

New Provisions in ASTM e1300-16

A comparison of the Basic and New Analytical Procedures for Determining the Load Resistance of Window Glass

Stephen M. Morse/ Michigan Tech University

Overview

- Basic Method Overview
- Analytical Method Overview
- Analytical Method Example
- Analytical Method vs. Basic Method
- Summary and Future Work

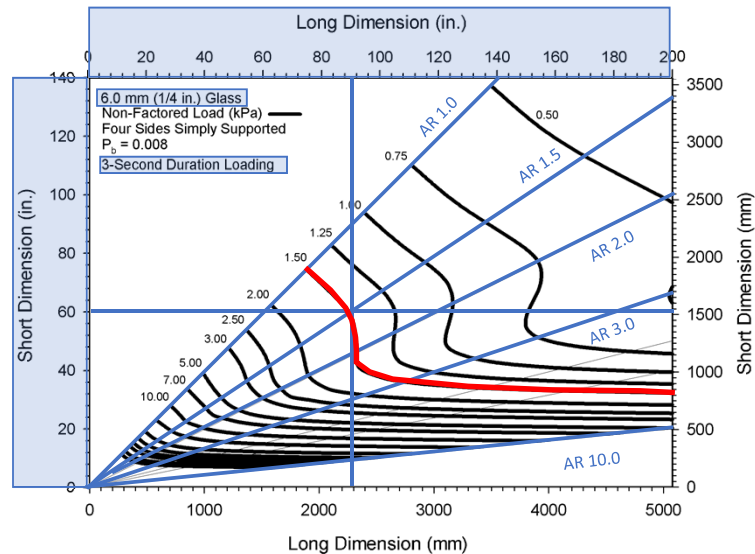
Procedure Overview

Original Procedure

Basic Procedure (*Section 6.2*)

- Determine Non-factored load from charts
 - Monolithic glass or Laminated Glass (PVB)
 - Thickness,
 - # of supported edges
- Factor NFL
 - Glass type
 - Load duration
 - IGU configuration
 - IGU Load Sharing

ASTM E1300 Glass NFL Chart



Basic Procedure

- Heat-Treated
 - Heat-strengthened $31.32 \text{ psf} \times 2.0 = 63 \text{ psf}$
 - Fully Tempered $32 \text{ psf} \times 4.0 = 63 \text{ psf}$
- Duration factors combined with glass type factors
- Separate Charts for Laminated Glass (PVB only)
- Simple load share model “*cubed thickness*”
 - *Lites in symmetric IGUs share load equally*
 - *Not a function of construction orientation*

New Analytical Procedure

Analytical Procedure (Section 6.3)

- Limited to 4 sides supported, *currently*
- Directly uses the glass failure prediction model (GFPM)
- Incorporates residual compressive surface stress (RCSS) into the GFPM for heat treated glass.
- Provides procedures for *asymmetric* laminated glass (thickness and glass type)
- Allows for interlayer types *other* than PVB
- Requires methods based on the *ideal gas law* to determine the load sharing of lite comprising insulating glass units

E1300 - Glass Failure Prediction Model

$$P_b = 1 - e^{-B}$$

$$B = k \cdot \sum_{i=1}^N \left[c_i \cdot \left(\frac{t_d}{60} \right)^{\frac{1}{n}} \cdot \left(\tilde{\sigma}_{\max_i} - \text{RCSS} \right) \right]^m \cdot A_i$$

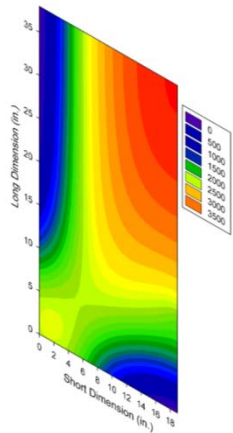
$$c_i = -0.005 \cdot r_i^6 + 0.022 \cdot r_i^5 + 0.055 \cdot r_i^4 + 0.039 \cdot r_i^3 + 0.031 \cdot r_i^2 + 0.06 \cdot r_i + 0.8$$

$$r_i = \frac{(\sigma_{\min_i} - \text{RCSS})}{(\sigma_{\max_i} - \text{RCSS})}$$

