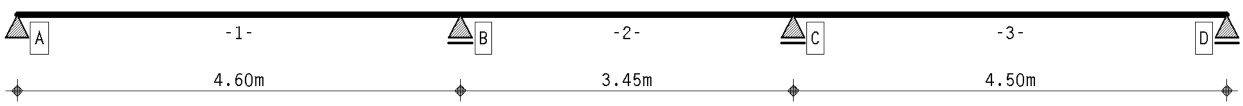
1. Options for Calculations

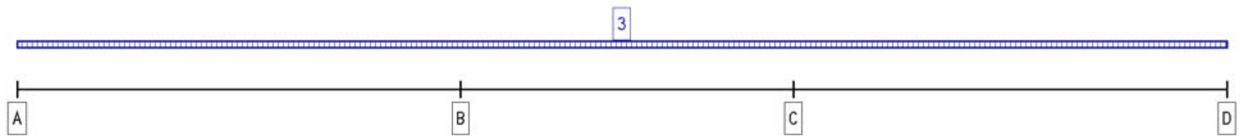
calculation DIN EN 1995:2010, Germany
service class 1

2. Structural system

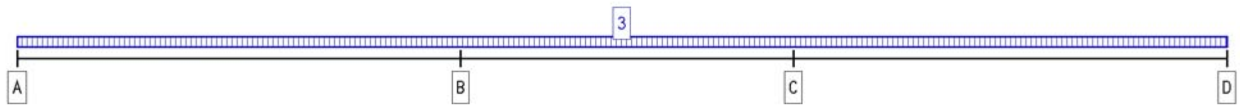


main beam

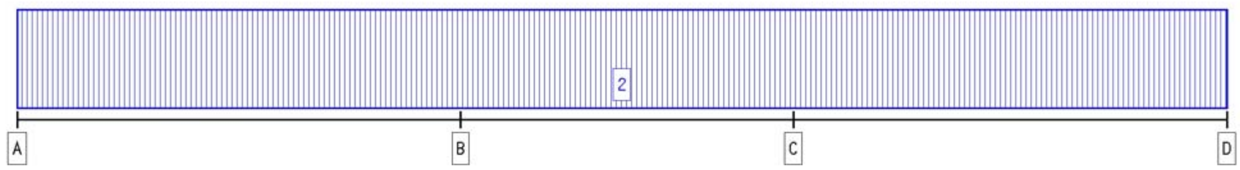
3. Loading



action effect 1: permanent loads (permanent, 2 load cases)



D

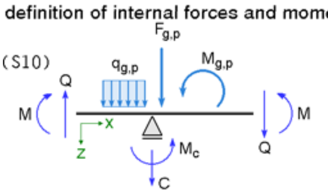


action effect 2: live loads (1) (transient, 1 load cases)

4. material parameters

```
beam Cross Laminated Timber     Leno, 160
structure                          34.0-34.0-24.0-34.0-34.0 solid coniferous timber, C24 (S10)
direction of fibre              x-axis (strong axis)
service class                   1
beam width/-höhe              b/h = 1000 mm / 160 mm
coeff. thermal expan. timber     0.500 *10-5 /°K
shear coefficient κ           0.166597
```

definition of internal forces and moments:



5. Beam sections

beam sections

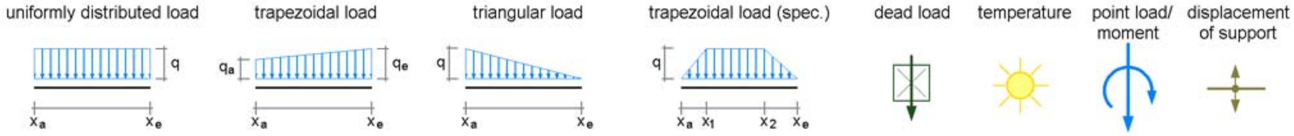
section	x_A m	x_E m	l m	l_v m	cantil.	EI_{eff} Nmm2	GA_{eff} N	EA_{eff} N	$EI_{eff,fire}$ Nmm2	$GA_{eff,fire}$ N	$EA_{eff,fire}$ N	$z_{s,fire}$ mm
1	-∞	4.60	4.60	4.60	-	3053.541	11142003.00	1012000000.	831.287	7539340.500	662750016.0	46.2
2	-∞	8.05	3.45	3.45	-	3053.541	11142003.00	1012000000.	831.287	7539340.500	662750016.0	46.2
3	-∞	12.55	4.50	4.50	-	3053.541	11142003.00	1012000000.	831.287	7539340.500	662750016.0	46.2

6. Supports

coordinates of supports

supp.name	x	width	depth	c_F	c_M	restraint	
	m	mm	mm	kN/m	kNm/-	(F)	(M)
A	0.00	100	1000	fix	----	X	-
B	4.60	111	1000	fix	----	X	-
C	8.05	111	1000	fix	----	X	-
D	12.55	100	1000	fix	----	X	-

7. Action effects



Permanent action effect: permanent loads
3. additive load case: EG
⇒ unif.distr.load: q = 0.82 kN/m from x_a = 0.00 m to x_e = 12.55 m
⇒ unif.distr.load: q = 1.32 kN/m from x_a = 0.00 m to x_e = 12.55 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 = 12.55 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 vom Benutzer definiert!
w_{inst} ≤ l_v / 300, cantilever: l_v / 150
w_{fin} ≤ l_v / 200, cantilever: l_v / 100
$w_{net,fin}$ ≤ l_v / 200, cantilever: l_v / 100
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	x	30.00	-	50.00	0.75	31.75

