Design by Testing / Calculation of Sandwich Panels

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iS-mainz

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

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

Design by Calculation

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

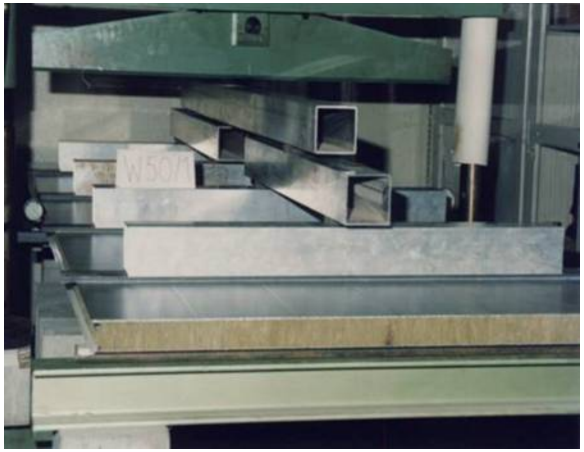
= 6 x 3 x 3 x 3 = 162 different Elements

Step 1 – Mechanical Properties:

Necessary Tests for 162 different Elements:

$(D_{max}, D_{min}, D_{med})$ x (pos/neg) x n = 3 x 2 x 3 = 18 Tests

simply supported panel, covers the whole family
+ **<u>small</u>** scale tests



Design by Calculation

Conclusion for Step 1 – Mechanical Properties:

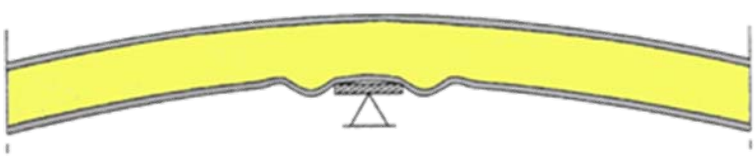
Minimize number of necessary panel tests by

Defining a product-family and

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

f 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

Design by Calculation

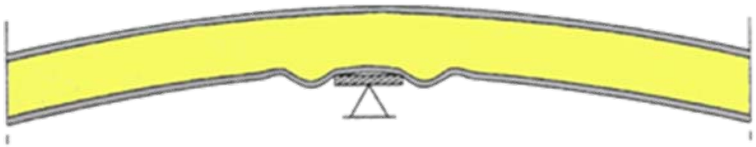
Conclusion for Step 1 – Mechanical Properties:

Reduction in wrinkling stress caused by higher temperature:

Avoid thermal panel tests by

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

…at mid span



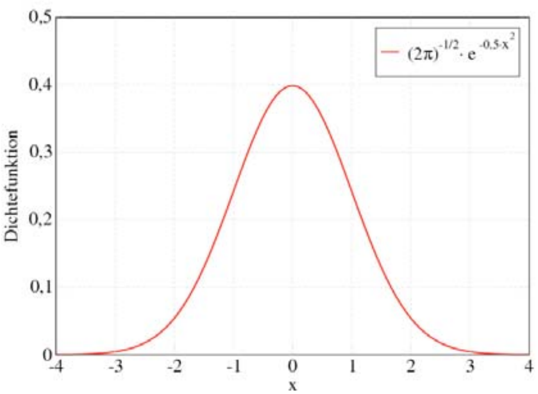
…at intermediate support

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 γ_m
(according to ISO 12491 and EN 1990)

Correction Factor: ➔ David

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

Design by Calculation

Step 2: Statistical Evaluation

Please note: Increase number of tests = Better values x_p and γ_m

Advantage of Design by Calculation:

