Surface Distortion in Horizontally Produced Toughened Safety Glass and Heat Strengthened Glass

The use of heat treated glass has increased over recent years as issues of strength, safety and thermal performance, supported by the introduction of more onerous European Standards and Building Regulations, have become increasingly important design considerations and have had a dramatic impact on glass use in building projects.

The vastly expanded aesthetic options, combined with the improved energy conservation and comfort capabilities of tinted and coated glasses allow architects to use more glass, as well as larger sizes in their designs. A consequence of this trend is a corresponding increase in the use of toughened and heat-strengthened glass in order to meet both thermal and wind load design requirements. The demand for toughened glass further increased with the passing of safety glazing legislation, which mandated its use in certain locations.

Currently, there are three types of heat-treated glass as defined in the European Standards, heat strengthened, toughened and heat soak tested. The first two types of glass are produced using the same equipment, the third in separate process.

The majority of the heat-treated glass produced in recent years has been processed in oscillating horizontal roller hearth furnaces. The preparation stage for the heat-treatment process requires annealed float glass to be cut to the required final size, the edges to be treated according to the specified finish (commonly manually arrissed) and the glass to be washed and dried. The process then requires the glass to be transported on horizontal rollers, of fused silica, through an oven and heated, from room temperature, to beyond its softening point to approximately 630º C in a very short period of time. Upon exiting the furnace, the glass is rapidly cooled (quenched) by blowing air, at high pressure onto both surfaces simultaneously. The cooling process leaves the surfaces of the glass in a state of compression and the central core in compensating tension.

The color, chemical composition and light transmission characteristics of glass remain essentially unchanged after heat-treating. Likewise, hardness, specific gravity, expansion coefficient, softening point, thermal conductivity, solar optical properties and stiffness remain unchanged by the heat-treating process. The only physical properties that change are improved flexural and tensile strength, and improved resistance to thermal stresses and thermal shock. Under uniform loading, heat-treated glass is stronger than annealed glass of the same size and thickness. The heat-treating process does change the break pattern of the glass, i.e. toughened glass disintegrates into relatively small pieces meeting the safety glazing requirements of the Building Regulations and thereby greatly reducing the likelihood of serious cutting or piercing injuries.

The visual quality of heat-treated glass is a compromise with its performance characteristics and the economies of bespoke production.

During the production of toughened safety glass and heat-strengthened glass in an oscillating roller hearth furnace, the glass is heated beyond its softening point. The heating occurs in a furnace section where the glass is continually transported back and forth on fused silica rollers. The edges of thinner glasses (3mm to 6mm) often bow upward during the initial heating of the glass, a result of which is that the glass is transported on its central portion, which, as a consequence is at higher temperature than the remaining glass, occasionally resulting in slightly flattened areas with the appearance of an elongated optical lens occurring in the centre of the pane, however this is not normally visible from within the building and does not impede the performance of the glass. As the glass temperature increases, the glass becomes pliable and tends to sag slightly between the rollers during reversals at each end of the furnace.

The result is a reduction in surface flatness known as ‘roller wave’, a periodic wave running at right angles to the direction of travel, and is measured from the lowest peak to the highest trough of the waves. Roller wave is most easily identified, when viewing the glass by reflection of rectilinear images, from the outside of a building in which it is installed.

The ends of each piece of glass tend to sag to a greater degree due to the cantilever effect of the unsupported ends of glass at the leading and trailing edges, this sag is known as ‘edge dip’.

Glass which has a high thermal insulation performance, with a low emissivity coating applied to one surface, is designed to reflect heat. As a consequence, the glass takes longer to heat above its softening point during the thermal process and may have increased levels of distortion when compared to uncoated glass products.

When the lower glass surface becomes soft at high temperatures, heavier glasses of 8mm or greater thickness may be imprinted by minute surface distortions on the fused silica roller surface, which is known as ‘roller pick-up’, often similar in appearance to tiny raindrops.

These surface distortions are recognized by current European Standards as seen in the following extract from BS EN 12150-1.

Thermally toughened soda lime silicate safety glass produced by horizontal toughening

While the hot glass is in contact with the rollers during the toughening process, a surface distortion is produced by a reduction in surface flatness, known as ‘roller wave’. Roller wave is generally noticed in reflection. Glass which is thicker than 8mm can show signs of small imprints in the surface (‘roller pick-up’).

In order to ensure the break safe characteristics of the glass, once heated to the appropriate temperature, the glass is then transported directly into a quench section where the glass is rapidly cooled by high-pressure jets of cold air. During this period any slight variation in temperature within the glass, manifests itself by way of producing overall and local bow.

The overall bow is measured as the deformation from flatness, expressed as the amount of deformation in millimeters divided by the appropriate glass length being considered. The local bow is expressed in the same manner as the overall bow but usually for a distance of 300mm length.

The distortion from flatness is controlled within the relevant product standards. The surface conditions, which do not do not threaten the structural integrity of the product, and are not reason for rejection of glass.