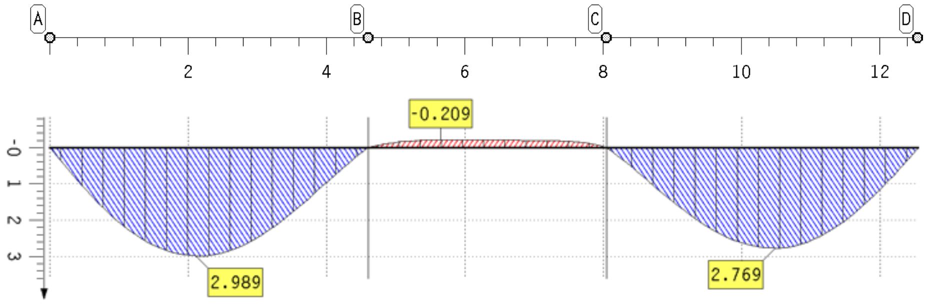
Extreme rule 1: standardkombination

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 innerhalb einer Nutzungseinheit ⇒ f_{grenz} = 6 Hz, w_{grenz} = 1.0 mm, a_{grenz} = 0.10 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 %
60 mm, E = 25000 N/mm^2, g = 0.220 kN/mm^2, I_{screed} = 18 mm^4
in consideration of 2-dimensional effects

9. Results of load cases

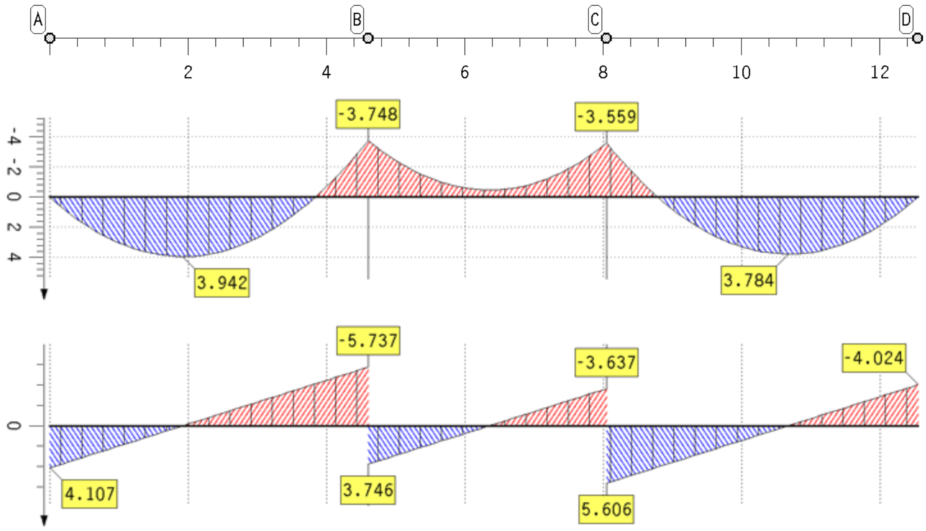
9.1. Action effect 1: load case 3: EG

deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: -0.21
Max: 2.99

internal forces and moments



flexural moment
main beam
M in kNm
Min: -3.75
Max: 3.94

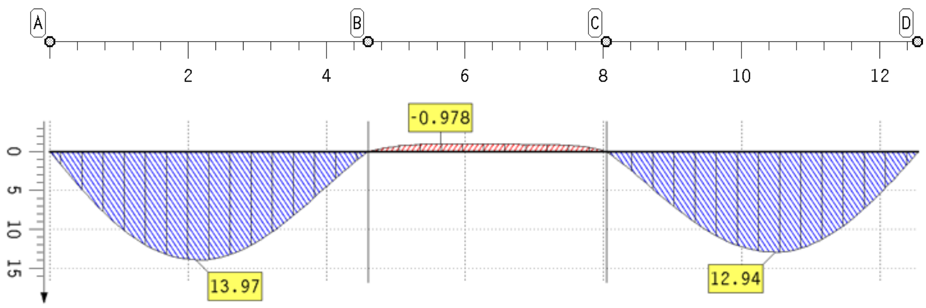
shear force
main beam
V in kN
Min: -5.74
Max: 5.61

