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Assuring Safety of Building Envelop with Disaster Resistant Glass

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ABSTRACT

Urban landscape in today's context exhibits the large scale use of architectural glass in modern building design as it orchestrate bold and brilliant aesthetic statements. The building envelope design practice do not generally considers the potential life safety hazards of falling glass on occurrence of a disaster whether it is a severe earthquake, a hurricane or a terrorist attack. It has been noticed that architectural design, and in the wind engineering field, building codes contain only minimal information regarding the seismic design of architectural glazing systems. In addition to various Physical-chemical properties of such glasses is not commonly known to the architects and planners which limit their potential use in buildings in order to render them safe from disasters. This paper discusses the performance of glass in disasters. The characteristics of various types of glasses which can prove instrumental in assuring safety to the occupants are presented. It is stated that life safety considerations should be considered In selecting right type of glass to check damages, hamper rescue efforts,, disruptions to building operations that can occur when glass breaks during disasters.

Keywords: Architectural, Glass, Envelop, Disaster, Damages.

I. INTRODUCTION

Architectural glass components like windows and the curtain wall systems within which they are glazed are referred as "non-structural" elements of a building. Past events demonstrated that not only can damage to the facade cause a building to be unusable, but there is also the risk of injury or death from damage to non-structural elements like falling panels, masonry or glass. Large scale damages to glass in past earthquakes indicated the vulnerability of glass on occurrence of an earthquake as observed in 1985Mexico city earthquake where about 263 multistorey office buildings were damaged out of which 25% reported serious damage of glass (Suculoglu,Vallabhan 1996). In recent Chile earthquake of 2010 and Christchurch earthquake of the 22nd February 2011 caused widespread damage to the multi-story buildings within Christchurch's central business district (CBD). Damage to the facades of these buildings was a clear contributor to the overall building damage (Baird et al 2011)Figure 1. In addition the breakage of glass hampers evacuation operation which result in an increased panic (Fig 2)

Figure 1. Damaged Building Facade in 2010 Chile Earthquake.
Source: fema.gov

Figure 2: Blocked Evacuation route
Source: climatepro.com

In recent terrorist attacks the bomb has become the weapon and the high-explosive detonation, with its associated property damage, injury, flames and noise, draws immediate attention. In events in New York, Oklahoma, London, Israel and many other locations it has been found that the blast energy caused collateral damage to many surrounding structures, not just the intended target. In these events glass fragmentation hazards had been identified as a main cause of injury in the targeted as well as the peripheral sites. This phenomenon calls for use of glass which could sustain damages as far as possible in case of occurrence of a disaster.

Causes of Breakage of Glass

Glass being a brittle material acts elastically until it fractures at ultimate load. Research indicated that the ultimate load varies according to the type and duration of the loads applied as well as the distribution, orientation and severity of the inhomogeneity's and micro-flaws existing in the surface of the glass. Glass is a building material which has different physical and chemical properties and it cannot be engineered in the same way as other material used for building envelope with a predictable specific strength. In such cases it is desirable to minimize the likelihood that breakage will occur at the selected design load. Because the ultimate strength of glass varies, its strength is described statistically. In selecting a particular type of glass it is important for Architects when specifying a design factor for glass in buildings, must choose the anticipated wind load, its duration and the probability of glass breakage which is defined as x per 1000 lites of glass at the initial occurrence of the design load.

Glass are annealed, heat strengthened or fully tempered for earthquake resistance. Heat treatment of glass i.e. heat strengthen (HS) or fully tempered (FT) result in the creation of resiodual surface compressive stress which is about 24.13 MPa (3500 psi) to 51.71 MPa (7500 psi) for Heat strengthened glass while it is more than 68.95 MPa (10000 psi) for fully tempered glass. This phenomenon increases the stress resistance of glass to fracture under bending stress substantially. The resulting surface residual stress render HT and FT glass two to four times stronger in out of plane flexure for the same size of thickness of annealed glass ((Behr 2002)

