WITH A "STIFF" INTERLAYER AT ROOM TEMPERATURE

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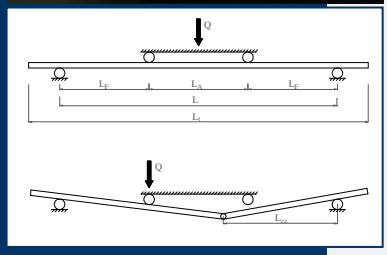
Problem statement

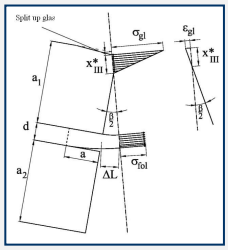
In construction industry, **laminated glass** is used more and more for transparent load-bearing building components such as glass floors, stair steps, beams, etc. The **choice of the interlayer** used to bond the different glass panes one to another is known to affect the **post-breakage behaviour**, namely the residual load bearing capacity after breakage of one or more glass sheets. However, no validated and generally accepted model currently exist to be used for practical purposes. In particular, for the design of non-standard structural applications, full-scale validation tests are often necessary, but shortages remain, among others due to the sensitivity of the post-breakage behaviour to the temperature and to the load duration. Besides the most often used interlayer polyvinyl butyral (PVB), other interlayer products are developed that could provide better post-breakage performances. One of those is the SentryGlas® Plus (SGP) of Dupont de Nemours, known to be stiffer than PVB. The current research aims to better characterize the interlayer and adhesion properties for modeling purposes of the post-breakage behaviour of laminated glass.

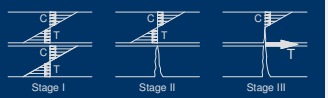
"It should not break, but what if it does ?"

Consequence versus probability of glass breakage

Preliminary test results







Four-points bending tests

The tests focus on the post-breakage behaviour in bending around the weak axis of laminated glass plates made of 2 float glass sheets of 8 mm, bonded by a single SGP-interlayer of 1.52 mm, with a length of 1100 mm and different widths.

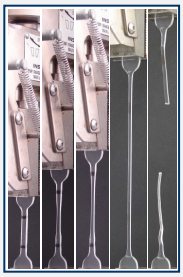
The main outcomes of those tests are the identification of important mechanisms ruling the failure behaviour, namely :

1. the **stretching of the interlayer** under tensile force, eventually up to rupture;
2. the **delamination** (debonding) between the glass pieces and the interlayer mainly under shear stress;
3. the **splitting up of the glass** in the contact zones where the glass pieces scrape against each other.

Observations for the tested four-points configurations :

- SGP-laminates show some residual resistance in post-breakage stage, contrary to PVB-laminates, which fail under the dead load of the plate
- For SGP-laminates a "yield-section" (similar to a plastic hinge) often forms naturally round a cracked zone in the width of the plate
- The failure of the SGP-laminates is often due to the tearing up (breakage) of the interlayer in the "yield-section", but the splitting up of the glass at the upper face (in compression) also plays a significant rol in the failure process

Material properties

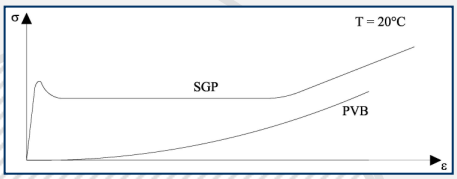


Mechanical behaviour of interlayers investigated with standard uniaxial tensile tests (ISO 527).

Limitations :
- occurence of necking neglected
- sample geometry dependency
- carried only at room temperature

Qualitative results for (nominal) stress-strain curves :
- **PVB** ($T \geq T_g$=15-18°C) : (viscoelastic) hyperelastic behaviour typical of rubber state (almost fully reversible deformations)
- **SGP** ($T < T_g$=55-60°C) : elasto-visco-plastic behaviour typical of glassy state (important plastic deformation).

(T_g: glass-transition temperature, T: room temperature)



Main outcomes :

- There is a fundamental **difference** in mechanical behaviour of SGP and PVB at room temperature, but considering the broader temperature range that can occur in practical cases (from below the glass transition temperature of PVB to above the glass transition temperature of SGP), they show a **similar** behaviour typical for polymers. Consequently, we expect to apply similar methodology for the material modelling of the interlayer.
- There is a clear **interaction and interdependence** between the 3 identified mechanisms ruling the failure : the safety of the failure of laminated glass in static conditions is dependent of the stiffness of the interlayer AND of its adhesion level to glass, and also depends on the breakage pattern of the glass.
- **No general rules** can yet be extrapolated to assess the safety (post-breakage behaviour) of laminated glass regarding to the choice of the interlayer material !

Next steps...

- Investigate - with aim to characterize - the **material modelling of the interlayer** at large strains, for quasi-static loading conditions and on a temperature range from ~-15°C to ~+65°C
- Investigate - with aim to characterize - the **adhesion properties and behaviour**, in particular in SGP-laminates, for similar conditions

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