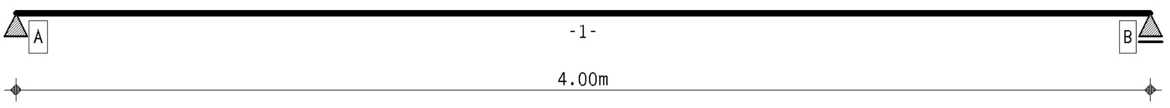
1. Options for Calculations

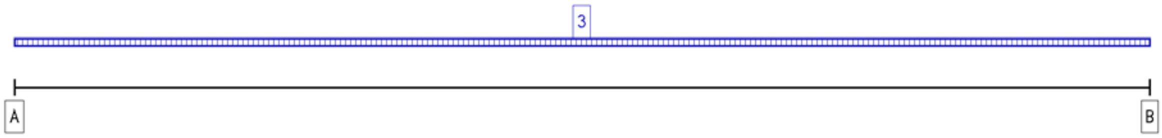
calculation DIN EN 1995:2010, Germany
service class 1

2. Structural system

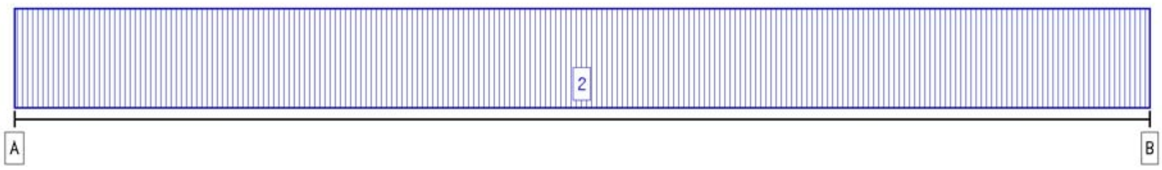


main beam

3. Loading



action effect 1: permanent loads (permanent, 1 load cases)

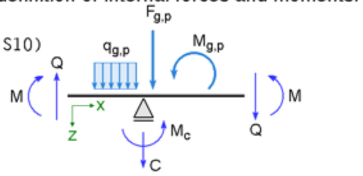


action effect 2: live loads (1) (transient, 1 load cases)

4. material parameters

beam Cross Laminated Timber	**Decker ED BSP, 200L/5s**
structure	**40.0**-40.0-**40.0**-40.0-**40.0** solid coniferous timber, C24 (S10)
direction of fibre	x-axis (strong axis)
service class	1
beam width/-höhe	b/h = 1000 mm / 200 mm
coeff. thermal expan. timber	0.500 $*10^{-5}$ /°K
shear coefficient κ	0.174823

definition of internal forces and moments:



5. Beam sections

beam sections

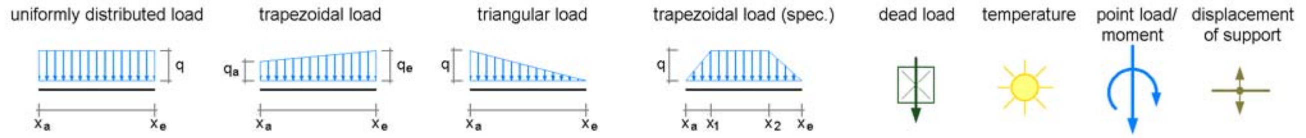
section	x_A m	x_E m	l m	l_v m	cantil.	EI_{eff} Nmm2	GA_{eff} N	EA_{eff} N	$EI_{eff,fire}$ Nmm2	$GA_{eff,fire}$ N	$EA_{eff,fire}$ N	$z_{s,fire}$ mm
1	0.00	4.00	4.00	4.00	-	5808.000	15174672.00	1320000000.	1525.333	8412976.000	880000000.0	60.0

6. Supports

coordinates of supports

supp.name	x m	width mm	depth mm	c_F kN/m	c_M kNm/-	restraint (F)	(M)
A	0.00	100	1000	fix	----	X	-
B	4.00	100	1000	fix	----	X	-

7. Action effects



Permanent action effect: permanent loads

3. additive load case: EG

⇒ unif.distr.load: q = 0.92 kN/m from x_a = 0.00 m to x_e = 4.00 m

2. Transient action effect: live loads (1)

2. additive load case: live loads (1/1)

⇒ unif.distr.load: q = 10.00 kN/m from x_a = 0.00 m to x_e = 4.00 m

8. verifications

1: EC 5 load-carrying capacity

buckling analysis of compression flange acc. to DIN EN 1995, 6.3.2 will be executed

Extreme rule 1

2: EC 5 deformations

Grenzwerte für deformations acc. to DIN EN 1995-1-1, Tab. 7.2!

