CHRIS HARTNETT & ASSOCIATES - PRESERVATION ENGINEERS

March 6, 2024

Mr. John Ruprecht
Clear View Glass Railings
737 Quentin Avenue South
Lakeland, MN 55043

Subject: International Building Code Update to 2021
Clear View Glass Railings
Project Number: 24001

Dear John:

This letter is intended to provide information to you and to your clients on the basis for Hercules Glass Panels and Lever Spigots code compliance, and to update this information for the 2021 International Building Code (IBC). It includes a brief background of code requirements, information on past code compliance to date and the updates to this for the 2021 IBC.

All commercial and most residential projects built within the United States are required to meet local building codes to ensure a minimum of safety and construction quality. Each municipality crafts their own codes and usually uses their State Building Code as the basis for their requirements; they tend to add and subtract things, as needed. In publishing its State Building Code, each state within the US uses as a guide a “model” code that is published by the International Code Council (ICC; iccsafe.org), titled the International Building Code; this is a bit of misnomer because most countries have their own building codes. The IBC uses information from many organizations to create its rules, from engineering groups such as the American Society of Civil Engineers (ASCE) to building material groups such as the American Institute Steel Constructors (AISC). The term “model” code is intended as just that, a model that states and municipalities can pull from to create their own rules.

The ICC updates their model codes every three years: 2018, 2021, 2024, etc.; the latest published code is the 2021, the 2024 IBC is in development and is expected to be published in early 2025. Each state also updates their State Building Code periodically, with every state publishing on a different schedule. Most states publish their updates one to two years after the IBC, which allows them to digest the latest IBC and accept or reject the changes. For example, Minnesota projects are governed by the 2020 Minnesota State Building Code, which looks to the 2018 for guidance. Minnesota updates the code every six years, so the next state code will be published in 2026 and will likely reference the 2024 IBC.

The code compliance reviews that we have performed for your Hercules Glass panels, based on physical testing and finite-element computer modelling, have used the 2018 IBC as a standard. You have white papers that describe this testing and evaluations. Now, in 2024, some states are adopting the 2021 IBC as their model code, which requires an update of your code compliance analysis to this new standard. This exercise is described below.

There are two IBC chapters that provide requirements for glass guard panels and floors. These are described separately, with changes between the 2018 and 2021 editions explained.

Chapter 16 *Structural Design* paragraph 1607.8.1 describes glass railing requirements (sections below are taken from the 2018 IBC): it requires a guard panel be able to resist a 50 plf horizontal load and a 200# point load (these are not simultaneous loads). It exempts one and two-family houses from the 50 plf line load.

1607.8.1 Handrails and guards.

Handrails and *guards* shall be designed to resist a linear load of 50 pounds per linear foot (plf) (0.73 kN/m) in accordance with Section 4.5.1.1 of ASCE 7. Glass handrail assemblies and *guards* shall comply with Section 2407.

Exceptions:

1. For one- and two-family dwellings, only the single concentrated load required by Section 1607.8.1.1 shall be applied.
2. In Group I-3, F, H and S occupancies, for areas that are not accessible to the general public and that have an *occupant load* less than 50, the minimum load shall be 20 pounds per foot (0.29 kN/m).

1607.8.1.1 Concentrated load.

Handrails and guards shall be designed to resist a concentrated load of 200 pounds (0.89 kN) in accordance with Section 4.5.1.1 of ASCE 7.

Glass handrails and guard panels are also required to comply with paragraph 2407, which describes required glass panel construction and increases the loads by a factor of four – a 200 plf line load and an 800# point load (not simultaneous):

SECTION 2407
GLASS IN HANDRAILS AND GUARDS ES

2407.1 Materials. P

Glass used in a handrail or a *guard* shall be laminated glass constructed of fully tempered or heat-strengthened glass and shall comply with Category II or CPSC 16 CFR Part 1201 or Class A of ANSI Z97.1. Glazing in railing in-fill panels shall be of an *approved* safety glazing material that conforms to the provisions of Section 2406.1.1. For all glazing types, the minimum nominal thickness shall be $^{1}/_{4}$ inch (6.4 mm).

Exception: Single fully tempered glass complying with Category II of CPSC 16 CFR Part 1201 or Class A of ANSI Z97.1 shall be permitted to be used in handrails and guardrails where there is no walking surface beneath them or the walking surface is permanently protected from the risk of falling glass.

Premium Code Insights : Code Change Details Key Changes

2407.1.1 Loads. P

The panels and their support system shall be designed to withstand the loads specified in Section 1607.8. Glass guard elements shall be designed using a factor of safety of four.

Your manufacturing process conforms with paragraph 2407.1; your testing and our analyses confirms that your Hercules Glass panels and Lever Spigotsconform to paragraph 207.1.1.

Your Hercules Glass floor panels are required to comply with floor "live" loading, as described in IBC Table 1607.1 and described below (excerpts of the table were cut-and-pasted for brevity):

TABLE 1607.1 MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS, L_o, AND MINIMUM CONCENTRATED LIVE LOADS[g]

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (pounds)
22. Office buildings		
Corridors above first floor	80	2,000
Offices	50	2,000
25. Residential		
One- and two-family dwellings		
Private rooms and corridors serving them	40	
Public rooms[m] and corridors serving them	100	

Our computer analysis has confirmed that your Hercules Glass floor panels conform to these requirements.

The 2021 IBC does not change these requirements except that paragraph 1607.8.1 in the 2018 IBC is changed to 1607.9.1 in the 2021 IBC. Therefore, your Hercules Glass guard panels and Hercules Glass floor panels conform to the 2018 and 2021 IBC.

I hope this letter clearly explains the strength and construction requirements of your Hercules Glass panels and Lever Spigots, as required by the International Building Code, and how these requirements are used by each state. Previous correspondences have described specific state adoptions and modifications to the IBC, as they pertain to your panels; we will continue to evaluate these, at your request. It is generally the responsibility of the panel installer to confirm that the municipality of their installation follows these requirements, and that their installation and attachment to the building meet these requirements.

As always, it is a pleasure to work with you. Don't hesitate to reach out with questions or requests for clarifications.

Best regards,

Chris Hartnett & Associates

Chris A. Hartnett, PE
Principal Engineer
Phone: 612-503-0048
Chris@PreservationEngineers.net

APPLIED MATERIALS & ENGINEERING, INC.
980 41st Street
Oakland, CA 94608
Tel: (510) 420-8190
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e-mail: info@appmateng.com

May 25, 2021 (updated June 8, 2024) Project No. 1210339C

Mr. John Ruprecht
CLEAR VIEW GLASS RAILINGS COMPANY
737 Quentin Avenue South
Lakeland, MN 55043

Email: John@CVGRailings.com

Subject: ClearView Glass Railings

Dear Mr. Ruprecht:

This letter report summarizes our review and findings of the American Engineering Testing, Inc. (AET) reports dated October 15, 2020 and November 13, 2020 regarding Clear View's Hercules Glass panel testing.

The above reports are attached as an Appendix.

FINDINGS

AET determined that a 200 pounds (lbs) point load would be the required design load for this type of application, ie. glass handrails. This calculation is based on IBC (International Building Code) Section 1607.8.1.1.

I. October 15, 2020 Report

AET performed a dynamic test on a 60" x 40" glass panel. A pendulum load of 300 pounds was allowed to impact the panel at a height of 36" from the top of the panel. No damage was observed to the glass panel.

II. November 13, 2020 Report

AET performed static testing with a load of 800 pounds (this has a factory of safety of 4) vertical point load on a 60" x 40" glass panel. The tested panel withstood 800 lbs without failure.

AET also performed static testing with a load of 800 pounds horizontal (out-of-plane) load on the glass panel. The panel resisted a load of up to 820 pounds, loaded on its edge.

<u>CONCLUSION</u>

The calculations and tests performed by AET conform to the applicable industry standards and are valid for the stated application.

Please call if you have any questions regarding the above.

Sincerely,

APPLIED MATERIALS & ENGINEERING, INC.

Armen Tajirian, Ph.D., SE
Principal

Appendix

CONSULTANTS
• ENVIRONMENTAL
• GEOTECHNICAL
• MATERIALS
• FORENSICS

AMERICAN ENGINEERING TESTING, INC.

October 15, 2020

Mr. John Ruprecht
Clear View Glass Railings
737 Quentin Avenue South
Lakeville, MN 55043

Re: Field test of Clear View Glass Railings "Hercules Glass" guardrail panel
AET Project #: 05-20608

Dear Mr. Ruprecht,

This letter reports tests performed on Clear View's Hercules Glass panel on April 21, 2020 by Clear View and your agents at 1141 120th Street in Roberts, Wisconsin. These tests were the first of a series of tests that included the dynamic loading test described below, and vertical and horizontal static tests. All tests were performed to provide test data that the panels meet International Building Code (IBC) requirements.

The panel tested was a 13mm thick tempered and laminated glass panel with the brand name Hercules Glass. It measured 13mm thick x 39.37" tall x 60" wide, and is supported by two metal "spigots", each located 12" inside a side edge of the panel (spaced 36" apart). The panel are secured in slots within the spigots, and the spigots are bolted to the supporting structure. The total height of the panel and spigots is 42".

The dynamic testing involved hanging 300# sandbags against the side of the panel at the panel's top edge. The sandbags were pulled back 33" and released, causing the sandbags to swing into the top of the panel, simulating a dynamic horizontal guardrail load – a person or object falling into the panel. The panel deflected approximately 4" and returned to its original shape, without experiencing any damage.

Don't hesitate to contact us with questions about this testing or any other aspects of this evaluation program.

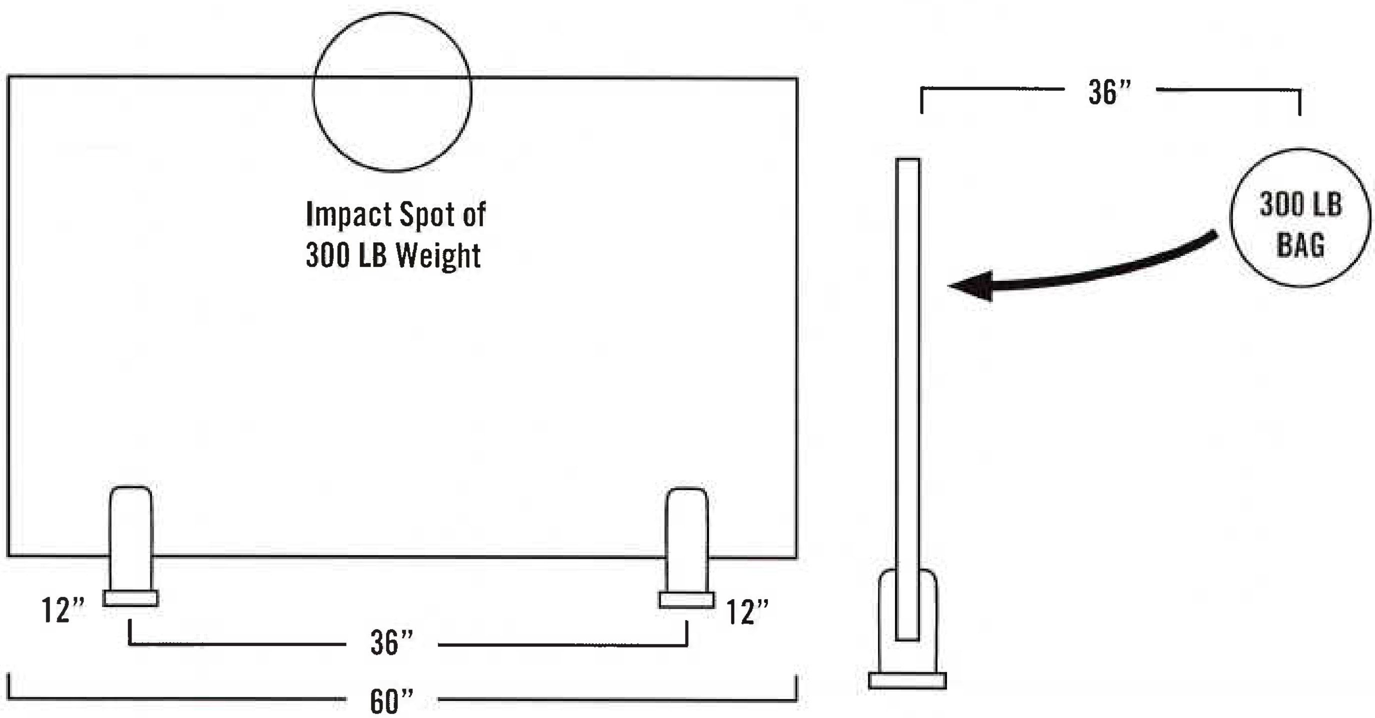
Sincerely,
American Engineering Testing, Inc.

Chris A Hartnett

Chris Hartnett, PE
Principal Engineer
MN Lic. No. 42371
Phone: 651-647-2750
chartnett@amengtest.com

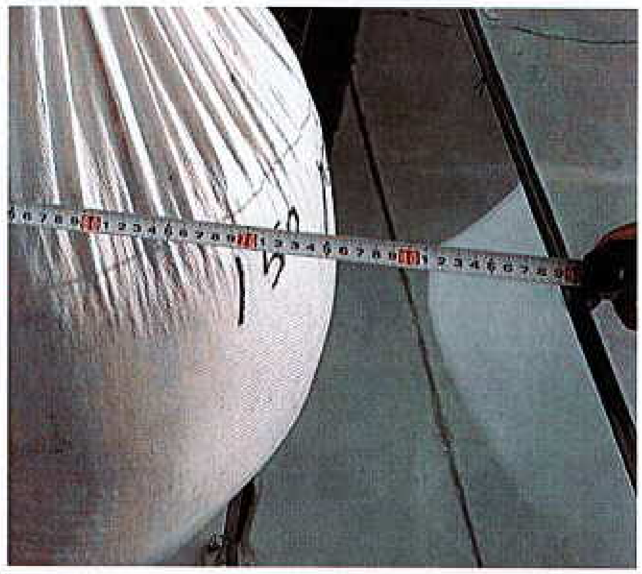
300 LB IMPACT TEST

This is an impact test of 60" x 39.37" x .53" thick CVGR Hercules tempered laminated glass panel mounted in two 316 solid core stainless steel spigots. Spigots are centered on glass 36" apart, 12" from end of glass. Plastic bags are weighted with 300 lbs of media, pulled back 36" from CVGR glass panel and then released to free fall to impact the top center of the CVGR panel. There is no damage or failure of the CVGR Hercules Glass panel or spigots from this 300 lb impact.



VIDEO STILLS ON REVERSE SIDE >

CVGR HERCULES GLASS 300 LB IMPACT TEST VIDEO STILLS



November 13, 2020

Mr. John Ruprecht
Clear View Glass Railings
737 Quentin Avenue South
Lakeland, MN 55043

Re: Code Requirements & Static Test of Clear View Glass Railings "Hercules Glass" guardrail panel
AET Project #: 05-20608

Dear Mr. Ruprecht,

This letter reports building code requirements for guardrails; it also reports test methods and results for static tests performed on Clear View's Hercules Glass panel.

