Design by Testing / Calculation of Sandwich Panels

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Introduction

Design by Testing = EASIE Workpackage No 2

WP-Leader: David Izabel, SNPPA

Experimental Programme:
Thermal Tests and 2 Span Panels

Evaluation with Design by Testing (SNPPA)

Validation with Design by Calculation (iS-mainz)

Intention:
Reach a comparable predictable Safety Level !!
Design by Calculation of Sandwich Elements means:

1. Get mechanical properties by different tests
2. Statistical evaluation
3. Calculation of stresses and deflections
4. Superposition of all relevant load cases
5. Identify the decisive limit state for each span
6. Result: span table for distributed load
Design by Calculation

Step 1: Get mechanical properties

Needed for calculation:

- Yield strength of the faces
- Shear strength of core material
- Compressive strength of core material
- Wrinkling stress for positive and negative bending at normal (20°C) and elevated (80°C) temperature for midspan and over central support

- Design thickness of the faces
- Shear modulus of core material
- Creep coefficient of core material
Step 1: Get mechanical properties

Seems to be complicate but:

- For an efficient calculation you need limit values for every possible failure mode

- You can reduce the number of necessary tests by defining a product family!

- You get these properties by doing the IT-Tests for your CE Marking Symbol anyway! (see Table 4 EN 14509)

- Most of these tests are small scale tests and easy to conduct
Step 1: Get mechanical properties

Example: Roof Element with

- Overall Depth: $D = 70, 80, 100, 120, 140$ and $160$ mm
- Outer face sheet: $t = 0.75$ mm, $0.60$ mm or $0.50$ mm
- Inner face sheet: $t = 0.60$ mm, $50$ mm or $0.40$ mm
- Colour Group: I, II, III

$= 6 \times 3 \times 3 \times 3 = 162$ different Elements
Step 1 – Mechanical Properties:

Necessary Tests for 162 different Elements:

\[(D_{\text{max}}, D_{\text{min}}, D_{\text{med}}) \times \text{(pos/neg)} \times n = 3 \times 2 \times 3 = 18 \text{ Tests}\]

simply supported panel, covers the whole family
+ **small** scale tests
Conclusion for Step 1 – Mechanical Properties:

Minimize number of necessary panel tests by

Defining a product-family and

Interpolation of $\sigma_{w,t2} = f \times \sigma_{w,t1}$ for variable $t_i$

\[
f \text{ is the reduction factor } = \frac{A_1 \times \sqrt[3]{I_2}}{A_2 \times \sqrt[3]{I_1}}
\]

...at mid span

...at intermediate support
Conclusion for Step 1 – Mechanical Properties:

Reduction in wrinkling stress caused by higher temperature:

Avoid thermal panel tests by

Reduction factor \( k_1 = \left( \frac{E_{Cr,+80^\circ C}}{E_{Cr,+20^\circ C}} \right)^{\frac{2}{3}} \) for variable Temperature

…at mid span

…at intermediate support
Design by Calculation

Step 2: Statistical Evaluation

- No difference between Design by Testing / Calculation
- Valid for each kind of building material

- You get

  Characteristic value $x_p$
  Mean value $x$
  Material safety factor $\gamma_m$

(according to ISO 12491 and EN 1990)

Correction Factor: $\Rightarrow$ David

$$R_{adj,i} = R_{obs,i} \left( \frac{f_y}{f_{y,obs}} \right)^a \left( \frac{t}{t_{obs}} \right)^\beta$$
Design by Calculation

Step 2: Statistical Evaluation

Please note: Increase number of tests = Better values $x_p$ and $\gamma_m$

Advantage of Design by Calculation:
Tests acc. to table 4 = ITT

= Independent test series for each mechanical property

= Deviations will be detected immediately (FPC)
Step 3: Calculation of Stresses and Deflections

For simple cases: 1 span, 2 span, 3 span, flat or profiled
Design by Calculation

Step 3: Calculation of Stresses and Deflections

Use ECCS equations:

Determination of the internal force variable and stresses of Sandwichpanels according to ECCS

Requirements

- profiled and/or flat respectively lightly profiled facing on one side
- single span or two spans with equal span width
- notations according to ECCS Recommendations for Sandwichpanels
- Report from 23.10.2009
- width for calculation 0 – 1 m = 1000 mm
- analytic (exact) solution according Stamm/Witte

Sprache / language

Cross sectional and characteristic values

Name of panel
Thermal

D = 84.5 mm

Nominal thickness of outer face

\( t_1 = 0.50 \) mm

Nominal thickness of inner face

\( t_2 = 0.04 \) mm

Thickness of zinc

\( t_{zinc} \) mm

Net thickness of faces

<table>
<thead>
<tr>
<th>Cross-sectional area of faces</th>
<th>( A )</th>
<th>(index 1)</th>
<th>(index 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moment of inertia of faces</td>
<td>( I )</td>
<td>mm²</td>
<td>mm²</td>
</tr>
<tr>
<td>Upper edge distance</td>
<td>( d_{u} )</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>Lower edge distance</td>
<td>( d_{l} )</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>E-Modul</td>
<td>( E )</td>
<td>N/mm²</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Thermal expansion coefficient</td>
<td>( \alpha )</td>
<td>1/°C</td>
<td>1/°C</td>
</tr>
<tr>
<td>Shear modulus</td>
<td>( G )</td>
<td>N/mm²</td>
<td>N/mm²</td>
</tr>
</tbody>
</table>

Excel-sheet from iS-mainz:

- Free download
- Easy to use
- Independent results for each load case
Step 3: Calculation of Stresses and Deflections

Results:

Deflection in mid span
Shear stress of the core
Stress in flat or profiled face
pressure at support

for

Distributed load (self-weight, snow, wind)
Temperature
Creeping
Step 4: Superposition of all relevant load cases

You can check > 20 combinations for a simple 2 span element…….

but

• Possible load combinations (small extract)
  \[ g + s \]
  \[ g + s + \Delta T_{\text{winter with snow}} \text{(20 K)} \]
  \[ g + \Delta T_{\text{winter}} \text{(40 K)} \]
  \[ g + s + \Delta g_{e} + \Delta s_{o} \]
  \[ g + s + \Delta g_{e} + \Delta s_{o} + \Delta T_{\text{winter with snow}} \text{(20K)} \]
  \[ g + w \]
  \[ g + w + \Delta T_{\text{winter}} \text{(40 K)} \]
  \[ g + w + \Delta T_{\text{summer}} \text{(55 K)} \]
Step 4: Superposition of all relevant load cases

You may check more than 20 combinations for a simple 2 span element…….

but

- Possible load combinations (small extract)
  - \( g + s \)
  - \( g + s + \Delta T_{\text{winter with snow}}(20 \text{ K}) \)
  - \( g + \Delta T_{\text{winter}}(40 \text{ K}) \)
  - \( g + s + \Delta g_{\phi} + \Delta s_{\phi} \)
  - \( g + s + \Delta g_{\phi} + \Delta s_{\phi} + \Delta T_{\text{winter with snow}}(20 \text{ K}) \)
  - \( g + w \)
  - \( g + w + \Delta T_{\text{winter}}(40 \text{ K}) \)
  - \( g + w + \Delta T_{\text{summer}}(55 \text{ K}) \)

With some experience the decisive load combinations will be evident quickly.
Design by Calculation

Step 5: Identify the decisive Limit State for each span

- Yield or wrinkling strength of face
- Shear strength of core
- Compressive strength of core
- Deflection incl. creeping
Step 6: Span Table for distributed load

Example:

Span Table for the Tests of WP 2

- 60 mm Roof element
- 2 span
Design by Calculation

Step 6: Span Table for distributed load

<table>
<thead>
<tr>
<th>span [m]</th>
<th>L/200 [kN/m²]</th>
<th>cs SLS [kN/m²]</th>
<th>fv SLS [kN/m²]</th>
<th>fy SLS [kN/m²]</th>
<th>cs ULS [kN/m²]</th>
<th>fv ULS [kN/m²]</th>
<th>fy ULS [kN/m²]</th>
<th>e/e_{obs}</th>
<th>k</th>
<th>relevant load</th>
<th>relevant criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,00</td>
<td>5,95</td>
<td>3,34</td>
<td>13,90</td>
<td>2,62</td>
<td>2,26</td>
<td>7,65</td>
<td>2,85</td>
<td>0,97</td>
<td>0,85</td>
<td>1,85</td>
<td>cs ULS</td>
</tr>
<tr>
<td>2,50</td>
<td>3,78</td>
<td>2,66</td>
<td>9,07</td>
<td>1,77</td>
<td>1,79</td>
<td>5,59</td>
<td>2,15</td>
<td>0,97</td>
<td>0,85</td>
<td>1,45</td>
<td>fy SLS</td>
</tr>
<tr>
<td>3,00</td>
<td>2,62</td>
<td>2,20</td>
<td>6,61</td>
<td>1,29</td>
<td>1,47</td>
<td>4,38</td>
<td>1,69</td>
<td>0,97</td>
<td>0,85</td>
<td>1,06</td>
<td>fy SLS</td>
</tr>
<tr>
<td>3,50</td>
<td>1,90</td>
<td>1,87</td>
<td>5,12</td>
<td>0,98</td>
<td>1,25</td>
<td>3,62</td>
<td>1,36</td>
<td>0,97</td>
<td>0,85</td>
<td>0,80</td>
<td>fy SLS</td>
</tr>
<tr>
<td>4,00</td>
<td>1,43</td>
<td>1,63</td>
<td>4,02</td>
<td>0,77</td>
<td>1,08</td>
<td>3,06</td>
<td>1,11</td>
<td>0,97</td>
<td>0,85</td>
<td>0,63</td>
<td>fy SLS</td>
</tr>
<tr>
<td>4,50</td>
<td>1,10</td>
<td>1,44</td>
<td>3,28</td>
<td>0,62</td>
<td>0,95</td>
<td>2,65</td>
<td>0,92</td>
<td>0,97</td>
<td>0,85</td>
<td>0,51</td>
<td>fy SLS</td>
</tr>
<tr>
<td>5,00</td>
<td>0,85</td>
<td>1,28</td>
<td>2,76</td>
<td>0,51</td>
<td>0,85</td>
<td>2,33</td>
<td>0,77</td>
<td>0,97</td>
<td>0,85</td>
<td>0,42</td>
<td>fy SLS</td>
</tr>
</tbody>
</table>

1 relevant load = min value [SLS & ULS] x e/e_{obs} x k
Design by Calculation

Conclusion:

Design by calculation means

- Minimize number of tests
- No thermal panel tests required
- Can be done with an excel sheet for 1, 2 or 3 span
- For each span, each section you get the effect of each load case!
Conclusion:

Design by calculation means also

- Mechanical properties can be used to calculate more complicated structures by means of special software
Design by Calculation

For effects like this:
Please pay attention to David Izabel
Design by Testing