Extreme rule 1

3: EC 5 fire protection

fire resistance duration t_f = 60 min

side	protected	t_{ch}	t_f=t_{ch}	t_f	k_2	d_{ef}
top	-	-	-	-	-	63.00

Extreme rule 1: standardkombination

4: EC 5 Verification of vibration

verification of vibration acc. to der Konstruktions- and Bemessungsregeln aus dem Forschungsvorhaben Winter/Hamm/Richter: "Schwingungs- and Dämpfungsverhalten from timber- and timber-Beton-Verbunddecken" TU München 2010 modal damping ratio ξ = 0.00

Decke zwischen unterschiedlichen Nutzungseinheiten ⇒ f_{grenz} = 8 Hz, w_{grenz} = 0.5 mm, a_{grenz} = 0.05 m/s²

numeric calculation with Fourier series

Attention! Gelenke bleiben unberücksichtigt

Federn werden nur in den Zwischenlagern berücksichtigt

Ohne Berücksichtigung from shear deformation

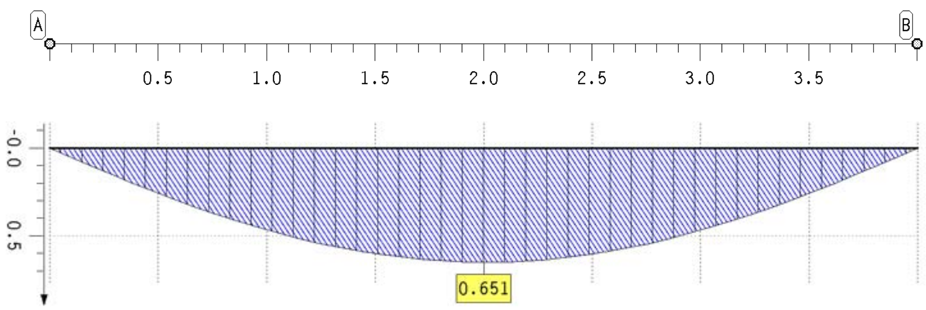
Poisson's ratio ν = 0.00, torsionstiffness = 0.0 %

screed wird nicht berücksichtigt

9. Results of load cases

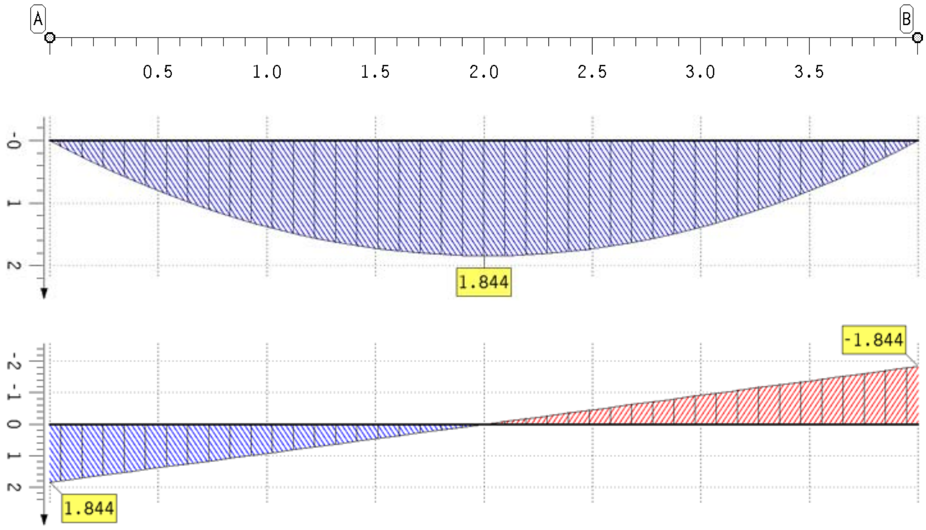
9.1. Action effect 1: load case 3: EG

deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: 0.00
Max: 0.65

internal forces and moments



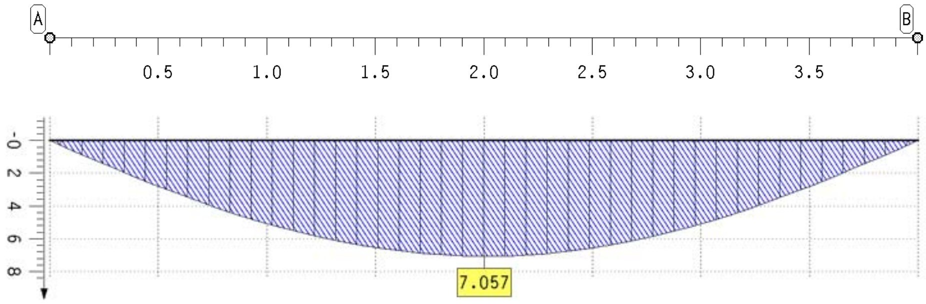
flexural moment
main beam
M in kNm
Min: -0.00
Max: 1.84

shear force
main beam
V in kN
Min: -1.84
Max: 1.84

support forces

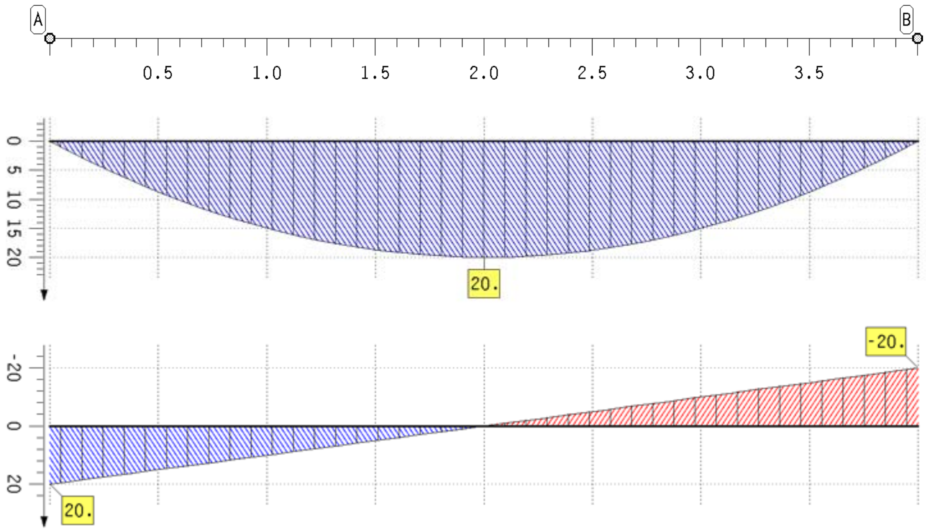
point	x	AP
-	m	kN
A	0.000	-1.84
B	4.000	-1.84

