Glazing Systems Engineering

Prepared by Layton Consulting Ltd.
For

BRITISH COLUMBIA
BUILDING ENVELOPE COUNCIL

Speaker: Mark S. Layton, P Eng, PE
January 17, 2013

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Structural vs. Building Envelope?

- The Purpose of this Seminar is to Aid in the Understanding of the Structural Requirements of Glazing Systems and How they Pertain to the Building Envelope.

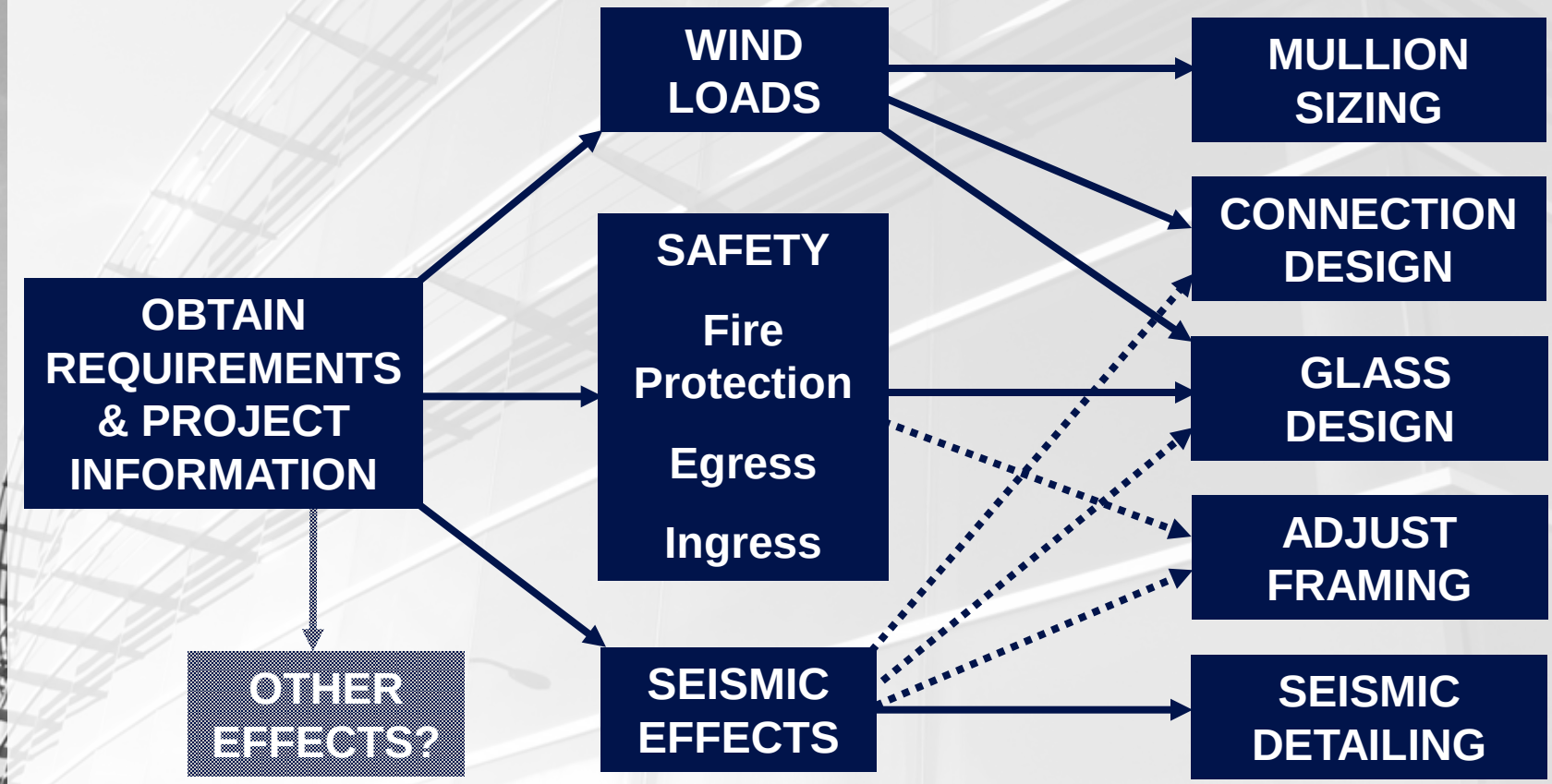
- Too Often We, as Professionals Find Ourselves Pitted Against Each Other, Resulting in One Discipline Often Feeling Ignored

Image from inmagine.com

Introduction

- Engineering Process
- Wind Loads
- Seismic Loads
- Structural Concerns
- Glazing Types
- Safety Glazing & Guard Loads
- Glass Design
- Design & Construction Process

Engineering Process



Wind Loads

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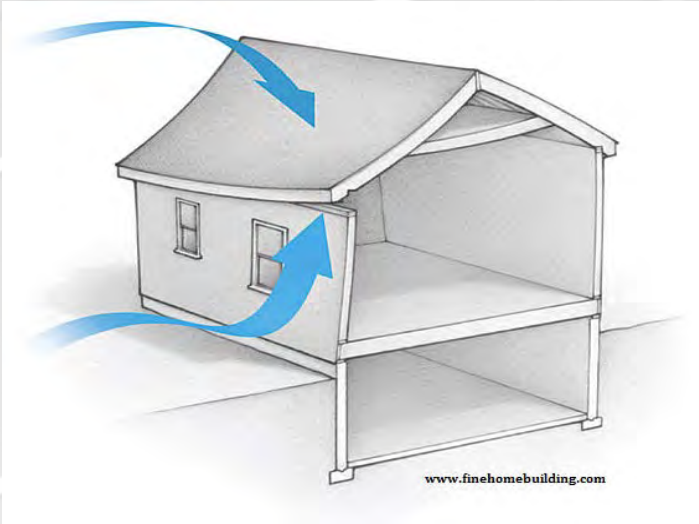
Wind Loads

- Calculated from the Building Code
- Different from NAFS 2008 Wind Pressures
- Cladding Loads on Structural Drawings
- Wind Tunnel Reports
- Wind Pressure Depends on:
  - Exposure
  - Geographical Location
  - Building Importance
  - Building Height
  - Local Terrain
  - Element Being Engineered
  - Location of the Element Being Engineered
  - Checking Stress or Deflection



