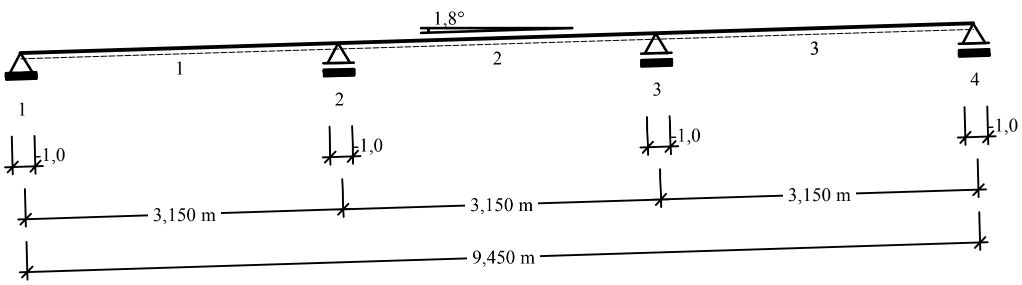
# VANDEMORTEELE à Reims (51)

## 1. STATIC SYSTEM

### 1.1 SKETCH




M = 1 : 75

roof-panel of 3 spans, parallel to the roof pitch of 1,8° (3,1%) installed.
-1: no definition from user. The necessary support width was determinated by the software.

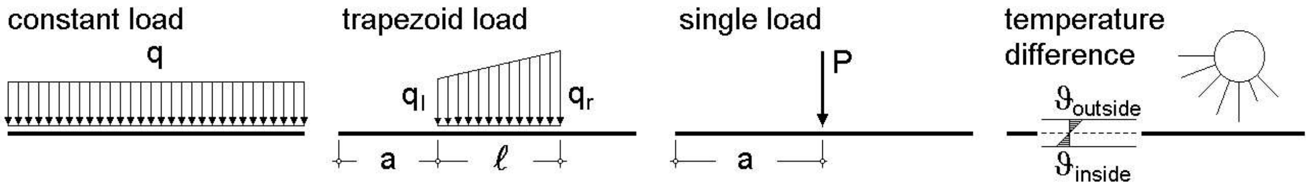
### 1.2 PANEL SPECIFICATION

Sel. panel: IND 200 0,75 0,50 Nervure/Nervure (PIR) NEW! 2021 (outside-colour classified as colour group 1)
(The datas of the panel are given by the user.)

Background: CE-Marking acc. Z-0946 (PIR)
Holder: Isocab (PIR)
Design: DIN EN 14509, annex E

