Structural and Acoustic Performance Interlayers for Façade and Window Safety Glass

Dr. Bernd Koll
Kuraray Europe GmbH
Trosifol®

Glasstech Asia Singapore, November 23, 2017
CONTENT

Short introduction Kuraray
Laminated safety glass basics
Structural interlayer and their applications
Component test for residual load strength glazing
Component test for fall preventing glazing and summary
Acoustic glazing performance determination
Acoustic PVB interlayer and their application
Summary
Kuraray PVB Division
Your Global Partner for Laminated Safety Glass

Global Total:
• Over 800 Employees
• 2016 Revenue > $0.6 B

• 7 Manufacturing Sites
• 5 R&D Labs
• Sales Offices
Glass is a fantastic material...
...but sometimes it breaks.

Wikipedia, building in Texas after a Tornado
Laminated glass is part of the ‘safety glass’ family

Its primary use in architectural applications is to ensure safety in case that the glass lite breaks.

It is constructed using two or more lites of glass and one or more interlayers.

Standard PVB, value added (stiff) PVB and Ionoplast interlayers can be used.

PVB interlayers were originally designed for laminated automotive windshields.

Laminated Safety Glass (LSG) can use annealed, heat-strengthened or tempered glass.
Laminated safety glass - penetration resistance
Application Based Classification of Interlayers

1. SAFETY
2. SECURITY
3. STRUCTURAL
4. ACOUSTICS
5. DECORATIVE
6. UV CONTROL
**PVB interlayer**

PVB is a resin normally used for applications that require binding, optical clarity, adhesion to glass surfaces, toughness and flexibility.

Trosifol® is an interlayer in laminated safety glass for architectural purposes and automotive windscreens.

PVB interlayers are tough and ductile, so brittle cracks will not pass from one side of the laminate to the other.

Usage: fully-framed windows, insulated glazing units and glass applications, where the edges of the glass are protected

Other types of PVB interlayer: Acoustic PVB and Stiff PVB

---

**Ionoplast interlayer**

SentryGlas®, a thermoplastic Ionoplast, is stronger and stiffer than conventional PVB

Market launch of SentryGlas® interlayer was in 1998 by DuPont company.

Developed specifically for construction applications, with the focus on improving the structural properties and weather resistance of the laminated glass, rather than PVB.

SentryGlas® Ionoplast interlayer is tougher, 100 times stiffer than PVB and performs better over a wider temperature range.
Trosifol® Standard PVB

**Trosifol® Clear:**

- Tough, resilient safety interlayers used in laminated architectural safety glass
- Several safety advantages by retaining dangerous shards in case of glass breakage
- Used in all basic Safety & Security laminated glasses

**Trosifol® UltraClear:**

- Highly transparent PVB film with superior glass adhesion
- Especially recommended for laminated safety glass consisting of fully tempered and heat-strengthened glass.
- Long-term stability
- Standard size or Jumbo size up to 3210 mm
- Lowest color of all globally available PVB interlayers especially in low-iron based laminated safety glass
What is Structural Glazing?

Examples of Structural Glazing

- Balustrades
- Overhead Canopies
- Floors
- Stairs
- Large Windows
- Curtain Walls
- Façade Glazing
SentryGlas® interlayer and Trosifol® ES interlayer are both high modulus stiff interlayers which provide a range of performance to meet all of your structural glazing demands.
Today: buildings are getting taller
Today: buildings are getting more complex
TROSIFOL® STRUCTURAL COMPONENT TEST

- SentryGlas®
- Trosifol® Extra Stiff
Post Breakage Behaviour

- 2-sides supported, without fixation, span ~ 1,10 m

Laminated glass with 2 x 6mm fully tempered glass and the following interlayers:
- TROSIFOL BG R20 1,52mm & 0,76mm
- TROSIFOL ES 1,52mm & 0,76mm

Load 20kg (=50kg/m²)
Post Breakage Behaviour (Trosifol® Standard PVB)
Post Breakage Behaviour (Trosifol® Extra Stiff)
Post Breakage Behaviour
balustrade (vertical) glazing

- 1-side supported, clamped, “free” height ~0.9 m (Standard PVB)
Post Breakage Behaviour
balustrade (vertical) glazing

- 1-side supported, clamped, “free” height ~0,9 m (Extra Stiff PVB)
Fall preventing LSG component test
DIN 18008 Test Setup Details

➢ Interlayer Test Candidates
  - 0.89 and 1.52 mm ionoplast Interlayer
  - 1.52 mm Standard (BG) PVB Interlayer
  - 1.52 mm Extra Stiff (ES) PVB Interlayer