Tempered Glass

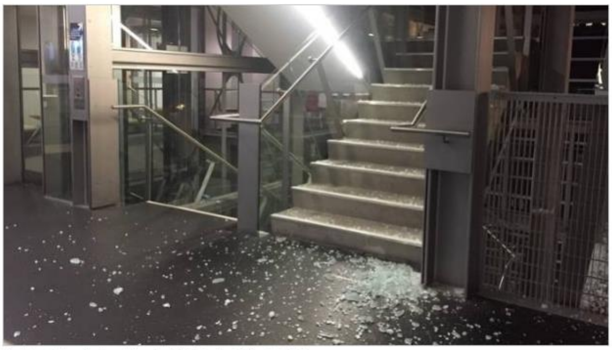
Glass is a brittle material which is susceptible to fail suddenly during an earthquake or from windborne debris, throwing shards of glass throughout a space and injuring those nearby. Tempered glass is designed in such a way that the glass will break but the pieces are less likely to be sharp, jagged pieces that will seriously injure someone.

Shatter- Proof Glass.

In this type of glass two sheets of water white anti-reflecting glass are laminated to a plastic interlayer, usually Polyvinyl Butyral (PVB). This clear plastic layer contains UV blocking agents and bonds the two pieces of glass together. The resulting sheet is kept at least 4.4mm thick in order to make it heavy, hard to cut. As a result the impact is less likely to break it and, if it breaks, it holds together.

Shatter Resistant Window Film (SRWF)

For providing shatter resistance anchored film is used which holds broken glass shreds in the glazed opening when glass is broken and save the damages to pothers. (Beason and Lingnell 2002). Toughened (tempered) glass is stronger than normal glass and when it is damaged it breaks into thousands of small glass fragments that present a much smaller falling hazard. Damage to toughened glass was typically observed as an empty frame and a pile of glass fragments on the evacuation route in Wellington earthquake shown in Fig .2



Shattered glass in the stairwell of Wellington's Spark building.

Figure 2. Glass shreds spread on evacuation route. Source: http://www.stuff.co.nz

In this type the plastic film is applied to the inside of the window to protect building occupants from shattered glass, which occurs when a considerable amount of pressure is applied to a window. Use of protective window film is a less expensive option than tempered glass to protect building occupants from glass fragments in case of disaster occurrence. Shatter Resistant Window Film is generally used in 4 or 8 mil thicknesses in order to provide a sufficient level of protection in emergency situations when used for earthquake and blast protection from broken window glass. Many times in has a coating that tints the window glass and reduce glare and solar heat gain. Another type is a film with a reflective coating and low solar heat gain co-efficient (SHGC) which offer energy efficiency benefit as well as glass shatter protection. Window film is self-adhering and applied with a light spray of water on clean glass with a squeegee. It is important that the films meant to protect against glass shatter by high winds should also be secured with an anchoring system around the glass perimeter, which holds the sheet in the frame should the glass break.

Manufacturing Process

Window glass manufacturing include a process called glazing, incorporates multiple panes of glass, gas fillings, and high-tech, heatsensitive coatings. There are four types of commonly used window glazing systems: annealed glass, heat strengthened glass, fully thermally tempered glass, and polycarbonate. In annealing process glass is cooled slowly to relieve internal stresses after it was formed allowing the glass to be cut by scoring and snapping (Collins E.F., 1921). Then it is heated until the temperature reaches a stress relief point (annealing temperature) at a viscosity, η, of 1013 Poise. At this stage the glass is still too hard to deform, but is soft enough for the stresses to relax which s is then allowed to heat soak until its temperature is even throughout.
The glass is then slowly cooled at a predetermined rate until its temperature is below the strain point (η = 1014.5 Poise). After this the temperature is dropped to room temperature at a rate limited by the heat capacity, thickness, thermal conductivity, and thermal expansion coefficient of the glass. After this process the glass is to required size, drilled or polished. As a result of annealing on breakage, the glass tends to form sharp-edged, pointed shards (Haldimann et al., 2008). Annealed glass is of relatively low strength, and upon failure, fractures into razor sharp, dagger shaped fragments. Fully thermally tempered glass is comparatively stronger than annealed glass, and when fractured, breaks into small cube shaped fragments, but it still presents a significant health hazard.