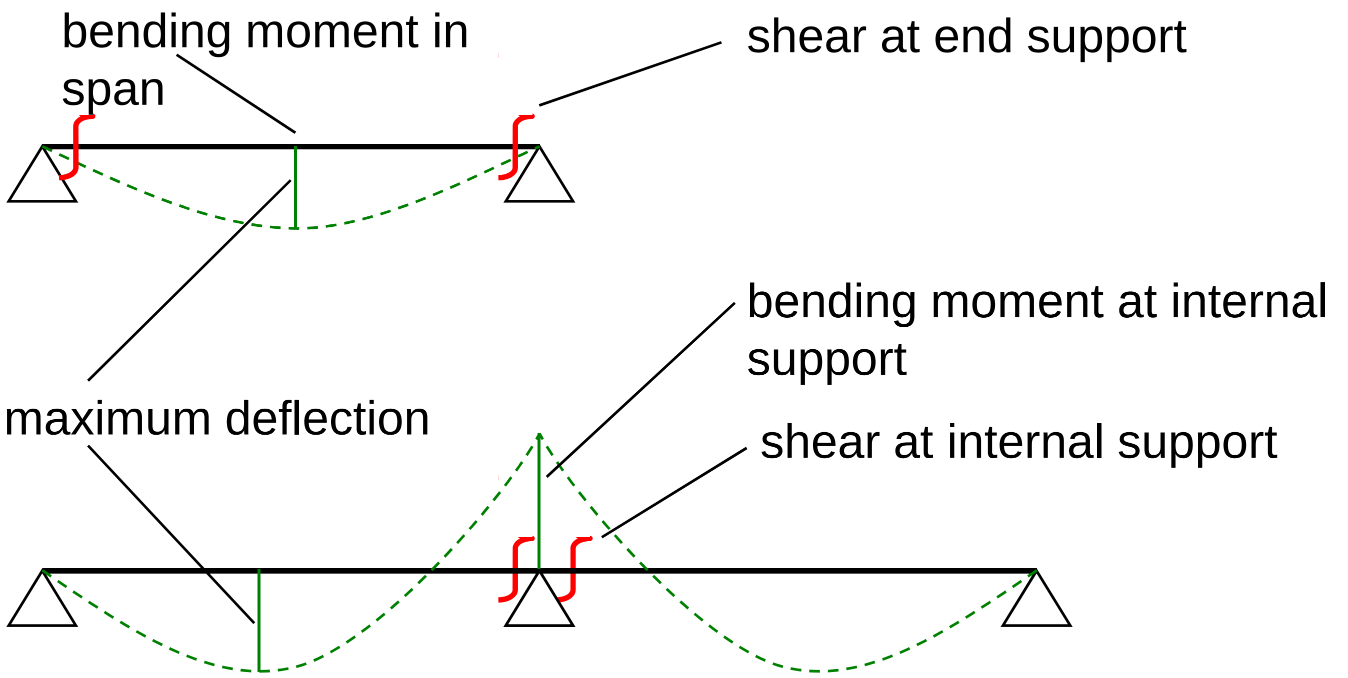
Tests acc. to table 4 = ITT

= 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

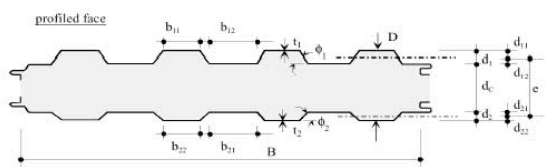
Step 3: Calculation of Stresses and Deflections

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 easul span width
- notations according to ECCS-Recommendations for Sandwichpanels
- Report from 23.10.2000
- width for calculation B = 1 m = 1000 mm
- analytic (exact) solution according Stamm/Witte



Sprache / language englisch/english

Cross sectional and characteristic values

Name of panel		test		
Thickness over all of panel	D =	84,5	mm	
Nominal thickness of outer face	t_1 =	0,63	mm	
Nominal thickness of inner face	t_2 =	0,50	mm	
Thickness of zinc		0,04	mm	
		außen (Index 1)	*innen* (Index 2)	
Net thickness of faces		0,59	0,46	mm
Cross-sectional area of faces	A_{Fi} =	7,088	4,652	cm²/m
Moment of inertia of faces	I_{Fi} =	10,690	0,000	cm⁴/m
Upper edge distance	d_{i1} =	28,630	0,600	mm
lower edge distance	d_{i2} =	7,970	0,300	mm
E-Modul	E_{Fi} =	2,10E+05	2,10E+05	N/mm²
Thermal expansion coefficient	α_{Ti} =	1,20E-05	1,20E-05	1/°
Shear modulus	G_C =	3,00	N/mm²	

Excel-sheet from iS-mainz:

- Free download
- easy to use
- Independent results for each load case

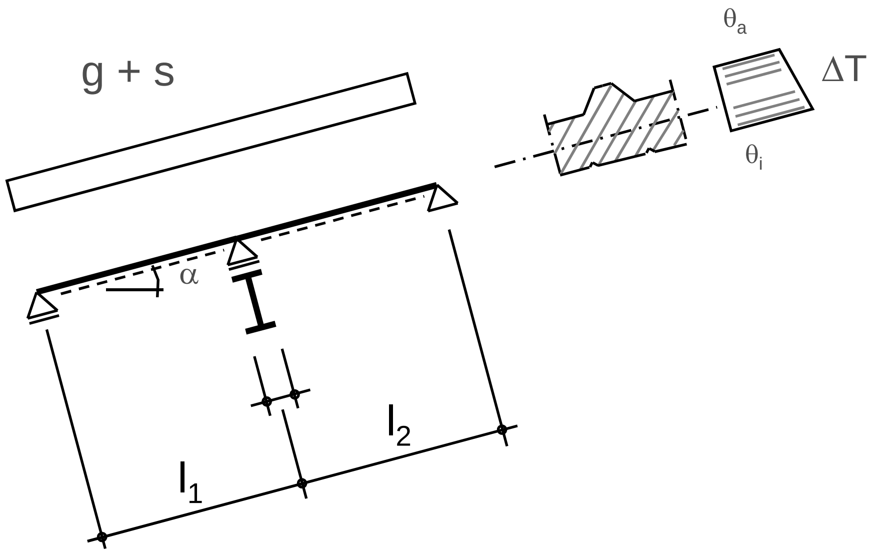
Step 3: Calculation of Stresses and Deflections

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



Design by Calculation

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)

  $g + s$

  $g + s + \Delta T_{\text{winter with snow(20 K)}}$

  $g + \Delta T_{\text{winter (40 K)}}$

  $g + s + \Delta g_{\varphi} + \Delta s_{\varphi}$

  $g + s + \Delta g_{\varphi} + \Delta s_{\varphi} + \Delta T_{\text{winter with snow (20K)}}$

  $g + w$

  $g + w + \Delta T_{\text{winter (40 K)}}$

  $g + w + \Delta T_{\text{summer (55 K)}}$

Step 4: Superposition of all relevant load cases

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

but

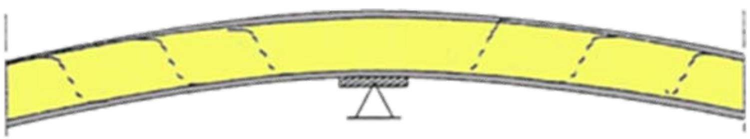
With some experience the decisive load combinations will be evident quickly.

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

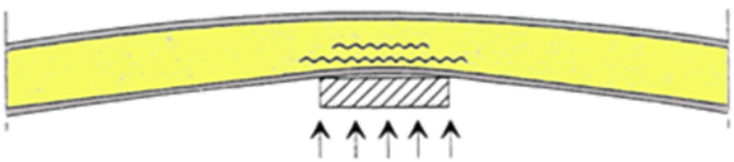
Design by Calculation

Step 5: Identify the decisive Limit State for each span

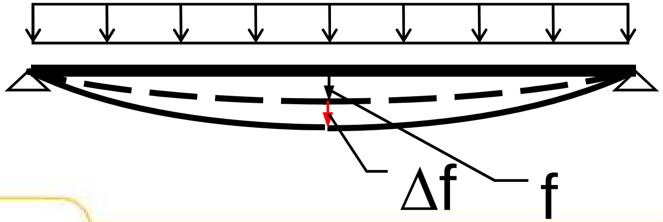
Yield or wrinkling strength of face



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

A-2-60 positive loading

Typ of panel: Arcelor 1001 TS, d=60mm, 2 span

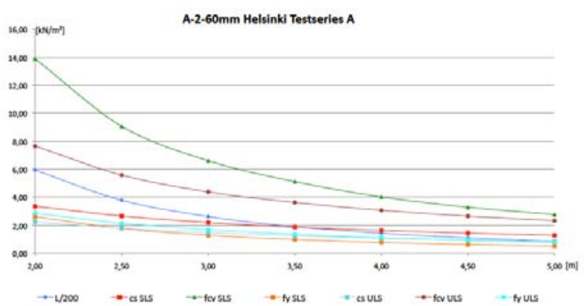
Testlocation: Helsinki, Testseries A

q_{obs}	0,115 kN/m²		supportwidth	60 mm	
temperature loading according EN 14509			statistical factor $k = \frac{x_5}{x}$		
ΔT =	55 °C	summer	k =	0,85	
ΔT =	40 °C	winter	k depends on number of tests and relevant criteria		

material properties			geometry		
$f_{y,nom}$	320 N/mm²	approval	e_{nom}	65,57 mm	approval
$f_{y,obs}$	395 N/mm²	measured mean value	e_{obs}	67,94 mm	calculated with excel
$f_{y,cal}$	0 N/mm²	calculated	D_{obs}	99,97 mm	measured mean value
$G_{C,obs}$	3,000 N/mm²	measured mean value	$t_{F1,nom}$	0,500 mm	approval
$f_{Cc,obs}$	0,106 N/mm²	5% fractile value	$t_{F2,nom}$	0,500 mm	approval
$f_{Ct,obs}$	0,131 N/mm²	5% fractile value	$t_{F1,c}$	0,435 mm	measured
φ_{LS}	7,00		$t_{F2,c}$	0,427 mm	measured
φ_{LQ}	1,70				