➢ Other Details
  - 6mm TG + Interlayer + 6 mm TG
  - Temperature Controlled Chamber
  - Samples conditioned for 3hrs before test
  - Glass Broken with Centre Punch
  - 50 Kg Twin Tyre Impactor (EN 12600)
  - Second layer broken with centre punch
  - Applied 100 Kg, 30 minutes wait
  - Load ramped up in increments of 100 kg up to 400 kg in 15 min. intervals to know ultimate loads.
Post Breakage Performance

Performance at +21° C / 70°F

Standard PVB 1.52 mm  Trosifol® ES 1.52 mm  SentryGlas® 0.89 mm

Only SentryGlas® (0.89 mm and 1.52mm) and Trosifol® ES sustained loads of 400 Kg. Standard PVB could not sustain a 100 kg load!
Post Breakage Performance

Performance at +50°C / 131°F

Standard PVB 1.52 mm

Trosifol® ES 1.52 mm laminate

SentryGlas® ionoplast 0.89 mm

Only SentryGlas® Ionoplast (0.89 mm or 1.52 mm) could sustain a 100 Kg load for 30 minutes!
Sub Zero Temp. Scenario  
(-20° C)

1.52 mm PVB

Room Temp. Scenario  
(21° C)

1.52 mm PVB

Elevated Temp. Scenario  
(50° C)

1.52 mm Ionomer

1.52 mm Stiff PVB
## Interlayer performance comparison

<table>
<thead>
<tr>
<th>Properties</th>
<th>Standard PVB</th>
<th>Other Stiff PVB</th>
<th>Trosifol® Extra Stiff</th>
<th>SentryGlas® Ionoplast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Breakage Performance at room temperature (21°C/70°F)</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
</tr>
<tr>
<td>Post Breakage Performance at elevated temperature (50°C/122°F)</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
</tr>
<tr>
<td>Structural Properties/ Coupling effect at room temperature (21°C/70°F)</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
</tr>
<tr>
<td>Structural Properties/ Coupling effect at elevated temperature (50°C/122°F)</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
</tr>
<tr>
<td>Clarity</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
</tr>
<tr>
<td>Sealant compatibility/ Edge stability</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
<td>![Icon]</td>
</tr>
</tbody>
</table>

* Not valid for Trosifol® UltraClear film
Free Standing Glass Balustrades

- Glass panel acts as a FULL structural member
- Not allowed by BCA in Singapore the interest of public safety
Post Breakage Performance

Glazing Retention (ASTM E 2353–06)
“The property of maintaining the glass or glazing material, post breakage, in a system, such that the glass must be held in the framing system with no opening sufficient to pass a 75 mm Dia. Solid steel sphere through the system using a horizontally applied force of 18 N”

BCA Regulations in Singapore on “Free Standing” Balustrades

1. Pre Breakage
- 1.5 KN/m Design Load (No breakage)
- 3.0 KN/m Proof Load (No breakage)

2. Post Breakage
- 1.5 KN/m, Deflection not to exceed 150 mm
Balustrade Testing with Q Railings India
Load Application in Post Breakage Condition

- Applied 1.5 KN/m
- 1 minute hold time
- Record deflection after 1 minute
Shanghai Tower - 632 m height

External-Skin Façade Construction
Glazing Construction:
- 2 x 12mm Low Iron Glass / 1.52mm SentryGlas®
- Linear fixation

Benefits with SentryGlas®
✓ Wider panels
✓ Higher wind-load resistance
✓ Clarity with low-iron glass
✓ Compatibility with ceramic color print
SOWAAH Square, Abu Dhabi

LSG external skin facade elements with SentryGlas® Ionoplast interlayer

Glazing criterias:
- Excellent open-edge stability
- High residual load strength at high temperatures
- High temperature (change) resistance at extreme climates
- Compatibility to ceramic printing
Glass Bridge Zhang Jia Jie, China

Architect: HaimDotan
Engineer: He’nan Chengjian Decoration Engineer Co., Ltd
Laminator: He’nan Fuxin Glass Co., Ltd
Interlayer: SentryGlas®
- Trosifol® SC Monolayer
- Trosifol® SC Multilayer
Urbanisation forces people to live close together. Noise pollution causes serious health issue and reduces the concentration of human beings.
What is Sound?

Sound spreads out in a similar manner to waves in water

Height of the wave
= volume of the sound

Number of waves in time
= frequency of the sound
What does acoustic insulation mean?