support forces

point	x	AP
-	m	kN
A	0.000	-4.11
B	4.600	-9.48
C	8.050	-9.24
D	12.550	-4.02

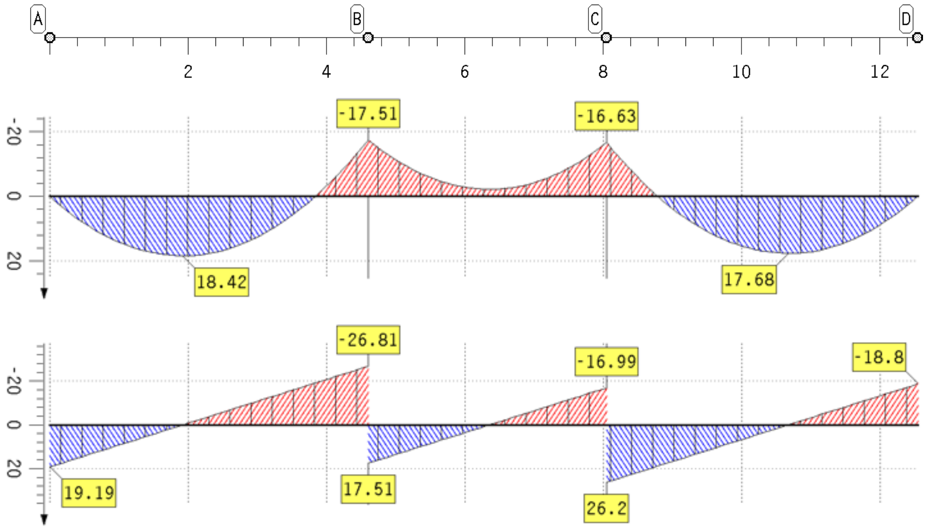
9.2. Action effect 2: load case 2: live loads (1/1)

deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: -0.98
Max: 13.97

internal forces and moments



flexural moment
main beam
M in kNm
Min: -17.51
Max: 18.42

shear force
main beam
V in kN
Min: -26.81
Max: 26.20

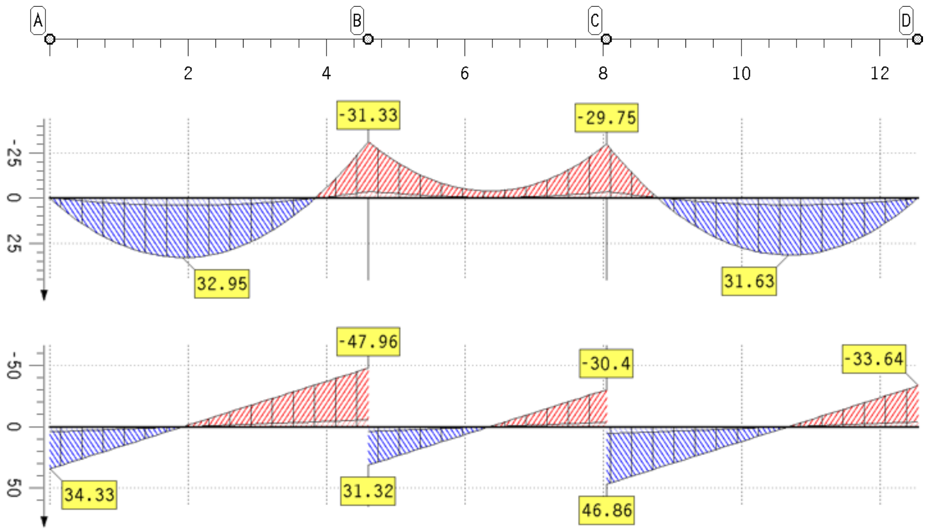
support forces

point	x	AP
-	m	kN
A	0.000	-19.19
B	4.600	-44.31
C	8.050	-43.19
D	12.550	-18.80

10. Results of verification of ultimate limit state

10.1. Verification of ultimate limit state

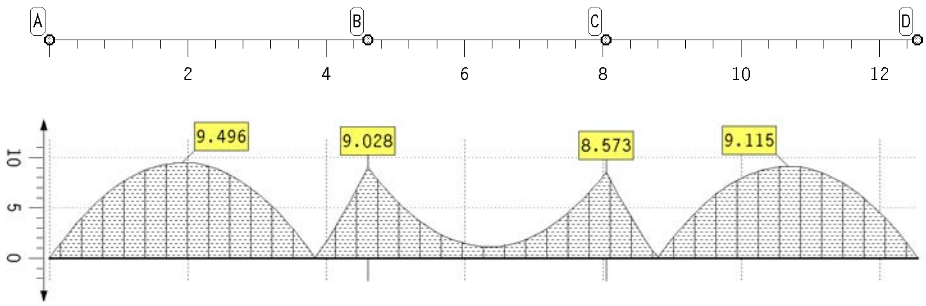
extremal internal forces



flexural moment
main beam
M in kNm
Min: -31.33
Max: 32.95

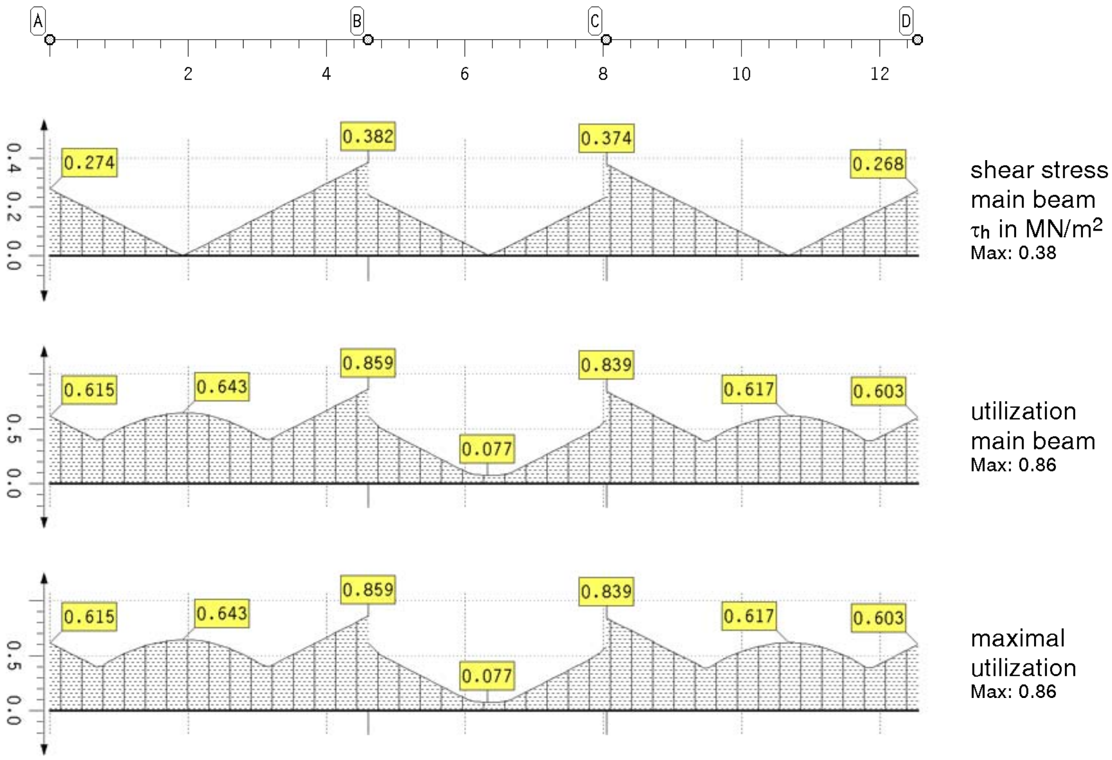
shear force
main beam
V in kN
Min: -47.96
Max: 46.86

results of verification of ultimate limit state



bending stress
main beam
σ_h in MN/m^2
Max: 9.50

results of verification of ultimate limit state



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	0.27	0.615
	0.671	0.000	5.48	0.18	0.400
	1.342	0.000	8.64	0.08	0.585
	1.917	0.000	9.50	0.00	0.643
	2.492	0.000	8.65	0.08	0.586
	3.162	0.000	5.51	0.18	0.398
	3.833	0.000	0.05	0.27	0.613
B	4.600	0.000	9.03	0.38	0.859
B	4.600	0.000	9.03	0.25	0.611
	5.463	0.000	3.16	0.13	0.285
	6.325	0.000	1.13	0.00	0.077
	7.188	0.000	2.93	0.12	0.268

point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m^2	MN/m^2	-
C	8.050	0.000	8.57	0.24	0.580
C	8.050	0.000	8.57	0.37	0.839
	8.800	0.000	0.11	0.27	0.599
	9.456	0.000	5.32	0.17	0.389
	10.113	0.000	8.32	0.08	0.563
	10.675	0.000	9.12	0.00	0.617
	11.238	0.000	8.28	0.08	0.561
	11.894	0.000	5.25	0.17	0.392
D	12.550	0.000	0.00	0.27	0.603
minimum		**0.000**	**0.00**	**0.00**	**0.077**
maximum		**0.000**	**9.50**	**0.38**	**0.859**

maximal utilization

point	x	U
-	m	-
A	0.000	0.615
	0.671	0.400
	1.342	0.585
	1.917	0.643
	2.492	0.586
	3.162	0.398

point	x	U
-	m	-
B	4.600	0.859
B	4.600	0.611
	6.037	0.100
	6.325	0.077
	6.708	0.115
C	8.050	0.580