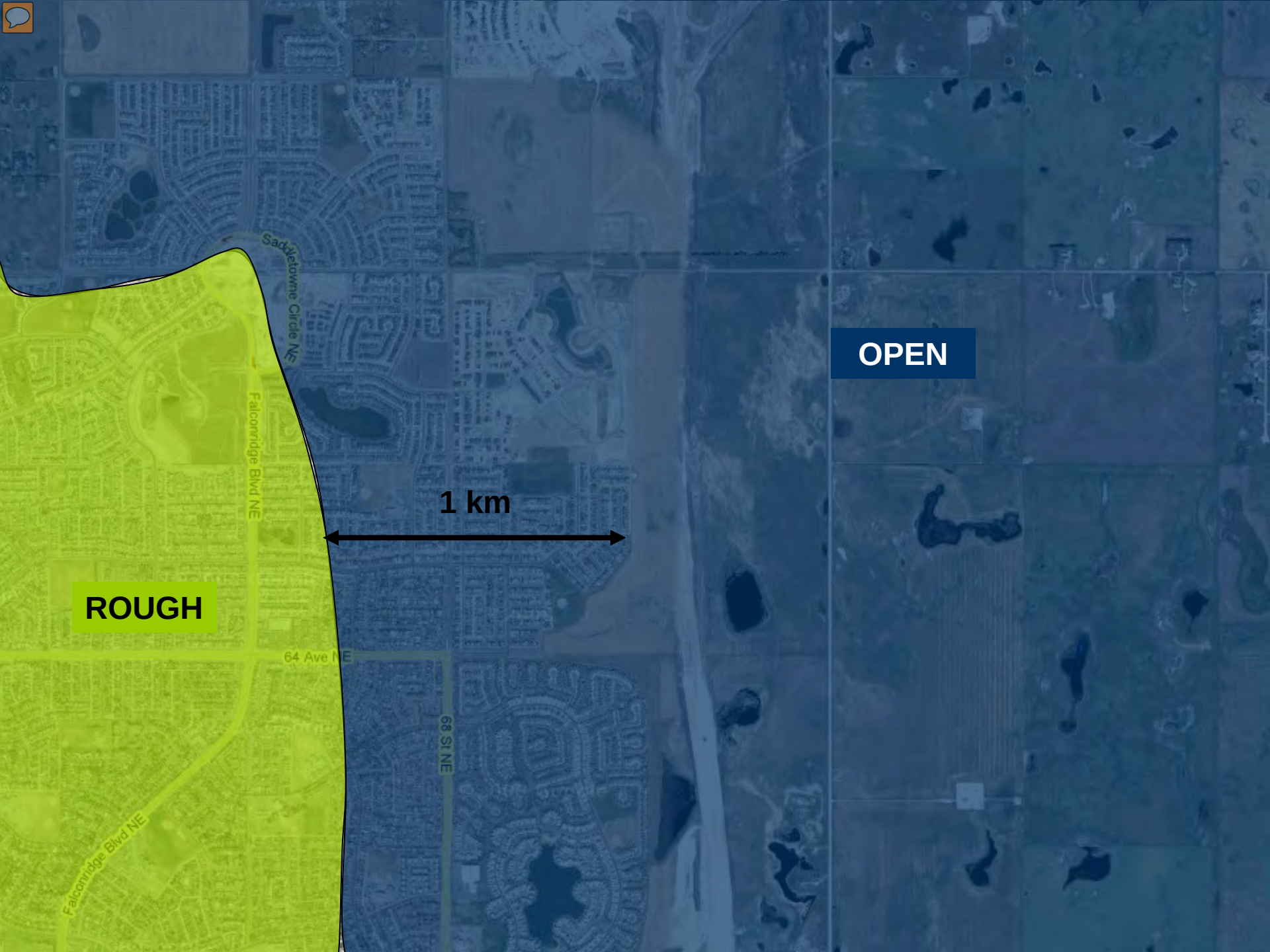
Exposure

OPEN

- Level Terrain
- Scattered Obstructions
- Open Water

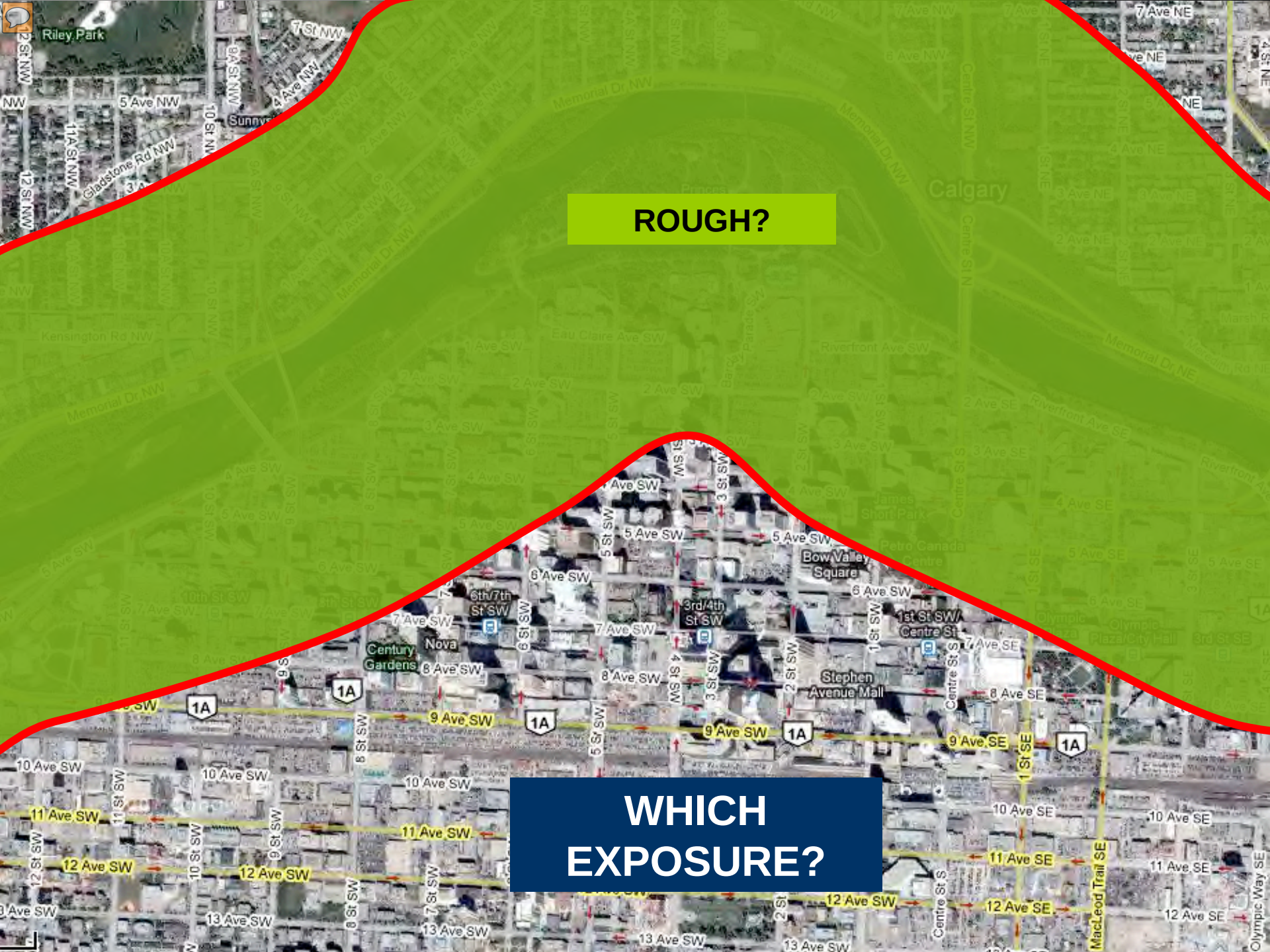
ROUGH

- Suburban
- Urban
- Wooded
- Extends upwind for:
  - 1 km, or
  - 10 x Building Height


OPEN
1 km
ROUGH
Saddletowne Circle NE
Falconridge Blvd NE
64 Ave NE
68 St NE
Falconridge Blvd NE


OPEN EXPOSURE
ROUGH EXPOSURE
OPEN EXPOSURE
50 STOREY HIGH-RISE?
English Bay
W 4th Ave
Point Grey
Alma St
W Broadway
W 9th Ave
Kitsilano
Burrard St
Granville St
Vancouver
MacDonald St
16th Ave W
Dunbar
Arbutus
W King Edward Ave
Quilchena
99


OPEN?
ROUGH?
Lost Lagoon
Lake
1A
99
West End
Georgia St
W Pender St
W Hastings St
Burrard St
Dunsmuir St
7A
E Hastings St
Main St
English Bay
Burrard
Granville St
Granville Island
Expo Blvd
Georgia Viaduct
Pacific Blvd
Quebec St
Prior St
99A
Terminal Ave
E 2nd Ave
W 4th Ave
W 6th Ave
Kitsilano
W Broadway
Vancouver
Fairview


ROUGH?
WHICH EXPOSURE?
Riley Park
7 St NW
5 Ave NW
Gladstone Rd NW
Calgary
Memorial Dr NW
Kensington Rd NW
Eau Claire Ave SW
Riverfront Ave SW
James Short Park
Bow Valley Square
Petro Canada Centre
6th/7th St SW
3rd/4th St SW
1st St SW/ Centre St
Century Gardens
Nova
Stephen Avenue Mall
5 Ave SW
6 Ave SW
7 Ave SW
8 Ave SW
9 Ave SW
10 Ave SW
11 Ave SW
12 Ave SW
13 Ave SW
9 Ave SE
10 Ave SE
11 Ave SE
12 Ave SE
MacLeod Trail SE
Olympic Way SE
1A

Wind Loads

- Geographical Location
  - Determines q_{50}
  - Provided in Appendix C of Building Code
- Building Importance
  - Table 4.1.2.1 of Building Code
  - Check Architectural & Structural Drawings or Specifications

Wind Loads

- Local Terrain
  - Hill or Escarpment Effects
- Building Pressure vs. Cladding Pressure
- Low-Rise and High-Rise
- Corner and Non-Corner Zones

Low-Rise Buildings

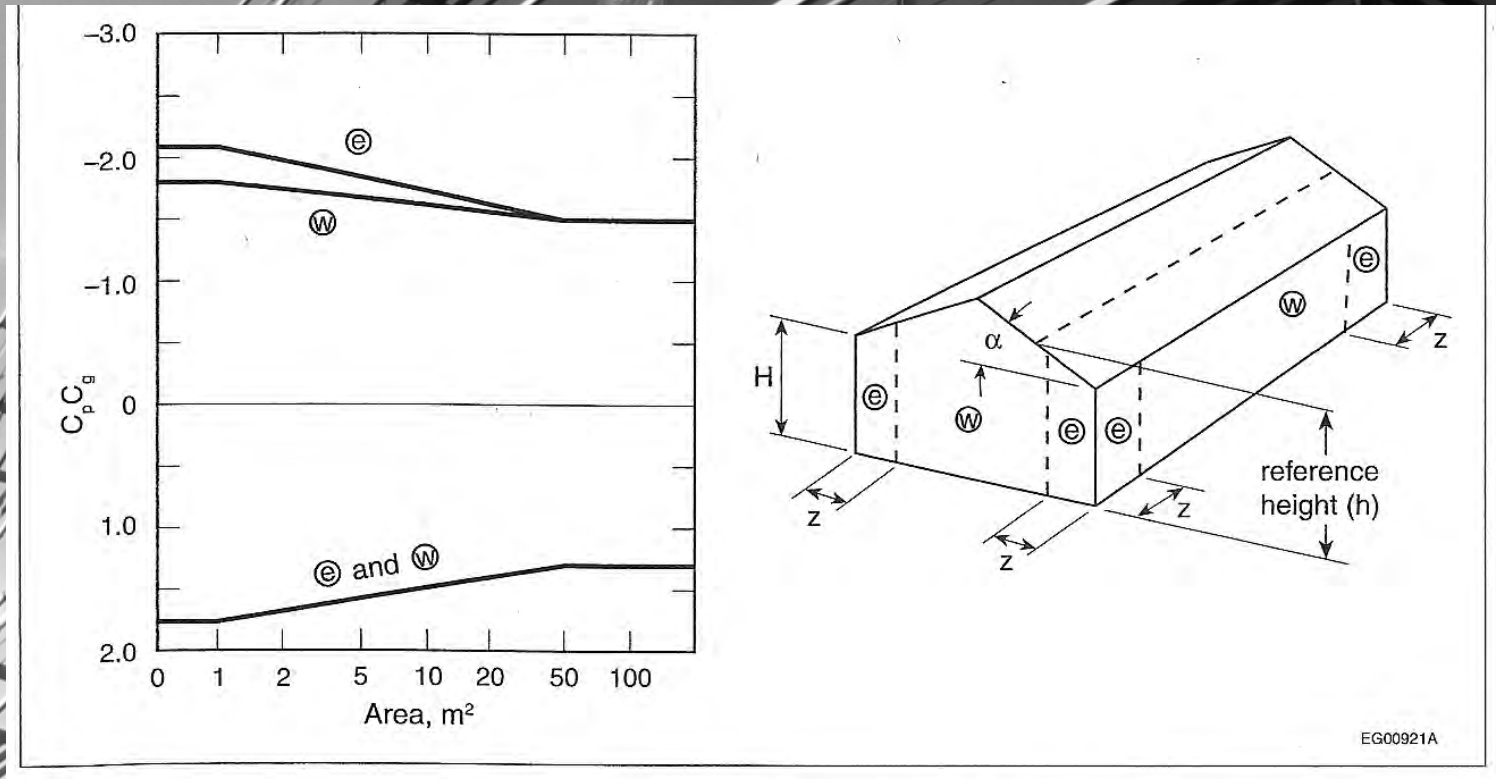


Figure I-8
External peak composite pressure-gust coefficients, C_pC_g, on individual walls for the design of structural components and cladding