The International Building Code (IBC) and International Residential Code (IRC) are "model codes" created by the International Code Council, intended to be used by states and municipalities as they publish their own building codes. Section 1607.8 of the IBC requires that "handrails and guards shall be designed to resist a linear load of 50 plf." It also requires the system to resist a 200# concentrated load that produces the "maximum load effect" on any element within the system. The 2018 IRC Table R201.5 extends this requirement into residential construction. It is understood within the building design industry that laterial loads applied to the top of the panel create the maximum load effect; structural design assumes this loading condition.

Section 1607.8 of the IBC also refers to IBC section 2407 Glass in Handrails and Guards that adds a requirement for all-glass handrails and guards to "be laminated glass constructed of fully tempered or heat-strengthened glass"; this requirement was added in the 2015 IBC code cycle. Section 2407.1.1 adds the significant requirement: "a design factor of four shall be used for safety". This addition bumps up the linear load to 200 plf and the concentrated load to 800#..

Exterior glass guardrail panels are designed to resist two load types: wind loads, and "live" loads such as a person or object pushing on or striking the panel from the side or from above. Wind loading on a panel can vary greatly based on location, terrain (wooded vs open) and elevation above ground; these are governed by publication ASCE 7 (American Society of Civil Engineers) Minimum Design Loads for Buildings and Other Structures. Wind speeds of 115 psf are used to calculate wind pressures against the glass, which generally vary from 17 psf (2nd story in wooded area) to 35 psf (30 stories tall in open terrain). The wind speeds required to match the stresses created by the 800# point load are 192 mph for the 42" tall panel and 215 mph for the 36" tall panel; these are only seen in a Category 5 hurricane or a tornado. Therefore, the 800# horizontal point load requirement is the worst-case scenario for the panels. Calculation methods to arrive at these values include computer modeling using finite element analysis, using criteria specific to Clear View's panels and support configuration.

Hercules Glass Testing

Testing was performed on the Hercules Glass panel by Clear View's glass supplier, to simulate the forces created by 800# horizontal and vertical point loads on the panel (loads are not required to be simultaneous). The vertical load test is fairly straightforward and is shown in photo 1. Note: the intent was to load the panel to failure; however, the testers ran out of sandbags at 2,520 pounds, without failure.

Photo 1: Panel loaded vertically with 2,520 pounds.

Given the difficulty of pushing an 800# load horizontally against the panel, a test rig was set up that supports the panel on its side and places sandbags vertically on the panel. The panel is supported 28" from the top of panel (creating a 28" cantilever), with a heavy counterweight holding down the bottom of the panel mounted in its spigots. Sandbags were placed at the top edge of the panel until failure. See Diagram 1 and photo 2. The panel failed after one minute with 820 pounds loaded on its edge, which is equivalent to 547 pounds for a 42" tall panel. Using a finite element computer model, it was determined that the stresses caused by the 547 pound point load are equivalent to those caused by a 147 mph wind.

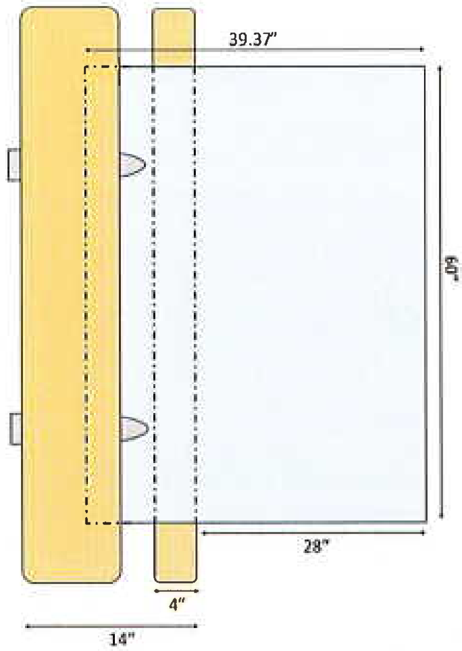


Diagram 1: Test rig lying on its side, looking from above, showing panel supported at 28" and at bottom of panel

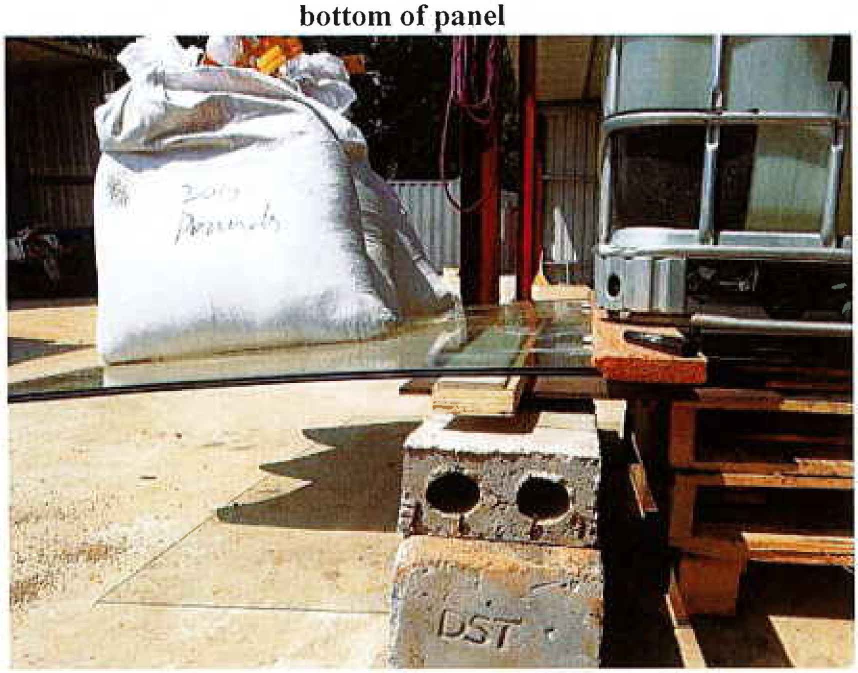


Photo 2: Loading of panel with sandbags, simulating horizontal force

Due to the laminate construction of the panels (similar to a vehicle windshield), the panel broke into small pieces that were retained within the panel, preventing dangerous flying glass debris. See photo 3.

Photo 3: Panel after failure, showing all glass intact within laminate structure.

This test shows that the panel meets the intent to create a strong and safe barrier that can withstand reasonable loading (factor of safety of 2.5), and does not explode with dangerous glass shards during excessive loading.

Don't hesitate to contact us with questions about this testing or any other aspects of this evaluation program.

Sincerely,
American Engineering Testing, Inc.

Chris Hartnett, PE
Principal Engineer
MN Lic. No. 42371
Phone: 651-647-2750
chartnett@amengtest.com

300 LB IMPACT TESTING

October 15, 2020

Mr. John Ruprecht
Clear View Glass Railings
737 Quentin Avenue South
Lakeland, MN 55043

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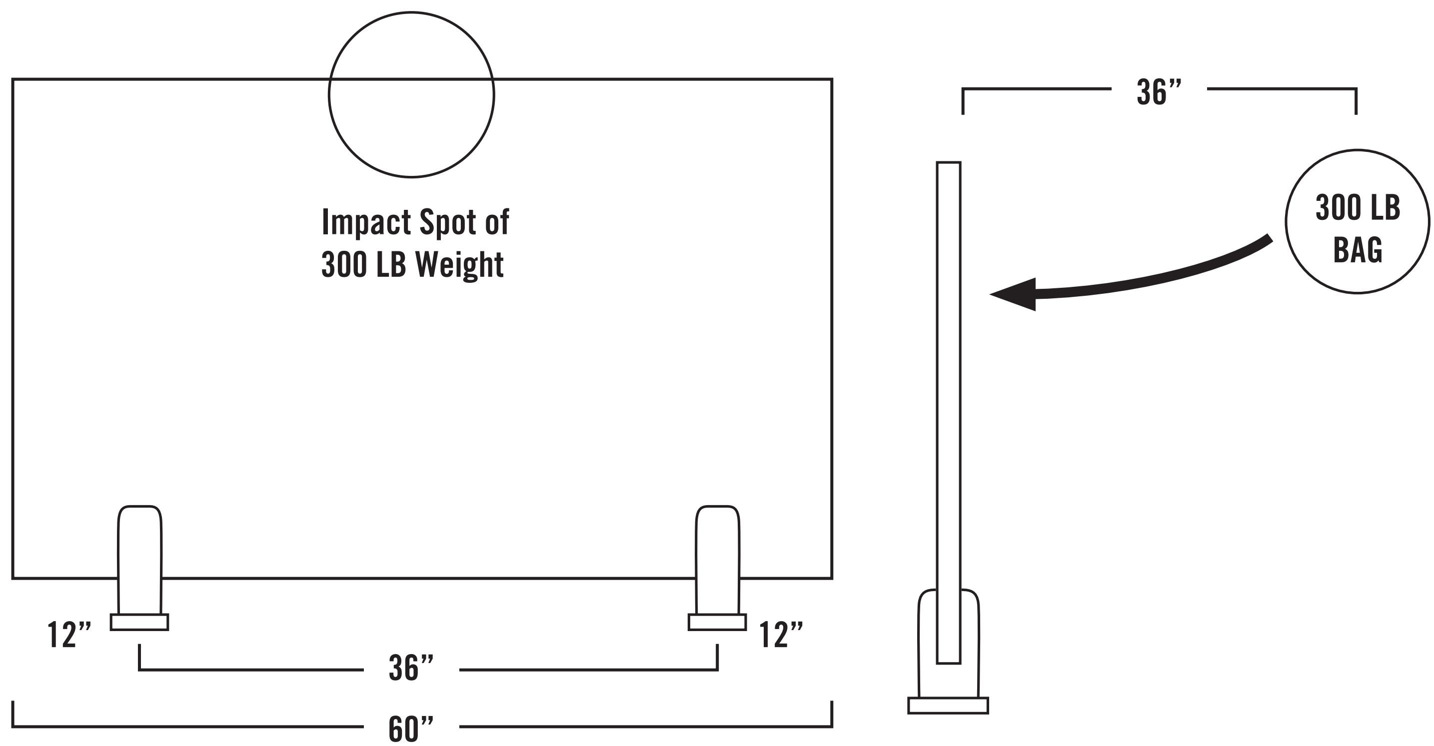

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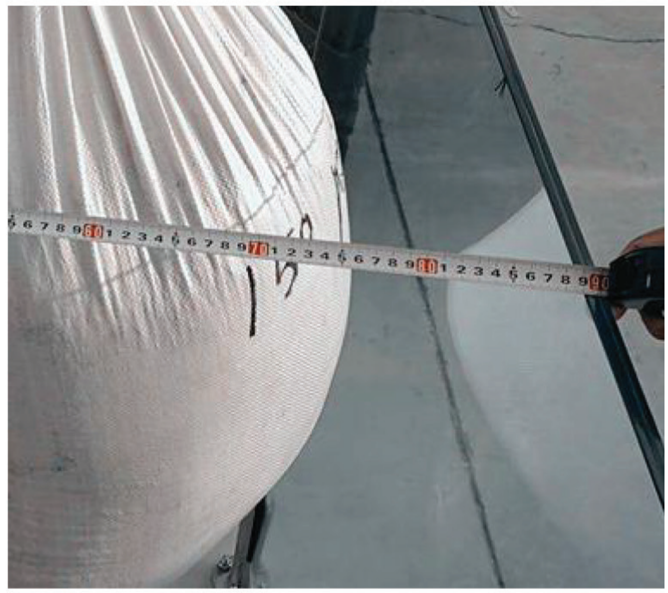

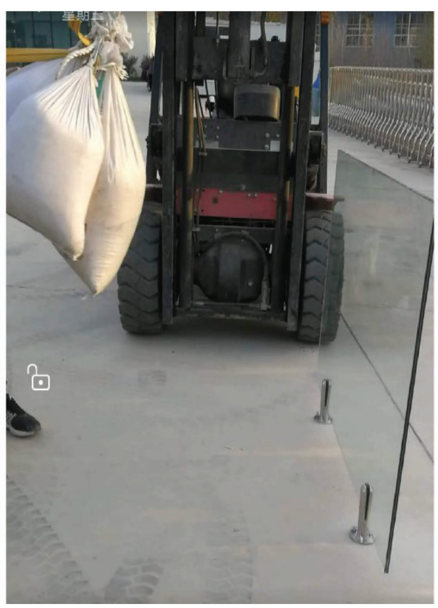

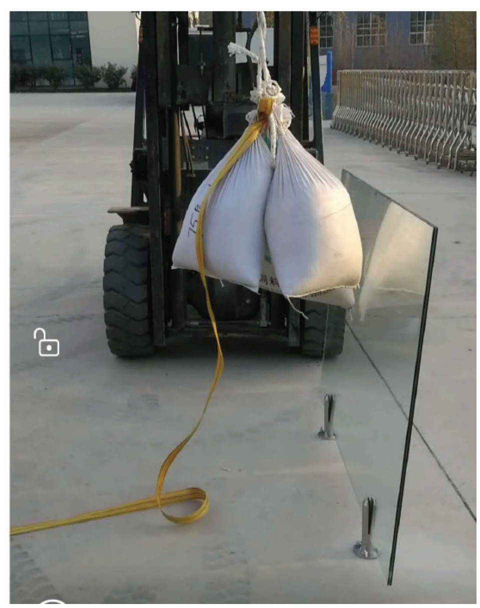

LOAD TESTING

CONSULTANTS
· ENVIRONMENTAL
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· MATERIALS
· FORENSICS

AMERICAN ENGINEERING TESTING, INC.

November 13, 2020

Mr. John Ruprecht
Clear View Glass Railings
737 Quentin Avenue South
Lakeland, MN 55043

Re: Code Requirements & Static Test of Clear View Glass Railings "Hercules Glass" guardrail panel
AET Project #: 05-20608

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Section 1607.8 of the IBC also refers to IBC section 2407 Glass in Handrails and Guards that adds a requirement for all-glass handrails and guards to "be laminated glass constructed of fully tempered or heat-strengthened glass"; this requirement was added in the 2015 IBC code cycle. Section 2407.1.1 adds the significant requirement: "a design factor of four shall be used for safety". This addition bumps up the linear load to 200 plf and the concentrated load to 800#..