Same procedure used to create the Basic Method NFL charts

Values determined using numerical analysis

Analytical Procedure - Monolithic Glass



Perform Numerical
Stress Analysis



Min Principal	Max Principal	Calculation Factor (Do not Modify)	Ratio (mm/mm)
-3199.83	3199.83	0.5984099	0.5984099
-3190.96	3190.96	0.5984099	0.5984099
-2997.11	2997.11	0.4681441	0.4681441
-2991.82	2991.82	0.4681441	0.4681441
-2727.59	2727.59	0.4681441	0.4681441
-2598.12	2598.12	0.4681441	0.4681441
-2475.54	2475.54	0.4681441	0.4681441

Calculate P_b

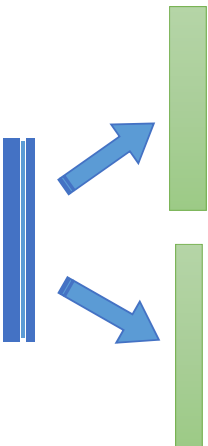


≤ 0.008 ✓

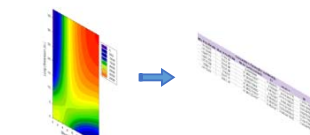
> 0.008 ✗

Check Limit

Analytical Procedure – Laminated Glass



Calculate
Effective Thickness



Perform Numerical
Stress Analysis



Perform Numerical
Stress Analysis



Calculate P_b

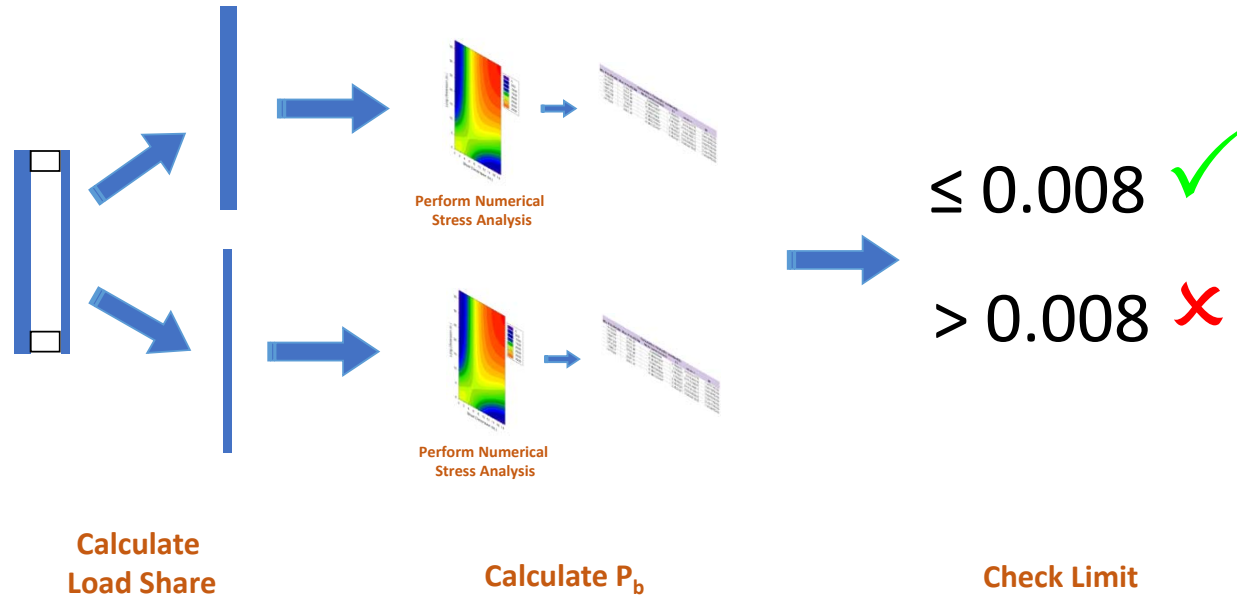


≤ 0.008 ✓

> 0.008 ✗

Check Limit

Analytical Procedure – Insulating Glass Unit



Analytical Procedure Examples

Laminated Glass Example

- Geometry
 - Rectangular Lite, 38in. X 76in. (1/8 in. | 0.03 PVB | 5/32 in.)
- Glass Properties
 - $E = 10.4 \times 10^6$ psi, $\nu = 0.22$
 - $m = 7$; $k = -1.365 \times 10^{-29}$ (60s)
- Interlayer Properties
 - $G = 61.9$ psi
- Uniform Lateral load,
 - $P = 50$ psf, 3s duration
- Model Boundary Conditions
 - Simply Support on all edges
 - Lateral displacement = 0
 - In plane displacements and edge rotations unrestrained