Shatter resistant film is also known as fragment retention film (FRF), safety film, security film, protective film, air blast resistant, fragment retention film, or shatterproof film which is largely is used to reduce the flying glass shards shown to be a major contributor to injuries in explosive events. The film adheres to the inside of the window and helps reduce the fragmentation of the glass and the velocity of the glass fragments at failure. Because the film adheres directly to the glass it is beneficial for use on existing windows as well as new windows.

Bullet-Resistant Glass

Laminated glass can be designed to resist attacks by a wide range of weapons. A Bullet-Resistant Glassresist penetration by specified ballistics and its spall or flying shards leaving the rear face, as a result of the impact are within the limits of the specified test criteria. A bullet-resistant glass is a multi-ply laminated glass having multiple layers of glass and PVB bonded together into a monolithic unit. The rear most lite of glass is usually a thin glass is a combination of glass and polycarbonate. In this PVB and/or a Thermo Plastic Urethane (TPU) is used as the interlayer. Polycarbonate is one of the toughest clear plastics, having 250 times the impact strength of glass and is used toward the rear of the laminate to flex and absorb the energy of the bullet. The rear face is always exposed polycarbonate with a scratch-resistant coating. Polycarbonates are produced by two processes first by an interfacial polymerization process which utilize phosgene another is transesterification or melt process. An interfacial polymerization process utilizing phosgene involves stirring a slurry or solution of bisphenol A (BPA)and 1-5% of a chain stopper such as phenol, p-tbutylphenol or p-cumylphenol in mixture of methylene chloride and water. Phosgene is added in the presence of a small amount (0.1-3%) of a tertiary amine catalyst.

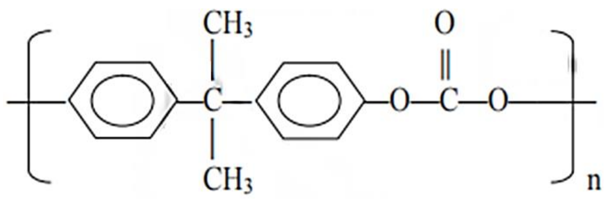


Figure 3. Chemical Structure Unit of Polycarbonate made from BPA

Preparation of polycarbonates through melt process is advantageous as it eliminates the use of solvents and phosgene.

Hurricane Impact-Resistant Glass

Glass buildings also found vulnerable failure during hurricane as observed in many states of United States of America like Florida, Louisiana, and Texas etc. Many buildings envelops in current architectural development are designed with glass that are resistant to impact of hurricane. One of such building is The Salvador Dalí Museum is an art museum in St. Petersburg, Florida, United States. This iconic structure is characterized by a large glass entryway and skylight which is made of 1.5 inch thick glass. Referred to as the "Enigma", the glass entryway is 75 feet tall and encompasses a spiral staircase is designed to protect the building from hurricanes.

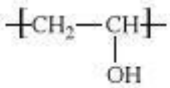
Source : https://whatijustlearned.files.wordpress.com/2013/04/dscn37051.jpg

Hurricane Impact-Resistant Glass includes the laminate made up of two pieces of glass of the same thickness; however, the two pieces of glass are annealed, heat-strengthened or tempered, depending on the system in which it was tested. For small missile performance, glass with a 0.060" PVB interlayer is normally used. The outer lite of glass should be tempered and the inner lite heat-strengthened for best performance,. For large missile performance up to about 25 SQ FT and 65 PSF design pressure, laminated glass with an 0.090" PVB interlayer is usually used. This is combined with various glass configurations, depending on the opening size, design pressure and window or glazing system design. For the higher-level performance that is required for curtain wall, storefront and large residential applications, it is often necessary to use Storm Glass which has a unique, high-performance interlayer that are much stiffer than regular PVB, and that can sustain much greater design pressures.

Laminated glass is a strong material and an excellent choice for building envelop in all types of buildings that may be subjected to bomb blasts. It has a tough plastic interlayer which holds the glass together after an impact, and with the proper framing systems, the glazing will be retained in the opening. Thus, the amount of flying glass, as well as the consequent injuries minimized dramatically.