9.2. Action effect 2: load case 2: live loads (1/1)
deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: 0.00
Max: 7.06

internal forces and moments



flexural moment
main beam
M in kNm
Min: -0.00
Max: 20.00

shear force
main beam
V in kN
Min: -20.00
Max: 20.00

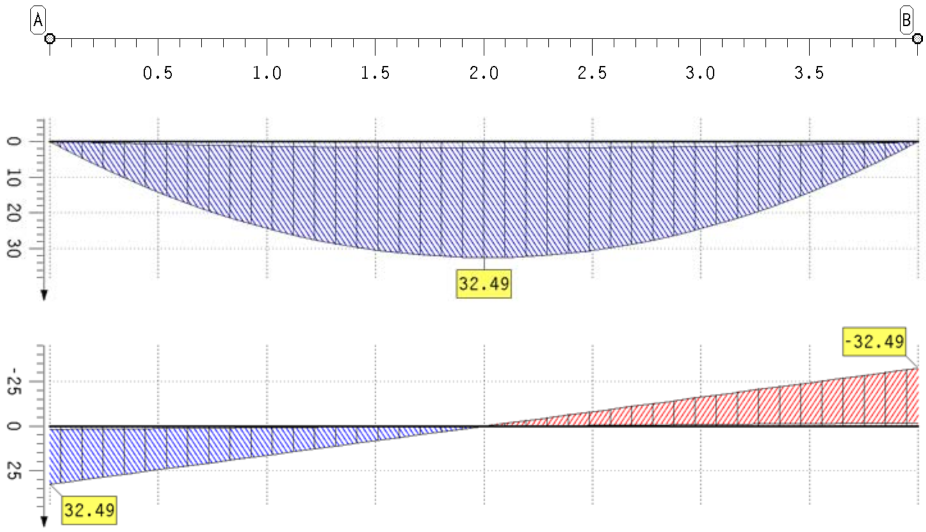
support forces

point	x	AP
-	m	kN
A	0.000	-20.00
B	4.000	-20.00

10. Results of verification of ultimate limit state

10.1. Verification of ultimate limit state

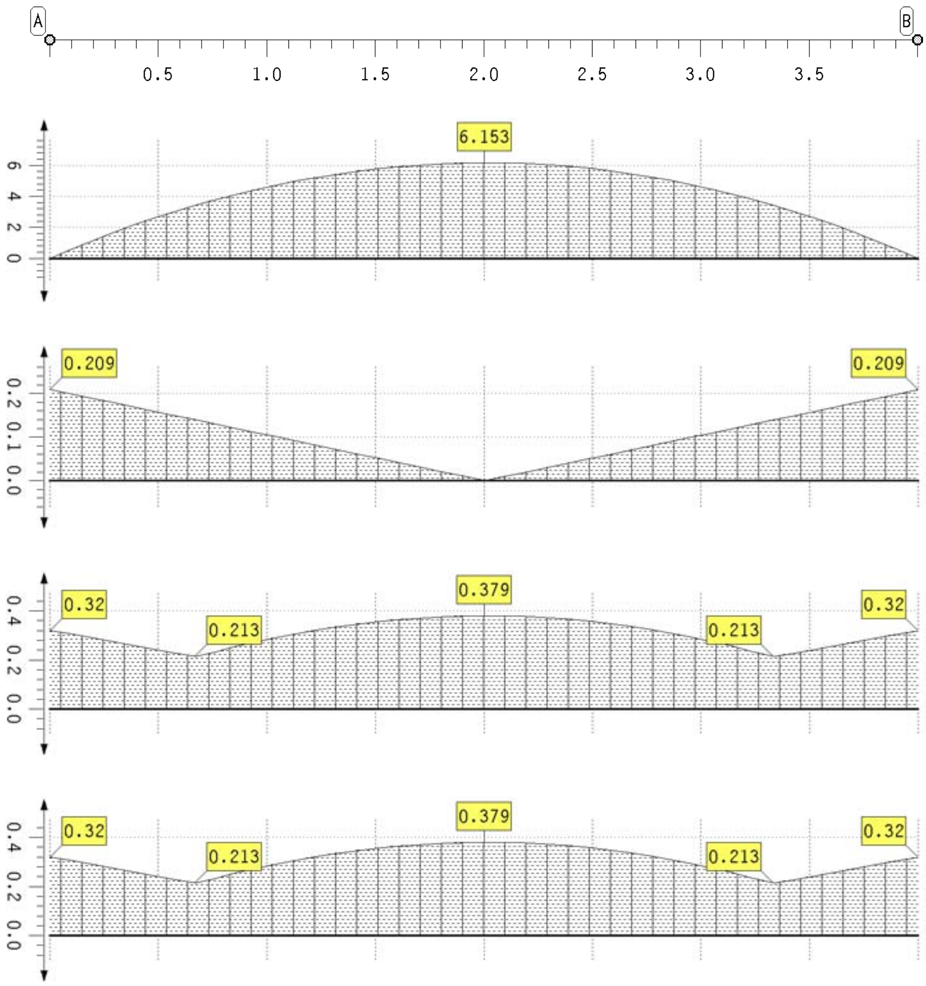
extremal internal forces



flexural moment
main beam
M in kNm
Min: -0.00
Max: 32.49

shear force
main beam
V in kN
Min: -32.49
Max: 32.49

results of verification of ultimate limit state



bending stress
main beam
σ_h in MN/m²
Max: 6.15

shear stress
main beam
τ_h in MN/m²
Max: 0.21

utilization
main beam
Max: 0.38

maximal
utilization
Max: 0.38

verification of ultimate limit state of main beam