Laminated Glass Example

- Calculate the effective thickness for each glass ply
 - $h_{1,eff,\sigma} = 0.255$ in.
 - $h_{2,eff,\sigma} = 0.241$ in.
- Calculate the probability of breakage for each glass ply
 - $pb_1 = 0.0071 < 0.008$ Works
 - $pb_2 = 0.011 > 0.008$ Does not Work

This configuration does not work

Laminated Glass Example

- Change a ply thickness, interlayer type or glass type
 - Ply 2 thickness = 0.180 in. (3/16 in.)
 - $h_{1,eff,\sigma} = 0.292$ in. $\rightarrow pb_1 = 0.0020 < 0.008$ Works
 - $h_{2,eff,\sigma} = 0.263$ in. $\rightarrow pb_2 = 0.0056 < 0.008$ Works
 - Interlayer G = 3800 psi
 - $h_{1,eff,\sigma} = 0.290$ in. $\rightarrow pb_1 = 0.0021 < 0.008$ Works
 - $h_{2,eff,\sigma} = 0.293$ in. $\rightarrow pb_2 = 0.0018 < 0.008$ Works
 - Ply 2 RCSS = 3500 psi
 - $h_{1,eff,\sigma} = 0.256$ in. $\rightarrow pb_1 = 0.0071 < 0.008$ Works
 - $h_{2,eff,\sigma} = 0.241$ in. $\rightarrow pb_2 = 2.00 \times 10^{-9} < 0.008$ Works

Insulating Glass Example

- Geometry
 - Rectangular Lite, 38in. X 76in. (5/32 in. | 1/2in AS | 5/32 in.)
- Glass Properties
 - $E = 10.4 \times 10^6$ psi, $\nu = 0.22$
 - $m = 7$; $k = -1.365 \times 10^{-29}$ (60s)
- Uniform Lateral load,
 - $P = 50$ psf, 3s duration
- Model Boundary Conditions
 - Simply Support on all edges
 - Lateral displacement = 0
 - In plane displacements and edge rotations unrestrained

Insulating Glass Example

- Calculate the load carried by each glass ply
 - $L_1 = 25.5$ psf (50.9 %)
 - $L_2 = 24.5$ psf (49.1 %)
- Calculate the probability of breakage for each glass ply
 - $pb_1 = 0.0048 < 0.008$ Works
 - $pb_2 = 0.0042 < 0.008$ Works

Comparison of Basic and Analytical
results for select glazing constructions

Select Glazing Constructions

• Monolithic

- 1/4 in. – Annealed (RCSS = 0)
- 1/4 in. – Heat-strengthened (RCSS = 3500 psi)
- 1/4 in. – Fully-Tempered (RCSS = 10000 psi)

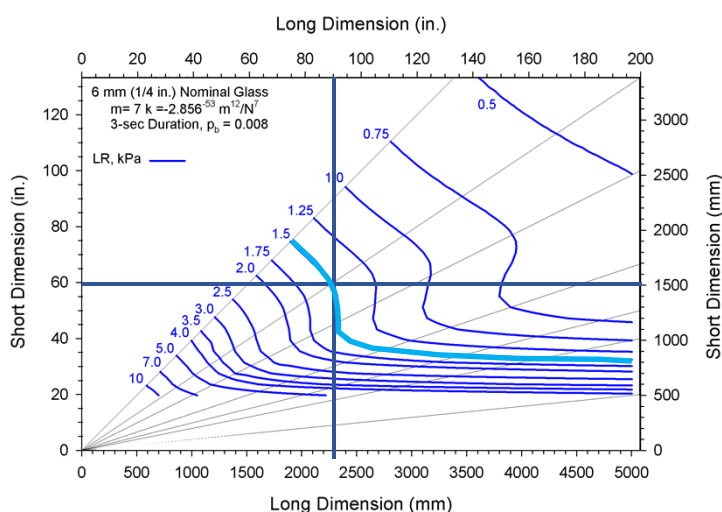
• Laminated

- 1/8 in. | 0.060 in. PVB | 1/8 in.
- 5/32 in. | 0.060 in. PVB | 5/32 in.
- 1/8 in. | 0.060 in. PVB | 3/16 in.
- 3/8 in. | 0.060 in. PVB | 3/8 in.
- 5/32 in. | 0.060 in. PVB | 5/8 in.

