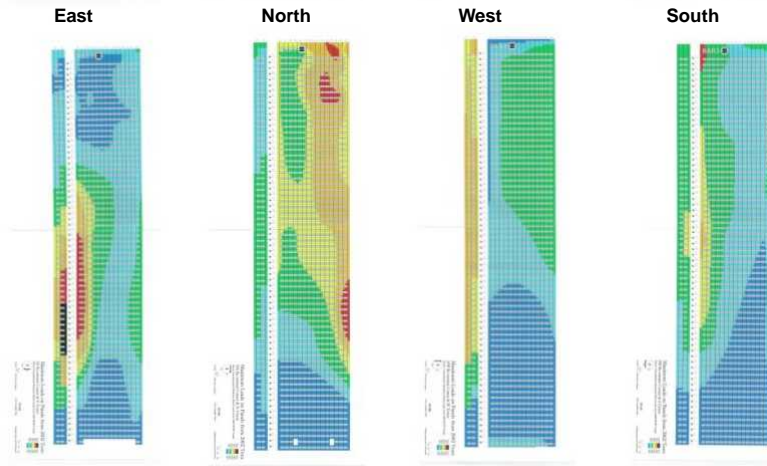
Cladding designed for +/- 60 psf

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2002 Wind Tunnel Testing

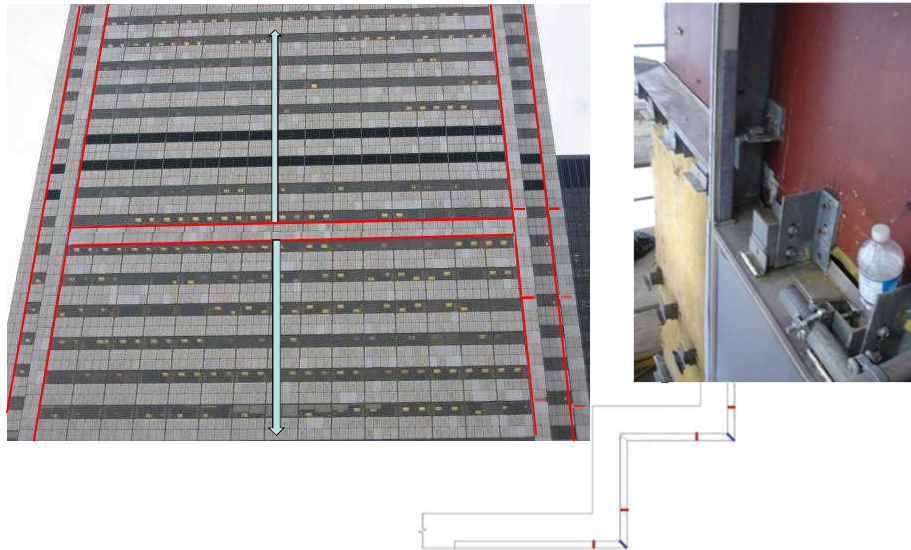
Max -92 psf and +53 psf



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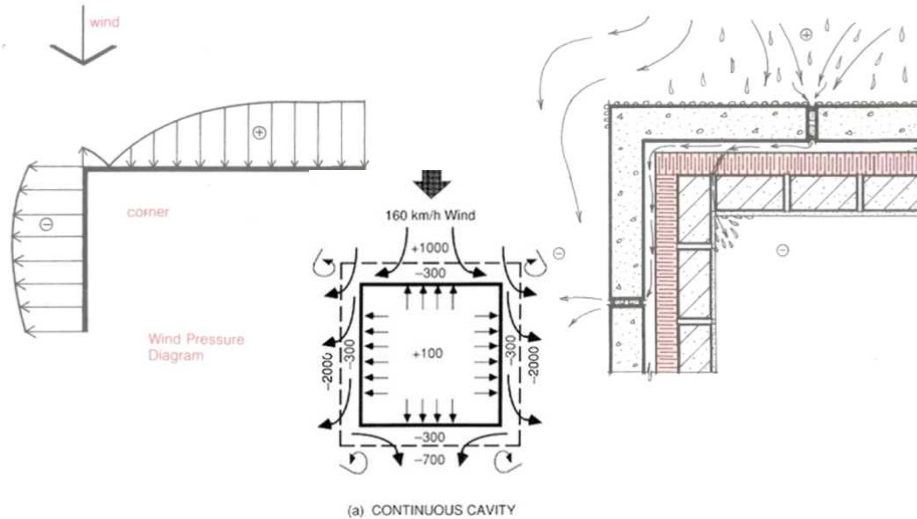
Original FCP Compartment Layout (Red)



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Corner Closure Influence



Images Adopted from "Guide to Energy Efficiency in Masonry and Concrete Buildings" (1982) and Wind and Air Pressures on the Building Envelope (1986)

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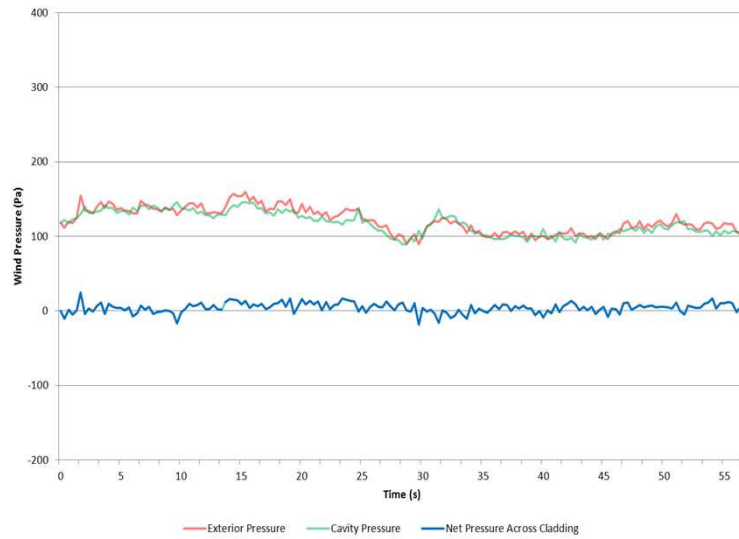
Pressure Measurement



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Pressures at Middle of Wall



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Pressures at Corners



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Prioritized Replacement by Safety Factor

Search Parameters Drop Floor Mark

** Please note you do not have to enter all fields

Drop 01 Floor 05 Mark 1

Elevation

Status Replacement Size

Description

Marble Type

Width (in.) Height (in.)

Strength (psi) Assumed/ CS 880

Thickness (mm) Assumed/ Measured

Wood

2002 Wind Data

+ve Wind Pressure (psf) -ve Wind Pressure (psf)

Pressure Factor

Assumed Max Load (psf)

Bow/ Dish (mm)

Crack Length (inches)

Top Left Top Right

Middle Left Middle Right

Bottom Left Bottom Right

Total Number of Cracks

Joint Thickness (mm)

Top Location of Joint Compression

Bottom

Distress of Anchor

Acoustic Test Results (m/s)

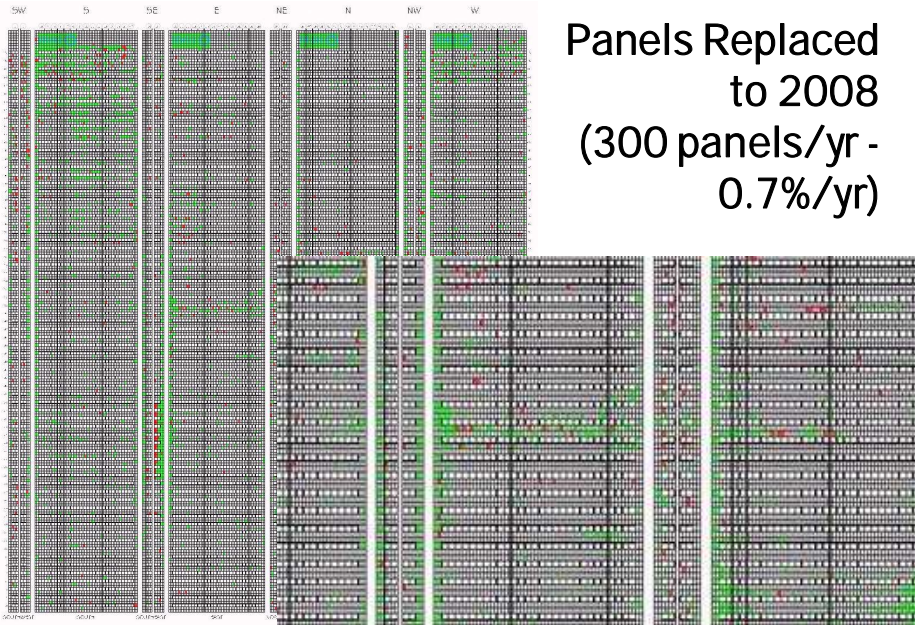
Horizontal Vertical

Surface Corrosion Wedges Present

Rotates Anchor Back of Panel Scratched

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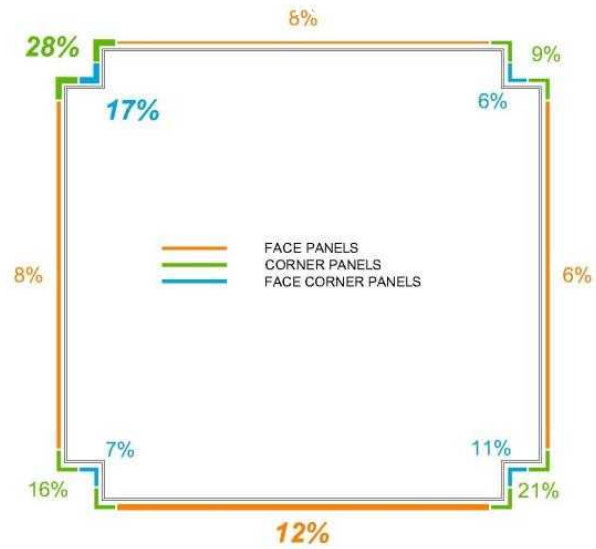
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Percent Replacement



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Silicone Strip Testing for Secondary Restraint



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Decision to Reclad – Business Drivers

- Minimize Risks/Improve Durability
- Eliminate Ongoing Disruption and Cost
- Marketability (LEED EB)
- Renewed Image



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Outline

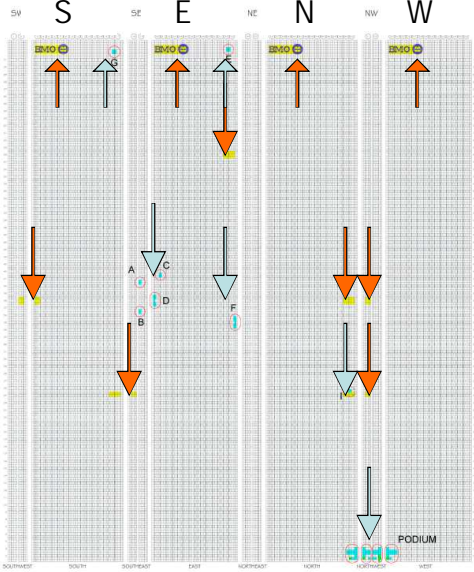
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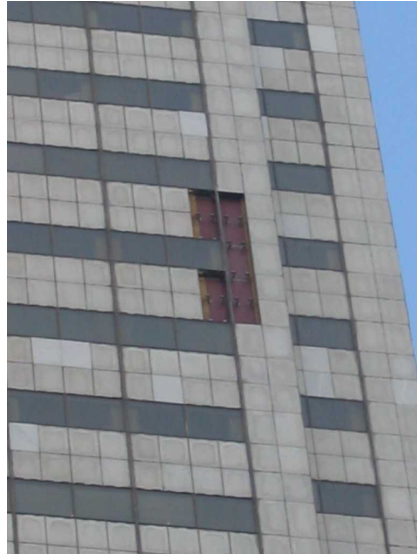
Interior/Exterior Evaluation (Scope)