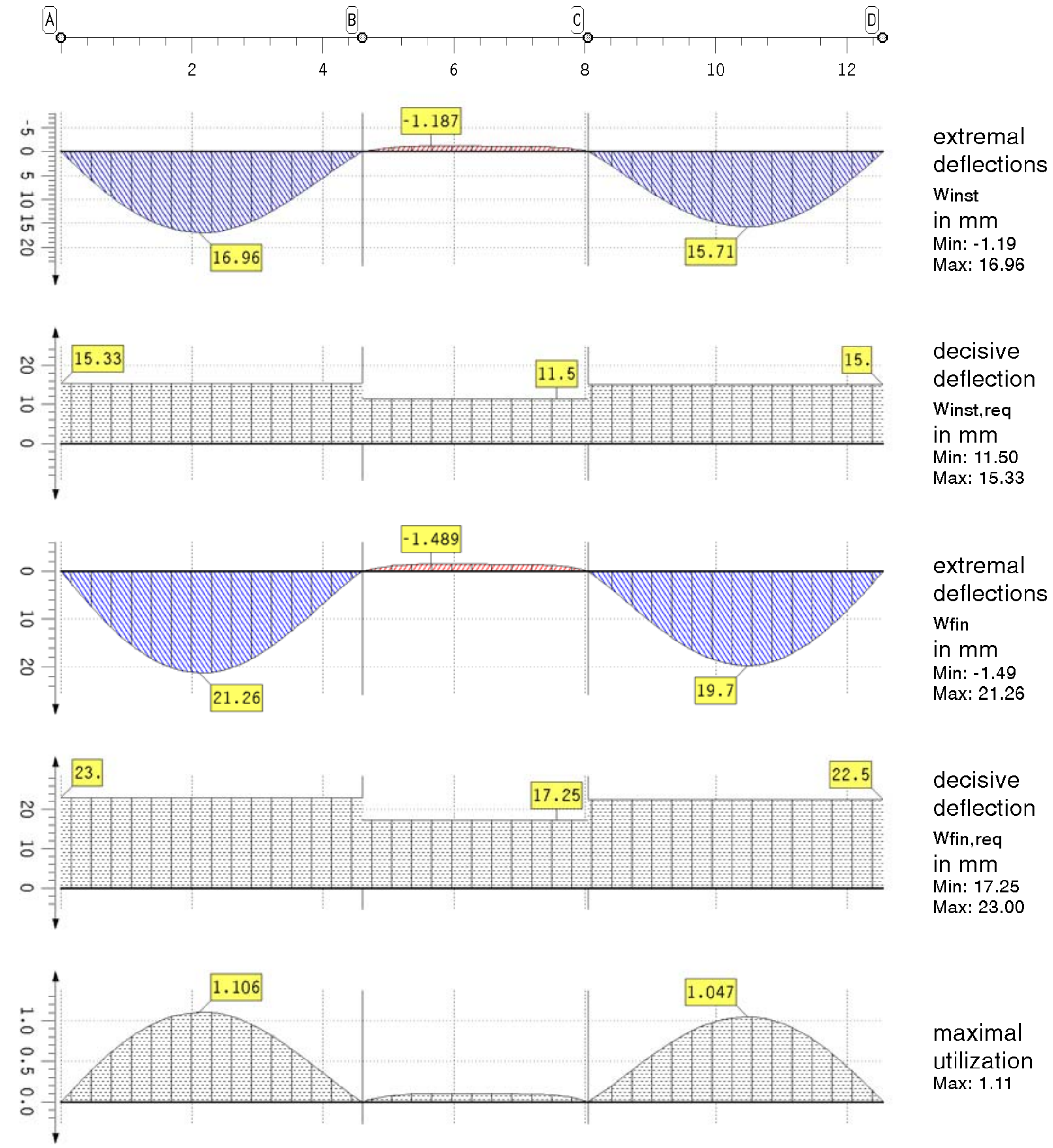
point	x	U
-	m	-
C	8.050	0.839
	9.456	0.389
	10.113	0.563
	10.675	0.617
	11.238	0.561
	11.894	0.392

point	x	U
-	m	-
D	12.550	0.603
minimum		**0.077**
maximum		**0.859**

11. Results of verification of deflections

11.1. Verification of deflections

results of verification of deflections



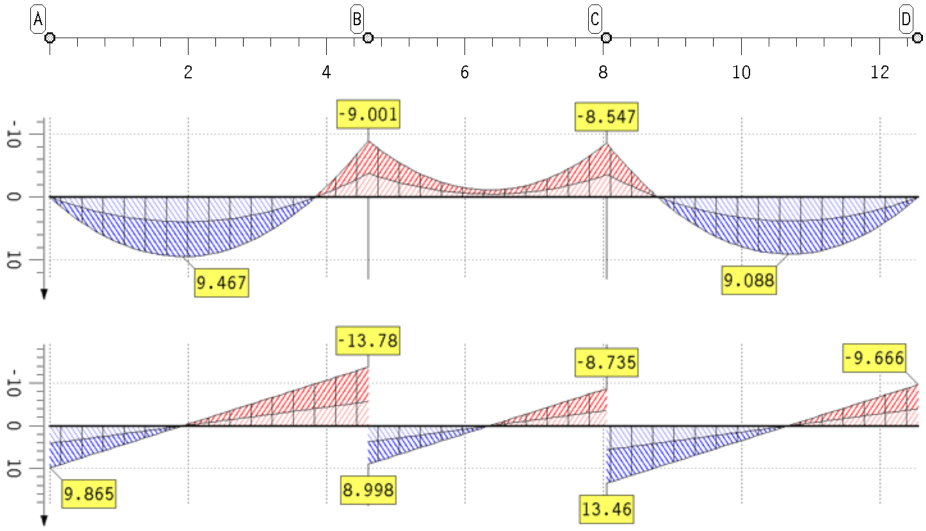
verification of deflections

point	x	min/max/req Winst			min/max/req Wfin			min/max/req Wnet,fin			U
-	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	-
A	0.000	0.00	0.00	15.33	0.00	0.00	23.00	----	----	----	0.000
	1.150	0.00	12.92	15.33	0.00	16.20	23.00	----	----	----	0.842
	2.108	0.00	16.96	15.33	0.00	21.26	23.00	----	----	----	1.106
	3.067	0.00	13.61	15.33	0.00	17.07	23.00	----	----	----	0.888
B	4.600	0.00	0.00	15.33	0.00	0.00	23.00	----	----	----	0.000
B	4.600	0.00	0.00	11.50	0.00	0.00	17.25	----	----	----	0.000
	4.792	-0.50	0.00	11.50	-0.63	0.00	17.25	----	----	----	0.043
	5.079	-0.94	0.00	11.50	-1.18	0.00	17.25	----	----	----	0.082
	5.654	-1.19	0.00	11.50	-1.49	0.00	17.25	----	----	----	0.103
	7.379	-1.03	0.00	11.50	-1.29	0.00	17.25	----	----	----	0.089
	7.762	-0.64	0.00	11.50	-0.80	0.00	17.25	----	----	----	0.056
C	8.050	0.00	0.00	11.50	0.00	0.00	17.25	----	----	----	0.000
C	8.050	0.00	0.00	15.00	0.00	0.00	22.50	----	----	----	0.000
	9.550	0.00	12.64	15.00	0.00	15.85	22.50	----	----	----	0.842
	10.488	0.00	15.71	15.00	0.00	19.70	22.50	----	----	----	1.047
	11.425	0.00	11.96	15.00	0.00	15.00	22.50	----	----	----	0.797
D	12.550	0.00	0.00	15.00	0.00	0.00	22.50	----	----	----	0.000
minimum		**-1.19**	**0.00**	**11.50**	**-1.49**	**0.00**	**17.25**	**0.00**	**0.00**	**0.00**	**0.000**
maximum		**0.00**	**16.96**	**15.33**	**0.00**	**21.26**	**23.00**	**0.00**	**0.00**	**0.00**	**1.106**