point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m^2	MN/m^2	-
A	0.000	0.000	0.00	0.21	0.320
	0.667	0.000	3.42	0.14	0.213
	1.333	0.000	5.47	0.07	0.337
	2.000	0.000	6.15	0.00	0.379
	2.667	0.000	5.47	0.07	0.337
	3.333	0.000	3.42	0.14	0.213
B	4.000	0.000	0.00	0.21	0.320
minimum		**0.000**	**0.00**	**0.00**	**0.213**
maximum		**0.000**	**6.15**	**0.21**	**0.379**

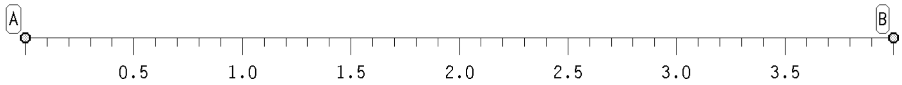
maximal utilization

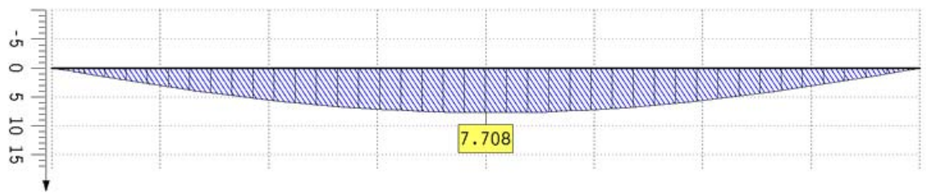
point	x	U
-	m	-
A	0.000	0.320
	0.667	0.213
	1.333	0.337
	2.000	0.379
	2.667	0.337
	3.333	0.213
B	4.000	0.320
minimum		**0.213**
maximum		**0.379**

11. Results of verification of deflections

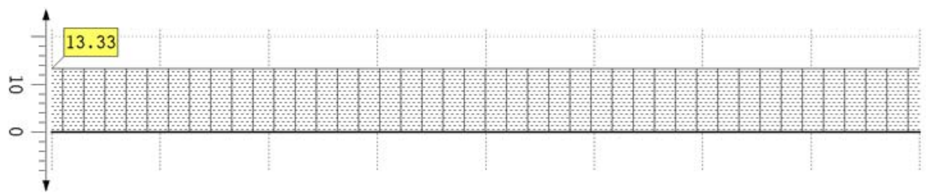
11.1. Verification of deflections

results of verification of deflections

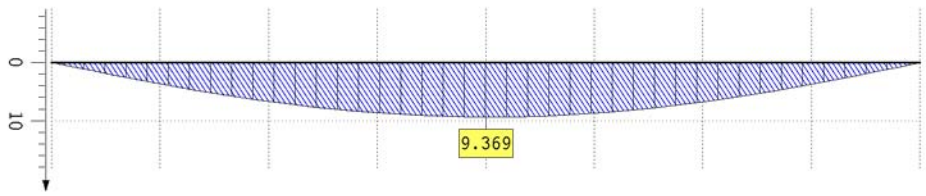




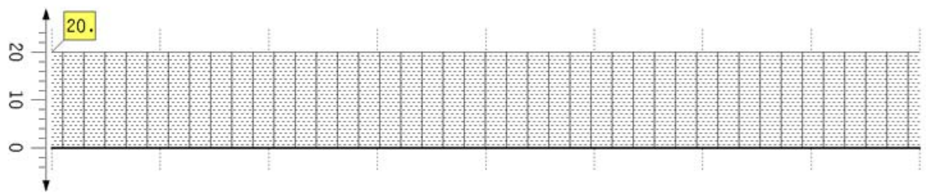
extremal deflections
w_{inst}
in mm
Min: 0.00
Max: 7.71