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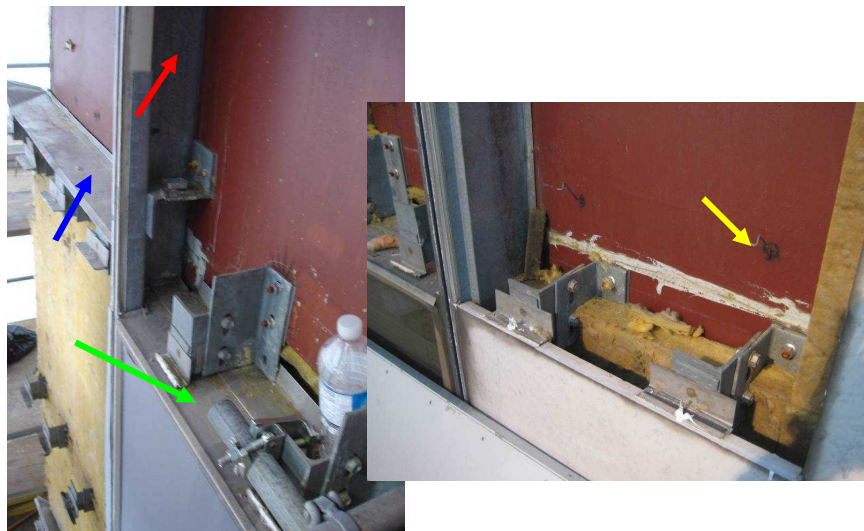
Interior/Exterior Evaluation



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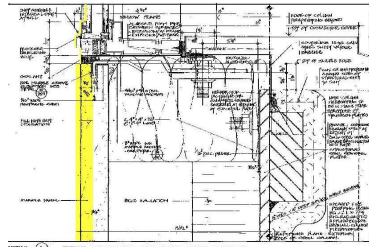
Typ. Section



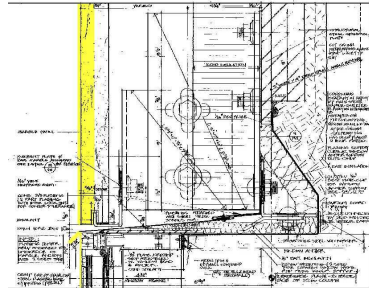
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Finishes



DETAIL (1) TYPICAL MARBLE PANEL CONNECTIONS AT SILL OF WINDOW



DETAIL (2) TYPICAL MARBLE PANEL CONNECTIONS AT HEAD OF WINDOW

EXTERIOR FINISHES

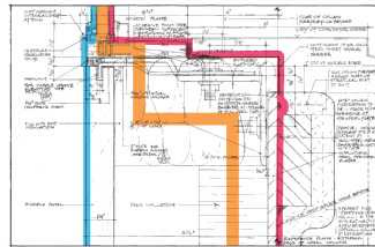


- spandrels
- window components
- sealants

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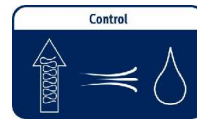
Control Layers



DETAIL (1) TYPICAL MARBLE PANEL CONNECTIONS AT SILL OF WINDOW



DETAIL (2) TYPICAL MARBLE PANEL CONNECTIONS AT HEAD OF WINDOW



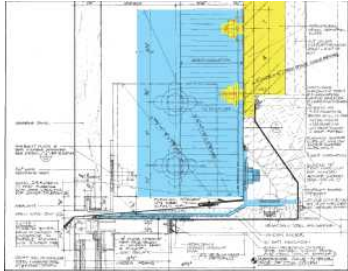
- RAIN
- THERMAL
- AIR FLOW

- Others:
- condensation
 - fire/smoke
 - uv/solar

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Supports



DETAIL (5) TYPICAL MARBLE PANEL CONNECTIONS AT HEAD OF WINDOW

LEGEND
■ WINDOW SUPPORT AND ANCHORAGE
■ SPANDREL PLATE AND WELDED STUD ANCHORAGE



- anchorage/structure
 - wind
 - seismic
 - movement accom.

Key Considerations



- Frame fading/staining
- IGU aesthetics and service life



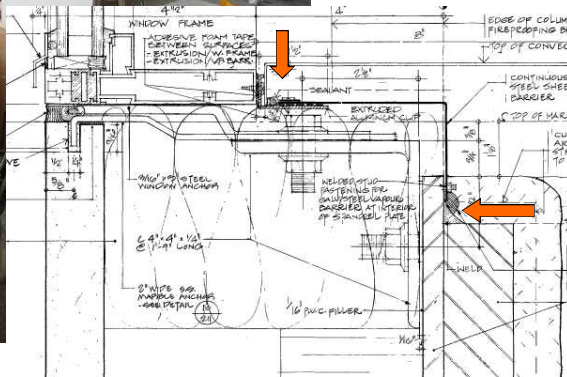
- Air/water tightness
- Solar/glare/comfort
- Thermal/condensation
- Fire



- Frame/anchorage/glass capacity and condition
- Blast resistance
- Cavity Air Pressures



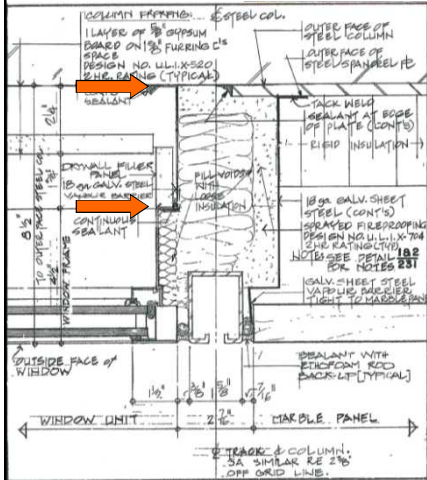
Air Seals Generally in Good Condition



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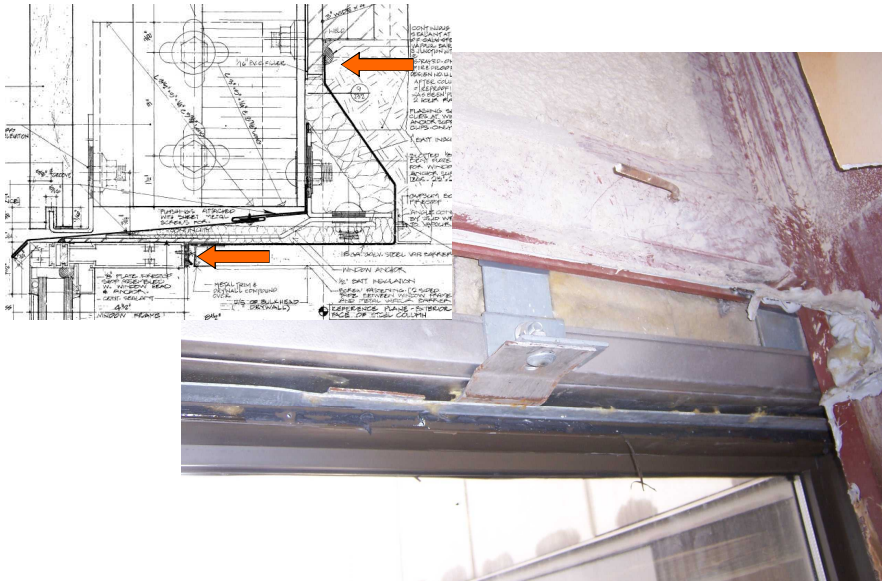
Air Seals Generally in Good Condition



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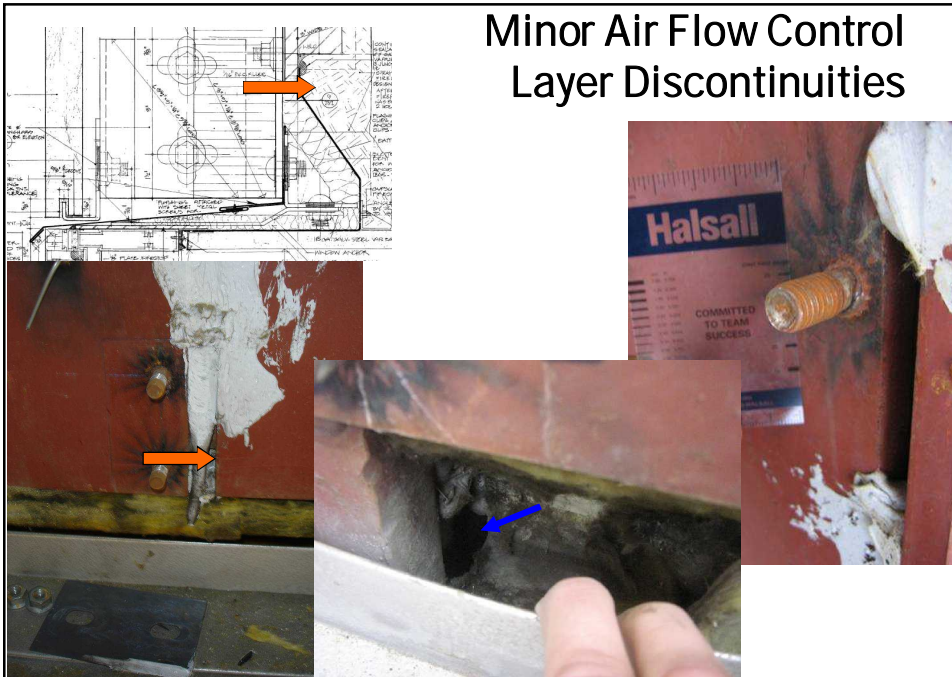
Air Seals Generally in Good Condition



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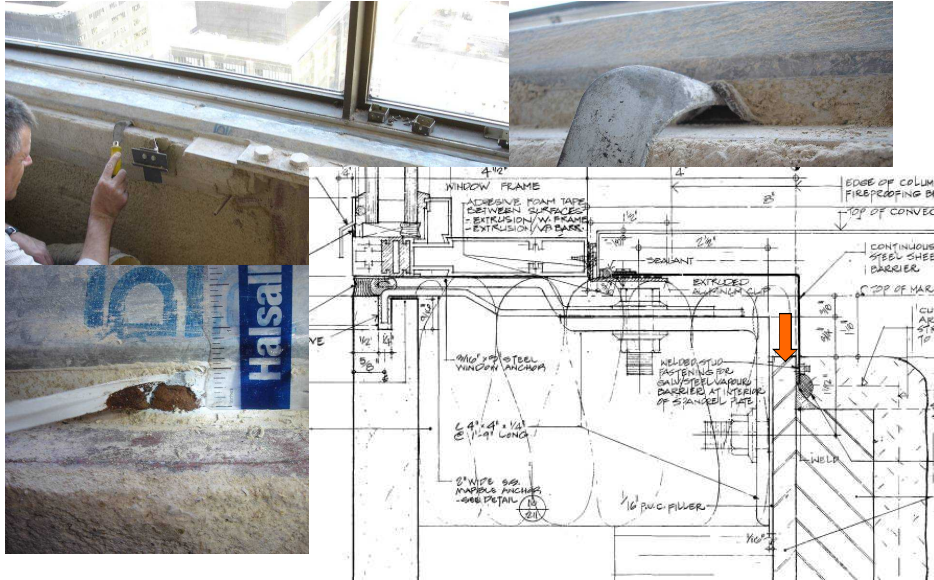
Minor Air Flow Control Layer Discontinuities



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Corrosion Impacting Air Seal Durability



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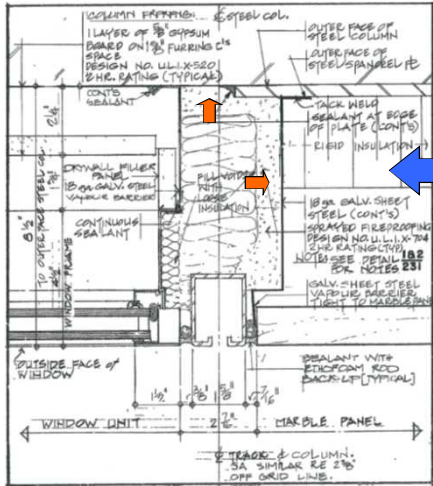
Corrosion Impacting Air Seal Durability



