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Fail-safe point fixing of structural glass. New advances

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ABSTRACT

The intrinsic brittleness of glass renders its architectural use in monolithic panels quite problematic. For this reason, glass plies are usually laminated with polymeric interlayers that can maintain coherent fragments after glass breakage, so avoiding sudden collapse (fail-safe response). However, the safety performance disappears if the connection to the rear load-bearing structure is not able to retain the panels in their place after glass breakage. To this aim, an innovative point-fixing system for frameless glass glazing has been developed, that exploits the enhanced mechanical properties of a new generation of ionoplast polymer interlayers. Bending tests on small scale glass beams have been performed at various levels of loading, temperature and aging. Laminated glass connected with the new device exhibit a noteworthy resistance and interesting post-glass-breakage performances.

1. Introduction

Glass is a brittle material *par excellence* and may be broken even by an insignificant stroke if this is applied at critical spots such as edges or corners. This intrinsic brittleness renders the structural use of glass quite problematic, because even a small accident can produce a rupture. Thus, to construct reliable structures, it is fundamental to consider, starting from the design phase, that glass breakage may occur due to an unforseen accident. In any case the event must be *not dangerous*, in the sense that the rupture of glass does not produce a sudden collapse, and the structure maintains a sufficient load bearing capacity for a time adequate to allow for replacement or evacuation (fail safe response) [1,2]. This issue is in practice much more important than the simple elastic calculation of the stress level under static design loads prior to glass fracture. The extreme accidental loading condition is that of blast mitigation, for which it is expected that glass panels assure post-breakage ductility and high pressure/impulse resistance.

To improve the post glass-breakage performance, an effective technology is to bond together two or more glass plies with polymeric sheets, which can maintain coherent fragments after glass breakage, thus avoiding sudden collapse [3,4]. This bond, that is formed with a process at high temperature and pressure (lamination), is chemical in type, being due to the union between the hydroxyl groups along the polymer and silanol groups on the glass surface. The reliability of laminates is therefore associated with the mechanical properties and resistance of the polymeric materials and the glass-interlayer adhesion. The type of interlayer is of primary importance in the uncracked stage [5], but even more so in the post-glass-breakage phase [6]. However, the safety performance inevitably disappears if the connection to the back structure is not able to retain the panels in the event of glass breakage.

There are many ways of fixing glass panels (e.g., metallic frames, structural silicone adhesives), but perhaps the most interesting one, at least from an aesthetic point of view, is the frameless glazing retention technique. This relies upon the point-fixing of the panels through metallic holders without the insertion of a contouring frame. Many different technologies are available, presenting an extremely large variability in performance associated with the modality of rupture when holders are pulled out of the laminate. In general, such attachments are quite safe provided that a metallic bolt passes through the whole glass thickness and is secured on the external surface with a knob. However, in general this is not tolerated from the point of view of aesthetics, so that possible alternatives retain either the use of stud bolts, connected with the internal glass ply only, or the direct gluing of metallic holders to the internal surface of the laminated panels. Such solutions, however, may dangerously collapse in case of glass rupture.

In this paper, a somehow innovative solution for the fail-safe point-fixation of laminated glass is presented. In this technology, the glass panel is already associated, *via* the lamination process, with metallic winglets in proximity of the borders which, in turn,

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