## 2. LOAD

### 2.1 PRINCIPLE SKETCH OF THE INTRODUCED LOADS

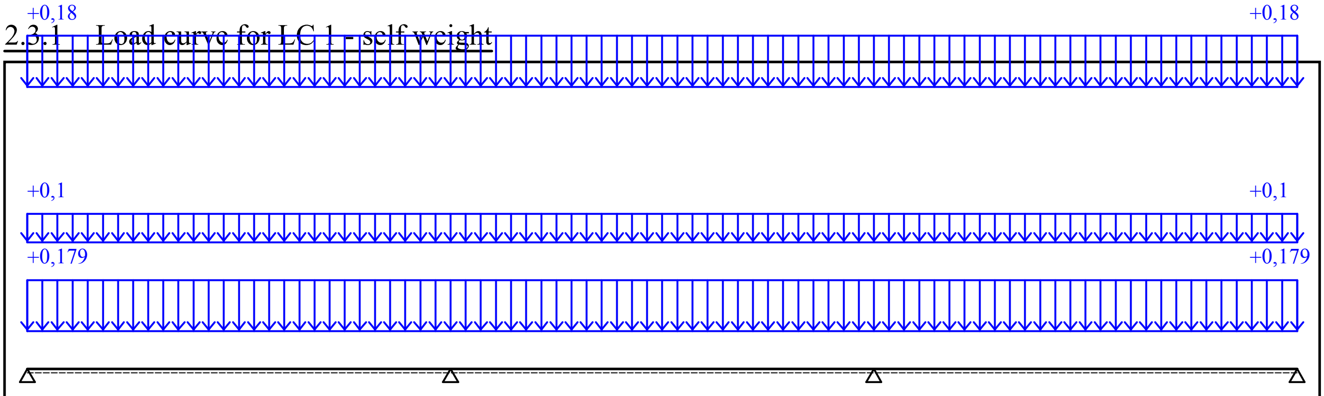


## 2.2 INTRODUCED LOADS

| | | | |
|---|---|---|---|
| 1a. | permanent load over entire length | $g_{\perp}$ | = 0,179 kN/m² |
| 1b. | permanent load over entire length | $g_{\perp}$ | = 0,100 kN/m² |
| 1c. | permanent load over entire length | $g_{\perp}$ | = 0,180 kN/m² |
| 2. | long-term effect of permanent loads | | |
| 3a. | snow trapezoid load | $s_{\perp le}$ | = 0,720 kN/m², $s_{\perp ri}$ = 0,360 kN/m², a = 0,00 m, l = 5,00 m |
| 3b. | snow | $s_{\perp}$ | = 0,360 kN/m², a = 5,00 m, l = 4,45 m |
| 4. | long-term effect of snow | | |
| 5. | wind pressure over entire length | $w_d$ | = 0,380 kN/m² |
| 6. | wind suction over entire length | $w_s$ | = -1,000 kN/m² |
| 7. | summer temperatures for SLS | $\vartheta_{outs}$ | = +50°C, $\vartheta_{ins}$ = -20°C |
| 8. | summer temperatures for ULS | $\vartheta_{outs}$ | = +50°C, $\vartheta_{ins}$ = -20°C |
| 9. | winter temperatures | $\vartheta_{outs}$ | = -10°C, $\vartheta_{ins}$ = -20°C |
| 10. | winter temperatures with snow | $\vartheta_{outs}$ | = ±0°C, $\vartheta_{ins}$ = -20°C |