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Missing Fire Separation (window term. at full height marble)



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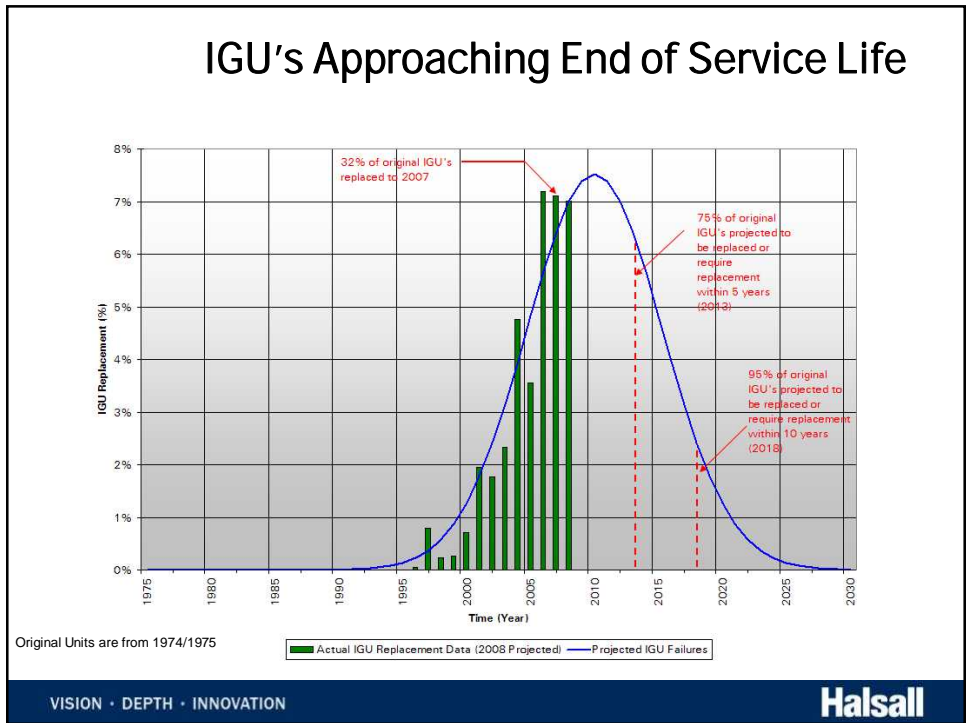
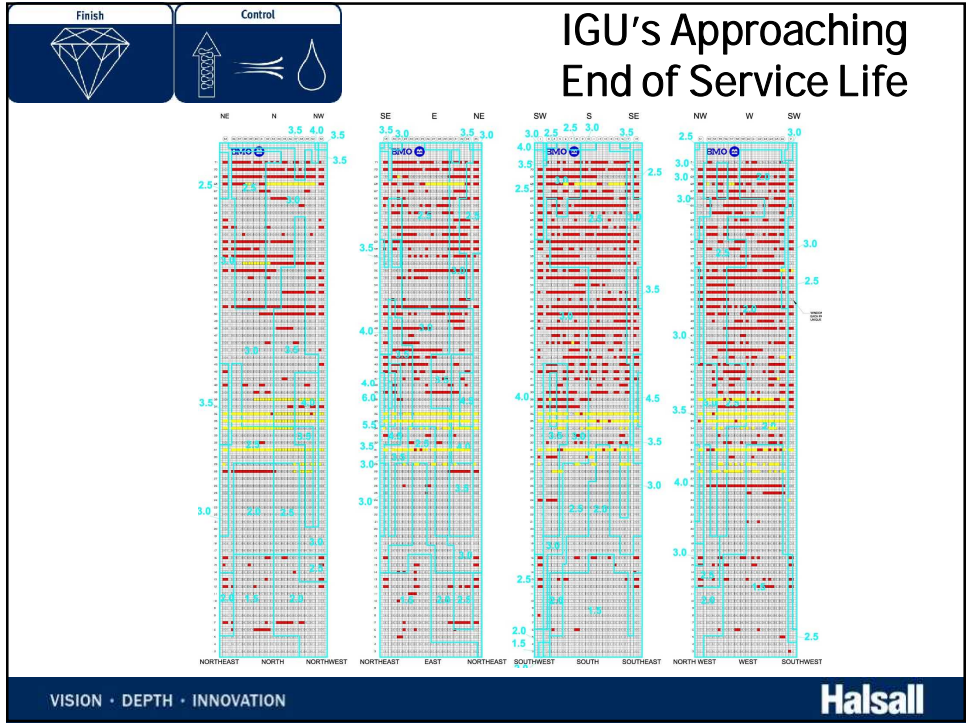


Exterior Window Frame and Metal Flashing Finish Faded/Stained

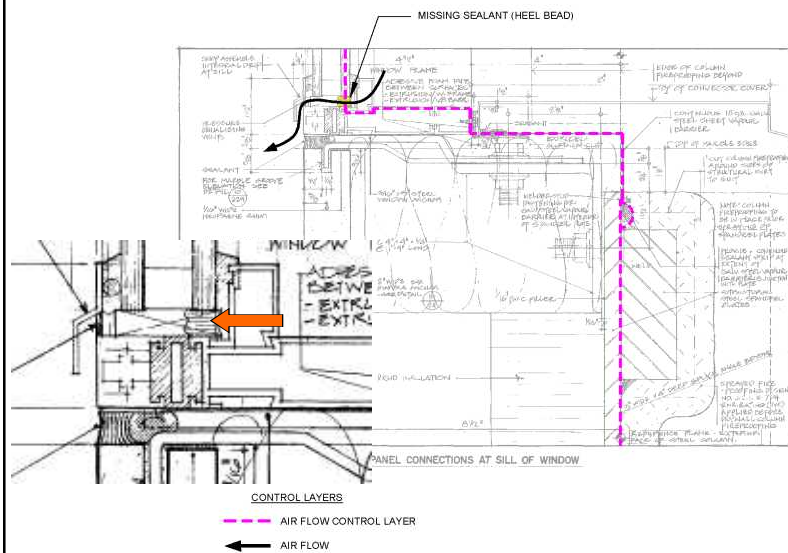


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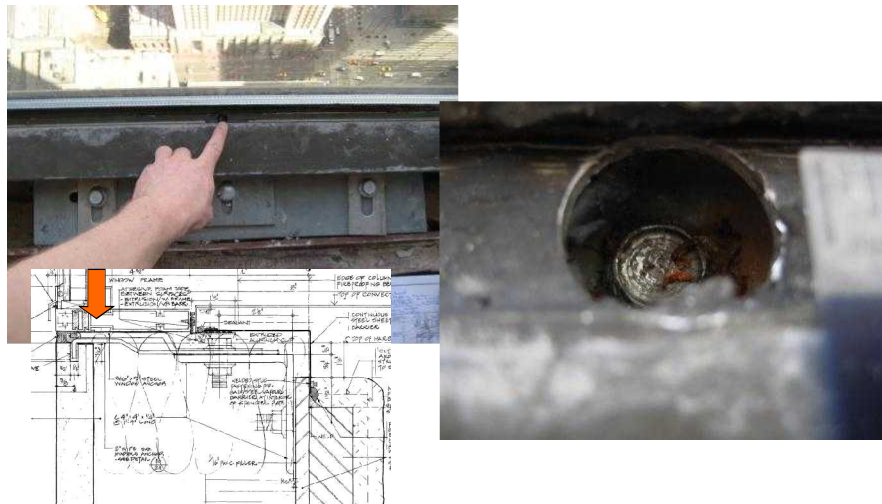
Premature IGU Failures Where Original Units Replaced



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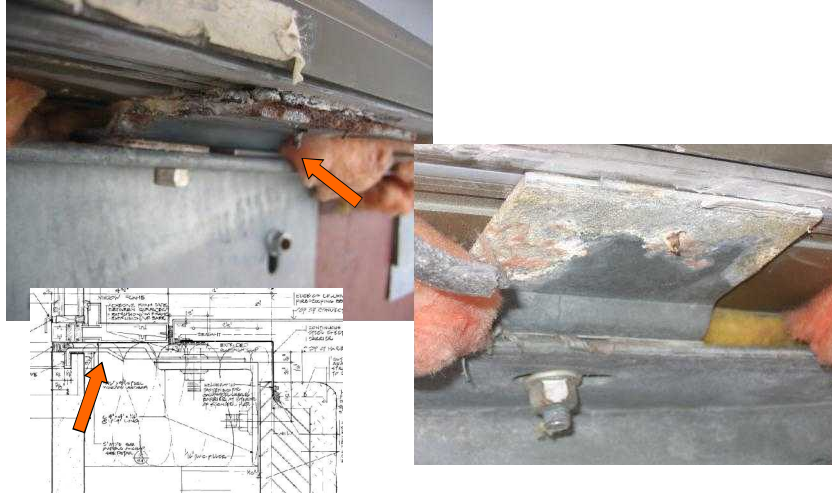
Window Sill Connection Required Reinforcement



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Corrosion at Window Sill Connection

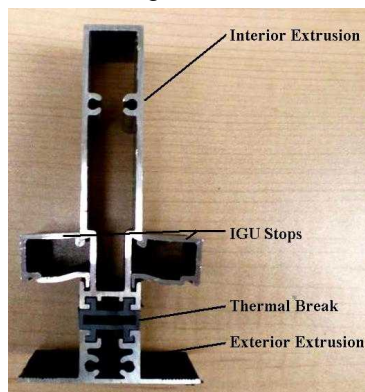


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Window Assembly Capacity Satisfactory for New Wind Loads

- Mullion Assembly Structural Capacity
- Full Scale Testing – ASTM E330

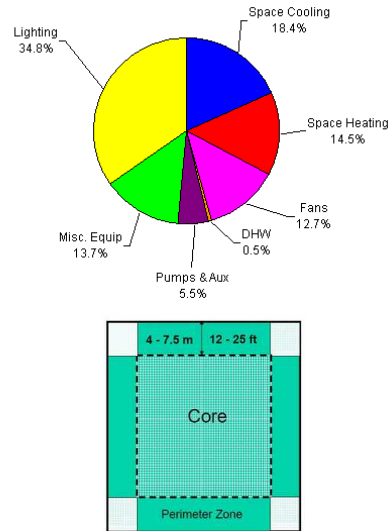


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Energy Consumption Not Sensitive to Cladding Upgrades

- low glazing-to-wall ratio
- core dominated building
- enclosure's role is largely comfort-related in the perimeter zones



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Re-Cladding vs. Over-Cladding

- | | |
|--|--|
| <ul style="list-style-type: none">• New Cladding Finish at Spandrels• Repair Existing Support/ Control at<ul style="list-style-type: none">– Spandrels– Windows• Restore Finish at Window Frames• Replace IGU's where Required | <ul style="list-style-type: none">• New Continuous façade:<ul style="list-style-type: none">– Finish– Control– Support• Remove Existing IGU's• Interior Trim Modifications |
|--|--|

Over-cladding rejected:
cost
schedule
tenant disruption
change to original design intent

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Design Objectives

- Renew Image
- Improve Durability
- Restore Performance
- Streamline Process/Schedule
- Facilitate Future Maintenance
- Economical



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Project Challenges

- Several Owners
- Building Fully Occupied
- Aggressive Schedule
- Architectural Requirements
- Site Constraints



