EXTRALUM

Technical Bulletin.

Distortion in Heat-Treated Architectural Glass.

Introduction.

When using heat-treated glass (heat-strengthened or tempered, in monolithic application, laminated or Insulated-IG) some critical design considerations must be taken into account.

The manufacturing process of tempered glass involves rapid cooling of the hot glass which gives it that special resistance, but creates a degree of distortion, by waviness, caused by the rollers of the tempering system. For this reason, linear objects (buildings) and moving objects (cars) can reflect distorted images on the glass.

Figure 1. Linear structure reflection in tempered glass.

What is distortion?

Reflected images can be seen on the glass because the light rays, which move in waves, collide with the surface of the glass and are reflected back to the eye. When the glass is flat, the reflected image looks normal, with the incident rays of light reflected in the same way, but at opposite angles (equal angles).

When light rays hit a glass surface that is not flat, the reflected image is modified or distorted because the angles of incidence and reflection are not equal. On a concave surface, the reflected image appears shorter and thinner, while on a convex surface, the image appears wider.

Combined with the two effects (concavity and convexity), as in heat-treated glass, images can be created that reflect wider and/or narrower, depending on the movement and position of the observer in relation to the surface of the glass.

What causes greater distortion in tempered glass?

Distortion in tempered or heat-strengthened glass is caused by the heat treatment process. The glass is heated up to approximately 650°C, at which temperature the glass becomes a plastic material that curls slightly (tenths of a millimeter) during its oscillatory movement on the ceramic rollers of the furnace. The glass leaves the furnace when the heating cycle is completed, to be immediately subjected to rapid cooling or thermal shock that does not allow it (the glass) to fully recover its original flat surface. Even a minimal level of waviness can cause apparent distortion of objects when looking at the glass from a critical angle from the outside.

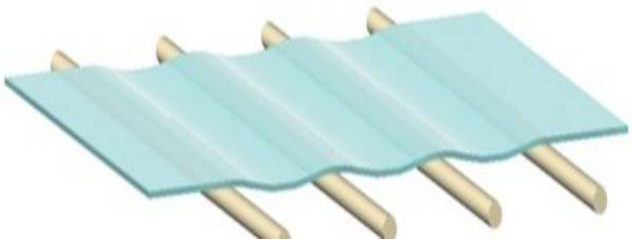

Figure 2. Waviness during glass heating.

Other factors that magnify the effect of dystorsion.

Although image distortion is a characteristic of glass, many variables contribute to magnifying the perceived effect. Distortion is related to many factors and is mainly caused by environmental conditions and glass processing techniques. The magnitude of the defect is highly subjective and its degree of perception is influenced among other factors, by the angle of view, the distance between the observer and the glass, the object reflected in the glass, the conditions of the sky (lighting), as well as by the type, color and thickness of the glass.

Figure 3. Distortion caused by glass outside the facade plane.

Variation of Thickness.

Each sheet of glass is different. Even in the same sheet you can have small differences or variations in thickness. The effect of thickness variation is not very noticeable when it comes to normal glass, however, when processing glass (heat treatment, laminate and/or IG) this effect is combined with others that increase image distortion.

Installation.

The way the glass is installed can amplify perceived distortions. Out-of-plan frames, where two sides of an opening are not parallel, can easily twist a sheet of glass and cause distortion in the reflected image. Side distortions are also visible when there are non-uniform pressures in the glass, due to clamping methods. This can generate concave or convex surfaces that will immediately increase distortion in reflected images.

Distance and angle of observation.

One factor that is usually forgotten is observation geometry. Many people know that as the angle of incidence of vision increases from 0 degrees (perpendicular to glass, observer 1), to 90 degrees (parallel to glass, observer 2), any distortion seen in reflection or transmission will be increased.

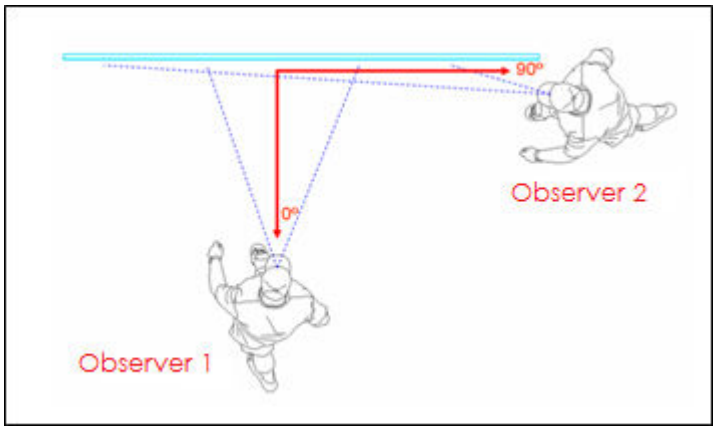

Figure 4. Observation angle.