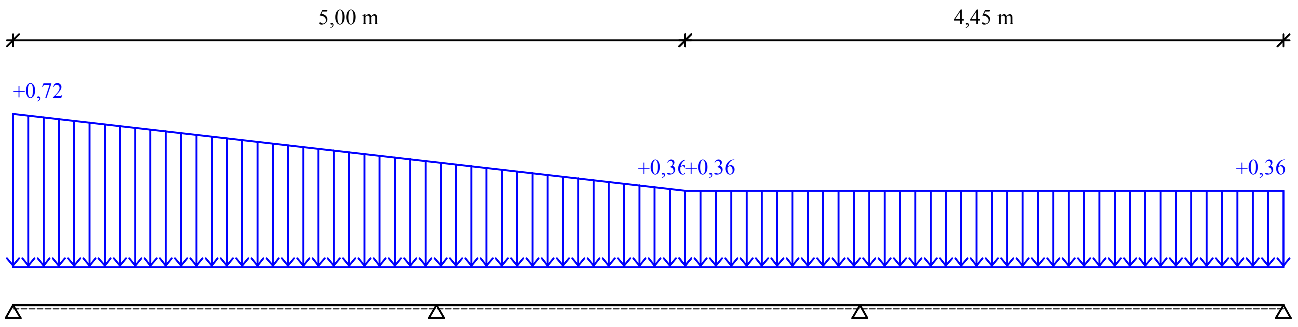
## 2.3 LOAD CURVE OVER THE PANEL LENGTH

### 2.3.1 Load curve for LC 1 - self weight



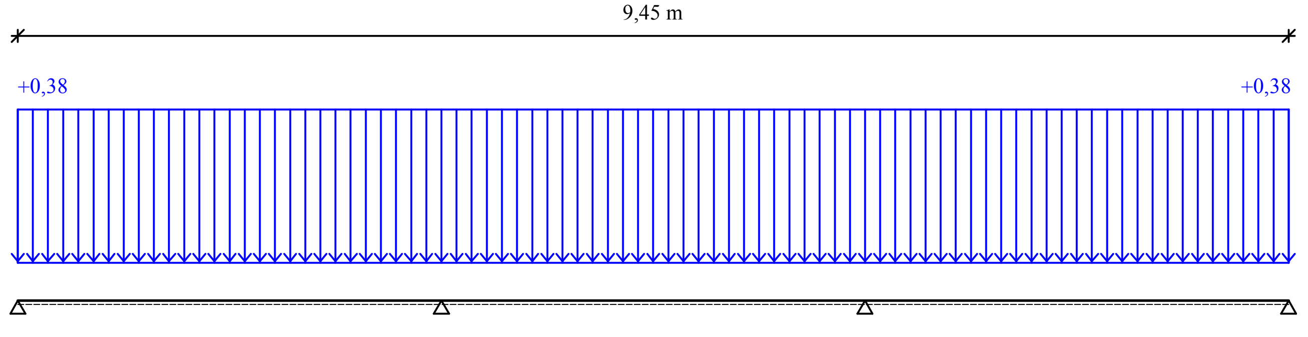

Load curve for LC 1 - self weight [kN/m², kN/m]

### 2.3.2 Load curve for LC 3 -



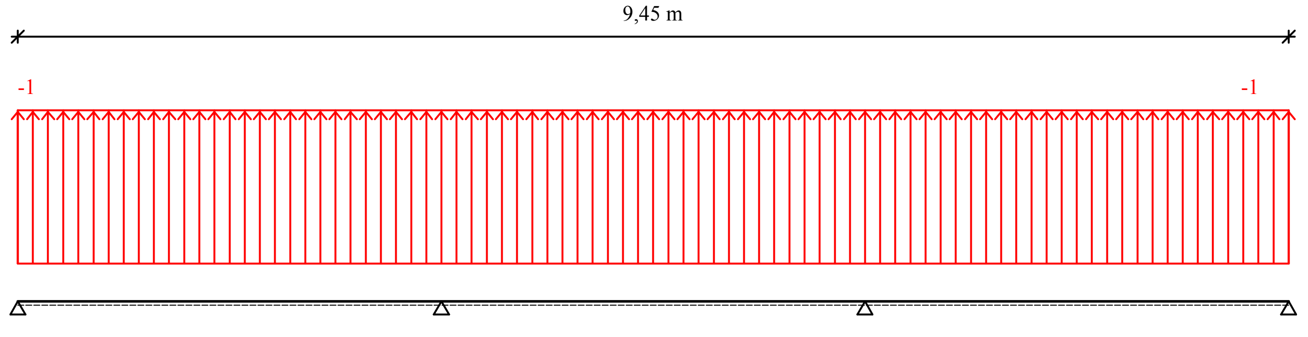

Load curve for LC 3 - [kN/m², kN/m]

### 2.3.3 Load curve for LC 5 - wind pressure



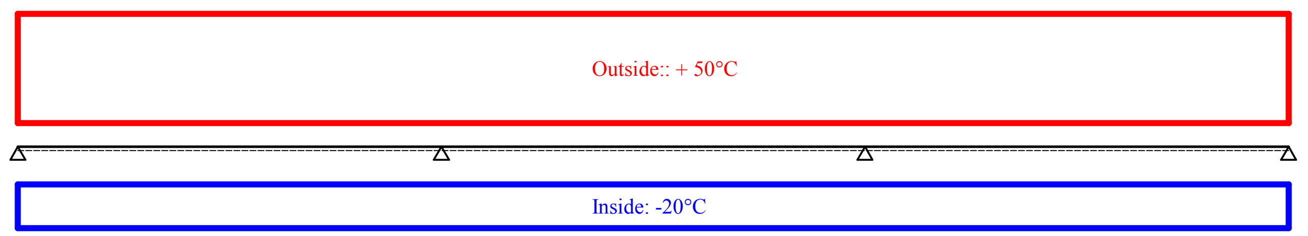

Load curve for LC 5 - wind pressure [kN/m², kN/m]