12. Results of verification of fire protection

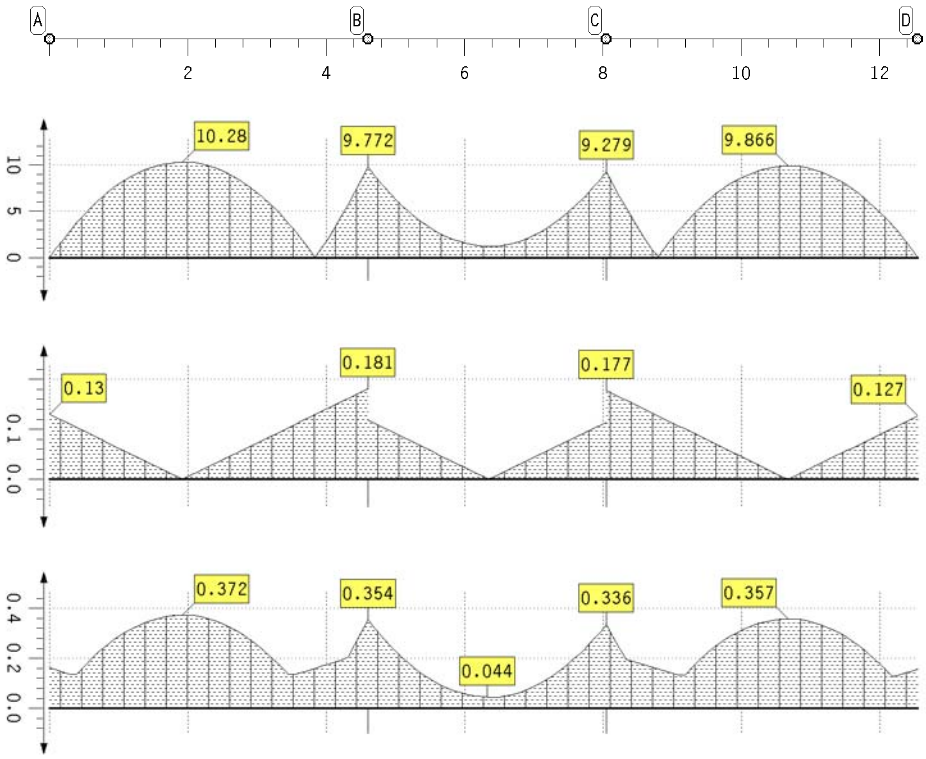
12.1. Verification of fire protection

extremal internal forces



flexural moment
main beam
M in kNm
Min: -9.00
Max: 9.47

shear force
main beam
V in kN
Min: -13.78
Max: 13.46



bending stress
main beam
σ_h in MN/m²
Max: 10.28

shear stress
main beam
τ_h in MN/m²
Max: 0.18

utilization
main beam
Max: 0.37

verification of ultimate limit state of main beam

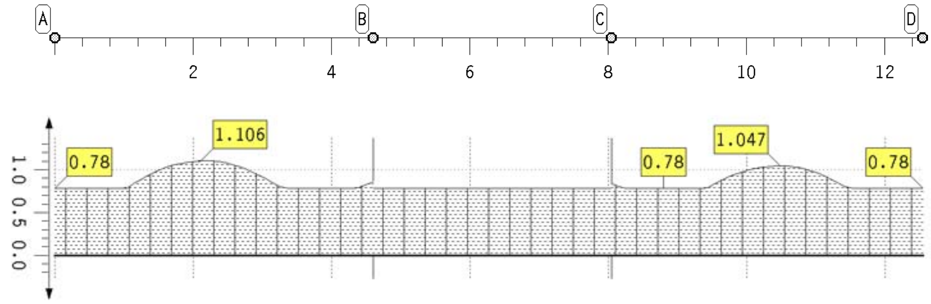
point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m²	MN/m²	-
A	0.000	0.000	0.00	0.13	0.161
	0.383	0.000	3.70	0.10	0.134
	1.150	0.000	8.63	0.05	0.313
	1.917	0.000	10.28	0.00	0.372
	2.683	0.000	8.65	0.05	0.313
	3.450	0.000	3.74	0.10	0.136
	3.833	0.000	0.06	0.13	0.161
	4.312	0.000	5.70	0.16	0.207
B	4.600	0.000	9.77	0.18	0.354
B	4.600	0.000	9.77	0.12	0.354
	5.463	0.000	3.42	0.06	0.124
	6.325	0.000	1.22	0.00	0.044
	7.188	0.000	3.18	0.06	0.115

point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m²	MN/m²	-
C	8.050	0.000	9.28	0.11	0.336
C	8.050	0.000	9.28	0.18	0.336
	8.331	0.000	5.39	0.16	0.196
	8.800	0.000	0.11	0.13	0.157
	9.175	0.000	3.63	0.10	0.132
	9.925	0.000	8.32	0.05	0.301
	10.675	0.000	9.87	0.00	0.357
	11.425	0.000	8.27	0.05	0.300
	12.175	0.000	3.54	0.10	0.128
D	12.550	0.000	0.00	0.13	0.158
minimum		**0.000**	**0.00**	**0.00**	**0.044**
maximum		**0.000**	**10.28**	**0.18**	**0.372**