High Rise Buildings

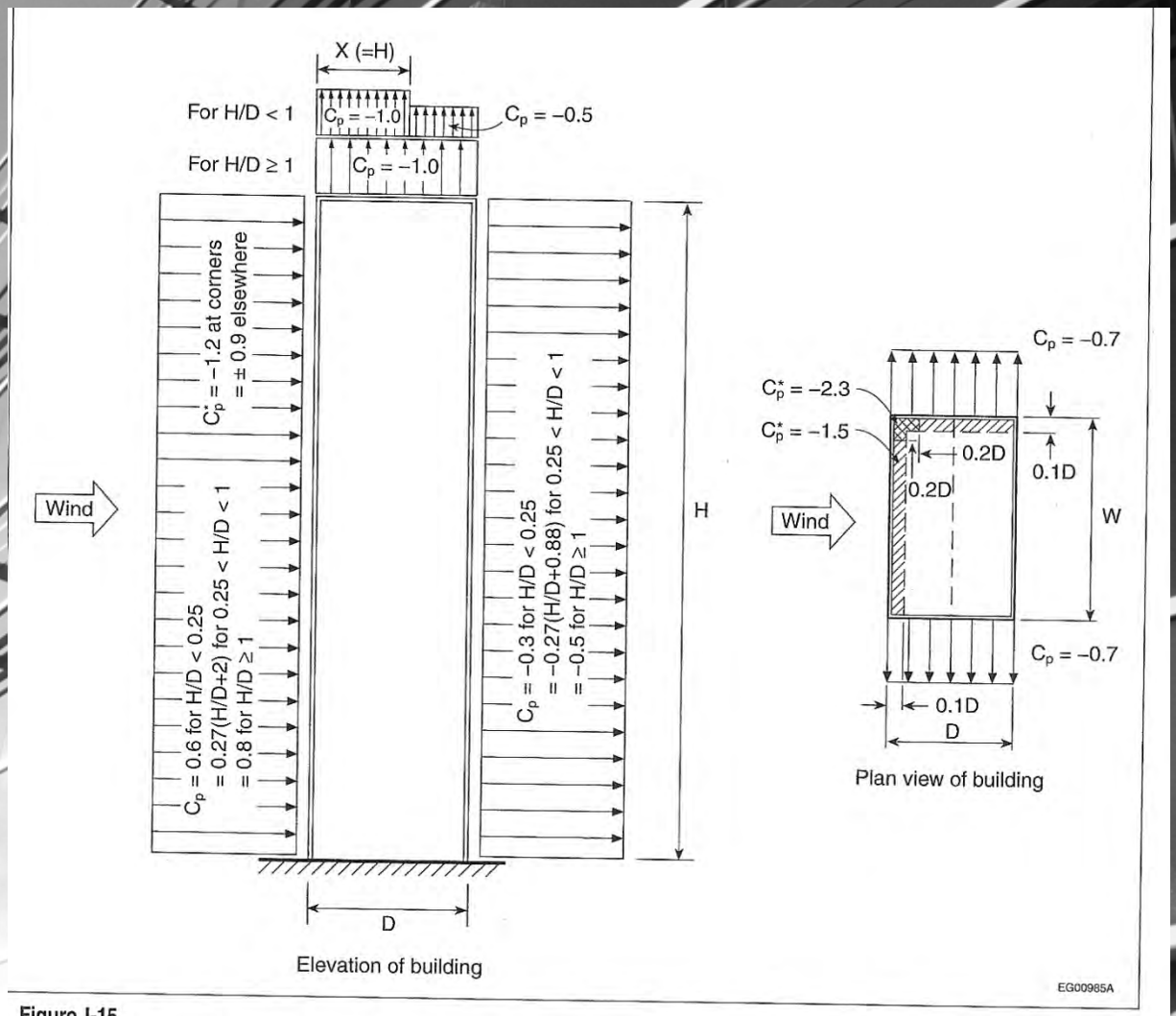


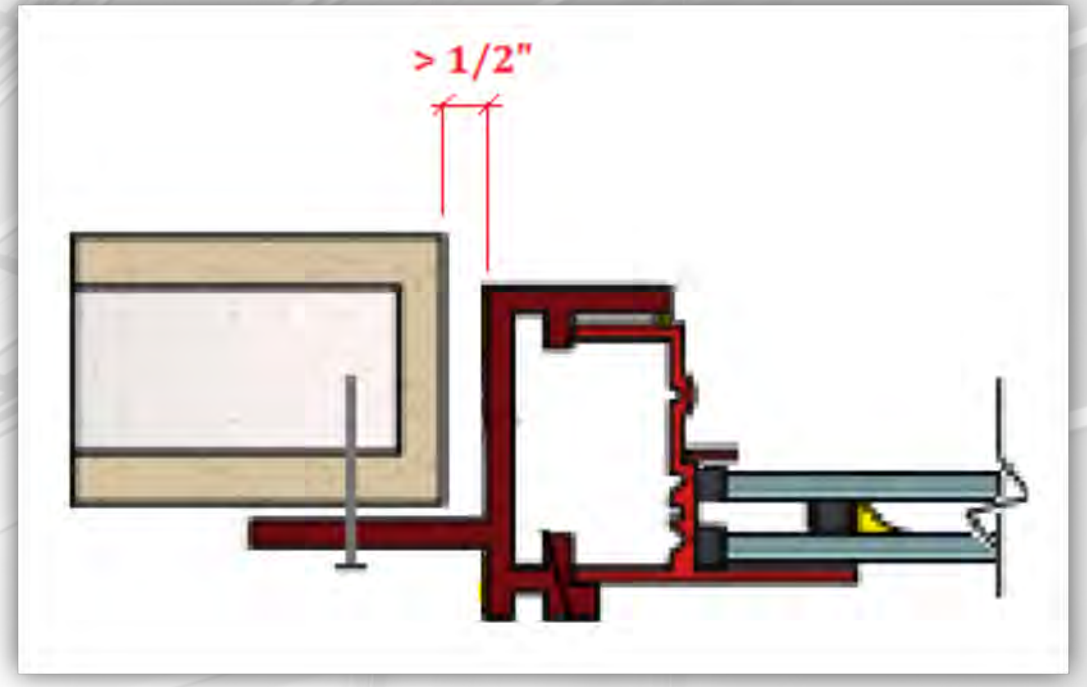
Figure I-15
External pressure coefficients, C_p and C_p^*, for flat-roofed buildings
Notes to Figure I-15:

Wind Loads

- Stress vs. Deflection
  - Stress is Checked at Higher Wind Pressure
  - Deflection Checked at 0.75 of Stress Load
  - Either Could Govern Design
- Wind Drift
  - Drift Can Affect Jamb Joint Detailing
  - Wind Drift Governs on Tall Structures

Drift

- What Do You Do when the Drift Exceeds 1/2” ?



Low-Rise Wind Chart

ROUGH EXPOSURE - METRIC (kPa)					
CITY	BUILDING HEIGHT				
	4m	8m	12m	16m	20m
British Columbia					
Burnaby	1.0	1.0	1.0	1.1	1.1
Coquitlam	1.0	1.0	1.0	1.1	1.1
Kamloops	0.8	0.8	0.8	0.9	0.9
Kelowna	1.0	1.0	1.0	1.0	1.1
Nanaimo	1.3	1.3	1.3	1.4	1.5
New Westminster	1.0	1.0	1.0	1.0	1.1
Penticton	1.2	1.2	1.2	1.3	1.4
Prince George	0.8	0.8	0.8	0.8	0.9
Prince Rupert	1.1	1.1	1.1	1.2	1.3
Richmond	1.0	1.0	1.0	1.1	1.1
Surrey	1.0	1.0	1.0	1.0	1.1
Vancouver	1.0	1.0	1.0	1.1	1.1
Victoria	1.3	1.3	1.3	1.4	1.5
Whistler	1.0	1.0	1.0	1.1	1.1

High Rise Wind Chart

	ROUGH EXPOSURE – METRIC (kPa)							
CITY	15m	30m	45m	60m	75m	90m	105m	120m
British Columbia								
Burnaby	1.4	1.7	1.9	2.0	2.2	2.3	2.4	2.5
Coquitlam	1.4	1.7	1.9	2.0	2.2	2.3	2.4	2.5
Kamloops	1.2	1.4	1.6	1.7	1.8	1.9	2.0	2.1
Kelowna	1.4	1.6	1.8	2.0	2.1	2.2	2.4	2.4
Nanaimo	1.8	2.2	2.4	2.7	2.9	3.0	3.2	3.3
New Westminster	1.4	1.6	1.8	2.0	2.1	2.2	2.4	2.4
Penticton	1.7	2.0	2.3	2.5	2.7	2.8	3.0	3.1
Prince George	1.1	1.3	1.4	1.6	1.7	1.8	1.9	1.9
Prince Rupert	1.6	1.9	2.1	2.3	2.4	2.6	2.7	2.8
Richmond	1.4	1.7	1.9	2.0	2.2	2.3	2.4	2.5
Surrey	1.4	1.6	1.8	2.0	2.1	2.2	2.4	2.4
Vancouver	1.4	1.7	1.9	2.0	2.2	2.3	2.4	2.5
Victoria	1.8	2.2	2.4	2.7	2.9	3.0	3.2	3.3
Whistler	1.4	1.7	1.9	2.0	2.2	2.3	2.4	2.5

