Strain Pattern in Tempered and Heat Strengthened Glass

Strain pattern, also called anisotropy, present in tempered or heat strengthened glass is sometimes visible from the exterior and/or interior under certain polarized light conditions such as a clear blue north sky, near a body of water or snow covered areas, or in sunlight reflected from glass at the necessary polarizing angle.

Strain pattern or anisotropy appears as an iridescent effect which may be seen as a checkerboard, link chain, multi-circular pattern, or more often in architectural windows is seen as a pattern of various width lines (see figure 1). Strain patterns become more pronounced when viewing heat treated glass with polarized sunglasses since they permit only polarized light to pass to the viewer's eyes. These iridescent patterns are related to the effects of the multi-nozzle/tube high velocity air quench sections used in glass heat treating processes.

Figure 1 – anisotropy viewed from exterior

Strain pattern is a characteristic of all tempered and heat strengthened glass and should not be considered a defect. Nothing can be done to eliminate this effect when the lighting conditions are present to observe it. Strain pattern is positive confirmation that the glass has been heat treated and thermally strengthened.

The observation, of strain pattern or anisotropy in fully tempered or heat strengthened glass is due to an optical phenomenon known as birefringence. When visible light interacts with glass that has been thermally strengthened, the light waves will travel at different velocities in the X (width) and Y (length) directional axes of a glass plate. Birefringence occurs because of the surface compression and center tension stresses that are introduced into glass by the heat treating process.

In theory, the objective of the heat treating process is to perfectly balance the compression and tension stresses within the glass (figure 2). However, in practice there are always some areas of unbalanced stress (Figure 3). These areas of imbalance, regardless of how small, will affect light differently based on its state of polarization causing birefringence patterns to be visible under certain lighting conditions. Yet under other lighting conditions (i.e. time of day, time of year, viewing angle, background, etc.), the birefringence pattern may be more subtle or not visible at all.

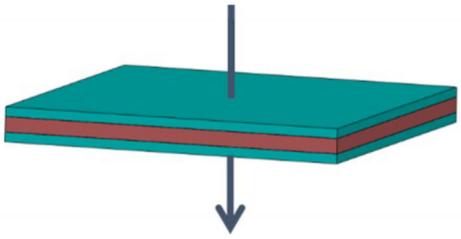

Figure 2: Balanced Compression and tension bands

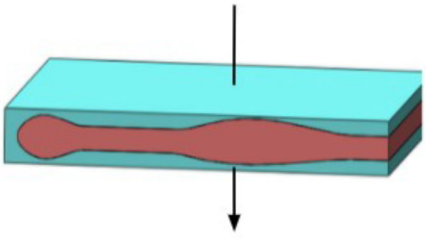

Figure 3: Imbalanced parabola causes anisotropy

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In many cases, once the building interior is finished out the presence of strain pattern may be muted as shown by the area of glass in front of the white sheet compared to the glass with the unfinished interior behind it (see figure 4).

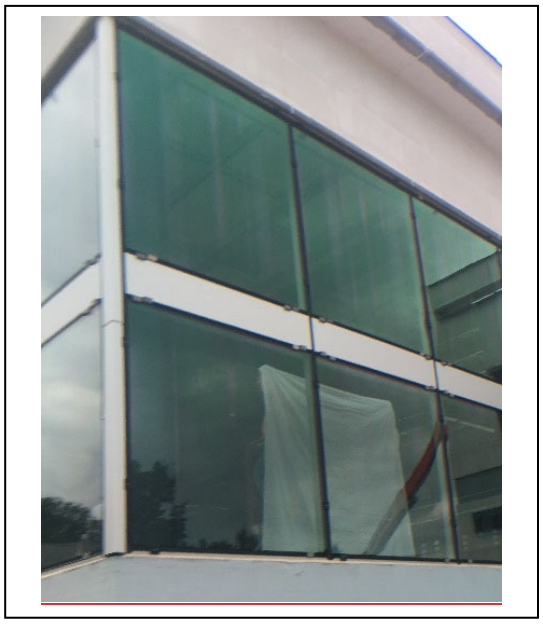

Figure 4 – background and lighting conditions effect strain pattern visibility

In fact, birefringence is the property of special glass that is utilized in optical instrumentation such as the Differential Surface Refractometer (DSR) and the Grazing Angle Spherical Polarimeter (GASP). These instruments are used to non-destructively measure surface compression in tempered and heat strengthened glass. This effect is quantified by the optical property known as retardance or retardation which is typically measured in nanometers (nm).