### 2.3.4 Load curve for LC 6 - wind suction



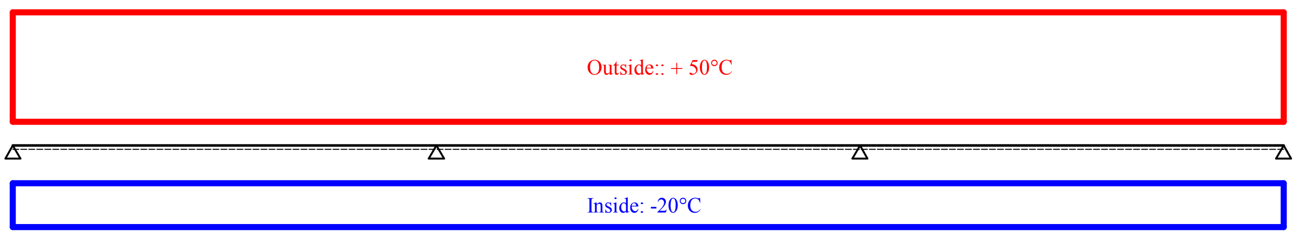

Load curve for LC 6 - wind suction [kN/m², kN/m]

### 2.3.5 Load curve for LC 7 - temperatures at summer for SLS



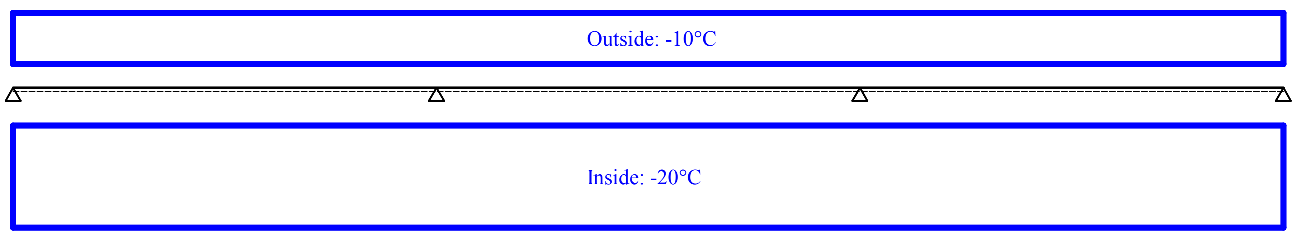

Load curve for LC 7 - temperatures at summer for SLS

### 2.3.6 Load curve for LC 8 - temperatures at summer for ULS



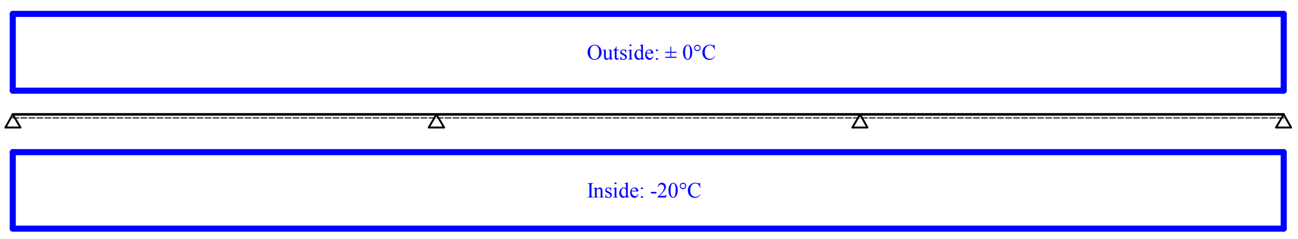

Load curve for LC 8 - temperatures at summer for ULS

### 2.3.7 Load curve for LC 9 - temperatures at winter




Load curve for LC 9 - temperatures at winter

### 2.3.8 Load curve for LC 10 - temperature at winter with snow




Load curve for LC 10 - temperature at winter with snow

## 2.4 Combination coefficients and load factors

### 2.4.1 Combination coefficients

| Combination coefficients | Snow | Wind | Temperature | Live load |
|---|---|---|---|---|
| $\Psi_0$ | 0,60 | 0,60 | 0,60 / 1,00[a] | 0,00 |
| $\Psi_1$ | 0,75 / 1,00[b] | 0,75 / 1,00[b] | 1,00 | 0,00 |

a Coefficient is used if the winter temperature T = 0 °C is combined with snow.
b Coefficient is used if there is, in the combination, only a single action effect representing the variable actions and it is caused by either the sole snow load or the sole wind load, acting alone.

