### Project sheet

<table>
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<th>Research project</th>
<th>Post-breakage behaviour of laminated safety glass in structural applications</th>
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<td><strong>Images:</strong></td>
<td><img src="image" alt="TCT-tests: cdr series (constant displacement rate)" /></td>
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<tr>
<td><strong>Keywords:</strong></td>
<td>Laminated glass, Polymer interlayer, Post-breakage behaviour, Experiment</td>
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| **Researchers involved:** | Delincé, Didier; (PhD researcher)  
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| **Time span:** | 2007 – ongoing |
| **Description:** | Laminated safety glass becomes more and more popular in structural applications, in particular regarding the important requirements on post-breakage performances, thanks to the ability of its interlayer to hold the broken glass pieces bonded together in case of breakage of the constitutive glass sheets. Although laminated safety glass is known for several decades, there is still a shortage in design rules, calculation models and corresponding characterization methods of the product properties. Consequently, in many cases extra tests are required to assess the performances for particular projects. Also, existing interlayer products made of traditional polyvinyl butyral (PVB) evolved and new ones appeared more recently, generally being stiffer. There are still many open questions related to 1) the selection of the optimal interlayer material in function of the design configuration and 2) the effective contribution of the interlayer material to the overall post-breakage performance, especially when the influence of temperature and load duration has to be considered.

This research aims at gaining a better understanding of those questions, in particular considering the SentryGlas® (SG) as interlayer material, a product known to be stiffer than conventional PVB. The more general goal is to contribute to the development of practical design methods and characterization methods of the material properties for laminated glass used in structural applications, which would account with the time-temperature dependent properties of interlayer polymer, including possible physical ageing effects.

The experimental research focuses on the different mechanisms ruling the bridging behaviour of the interlayer near the crack opening. More specifically, the combination of the tearing of the interlayer and its delamination from the glass surfaces are investigated. To do so, the influence of random breakage pattern and crack propagation in the glass sheets, including the interaction and crushing between the glass fragments, was avoided in the chosen testing configurations.

Different orientation tests were carried out the first years at the different identified scales: uniaxial tensile tests were used for the material scale (ref 2), bending tests on pre-cracked plates and beams at different temperatures were used for the element scale (refs 1 and 2), through-crack tensile tests (TCT-tests) were used for the
intermediate scale, namely for investigating the local bridging behaviour in post-fracture stage around a section where the two glass sheets are cracked (ref 3). Qualitative differences were observed between PVB and SG-laminates, which lead to choose for a deeper experimental investigation of the time-temperature dependent behaviour at the intermediate scale in the quasi-static range, by mean of TCT-tests on small pre-cracked specimens of SG-laminates. These TCT-tests are executed inside a climatic chamber with use of optical measurement methods of the deformation patterns. Two complementary loading configurations are used: tests at constant displacement rate (constant crack opening rate) and creep tests (constant force). The analysis of the tests results attempt to link the observed behaviour in TCT-tests to mechanical models of polymers accounting for the time-temperature dependent behaviour in the non-linear large strain range.

The experimental program has been set up for investigating a wide application scope with a relatively limited amount of test specimens. First part of test series at 20°C, 40°C and 60°C has been realized and is currently being completed by test series at colder temperatures. Different delamination and failure patterns are identified among the test results.

The bridging behaviour at intermediate scale will be compared to the one observed at element scale, and the test results are expected to support modeling efforts of the post-breakage behaviour using more complex material and interfacial models in finite elements formulations.

Most important publications:

DELINCÉ, Didier; CALLEWAERT, Dieter; BELIS, Jan; VAN IMPE, Rudy
Influence of Temperature on Post-Breakage Behaviour of Laminated Glass Beams : Experimental Approach

BELIS Jan; DEPAUW, Jeffrey; CALLEWAERT, Dieter; DELINCÉ, Didier; VAN IMPE, Rudy
Failure mechanisms and residual capacity of annealed glass/SGP laminated beams at room temperature
Eng Fail Anal 2009: 16(6) 1866-1875.

DELINCÉ, Didier; SONCK, Delphine; BELIS, Jan; CALLEWAERT, Dieter; VAN IMPE, Rudy
Experimental investigation of the local bridging behaviour of the interlayer in broken laminated glass

DELINCÉ, Didier; CALLEWAERT, Dieter; BELIS, Jan; VAN IMPE, Rudy
Post-breakage behaviour of laminated glass in structural applications

DELINCÉ, Didier; DEPAUW, Jeffrey; CALLEWAERT, Dieter; VANLAERE, Wesley; BELIS, Jan
Plastic deformation of polymer interlayers during post-breakage behavior of laminated glass – Partim 2: Experimental Validation