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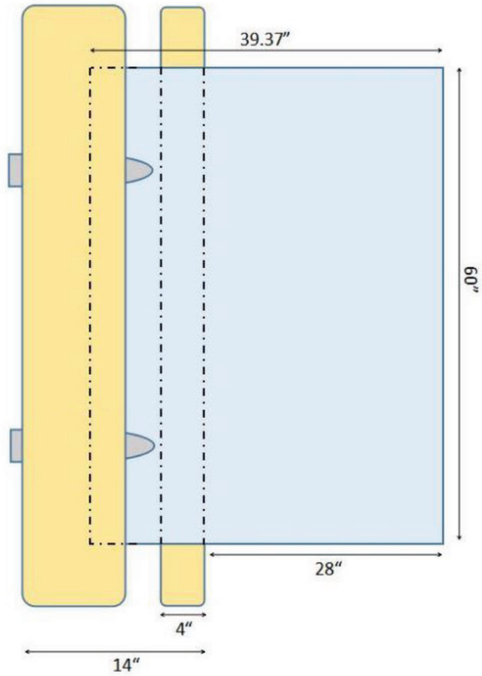

Diagram 1: Test rig lying on its side, looking from above, showing panel supported at 28" and at bottom of panel

Photo 2: Loading of panel with sandbags, simulating horizontal force

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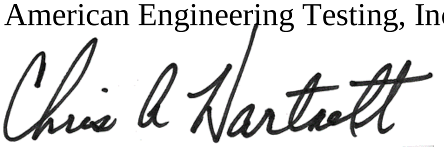

Chris Hartnett, PE
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FLORIDA HURRICANE TESTING

AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
· ENVIRONMENTAL
· GEOTECHNICAL
· MATERIALS
· FORENSICS

November 17, 2020

Mr. John Ruprecht
Clear View Glass Railings
737 Quentin Avenue South
Lakeland, MN 55043

Re: Florida Wind Load Requirements for Wind-Borne Debris Regions, and Considerations for "Hercules" Glass Guardrail Panel
AET Project #: 05-20608

Dear Mr. Ruprecht,

This letter reports the findings of our review of the Florida Building Code (FBC) wind requirements for Wind-Borne Regions, as defined by the FBC. We compare these requirements to the published and tested strength of the Hercules Glass Guardrail Panel, model CVGR 1001 FWP, and provide conclusions regarding panel design requirements to meet specific portions of the FBC code.

The Florida Building Code (FBC) Section 2407 addresses glass used in handrails and guards; it specifies materials, loads, support conditions and wind-borne debris regions. According to the FBC and in compliance with Category II of the Consumer Product Safety Commission (CPSC) and Class A of ANSI Z97.1, glass used in guardrails must be laminated glass constructed of fully tempered or heat strengthened glass and tested for its water penetration resistance, wind loading, impact, durability, thermal properties, and mechanical performance. It is our understanding that the panel is laminated and fully tempered. Our analysis addresses only the wind loading and impact requirements.

The FBC follows the International Building Code (IBC) requirements for wind loads, with ultimate (factored) wind speeds up to 180 mph; this is significantly higher than most areas within the United States. See the attached reference maps for determining the nominal ground wind speed from the Florida Building Code.

Our analysis converted the 180 mph required factored wind speed into a stress, using accepted analysis techniques, then compared this to the published (and tested) capacity of the panels. The American Society of Civil Engineers (ASCE) Standard 7-10, Chapter 29, provides the analysis method to convert wind speed (in mph) to pressure (in psf). Using Exposure Category C (open terrain) and a height of 100 feet above ground, a 180 mph factored wind produces a calculated pressure of 54 psf. This was plugged into a finite element model (FEM), using Risa-3D software (version 10.0.1), that models the 60" x 39" x 13mm tempered and laminated panels, supported on three "spigot" supports. The model generated a 5,500 psi principal axis stress (σ) in the panel.

The glass used in the panels has a published capacity of 10,000 psi tensile strength. Using the FEM, the pressure was increased until the capacity was reached, which was 100 psf. Plugging this into the ASCE 7-10 equations yields a service wind speed of 155 mph, or 250 mph factored wind speed. This is higher than the FBC's 180 mph factored wind speed requirement.

For building envelope glazing in wind-borne debris regions, glass that is part of a building envelope must be tested for impact resistance in accordance with American Society for Testing and Materials (ASTM) E1996. This requirement protects a closed building envelope from being penetrated and prevents high wind pressures from filling the building, potentially blowing out windows and lifting the roof off the building. Because these panels are not part of the building enclosure, damage from wind-borne debris would not penetrate the enclosure and its structural elements. Therefore, this test is not required for the panels used as a guardrail system.

FBC Section 2407.1.2 requires that all panels "shall be supported by a minimum of three glass balusters or shall be otherwise supported to remain in place should one baluster panel fail". We interpret this to mean that the panels will require three spigot supports, which is an increase from two supports in your standard panels. FBC Section 2407.1.2 also includes an exception that states, "A top rail shall not be required where the glass balusters are laminated glass with two or more glass plies of equal thickness and the same glass type when approved by the building official". We understand the panel meets this exception, so a top rail is not required.

In summary, based on our understanding of the FBC requirements, our conclusions are as follows:

1. Wind pressure – previous testing confirms that the panels meet the 180 mph factored wind speed requirement.
2. The panels do not require wind debris projectile testing.
3. Each panel requires three support points to the structure.
4. A top rail is not required for these panels.

Our calculations and computer model information and output is available upon request. Please call or e-mail us to discuss this analysis or any portion of the project to evaluate your panels.

Sincerely,
American Engineering Testing, Inc.

Chris A Hartnett

Chris Hartnett, PE*
Principal Engineer
*MN, WI, AL, MD, MO, NC, ND, OH, PA, TN VA
Phone: 651-647-2750
chartnett@amengtest.com

Daniel J. Larson, PE
Principal Engineer
Florida License #70286
Phone: 651-659-1337
dlarson@amengtest.com

Attachment: FBC Section 1609.3 - Ultimate Design Wind Speed Map

STRUCTURAL ASSESSMENT FOR NORTH CAROLINA CODE OFFICIALS

AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
- ENVIRONMENTAL
- GEOTECHNICAL
- MATERIALS
- FORENSICS

CLEARVIEW GLASS RAILINGS – STRUCTURAL ASSESSMENT
FOR NORTH CAROLINA CODE OFFICIALS

AET Project No. 05-20608

STRUCTURAL TESTING, FINITE ELEMENT ANALYSIS AND CODE EVALUATION

MARCH 3, 2021

PREPARED FOR:
MR. JOHN RUPRECHT
CLEAR VIEW GLASS RAILINGS
737 QUENTIN AVENUE SOUTH
LAKELAND, MN 55043

PREPARED BY:
CHRIS HARTNETT, PE*

*MINNESOTA AND WISCONSIN

St. Paul, MN
Duluth, MN
Mankato, MN
Marshall, MN
Rochester, MN
Williston, ND
Pierre, SD
Rapid City, SD
Sioux Falls, SD
Wausau, WI
Sheridan, WY
Gillette, WY
Casper, WY

March 2, 2021

Mr. John Ruprecht
Clear View Glass Railings
737 Quentin Avenue South
Lakeland, MN 55043

Re: Wind Load Requirements for Wind-Borne Debris Regions, and Considerations for "Hercules" Glass Guardrail Panel
AET Project #: 05-20608

Dear Mr. Ruprecht,

This letter reports the findings of our review of the North Carolina wind requirements for Wind-Borne Debris Regions, as described by North Carolina Building Code Section 1609. These requirements closely follow ASCE 7. We compare these requirements to the published and tested strength of the Hercules Glass Guardrail Panel, model CVGR 1001 FWP, and provide conclusions regarding panel design requirements to meet specific portions of the NCBC code.

Panel Construction

The North Carolina State Building Code (NCBC) Section 2407 addresses glass used in handrails and guards; it specifies materials, loads, support conditions and wind-borne debris regions. According to the NCBC and in compliance with Category II of the Consumer Product Safety Commission (CPSC) and Class A of ANSI Z97.1, glass used in guardrails must be laminated glass constructed of fully tempered or heat strengthened glass and tested for its water penetration resistance, wind loading, impact, durability, thermal properties, and mechanical performance. It is our understanding that the panel is laminated and fully tempered.

Panel Support

NCBC Section 2407.1.2 requires that all panels "shall be supported by a minimum of three glass balusters or shall be otherwise supported to remain in place should one baluster panel fail". We interpret this to mean that the panels will require three spigot supports. The Hercules Glass Guardrail Panel is available with three spigots, where required by North Carolina Building Code.

The stainless steel spigots have been reviewed to confirm they possess the strength to support the shear and bending forces placed on them by the glass panels. When three spigots support the panels, they have sufficient capacity to resist wind loads required by the North Carolina Building Code. To meet the 4 * multiplier for live loads shown in 2015 IBC section 2407.1.1 (required by some municipalities) a high strength cement is required between the glass and the spigot, to increase the friction coefficient and the spigot "gripping" strength of the panel.

The code-mandated wind and live load forces create an overturning force through the panels and spigots that is resisted by the supporting structure. Using the diagram provided by ClearView Glass Railings, showing 3.149" between two bolt holes between the spigot and the supporting structure, the hold down force for each bolt is 2,500#. A 3/8" diameter A354 structural bolt has sufficient capacity to resist this force. A review of the existing structure to support these loads is beyond the scope of this document, and is left for the project Structural Engineer of Record (SER) to certify.

NCBC Section 2407.1.2 includes an exception that states, "A top rail shall not be required where the glass balusters are laminated glass with two or more glass plies of equal thickness and the same glass type when approved by the building official". We understand the panel meets this exception; therefore, a top rail is not required.

Wind Loading vs. Panel Capacity

The NCBC follows the International Building Code (IBC) requirements for wind loads, with ultimate (factored) wind speeds up to 160 mph. These panels were tested to 180 mph for wind loads across the Southeast US. Table 1609.3.1 converts this to 139 psf for unfactored loading, which was used in the analysis. See Attachment 1 for nominal ground wind speed reference maps from the North Carolina Building Code.

The American Society of Civil Engineers (ASCE) Standard 7-10, Chapter 29, provides the analysis method to convert wind speed (in mph) to pressure (psf) against the glass panel. Using Exposure Category C (open terrain) and a height of 100 feet above ground; a 139 mph wind produces a calculated pressure of 81psf. See Attachment 2. The three distinct support points, "spigots", for these panels creates stress concentrations around the supports that are best modeled using a finite element model (FEM). A FEM model was created for this panel using Risa-3D software (version 10.0.1), that modeled a 60" wide x 39" tall x 13mm thick tempered and laminated panel, with a 81psf surface load applied. The model generated a 15,979 psi principal axis stress (σ) in the panel. See Attachment 3.

The glass used in the panels was tested to determine its structural capacity, using a static load applied to a test specimen. The specimen was loaded to failure, and the loading was applied to the FEM to determine the equivalent stresses. The failure stress was 35,767 psi. This modeling shows that the panels have calculated factor-of-safety of 2.24. See Attachment 4.

Impact Resistance

For building envelope glazing in wind-borne debris regions, glass that is part of a building envelope must be tested for impact resistance in accordance with American Society for Testing and Materials (ASTM) E1996. This requirement protects a closed building envelope from being penetrated and prevents high wind pressures from filling the building, potentially blowing out windows and lifting the roof off the building. Because these panels are not part of the building enclosure, damage from wind-borne debris would not penetrate the enclosure and its structural elements. Therefore, this test is not required for the panels used as a guardrail system.

Summary

Based on our understanding of the NCBC requirements, our conclusions follow:

1. Each panel is constructed of fully tempered, laminated glass.
2. Each panel is secured to the structure with three supports.
3. A top rail is not required for these panels.
4. Wind pressure – previous testing confirms that the panels meet the 180 mph factored wind speed requirement, with a calculated factor-of-safety of 2.24.
5. The panels do not require wind debris projectile testing.

Please call or e-mail us to discuss this analysis or any portion of the project to evaluate your panels.

Sincerely,
American Engineering Testing, Inc.

Chris Hartnett, PE*
Principal Engineer
*MN, WI
Phone: 651-647-2750
chartnett@amengtest.com

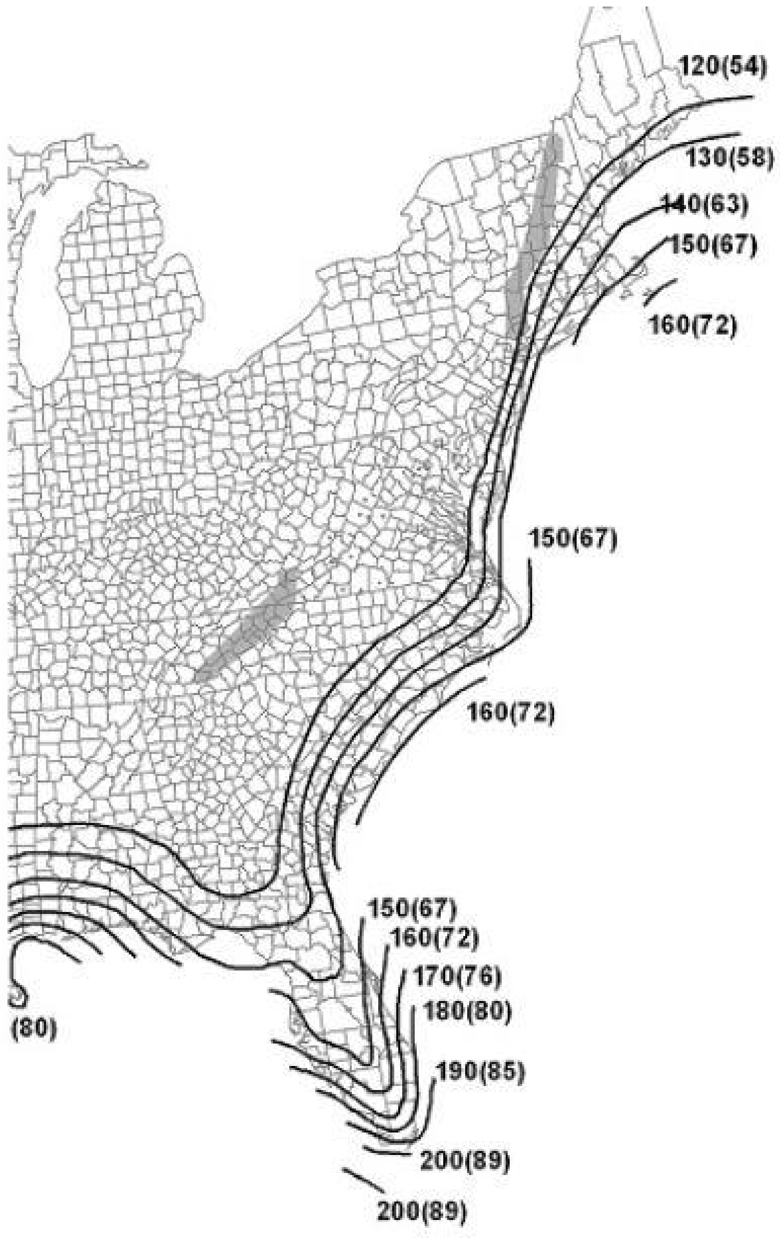
Attachment: Testing and Code Evaluation

1: North Carolina Figure 1609.1 – Ultimate Wind Design Speed.
2: ASCE 7-10 Wind & Pressure Calculations.
3. Finite Element Modelling.
4: Physical Testing

1609.3 Ultimate Design Wind Speed

The ultimate design wind speed, V_{ult}, in mph, for the determination of the wind loads shall be determined by Figures 1609.3(1), 1609.3(2) and 1609.3(3). The ultimate design wind speed, V_{ult}, for use in the design of Risk Category II buildings and structures shall be obtained from Figure 1609.3(1). The ultimate design wind speed, V_{ult}, for use in the design of Risk Category III and IV buildings and structures shall be obtained from Figure 1609.3(2). The ultimate design wind speed, V_{ult}, for use in the design of Risk Category I buildings and structures shall be obtained from Figure 1609.3(3). The ultimate design wind speed, V_{ult}, for the special wind regions indicated near mountainous terrain and near gorges shall be in accordance with local jurisdiction requirements. The ultimate design wind speeds, V_{ult}, determined by the local jurisdiction shall be in accordance with Section 26.5.1 of ASCE 7. The exact location of wind speed lines shall be established by local ordinance using recognized physical landmarks such as major roads, canals, rivers and lake shores wherever possible.

