Toughened and Heat Strengthened glass Associated distortions and visual effects

Purpose of this document.
The purpose of this document is to make the reader aware of some of the physical distortions and visual characteristics of Toughened and Heat Strengthened glass. This document should not be used alone to make an assessment or decision relating to how any product should be used or any potential fitness for any purpose of any Toughened or Heat Strengthened glass product.

Introduction

The heat treatment is glass is used to produce both Toughened and Heat Strengthened glass. Toughened glass is a safety glass used widely through the domestic and commercial markets. It is much stronger then annealed glass and breaks in a much safer manner. However the manufacturing process does impart some visible distortion to the product. This document sets out the nature of this distortion.

Physical character of toughened glass

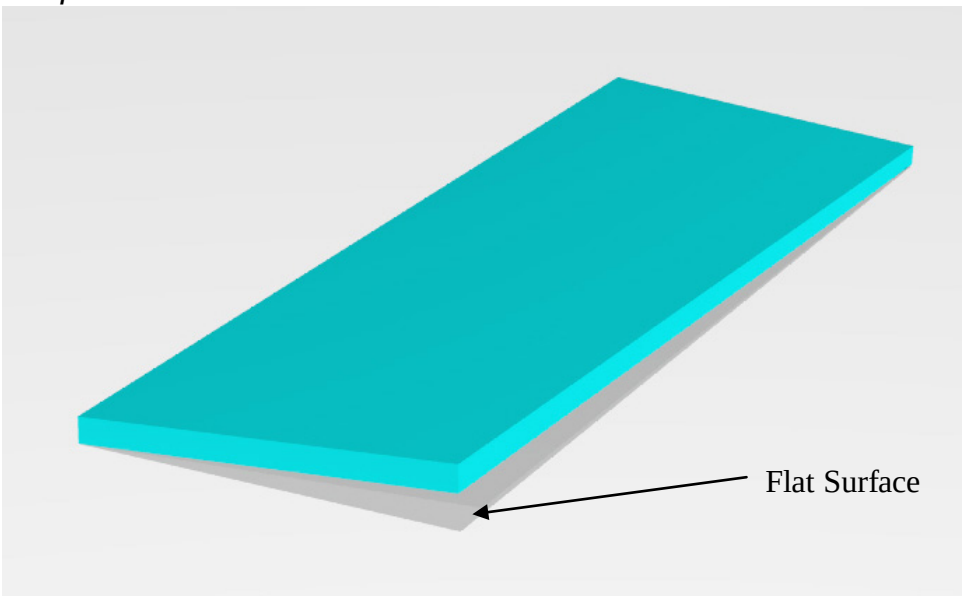
The process of toughening glass involves heating the glass in excess of 600°C and quickly cooling it. This induces significant compressive and tensile stresses in the glass which produces increased strength over ordinary glass and a much safer breakage process than ordinary glass.

This tortuous manufacturing process causes the glass to suffer some physical distortions. These distortions are evident as visual effects which are present in all toughened glass but are not present in non-heat treated glass. In a measured numerical sense the distortions are very small, but because glass has a smooth shiny surface it is easy to detect these distortions in the reflected image from the glass. It is also possible to see some distortion of the transmitted image when looking through the glass. The more oblique the angle of view the more noticeable the distortions become.

The following diagrams illustrate the possible distortions individually and in a greatly exaggerated way so the nature of the distortion can be clearly seen. It should also be noted that an individual sheet of toughened glass will have a unique combination of the distortions shown below. The distorted shape of each glass panel is generically similar but specifically individual.

