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Laminated glass

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Automobile windshield with "spider web" cracking typical of laminated safety glass.

Laminated glass is a type of safety glass that holds together when shattered. In the event of breaking, it is held in place by an interlayer, typically of polyvinyl butyral (PVB) or ethylene-vinyl acetate (EVA), between its two or more layers of glass. The interlayer keeps the layers of glass bonded even when broken, and its high strength prevents the glass from breaking up into large sharp pieces. This produces a characteristic "spider web" cracking pattern when the impact is not enough to completely pierce the glass. In the case of the EVA, the thermoset EVA, offers a complete bounding (cross-linking) with the material whether it is glass, polycarbonate, P.E.T. or other types products.

Laminated glass is normally used when there is a possibility of human impact or where the glass could fall if shattered and also for architectural applications. Skylight glazing and automobile windshields typically use laminated glass. In geographical areas requiring hurricane-resistant construction, laminated glass is often used in exterior storefronts, curtain walls and windows.

Laminated glass is also used to increase the sound insulation rating of a window, where it

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significantly improves sound attenuation compared to unlaminated glass panes of the same thickness. For this purpose a special "acoustic PVB" compound is used for the interlayer. In the case of the EVA material, no additional acoustic material is required, since the EVA provides sound insulation.[1] [2] An additional property of laminated glass for windows is that a PVB and EVA interlayer can block essentially most ultraviolet radiation. A thermoset EVA could block up to 99,9% of the UV rays.

Contents [hide]

History [edit]

In 1902, the French *Le Carbone* corporation obtained a patent for coating glass objects with celluloid in order to render them less susceptible to cracking or breaking.[3]

Laminated glass was invented in 1903 by the French chemist Édouard Bénédictus (1878-1930), inspired by a laboratory accident. A glass flask had become coated with

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the plastic cellulose nitrate and when dropped shattered but did not break into pieces.[4] However, it was not until 1909 that Benedictus filed a patent.[5] In 1911, he formed the *Société du Verre Triplex*, which fabricated a glass-plastic composite to reduce injuries in car accidents.[6] Production of Triplex glass was slow and painstaking, making it expensive. It was not immediately widely adopted by automobile manufacturers, but laminated glass was widely used in the eyepieces of gas masks during World War I. In 1912, the process was licensed to *The English Triplex Safety Glass Company*. Subsequently, in the United States, both Libbey Owens-Ford and Du Pont de Nemours with Pittsburg Plate Glass produced Triplex.[7]

Firefighters breaking through a laminated windshield

Meanwhile, in 1905, John Crewe Wood, a solicitor in Swindon, Wiltshire, England, patented a laminated glass for use as windscreens / windshields. The layers of glass were bonded together by Canada balsam.[8] In 1906 he founded the Safety Motor Screen Co. to produce and sell his product.[9]

In 1927, the Canadian chemists Howard W. Matheson and Frederick W. Skirrow invented the plastic polyvinyl butyral (PVB).[10] By 1936, United States companies had discovered that laminated "safety glass" consisting of a layer of polyvinyl butyral between two layers of glass would not discolor and was not easily penetrated during accidents. Within five years, the new safety glass had virtually replaced its predecessor.[11][12]

In the Road Traffic Act of 1930, the British parliament required new cars to use windscreens of "safety glass".[13]

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By 1939 some 600,000 square feet (56,000 m^2) of "Indestructo" safety glass was being used every year in vehicles produced at the Ford Motor Company works in Dagenham, England.[14] "Indestructo" safety glass was manufactured by British Indestructo Glass, Ltd. of London.[14] This was the laminated glass used by the Ford Motor Company in 1939, chosen because "it gives the most complete protection. In addition to being splinter-proof, it is crystal clear and permanently non-discolourable."[14] This quote hints at some of the technical issues, problems and concerns that stopped laminated glass from being widely used in automobiles immediately after it was invented.

