Durability and Postbreakage Behaviour of Laminated Safety Glass

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5 = mechanical strength 6 = Sealants 7 = water/moisture

Abstract

Architect Engineering Offices are increasingly specifying laminated safety glass based on PVB not only for its well-recognized safety, security, sound and solar characteristics but also for its durability and safe postbreakage behaviour. This session will demonstrate how laminated safety glass can provide an effective response to the need to protect the people and the building envelope even in case of breakage.

Foreword

Good morning and welcome to GPD 2001 session 14: "Durability and Postbreakage Behaviour of Laminated Safety Glass".

Francis Serruys (Saint Gobain Glass - Belgium) and I (Gérard Savineau – Solutia Europe S.A.) have the great honour of chairing this session and serving as your guide on this fact-finding exploration. We term this an exploration because that's just how we want you to approach this session, with curiosity, with a sense of adventure, with a thirst for knowledge. There will be more than enough information to quench your thirst and to go beyond the fear of the common cliché or "a priori" which continue to adversely stick to laminated glass performances. Indeed based on our day-to-day business we came to the conclusion that the following questions should be addressed during this seminar.

With ever developing technology enabling laminated safety glass to be used in a much more versatile manner than even ten years ago, how much has legislation managed to keep up with product developments?

Without comprehensive standards and/or fundamental technical studies on laminated glass durability, mechanical strength and postbreakage behaviour, how much has this hampered designers and specifiers in their desire to "get it right"?

Is the lack of (current) regulation in several countries a glorious freedom, or a millstone?

Is it ever possible, or desirable, for regulations to keep pace with industry developments? – After all it's not possible to legislate for every individual building.

Are there new developments that can make the specification of laminated safety glass and glazing systems easier for all those professionally involved?

While safety is always paramount within building design and construction with associated liability implications there are also concerns over costs and aesthetics. How have these concerns been addressed in the world?

To unravel the mysteries of laminated safety glass we've asked the best experts in their respective field to disclose their most recent works and findings on this subject. Some important results will be presented by the speakers of this session 14. They have looked at how their countries – in particular within the EC and US – have come to grips with these issues and what the pros and cons of their solutions might be.

Introduction

To prevent from the dangerous effect of possible brittle fracture of a glass pane, laminated safety glass - usually based on the most common plastic interlayer PVB - is specified in lieu and place of monolithic glass and designed to meet - and even to exceed - expected performances under most adverse conditions.

However, issues relating to the durability, to the mechanical strength and to the postbreakage behaviour of laminated safety glass have been under the spotlight in recent years. Several research and testing programmes have been initiated worldwide to address these concerns. The most recent publications demonstrate that, when

properly designed and installed, laminated safety glass presents excellent performances in terms of durability and integrity – even under high temperatures, high wind loads, voluntary or accidental impacts.

Designing with laminated safety glass

Durability

A primary concern in specifying any architectural or construction product is durability and that includes laminated glass. Laminated safety glass based on PVB is proven technology that has been used effectively for over 60 years. Laminated safety glass should conform to worldwide standards (see session 31). More, PVB -such as Saflex interlayer- is formulated to withstand the rigors of exposure to natural environmental effects without change by product ageing to any key performance characteristics. Among the properties tested are mechanical performance (glass adhesion and penetration resistance), bubble formation, delamination and visual quality (colour and clarity). Testing conducted in both natural (Florida and Arizona) and accelerated (QUV and Xenon weathero-meters) exposure conditions has confirmed that by all measurement systems, when properly laminated and installed, glass laminates produced with PVB will look and perform the same after years of exposure as they did on the day of installation.

Water/Moisture and Laminated Glass

It is known that all PVB products are hydroscopic, and direct exposure of the PVB to water or to very high concentrations of moisture will result in moisture absorption and potential clouding of the PVB material called “edge blush” (whitish haze). To some extend, this moisture absorption is reversible, and the opaque clouding at the edge may reverse when the laminate edges lose moisture. However, prolonged exposition to water will result in irreversible and subsequent delamination. Usually this is seen if the glass has not been properly stored prior to installation or if water is allowed to enter the glazing frame and proper weep systems are not provided. Delamination will not occur unless there is a combination of factors acting on the glass unit. The most common factors are some combination of glass mismatch, excessive moisture, water stagnation, contamination, glass stress, and/or PVB thinning.

Although improved edge stability and long-term durability has been demonstrated with the last PVB generation, improper lamination processing or installation can affect the durability of the laminate.

Sealants and Laminated Glass

Architects, engineers and glaziers are faced with a complex decision when selecting sealants to best satisfy building project requirements. There are a number of generic type sealants, each with its proprietary base material. Within a generic type, individual sealant formulations will have varying quantities of plasticizers, solvents, curing agents and/or fillers. Each product is specifically formulated to provide properties making it suitable for some applications but not for others. Understanding these products and their inherent properties is a critical requirement in making the proper overall sealant choice. In any case, the laminators recommend that sealant compatibility be checked prior to installation.

