“**Toughened** or **tempered glass** is a type of safety glass processed by controlled thermal or chemical treatments to increase its strength compared with normal glass. Tempering creates imbalanced internal stresses which cause the glass, when broken, to crumble into small granular chunks instead of splintering into jagged shards. The granular chunks are less likely to cause injury.

As a result of its safety and strength, tempered glass is used in a variety of demanding applications, including passenger vehicle windows, shower doors, architectural glass doors and tables, refrigerator trays, as a component of bulletproof glass, for diving masks, and various types of plates and cookware.

Toughened glass is physically and thermally stronger than regular glass. The greater contraction of the inner layer during manufacturing induces compressive stresses in the surface of the glass balanced by tensile stresses in the body of the glass. For glass to be considered toughened, this compressive stress on the surface of the glass should be a minimum of 69 MPa. For it to be considered safety glass, the surface compressive stress should exceed 100 MPa. The greater the surface stress, the smaller the glass particles will be when broken.

It is this compressive stress that gives the toughened glass increased strength. This is because any surface flaws tend to be pressed closed by the retained compressive forces, while the core layer remains relatively free of the defects which could cause a crack to begin.

Any cutting or grinding must be done prior to tempering. Cutting, grinding, sharp impacts and sometimes even scratches after tempering will cause the glass to fracture. The glass solidified by dropping into water, known as "Prince Rupert's Drops", which will shatter when their "tails" are broken, are extreme examples of the effects of internal tension.

The strain pattern resulting from tempering can be observed with polarized light or by using a pair of polarizing sun glasses.

Toughened glass is made from annealed glass via a thermal tempering process. The glass is placed onto a roller table, taking it through a furnace that heats it above its annealing point of about 720 °C. The glass is then rapidly cooled with forced air drafts while the inner portion remains free to flow for a short time.

An alternative chemical toughening process involves forcing a surface layer of glass at least 0.1mm thick into compression by ion exchange of the sodium ions in the glass surface with the 30% larger potassium ions, by immersion of the glass into a bath of molten potassium nitrate. Chemical toughening results in increased toughness compared with thermal toughening, and can be applied to glass objects of complex shape

Heat Soaking

Heat Soaking is a destructive process in which a pane of tempered glass is subjected to temperatures up to 280° C for several hours over a specific temperature gradient to induce fracture. This test insures that if there is probability of breakage then the infected panes break inside the furnace at the factory itself. Up to 95 % NiS infested panes are usually destroyed inside the heat soak chamber at the factory premises and hence reduce the chances of onsite breakages.

The heat soaking process is one method of reducing the incidence of NiS induced failure in tempered glass by causing the phase change to occur before the glass panel is installed in the building. Numerous heat soaking criteria have been developed with different levels of success. In any event the heat soaking process is not 100% effective and failures have known to occur with heat soaked tempered glass.

The time to fracture due to NiS induction depends on various factors like: -

- Purity of the inclusion.
- Location of the inclusion within the tensile zone of the tempered glass.
- Magnitude of the tensile stress within the body of the glass.
- Size of vent associated with the inclusion.
- Environmental conditions – temperature and lateral wind pressure.
- Panel size – membrane stress developed in the window.

The presence of nickel sulphide is adventitious in most glass. It has been estimated that in normal float glass production NiS inclusions occur at a frequency of about one per 8 tonnes of raw glass It has been estimated that 1 gram of nickel sulphide can produce approximately 1000 inclusions of 0.15 mm diameter. Consequently, it does not require too much contamination to produce a serious problem.

NiS induced fracture in tempered glass has generally been found to be restricted to a batch of glass rather than all tempered glass. Numerous large high rise glass facades around the world have experienced NiS induced fracture. Yet in comparison there are literally thousands of high rise glass
facades that have not reported any fracture of tempered glass. The failure pattern is unique to each building. Some batches of NiS contaminated tempered glass experience glass breakage from the installation stage of the facade while others have an incubation period before failure commences.
Furthermore, failures have been known to occur up to 20 years after manufacture.

Nickel Sulphide inclusions often contain other metals such as iron, copper and cobalt. These impurities also generally influence the fracture behavior of the NiS inclusion.

The glass that is to be installed inside a framed glazing, point fixed infill panels, canopies, balustrades, external facades, should be tempered as well as heat soaked because these are the concern areas due to NiS induced glass failure which can cause:

- Personal injury due to falling glass:- An occupant or passer-by may be hit by falling fragments. When a pane of toughened glass falls spontaneously it produces a loud noise which may be heard from a significant distance away. The reaction of many people when hearing a noise above them is to look up, and this may result in fragments of glass striking a person in the face, or getting into the eyes.

- Result in unusable area: - An area of the building may be rendered unsafe or unusable until the glass can be replaced.”