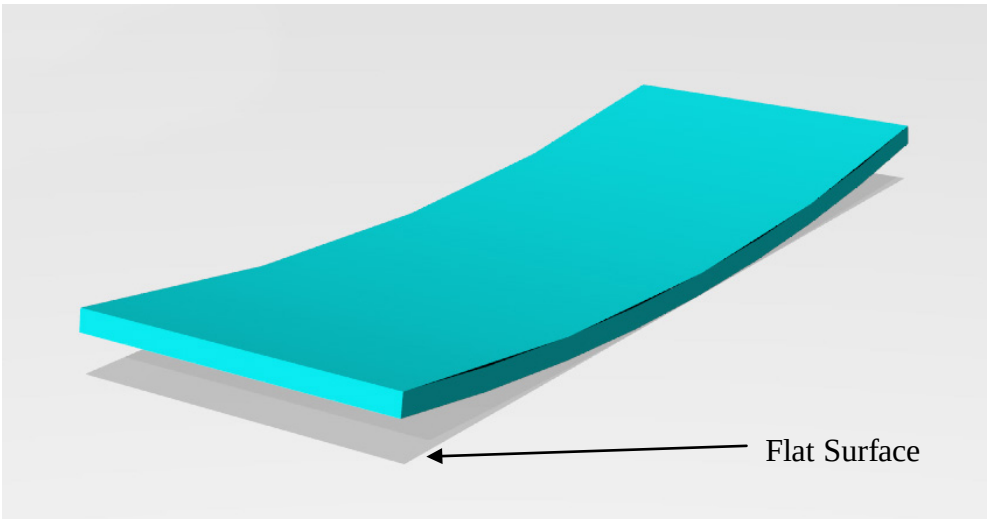
Illustration of possible distortions

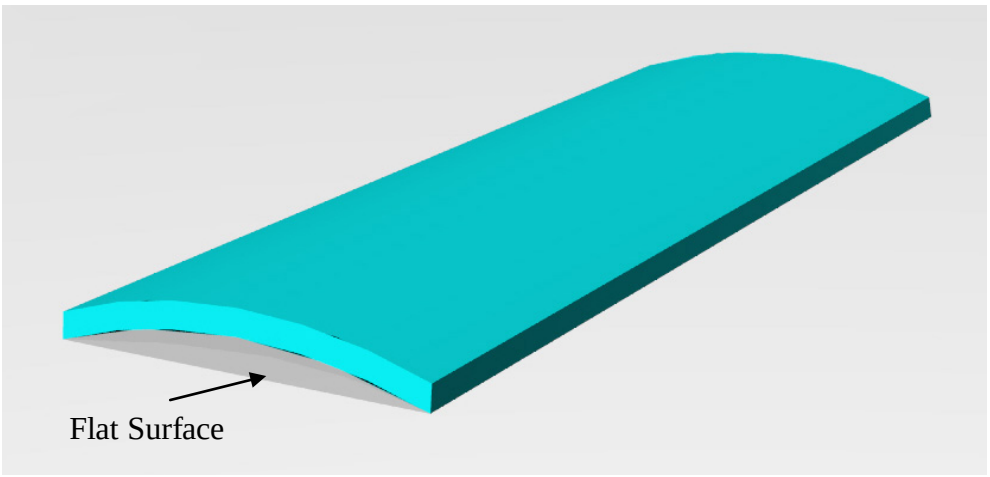
Warp

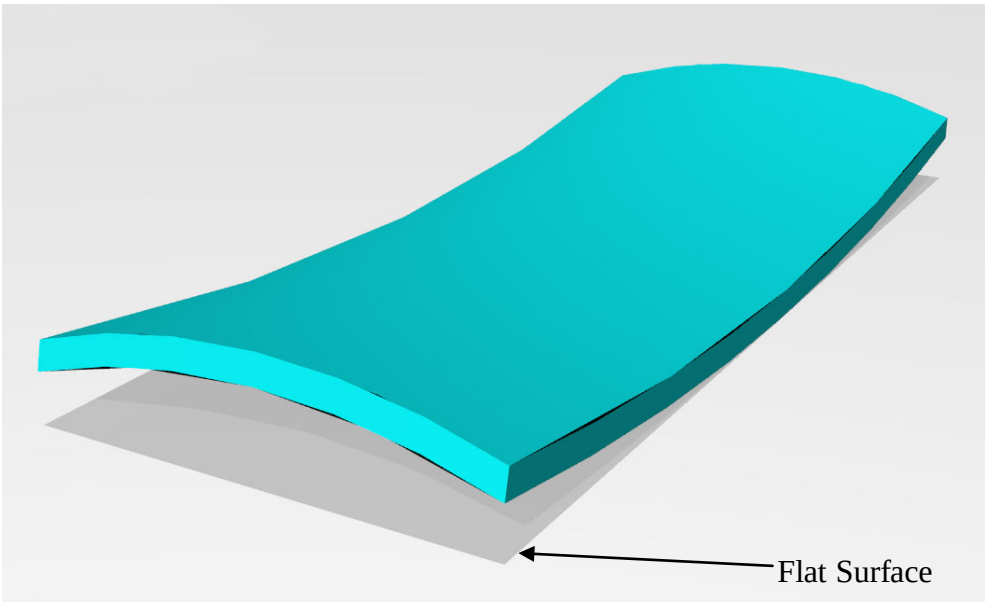


Warp refers to a twist or diagonal bend in the glass

Bow

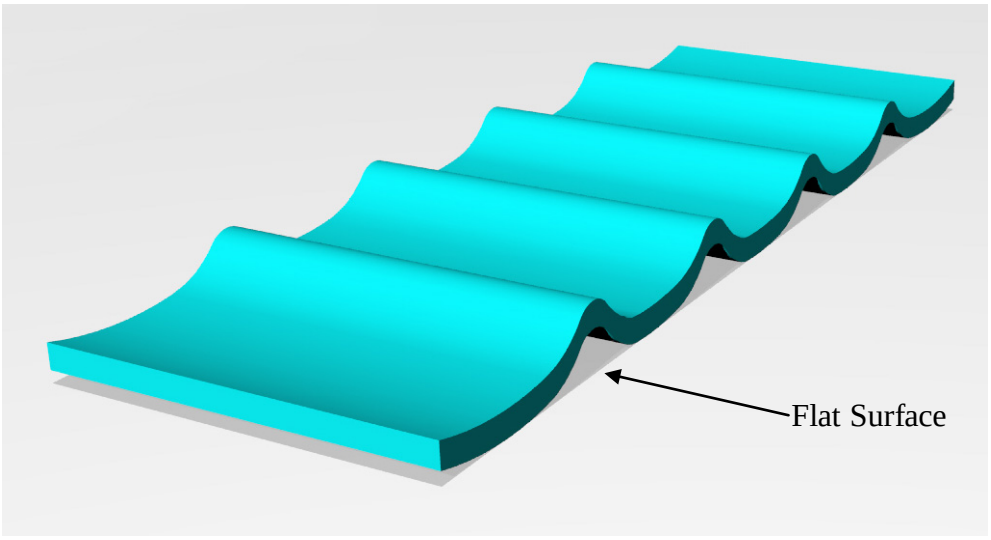