„Heights of the waves“ must be reduced quickly!
Noise Sources and Perception

0-2 dB imperceptible
3-5 dB barely perceptible
6-10 dB clearly perceptible
11-20 dB big and significant
Measurement of acoustic insulation
Glazing Standard acc. to EN 717

Double chamber with glazing window for sound proof determination
Acoustic glazing performance

Acoustic performance levels are expressed using index \( R_w \) (\( C; \ C_{tr} \)), expressed in decibels, as follows:

- \( R_w \) is used to categorize glazing products and compare them to each other. Values are given in dB (decibel) according to standard EN 20140-3 (USA/CND : STC ratings according to standard ASTM E 90, E 413)

- For noise containing predominantly high- and medium-range frequencies, sound insulating level is determined using the index \( R_w + C \) (e.g. noise from trains, schools, motorways, living areas etc.)

- For noise containing predominantly low- and medium-range frequencies, sound insulating level is determined using the index \( R_w + C_{tr} \) (e.g. noise from airports, traffic/trucks, disco music etc.)
Measurement Sound Insulation

- Determination of Acoustical Rating Rw

![Graph showing measurement sound insulation with reference curve and shifted reference curve for 0.76 mm TROSIFOL Acoustic (37dB).]
Influence factors for sound damping

- Comparison laminated vs. monolithic glass

![Graph showing sound damping vs. frequency for different materials.]

- 8 mm Monolithic (34dB)
- 0.76 mm TROSIFOL BG (35dB)
- 0.76 mm TROSIFOL Acoustic (37dB)
Application based classification of AC glazing

Glazing Acoustic performance

- **Rw < 34 dB**
  - Single Monolithic Glass:
    - 3 mm - 28 dB
    - 4 mm - 29 dB
    - 5 mm - 30 dB
    - 6 mm - 31 dB
    - 8 mm - 32 dB
    - 10 mm - 33 dB

- **Rw > 34 dB**
  - Laminated (IG) glazing elements with:
    - Standard PVB (Trosifol® Clear, UltraClear)
    - Sound Control PVB (Trosifol® SC, SC+)
# Trosifol® Sound Control PVB

<table>
<thead>
<tr>
<th></th>
<th>Trosifol® PVB</th>
<th>Multilayer</th>
<th>Monolayer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acoustic performance</strong></td>
<td>some</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td><strong>Optic</strong></td>
<td>Great Good</td>
<td>Risk for Orange peel</td>
<td>Great Good</td>
</tr>
<tr>
<td><strong>Films’ Combination</strong></td>
<td>Yes, standard and color</td>
<td>Yes, standard and color</td>
<td>No</td>
</tr>
<tr>
<td><strong>Safety class EN 356 P2A</strong></td>
<td>yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Yellowness Index</strong></td>
<td>Low for UltraClear</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
How can I achieve noise insulation with monolithic glass, reduce weight of the construction and save costs?

Monolithic glass

0.76 mm, 11 mm thick

$L_w = 33$ dB

Laminated glass

0.76 mm, 7 mm thick

5 mm

5 mm

$L_w = 35$ dB

Acoustic laminated glass

0.76 mm, 7 mm thick

3 mm

3 mm

$L_w = 36$ dB

Trosifol® Clear

Trosifol® Sound Control
How can I achieve noise insulation with insulating glass units reduce weight of the construction and save costs?

Laminated glass 0,76 mm

Rw = 38 dB

Trosifol® Clear

Acoustic laminated glass 0,76 mm (2mm thinner!)

Rw = 40 dB

Trosifol® Sound Control
Acoustic Performance Estimation Guideline
Monolithic ⇒ Acoustic PVB Laminate

<table>
<thead>
<tr>
<th>Interlayer</th>
<th>Rw (C,Ctr) [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annealed glass 10mm</td>
<td>33 (-1/-2)</td>
</tr>
<tr>
<td>SentryGlas 0,89mm</td>
<td>35 (-2/-3)</td>
</tr>
<tr>
<td>TROSIFOL ES 0,76mm</td>
<td>35 (-1/-3)</td>
</tr>
<tr>
<td>TROSIFOL BG 0,76mm</td>
<td>35 (0/-2)</td>
</tr>
<tr>
<td>TROSIFOL SC+ 0,76mm</td>
<td>38 (-1/-3)</td>
</tr>
<tr>
<td>TROSIFOL SC 0,76mm</td>
<td>38 (0/-2)</td>
</tr>
</tbody>
</table>