Modern laminated glass is produced by bonding two or more layers of ordinary annealed glass (or tempered glass) together with a plastic interlayer, usually polyvinyl butyral or ethylene-vinyl acetate (EVA). The PVB or the EVA are sandwiched by the glass, which is either passed through a series of rollers, or vacuum bagging systems, and ovens, or auatoclaves, to expel any air pockets. Then it is heated to form the initial melting. These constructions are then heated under pressure in an autoclave or oven, to achieve the final bounded product(fully crosslinked in the case of the thermoset EVA). The tint at the top of some car windshields is in the PVB. Also, colored P.E.T. films can be combined with the thermoset EVA material, during the laminating process, in order to obtain a colored glass.

Once a thermoset EVA is properly laminated during the process, the glass could be exposed frameless and there will be no water/moisture infiltration, the yellowing index is very low and it shoudln't delaminate, due to the high level of bounding (crosslinking).[15]

Specifications [edit]

A typical laminated makeup is 2.5 mm glass / 0.38 mm interlayer / 2.5 mm glass. This gives a final product that would be referred to as 5.38 laminated glass.

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Multiple laminates and thicker glass increases the strength. Bullet-resistant glass is usually constructed using polycarbonate, thermoplastic materials, thermoset EVA, and layers of laminated glass. A similar glass is often used in airliners on the front windows, often three sheets of 6 mm toughened glass with thick PVB between them.

Newer developments have increased the thermoplastic family for the lamination of glass. Beside PVB, important thermoplastic glass lamination materials today are ethylene-vinyl acetate (EVA),[16] thermoset EVA ethylene-vinyl acetate (EVA)[17] and thermoplastic polyurethane (TPU).[18] The adhesion of PVB/TPU and EVA is not only high to glass, but also to polyester (PE) interlayers. Since 2004 metallised and electroconductive polyethylene terephthalate (PET) interlayers are used as substrate for light emitting diodes and laminated to or between glass.

- Top layer: Glass
- Interlayer: Transparent thermoplastic materials (TPU or PVB, EVA) or transparent thermoset material (EVA)
- Interlayer: LED (light emitting diodes)on transparent conductive Polymer
- Interlayer: Transparent thermoplastic materials (TPU or PVB, EVA) or transparent thermoset material (EVA)
- Bottom layer: Glass

Laminated glass is also sometimes used in glass sculptures.

Manufacture [edit]

There are several laminated glass manufacturing processes:

1. using two or more pieces of glass bonded between one or more pieces of adhesives; such as PVB or EVA, using heat and pressure.
2. using two or more pieces of glass and polycarbonate, bonded together with aliphatic

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urethane or EVA interlayer under heat and pressure.
3. interlaid with a cured resin or EVA.

Each manufacturing process may include glass lites of equal or unequal thickness.

Cutting [edit]

Plastic interlayers in laminated glass make its cutting difficult. There is an unsafe practice of cutting both sides separately, pouring a flammable liquid such as denatured alcohol into the crack, and igniting it to melt the interlayer to separate the pieces. The following safer methods were recommended by the UK Government's Health and Safety Executive in 2005:[19]

- Special purpose laminated cutting tables
- Vertically-inclined saw frames
- A blowlamp or hot air blower.

Repair [edit]

According to the United States National Windshield Repair Association, laminated glass repair is possible for minor impact damage using a process that involves drilling into the fractured glass to reach the lamination layer. Special clear adhesive resin is injected under pressure and then cured with ultraviolet light. When done properly, the strength and clarity is sufficiently restored for most safety related purposes. The process is widely used to repair large industrial automotive windshields where the damage does not interfere with the view of the driver.[20]

Disposal [edit]

Waste disposal of laminated glass is no longer permitted in landfill in most European countries as

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the End of Life Vehicles Directive (ELV) is implemented. A study by University of Surrey and Pilkington Glass proposes that waste laminated glass be placed into a separating device such as a rolling mill where the glass is fragmented and the larger cullet is mechanically detached from the inner film. The application of heat then melts the laminating plastic, usually polyvinyl butyral (PVB), enabling both the glass and the interior film to be recycled. The PVB recycling process is a simple procedure of melting and reshaping it.[21]

See also [edit]

- Toughened glass
- BS 857
- LED Film

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External links [edit]

- UNECE Reg. 43 Safety glazing material
- BS 857:1967 Specification for safety glass for land transport

Categories: Glass coating and surface modification | Vehicle technology

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