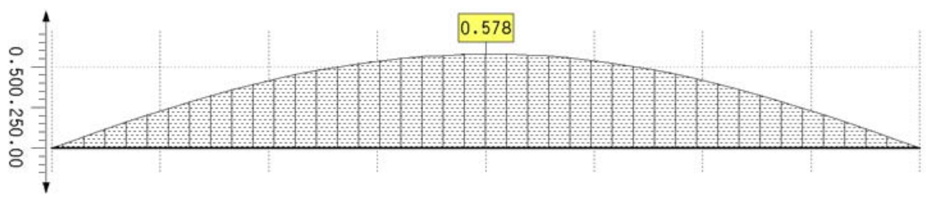
decisive deflection
$w_{inst,req}$
in mm
Min: 13.33
Max: 13.33



extremal deflections
w_{fin}
in mm
Min: 0.00
Max: 9.37



decisive deflection
$w_{fin,req}$
in mm
Min: 20.00
Max: 20.00



maximal utilization
Max: 0.58

verification of deflections

point	x	min/max/req w_{inst}			min/max/req w_{fin}			min/max/req $w_{net,fin}$			U
-	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	-
A	0.000	0.00	0.00	13.33	0.00	0.00	20.00	----	----	----	0.000
	1.048	0.00	5.74	13.33	0.00	6.98	20.00	----	----	----	0.430
	2.000	0.00	7.71	13.33	0.00	9.37	20.00	----	----	----	0.578
	2.952	0.00	5.74	13.33	0.00	6.98	20.00	----	----	----	0.430
B	4.000	0.00	0.00	13.33	0.00	0.00	20.00	----	----	----	0.000
minimum		**0.00**	**0.00**	**13.33**	**0.00**	**0.00**	**20.00**	**0.00**	**0.00**	**0.00**	**0.000**
maximum		**0.00**	**7.71**	**13.33**	**0.00**	**9.37**	**20.00**	**0.00**	**0.00**	**0.00**	**0.578**

12. Verification of vibrationergebnisse

12.1. Eigenfrequenz

$EI_{längs}$ = 5.808000 MNm²/m, EI_{quer} = 1.525333 MNm²/m
f_e = 24.878 Hz ≥ f_e = 8 Hz ⇒ **Kriterium successful!**

12.2. Steifigkeitskriterium

Raumbreite b = 1.000 m, b_{ef} = 1.000 m, $x_{max\ F}$ = 2.000 m, $x_{max\ w}$ = 2.000 m ⇒ w_{max} = 0.230 mm
w(2kN) = 0.46 mm ≤ w_{grenz} = 0.5 mm ⇒ **Kriterium successful!**

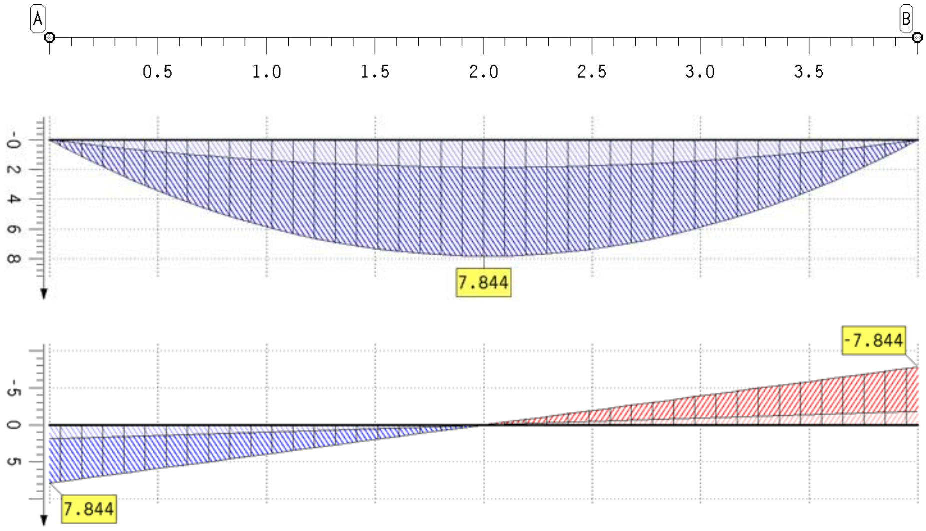
12.3. Konstruktive Anforderungen

Schwimmende supportung des screeds ist unbedingt erforderlich!
Nach [Winter/Hamm/Richter], TU München 2010 gilt:
Nassestriche sind aufgrund ihrer höheren Masse and höheren Steifigkeit gegenüber Trockenestrichen günstiger zu bewerten, was das Schwingungsverhalten der Decken betrifft.
Eine (möglichst schwere) Schüttung verbessert das Schwingungsverhalten.
Je schwerer die Schüttung, desto größer die Verbesserung der subjektiven Bewertung. Als schwere Schüttung werden Schüttungen with einem areangewicht from mindestens 60 kg/m² bezeichnet.