Reference: EN 14509, Tab. E.6

### 2.4.2 Load factors

| $\gamma_F$ at | ultimate limit state | serviceability limit state |
|---|---|---|
| Permament actions | 1,35 / 1,00 | 1,00 |
| Variable actions | 1,50 | 1,00 |
| Temperature actions | 1,50 | 1,00 |
| Creep effects | 1,00 | 1,00 |

Reference: EN 14509, Tab. E.8

# 3. ACTION EFFECTS OF EACH LOADCASE

## 3.1 SUPPORT REACTIONS AT MULTI-SPAN PANEL

Support reactions for multi-span-panels without load factors. The numbers of the load cases correspond with the numbers under Load. The additional support actions from long-term effects are close to 0 and are not printed out.

| | Load case | | | | | | |
|---|---|---|---|---|---|---|---|
| support | LC 1 | LC 3 | LC 5 | LC 6 | LC 7 | LC 9 | LC 10 |
| - | [kN/m] | [kN/m] | [kN/m] | [kN/m] | [kN/m] | [kN/m] | [kN/m] |
| 1 | +0,63 | +0,92 | +0,52 | -1,37 | +2,30 | +0,33 | +0,66 |
| 2 | +1,54 | +1,68 | +1,27 | -3,35 | -2,30 | -0,33 | -0,66 |
| 3 | +1,54 | +1,22 | +1,27 | -3,35 | -2,30 | -0,33 | -0,66 |
| 4 | +0,63 | +0,49 | +0,52 | -1,37 | +2,30 | +0,33 | +0,66 |

## 3.2 SHEAR FORCES AT MULTI-SPAN PANEL

The given results are the maximum for continuous multi span panels without load factors.

### 3.2.1 Shear force in core

| $V_C$ [kN/m] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Load Case | | | | | | | | |
| span/ support | LC 1 | LC 2 | LC 3 | LC 4 | LC 5 | LC 6 | LC 7 | LC 9 | LC 10 |
| support 1 | +0,63 | +0,04 | +0,92 | +0,03 | +0,52 | -1,37 | +2,30 | +0,33 | +0,66 |
| span 1 | -0,81 | +0,07 | -0,99 | +0,06 | -0,67 | +1,77 | +2,30 | +0,33 | +0,66 |
| support 2 | -0,05 | +0,02 | -0,15 | +0,01 | -0,04 | +0,10 | +1,15 | +0,16 | +0,33 |
| span 2 | +0,72 | -0,03 | +0,68 | -0,03 | +0,59 | -1,56 | ±0,00 | ±0,00 | ±0,00 |
| support 3 | +0,05 | -0,02 | +0,04 | -0,02 | +0,04 | -0,10 | -1,15 | -0,16 | -0,33 |
| span 3 | +0,81 | -0,07 | +0,64 | -0,04 | +0,67 | -1,77 | -2,30 | -0,33 | -0,66 |
| support 4 | -0,63 | -0,04 | -0,49 | -0,03 | -0,52 | +1,37 | -2,30 | -0,33 | -0,66 |

## 3.3 BENDING MOMENTS AT MULTI-SPAN PANEL

The given results are the maximum for continuous multi span panels without load factors.

### 3.3.1 Sandwich moment

| $M_C$ [kNm/m] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Load Case | | | | | | | | |
| span/ support | LC 1 | LC 2 | LC 3 | LC 4 | LC 5 | LC 6 | LC 7 | LC 9 | LC 10 |
| support 1 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 |
| span 1 | +0,43 | - | +0,61 | - | +0,36 | -0,94 | - | - | - |
| support 2 | -0,29 | +0,12 | -0,31 | +0,11 | -0,24 | +0,64 | +7,24 | +1,03 | +2,07 |
| span 2 | +0,28 | +0,12 | +0,20 | +0,08 | +0,23 | -0,60 | +7,24 | +1,03 | +2,07 |
| support 3 | -0,29 | +0,12 | -0,25 | +0,08 | -0,24 | +0,64 | +7,24 | +1,03 | +2,07 |
| span 3 | +0,43 | - | +0,33 | - | +0,36 | -0,94 | - | - | - |
| support 4 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 |

