ProCurve
GLASS DESIGN, INC.

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Heat-Treated Glass vs. Chemically Strengthened . . . Know the Differences

HEAT-TREATED GLASS

Heat-treating of annealed glass provides greater resistance to thermal and mechanical stresses and achieves specific break patterns for safety glazing applications. The most commonly used process for heat-treating requires cutting the glass to the desired size, transporting it through a furnace and uniformly heating it to approximately 1150°F (621° C). Upon exiting the furnace, the glass is rapidly cooled by blowing air uniformly onto both surfaces simultaneously. The cooling process locks the surfaces of the glass in a state of high compression and the central core in compensating tension. Heat-treated glass has two compression layers or zones, one starting at each surface, plus an interior tension zone centered in the middle of the glass. Each of the two compression zones is approximately 20% of the glass thickness. The remainder is in the tension zone.

The heat-treating process does not affect the color, clarity, chemical composition and light transmission of the glass. Likewise, hardness, specific gravity, expansion coefficient, softening point, thermal conductivity, solar transmittance and stiffness remain unchanged. 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.

Heat-treated glass can be heat-strengthened or fully tempered, depending on the degree of residual surface compression or edge compression. According to ASTM C 1048, heat-strengthened glass is produced with surface and edge compression levels less than fully tempered glass. The lower compression levels yield a product that is generally twice as strong as annealed glass of the same thickness, size and type. Heat-strengthened glass with low compression levels will tend to fracture into large fragments similar to annealed glass breakage. As the compression levels increase, the size of the particles of broken glass tend to become smaller.

Heat-strengthened glass with surface compression levels in the range of 3,500 psi to 7,500 psi is probably the most desirable for most uses. The break pattern is relatively large. It does not meet the safety glazing requirements of ANSI Z97.1 American National Standard for Safety Glazing Materials Used in Buildings-Safety Performance Specifications Method of Test, or CPSC 16 CFR 1201 Safety Standard for Architectural Glazing Materials unless it has been laminated.

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Fully tempered glass conforms to ASTM C 1048 – Standard Specification for Heat-Treated Flat Glass- Kind HS, Kind FT. The higher compression levels usually yield a product that is generally four times stronger than annealed glass and twice as strong as heat-strengthened glass of the same thickness and type.

When broken, fully tempered glass usually breaks into a multitude of small fragments. American fabricators typically offer fully tempered glass in thicknesses of 1/8" to 3/4".

CHEMICALLY STRENGTHENED GLASS

Chemical strengthening is achieved through a process known as ion-exchange. Glass is submersed in a molten salt bath at temperatures below the annealing range of the glass. In the case of soda-lime glass, the salt bath consists of potassium nitrate. During the submersion cycle, the larger alkali potassium ions exchange places with the smaller alkali sodium ions in the surface of the glass. The larger alkali potassium ions "wedge" their way into the voids in the surface created by the vacating smaller sodium ions. The "strengthened" surface may penetrate to a case depth of only a few thousandths of an inch.

Chemically strengthened glass is significantly stronger than annealed glass, depending upon the glass composition, strengthening process, level of abrasion, and the application environment. The strengthening process does not contribute significantly to optical distortion.

When chemically strengthened glass is broken, it breaks in a pattern similar to annealed glass and, therefore, should not be used by itself as a safety glazing material unless laminated. Chemically strengthened glass can experience a loss of strength due to post fabrication cutting and scratching.

An ASTM Task Group has developed a quality standard for chemically strengthened glass. The standard categorizes chemically strengthened glass according to case depth and surface compression. These levels are independent of each other. Increasing levels of surface compression permit an increasing amount of flexure. Greater case depths offer more protection from strength reduction caused by abuse and abrasion.

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The classifications are as follows:
Surface Compression

- Level 1 – surface compression > 1000 psi $\leq$ 25,000 psi
- Level 2 – surface compression > 25,000 psi $\leq$ 50,000 psi
- Level 3 – surface compression > 50,000 psi $\leq$ 75,000 psi
- Level 4 – surface compression > 75,000 psi $\leq$ 100,000 psi
- Level 5 – surface compression > 100,000 psi

Case Depth

- Level A – case depth $\leq$ 0.002 inch
- Level B – case depth > 0.002 inch and $\leq$ 0.006 inch
- Level C – case depth > 0.006 and $\leq$ 0.010 inch
- Level D – case depth > 0.010 inch and $\leq$ 0.014 inch
- Level E – case depth > 0.014 inch and $\leq$ 0.020 inch
- Level F – case depth > 0.020 inch

The classification system of the ASTM standard does not address end use performance. Other tests may be required to assess conformance with a particular end use application. For instance, chemically strengthened glass-clad polycarbonates installed in detention facilities is tested to physical attack, ballistics, or mechanical impact tests. Chemically strengthened transit glass is tested to FRA Part 223. In some cases, ASTM C 158, 3-point bending test, is used to determine flexural strength (MOR) and a load-deflection curve is used to determine flexural stiffness (modulus of elasticity).

MECHANICAL PROPERTIES (Average)

GLASS TYPE	FLEXURAL STRENGTH	FLEXURAL STIFFNESS
Tempered Monolithic	17,200 psi	10.6×10^6 psi
Tempered Laminated Glass	10,000 psi	380,000 psi
Chemically strengthened Laminated Glass	25,000 psi	6.487×10^6 psi
Polycarbonate	13,500 psi	340,000 psi
Acrylic (PMMA)	16,000 psi	435,000 psi