Flat Surface


Flat Surface



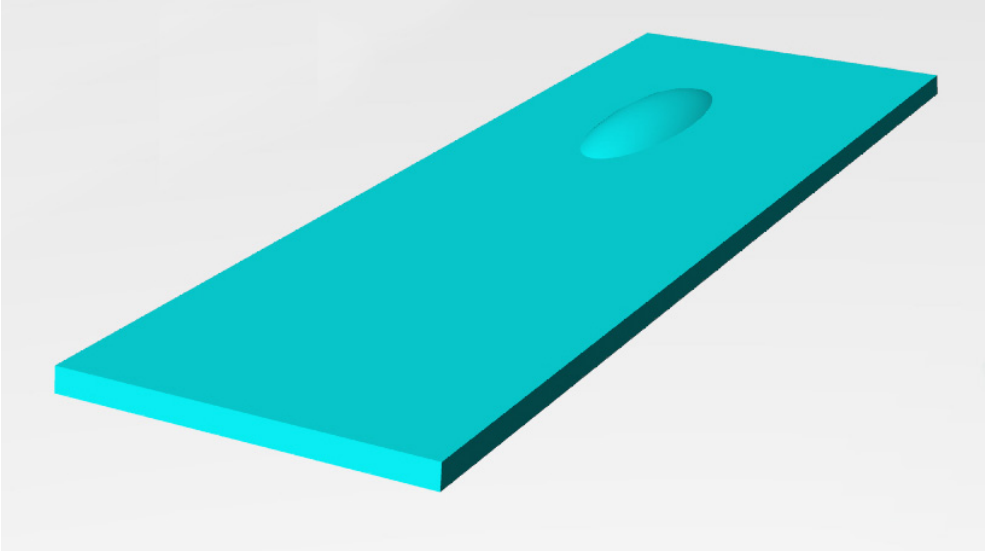
Bow refers to a slight bend in the glass

Rollerwave



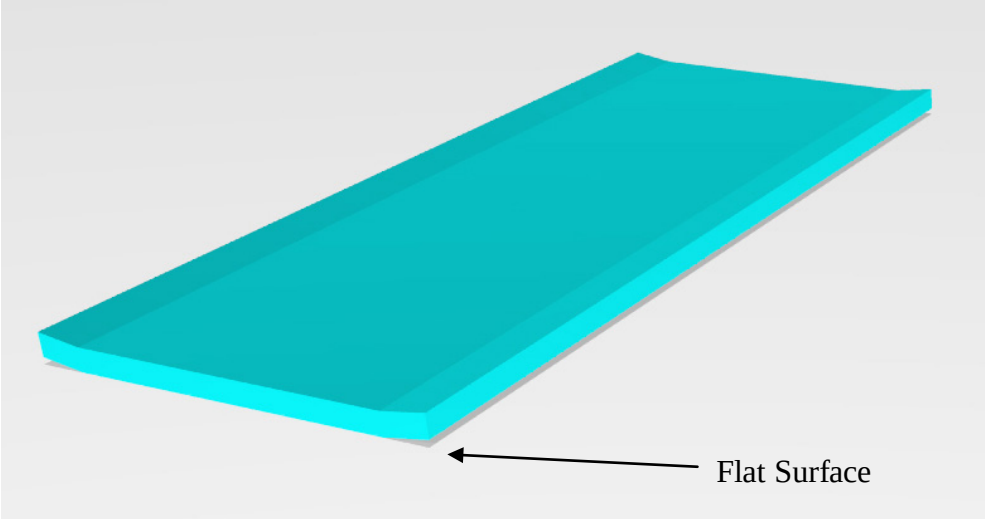
Rollerwave refers to a series of waves at regular intervals running in one direction