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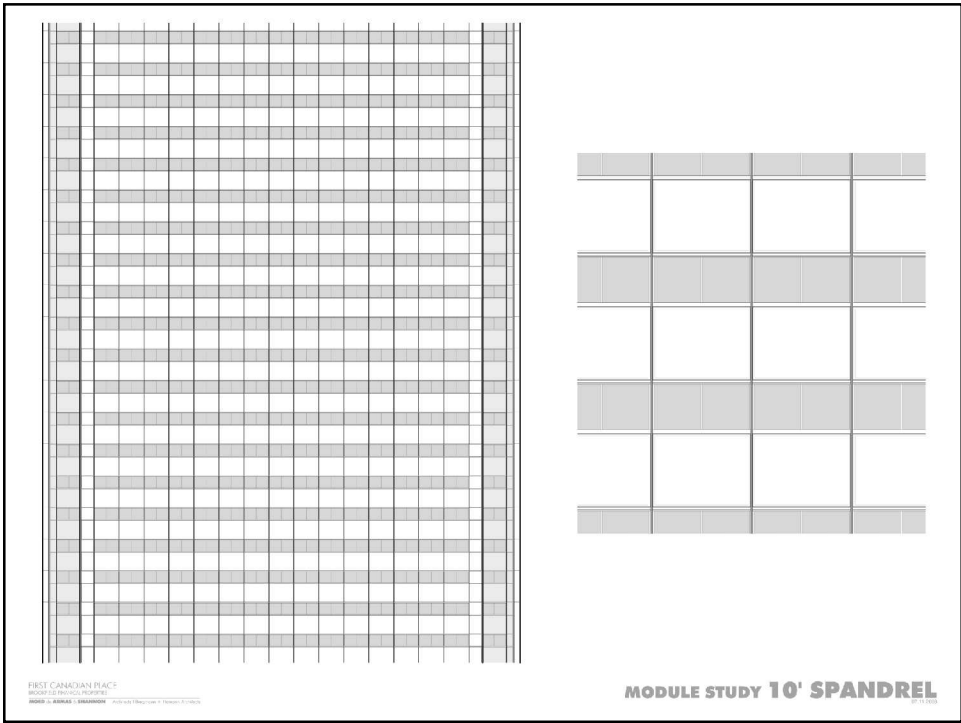
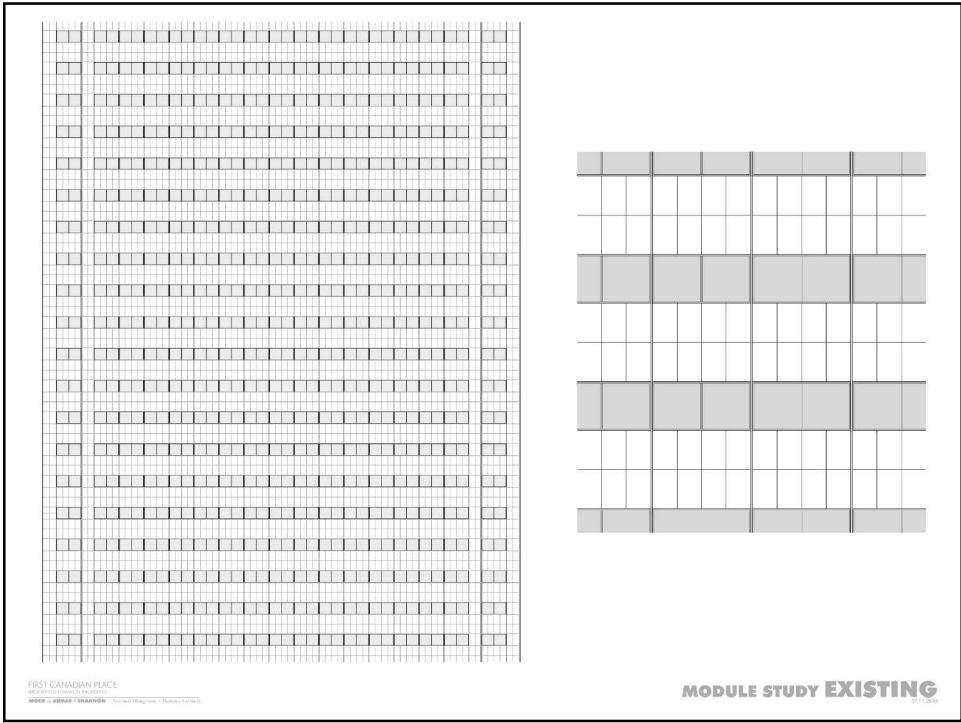
Architect's Vision

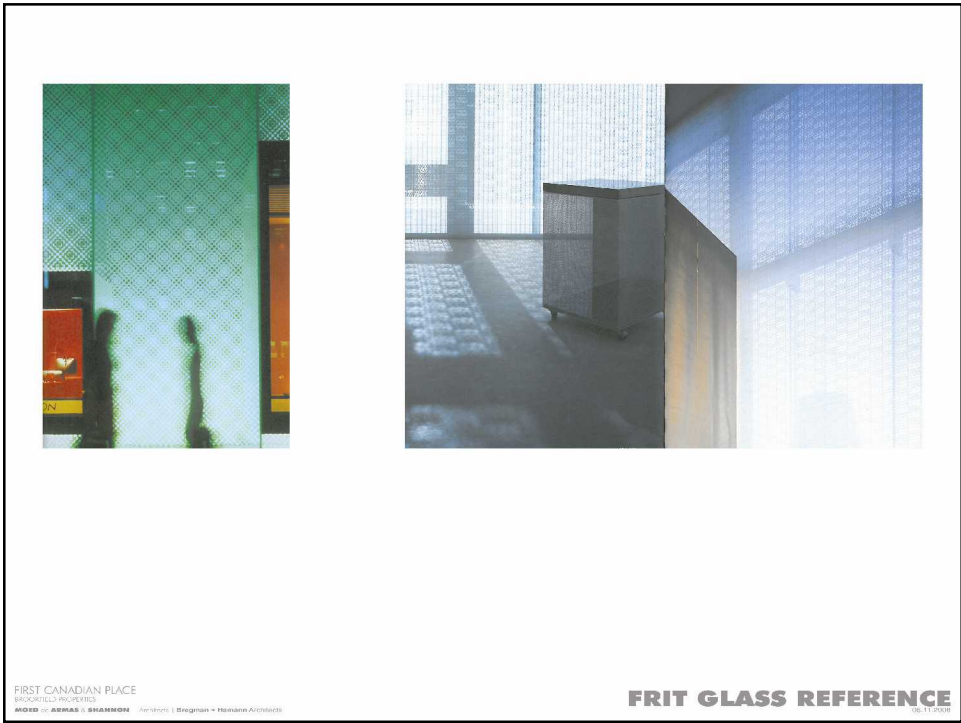
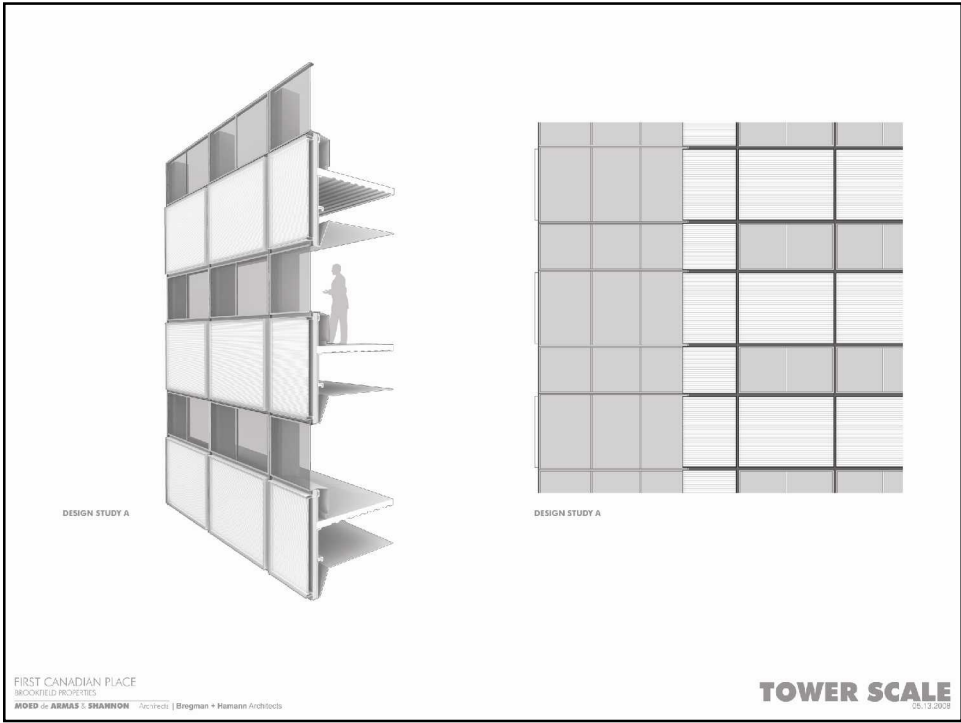
White/Bright
Improved Scale
Patterned Glass

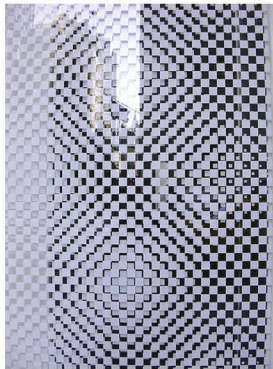


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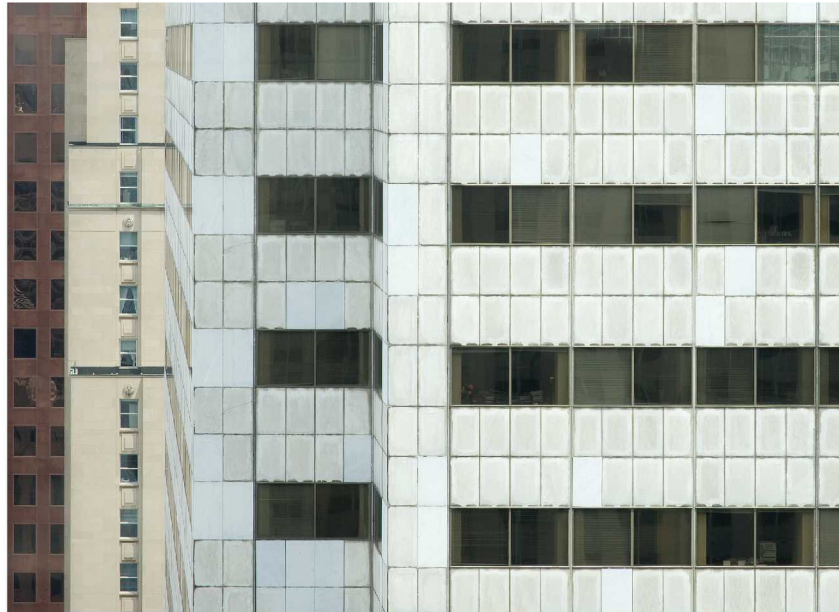






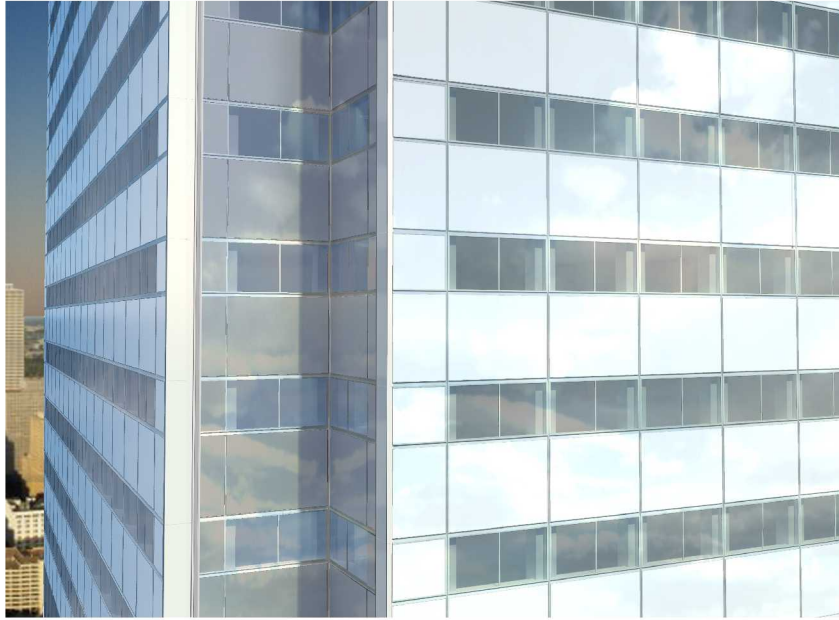
FIRST CANADIAN PLACE
PROJECTED PROPERTIES
ANDERSON, KEMAS & SHANNON ARCHITECTS | Bregman + Plonkowsky Architects