Seismic Loads

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Seismic Loads

- Wind Load Typically Governs On Glazing
- Must Consider Seismic Effects

- Inter-storey Drift Limited to 0.02 or 0.025 x h_s
- Example:
  - Floor Height = 9 ft (2.74 m)
  - Drift Limit = 2.7 in (68.6 mm)

Seismic Loads

- Design Lateral Drift Depends on:
  - Seismic Force
  - Building Stiffness
  - Location Geological Conditions
- Lateral Drift Information Must Come From Structural Engineer
- Drift Will Affect the Building Design and Glazing Requirements at Head and Jamb

Structural Concerns: Lateral Drift

- **Wood Frame**: Drift is Difficult to Calculate or Model. Building Code Requirement is ½”
- **Concrete/Steel**: Drift Can Be Reduce by Bracing And Shear Elements

Structural Concerns

- Building Flexibility
  - The More **Flexible the Building**, the More it can Absorb Energy.
  - The **Stiffer the Building,** the Less it can Absorb Energy. This Results in Very High Reaction Forces, Requiring **Complicated Computer Modeling**

Other Effects

- **Thermal Performance:**
  - Shading From Sun Shades/ Bldg. Facades
  - U - Values
  - Solar Heat Gain
- **Moist Conditions**
  - Swimming Pools, Solariums & Saunas
  - Poor HVAC Design or Ventilation

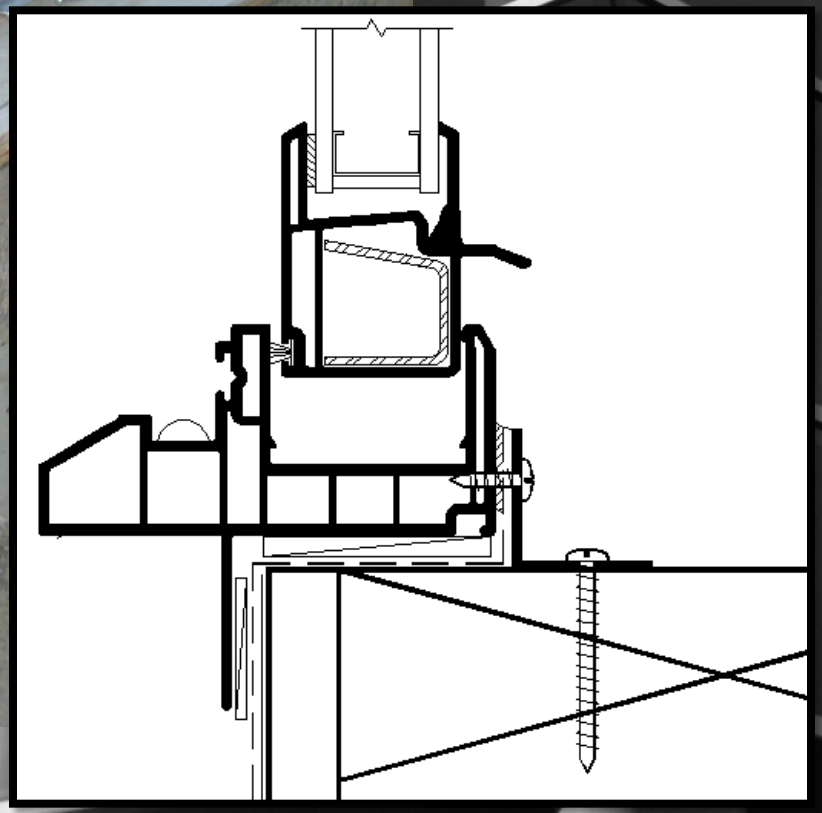
Building Envelope Concerns

- Drift Affects Structure on a Spectrum
  - The Higher the Drift, the More Flexible the Structure
  - The Lower the Drift, the more Stiff the Structure
- Load Bearing Affects On Membrane/Sealants
  - Uniform Load (Distributed over shims) vs. Point Load
- Penetration of Building Envelope for Fastening of Windows, Doors and Exterior Cladding.
  - Example: Sliding Door Sill Fastening

Sill Fastening Through Flange

- Often We Find That the Sills Require Fastening, Yet There is a Reluctance to Penetrate the Membrane

Interior Fastening



Blueskin WB Window and Door Flashing is a self-adhering membrane consisting of an SBS rubberized asphalt compound, which is integrally laminated to a blue-engineered film. The membrane is specifically designed to be self-adhered to a prepared substrate.

Features

- SBS modified membrane can be applied in temperatures as low as -12°C
- Excellent adhesion to prepared substrates of concrete, concrete block, primed steel, aluminum mill finish, anodized aluminum, galvanized metal, gypsum board and plywood
- Impermeable to air, moisture vapor and water
- Easy to install peel and stick application, no flame required
- Thickness controlled at point of manufacture
- Membrane is self-sealing when penetrated with self-tapping screws or nails

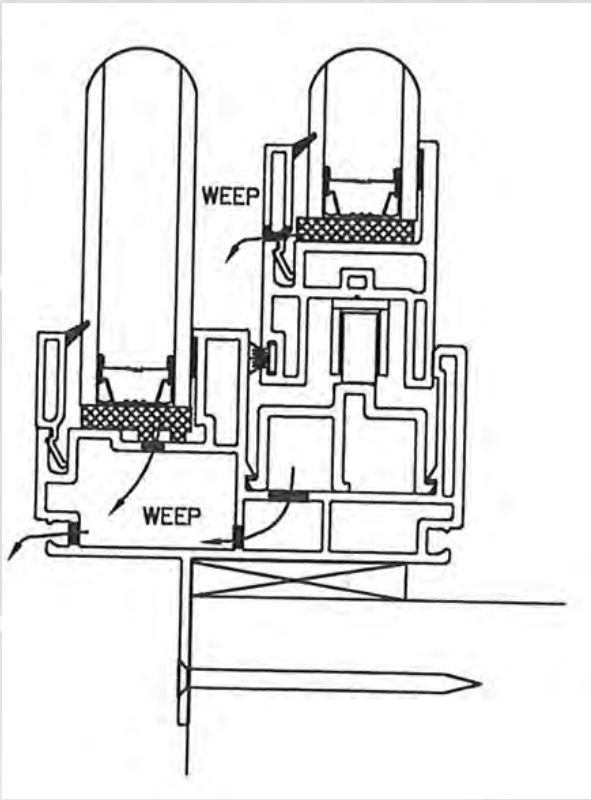
Air Barrier Brochure

Henry Building Envelope Systems Brochure

copied directly from www.henry.com

Exterior Fastening OK?

- Can We Trust The Manufacturers Specifications/ Warrantee?



Glazing Types

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Glass Types

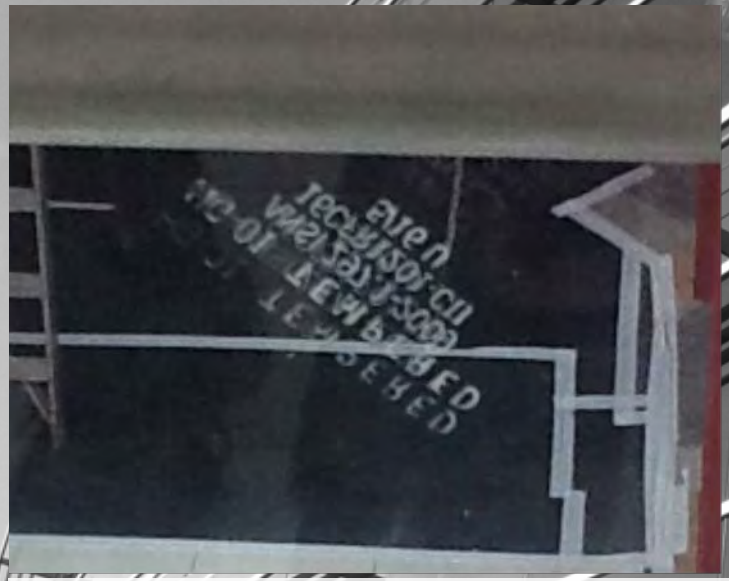
There are 4 Main Types of Glass that we use in the Glazing Industry:

- Float Glass
- Tempered Glass
- Heat Strengthened Glass
- Laminated Glass
  - PVB
  - SGP

Float Glass

- Float Glass is Manufactured by Pouring or “Floating” Molten Glass onto a Bed of Molten Metal (Tin)
- Float Glass is the Least Expensive
- Float Glass is Not a Safety Glass
- Failure Under Stress Creates Large, Jagged Shards
- It is the Base Material from which tempered and laminated glass is made

Tempered Glass

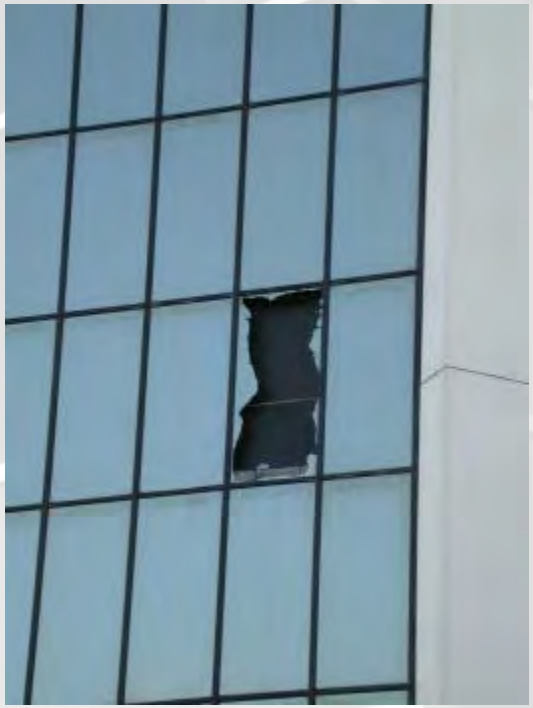


Tempered Burn Marks Are Usually Clearly Visible in One of the Four Corners of The Glass Panels. Look at the Glass Sliding Doors on Your Next Residential Project!