over the glass. These are caused by the hot glass sagging slightly over the furnace rollers.

Local distortion



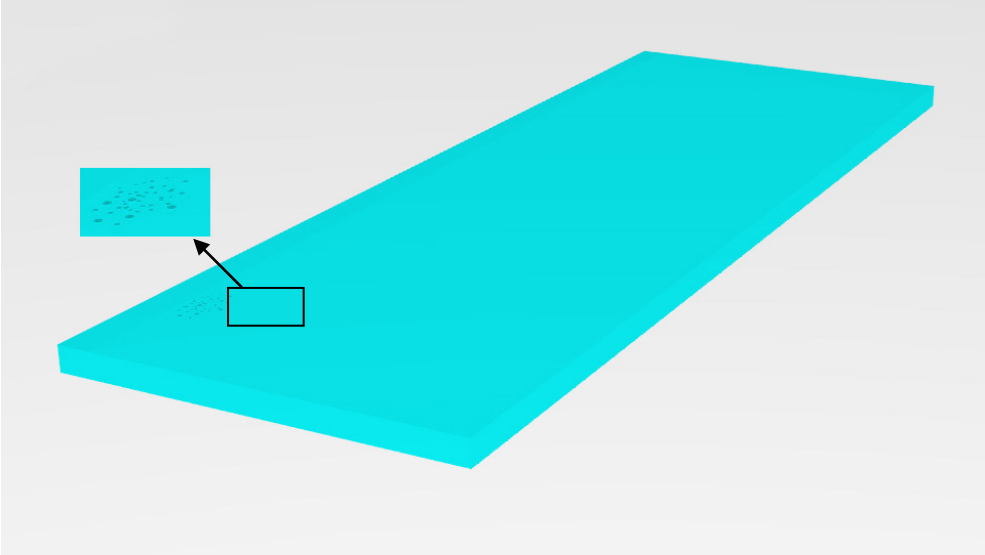
Local distortion refers to an undulation forming in one part of the glass only. It can be of any shape.