Vitro (formerly PPG Industries) developed the DSR and GASP instrumentation and has licensed this technology to optical instrument manufacturing companies who provide this instrumentation to the glass fabrication industry.

Anisotropy and Distortion are NOT the same.

Anisotropy and distortion are distinctly different properties of heat treated glass. This makes perfect sense since each property has a fundamentally different root cause. Anisotropy is due to an internal imbalance of stress inside the body of the glass. Distortion is caused by physical deformation or localized warpage of the glass. Although significant levels of anisotropy and distortion are not desirable from an aesthetic perspective, any process changes may only impact distortion and have minimal impact on anisotropy.

A polarized film (outlined with yellow dash lines) placed between the window and the observer's eye when rotated to the optimal angle can highlight strain pattern in the glass which may not be visible under normal viewing conditions. Polarized sunglasses will have the same effect.

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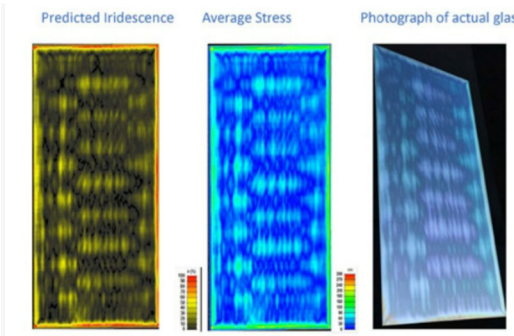
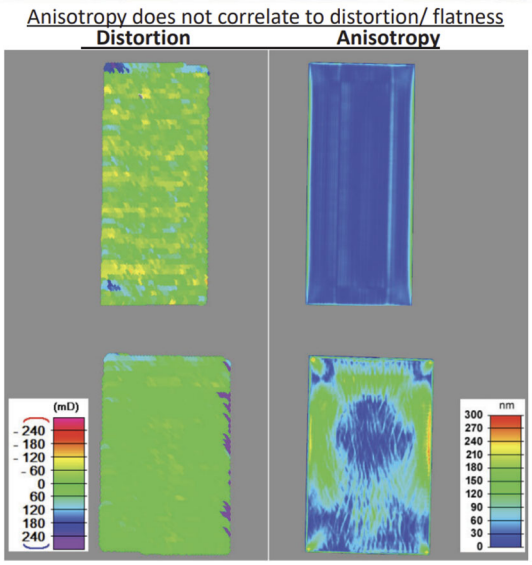
Anisotropy as viewed from inside a condo near a large body of water with ample amount of polarized light. In a different setting and viewing conditions, this strain pattern may not be as noticeable.



Equipment is available to show the strain pattern as glass exits the heat treating process and to measure the amount of retardation in the glass and correlate it to the visible anisotropy effect.

Automated Detection & Inspection

In the early 2000's, equipment was introduced to allow for detection and inspection of anisotropy as part of the heat treating process. The ability to better control and reduce anisotropy to an acceptable level follows from being able to detect the level of anisotropy in real time. As of the writing of this revision, there remains no agreed upon industry standard for what is an acceptable level of anisotropy. However, ASTM has published a testing protocol for how to measure anisotropy using automated equipment, ASTM C1901. In the near future, it is anticipated that with more experience and data available that a limit of anisotropy in heat treated glass may be established.



Measuring equipment can also decipher the difference between distortion and anisotropy as shown in the two pieces of glass above.

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References:

ASTM C1901 *Standard Test Method for Measuring Optical Retardation in Flat Architectural Glass*

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HISTORY TABLE		
ITEM	DATE	DESCRIPTION
Original Publication	March 1993	
Revision #1	1/15/2002	Transferred to TD-115
Revision #2	10/04/2016	Updated to Vitro Logo and format
Revision #3	1/24/2019	Updated the Vitro Logo and format
Revision #4	9/3/2024	General update, added reference to anisotropy, inspection device information, added photo examples