Of equal or greater importance is the effect of the distance from which the glass is observed. The light travels in a straight line, a small deviation from the glass planimetry causes a great deviation if the distance is large. Therefore no distortions are observed in domestic mirrors, the two distances (mirror-observer and mirror-object observed) are small, so that even if there is distortion, the reflected image is acceptable.

Reflected environment.

Another factor to consider is the type of mirrored image. In a city, where buildings create straight patterns and latticework, distortions will be easily perceived. However, in buildings located on the outskirts of cities where the reflected images contain trees, the sky cleared or cloudy or simply an irregular horizon, it will be much more difficult to discern the degree of distortion in the glass, since there are no straight lines or angles of 90°.

Recognition of the importance of observational conditions makes it possible to understand the effect of optical distortions. In some buildings, the geometry of the observation is such that it is impossible to get a reflected image correctly. At other times even tempered glass may seem flat.

In la Figure 5, you can see how the shapes or landscape reflected in the glass influence. The reflection of a nearby building (left) reveals the magnitude of the distortion, while reflected clouds (remnant of the image) are observed normal.

Figure 5. Effect of the landscape (environment) reflected in the glass.

Insulated glass (IG).

The air pressure in An IG unit will vary with changes in altitude (from the manufacturing site, to the installation site) due to differences in atmospheric pressure; it will also vary with changes in temperature. By increasing the altitude or temperature, the air inside the chamber expands, bending the glasses outwards (see Figure 6, left) and changing the shape of the surface. On the other hand, at a lower temperature, the air in the chamber is compressed, sucking the glass and changing the shape of the surface (see Figure 6, right).

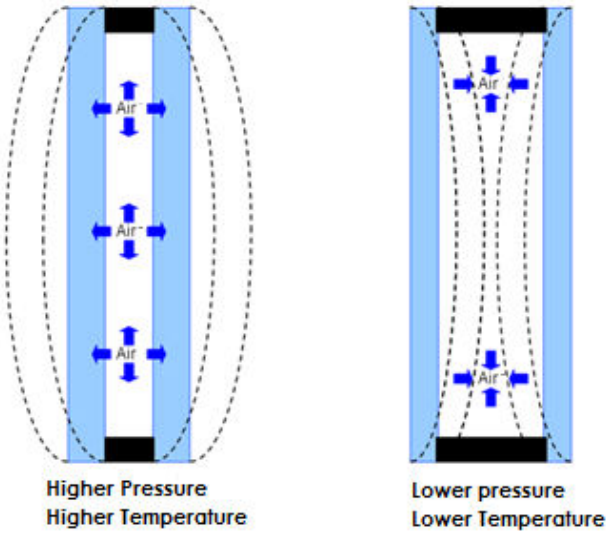

Figure 6. Effect of pressure and temperature on insulated glass.

These temperature effects can occur continuously in double glazing and cause distortion in images that can vary in magnitude and shape depending on time, solar radiation, season of the year, etc.

Laminated.

When two pieces of glass are joined with one between layer of flexible material (PVB polyvinyl, resin, EVA), any distortion of the glass interacts and adds up, increasing the distortion effect of the images. If the two glass panels have been heat-treated, not only will the distortion by ripple accumulate, but also a lens effect can be originated, due to the deflection or curvature characteristic of the heat-treated glass.

Coating.

When it comes to colorless glass, there is a relative low reflection and therefore the distortion effect is little perceived.

When layers of low-emission reflective coatings are added (to increase the performance of the glass in terms of solar control or thermal insulation), the reflection is significantly increased, making any distortion in the glass easier to see.

Combined effects.

In any installation you can find a distortion effect. For example, a IG that includes in its design a low-emissive, heat-treated and laminated reflective glass, installed with a lot of pressure on the edges during installation and mounted in a geographical location with different temperature conditions and different altitude to that of the point of manufacture, can produce the most distorted images (see Figures 7 to 10).

Figure 7

Figure 8

Figure 9

Figure 10

Industrial Standard.

Because distortion is a characteristic of glass, there is currently no globally accepted standard that regulates the issue of how much distortion should be accepted or how to measure it.