• Insulating Glass Unit

- 1/8 in. | 3/8 in. | 1/8 in.
- 1/8 in. | 3/8 in. | 1/4 in.
- 1/8 in. | 3/8 in. | 5/32 in. | 3/8 in. | 3/16 in.
- 3/16 in. | 3/8 in. | 5/32 in. | 3/8 in. | 1/8 in.

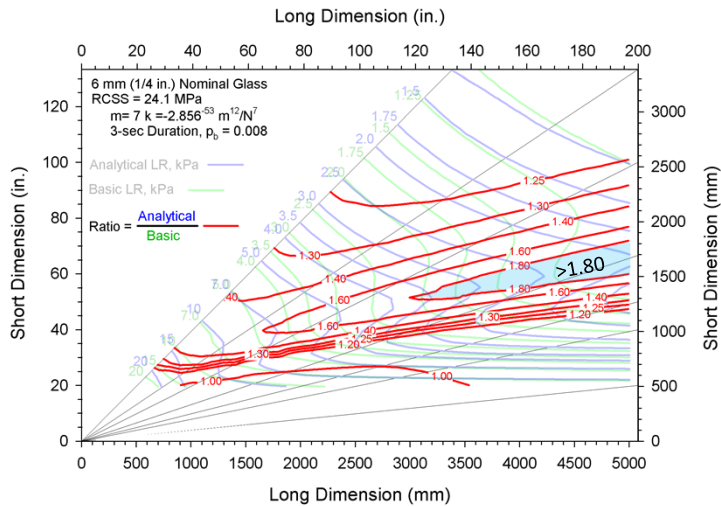
Monolithic 1/4 in. – (RCSS = 0)



No Change

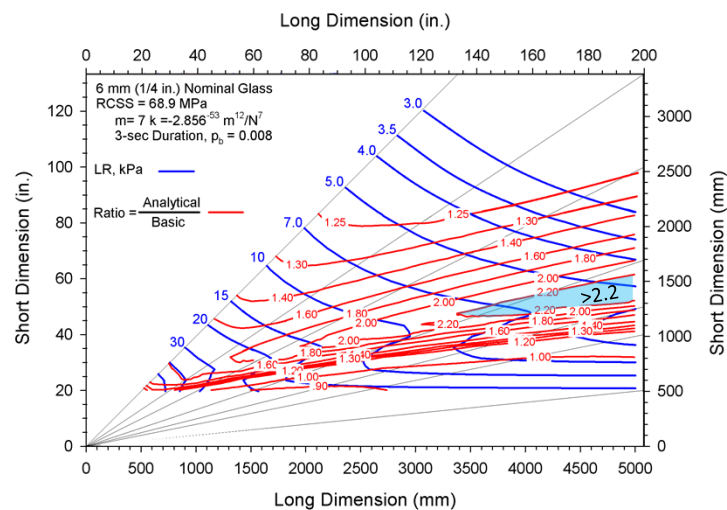
Analytical Procedure returns the same results as the NFL Charts

Monolithic ¼ in. – (RCSS = 3500 psi)