13. Results of verification of fire protection

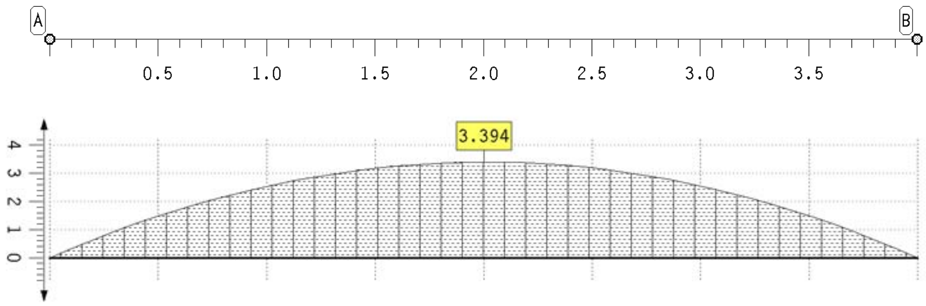
13.1. Verification of fire protection

extremal internal forces

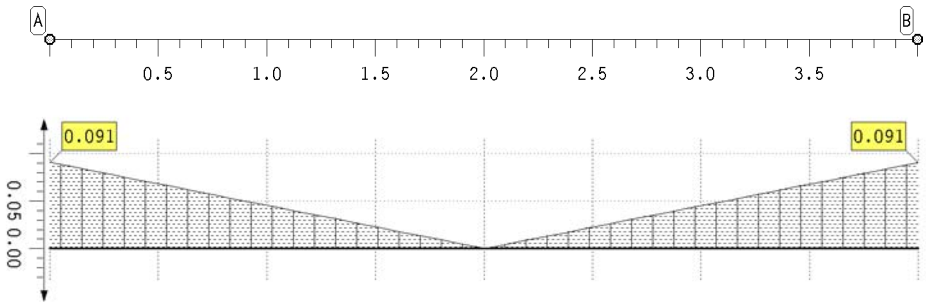


flexural moment
main beam
M in kNm
Min: -0.00
Max: 7.84

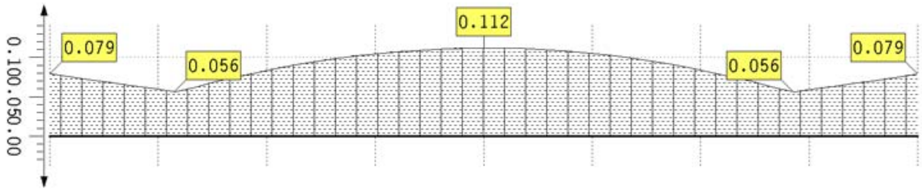
shear force
main beam
V in kN
Min: -7.84
Max: 7.84



bending stress
main beam
σ_h in MN/m²
Max: 3.39



shear stress
main beam
τ_h in MN/m²
Max: 0.09



utilization
main beam
Max: 0.11

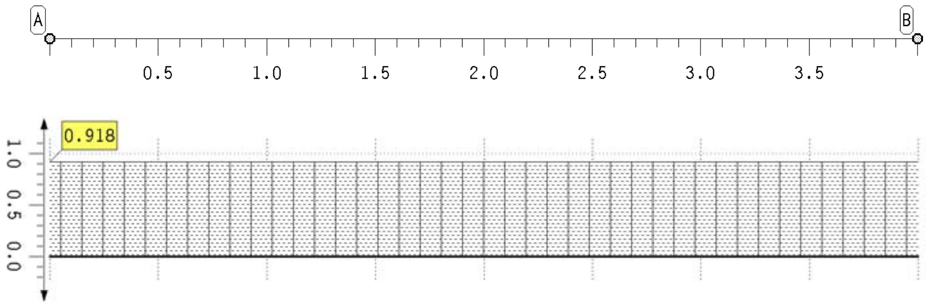
verification of ultimate limit state of main beam

point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m²	MN/m²	-
A	0.000	0.000	0.00	0.09	0.079
	0.571	0.000	1.66	0.06	0.056
	1.333	0.000	3.02	0.03	0.099
	2.000	0.000	3.39	0.00	0.112
	2.667	0.000	3.02	0.03	0.099
	3.429	0.000	1.66	0.06	0.056
B	4.000	0.000	0.00	0.09	0.079
minimum		**0.000**	**0.00**	**0.00**	**0.056**
maximum		**0.000**	**3.39**	**0.09**	**0.112**

14. Summary

14.1. Summary of all verifications

maximal utilization



utilization
Max: 0.92

14.2. Eigenfrequenz

$EI_{längs}$ = 5.808000 MNm²/m, EI_{quer} = 1.525333 MNm²/m
f_e = 24.878 Hz ≥ f_e = 8 Hz ⇒ **Kriterium successful!**

14.3. Steifigkeitskriterium

Raumbreite b = 1.000 m, b_{ef} = 1.000 m, $x_{max\ F}$ = 2.000 m, $x_{max\ w}$ = 2.000 m ⇒ w_{max} = 0.230 mm
w(2kN) = 0.46 mm ≤ w_{grenz} = 0.5 mm ⇒ **Kriterium successful!**