- Tempered Glass is Much Stronger than Float Glass, but Also Much More Expensive
- Tempered Safety Glass is Float Glass that is Heated and than Rapidly Cooled
- If Broken, Tempered Safety Glass Will Shatter into Small, Similar Sized Fragments.
- Tempered Glass Cannot Be Re-cut, Drilled or Ground Once it is Tempered

Heat Strengthened Glass

- Heat Strengthened Glass is Semi-Tempered Glass And is Therefore Not as Strong
- Heat Strengthened Glass Is Used In Areas Where There is a High Thermal Differential
- Heat Strengthened Glass Is usually Used in Single Glazed Spandrel Panels Where the Inner Layer is An Insulated Metal Back Pan



Laminated Glass

- Laminated Glass is The Binding of at Least Two Glass Sheets Into One or More Layers With Plastic Foils Utilizing high temperature and Heat
- There Are Two Types Of Laminated Glass:
  - **Poly Vinyl Butyl**: PVB inner layer remains soft (You Can Squish it With Your Fingernail). It is the Most Common Safety Glass
  - **Polycarbonate**: SGP Laminated PVC is Hard, Expensive and Used Mostly in High to Post Disaster Importance Buildings
- If Laminated Glass Breaks it Will Follow the Glass Break Pattern, but Will Remain Bonded to the Laminated Inner Layer

Laminated Glass

Safety Glazing & Guard Loads

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Safety Glazing

- Section 4.1.5.17 of 2006 BCBC:

4.1.5.17. Loads on Walls Acting As Guards

1) Where the floor elevation on one side of a wall, including a wall around a shaft, is more than 600 mm higher than the elevation of the floor or ground on the other side, the wall shall be designed to resist the appropriate lateral design loads prescribed elsewhere in this Section or 0.5 kPa, whichever produces the more critical effect.

- Determining if Window Wall Meets Guard Load is Duty of Signing Professional
- FEN BC Technical Committee Guidelines
  - Rule is 30” or Less
- USA Code – IBC 18” or Less

Safety Glazing

- Section 9.6 and 9.7 of 2006 BCBC
  - Prescriptive Safety Glazing Requirements
  - Local Authority Modifications (**VBBL requires cap/railing**)
- LCL Reviews Structural Safety Aspects Only
- Architect / Code Consultant to Determine Emergency, Egress etc.

9.7.5.3. Windows over Stairs, Ramps and Landings

1) <Except as provided in Sentence (2), windows over *stairs*, ramps and landings> that extend to less than 1 070 mm above the <surface of the treads, ramp or> landing shall be

a) protected by *guards*, in accordance with Subsection 9.8.8., or

b) non-openable and designed to withstand the specified lateral loads for balcony *guards* as provided in <Article 4.1.5.15.>

< 2) In *dwelling units*, windows over *stairs*, ramps and landings that extend to less than 900 mm above the surface of the treads, ramp or landing shall be

a) protected by *guards*, in accordance with Subsection 9.8.8., or

b) non-openable and designed to withstand the specified lateral loads for balcony *guards* as provided in Article 4.1.5.15.>

9.7.5.4. Windows above the Second Storey

1) Windows in public areas that extend to less than 1 m from the floor and are located above the second *storey* in *buildings* of *residential occupancy* shall be

a) protected by *guards* in accordance with Subsection 9.8.8., or

b) non-openable and designed to withstand the specified lateral loads for balcony *guards* as provided in Article 4.1.5.15.

Glass Guard

- Three Main Components to All Glass Guards:
  - Fastening to Structure: Shoe, Standoffs or Bracket
  - Glass Considerations: Type and Size
  - Cap or Handrail Requirements

Connection To Structure

Connection To Structure

Connection To Structure

Connection To Structure

Considerations

- Edge Distance
- Substrate material: Wood, Concrete, Steel Embeds
- Type of Fasteners: Stainless Steel, Cadmium Plated
- Connections: Bolts, Screws or Welds
- Steel Shoe Finishes: Painted or Galvanized
- Steel Shoe Thickness: 1/4”, 5/16”, 3/8”
- Grout Type: Expanding, Exterior Rated, Non Shrink
- Shims: Wood or Plastic

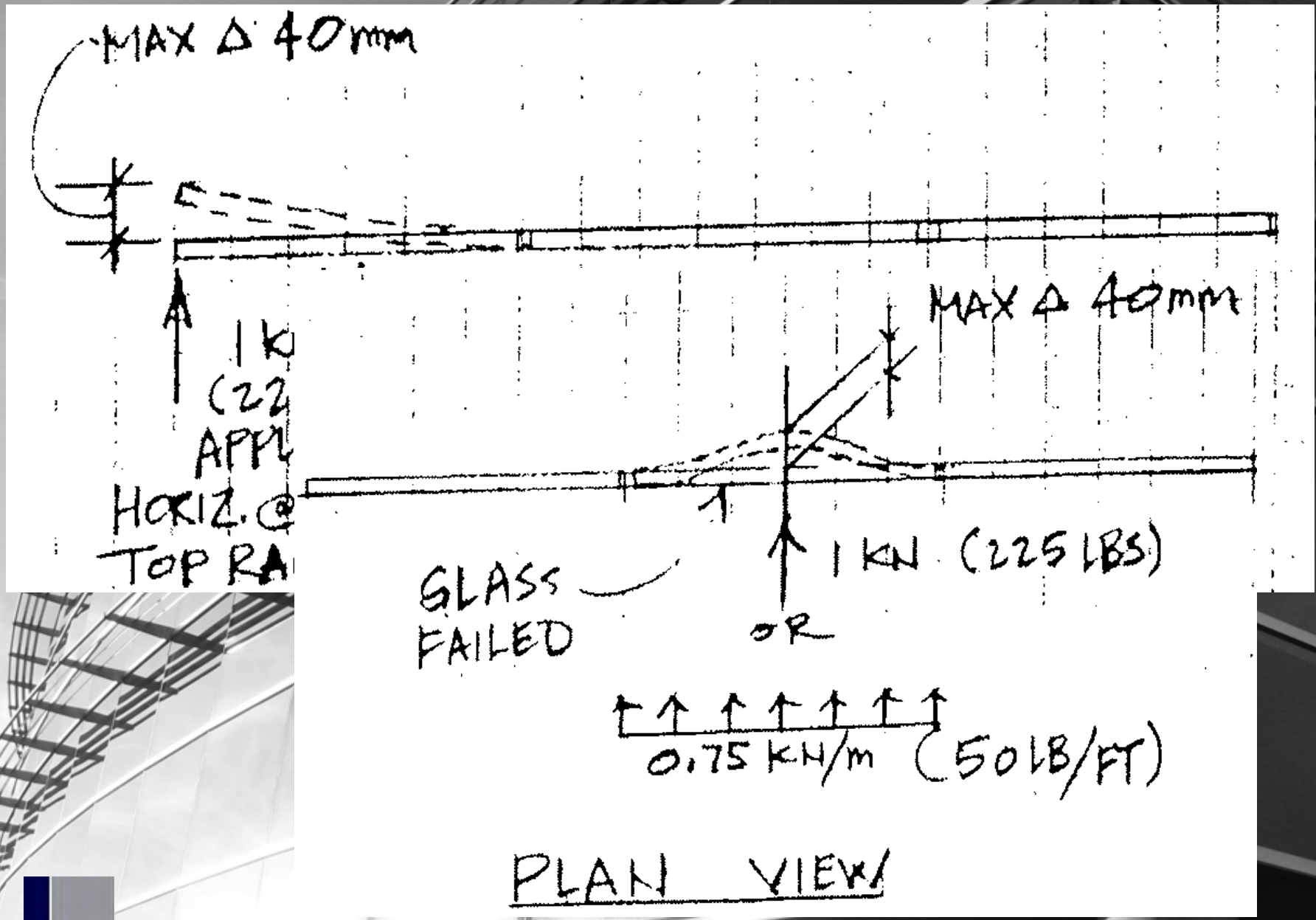
Glass Guard Considerations

MONOLITHIC

- Advantages:
  - Solid
  - Tempered Glass
- Disadvantages:
  - Breakable
  - Open Void Once Glass Breaks

LAMINATED

- Advantages:
  - Each Lite Tempered And Adhered to Laminate
  - Alerts Public When One Lite Is Broken Without Completely Failing.
- Disadvantages:
  - When Both Lites Break They Act Like a Very Heavy Wet Blanket
  - Delamination is a Concern in Wet/Moist Conditions


MAX Δ 40mm
1 K
(22
APPL
HORIZ. @
TOP RA
MAX Δ 40mm
GLASS
FAILED
OR
1 KN (225 LBS)
0.75 KN/m (50 LB/FT)
PLAN VIEW

Cap & Handrail

- In 2012, The City of Toronto Put Together a Panel to Discuss the Issue of Glass Guard Failures After 30 Incidents Were Reported In The Previous Year. One of the Main Attributes To this Problem was Found to be That “Balcony Glass has Not Been Designed with Glass Breakage In Mind” (www.mah.gov.ca/Page9948.aspx)
- The Building Code Requires That All Guard Rails Be:
  - Fully Installed Prior to Occupancy
  - Adequately Secured to Glass / Structure
  - Sufficiently Strong

According to Sentence 4.3.6.1.(1) of Division B of 2007 VBBL, glass shall be designed in accordance with CAN/CGSB-12.20-M for all Part 3 buildings.

4.3.6.1. Design Basis for Glass

1) Glass used in *buildings* shall be designed in conformance with CAN/CGSB-12.20-M, "Structural Design of Glass for Buildings".

Under 7.1 **Glass Guards and Balustrade** of CAN/CGSB-12.20-M states that:

b. Any free standing **glass guard shall be capped** by a rail which is continuous over two or more lights. The glass guard shall resist the factored design load after failure of alternate lights.