One form of known edge effects is normally caused by intimate sealant contact with the PVB at the edge of laminated glass. This is typically seen as very small “bubble shaped let-goes” which is usually not continuous along a laminate edge. This edge effect is caused only when the sealant material comes into intimate contact with the laminate edge. This is most common in butt-glazed systems or in heals or toe bead applications. The edge effect normally does not occur when glazed in a traditional four-side support system. In a four-side support system, the sealant is typically caulked between the face of the glass and the frame; it is not intended to come in contact with the PVB interlayer at the laminated glass edge.

Mechanical Strength of Laminated Glass

The strength or structural performance of laminated glass is based on a number of factors: the type of glass employed, the thickness of each glass plies, condition of the glass surfaces and edges, unit geometry, the nature of loading, the unit thickness, the total glazing area, the aspect ratio, the number of supporting sides and the type of glazing systems. All these need to be taken into account when specifying laminated glass to meet a specific safety requirement.

Some of these parameters have been treated in Tuesday’s session 11 (Current trend for glass Exterior Glazing and Interior Use) and Wednesday’s session 13 (Safety Glass in High-Rise Curtain Wall Structure) and will be completed this afternoon by:

- Dr. Pol d’Haene (Solutia) – Structural Glazing: Creep Deformation of PVB in Architectural Application.

- Dr. Frederic A. Veer (Delft University – Structurally Efficient Glass Laminated Composite Beams
- Dr. Stephen Bennisson (Dupont De Nemours &Co Inc.) – Strength of Laminated Safety Glass
- Prof. Scott Norville (Texas Tech University) – Strain Measurements in Laminated Glass
- Dr. Yuri Rodichev (National Academy of Sciences, Ukraine - Poster session
- Dr. Frederic A. Veer (Delft) – Poster session

The main conclusion of these researches is straightforward: laminated safety glass based on PVB is at least as strong as monolithic glass under most loading and temperature conditions which occur in building applications. This should enable specifiers and Standards bodies to better understand, to predict and to treat objectively laminated safety glass

Postbreakage Safe Behaviour of Laminated Glass

Let me begin reiterating a fact we all know: all glass will break and that includes laminated glass. However the new EN/ISO Standard (EN/ISO 12543-1) draws the distinction between laminated glass and laminated safety glass. With regards to laminated safety glass, which is generally based on PVB, the interlayer has the function of holding in place the glass fragments, of limiting the size of the aperture, of providing residual strength and of reducing the risks of injury due to broken glass or falling glass. Laminated safety glass brake safely and even if broken it will stay in place in its frame or around its fixing points. This exceptional performance is proven primarily by the pendulum impact tests but also by several technical studies that will be developed this morning by:

- Mr. D. Smith (Police Scientific Development Branch) – Glazing for injury Alleviation Under Blast Loading, UK Practice
- Prof. Dr. Behr (Penn State University) – Architectural glass for Earthquake Resistant Buildings
- Dr. G. Savineau (Solutia Europe S.A.) – Laminated Architectural Glass for Effective Hurricane Protection
- Mr. Eng. C. Abou Kahlil (RFR) Ultimate Situations and Postbreakage Behaviour of laminated glass
- Dr. Scott Norville – Poster session
- Mr. Hirotsune Okubo (Asahi) – Poster session

The enhanced resistance and reliability of laminated safety glass at ultimate limit state after breakage provide a high safety level

Conclusion

Nobody can deny the fact that quality or performance deviations may occur with laminated safety glass as we any other glass or glazing systems. However, when properly designed, laminated, maintained, and installed, laminated safety glass based on PVB will provide reliable quality laminates many years of use under the most severe natural exposure conditions (high temperature, high humidity, natural disasters) or human attack (burglary, bomb blasting). Its mechanical resistance with regards to its long-term durability, integrity and safe postbreakage behaviour is unsurpassed. This being said, nothing great will be possible without the Architect's vision. The growing synergy between the Architects and the Architectural Engineering Offices and the University has resulted in breathtaking structures and buildings. We are delighted to welcome now Professor Werner Sobek who will explain its "Archi-neering" concept – a vision of architecture for the 21st Century.

Acknowledgements

Because of the limited places as conference speaker, the chairmen had to make a difficult choice in selecting among the candidates who submitted highly valuable papers. Some of these papers could be displayed only as a poster. We would like to apologize for this inconvenience but we are very grateful for the hard work and dedication demonstrated by all speakers and poster presenters. Thank you for sharing with the audience the best of your knowledge and for ensuring the success of this session 14.