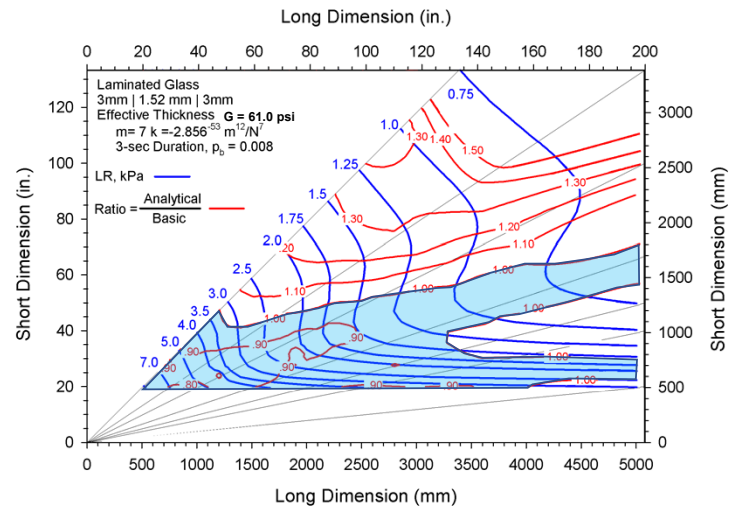


Ratios > 1.0 Indicate
 Analytical Method LR
 is larger than Basic
 Method

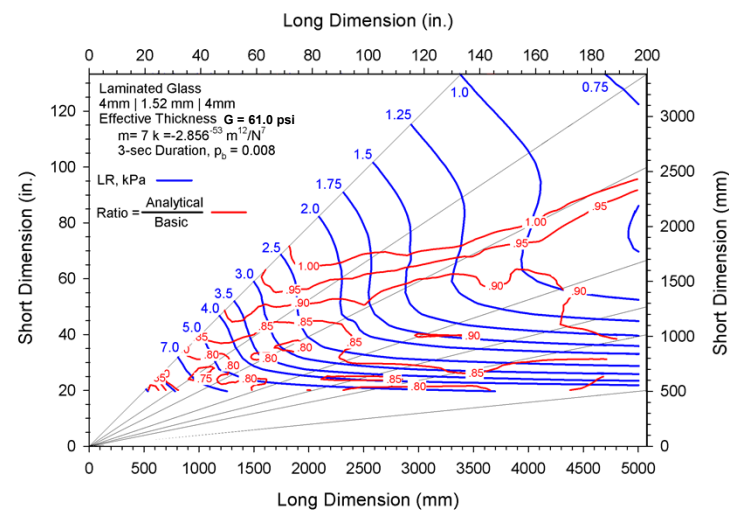
Monolithic ¼ in. – (RCSS = 10000 psi)



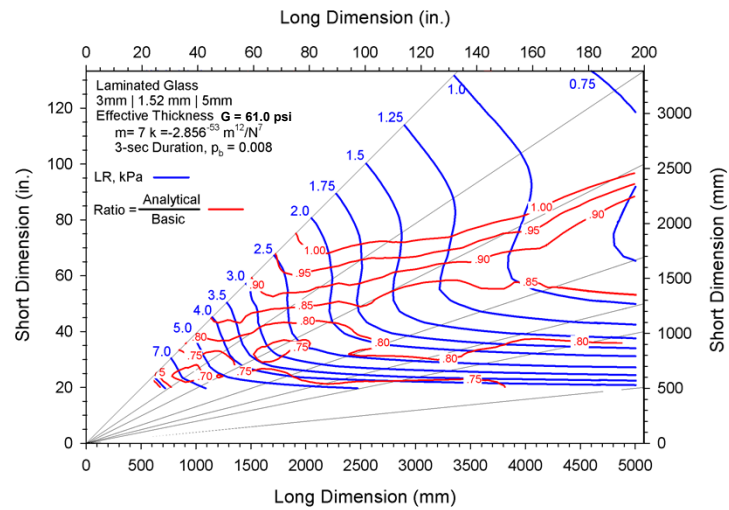
Laminated 1/8 in. | 0.060 in. PVB | 1/8 in.



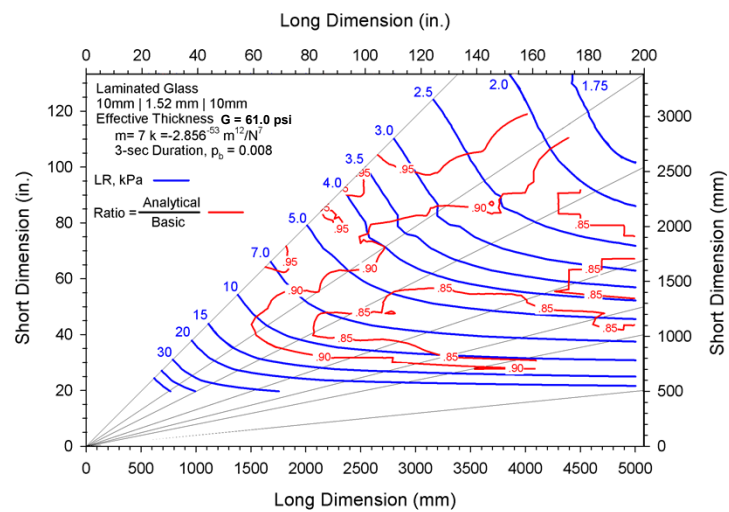
Laminated 5/32 in. | 0.060 in. PVB | 5/32 in.