In nonhurricane-prone regions, when the ultimate design wind speed, V_{ult}, is estimated from regional climatic data, the ultimate design wind speed, V_{ult}, shall be determined in accordance with Section 26.5.3 of ASCE 7.

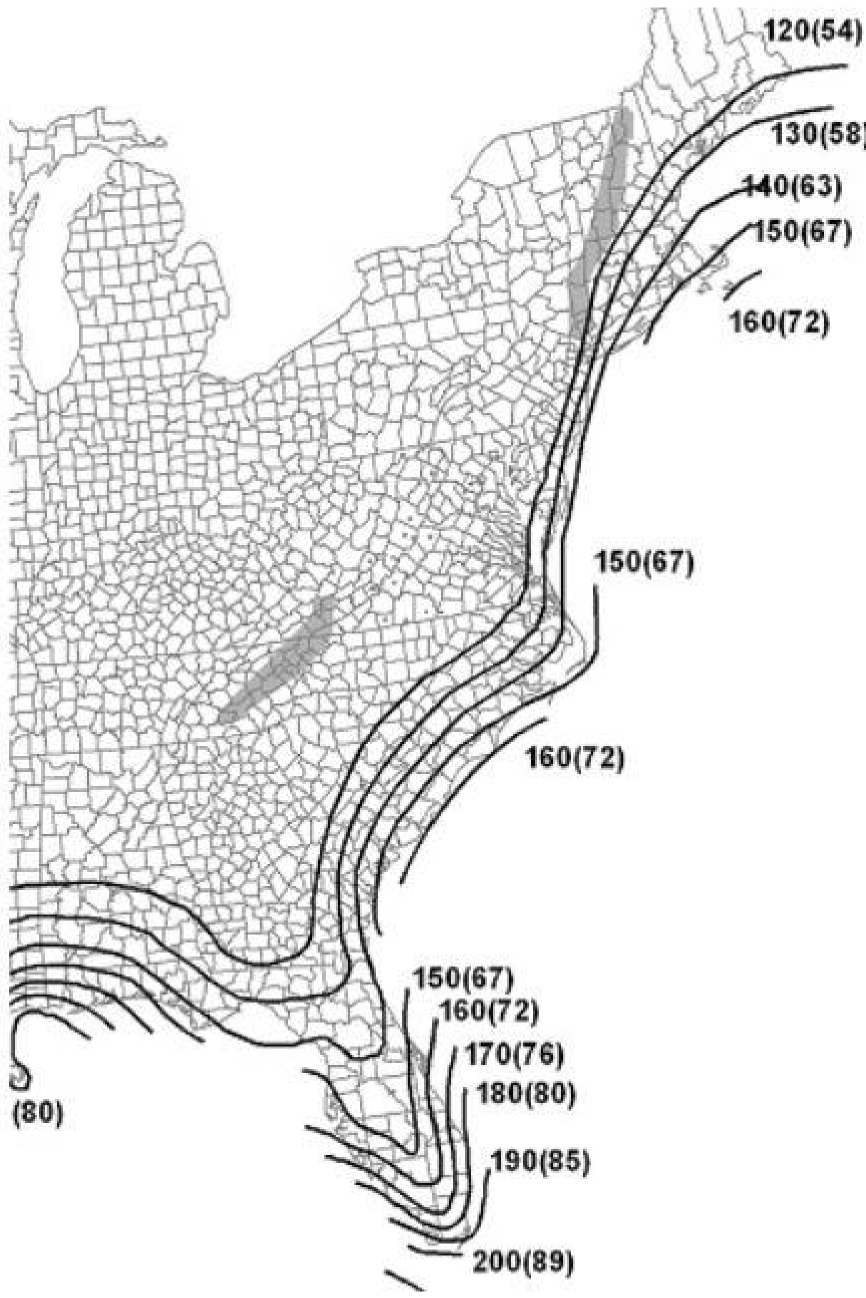


Notes:

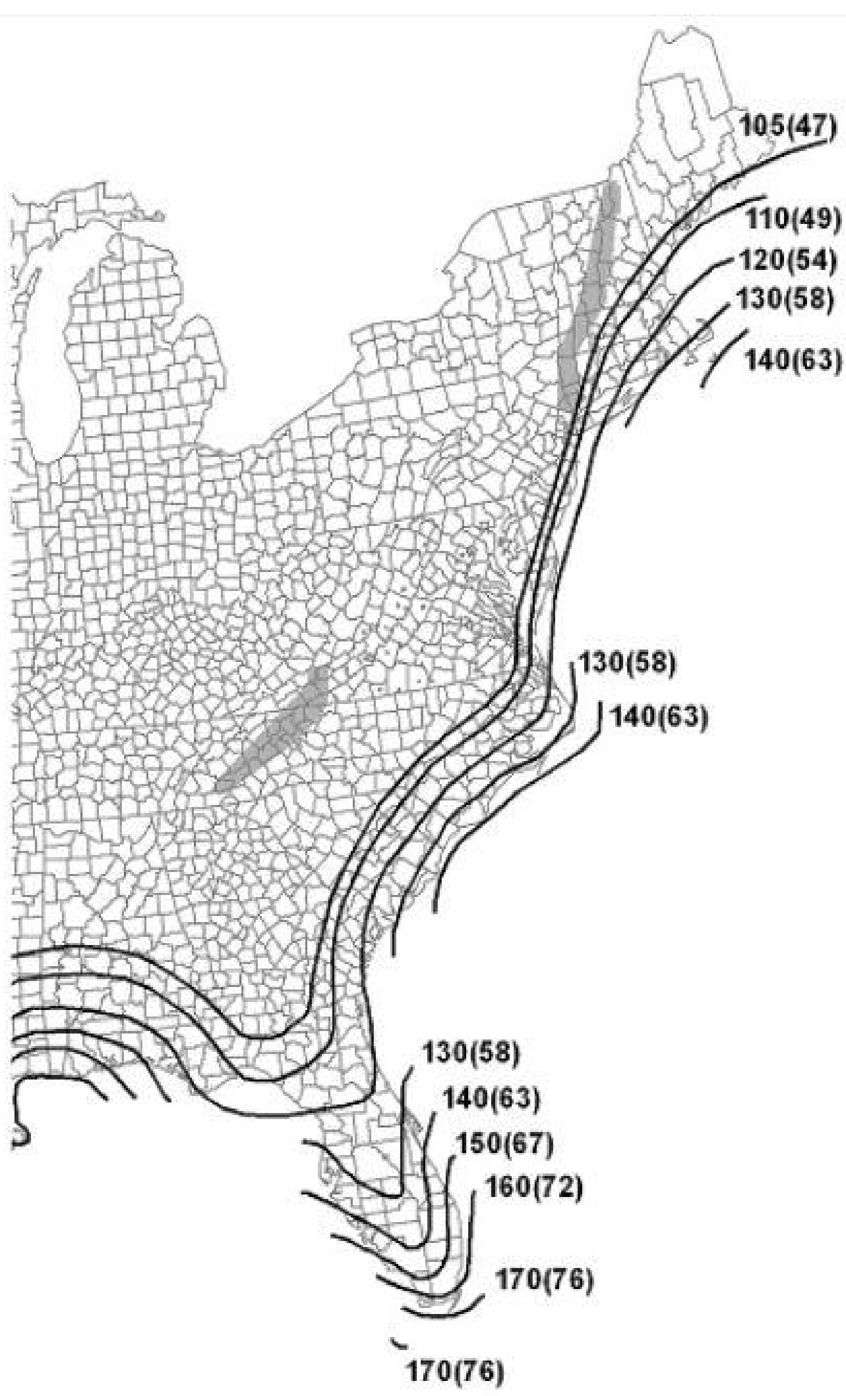
1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00143, MRI = 700 Years).
6. Location-specific basic wind speeds shall be permitted to be determined using www.atcouncil.org/windspeed.

FIGURE 1609.3(1)ULTIMATE DESIGN WIND SPEEDS, V_{ult}, FOR RISK CATEGORY II BUILDINGS AND OTHER STRUCTURES

Attachment 1



ULTIMATE DESIGN WIND SPEEDS, V_{ULT}, FOR RISK CATEGORY III AND IV BUILDINGS AND OTHER STRUCTURES



ULTIMATE DESIGN WIND SPEEDS, V_{ULT}, FOR RISK CATEGORY I BUILDINGS AND OTHER STRUCTURES

1609.3.1 Wind Speed Conversion

When required, the ultimate design wind speeds of Figures 1609.3(1), 1609.3(2) and 1609.3(3) shall be converted to nominal design wind speeds, V_{asd}, using Table 1609.3.1 or Equation 16-33.

$$V_{asd} = V_{ult}\sqrt{0.6}$$

(Equation 16-33)

where:

V_{asd} = Nominal design wind speed applicable to methods specified in Exceptions 4 and 5 of Section 1609.1.1.

V_{ult} = Ultimate design wind speeds determined from Figures 1609.3(1), 1609.3(2) or 1609.3(3).

TABLE 1609.3.1

WIND SPEED CONVERSIONS[a, b, c]

V_{ult}	100	110	120	130	140	150	160	170	180	190	200
V_{asd}	78	85	93	101	108	116	124	132	139	147	155

For SI: 1 mile per hour = 0.44 m/s.

a. Linear interpolation is permitted.

b. V_{asd} = nominal design wind speed applicable to methods specified in Exceptions 1 through 5 of Section 1609.1.1.

c. V_{ult} = ultimate design wind speeds determined from Figure 1609.3(1), 1609.3(2) or 1609.3(3).

Attachment 1

Attachment 2: Wind Loading Calculation

IBC Wind Load Calculations

Project: CVG Railings - North Carolina High Wind Region
Project #: 05-20608
11/5/2020
Code: North Carolina Building Code
Source Document: ASCE 7-10, Chapter 29

Other Structures (Section 6.5.13)

Coefficients

Coefficient	value	source
Risk Category	ii	Table 1.5-1
V (mph):	139	Figures 26.5-1A-C. All of US e:
Exposure:	c	para 26.7
direction factor, Kd:	0.85	Table 26.6-1
topography fact , Kzt	1	para 26.8
gust factor, G	0.85	Section 26.9
Larger dimension of sign, M (ft)	5	Table 6-11
Smaller dimension of sign, N (ft)	3	Table 6-11
Net force coefficients, Cf	1.8	Figure 29.4-1 through 29.5-3
Average height above ground, (ft)	100	
velocity pres. Expose coeff, Kz		Table 29.3-1
Building height (ft):		
0-15	0.85	
20	0.9	
25	0.94	
30	0.98	
40	1.04	
50	1.09	
60	1.13	
70	1.17	
80	1.21	
90	1.24	
100	1.26	Kh (K @ mean roof ht
velocity pres. Expose coeff, Kh	1.26	Choose highest value of Kz
Velocity pressure, qz	52.97	qz=.00256*Kz*Kzt*Kd*V^2
Projected area normal to wind, Af (sq ft)	15	=M*N
Total Force on Supports, F (kips)	1.22	F=qz*G*Cf*Af
Equivalent pressure, P (psf)	81.0	P=F/(M*N)

Attachment 3: Finite Element Modelling

A finite-element-model (FEM) was created to model the Hercules Glass Panel. The model measures 60" x 39" x 13mm (0.51") thick, and includes 960 elements sized approximately 1.5" square x 13mm (0.51") thick. The model is supported at three points, at the panel "spigots. The spigots are approximately 4" tall x 3" wide. See Figure 1 below.

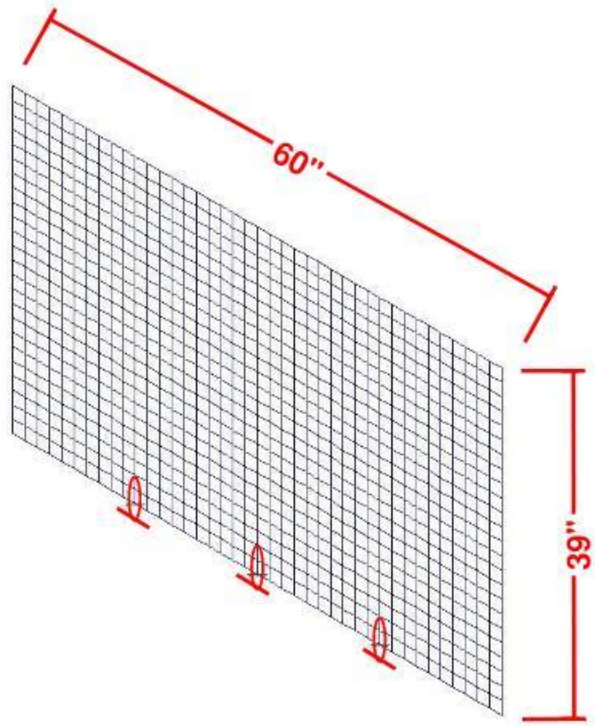


Figure 1: Panel Configuration

The highest stresses caused by a lateral wind load are experienced at the elements around the spigots. Figure 2 shows the element numbers of the panel and a close-up of the elements around the spigots. Note that the elements supported directly by the spigots are blanked out because they are supported by the spigots and are not stressed.

Left spigot	Middle spigot	Right spigot
Element 899	919	939
897	917	937
819	839	859
820	840	860
823	842	863
824	844	864
902	922	942
904	924	944

Attachment 3: Finite Element Modelling

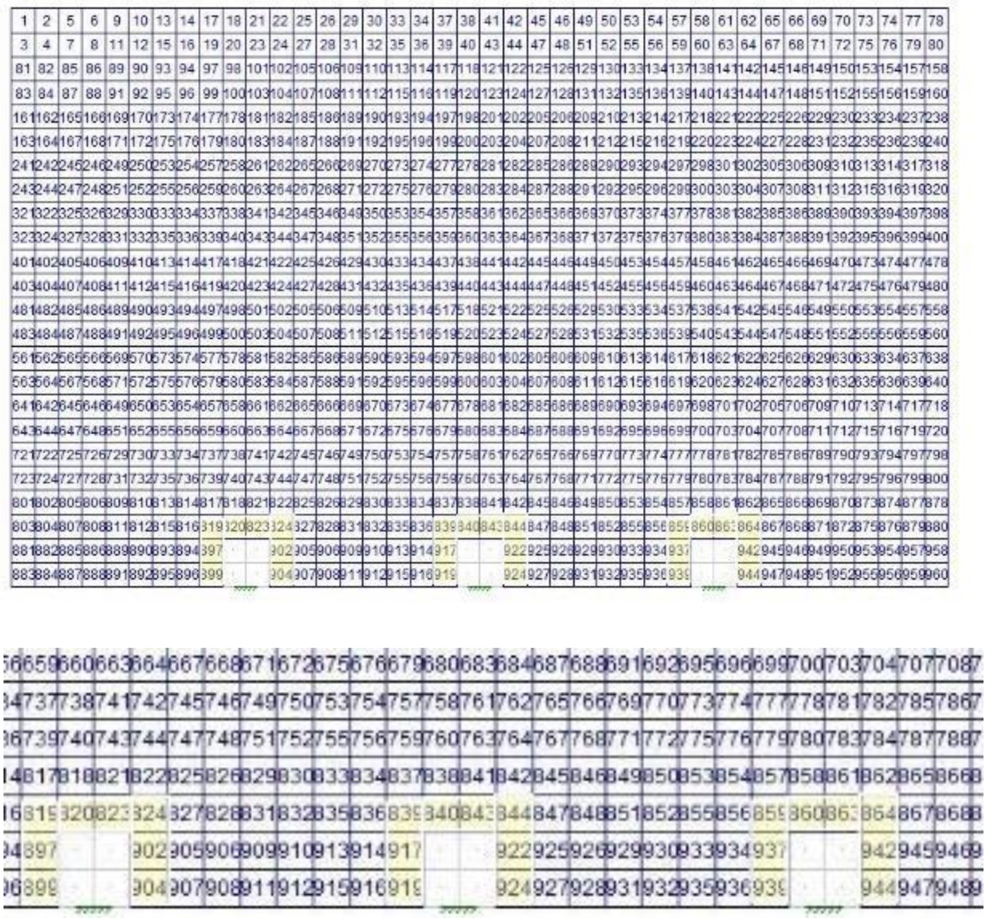


Figure 2: Element numbering – full panel and close-up of elements surrounding three spigots

Two load cases were run to estimate the stresses surrounding the spigot:

1. An 81 psf wind load that is equivalent to a 139 mph unfactored load (180 psf factored load). Figure 3;
2. The loading-to-failure test: 820# loaded at 42” above the spigots (see attachment 4 for an explanation of this). Figure 4.