FRIT GLASS REFERENCE
06.11.2008



FIRST CANADIAN PLACE
PROJECTED PROPERTIES
ANDERSON, KEMAS & SHANNON ARCHITECTS | Bregman + Plonkowsky Architects

CORNER VIEW EXISTING
06.11.2008



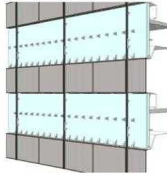
FIRST CANADIAN PLACE
 100 KING STREET WEST, TORONTO, ONTARIO
 4889-1-ARABIAN / 1-800-387-7222

CORNER VIEW BRONZE GLASS

Conceptual Work Flow



Step 1: Existing marble panels are removed



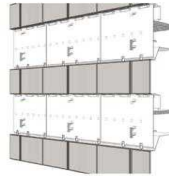
Step 2: Existing insulation is removed



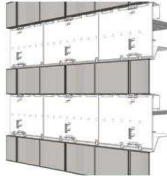
Step 3: Existing marble support clips are removed



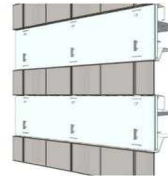
Step 4: Window washing tracks are removed



Step 5: Remedial work



Step 6: New anchors for curtainwall and new window washing tracks are installed



Step 7: New insulation is installed



Step 8: USP curtainwall and trim is installed

image by MdeAs

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Removals



Image by B&H

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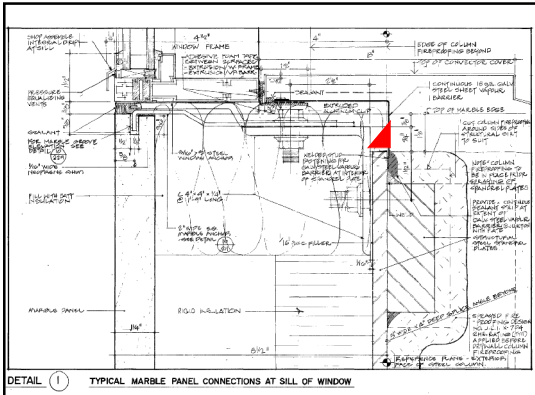
Restore Concealed Seals



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Restore Concealed Seals



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Upgrade Secondary Drainage Plane Seals



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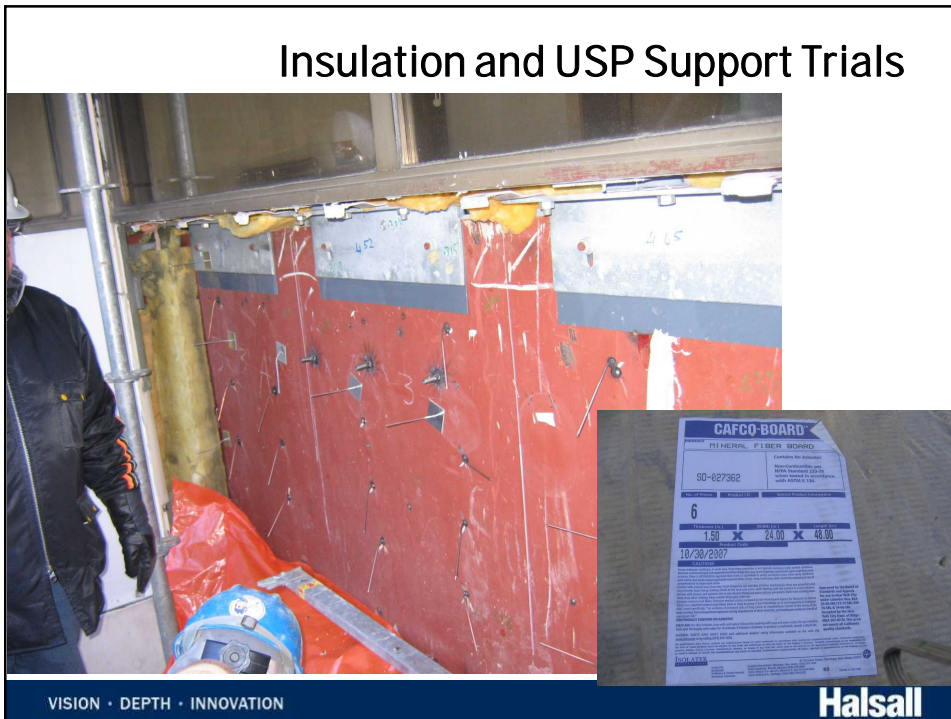
Supplemental Anchors and Corrosion Protection



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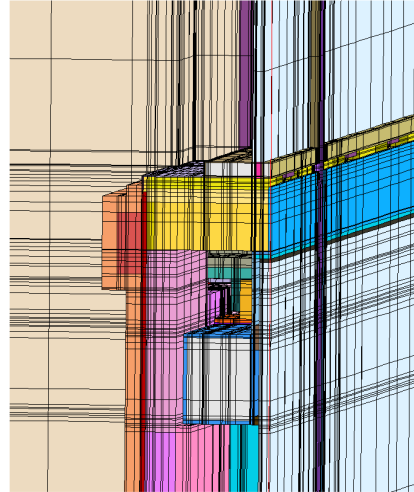
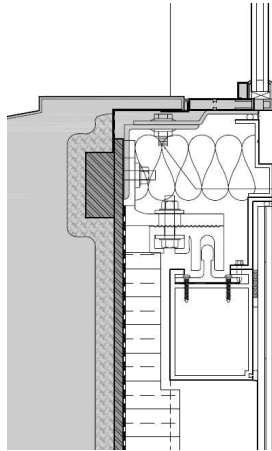
Insulation and USP Support Trials



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Thermal Modeling



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Performance Modeling Glare Analysis



FCP West Elevation

Simulated a Cladding with Reflective (Mirror-like) Glass Spandrels
 View from Exchange Tower 38th Floor, September 21, 5:00pm

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Architects and Glass



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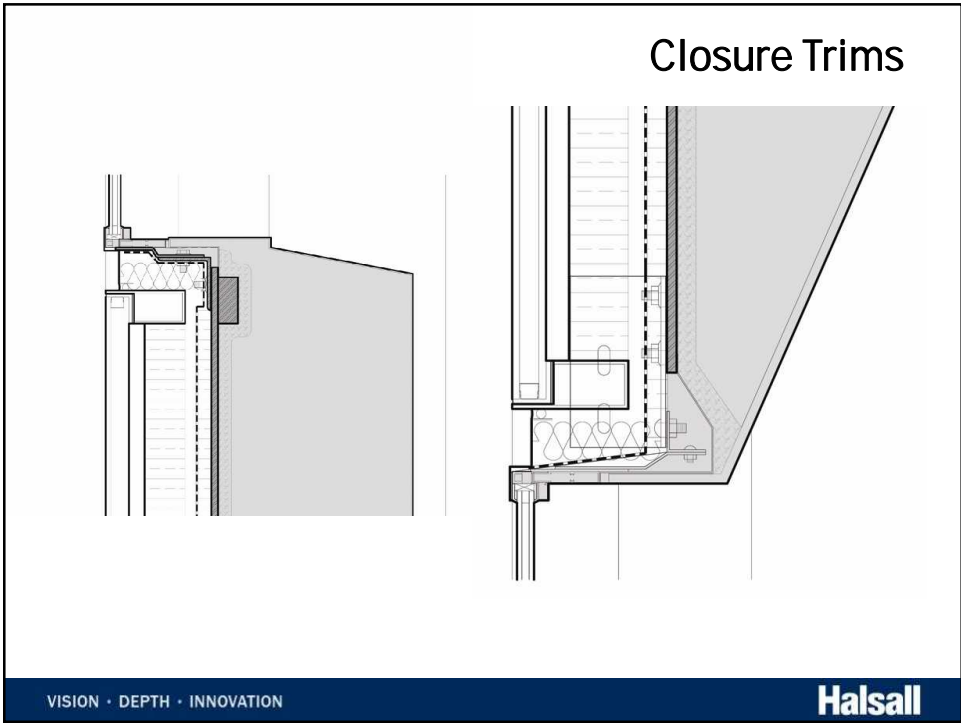
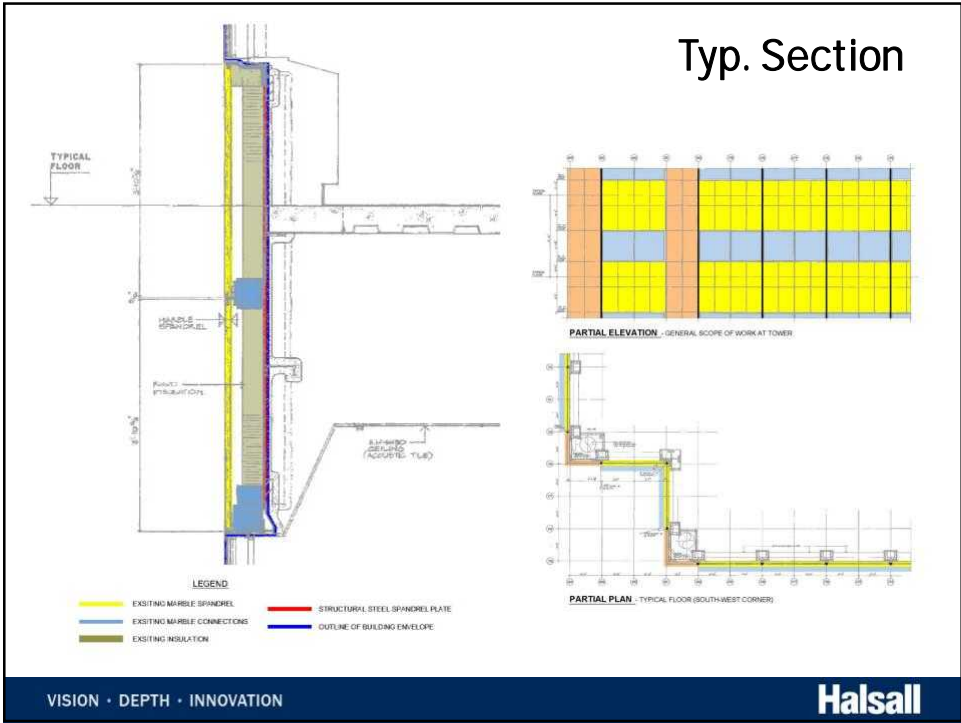
Key Considerations – Finish/Support

- Glass Size
- Glass Colour/Pattern
- Glass Type



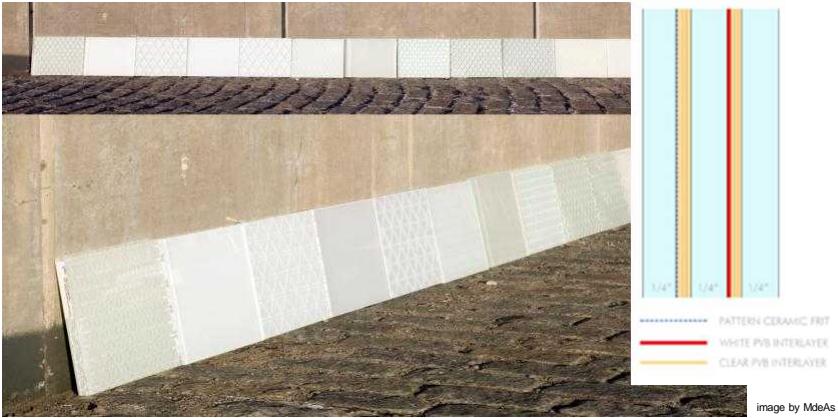
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Glass