Therefore, top cap is mandatory for free standing glass guard as per CAN/CGSB-12.20-M and it is further explained in the Appendix notes:

A5. **GLASS GUARDS AND BALUSTRADES**

A5.1 When a brittle material with variable mechanical properties like glass is used as structural component with **the potential for catastrophic consequences in the event of failure**, both increased load factors and **alternative load paths are required in the design**. For glass guards and balustrades the standard addresses these factors by the requirement for alternate lights to be assumed failed in the strength determination, and a rigid continuous guard over two or more lights.

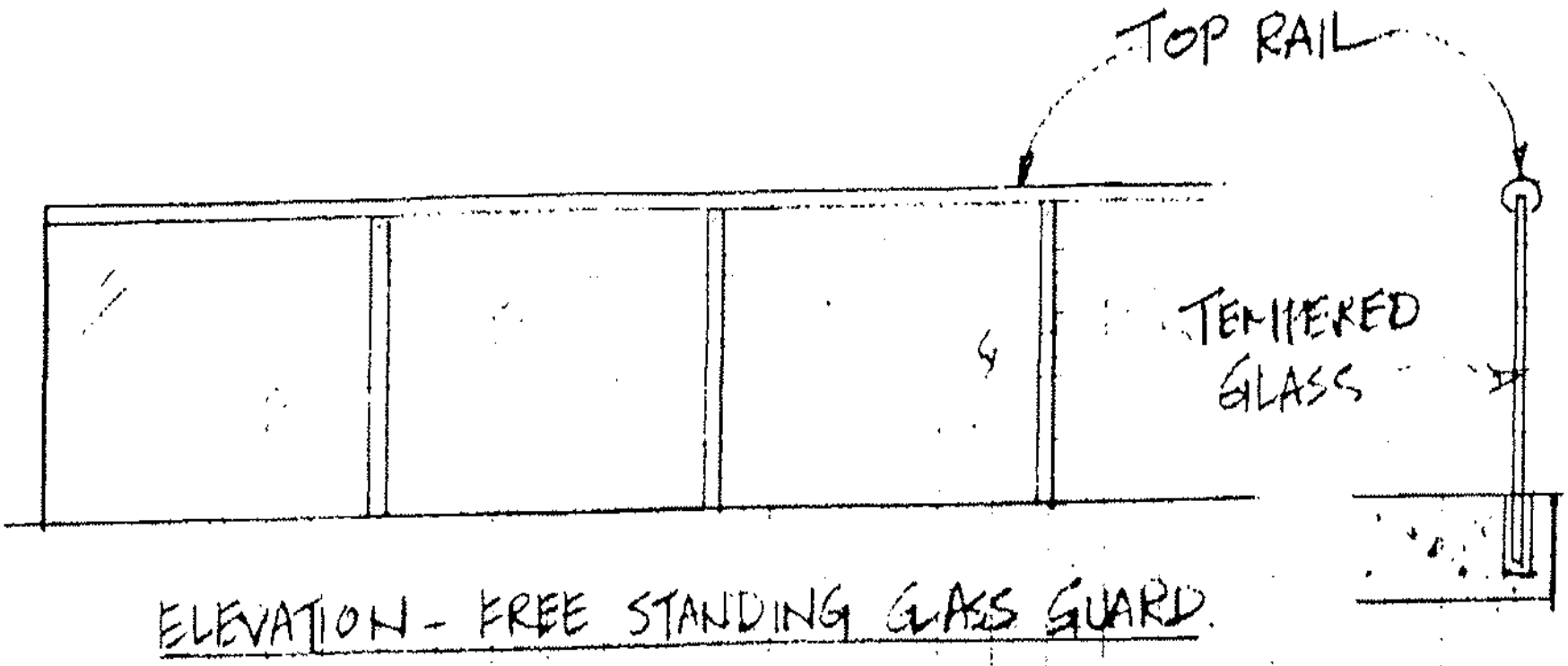
For Part 9 buildings, **Article 9.8.8.7. Glass in Guards** applies to glass forming part of the metal or wood guards and does not applies to free standing glass guards or glass panel without top guard. Sentence 9.8.8.7.(1) refers to CAN/CGSB-12.1-M, "Tempered or Laminated Safety Glass". In the Scope of CAN/CGSB-12.1 it states that this standard applies to safety glass intended primarily for use in doors and adjacent glazed panels etc..

Therefore, if glass used in Part 9 buildings other than those under the prescriptive provisions, such as 9.8.8.7., shall be designed according to Part 4 as specified in Article 9.4.1.1. That means Sentence 4.3.6.1.(1) of Division B of VBBL, and CAN/CGSB-12.20-M applies to structural design of free standing glass guard for all Part 9 buildings.

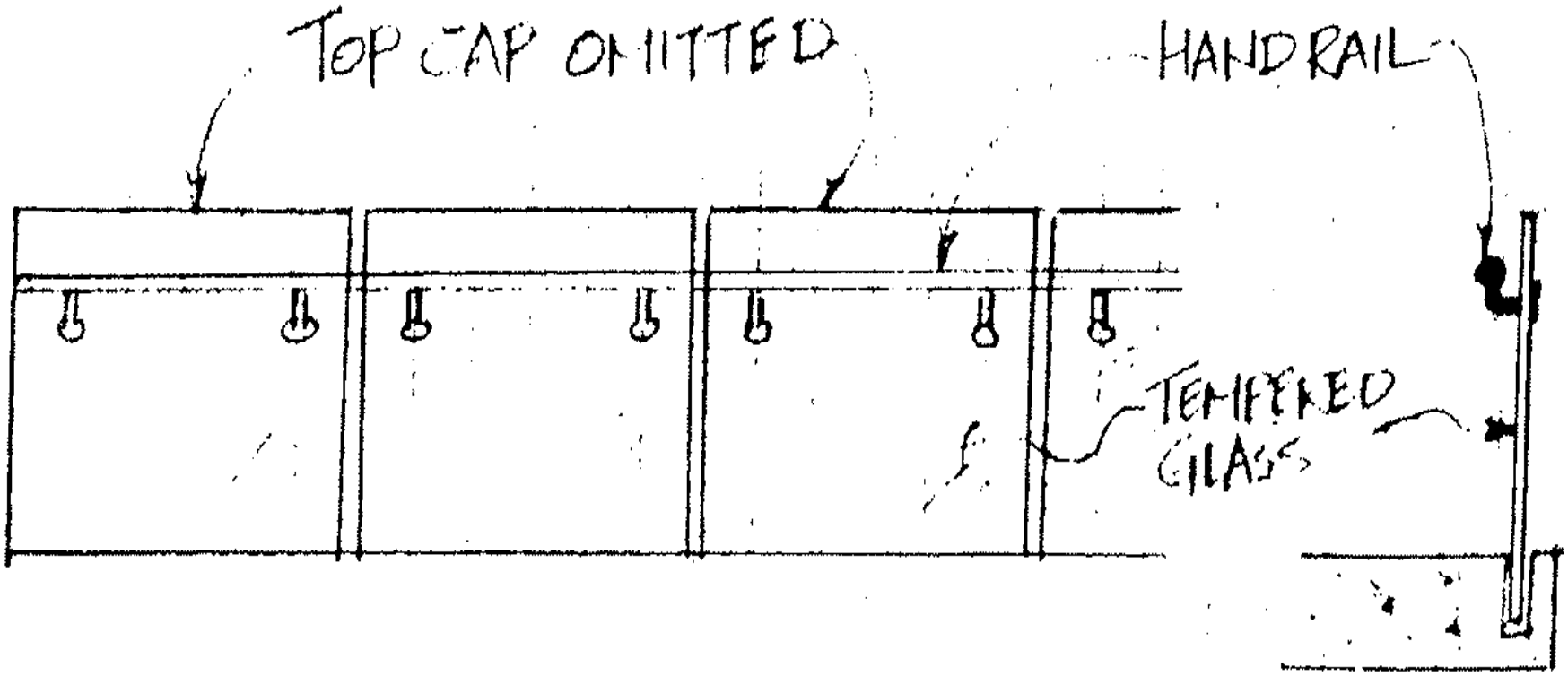
In conclusion, free standing glass guard shall be capped by a rail which is continuous over 2 or more lights for all Part 3 and Part 9 buildings and glass panel without top rail is not permitted.

GLASS GUARDS AND GLASS IN GUARDS

Free standing glass guard must be designed to Part 4 for all Part 3 and Part 9 Buildings:

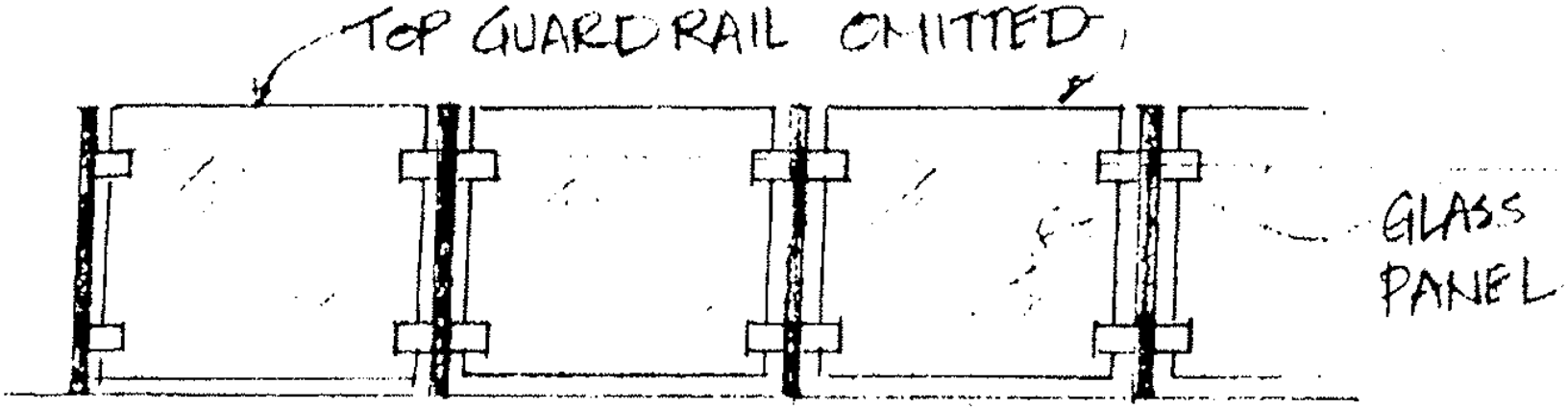


ELEVATION - FREE STANDING GLASS GUARD.