Edge lift



Glass within a small distance of the edge has tilted slightly out of the plane of the glass.

Orange peel



Imprint left on the glass from the furnace roller.

The Australian Standard AS/NZS 2208 covers the testing of safety glass, of which toughened is one type. It specifies permitted tolerances for the various distortions illustrated above, except for rollerwave and orange peel. Manufacturers have their own tolerances for rollerwave and orange peel. Unfortunately it is not possible for toughened glass not to exhibit some distortion. So it is important to note that toughened or heat strengthened glass which falls within manufacturing tolerances for distortion will appear to have visual distortion when installed in a building.

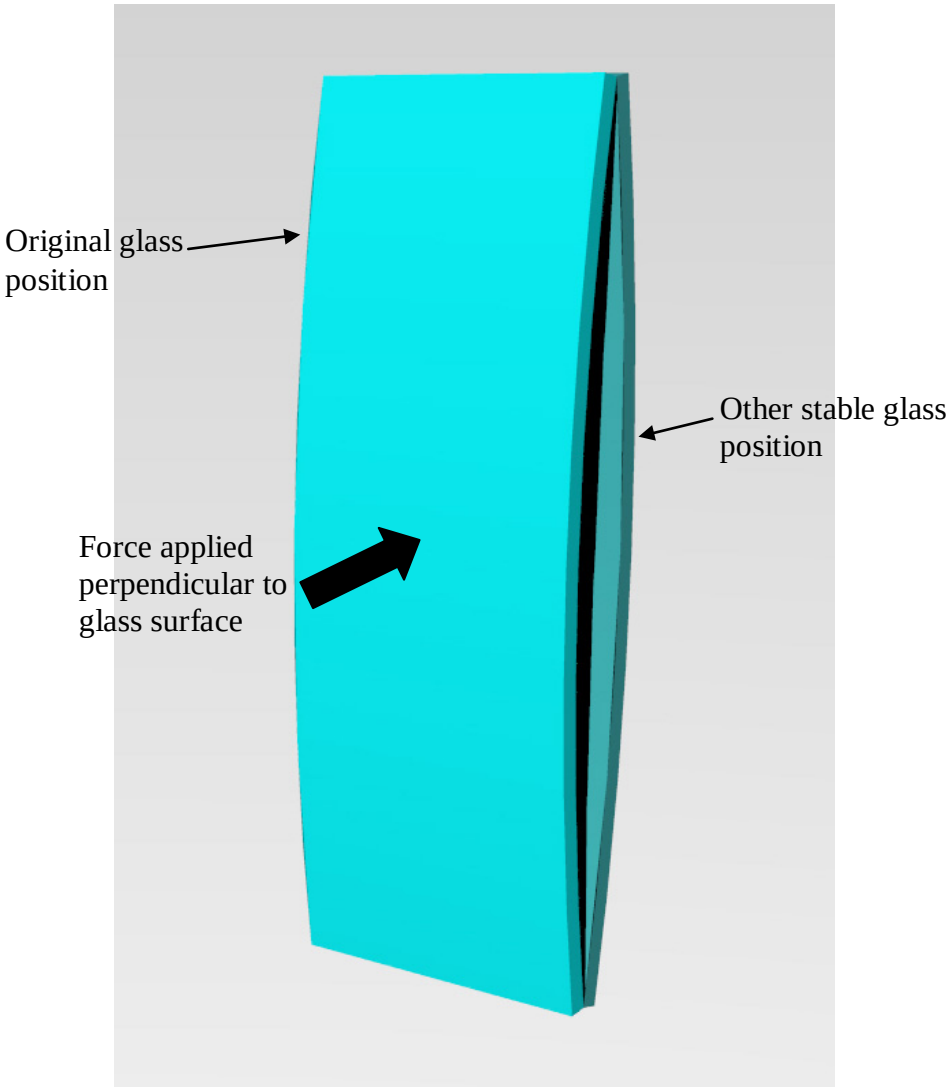
Physical effects due to distortion of the glass

