Evaluation of Triple Glazed Insulating Glass Strength

More stringent energy code requirements, the Energy Star program and energy-based tax incentive programs have placed a premium on the energy efficiency of the glass in doors and windows. To achieve the high-performance U-values required of these programs, many window manufacturers are offering triple glazed insulating glass units as an option for their high-performance windows. Because these triple glazed insulating units are typically an untested option substituted into a window that was previously tested for air/water/structural performance, many interested parties, including some building officials, have asked how the structural performance of the triple glazed insulating glass strength compares to the standard insulating glass unit.

This article was prepared to explain how the most recent version of ASTM E1300 (ASTM E1300-12a Standard Practice for Determining Load Resistance of Glass in Buildings) evaluates triple glazed insulating glass. Although this version of the ASTM E1300 standard is not the current version referenced by most current building codes, the procedures for evaluating triple glazed insulating glass introduced in this version of the standard provide a legitimate technical means for evaluating triple glazed insulating glass.

All glass evaluations using ASTM E1300 begin by determining a Non-Factory Load (NFL) for a piece of glass. This NFL is established as if the glass is annealed glass and is a function of the glass size (length and width) and thickness. The NFL is adjusted by a Glass Type Factor (GTF) based on the level of thermal tempering of the glass. There are three common levels of thermal tempering addressed by the standard: annealed, heat-strengthened and fully tempered. And, if the glass is one component of a double glazed insulating glass construction, the NFL is further adjusted by a Load Share Factor (LSF). The Load Share Factor establishes how the glass load is divided between the lites of an insulating glass unit. It is a function of the relative thicknesses of the individual lites. The Load Resistance (LR) of the glass construction, which should be compared to the design wind pressures established for the window, is calculated as:

\[ LR = NFL \times GTF \times LSF \]

For insulating glass, one calculates a Load Resistance for the exterior sheet and interior sheet separately. The least of these Load Resistances establishes the overall Load Resistance of the insulating glass unit.
ASTM E1300 is a complicated standard based on decades of empirical studies and scientific analysis and addresses almost any combination of glass types including laminated glass and insulating glass made of components of different thickness and glass type. Thus, there are many NFL, GTF and LSF to consider in any one analysis. ASTM E1300-12a presents Glass Type Factors to be used with triple glazed windows for each glass type and the following formula for Load Share Factors based on glass thickness, \( t \):

\[
LSFi = (t1^3 + t2^3 + t3^3)/ti^3
\]

Thus, the Load Share Factor for each piece of glass is a function of the thicknesses of all pieces of glass in the construction. For the basic case where all pieces of glass have the same thickness, the Load Share Factor would be the same for all pieces of glass; LSF = 3.0.

To explain how the strength of a triple glazed insulating glass panel relates to a double glazed insulating glass panel, we can compare constructions of one type of non-laminated glass with equal thickness. Table 1 only considers short-duration load resistances as these are appropriate for wind loads. This comparison is presented below.

**Table 1.** Double Glazed and Triple Glazed Load Resistance (all lites same thickness)

<table>
<thead>
<tr>
<th>Construction</th>
<th>Glass Type</th>
<th>Glass Type Factor (GTF)</th>
<th>Load Share Factor (LSF)</th>
<th>Load Resistance (LR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Glazed</td>
<td>Annealed</td>
<td>0.90</td>
<td>2.0</td>
<td>1.80 x NFL</td>
</tr>
<tr>
<td></td>
<td>Heat Strengthened</td>
<td>1.80</td>
<td>2.0</td>
<td>3.60 x NFL</td>
</tr>
<tr>
<td></td>
<td>Fully Tempered</td>
<td>3.60</td>
<td>2.0</td>
<td>7.20 x NFL</td>
</tr>
<tr>
<td>Triple Glazed</td>
<td>Annealed</td>
<td>0.81</td>
<td>3.0</td>
<td>2.43 x NFL</td>
</tr>
<tr>
<td></td>
<td>Heat Strengthened</td>
<td>1.62</td>
<td>3.0</td>
<td>4.86 x NFL</td>
</tr>
<tr>
<td></td>
<td>Fully Tempered</td>
<td>3.24</td>
<td>3.0</td>
<td>9.72 x NFL</td>
</tr>
</tbody>
</table>

In the comparison, the NFL is constant (i.e. all pieces of glass in all constructions are the same size and thickness) the Load Resistance for the double glazed and triple glazed of each glass type can be compared using a ratio as shown in Table 2.

Thus, a triple glazed window will have 1.35 times more Load Resistance than a double glazed window when all pieces of glass in the comparison are of the same type and thickness.

However, without careful consideration of the impact of adding a third lite to an insulating glass unit, it is possible to actually reduce the Load Resistance. For example, adding a 3/32” thick interior lite to an insulating glass unit made of two 3/16” thick lites will reduce the Load Resistance for a typical size unit (see example calculations).
Conclusion

In conclusion, ASTM E1300-12a provides a means for establishing the Load Resistance of triple glazed insulating glass units. The method is limited to insulating glass units with monolithic glass where all lites are of the same glass type, but may be of different thicknesses. If all glass lites have the same thickness, the load resistance of a triple glazed unit is 35% higher than the double glazed unit. It is possible, by choosing an interior lite thinner than the exterior lites, to develop a Load Resistance for the triple glazed unit lower than the double glazed unit. The Load Resistance should be compared to the project design pressures; if the Load Resistance is greater than the project design pressures, the glazing satisfies code requirements for strength.

Example:

**Unit #1: 40" x 40" IG comprised of two 3/16" lites of annealed glass**

\[
\begin{align*}
NFL &= 66.7 \text{ psf (both lites)} \\
GTF &= 0.90 \\
LSF &= 2.00 \\
LR &= NFL \times GTF \times LSF = (66.1 \text{ psf})(0.90)(2.00) \\
&= 119.0 \text{ psf (both lites)}
\end{align*}
\]

*Load Resistance of Unit is 119.0 psf*

**Unit #2: 40" x 40" Triple IG comprised of two 3/16" lites and one 3/32" lite of annealed glass**

\[
\begin{align*}
NFL &= 66.7 \text{ psf (both 3/16" lites)} \\
GTF &= 0.81 \\
LSF &= \left(\frac{3/32^3 + 3/16^3 + 3/16^3}{3/16^3}\right) = 2.13 \\
LR &= NFL \times GTF \times LSF = (66.1 \text{ psf})(0.81)(2.13) \\
&= 114.0 \text{ psf (both 3/16" lites)} \\
NFL &= 25.0 \text{ psf (3/32" lite)} \\
GTF &= 0.81 \\
LSF &= \left(\frac{3/32^3 + 3/16^3 + 3/16^3}{3/32^3}\right) = 17.0 \\
LR &= NFL \times GTF \times LSF = (25.0 \text{ psf})(0.81)(17.0) \\
&= 344 \text{ psf}
\end{align*}
\]

*Load Resistance of Unit is 114.0 psf*

**About The Author**

Joe Reed, P.E. | Director - Engineering Services

Mr. Joseph Reed has continual engineering experience since 1988 and joined Architectural Testing in 2002. He is a Professional Engineer licensed in seven states. He has Master of Science in Civil Engineering from Lehigh University.