13. Summary

13.1. Summary of all verifications

maximal utilization



utilization
Max: 1.11

13.2. Eigenfrequenz

$EI_{längs}$ = 3.503541 MNm²/m, EI_{quer} = 1.151125 MNm²/m

f_e = 11.036 Hz ≥ f_e = 6 Hz ⇒ **Kriterium successful!**

13.3. Steifigkeitskriterium

Raumbreite b = 1.000 m, b_{ef} = 1.000 m, $x_{max\ F}$ = 2.119 m, $x_{max\ w}$ = 2.119 m ⇒ w_{max} = 0.390 mm

w(2kN) = 0.78 mm ≤ w_{grenz} = 1.0 mm ⇒ **Kriterium successful!**

13.4. Konstruktive Anforderungen

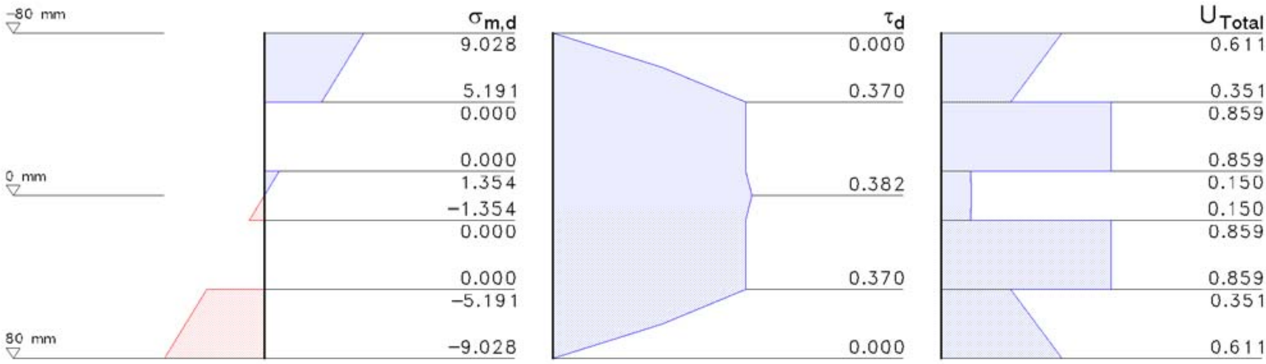
Schwimmende supportung des screeds ist unbedingt erforderlich!
Nach [Winter/Hamm/Richter], TU München 2010 gilt:
Nassestriche sind aufgrund ihrer höheren Masse and höheren Steifigkeit gegenüber Trockenestrichen günstiger zu bewerten, was das Schwingungsverhalten der Decken betrifft.
Eine (möglichst schwere) 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.

14. Utilizations of all verifications

verification der deformations (u = 1.106) does not meet the requirements!

15. Detailed verification piont

15.1. Verification of load-carrying capacity at x = 4.60 m, maxV_d = -5.74 kN, minM_d = -31.33 kNm, maxM_d = -3.75 kNm

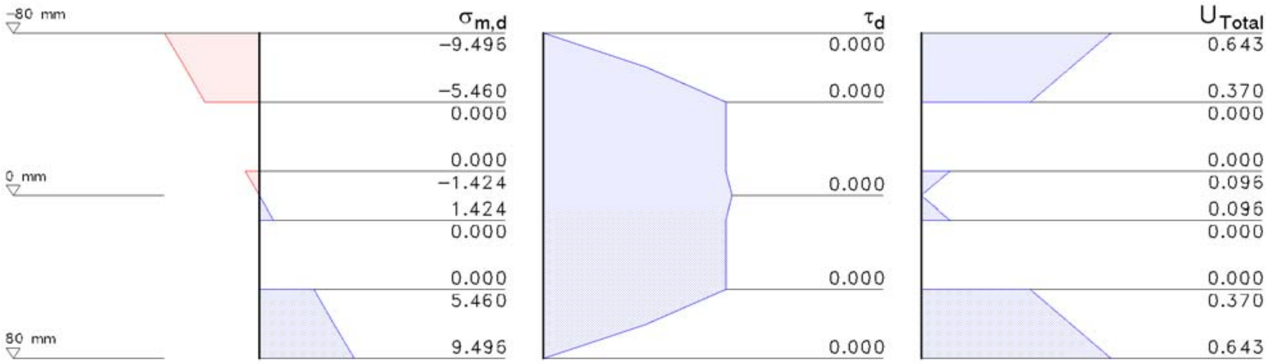


mechanical resistance and static terms: stiffness B_x = 3053.541 Nmm

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
80.0	0.000	-9.028	14.77	0.000	2.46
63.0	-13.370	-7.110	14.77	0.210	2.46
46.0	-23.562	0.000	14.77	0.370	0.43
29.0	-23.562	0.000	14.77	0.370	0.43
12.0	-23.562	-1.354	14.77	0.370	2.46
0.0	-24.354	-0.000	14.77	0.382	2.46