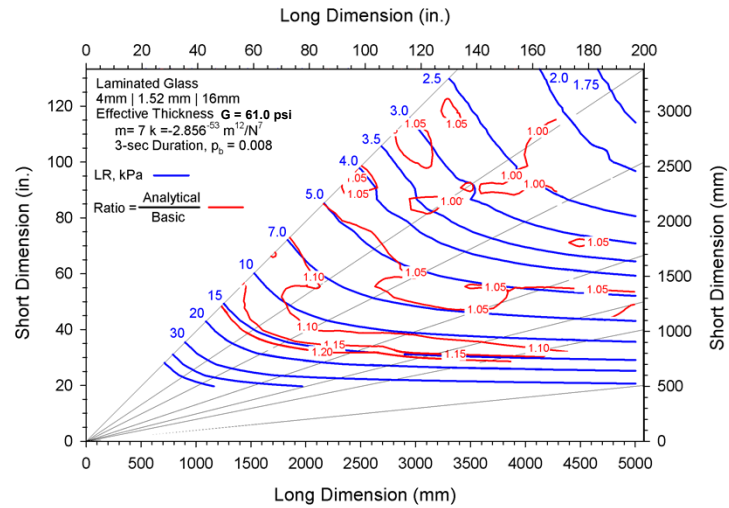
Laminated 1/8 in. | 0.060 in. PVB | 3/16 in.



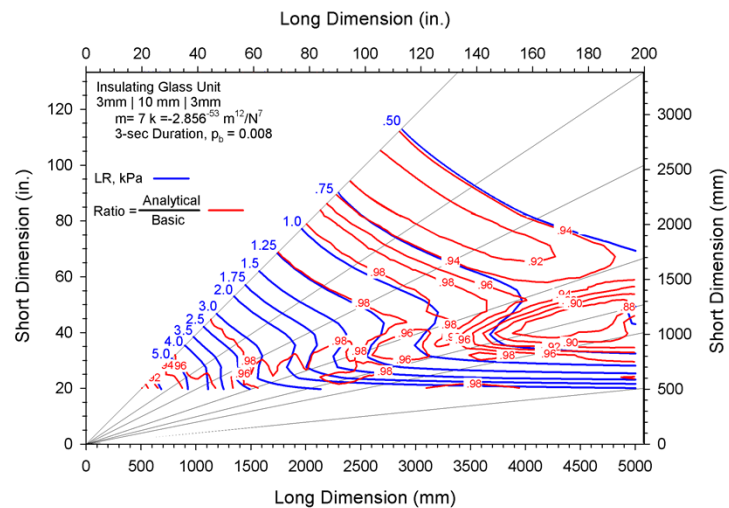
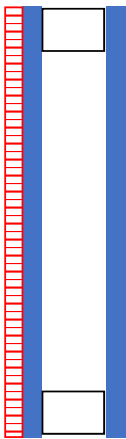
Laminated 3/8 in. | 0.060 in. PVB | 3/8 in.



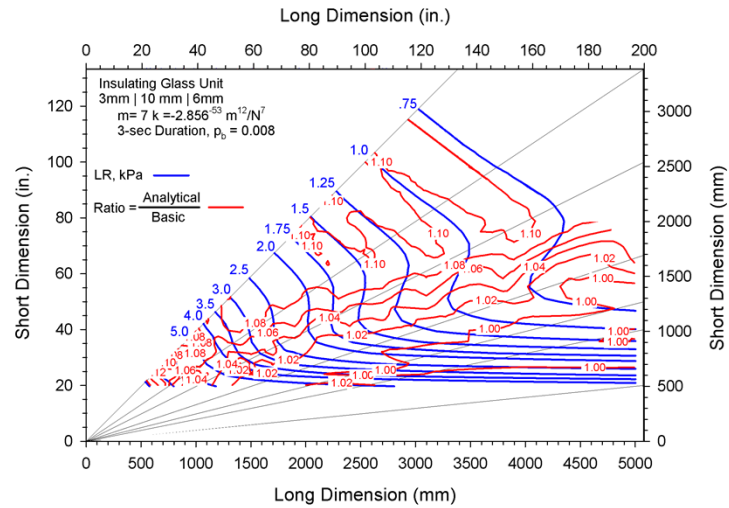
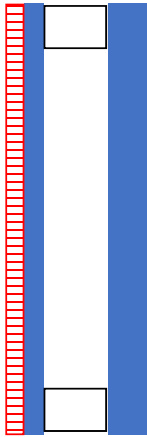
Laminated 5/32 in. | 0.060 in. PVB | 5/8 in.