## 3.4 DEFLECTIONS AT MULTI-SPAN PANEL

Maximum deflections at each span without load factors.

| | Load Case | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| span | LC 1 | LC 2 | LC 3 | LC 4 | LC 5 | LC 6 | LC 7 | LC 9 | LC 10 |
| - | [cm] | [cm] | [cm] | [cm] | [cm] | [cm] | [cm] | [cm] | [cm] |
| 1 | +0,135 | +0,236 | +0,181 | +0,229 | +0,112 | -0,295 | -0,325 | -0,046 | -0,093 |
| 2 | +0,127 | +0,239 | +0,107 | +0,151 | +0,105 | -0,277 | -0,118 | -0,017 | -0,034 |
| 3 | +0,135 | +0,236 | +0,106 | +0,136 | +0,112 | -0,295 | -0,325 | -0,046 | -0,093 |

## 3.5 STRESSES AT MULTI-SPAN PANEL

The given results are the maximum stresses for continuous multi-span panels without load factors.

### 3.5.1 Normal stresses in upper face

| $\sigma_1$ [N/mm²] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Load Case | | | | | | | | |
| span/ support | LC1 | LC2 | LC3 | LC4 | LC5 | LC6 | LC7 | LC9 | LC10 |
| support 1 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 |
| span 1 | -3,18 | - | -4,51 | - | -2,63 | +6,92 | - | - | - |
| support 2 | +2,16 | -0,90 | +2,26 | -0,81 | +1,79 | -4,71 | -53,26 | -7,61 | -15,22 |
| span 2 | -2,03 | -0,89 | -1,51 | -0,60 | -1,68 | +4,41 | -53,26 | -7,61 | -15,22 |
| support 3 | +2,16 | -0,90 | +1,85 | -0,60 | +1,79 | -4,71 | -53,26 | -7,61 | -15,22 |
| span 3 | -3,18 | - | -2,42 | - | -2,63 | +6,92 | - | - | - |
| support 4 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 |

### 3.5.2 Normal stresses in lower face

| $\sigma_2$ [N/mm²] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Load Case | | | | | | | | |
| span/ support | LC1 | LC2 | LC3 | LC4 | LC5 | LC6 | LC7 | LC9 | LC10 |
| support 1 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 |
| span 1 | +4,96 | - | +7,04 | - | +4,11 | -10,81 | - | - | - |
| support 2 | -3,38 | +1,40 | -3,52 | +1,26 | -2,80 | +7,36 | +83,18 | +11,88 | +23,76 |
| span 2 | +3,16 | +1,39 | +2,36 | +0,93 | +2,62 | -6,89 | +83,18 | +11,88 | +23,77 |
| support 3 | -3,38 | +1,40 | -2,89 | +0,93 | -2,80 | +7,36 | +83,18 | +11,88 | +23,76 |
| span 3 | +4,96 | - | +3,79 | - | +4,11 | -10,81 | - | - | - |
| support 4 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 | ±0,00 |

### 3.5.3 Shear stresses in core

| $\tau_C$ [N/mm²] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Load Case | | | | | | | | |
| span/ support | LC1 | LC2 | LC3 | LC4 | LC5 | LC6 | LC7 | LC9 | LC10 |
| support 1 | +0,0032 | +0,0002 | +0,0046 | +0,0002 | +0,0026 | -0,0069 | +0,0116 | +0,0017 | +0,0033 |
| span 1 | -0,0041 | +0,0003 | -0,0050 | +0,0003 | -0,0034 | +0,0089 | +0,0116 | +0,0017 | +0,0033 |
| support 2 | -0,0002 | +0,0001 | -0,0008 | +0,0001 | -0,0002 | +0,0005 | +0,0058 | +0,0008 | +0,0017 |
| span 2 | +0,0036 | -0,0001 | +0,0034 | -0,0002 | +0,0030 | -0,0079 | ±0,0000 | ±0,0000 | ±0,0000 |
| support 3 | +0,0002 | -0,0001 | +0,0002 | -0,0001 | +0,0002 | -0,0005 | -0,0058 | -0,0008 | -0,0017 |
| span 3 | +0,0041 | -0,0003 | +0,0032 | -0,0002 | +0,0034 | -0,0089 | -0,0116 | -0,0017 | -0,0033 |
| support 4 | -0,0032 | -0,0002 | -0,0025 | -0,0001 | -0,0026 | +0,0069 | -0,0116 | -0,0017 | -0,0033 |