14.4. Konstruktive Anforderungen

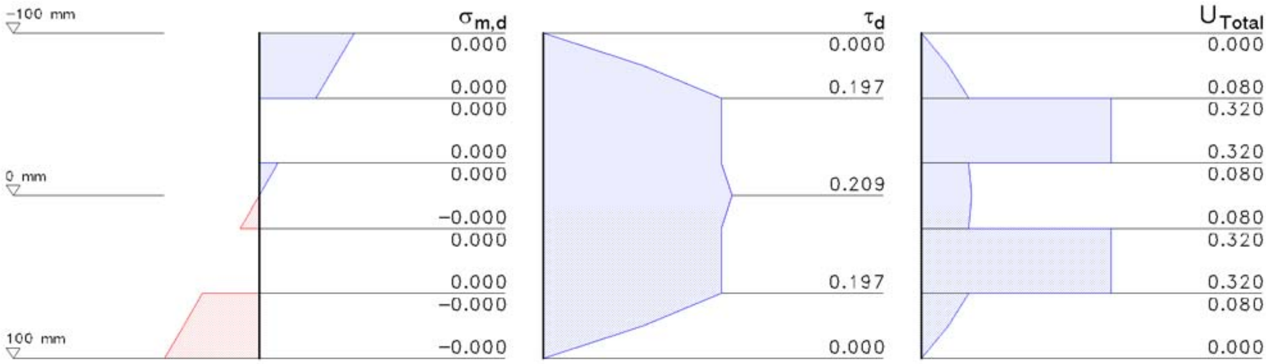
Schwimmende supportung des screeds ist unbedingt erforderlich!
Nach [Winter/Hamm/Richter], TU München 2010 gilt:
Nassestriche sind aufgrund ihrer höheren Masse and höheren Steifigkeit gegenüber Trockenestrichen günstiger zu bewerten, was das Schwingungsverhalten der Decken betrifft.
Eine (möglichst schwere) Schüttung verbessert das Schwingungsverhalten.
Je schwerer die Schüttung, desto größer die Verbesserung der subjektiven Bewertung. Als schwere Schüttung werden Schüttungen with einem areangewicht from mindestens 60 kg/m² bezeichnet.

15. Utilizations of all verifications

all verifications successful!

16. Detailed verification piont

16.1. Verification of load-carrying capacity at x = 4.00 m, maxV_d = -1.84 kN, minM_d = -0.00 kNm, maxM_d = -0.00 kNm

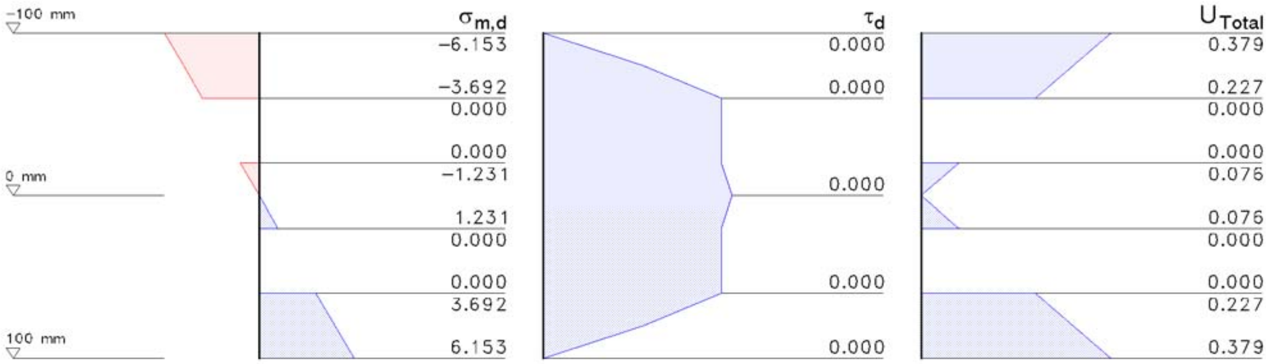


mechanical resistance and static terms: stiffness B_x = 5808.000 Nmm

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm^2	$f_{m,d}$ N/mm^2	$\tau_{v,d}$ N/mm^2	$f_{v,d}$ N/mm^2
100.0	0.000	-0.000	16.25	0.000	2.46
80.0	-19.800	-0.000	16.25	0.111	2.46
60.0	-35.200	0.000	16.25	0.197	0.62
40.0	-35.200	0.000	16.25	0.197	0.62
20.0	-35.200	-0.000	16.25	0.197	2.46
0.0	-37.400	-0.000	16.25	0.209	2.46

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm^2	$f_{m,d}$ N/mm^2	$\tau_{v,d}$ N/mm^2	$f_{v,d}$ N/mm^2
-20.0	-35.200	0.000	16.25	0.197	0.62
-40.0	-35.200	0.000	16.25	0.197	0.62
-60.0	-35.200	0.000	16.25	0.197	2.46
-80.0	-19.800	0.000	16.25	0.111	2.46
-100.0	0.000	0.000	16.25	0.000	2.46