The wind load created a surface tensile stress (σ, pulling the face of the glass apart, which is the failure mechanism for a brittle material) of 15,979 psi. See Figure 3. The test-to-failure created tensile stress of 35,767 psi. This shows the panel has a factor of safety of 2.24 against failure due to Florida’s highest winds of 180 mph (factored). See Figure 4.

The FEM model is available for review, upon request.

Attachment 3: Finite Element Modelling

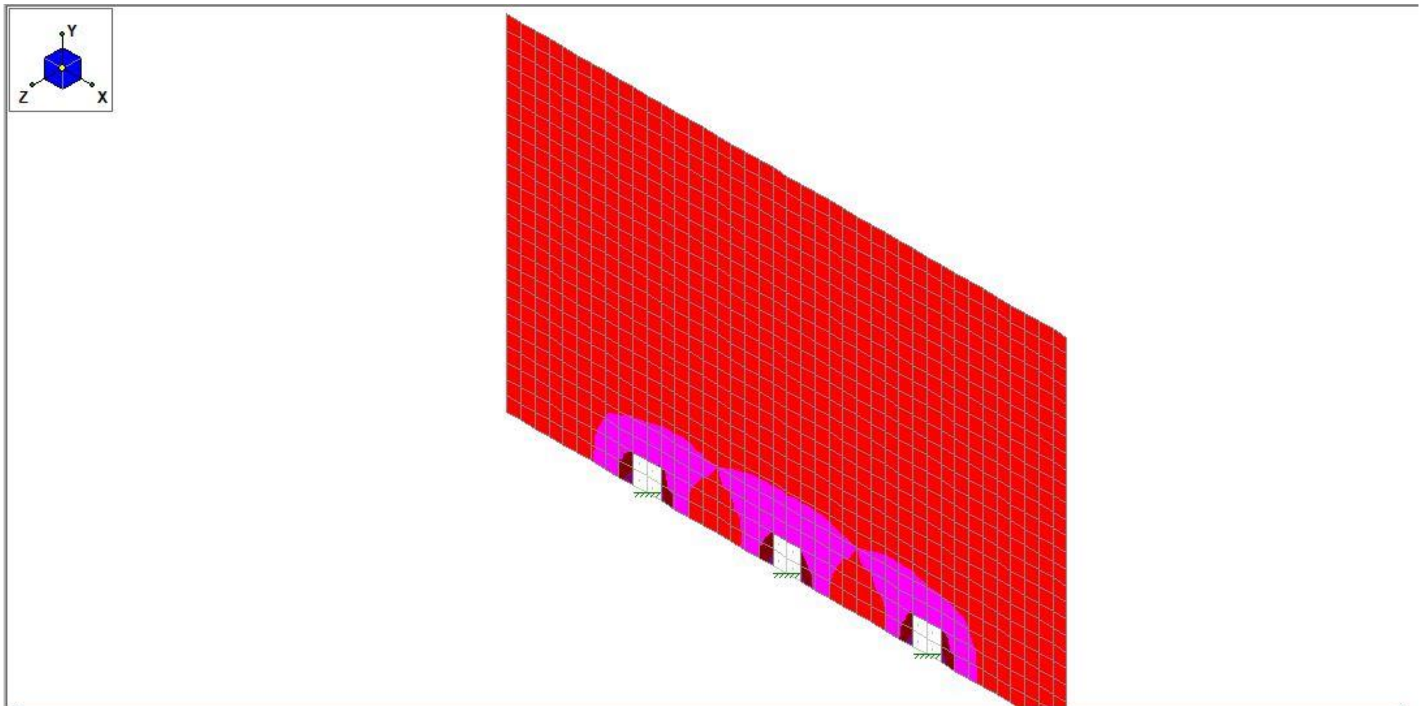


Plate Principal Stresses (By Combination)

	L...	Plate Label	Loc	Sigma1[ksi]	Sigma2[ksi]	Tau Max[ksi]	Angle[rad]	Von Mises[ksi]
1	8	899	T	8.475	-15.979	12.227	.743	21.507
2			B	15.979	-8.475	12.227	2.314	21.507
3	8	944	T	8.475	-15.979	12.227	-.743	21.507
4			B	15.979	-8.475	12.227	.828	21.507
5	8	919	T	6.849	-14.29	10.569	.738	18.681
6			B	14.29	-6.849	10.569	2.309	18.681
7	8	924	T	6.849	-14.29	10.569	-.738	18.681
8			B	14.29	-6.849	10.569	.833	18.681
9	8	939	T	6.245	-14.211	10.228	.74	18.158
10			B	14.211	-6.245	10.228	2.311	18.158
11	8	904	T	6.245	-14.211	10.228	-.74	18.158

Results for LC 8, 81 psf

Figure 3: Stresses due to 81 psf (180 mph factored winds)

Attachment 3: Finite Element Modelling

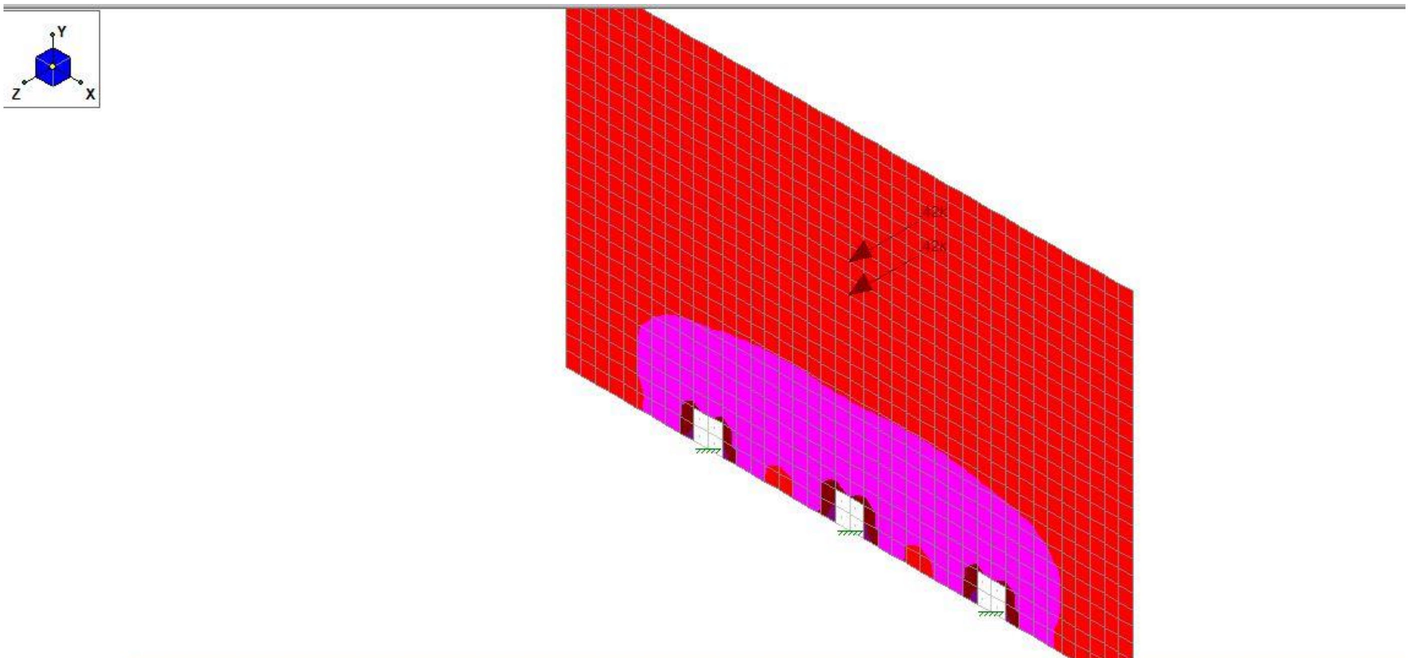


Plate Principal Stresses (By Combination)

	L...	Plate Label	Loc	Sigma1[ksi]	Sigma2[ksi]	Tau Max[ksi]	Angle[rad]	Von Mises[ksi]
1	5	943	T	8.444	-35.767	22.106	-.277	40.653
2			B	35.767	-8.444	22.106	1.293	40.653
3	5	900	T	8.444	-35.767	22.106	.277	40.653
4			B	35.767	-8.444	22.106	1.848	40.653
5	5	899	T	8.435	-12.214	10.324	.676	17.982
6			B	12.214	-8.435	10.324	2.247	17.982
7	5	944	T	8.435	-12.214	10.324	-.676	17.982
8			B	12.214	-8.435	10.324	.895	17.982
9	5	939	T	6.371	-11.874	9.122	.724	16.038
10			B	11.874	-6.371	9.122	2.295	16.038
11	5	904	T	6.371	-11.874	9.122	-.724	16.038

Loads: BLC 5, 820#@28"
Results for LC 5, 820@28"

Figure 4: Stresses due to failure load (820 psf @ 28")

Attachment 4: Physical Testing

July 13, 2020

Building Code Requirements

The International Building Code (IBC) and International Residential Code (IRC) are "model codes" created by the International Code Council, intended to be used by states and municipalities as they publish their own building codes. Section 1607.8 of the IBC requires that "handrails and guards shall be designed to resist a linear load of 50 plf." It also requires the system to resist a 200# concentrated load that produces the "maximum load effect" on any element within the system. The 2018 IRC Table R201.5 extends this requirement into residential construction. It is understood within the building design industry that loads applied to the top of the panel create the maximum load effect; structural design assumes this loading condition.

Section 1607.8 of the IBC also refers to IBC section 2407 that adds a requirement for all-glass handrails and guards to "be laminated glass constructed of fully tempered or heat-strengthened glass"; this requirement was added in the 2015 IBC code cycle. Section 2407.1.1 adds the significant requirement: "a design factor of four shall be used for safety". This addition bumps up the linear load to 200 plf and the concentrated load to 800#. Presumably, this is intended to prevent the glass from shattering and injuring people below.

Exterior glass guardrail panels are designed to resist two load types: wind loads, and "live" loads such as a person or object pushing on or striking the panel from the side or from above. Wind loading on a panel can vary greatly based on location, terrain (wooded vs open) and elevation above ground; these are governed by publication ASCE 7 (American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures). Wind speeds of 115 psf are used to calculate wind pressures against the glass, which generally vary from 17 psf (2nd story in wooded area) to 35 psf (30 stories tall in open terrain). The wind speeds required to match the stresses created by the 800# point load are 192 mph for the 42" tall panel and 215 mph for the 36" tall panel; these are only seen in a Category 5 hurricane or a tornado. Therefore, the 800# horizontal point load is the worst-case scenario for the panels. Note: panel design in "high wind" regions such as the coastal Southeast US are designed to resist flying debris and are subject to different loading requirements. Calculation methods to arrive at these values include computer modeling using finite element analysis; criteria specific to Clear View's panels and support configuration were used.

Hercules Glass Testing

Testing was performed on the Hercules Glass panel by Clear View's glass supplier, to simulate the forces created by 800# horizontal and vertical point loads on the panel (loads are not required to be simultaneous). The vertical load test is straightforward and is shown in photo 1. Note: the intent was to load the panel to failure; however, the testers ran out of sandbags at 2,520 pounds, without failure. Given the difficulty of pushing an 800# load horizontally against the panel, a test rig was set up that supports the panel on its side and places sandbags vertically on the panel. The panel is supported 28" from the top of panel (creating a 28" cantilever), with a heavy counterweight holding down the bottom of the panel mounted in its spigots. Sandbags were placed at the top edge of the panel until failure. See Diagram 1 and photo 2. The panel failed after one minute with 820 pounds loaded on its edge, which is equivalent to 547 pounds for a 42" tall panel. Due to the laminate construction of the panels (similar to a vehicle windshield), the panel broke into small pieces that were retained within the panel, preventing dangerous flying glass debris. See photo 3. This test shows that the panel meets the intent to create a strong and safe barrier that can withstand reasonable loading (factor of safety of 2.5), and does not explode with dangerous glass shards during excessive loading.

Photo 1: Panel loaded vertically with 2,520 pounds.

Photo 2: Loading of panel with sandbags, simulating horizontal force

Attachment 4: Physical Testing

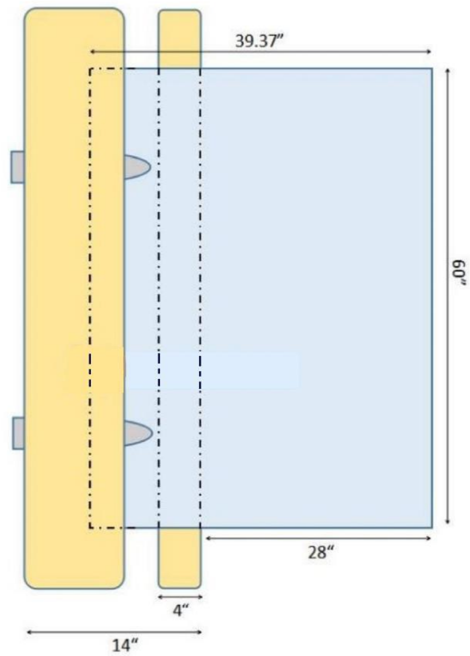


Diagram 1: Test rig lying on its side, looking from above, showing panel supported at 28" and at bottom of panel

Photo 3: Panel after failure, showing all glass intact within laminate structure.