# 4. CALCULATIONS

## 4.1 DESIGN OVERVIEW

| | |
|---|---|
| ultimate limit state of tension and pressure stresses | 17,7% |
| ultimate limit state of shear stresses | 37,1% |
| ultimate limit state of support reactions | 100,0% |
| serviceability limit state of tension and pressure stresses | 75,5% |
| serviceability limit state of shear stresses | 25,0% |
| serviceability limit state of support reactions | 100,0% |
| serviceability limit state of deflections | 25,5% |

The abbrevations given in the design calculation have to be understood as "provable stress as a result of load case...".

## 4.2 DESIGN OF ULTIMATE LIMIT STATE

The ultimate limit state is to be designed assuming for a single-span panel ("wrinkling"-hinges over the supports). All spans in multi-span panels are treated and tested as single-span panels. Each load combination is calculated with consideration to the system and load details. The printout shows the relevant place and the relevant load combination.

### 4.2.1 Design of limited normal stresses in face layers

Determining: design of the compressionstress in the upper face layer at span 1 at load case combination

$\Sigma\sigma = \gamma_g * \sigma_g + \gamma_s * \sigma_s + \gamma_{wd} * \Psi_{0,w_d} * \sigma_{w_d} + \gamma_{\vartheta,WmS} * \Psi_{0,\Delta\vartheta_{WmS}} * \sigma_{\Delta\vartheta_{WmS}} \leq \sigma_{w,1,span,k} / \gamma_M = \sigma_{w,1,>25°C,span,d}$

$\Sigma\sigma$ = 1,35 ∗ -4,19 + 1,50 ∗ -5,54 + 1,50 ∗ 0,60 ∗ -3,47 + 1,50 ∗ 1,0 ∗ 0,0000 = -17,1 N/mm² < -111,7 N/mm² / 1,16 = -96,3 N/mm²

### 4.2.2 Design of the limited shear stress in the core material

Determining: design of at the support 1. Different partial safety factors for short and long term actions need to be taken into account. Here, the following needs to be designed:

$(\gamma_{wd} * \Psi_{0,w_d} * \tau_{w_d} + \gamma_{\vartheta,WmS} * \Psi_{0,\Delta\vartheta_{WmS}} * \tau_{\Delta\vartheta_{WmS}})/(f_{Cv,k} / \gamma_M) + (\gamma_g * \tau_g + \gamma_s * \tau_s + \gamma_{g,L} * \tau_{g_L} + \gamma_{s,L} * \tau_{s_L})/(f_{Cv,L,k} / \gamma_M) \leq 1$

(1,50 ∗ 0,60 ∗ 0,0030 + 1,50 ∗ 1,0 ∗ 0,0000 )/(0,0800 / 1,30) + (1,35 ∗ 0,0036 + 1,50 ∗ 0,0051 + 1,0 ∗ 0,0000 + 1,0 ∗ 0,0000 )/(0,0500 / 1,30) = 0,371 < 1.0

## 4.3 DESIGN OF SERVICEABILITY LIMIT STATE

The serviceability limit state is to be designed at the entire system in accordance with the standard. The different partial safety factors according to the technical approval need to be taken into account.