Generally minimum of 6-mm (1/4-in) nominal laminated glass is used for exterior windows, skylights and glazed doors. The 6-mm (1/4-in) laminated glass consists of two nominal 3-mm (1/8-in) glass panes which are bonded together with a minimum of a 0.75mm (0.030-in) polyvinyl-butyral (PVB) interlayer.
In 1909 a French artist and chemist, Édouard Bénédictus successfully used a sheet of celluloid bonded between two pieces of glass. In 1936 polyvinyl butyral (PVB) was found suitable for safety purpose as it possess many safety-desirable properties. Bulletproof glass is usually built up using several glass and plastic components with the heat-treatment method in which glass sheets are tempered at about 650 °C (1200 °F), followed by sudden chilling. This treatment increases the strength of the glass sheets approximately sixfold. When such glass does break, it shatters into blunt granules.

Laminated safety glasses are made by Polyvinyl alcohol (PVA) which is a colorless, water-soluble synthetic resin . It is different from other polymers as it is not built up in polymerization reactions from single-unit precursor molecules known as monomers. Instead, PVA is made by dissolving another polymer, polyvinyl acetate (PVAc), in an alcohol such as methanol and treating it with an alkaline catalyst such as sodium hydroxide. It results in hydrolysis, or "alcoholysis," reaction removes the acetate groups from the PVAc molecules without disrupting their long-chain structure. The chemical structure of the resulting vinyl alcohol repeating units is as follows:



On completion of the reaction the product is highly soluble in water and insoluble in practically all organic solvents. Incomplete removal of the acetate groups yields resins less soluble in water and more soluble in certain organic liquids. By reaction with butyraldehyde

(CH3CH2CH2CHO) and formaldehyde (CH2O), PVA is made into the resins polyvinyl butyral (PVB) which is a tough, clear, adhesive, and water-resistant plastic film, is widely used in laminated safety glass.

II. CONCLUSION

Large Glazing are sensitive to both accelerations and deformations and are subject to both in-plane and out-of-plane failures on occurrence of an earthquake. Glazing is particularly vulnerable in flexible structures with large inter-story drifts; large storefront windows are also vulnerable. Disaster -resistant glass should be used in all fenestration used in public buildings particularly in disaster -prone areas. It is particularly required to applications where glass can fall and potentially create a life safety issue. Consideration should also be given to using this type of glass in internal applications, particularly where large areas of glass are used, such as in malls and atriums. Blast proof, Earthquake-resistant glass, Hurricane resistant glass are also beneficial when maintaining maximum building functionality, in the aftermath of a disaster is desired.

III. REFERENCES

[1] Beason, W. Lynn and William A. Lingnell. 2002. A Thermal Stress Evaluation Procedure for Monolithic Annealed Glass, Pittsburgh: STP1434 ASTM Symposium on the Use of Glass in Buildings.

[2] Behr A Richard," Architectural Glass to Resist Seismic and Extreme Climatic Events , 2005.

[3] Collins, E. F. "Electrically Heated Glass Annealing Lehr" Journal of the American Ceramic Society, 1921, 4(5), 335-349.

[4] Haldimann, M.; Luible A.; Overend M. "Structural Use of Glass".Structural Engineering Documents, 10. IABSE, Zürich, (2008).

[5] http://023app01.guardian.com/cs/groups/sunguard/documents/native/gi_001675.pdf

[6] https://obe.com/sites/default/files/resources/11_Architectural_Glass_2014-5-20.pdf

[7] https://www.dhs.gov/sites/default/files/publications/WindowFilm-SUM_0904-508.pdf

[8] https://www.fema.gov/sites/default/files/orig/plan/prevent/earthquake/fema74/pdf/chapter6_3_1/chapter6_3_1_4.pdf

[9] http://www.homeinnovation.com/~/media/Files/ToolBase/InstallProtectiveFilmWindows.pdf

[10] https://www.britannica.com/technology/safety-glass#ref200507

[11] https://www.dhs.gov/sites/default/files/publications/WindowFilm-SUM_0904-508.pdf

[12] https://obe.com/sites/default/files/resources/11_Architectural_Glass_2014-5-20.pdf

[13] http://www.stuff.co.nz/national/86416268/Earthquake-Deaths-major-damage-after-severe-7-5-quake-hits-Hanmer-Springs-tsunami-warning-issued.

[14] http://climatepro.com/2014/08/25/window-film-earthquake-safety-know

[15]