FLORIDA AND MIAMI DADE COUNTY NOA DATA

January 28, 2021

Mr. Chris Frederick
Product Control Section
Department of Regulatory and Economic Resources
Miami-Dade County
11805 S. W. 26 Street, Room 208
Miami, Florida, 33175-2474

Re: ClearView Glass Railings – Request for Notice of Acceptance (NOA) for Hercules Glass Panels

Dear Mr. Frederick,

This letter is written to request a Notice of Acceptance (NOA) for our Hercules Glass Panels product. This is a request for a NOA for a new product. Our Hercules Glass Panels are sold as interior and exterior glass railings, to be installed on commercial and residential buildings as guardrails. They meet Florida Building Code requirements for guardrails, including special requirements for all-glass railings.The panels have been tested and evaluated to withstand the 180 mph winds in the high wind coastal area.

Included in this submittal packet:

1. Application
2. Application review fee
3. Indication of labeling to meet Miami-Dade County Labeling Guideline.
4. Signed letter by Florida Licensed PE stating that the produce conforms to current FBC.
5. Signed letter by same Florida PE that he has no financial interest with the lab that performed the test or the product supplier.
6. Packet signed by Florida PE that includes evaluation of FBC requirements, testing data, and structural analysis of testing results.
7. Marked-up drawing identifying all components of specimens.

Sincerely,

John Ruprecht

Clear View Glass Railings • 737 Quentin Avenue South • Lakeland, MN 55043
612.940.9946 • john@CVGRailings.com • CVGRailings.com

CONSULTANTS
· ENVIRONMENTAL
· GEOTECHNICAL
· MATERIALS
· FORENSICS

AMERICAN ENGINEERING TESTING, INC.

Attachment 4

February 1, 2021

Mr. Chris Frederick
Product Control Section
Department of Regulatory and Economic Resources
Miami-Dade County
11805 Southwest 26th St.
Miami, FL 33175

Re: ClearView Glass Railings – Florida Code Review
AET Project #: 05-20608

Dear Mr. Frederick,

This letter provides our statement regarding the Hercules Glass Panel, produced by ClearView Glass Railings of Lakeland, Minnesota, conformance to the Florida State Building Code relative to Sections 1607 and 1609 for exterior guardrails and more specifically, all-glass guardrails. Our scope included reviewing physical testing performed by others and performing our own stress calculations using Finite Element Analysis methods. Based on our analysis and to the best of our knowledge, it is our opinion that the Hercules Glass Panels meet the applicable sections of the Florida State Building Code. This letter is accompanied by a packet of information that describes our services with this product.

Contact us for additional information or with questions that you might have.

Sincerely,
American Engineering Testing, Inc.

Chris Hartnett, PE*
Principal Engineer
*MN, WI, AL, MD, MO, NC, ND, OH, PA, TN VA
Phone: 651-647-2750
chartnett@amengtest.com

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Florida License #70286
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Attachment 5

February 1, 2021

Department of Regulatory and Economic Resources – Product Control Section
Miami-Dade County
Stephen P. Clark Center
111 NW 1st St.
Miami, FL 33128

Re: "Hercules" Glass Guardrail Panel Testing – Statement of Non-Financial Interest
AET Project #: 05-20608

Dear Product Control Section,

This letter is written to support the application for a Notice of Acceptance (NOA) by Miami-Dade County, for Clear View Glass Railings (CVG) "Hercules" Glass Guardrail Panel. American Engineering Testing (AET) has been engaged by CVG to provide structural testing and engineering consulting services to address International Building Code (IBC) and Florida Building Code (FBC) requirements.

American Consulting Services and all subsidiaries including AET, officers and staff working on this project, have no financial interest in CVG or their products.

Sincerely,
American Engineering Testing, Inc.

Chris Hartnett, PE*
Principal Engineer
*MN, WI, AL, MD, MO, NC, ND, OH, PA, TN VA
Phone: 651-647-2750
chartnett@amengtest.com

Daniel J. Larson, PE
Principal Engineer
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Attachment 6

AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
- ENVIRONMENTAL
- GEOTECHNICAL
- MATERIALS
- FORENSICS

CLEARVIEW GLASS RAILINGS – STRUCTURAL ASSESSMENT
FOR MIAMI-DADE COUNTY NOTICE OF ACCEPTANCE (NOA)

AET Project No. 05-20608

STRUCTURAL TESTING, FINITE ELEMENT ANALYSIS AND CODE EVALUATION

JANUARY 28, 2021

PREPARED FOR:
MR. JOHN RUPRECHT
CLEAR VIEW GLASS RAILINGS
737 QUENTIN AVENUE SOUTH
LAKELAND, MN 55043

PREPARED BY:
CHRIS HARTNETT, PE
DANIEL LARSON, PE

St. Paul, MN
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Williston, ND
Pierre, SD
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Sioux Falls, SD
Wausau, WI
Sheridan, WY
Gillette, WY
Casper, WY

Attachment 6

February 1, 2021

Mr. John Ruprecht
Clear View Glass Railings
737 Quentin Avenue South
Lakeville, MN 55043

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AET Project #: 05-20608

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Wind Loading vs. Panel Capacity

The FBC follows the International Building Code (IBC) requirements for wind loads, with ultimate (factored) wind speeds up to 180 mph; Table 1609.3.1 converts this to 139 psf for unfactored loading, which was used in the analysis. See Attachment 1 for nominal ground wind speed reference maps from the Florida Building Code.

The American Society of Civil Engineers (ASCE) Standard 7-10, Chapter 29, provides the analysis method to convert wind speed (in mph) to pressure (psf) against the glass panel. Using Exposure Category C (open terrain) and a height of 100 feet above ground; a 139 mph wind produces a calculated pressure of 81psf. See Attachment 2. The three distinct support points, "spigots", for these panels creates stress concentrations around the supports that are best modeled using a finite element model (FEM). A FEM model was created for this panel using Risa-3D software (version 10.0.1), that modeled a 60" wide x 39" tall x 13mm thick tempered and laminated panel, with a 81psf surface load applied. The model generated a 15,979 psi principal axis stress (σ) in the panel. See Attachment 3.

The glass used in the panels was tested to determine its structural capacity, using a static load applied to a test specimen. The specimen was loaded to failure, and the loading was applied to the FEM to determine the equivalent stresses. The failure stress was 35,767 psi. This modeling shows that the panels have calculated factor-of-safety of 2.24. See Attachment 4.

Impact Resistance

For building envelope glazing in wind-borne debris regions, glass that is part of a building envelope must be tested for impact resistance in accordance with American Society for Testing and Materials (ASTM) E1996. This requirement protects a closed building envelope from being penetrated and prevents high wind pressures from filling the building, potentially blowing out windows and lifting the roof off the building. Because these panels are not part of the building enclosure, damage from wind-borne debris would not penetrate the enclosure and its structural elements. Therefore, this test is not required for the panels used as a guardrail system.

Summary

In summary, based on our understanding of the FBC requirements, our conclusions are as follows:

1. Each panel is constructed of fully tempered, laminated glass.
2. Each panel is secured to the structure with three supports.
3. A top rail is not required for these panels.
4. Wind pressure – previous testing confirms that the panels meet the 180 mph factored wind speed requirement, with a calculated factor-of-safety of 2.24.
5. The panels do not require wind debris projectile testing.

Please call or e-mail us to discuss this analysis or any portion of the project to evaluate your panels.

Sincerely,
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Attachment 1: Florida Building Code Figure 1609.1 – Ultimate Wind Design Speed.
Attachment 2: ASCE 7-10 Wind & Pressure Calculations.
Attachment 3. Finite Element Modelling.
Attachment 4: Physical Testing

1609.3 Ultimate Design Wind Speed

The ultimate design wind speed, V_{ult}, in mph, for the determination of the wind loads shall be determined by Figures 1609.3(1), 1609.3(2) and 1609.3(3). The ultimate design wind speed, V_{ult}, for use in the design of Risk Category II buildings and structures shall be obtained from Figure 1609.3(1). The ultimate design wind speed, V_{ult}, for use in the design of Risk Category III and IV buildings and structures shall be obtained from Figure 1609.3(2). The ultimate design wind speed, V_{ult}, for use in the design of Risk Category I buildings and structures shall be obtained from Figure 1609.3(3). The ultimate design wind speed, V_{ult}, for the special wind regions indicated near mountainous terrain and near gorges shall be in accordance with local jurisdiction requirements. The ultimate design wind speeds, V_{ult}, determined by the local jurisdiction shall be in accordance with Section 26.5.1 of ASCE 7. The exact location of wind speed lines shall be established by local ordinance using recognized physical landmarks such as major roads, canals, rivers and lake shores wherever possible.

In nonhurricane-prone regions, when the ultimate design wind speed, V_{ult}, is estimated from regional climatic data, the ultimate design wind speed, V_{ult}, shall be determined in accordance with Section 26.5.3 of ASCE 7.

Attachment 1

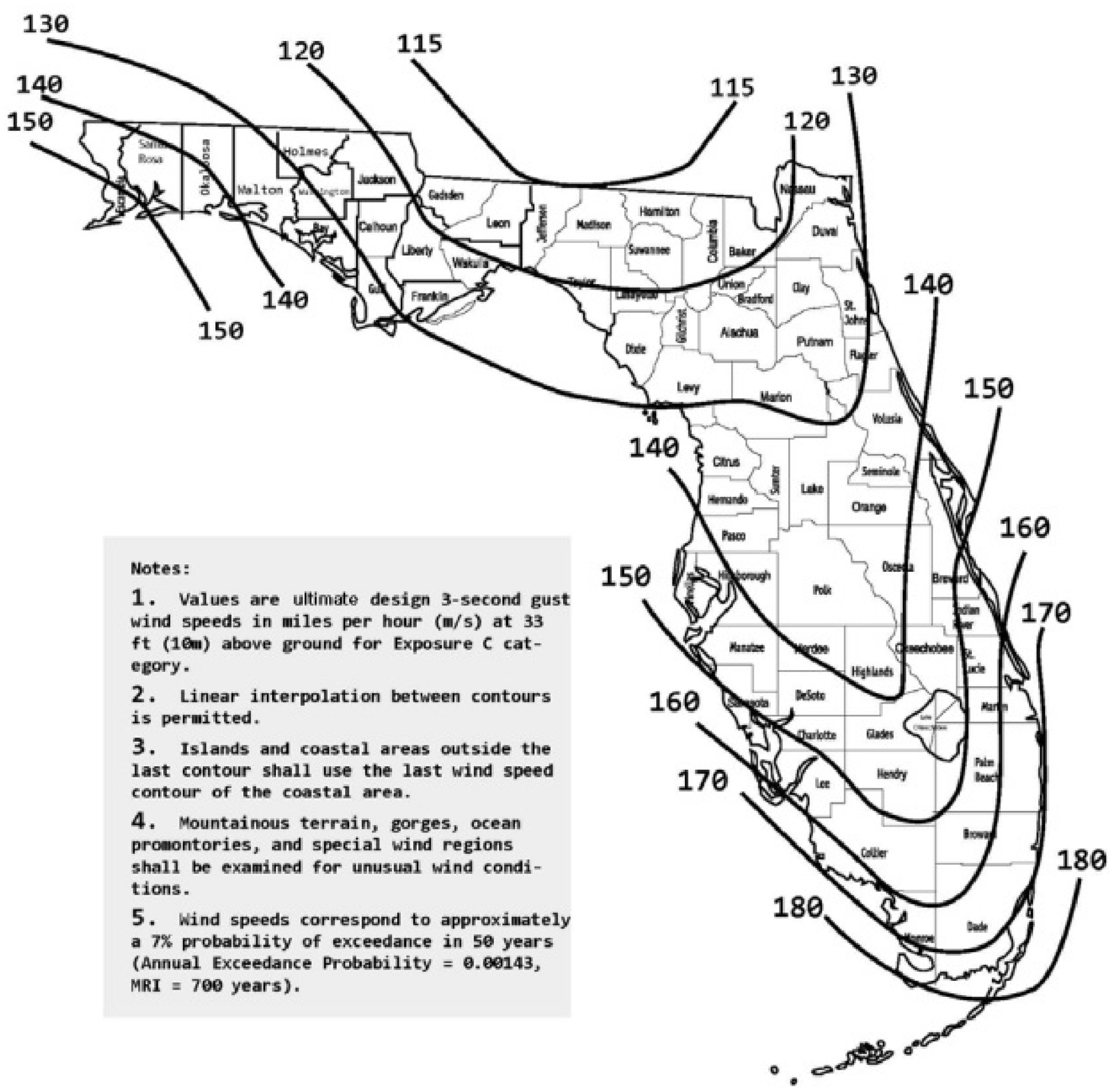


FIGURE 1609.3(1)

ULTIMATE DESIGN WIND SPEEDS, V_{ULT}, FOR RISK CATEGORY II BUILDINGS AND OTHER STRUCTURES

Attachment 1

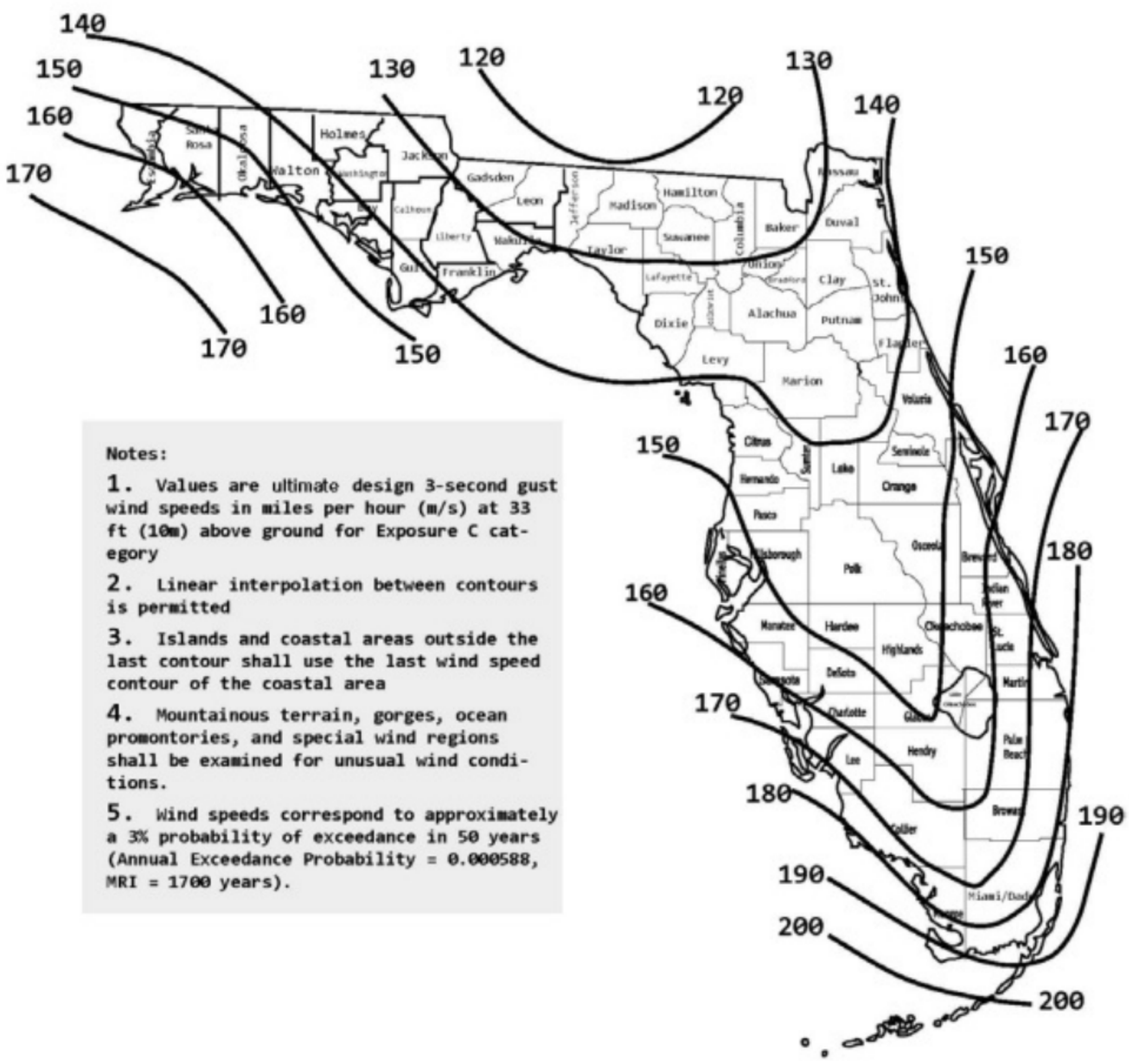


FIGURE 1609.3(2)