Image distortion

The most common effect associated with glass distortion is the deformation of images transmitted through the glass or reflected from the glass surface. For example straight lines in the image are curved, wavy or meander.

Bi-stability

It is possible on rare occasions for glass to form a distortion pattern which has more than one stable position. The easiest way to understand this is to imagine a bow in the glass which, by pushing on the glass surface, can be reversed, that is, the applied force causes it to pop through the flat plane and form an equivalent bow to the other side. It forms a bow of the reverse shape. It is typically quite stable in this new position and requires force to be applied to return to the original position. There are various other distortion shapes which can possess a bi-stability property. However the production of panels with bi-stability is quite rare.



The picture above shows the two stable positions for a sheet of toughened glass with a bi-stable characteristic. A force applied in the direction of the arrow will cause the panel to pop to the other stable shape.

The characteristic of bi-stability does not affect the strength of the glass or its capacity to perform as a safety glass (if it has been toughened). This characteristic is not a fault within the glass. There is no tolerance specified for this characteristic because it is either present or it is not present.

Visual effects not due to physical distortion of the glass.

Photoelasticity

The stress in toughened can cause some visual effects which do not relate to a physical distortion to the shape of the glass. These effects are only visible in the presence of polarised light. Light is fully polarised when all of the light waves in a beam of light are oriented in the same way. This can be caused deliberately by passing the light through a polarizing filter such as polarising sunglasses. It can occur naturally by passing through a significant thickness of the earth's atmosphere. In a particular location light striking that location passes through the greatest thickness of atmosphere in the early morning or late afternoon/evening when the light is at its shallowest angles for the day. Light can be partially polarised and this is the most common case with the degree of polarisation related to the conditions described above.

These visual effects have some common names such as "leopard spots". In the industry it is commonly known as the "quench pattern" or "toughening pattern". A more scientific description is "Photoelasticity". It can appear as a soft grid of lines or spots of alternating lighter and darker areas. In addition some furnaces will also produce a pattern of soft rectangular bars in addition to the grid pattern. "Leopard" spots can be commonly seen in the toughened rear window of motor cars in the early morning or late evening.

There is no limiting tolerance for Photoelasticity because it will always be present if there is some polarisation of the light source. Natural light will always have some polarisation and some artificial light sources can exhibit a degree of polarisation as well.

The darker areas in this photo show a leopard spot pattern and a bar pattern. This pattern was visible under natural light late in the day. The photo is taken at an acute angle because it accentuates the visibility of the pattern. The pattern would be far less obvious if the photo was taken from a position perpendicular to the glass.

Double Glazing

Double glazing may be assembled from two sheets of toughened or heat strengthened glass. This produces two sets of distortion patterns which overlap. The distortion patterns of each glass will be different and when they overlap the resulting total distortion will appear greater than the distortion of each component glass if they were viewed individually.

Summary

All Toughened and Heat Strengthened glass will have surface distortion due to the process of heat treatment imposed on the glass. It is important that designers determine the suitability of this effect before they specify the product for their project.