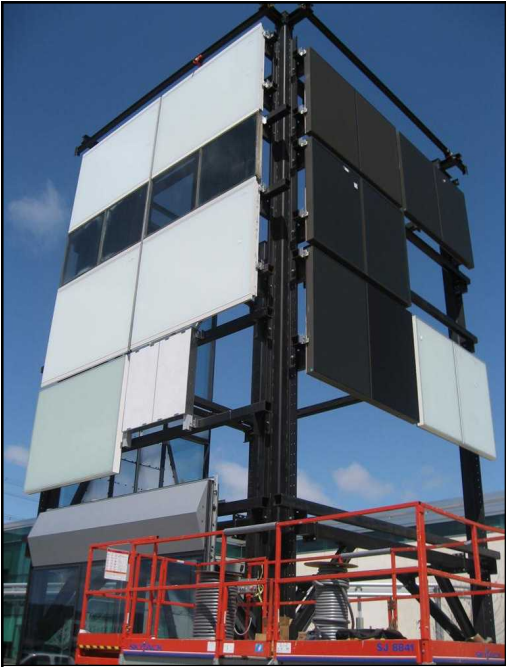
- IGU vs Laminated Glass
- Frit Study
- Flatness
- Retention



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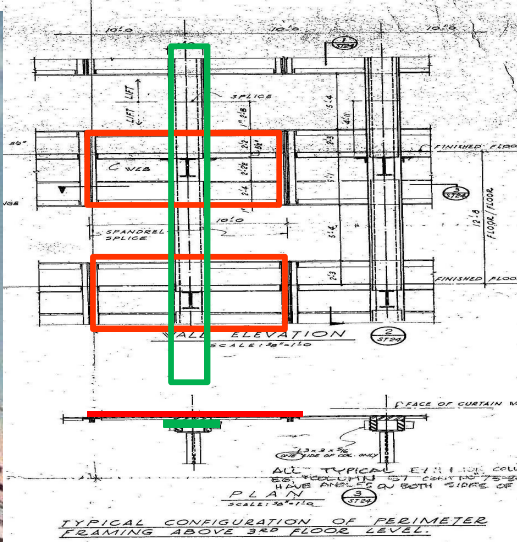
Glass Mockups



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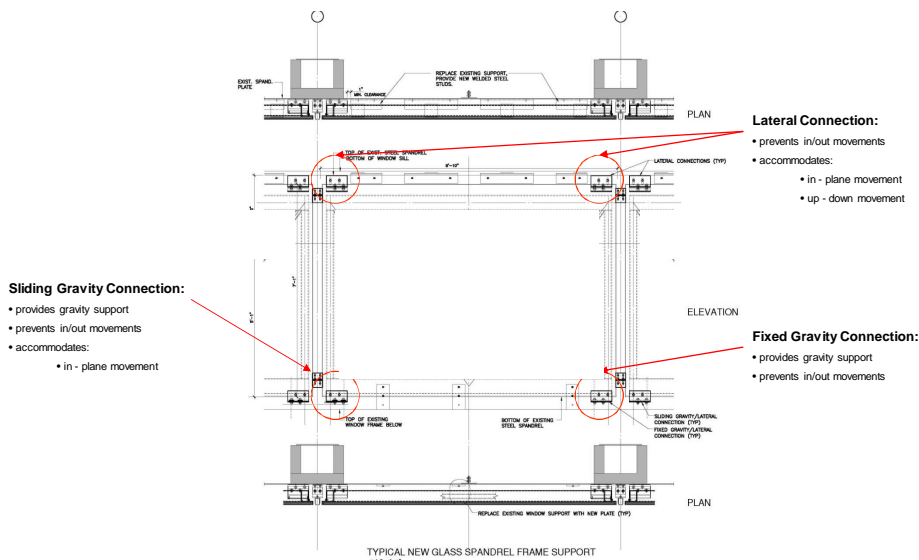
Typ. Perimeter Framing



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Unitized Spandrel Frame and Support



Sliding Gravity Connection:

- provides gravity support
- prevents in/out movements
- accommodates:
 - in - plane movement

Lateral Connection:

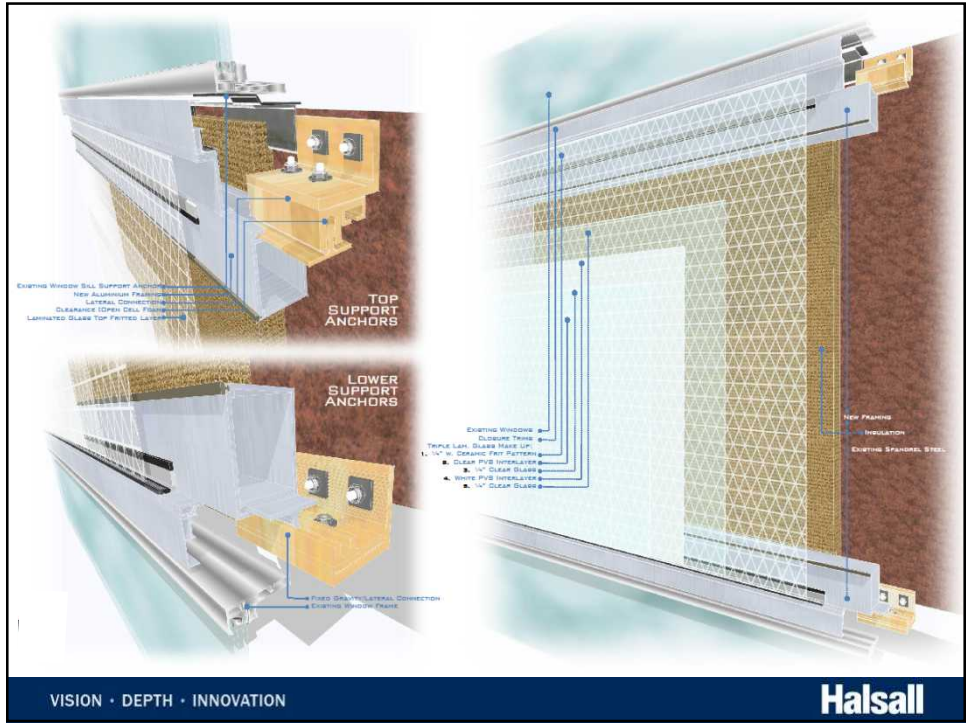
- prevents in/out movements
- accommodates:
 - in - plane movement
 - up - down movement

Fixed Gravity Connection:

- provides gravity support
- prevents in/out movements

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On-Site Mockups



Typical Panel



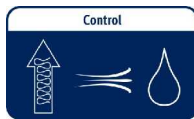
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Glass Design Considerations



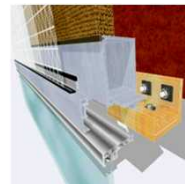
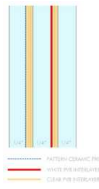
- Transparency
- Aesthetics
- Constructability
- Availability



- Exposure
- VLT/SHG/UV
- Comfort
- Condensation



- Load Types
- Glass Types
- Components
- Redundancy
- Post breakage



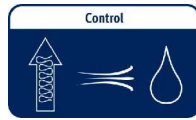
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Glass Design Considerations



- Transparency
- Aesthetics
- Constructability
- Availability

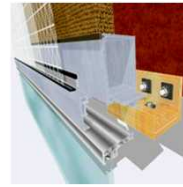
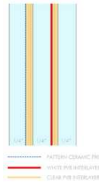


- Exposure
- VLT/SHG/UV
- Comfort
- Condensation



- Load Types
- Glass Types
- Components
- Redundancy
- Post breakage

Performance / Maintenance / Repair / Replacement / Cost



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Glass Design

Codes & Standards vs. Rational Engineering Analysis

Balance between Actions and Reactions

Action: Applied Loads

Reactions: Glass Strength

Limit State Design

– Strength and Stability

– Serviceability

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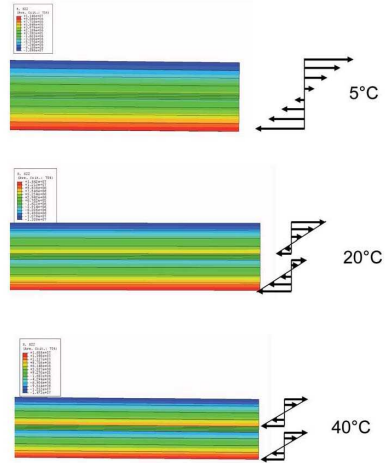
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Design Issues

- Laminated glass behavior
 - Monolithic
 - Laminated
 - Layered

Load Resistance

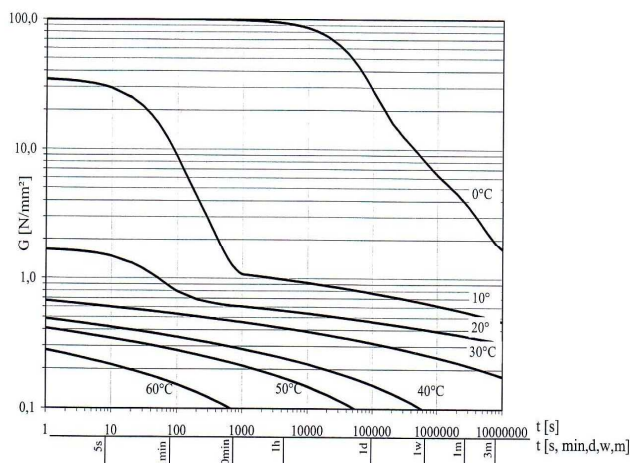
- Heat treatment
- Load duration
- Design temperature



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PVB Interlayer Shear Modulus



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Design Issues

- Laminated glass behavior
 - Monolithic
 - Laminated
 - Layered
- Load Resistance
 - Heat treatment
 - Load duration
 - Design temperature

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CGSB/ASTM

TABLE 3

Load Duration and Temperature Limits for Considering Laminated Glass as Monolithic or Layered Glass
 Limites de durée des charges et de température pour calculer le verre laminé comme du verre monolithique ou en couches

Load Duration Durée des charges	Temperature/Température		
	< 20°C	20° to/à 70°C	> 70°C
< 1 min	Monolithic Monolithique	Monolithic Monolithique	Layered En couches
1 min to 1 week 1 min à 1 semaine	Monolithic Monolithique	Layered En couches	Layered En couches
> 1 week 1 semaine	Layered En couches	Layered En couches	Layered En couches

CGSB12.20

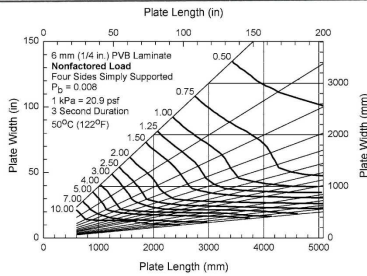


TABLE X6.1 Load Duration Factors
 Note 1—Calculated to 8/1000 lives probability of breakage (see 3.2.11).