ULTIMATE DESIGN WIND SPEEDS, V_{ULT}, FOR RISK CATEGORY III AND IV BUILDINGS AND OTHER STRUCTURES

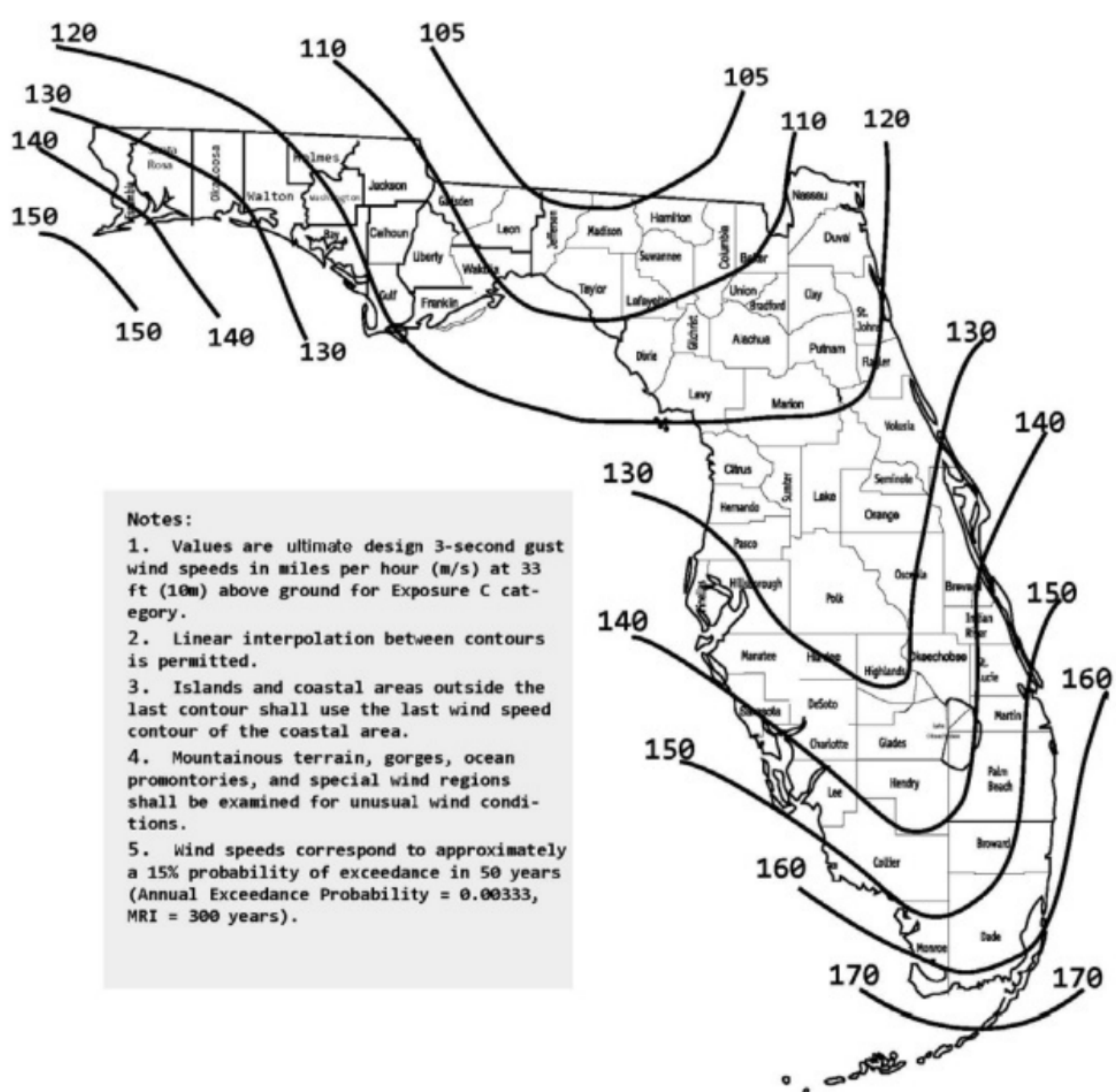


FIGURE 1609.3(3)

ULTIMATE DESIGN WIND SPEEDS, V_{ULT}, FOR RISK CATEGORY I BUILDINGS AND OTHER STRUCTURES

1609.3.1 Wind Speed Conversion

When required, the ultimate design wind speeds of Figures 1609.3(1), 1609.3(2) and 1609.3(3) shall be converted to nominal design wind speeds, V_{asd}, using Table 1609.3.1 or Equation 16-33.

$$V_{asd} = V_{ult}\sqrt{0.6}$$

where: **(Equation 16-33)**

V_{asd} = Nominal design wind speed applicable to methods specified in Exceptions 4 and 5 of Section 1609.1.1.

V_{ult} = Ultimate design wind speeds determined from Figures 1609.3(1), 1609.3(2) or 1609.3(3).

TABLE 1609.3.1

WIND SPEED CONVERSIONS[a, b, c]

V_{ult}	100	110	120	130	140	150	160	170	180	190	200
V_{asd}	78	85	93	101	108	116	124	132	139	147	155

For SI: 1 mile per hour = 0.44 m/s.

a. Linear interpolation is permitted.

b. V_{asd} = nominal design wind speed applicable to methods specified in Exceptions 1 through 5 of Section 1609.1.1.

c. V_{ult} = ultimate design wind speeds determined from Figure 1609.3(1), 1609.3(2) or 1609.3(3).

Attachment 1

IBC Wind Load Calculations

Project: CVG Railings - Florida High Wind Region
Project #: 05-20608
11/5/2020
Code: Florida Building Code
Source Document: ASCE 7-10, Chapter 29

Other Structures (Section 6.5.13)

Coefficients

Coefficient	value	source
Risk Category	ii	Table 1.5-1
V (mph):	139	Figures 26.5-1A-C. All of US e:
Exposure:	c	para 26.7
direction factor, Kd:	0.85	Table 26.6-1
topography fact , Kzt	1	para 26.8
gust factor, G	0.85	Section 26.9
Larger dimension of sign, M (ft)	5	Table 6-11
Smaller dimension of sign, N (ft)	3	Table 6-11
Net force coefficients, Cf	1.8	Figure 29.4-1 through 29.5-3
Average height above ground, (ft)	100	
velocity pres. Expose coeff, Kz		Table 29.3-1
Building height (ft):		
0-15	0.85	
20	0.9	
25	0.94	
30	0.98	
40	1.04	
50	1.09	
60	1.13	
70	1.17	
80	1.21	
90	1.24	
100	1.26	Kh (K @ mean roof ht
velocity pres. Expose coeff, Kh	1.26	Choose highest value of Kz
Velocity pressure, qz	52.97	qz=.00256*Kz*Kzt*Kd*V^2
Projected area normal to wind, Af (sq ft)	15	=M*N
Total Force on Supports, F (kips)	1.22	F=qz*G*Cf*Af
Equivalent pressure, P (psf)	81.0	P=F/(M*N)

Attachment 3: Finite Element Modelling

A finite-element-model (FEM) was created to model the Hercules Glass Panel. The model measures 60" x 39" x 13mm (0.51") thick, and includes 960 elements sized approximately 1.5" square x 13mm (0.51") thick. The model is supported at three points, at the panel "spigots. The spigots are approximately 4" tall x 3" wide. See Figure 1 below.

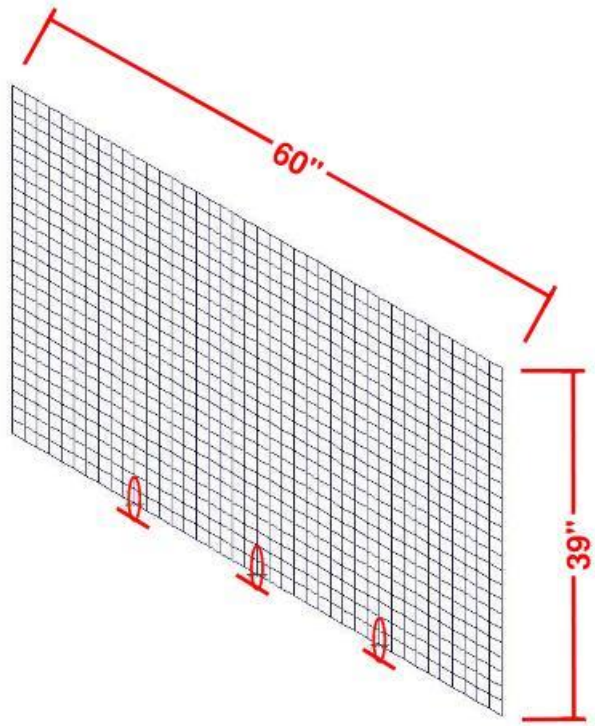


Figure 1: Panel Configuration

The highest stresses caused by a lateral wind load are experienced at the elements around the spigots. Figure 2 shows the element numbers of the panel and a close-up of the elements around the spigots. Note that the elements supported directly by the spigots are blanked out because they are supported by the spigots and are not stressed.

Left spigot	Middle spigot	Right spigot
Element 899	919	939
897	917	937
819	839	859
820	840	860
823	842	863
824	844	864
902	922	942
904	924	944

Attachment 3: Finite Element Modelling

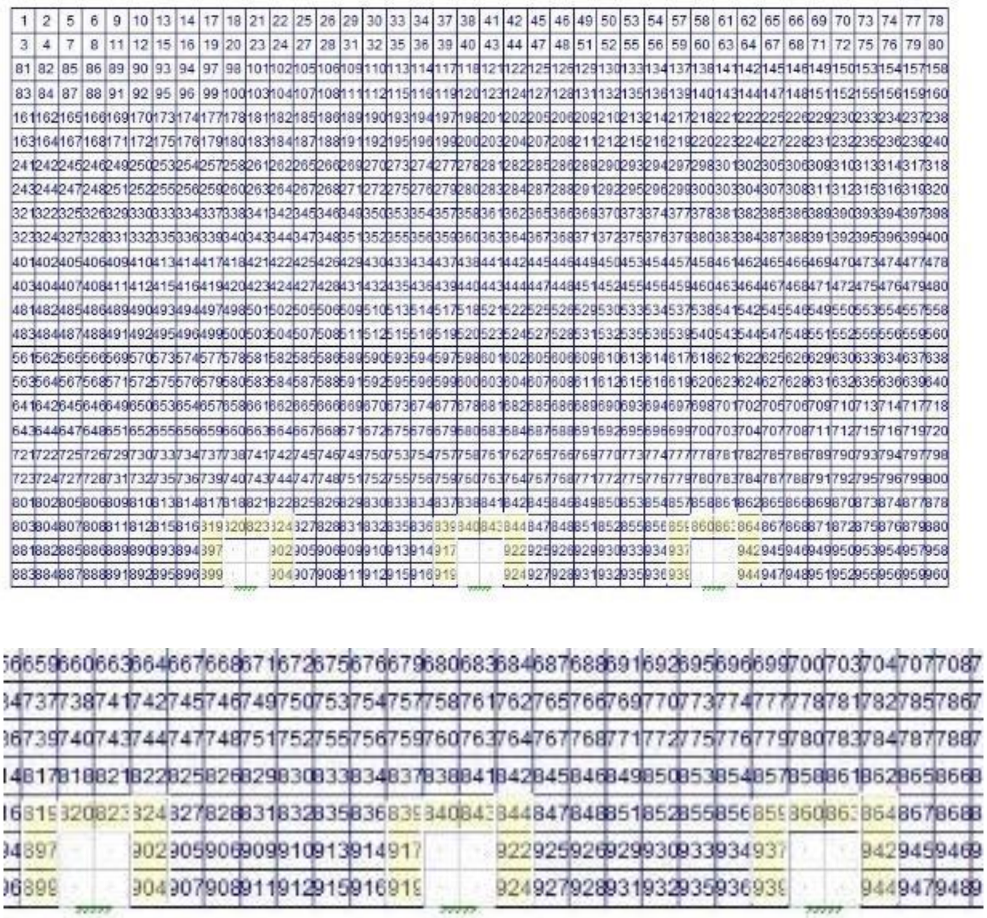


Figure 2: Element numbering – full panel and close-up of elements surrounding three spigots

Two load cases were run to estimate the stresses surrounding the spigot:

1. An 81 psf wind load that is equivalent to a 139 mph unfactored load (180 psf factored load). Figure 3;
2. The loading-to-failure test: 820# loaded at 42" above the spigots (see attachment 4 for an explanation of this). Figure 4.

The wind load created a surface tensile stress (σ, pulling the face of the glass apart, which is the failure mechanism for a brittle material) of 15,979 psi. See Figure 3. The test-to-failure created tensile stress of 35,767 psi. This shows the panel has a factor of safety of 2.24 against failure due to Florida's highest winds of 180 mph (factored). See Figure 4.

The FEM model is available for review, upon request.