Thumb rule
Monolithic ⇒ Laminate with acoustic PVB: +5 dB

+ 4-5 dB
# Acoustic Performance Estimation Guideline

## Summary for laminates

<table>
<thead>
<tr>
<th>Mono 8mm vs. Laminate 44.2</th>
<th>Mono 10mm vs. Laminate 55.2</th>
<th>Mono 12mm vs. Laminate 66.2</th>
<th>Mono 15mm vs. Laminate 88.2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interlayer</strong></td>
<td><strong>Rw (C,Ctr) [dB]</strong></td>
<td><strong>Interlayer</strong></td>
<td><strong>Rw (C,Ctr) [dB]</strong></td>
</tr>
<tr>
<td>Annealed glass 8mm</td>
<td>33 (-1/-2)</td>
<td>Annealed glass 10mm</td>
<td>33 (-1/-2)</td>
</tr>
<tr>
<td>TROSIFOL BG 0,76mm</td>
<td>35,2 (-1/-3)</td>
<td>SentryGlas 0,89mm</td>
<td>35,1 (-2/-3)</td>
</tr>
<tr>
<td>TROSIFOL SC+ 0,76mm</td>
<td>37 (0/-2)</td>
<td>TROSIFOL ES 0,76mm</td>
<td>35,1 (-1/-3)</td>
</tr>
<tr>
<td>TROSIFOL SC 0,76mm</td>
<td>37 (-1/-3)</td>
<td>TROSIFOL BG 0,76mm</td>
<td>37 (-1/-3)</td>
</tr>
<tr>
<td>TROSIFOL SC+ 0,76mm</td>
<td>38 (-1/-3)</td>
<td>TROSIFOL SC+ 0,76mm</td>
<td>40 (-1/-3)</td>
</tr>
<tr>
<td>TROSIFOL SC 0,76mm</td>
<td>38 (0/-2)</td>
<td>TROSIFOL SC 0,76mm</td>
<td>39 (0/-2)</td>
</tr>
</tbody>
</table>

## Thumb rules

- **doubling the mass + 3dB**
- **Monolithic ⇒ structural interlayer laminate: + 0 dB**
- **Monolithic ⇒ standard PVB laminate: + 1 dB**
- **Monolithic ⇒ acoustic PVB laminate: + 4-5 dB**
- **Standard PVB Laminate ⇒ acoustic PVB laminate: + 3 dB**
- **Laminate ⇒ PVB thickness +0 dB**
- **Laminate ⇒ Asymmetry/Symmetry +0 dB**
Noise Damping of Acoustic Laminated Glass

1. LSG containing TROSIFOL® SOUND CONTROL film
2. Double glazing containing TROSIFOL® SOUND CONTROL film
3. Triple glazing containing TROSIFOL® SOUND CONTROL film

1. $R_w = 35-43 \text{ dB}$
2. $R_w = 36-52 \text{ dB}$
3. $R_w = 40-52 \text{ dB}$

[Diagram showing the noise damping levels for different glazing configurations]
Trosifol® Sound Control

New York Pierhouse, Trosifol Sound Control

Town Hall Troisdorf, Trosifol Sound Control

Sky Tower Poland, Trosifol Sound Control
How can Trosifol® support you

<table>
<thead>
<tr>
<th>Consultancy Services</th>
<th>Laminated Glass Expertise</th>
<th>Online tools</th>
</tr>
</thead>
</table>
| ▪ Finite Element Analysis (SJ Mepla, SG Calc...)  
  – Effective thickness method (ASTM E1300-09)  
  – Thermal breakage  
| ▪ Interlayer advice and selection  
| ▪ Kuraray Network of Laminators : glass fabricators capabilities  
| ▪ Glass and Lamination training  
| ▪ Building Codes monitoring  
| ▪ Technical support and standard tests (Adhesion...)  
| ▪ New Applications development and tests  
| ▪ Global technical support team with 3 technical Labs in Korea, Germany and USA  
| ▪ Online Strength calculator  
| ▪ Technical Design Guide for Structural engineers  
  – list of Compatible Sealants  
| ▪ Library of technical papers and test reports  
| ▪ List of Glazing systems tested for hurricane glazing  
| ▪ Laminated Glass News Newsletter  
| ▪ Windows Glass design  
| ▪ Bomb blast performance  
  – Wingard suite of tools (ARA)  
| ▪ Thermal and energy performance  
  – Lawrence-Berkeley National Labs (LBNL), Optics, Window, Therm  
| ▪ Test design support  
  – Miami Dade County...  

November 29, 2017  
Asia Facade& Glass Conference 2017
Asia Pacific Team introduction - geographical split

- Collectively covering all major cities in the region.
- International ADEC hub cities in Asia-Pacific are; Shanghai, Hong Kong, Singapore
Thank you very much for your kind attention!