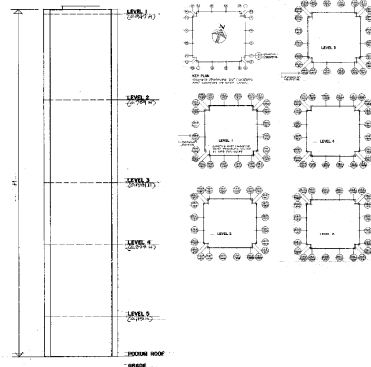
Duration	Factor
3 s	1.00
10 s	0.83
60 s	0.63
10 min	0.72
60 min	0.64
12 h	0.55
24 h	0.53
1 week	0.47
1 month (30 days)	0.43
1 year	0.36
beyond 1 year	0.31

ASTM E1300-09

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1974 Wind Loads



ELEVATION

- 1. EXISTING STRUCTURE TO BE REBUILT
- 2. NEW STRUCTURE TO BE ADDED TO EXISTING
- 3. EXISTING STRUCTURE TO BE DEMOLISHED
- 4. EXISTING STRUCTURE TO BE REBUILT WITH NEW MATERIALS
- 5. EXISTING STRUCTURE TO BE REBUILT WITH NEW MATERIALS AND STRUCTURE
- 6. EXISTING STRUCTURE TO BE REBUILT WITH NEW MATERIALS AND STRUCTURE
- 7. EXISTING STRUCTURE TO BE REBUILT WITH NEW MATERIALS AND STRUCTURE
- 8. EXISTING STRUCTURE TO BE REBUILT WITH NEW MATERIALS AND STRUCTURE
- 9. EXISTING STRUCTURE TO BE REBUILT WITH NEW MATERIALS AND STRUCTURE
- 10. EXISTING STRUCTURE TO BE REBUILT WITH NEW MATERIALS AND STRUCTURE

WLT: Max -50 / +30 psf

Design: +/- 60 psf

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Wind Tunnel Re-Analysis

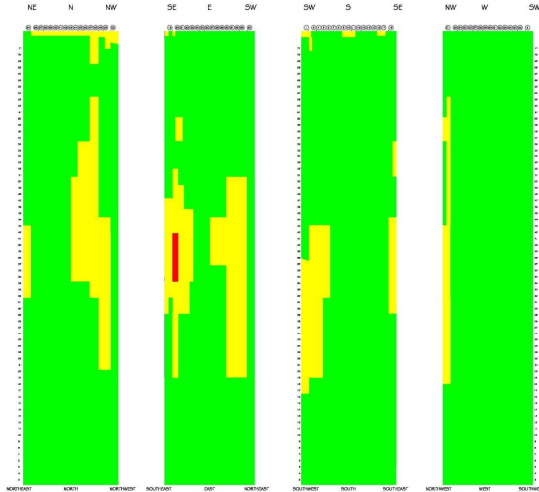


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2008 Wind Tunnel Study



Max loads
- 117 / +56 psf

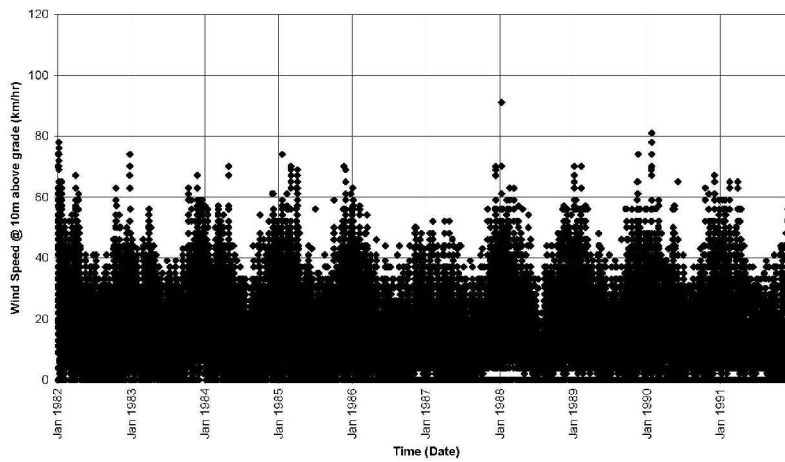
Design Loads
≤ 60 psf 85% area
60 to 94 psf 15% area
>94 psf <0.5% area

Original Cladding design
wind loads +/- 60 psf

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Wind vs. Temp



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Glass/USP QA/QC Considerations

- Performance Testing
 - Static and Cyclic Structural
 - Inter-storey Drift/Lateral Movement
 - Post-Breakage
- Fabrication Monitoring and testing
 - Heat Treatment
 - Lamination Process
 - Laminated Testing Services
 - Shop Reviews

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Construction Logistics

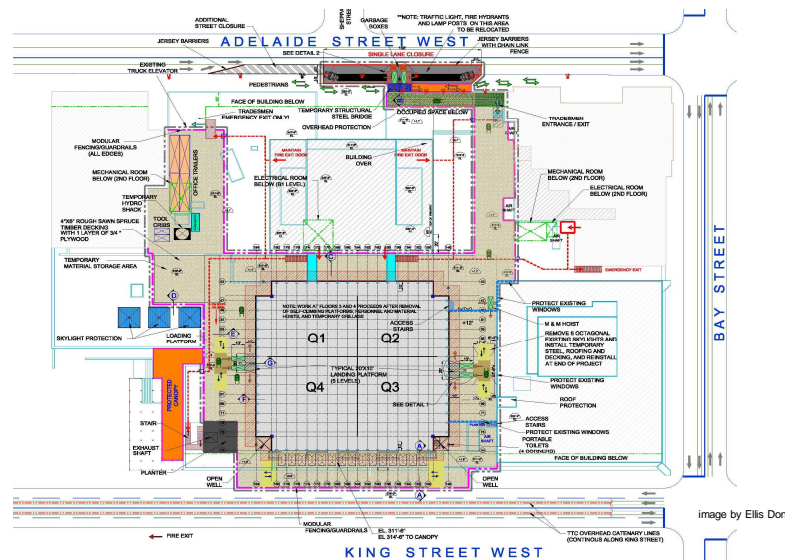
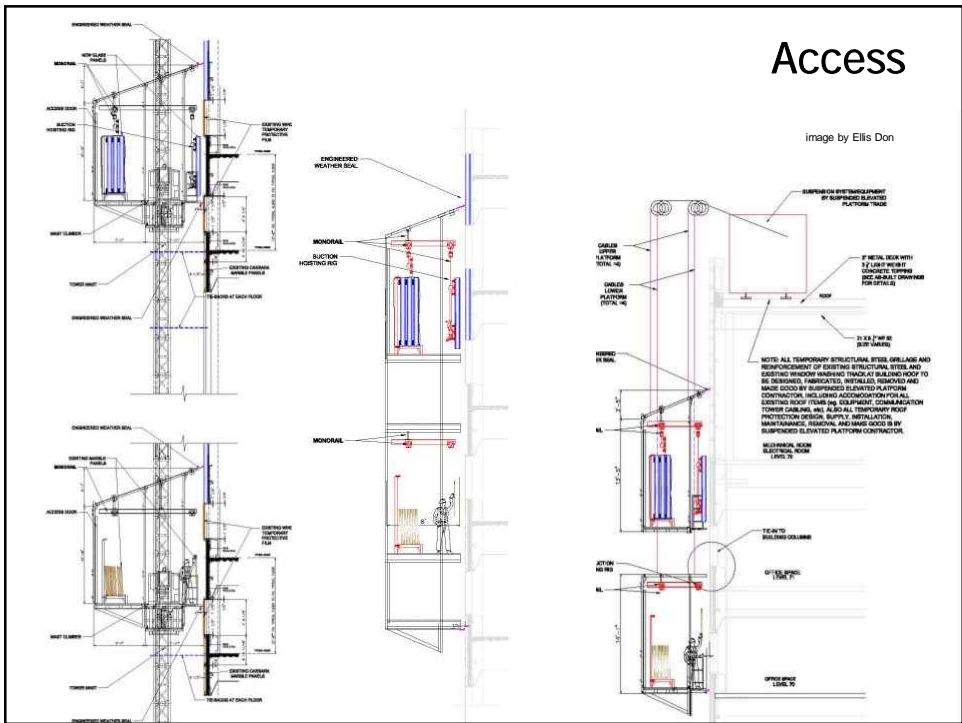
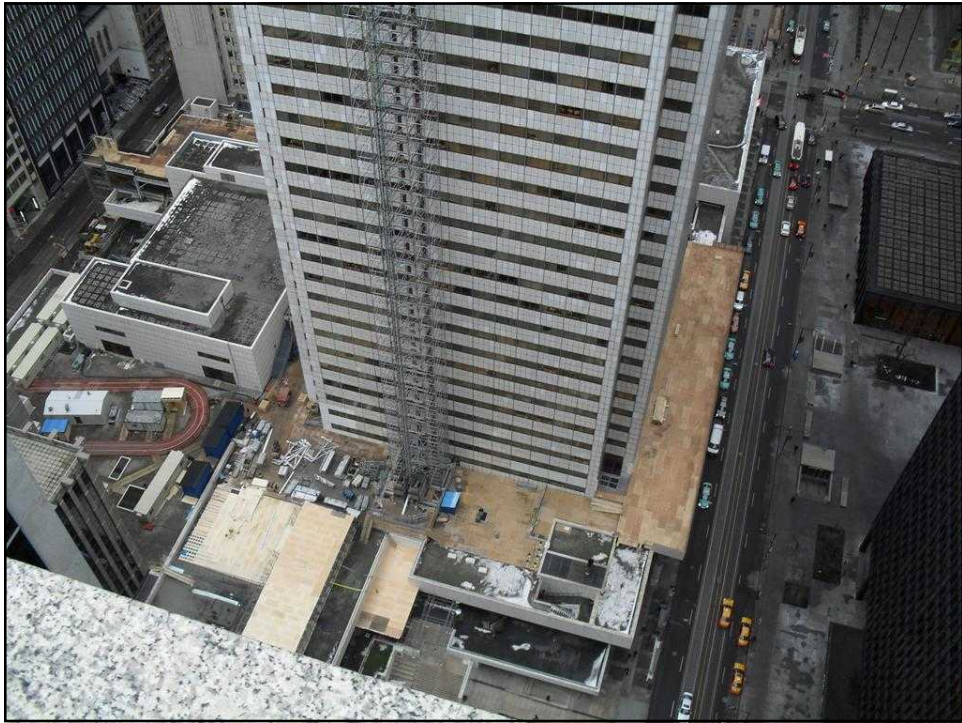


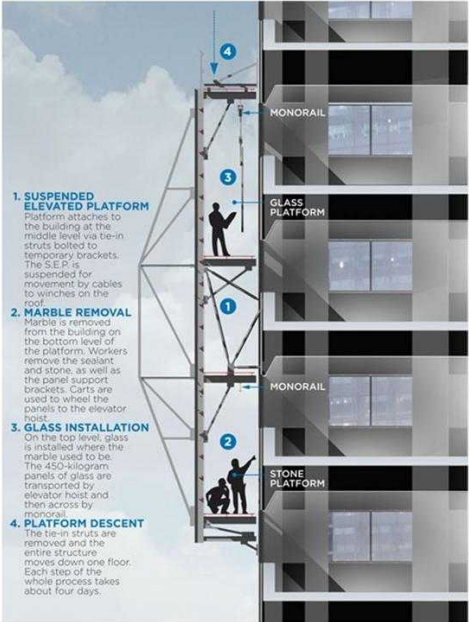
image by Ellis Don

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Access



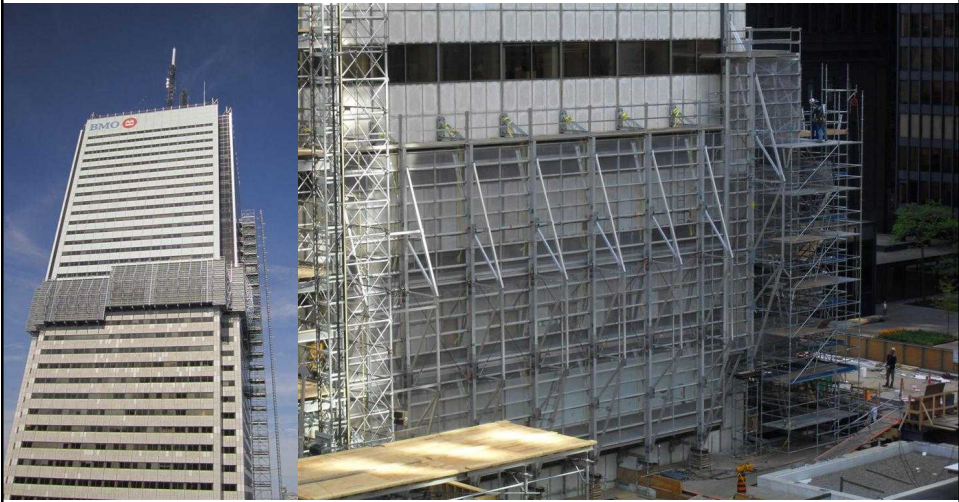
- 1. SUSPENDED ELEVATED PLATFORM**
Platform attaches to the building at the middle level via tie-in struts bolted to temporary brackets. The S.E.P. is suspended for movement by cables to winches on the roof.
- 2. MARBLE REMOVAL**
Marble is removed from the building on the bottom level of the platform. Workers remove the sealant and stone, as well as the panel support brackets. Carts are used to wheel the panels to the elevator hoist.
- 3. GLASS INSTALLATION**
On the top level, glass is installed where the marble used to be. The 450-kilogram panels of glass are transported by elevator hoist and then across by monorail.
- 4. PLATFORM DESCENT**
The tie-in struts are removed and the entire structure moves down one floor. Each step of the whole process takes about four days.

image by B&H

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Access



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Replacement



The image shows a tall skyscraper in a city center. The top portion of the building is under renovation, with a new, modern facade being installed. The old facade is visible on the lower part of the building. The BMO logo is visible on the top of the building. The sky is clear and blue.