### 4.3.1 Design of limited normal stresses in face layers

For this panel, the limit wrinkling strength at the intermediate support depends on the number of screws per metre. The designs were only made with the basic limited values neglecting any reduction factors because there is no definition of fasteners.
Determining: design of the compressionstress in the upper face layer at the support 2 at load case combination

$\Sigma\sigma = \gamma_g * \sigma_g + \gamma_{ws} * \Psi_{0,w_s} * \sigma_{w_s} + \gamma_{\vartheta,S,SLS} * \sigma_{\Delta\vartheta S,SLS} + \gamma_{g,L} * \sigma_{g_L} \leq \sigma_{w,1,>25°C,support,k} / \gamma_M = \sigma_{w,1,support,d}$

Σσ = 1,0 ∗ 2,16 + 1,0 ∗ 0,60 ∗ -4,71 + 1,0 ∗ -53,3 + 1,0 ∗ -0,896 = -54,8 N/mm² < -75,5 N/mm² / 1,04 = -72,6 N/mm²

### 4.3.2 Design of the limited shear stress in the core material

Determining: design of at the support 1. Different partial safety factors for short and long term actions need to be taken into account. Here, the following needs to be designed:

$(\gamma_{wd} * \Psi_{0,w_d} * \tau_{w_d} + \gamma_{\vartheta,S,SLS} * \tau_{\Delta\vartheta S,SLS}) / (f_{Cv,<25°C,k} / \gamma_M) + (\gamma_g * \tau_g + \gamma_{g,L} * \tau_{g_L}) / (f_{Cv,L,k} / \gamma_M) \leq 1$

(1,0 ∗ 0,60 ∗ 0,0026 + 1,0 ∗ 0,0116 ) / (0,0800 / 1,08) + (0,0032 + 1,0 ∗ 0,0002 ) / (0,0500 / 1,08) = 0,250 < 1.0

## 4.4 COMPRESSION STRESSES AT SUPPORT

The design of the compression stresses at the supports is carried out for each support with the decisive design procedure (ulitmate limit state, serviceability limit state, constructive demands).

| support | $\gamma * A_S$ 1) | $\gamma * A_U$ 2) | exist. b 3) | $A_{SLS,d}$ 4) | $A_{ULS,d}$ 5) | req. $b_S$ 6) | req. $b_U$ 7) | req. $b_k$ 8) | req. $b_{dec.}$ 9) |
|---|---|---|---|---|---|---|---|---|---|
| [-] | [kN/m] | [kN/m] | [cm] | [kN/m] | [kN/m] | [cm] | [cm] | [cm] | [cm] |
| 1 | 3,28 | 3,04 | -1,0 | 3,93 | 3,06 | 3,3 | 4,0 | 4,0 | 4,0 |
| 2 | 3,98 | 5,37 | -1,0 | 5,89 | 5,37 | 4,1 | 7,0 | 6,0 | 7,0 |
| 3 | 3,55 | 4,79 | -1,0 | 5,89 | 4,79 | 3,6 | 6,3 | 6,0 | 6,3 |
| 4 | 3,28 | 2,38 | -1,0 | 3,93 | 3,06 | 3,3 | 3,1 | 4,0 | 4,0 |

1) relevant support reactions including load factors at serviceability limit state
2) relevant support reactions including load factors at ultimate limit state
3) existing support width."-1": no definition from user.
4) allowable support reactions at serviceability limit state
5) allowable support reactions as ultimate limit state
6) required support width at serviceability limit state
7) required support width at ultimate limit state
8) support width required in the standard
9) decisive support width (maximum value index 6 to 8)

## 4.5 DEFLECTIONS

### 4.5.1 Design of deflections

The design of deflections is made with following assumptions (special user-input):

span-deflections: - at short-term: max $w_{positive} = l / 250$ max $w_{negative} = l / 200$
- at long-term: max $w_{positive} = l / 100$ max $w_{negative} = l / 100$

Determining is the deflection at span 1 with the sum

$$\Sigma w = \gamma_g * w_g + \gamma_s * \Psi_{1,s} * w_s + \gamma_{wd} * \Psi_{0,w_d} * \Psi_{1,w_d} * w_{w_d} \leq \max w = 315{,}0 \text{ cm} / 250 = 1{,}26 \text{ cm}$$

$$\Sigma w = 1{,}0 * 0{,}135 + 1{,}0 * 0{,}75 * 0{,}181 + 1{,}0 * 0{,}60 * 0{,}75 * 0{,}112 = 0{,}322 \text{ cm} < 1{,}26 \text{ cm}$$