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

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



Design by Calculation

Step 6: Span Table for distributed load

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

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

Design by Calculation

Conclusion:

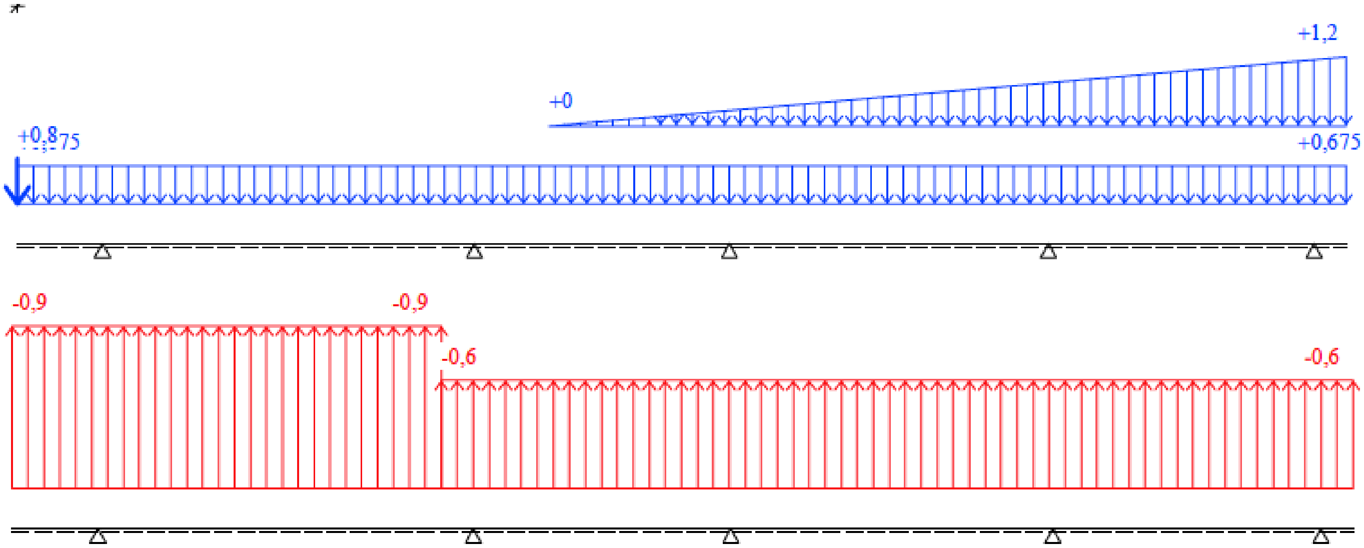
Design by calculation means

- 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!

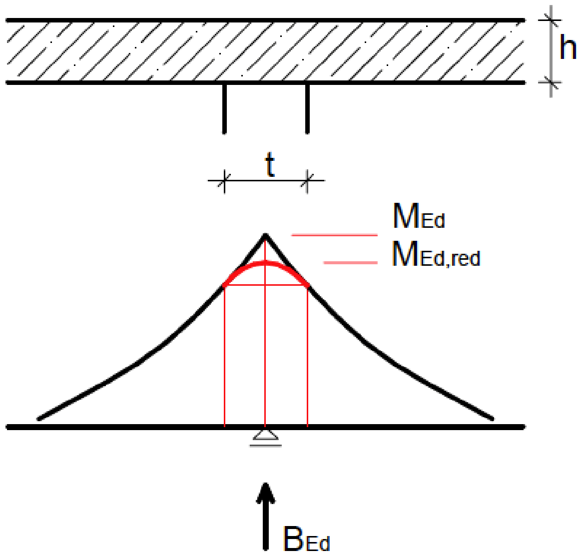
Conclusion:

Design by calculation means also

- Mechanical properties can be used to calculate more complicate structures by means of special software



For effects like this:



Design by Calculation

Please pay attention to David Izabel

Design by Testing