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Completed Product



The image shows a close-up view of the completed modern facade of the skyscraper. The facade is composed of a grid of white panels and glass windows. The windows are illuminated from within, showing a warm yellow light. The building is set against a clear sky.

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Completed Product



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photo by B&H



image by MleAs



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Outline

- Background
- Marble Management
- Building Renewal Vision
- Existing Construction Evaluation
- Re-Cladding Design
- Energy Retrofits



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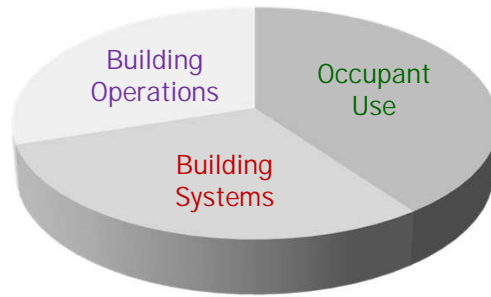
The Process

PLANNING → INVESTIGATION > IMPLEMENTATION > TEACHING > MONITORING

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Approach



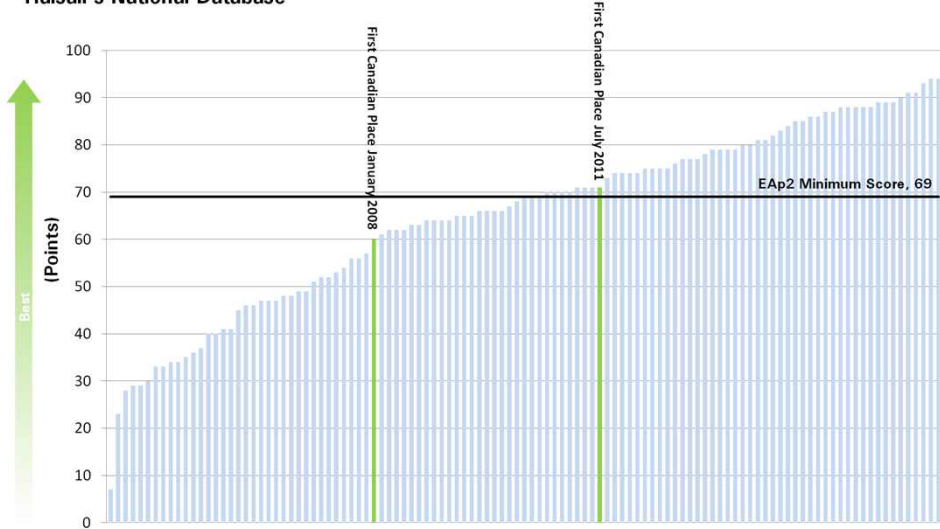
NOT: "Is this the most efficient pump?"
BUT: "Is this pump needed, and is it running when and how it should?"

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Benchmarking

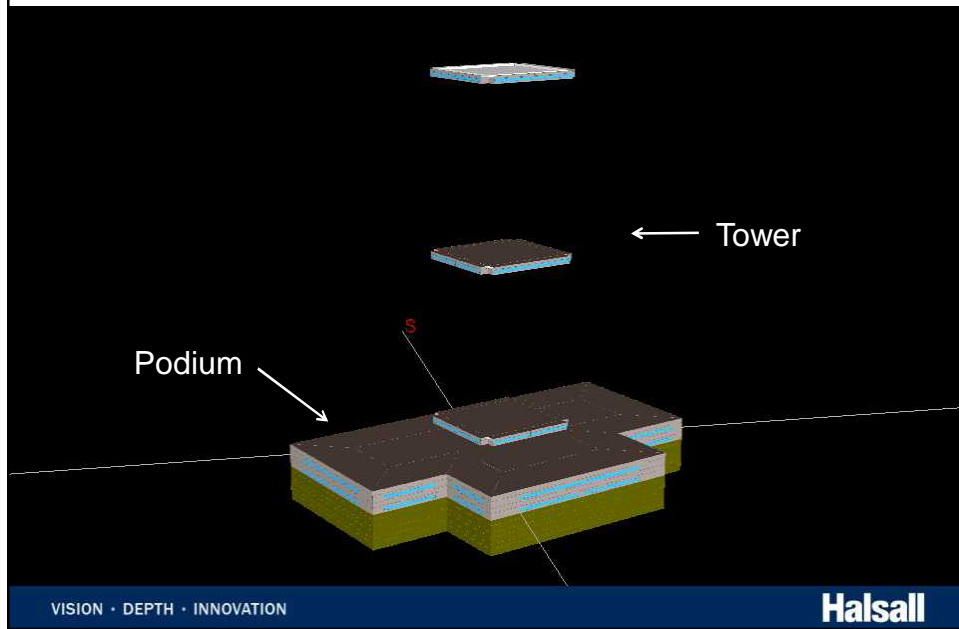
Halsall's National Database



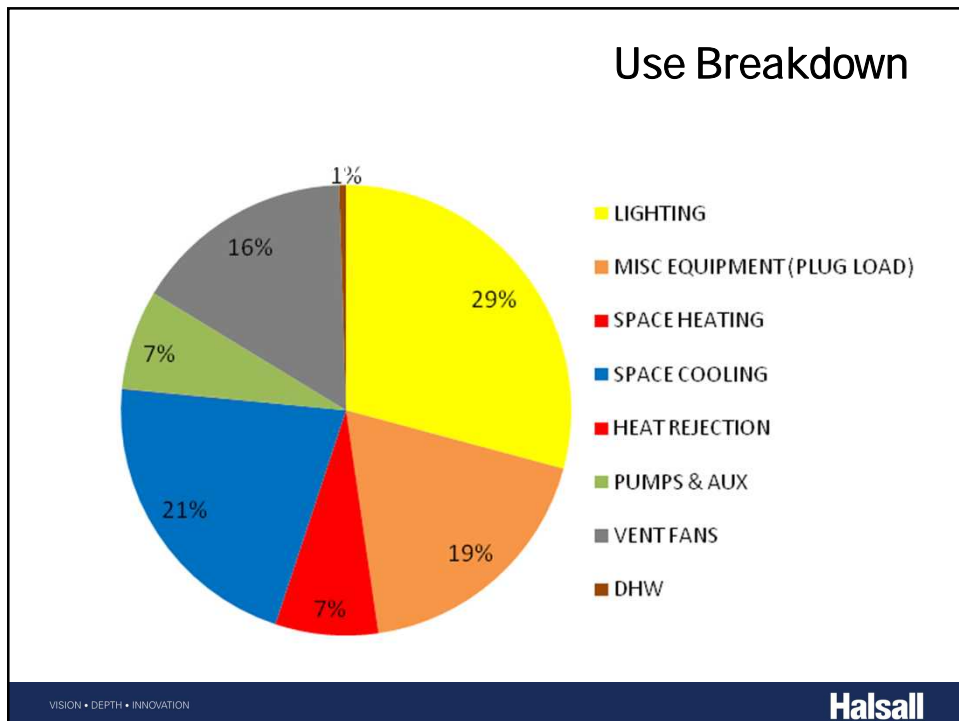
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Energy Modelling



Use Breakdown





Building Systems

- Tower Lighting Power Reduction
- Garage Lighting Power Reduction
- VFD's on MAU's
- Reduce OA to ASHRAE
- Demand Control Ventilation
- Exhaust Reduction
- Exhaust Heat Recovery
- Induction Unit Switchover
- Replace Chillers
- Consolidate Chiller Plant
- Replace Boilers
- Replace Condenser Pumps
- Replace Chilled Water Pumps
- Replace Low Temp Heating Pumps
- VFD on Induction Supply/Return Fans
- Full Floor Retrofits

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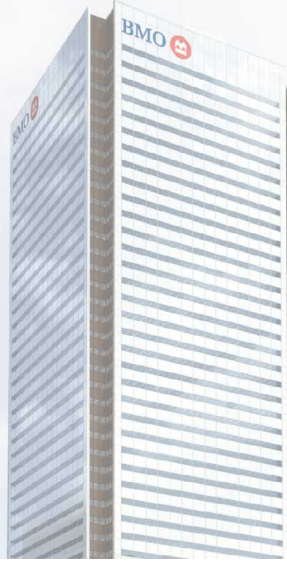
Building Operations

- Sub-metering
- Chiller Heat Recovery Plant
- Induction Unit Switchover
- Induction Unit Fans
- Boiler Plant
- Compartment Units
- Sanitary Exhausts
- Mechanical operating schedules
- Lighting schedules

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Occupant Use



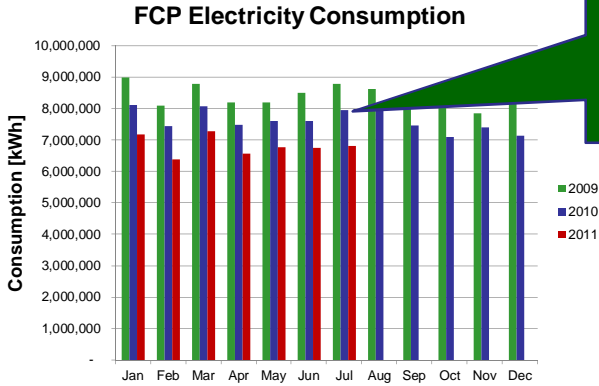
- Daytime cleaning
- Lighting schedules
- Operating schedules
- Supplemental cooling
- Tenant awareness/engagement

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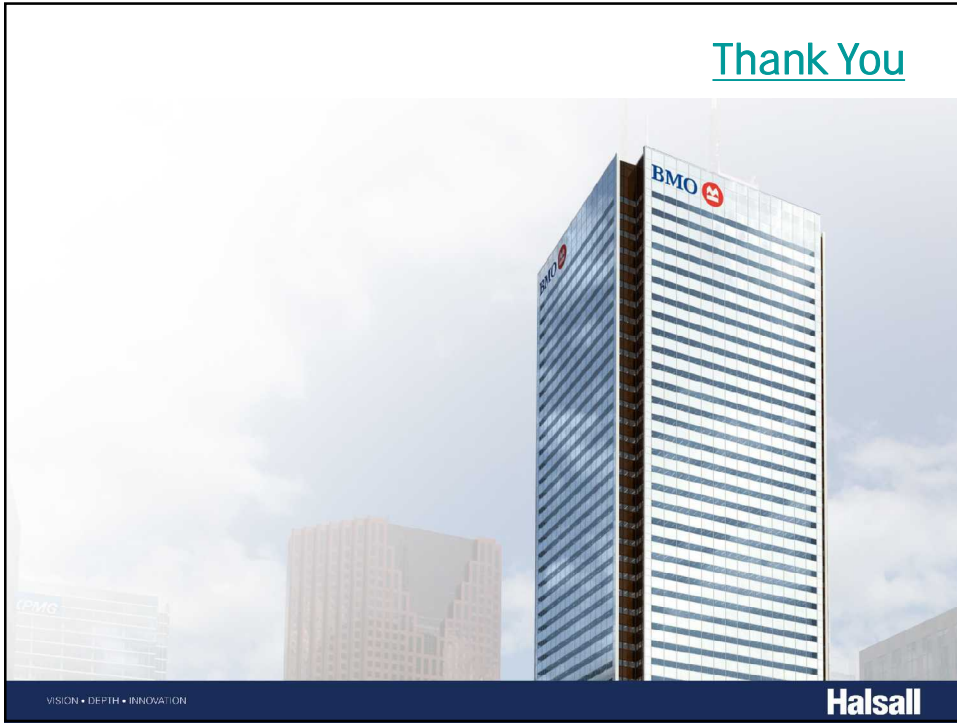
Energy Savings

strategic advisor for energy/LEED EB services

**22%
REDUCTION
from 2009
CONSUMPTION**



Thank You



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