Combining glass and sandwich panels for a novel façade generation

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building envelopes and structures

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introduction
a novel facade generation

iconic skin:
- glass sandwich panel GSP
introduction

building near Munich:
sandwich / glass / adhesive
bonding
temperatures
testing
approvals (Germany)
sandwich / glass / adhesive

elevation through GSP element
### sandwich / glass / adhesive properties

<table>
<thead>
<tr>
<th>Physical property</th>
<th>Typical values for sandwich-panels with a core of...</th>
<th>Approximate influence of bonded glass panel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>...polyurethane</td>
<td>...mineral wool</td>
</tr>
<tr>
<td>U-value</td>
<td>0.1 – 0.35 W/(m²K)</td>
<td>0.2 – 0.35 W/(m²K)</td>
</tr>
<tr>
<td>Weight</td>
<td>10 – 20 kg/m²</td>
<td>30 – 40 kg/m²</td>
</tr>
<tr>
<td>Sound insulation</td>
<td>~ 25 db</td>
<td>~ 31 db</td>
</tr>
<tr>
<td>Fire resistance</td>
<td>Euro class B-s2 /-s3</td>
<td>Euro class A2-s1</td>
</tr>
</tbody>
</table>

\[ D = 80 – 200\text{mm} \]
sandwich / glass / adhesive

main focus:
PU panels
(e.g., Brucha FP-P)
also:
mineral wool

width 900/1000 mm
thickness 80 – 200 mm
metal skins steel / steel
sandwich / glass / adhesive

- 6 mm thick
- toughened glass
- printed on inner side
- acc. to EN 1863-2 or German approval (e.g. Z-70.4-215 „sedak TVG“)
- strength \( f_k = 70 \text{ Mpa} \)
- breakage pattern similar to annealed glass
sandwich / glass / adhesive

ceramical printing glass

- digital print, or
- roller-coater print
- translucent or opaque
- colour transitions
- photos
- resolution 720 dpi
- coating 6 – 80 µm
sandwich / glass / adhesive bonding temperatures testing approvals (Germany)
• vertical adhesive joints: 10 mm wide, 8 mm deep
• surface 1: printed glass
• surface 2: sandwich metal skin
  - stainless steel, or
  - coil-coated steel
• max $T = 80^\circ C$
• tests: $T$, UV, RH, NaCl, SO$_2$, ...

• stresses: $\sigma_{\text{Wind}} ; \tau_{\text{Temp}} ; \tau_\infty$
load transfer from glass into sandwich

- load transfer tension and shear at -20°C / 23°C / 80°C
- Example: tension test, $A = 120 \times 10 = 1200 \text{ mm}^2$, $e = 8 \text{ mm}$
• load transfer tension and shear at -20°C / 23°C / 80°C
• shear failure: 100% cohesive
sandwich / glass / adhesive bonding

temperatures

testing

approvals (Germany)
temperatures tests in Germany and Saudi-Arabia

- natural environment in Germany and Saudi-Arabia
- variation of colour, orientation and inclination
- also: artificial lightning and
- theoretical studies

Pos #1 – glass outside
Pos #2 – glass inside
Pos #3 – metal skin
temperatures measurements in Germany (grey surface, south, vertical, March 2015)

Die Messungen fanden im Zeitraum vom 07-09. März 2015 statt.

<table>
<thead>
<tr>
<th>Messstelle</th>
<th>Typ; Position</th>
<th>Einheit</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Sternpyranometer</td>
<td>W/m²</td>
<td>728</td>
</tr>
<tr>
<td>0.1</td>
<td>Glastemperatur; außen</td>
<td>ºC</td>
<td>64,4</td>
</tr>
<tr>
<td>0.2</td>
<td>Glastemperatur;innen</td>
<td>ºC</td>
<td>72,0</td>
</tr>
<tr>
<td>0.3</td>
<td>Paneltemperatur; außen</td>
<td>ºC</td>
<td>71,7</td>
</tr>
</tbody>
</table>
sandwich / glass / adhesive bonding temperatures testing approvals (Germany)
bending tests (EN 14509)
testing bending of GSP

sagging and hogging moment (glass in compression or tension zone)
testing
photos LSL, Munich

iconic skin
testing
load distribution sandwich - glass

load distribution:

- PUR D100: $EI \approx 5700 \text{ MNcm}^2$
- TVG 6mm: $EI \approx 12.6 \text{ MNcm}^2$

iconic skin
testing structural performance

**ultimate capacity $M_u$**

<table>
<thead>
<tr>
<th></th>
<th>only sandwich</th>
<th>GSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crippling</td>
<td>10 kNm</td>
<td>10.1 kNm</td>
</tr>
<tr>
<td>Metal skin</td>
<td>Shear failure</td>
<td>Core</td>
</tr>
</tbody>
</table>

L = 4 m, D100 PUR sandwich 0.63/0.55 mm
**ultimate capacity** $M_u$

<table>
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<tr>
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<th>GSP</th>
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<tr>
<td>9.5 kNm</td>
<td>12.2 kNm</td>
</tr>
<tr>
<td>crippling metal skin</td>
<td>shear failure core</td>
</tr>
<tr>
<td>7.7 kNm</td>
<td>6.6 kNm</td>
</tr>
<tr>
<td>crippling metal skin</td>
<td></td>
</tr>
</tbody>
</table>

$L = 2.5$ m, D100 PUR sandwich 0.63/0.55 mm
testing

glass performance

heat strengthened   fully tempered

iconic skin
sandwich / glass / adhesive bonding

temperatures

testing

approvals (Germany)
• two “ZiE” (single case approval) for GSP-PUR100, vertical:
  - 10,50 m elements (three-span)
  - 4 m elements (one-span)

• application for “abZ” (national technical approval)
  - GSP-PUR 80 – 200 mm, vertical
  - max. 8 m span
  - challenges:
    > structural performance GSP
    > fixation
    > bonding
    > fire resistance classification
handling and installation
GSP – installation
GSP – installation
GSP – installation