16.2. Verification of load-carrying capacity at x = 2.00 m, maxV_d = 0.00 kN, minM_d = 1.84 kNm, maxM_d = 32.49 kNm

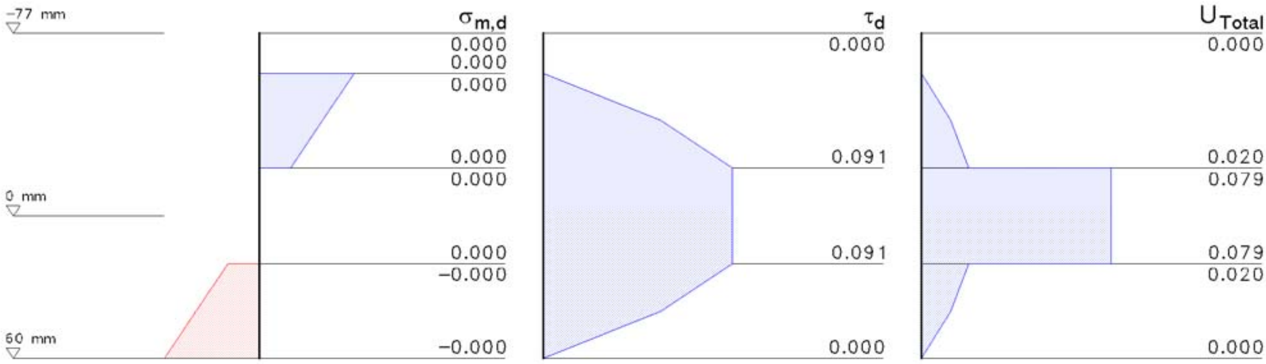


mechanical resistance and static terms: stiffness B_x = 5808.000 Nmm

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm^2	$f_{m,d}$ N/mm^2	$\tau_{v,d}$ N/mm^2	$f_{v,d}$ N/mm^2
100.0	0.000	6.153	16.25	0.000	2.46
80.0	-19.800	4.923	16.25	0.000	2.46
60.0	-35.200	0.000	16.25	0.000	0.62
40.0	-35.200	0.000	16.25	0.000	0.62
20.0	-35.200	1.231	16.25	0.000	2.46
0.0	-37.400	0.000	16.25	0.000	2.46

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm^2	$f_{m,d}$ N/mm^2	$\tau_{v,d}$ N/mm^2	$f_{v,d}$ N/mm^2
-20.0	-35.200	0.000	16.25	0.000	0.62
-40.0	-35.200	0.000	16.25	0.000	0.62
-60.0	-35.200	-3.692	16.25	0.000	2.46
-80.0	-19.800	-4.923	16.25	0.000	2.46
-100.0	0.000	-6.153	16.25	0.000	2.46

16.3. Resistance to fire at x = 4.00 m, maxV_d = -1.84 kN, minM_d = -0.00 kNm, maxM_d = -0.00 kNm

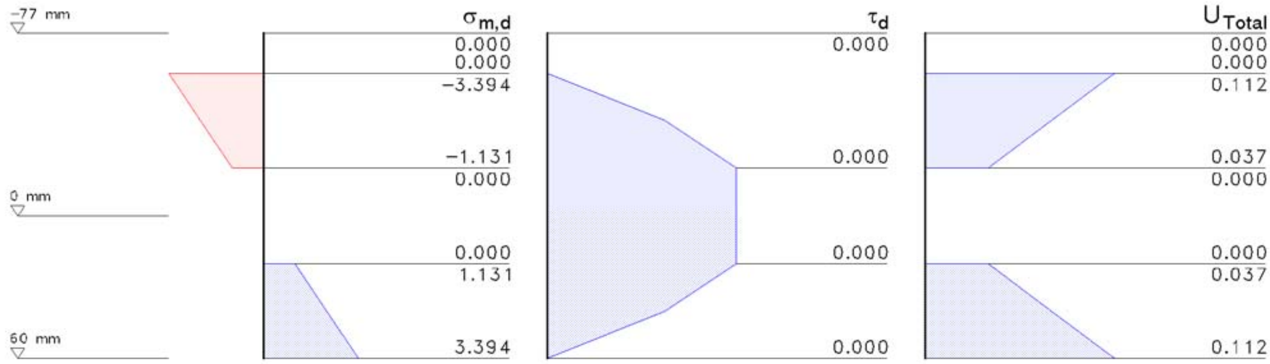


mechanical resistance and static terms: stiffness B_x = 1525.333 Nmm

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm²	$f_{m,d}$ N/mm²	$\tau_{v,d}$ N/mm²	$f_{v,d}$ N/mm²
60.0	0.000	-0.000	30.36	0.000	4.60
40.0	-11.000	-0.000	30.36	0.057	4.60
20.0	-17.600	0.000	30.36	0.091	1.15
0.0	-17.600	0.000	30.36	0.091	1.15
-20.0	-17.600	0.000	30.36	0.091	4.60

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm²	$f_{m,d}$ N/mm²	$\tau_{v,d}$ N/mm²	$f_{v,d}$ N/mm²
-40.0	-11.000	0.000	30.36	0.057	4.60
-60.0	0.000	0.000	30.36	0.000	1.15
-68.5	0.000	0.000	30.36	0.000	1.15
-77.0	0.000	0.000	30.36	0.000	1.15

16.4. Resistance to fire at x = 2.00 m, maxV_d = 0.00 kN, minM_d = 1.84 kNm, maxM_d = 7.84 kNm



mechanical resistance and static terms: stiffness B_x = 1525.333 Nmm

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm²	$f_{m,d}$ N/mm²	$\tau_{v,d}$ N/mm²	$f_{v,d}$ N/mm²
60.0	0.000	3.394	30.36	0.000	4.60
40.0	-11.000	2.263	30.36	0.000	4.60
20.0	-17.600	0.000	30.36	0.000	1.15
0.0	-17.600	0.000	30.36	0.000	1.15
-20.0	-17.600	-1.131	30.36	0.000	4.60

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm²	$f_{m,d}$ N/mm²	$\tau_{v,d}$ N/mm²	$f_{v,d}$ N/mm²
-40.0	-11.000	-2.263	30.36	0.000	4.60
-60.0	0.000	0.000	30.36	0.000	1.15
-68.5	0.000	0.000	30.36	0.000	1.15
-77.0	0.000	0.000	30.36	0.000	1.15