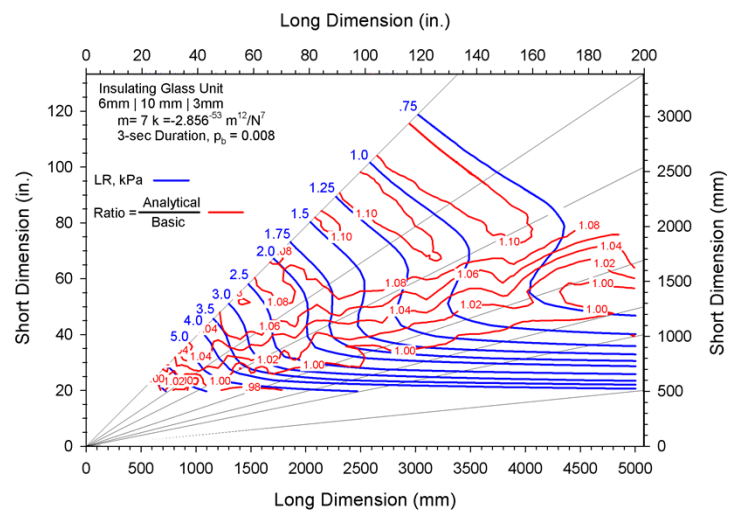
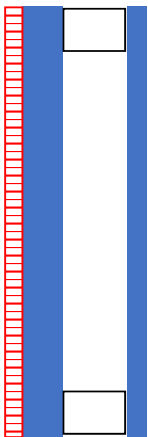
Insulating Glass Unit 1/8 in. | 3/8 in. | 1/8 in.



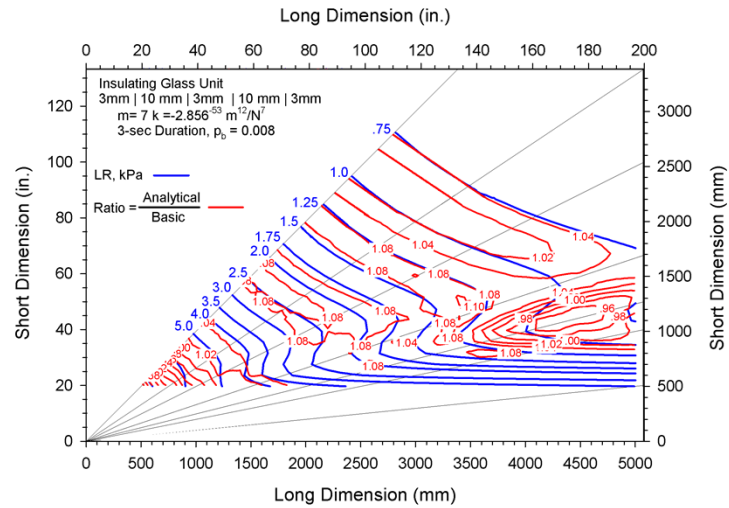
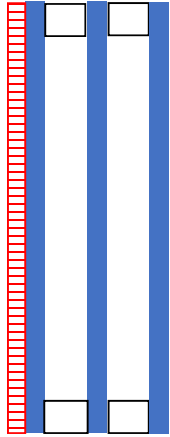
Insulating Glass Unit 1/8 in. | 3/8 in. | 1/4 in.



