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Dynamic torsion tests to characterize the thermo-viscoelastic properties of polymeric interlayers for laminated glass

Laura Andreozzi [a], Silvia Briccoli Bati [b], Mario Fagone [b], Giovanna Ranocchiai [b,*], Fabio Zulli [a]

[a] Department of Physics 'Enrico Fermi', University of Pisa, largo Bruno Pontecorvo 3, 56127 Pisa, Italy
[b] Department of Civil and Environmental Engineering, University of Florence, piazza F. Brunelleschi 6, 50121 Florence, Italy

HIGHLIGHTS

- New procedure for the experimental characterization of laminated glass interlayer.
- Specimens of laminated glass made with PVB interlayer were tested in torsion.
- The method of reduced variables was applied to build up a master-curve.
- The obtained results were compared with other results from the literature.
- Case studies were numerically analysed.

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ABSTRACT

The mechanical behaviour of laminated glass is strongly influenced by the coupling capability of interlayer that, in turn, depends on the shear modulus of the polymer. An accurate determination and a comprehensive description of the thermo-viscoelastic properties of polymeric interlayer is necessary to reliably predict the laminate behaviour in structural applications, both by simplified methods in which the mechanical behaviour of the polymer is described as elastic ("secant stiffness" approaches) and by step by step analysis, in which articulated load and temperature histories are reproduced.

In this paper, a test procedure is proposed to perform dynamic tests on polymer interlayer, that revels to be more simple and more reliable than the procedures presently in use; the first results of an experimental analysis on polyvinyl butyral laminated glass specimens are reported and the generalyzed Maxwell constitutive model obtained from the tests on the material is compared with analogous models reported in the literature. Some case studies are considered in order to evaluate the influence of the assumed constitutive behaviour on the response of structural elements.

1. Introduction

Laminated glass is a composite material made of two or more glass plies among which thin layers of polymer are interposed. Several polymers are employed as interlayer: these are requested to be not crystalline, weakly cross-linked and consequently highly amorphous. These amorphous polymers are characterized by a transition, without latent heat, from hard solid (glassy) state to highly viscous liquid, passing through the rubbery temperature range in which the material becomes viscoelastic [13,44]. Among the polymer materials used as interlayer, Poly-Vinyl-Butyral (PVB) is the most widely used; at room temperature it behaves as a rubber. For this reason, in case of glass breakage, the interlayer is able to produce a bridge ligament among glass fragments: in fact, the glass fracture is not able to propagate within the soft polymer, but deviates at the interface between glass and interlayer [7,35,42,43].

As well as avoiding the fall of glass fragments in case of glass breakage, the polymeric interlayer is able to produce coupling between the glass panes even in the serviceability domain; this ability, although related to the geometric characteristics of the laminated unit and to the boundary conditions [22,23,48], strongly depends on the interlayer shear stiffness [4,11,15,16,29,47]. In fact, the polymeric interlayer, whose flexural stiffness is negligible compared to that of glass plies, provides shear connection between the glass panes. In this way, laminated glass flexural stiffness takes a value between the layered (lower bound) and monolithic (upper bound) limits. It bottoms out to the layered limit when interlayer shows no shear stiffness and the composite behaves like

* Corresponding author. Tel.: +39 0552756830; fax: +39 055212083.
E-mail address: giovanna.ranocchiai@unifi.it (G. Ranocchiai).

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