To reduce optical distortion many aspects should be considered that optimize the tempering or heat-Strengthened process. From the glass transport system (rollers) and uniform temperature control, to the design of the cooling zone, it will certainly affect the optical quality of the glass heat treatment.

Extralum, through its certification process, has the ability to heat treat glass under normal production standards, ensuring minimal ripple and deflection in tempered glass. However, due to the nature of roller distortion, this can only be reduced, it cannot be eliminated in its entirety.

Important Considerations.

While it is true, distortion is a characteristic of glass, some important considerations could minimize the visual and contractual effects of this defect. In projects with high level of visual quality it is recommended:

- Install a complete model facade, in the place itself and in full size to be able to observe all the visual effects from different angles and distances. This will facilitate the agreement and definition of its own standard for the project. Of course, high levels of quality are usually associated with a higher cost of material.
- Feasibility and costs associated with a particular inspection criterion should always be verified. In cases where it is not specified, the visual inspection criterion established by Extralum S.A. will always prevail.

- You can also specify the direction or orientation of the ripples desired in the glasses, such as on very large facades or railings. This ensures a homogeneous pattern and not a combination of distortions that can generate more unpleasant visual effects.
- Whenever the dimensions of the glass allow, it is recommended that the ripple in heat treated glass is oriented parallel to the floor or base of the installation. See Figures 14 and 15.

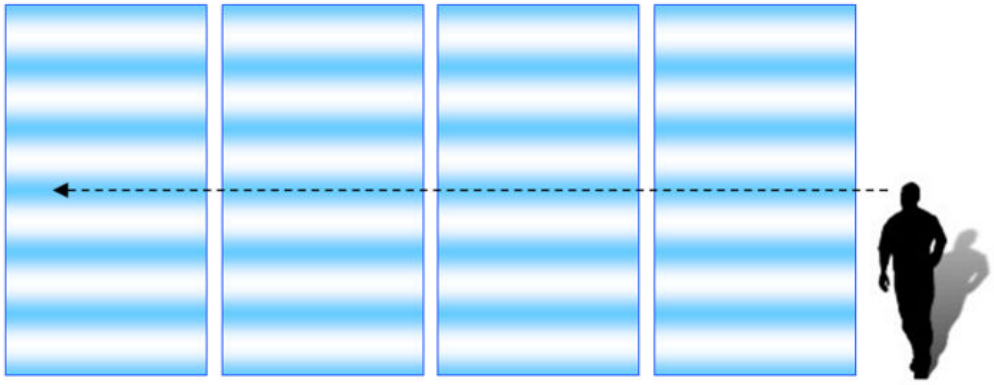

Figure 14. Ripple of the glasses with the same orientation and parallel to the floor. The observation line has no abrupt changes in image reflection.

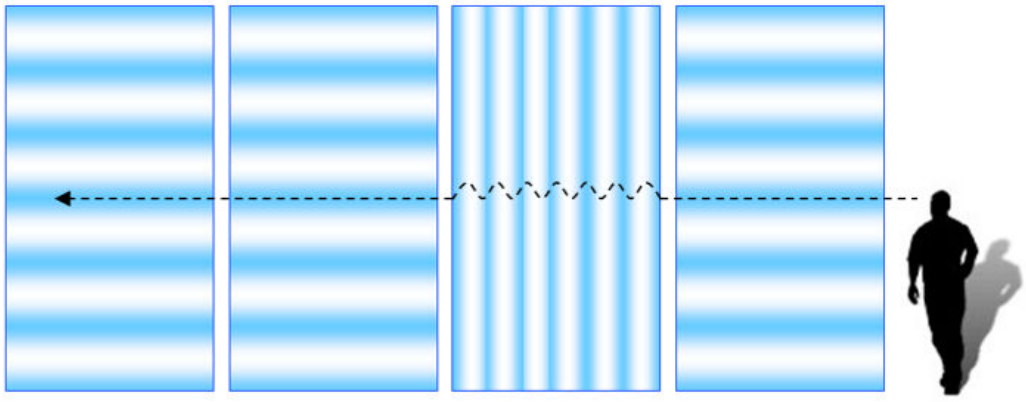

Figure 15. Ripple of the glasses with different orientation.
The observation line has abrupt changes in image reflection.

Finally, it should be clarified that glass used in architecture can be considered as "glazing quality", not as "optical quality" and that, under certain conditions of observation, some distortion will inevitably be visible. This distortion is not considered a reason for rejection of glass, unless any particular criteria have been defined, specified and accepted by all parties during the previous design and contracting phases of the project.

If you have any questions, consult the Sales Department of Extralum, S.A.