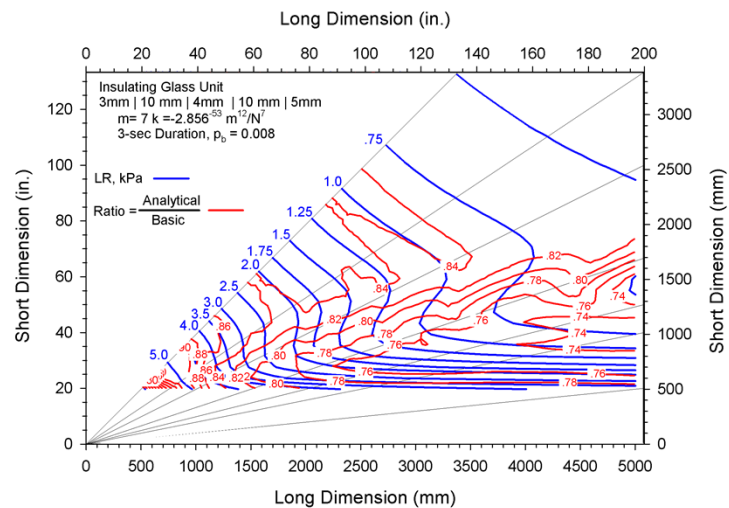
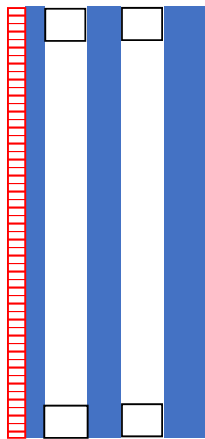
Insulating Glass Unit 1/4 in. | 3/8 in. | 1/8 in.



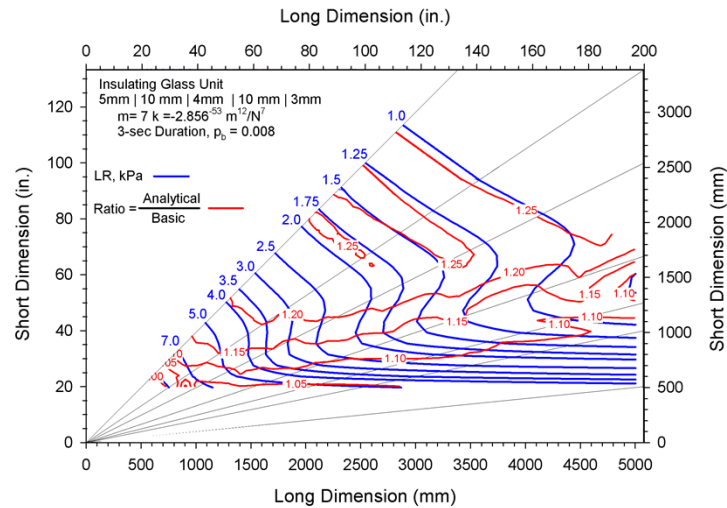
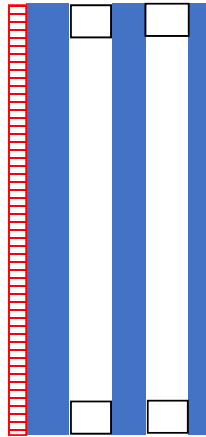
Insulating Glass Unit 1/8 in. | 3/8 in. | 5/32 in. | 3/8 in. | 3/16 in.



Insulating Glass Unit 1/8 in. | 3/8 in. | 5/32 in. | 3/8 in. | 5/16 in.



Insulating Glass Unit



Analytical Method Summary

- Heat Treated Glass
 - Up to 1.8 – 2.2 X larger when using the minimum RCSS
 - Increase varies with thickness, aspect ratio and area
- Laminated Glass
 - LR ratio varies with thickness, aspect ratio and area
 - Symmetric constructions
 - Smaller LRs for smaller dimensions
 - LRs increase over 1.0 as area increase for ARs near 1.0
 - Asymmetric constructions
 - LRs generally slightly larger LR
- Insulating glass
 - Symmetric IGUs LRs generally slightly smaller
 - Asymmetric IGUs LRs generally larger
 - Construction orientation affects load sharing

Future Work

- Extend GFPM to address edges and holes
 - Will cover most infill and some structural glass applications
 - Curved glass
- Surface Treatments
- VIGs

Continue the Dialogue.

Stephen M. Morse/ Michigan Tech University

- smmorse@mtu.edu