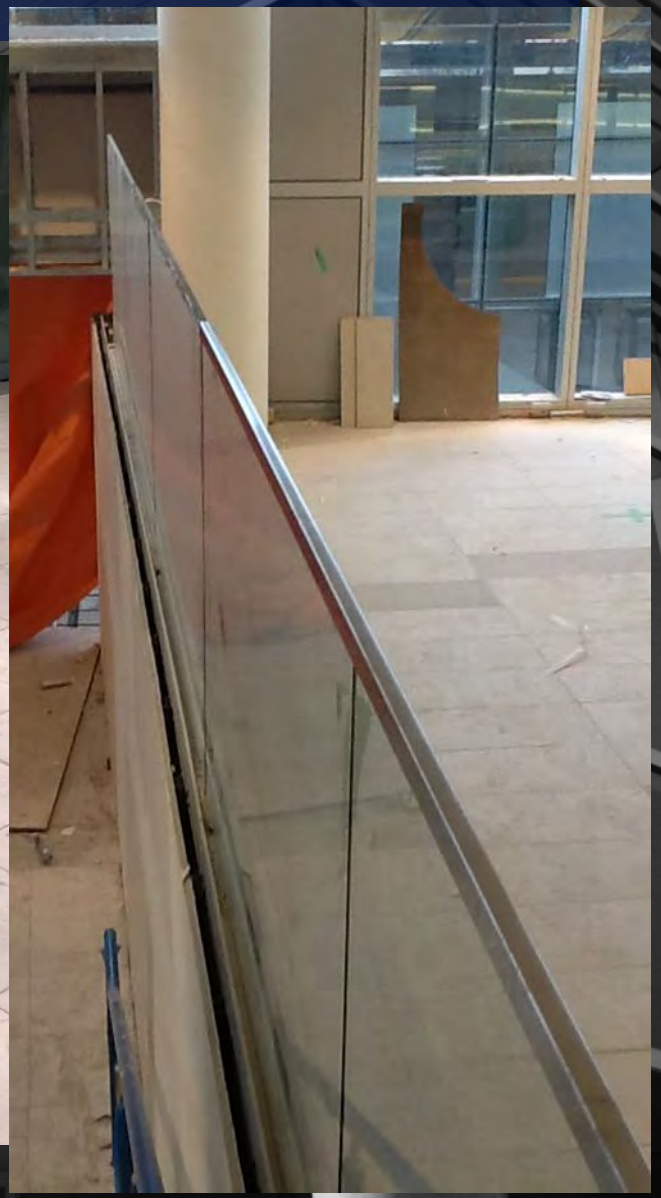
ELEVATION - FREE STANDING GLASS GUARD WITHOUT TOP CAP - NOT PERMITTED

Glass panel in guards without top rail is not permitted.



ELEVATION - GLASS IN GUARD WITHOUT TOP GUARDRAIL — NOT PERMITTED

Cap & Handrail



Glass Design

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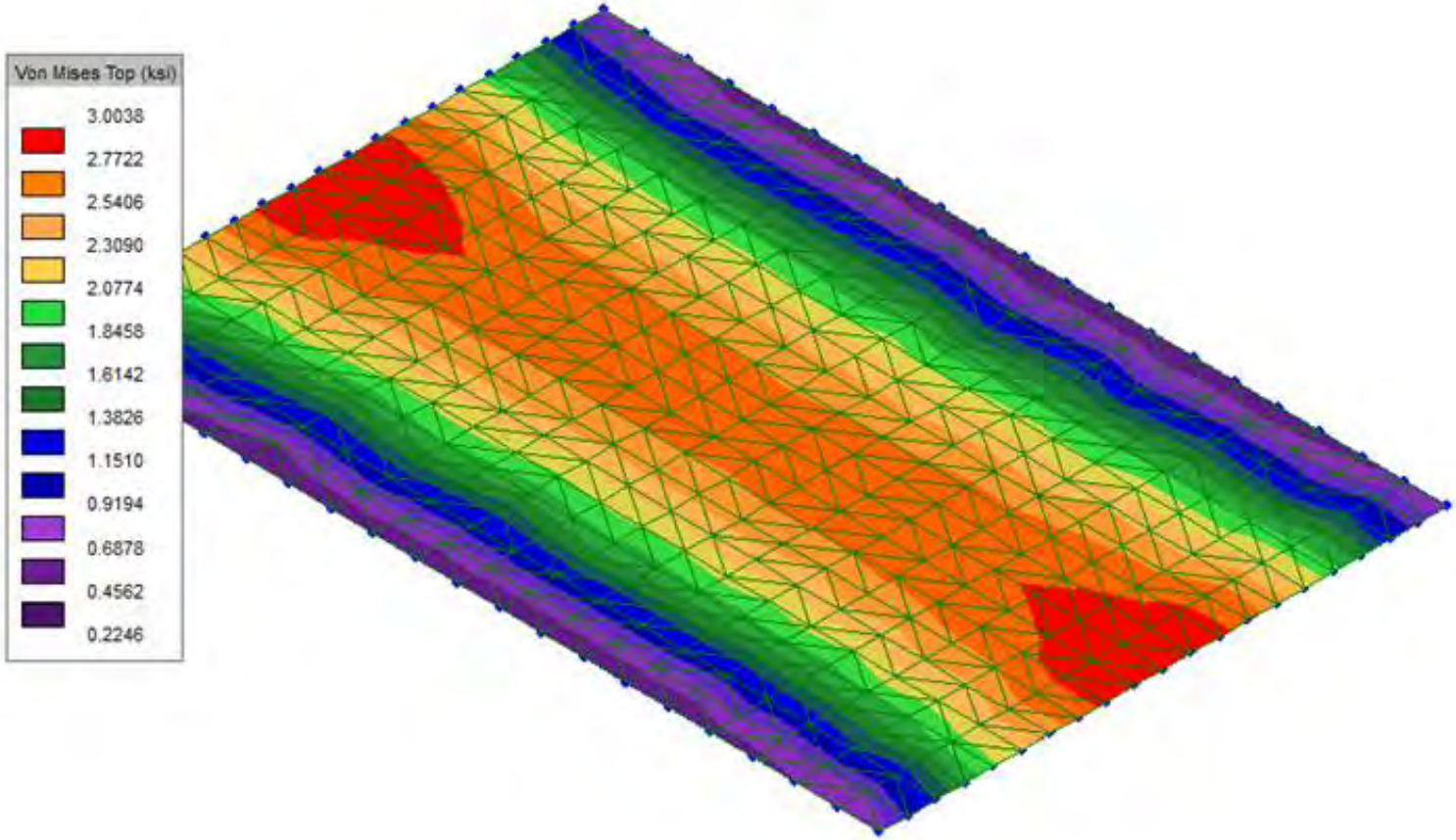
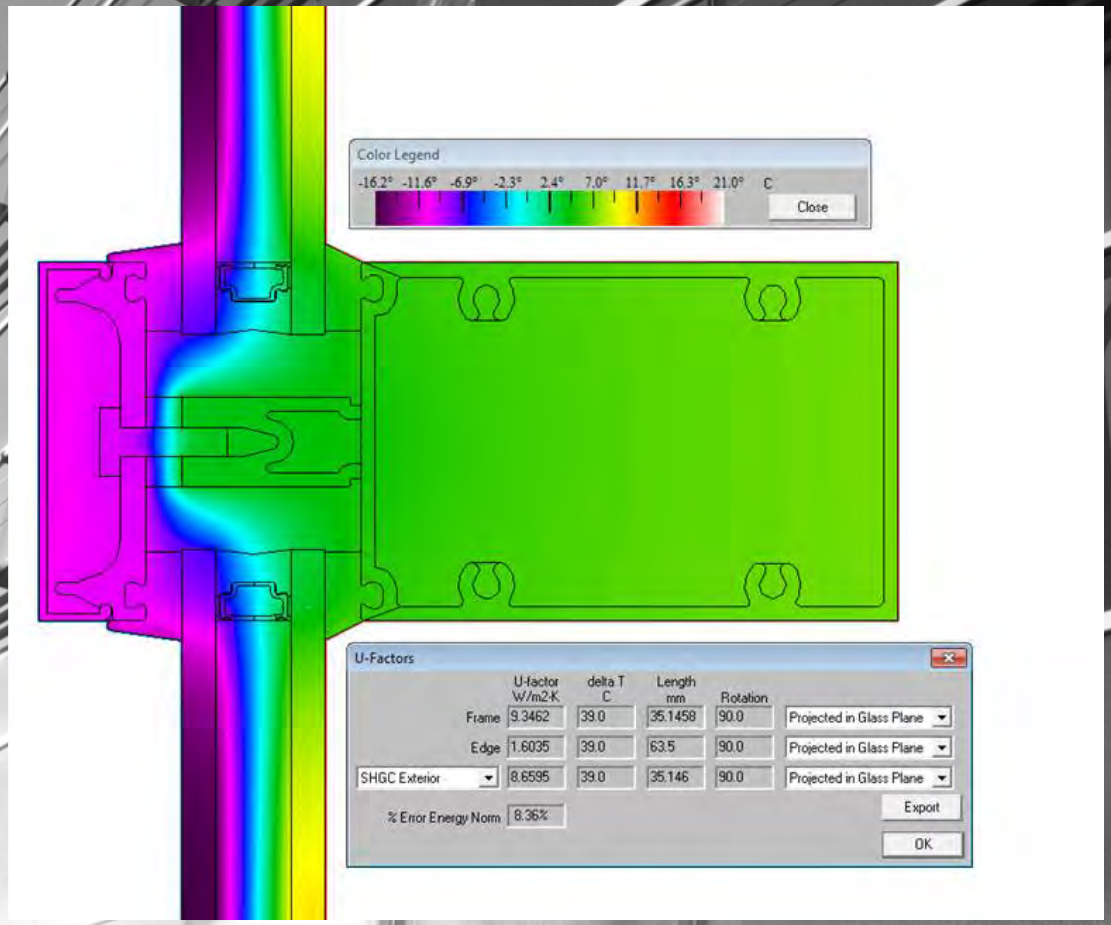
Glass Design