Attachment 3: Finite Element Modelling

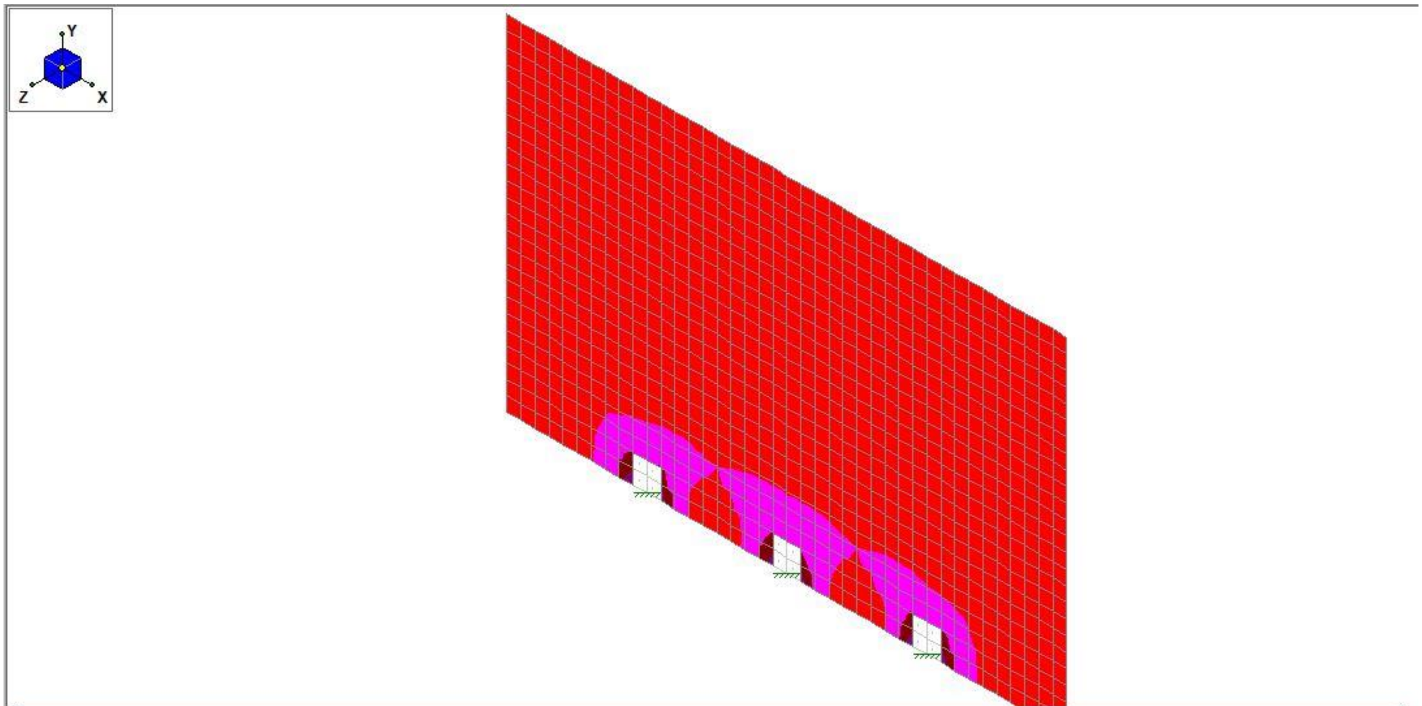


Plate Principal Stresses (By Combination)

	L...	Plate Label	Loc	Sigma1[ksi]	Sigma2[ksi]	Tau Max[ksi]	Angle[rad]	Von Mises[ksi]
1	8	899	T	8.475	-15.979	12.227	.743	21.507
2			B	15.979	-8.475	12.227	2.314	21.507
3	8	944	T	8.475	-15.979	12.227	-.743	21.507
4			B	15.979	-8.475	12.227	.828	21.507
5	8	919	T	6.849	-14.29	10.569	.738	18.681
6			B	14.29	-6.849	10.569	2.309	18.681
7	8	924	T	6.849	-14.29	10.569	-.738	18.681
8			B	14.29	-6.849	10.569	.833	18.681
9	8	939	T	6.245	-14.211	10.228	.74	18.158
10			B	14.211	-6.245	10.228	2.311	18.158
11	8	904	T	6.245	-14.211	10.228	-.74	18.158

Results for LC 8, 81 psf

Figure 3: Stresses due to 81 psf (180 mph factored winds)

Attachment 3: Finite Element Modelling

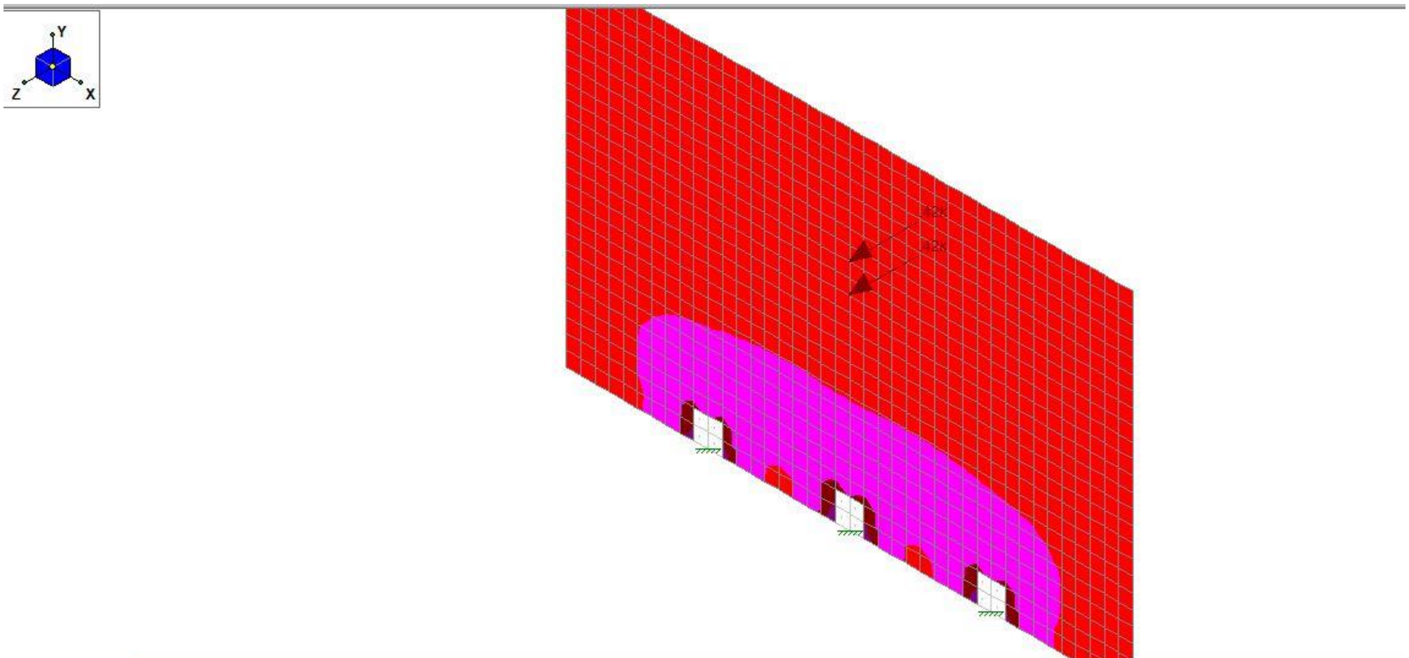


Plate Principal Stresses (By Combination)

	L...	Plate Label	Loc	Sigma1[ksi]	Sigma2[ksi]	Tau Max[ksi]	Angle[rad]	Von Mises[ksi]
1	5	943	T	8.444	-35.767	22.106	-.277	40.653
2			B	35.767	-8.444	22.106	1.293	40.653
3	5	900	T	8.444	-35.767	22.106	.277	40.653
4			B	35.767	-8.444	22.106	1.848	40.653
5	5	899	T	8.435	-12.214	10.324	.676	17.982
6			B	12.214	-8.435	10.324	2.247	17.982
7	5	944	T	8.435	-12.214	10.324	-.676	17.982
8			B	12.214	-8.435	10.324	.895	17.982
9	5	939	T	6.371	-11.874	9.122	.724	16.038
10			B	11.874	-6.371	9.122	2.295	16.038
11	5	904	T	6.371	-11.874	9.122	-.724	16.038

Loads: BLC 5, 820#@28"
Results for LC 5, 820@28"

Figure 4: Stresses due to failure load (820 psf @ 28”)

Attachment 4: Physical Testing

July 13, 2020

Building Code Requirements

The International Building Code (IBC) and International Residential Code (IRC) are "model codes" created by the International Code Council, intended to be used by states and municipalities as they publish their own building codes. Section 1607.8 of the IBC requires that "handrails and guards shall be designed to resist a linear load of 50 plf." It also requires the system to resist a 200# concentrated load that produces the "maximum load effect" on any element within the system. The 2018 IRC Table R201.5 extends this requirement into residential construction. It is understood within the building design industry that loads applied to the top of the panel create the maximum load effect; structural design assumes this loading condition.

Section 1607.8 of the IBC also refers to IBC section 2407 that adds a requirement for all-glass handrails and guards to "be laminated glass constructed of fully tempered or heat-strengthened glass"; this requirement was added in the 2015 IBC code cycle. Section 2407.1.1 adds the significant requirement: "a design factor of four shall be used for safety". This addition bumps up the linear load to 200 plf and the concentrated load to 800#. Presumably, this is intended to prevent the glass from shattering and injuring people below.

Exterior glass guardrail panels are designed to resist two load types: wind loads, and "live" loads such as a person or object pushing on or striking the panel from the side or from above. Wind loading on a panel can vary greatly based on location, terrain (wooded vs open) and elevation above ground; these are governed by publication ASCE 7 (American Society of Civil Engineers <u>Minimum Design Loads for Buildings and Other Structures)</u>. Wind speeds of 115 psf are used to calculate wind pressures against the glass, which generally vary from 17 psf (2nd story in wooded area) to 35 psf (30 stories tall in open terrain). The wind speeds required to match the stresses created by the 800# point load are 192 mph for the 42" tall panel and 215 mph for the 36" tall panel; these are only seen in a Category 5 hurricane or a tornado. Therefore, the 800# horizontal point load is the worst-case scenario for the panels. Note: panel design in "high wind" regions such as the coastal Southeast US are designed to resist flying debris and are subject to different loading requirements. Calculation methods to arrive at these values include computer modeling using finite element analysis; criteria specific to Clear View's panels and support configuration were used.

Hercules Glass Testing

Testing was performed on the Hercules Glass panel by Clear View's glass supplier, to simulate the forces created by 800# horizontal and vertical point loads on the panel (loads are not required to be simultaneous). The vertical load test is straightforward and is shown in photo 1. Note: the intent was to load the panel to failure; however, the testers ran out of sandbags at 2,520 pounds, without failure. Given the difficulty of pushing an 800# load horizontally against the panel, a test rig was set up that supports the panel on its side and places sandbags vertically on the panel. The panel is supported 28" from the top of panel (creating a 28" cantilever), with a heavy counterweight holding down the bottom of the panel mounted in its spigots. Sandbags were placed at the top edge of the panel until failure. See Diagram 1 and photo 2. The panel failed after one minute with 820 pounds loaded on its edge, which is equivalent to 547 pounds for a 42" tall panel. Due to the laminate construction of the panels (similar to a vehicle windshield), the panel broke into small pieces that were retained within the panel, preventing dangerous flying glass debris. See photo 3. This test shows that the panel meets the intent to create a strong and safe barrier that can withstand reasonable loading (factor of safety of 2.5), and does not explode with dangerous glass shards during excessive loading.

Photo 1: Panel loaded vertically with 2,520 pounds.

Photo 2: Loading of panel with sandbags, simulating horizontal force

Attachment 4: Physical Testing

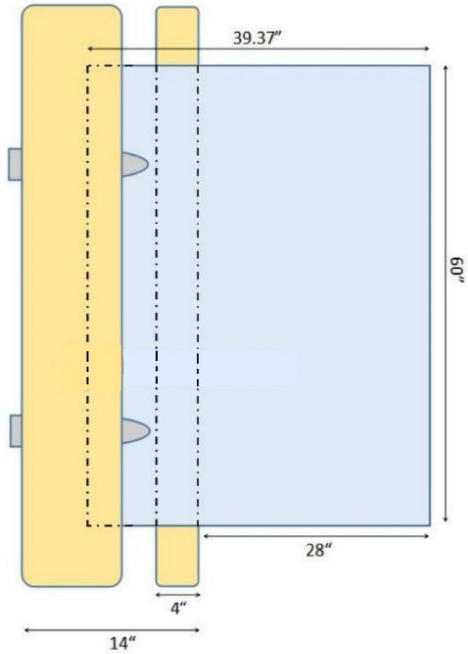
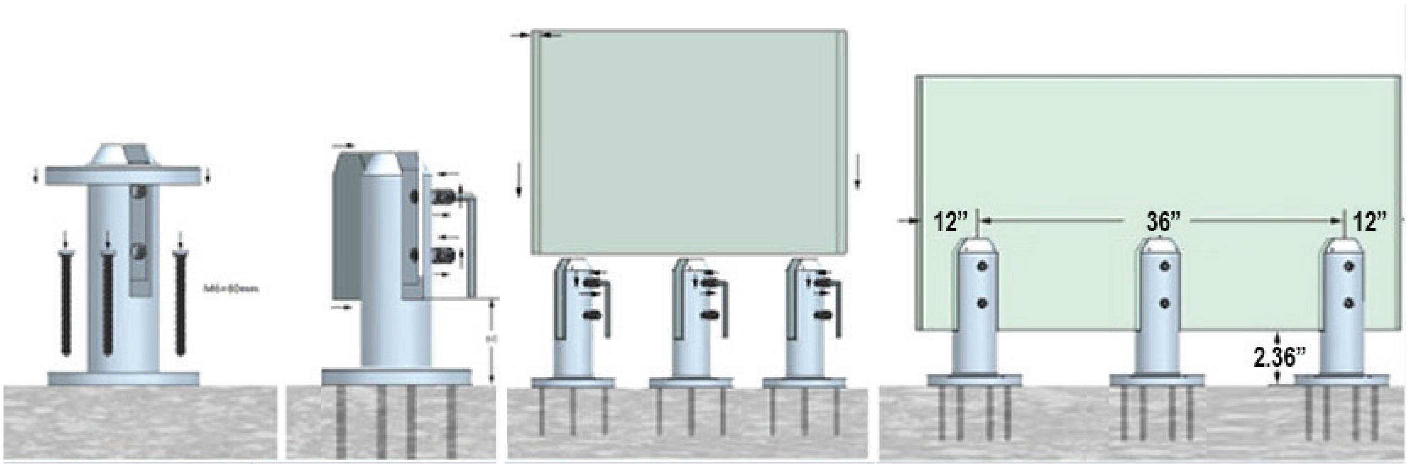


Diagram 1: Test rig lying on its side, looking from above, showing panel supported at 28" and at bottom of panel

Photo 3: Panel after failure, showing all glass intact within laminate structure.

ClearView GLASS RAILINGS

INSTALLATION WITH THREE SPIGOTS



Part Number	CVGR 316 SSOD48-180 Satin Finish
Product Name	Round Deck Mount Spigot
Spigot Size	1.9" diameter x 7.1" tall
Spigot Weight	5.5 lbs.
Glass Thickness/ Dimensions/Weight (per panel)	13mm/ 60" width x 39.37" height/98.5 lbs.
Accessories Included	Base Cover, Rubber Gasket

Wood Deck Installation

The hold down force for each spigot is 2,500 lbs. We suggest using 3/8" diameter x 3.5" A354 structural bolts as they have sufficient capacity to resist this force. Use with flat washer to fasten spigots to wood deck. A354 structural bolts and washer should be cadmium plated or stainless steel so they do not rust.

Lag bolts must be installed into rim joists or lam beam or properly blocked sub structure. If lag bolts are attached to deck planks only failure will occur as a result of improper installation. Improper installation and failure may result in injuries or death. Do it once and do it right!

Helpful Installation Tips

- Apply a bit of talcum powder to the inside of the spigot rubber boot to help the glass slide in the rubber boot, not grab the rubber boot.
- Mark spigot location on glass panels with a crayon or wax marker. This allows for fast and easier installation of panel in proper location.
- Some clients have suggested screwing the rim joist to the joist as the screws will hold the rim joist tight to the joist where as nails may not.

Attachment 7

ClearView
GLASS RAILINGS

SPIGOT SPECS