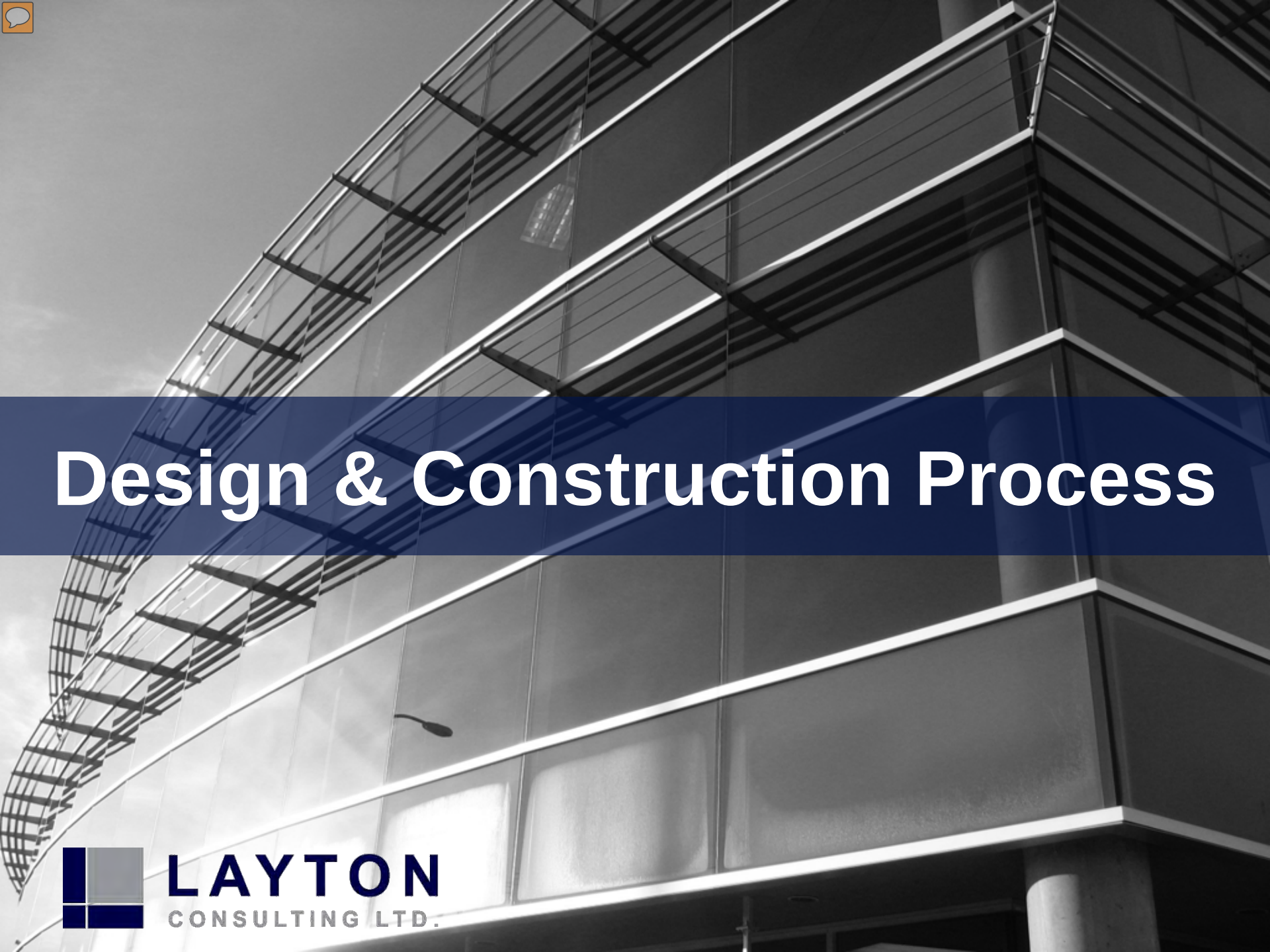
- Glass Design to CAN/CGSB 12.20-M89
- Glass Design Under BCBC
  - Current Wind Factors x 1.4 for Stress, 0.75 for Deflection

Software: S-Frame

- 

Thermal Modeling





Design & Construction Process

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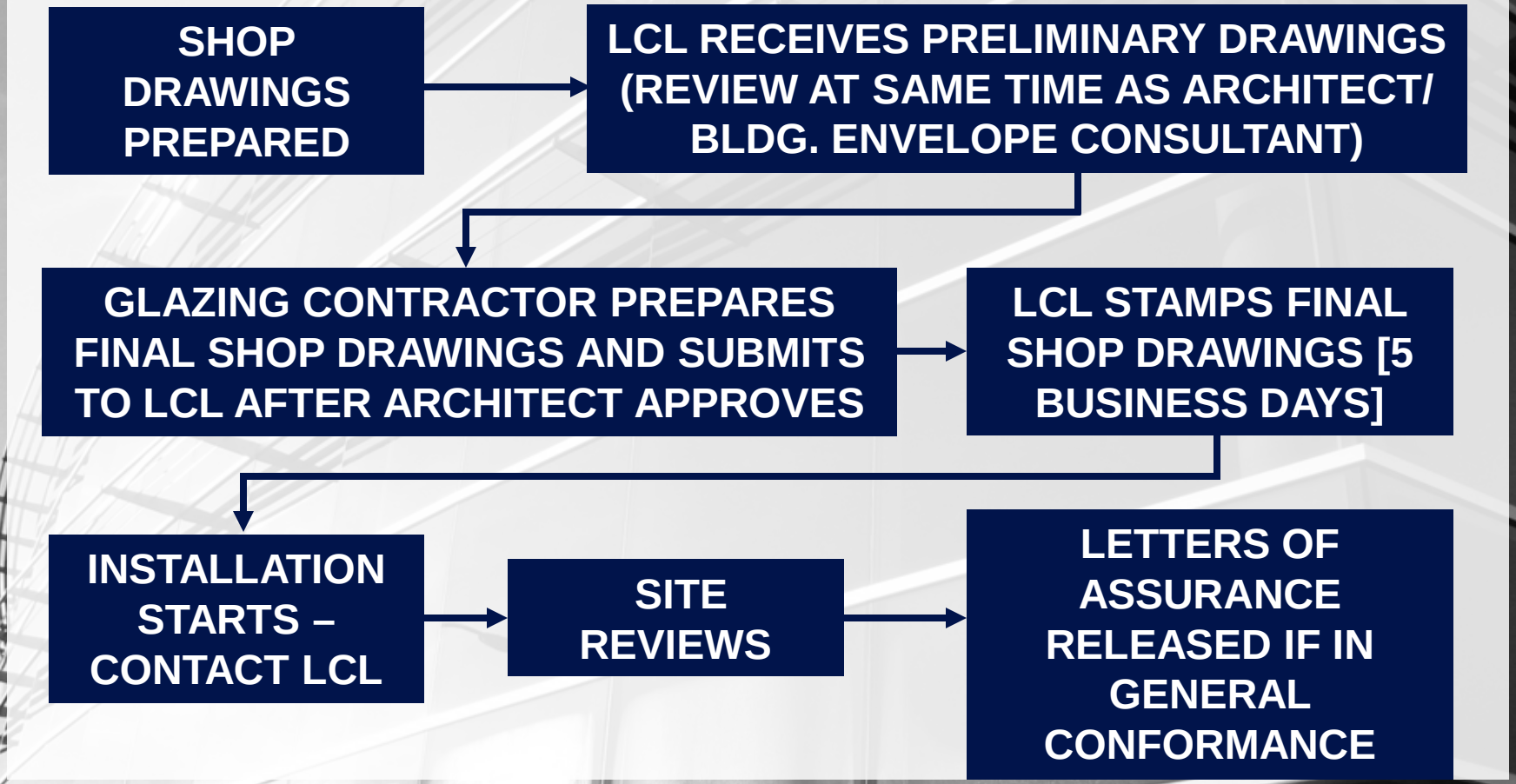
Engineering Process



Site Visits

- Purpose:
  - P.Eng. Must Determine if the Actual Installation is in General Conformance with the Shop Drawings and Building Code
- Not an Inspection
- Required by the Building Code
- Enforced by Local Municipality
- Letters of Assurance – SB, SC

Letters of Assurance

- **Schedule SB:**
  - Assurance of Professional Design and Commitment to Field Review
  - Guarantees That Drawings Have Been Professionally Engineered.
  - Summary of Design and Field Review Requirements
  - Indicates Scope of Work
- **Schedule SC:**
  - Assurance of Professional Field Review and Compliance
  - Submitted After Completion of Work
  - States that Scope of Work Complies with Schedule SB

Questions?

Layton Consulting Ltd.

#301-19978 72nd Avenue
Langley, BC
V2Y 1R7

Tel: 604-530-6611
Fax: 604-530-6101
Email: info@laytonconsulting.com

www.laytonconsulting.com

Primary Contacts

Mark Layton, P.Eng. P.E.
Principal
Email: mark@laytonconsulting.com

Ivan Chu, EIT
Design Engineer
Email: ivan@laytonconsulting.com

Eric Skytte, AScT
Manager of Residential Projects
Email: eric@laytonconsulting.com

Ashlee Flierl
Administrative Manager & Site Visit Coordinator
Email: ashlee@laytonconsulting.com

Jonathan Layton
Engineering technologist
Email: jonathan@laytonconsulting.com