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
-12.0	-23.562	0.000	14.77	0.370	0.43
-29.0	-23.562	0.000	14.77	0.370	0.43
-46.0	-23.562	5.191	14.77	0.370	2.46
-63.0	-13.370	7.110	14.77	0.210	2.46
-80.0	0.000	9.028	14.77	0.000	2.46

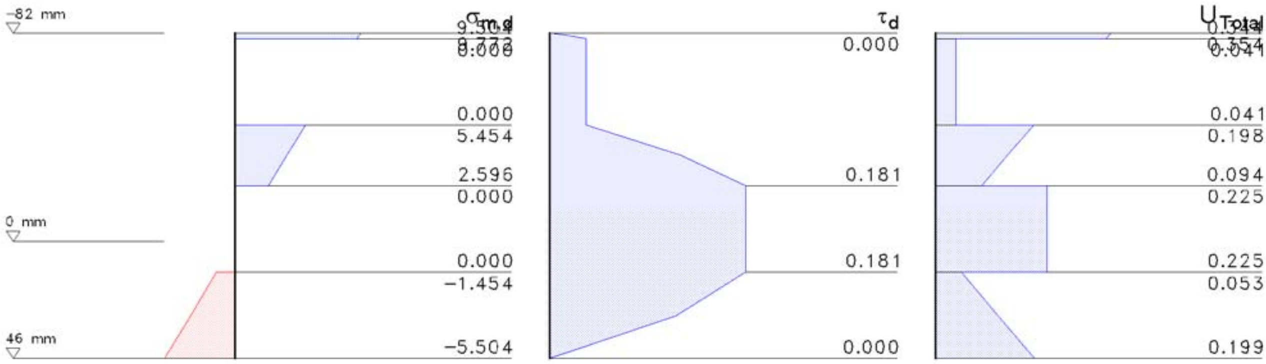
15.2. Verification of load-carrying capacity at x = 1.92 m, maxV_d = 0.05 kN, minM_d = 3.94 kNm, maxM_d = 32.95 kNm



mechanical resistance and static terms: stiffness B_x = 3053.541 Nmm

z mm	ESx Nmm	σm,d N/mm²	fm,d N/mm²	τv,d N/mm²	fv,d N/mm²
80.0	0.000	9.496	14.77	0.000	2.46
63.0	-13.370	7.478	14.77	0.000	2.46
46.0	-23.562	0.000	14.77	0.000	0.43
29.0	-23.562	0.000	14.77	0.000	0.43
12.0	-23.562	1.424	14.77	0.000	2.46
0.0	-24.354	0.000	14.77	0.000	2.46
-12.0	-23.562	0.000	14.77	0.000	0.43
-29.0	-23.562	0.000	14.77	0.000	0.43
-46.0	-23.562	-5.460	14.77	0.000	2.46
-63.0	-13.370	-7.478	14.77	0.000	2.46
-80.0	0.000	-9.496	14.77	0.000	2.46

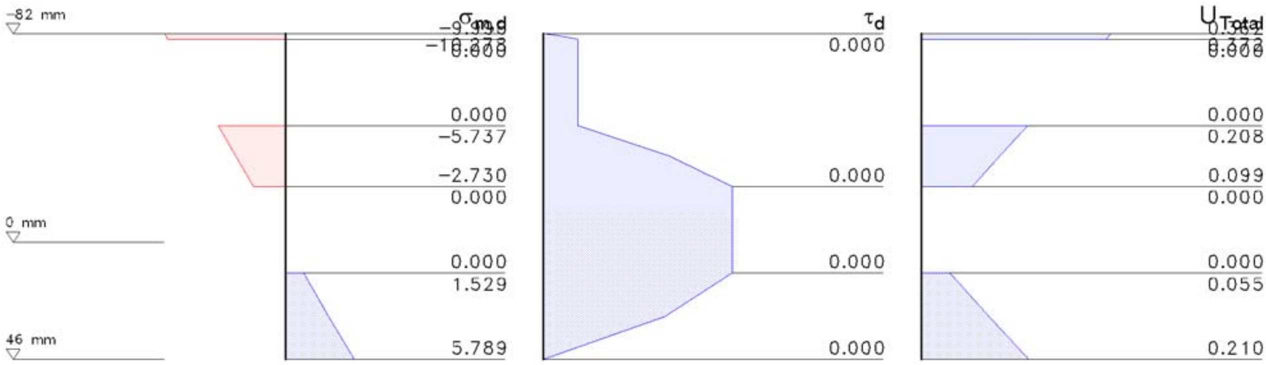
15.3. Resistance to fire at x = 4.60 m, maxV_d = -5.74 kN, minM_d = -9.00 kNm, maxM_d = -3.75 kNm



mechanical resistance and static terms: stiffness B_x = 831.287 Nmm

z mm	ESx Nmm	σm,d N/mm²	fm,d N/mm²	τv,d N/mm²	fv,d N/mm²
46.2	0.000	-5.504	27.60	0.000	4.60
29.2	-7.051	-3.479	27.60	0.117	4.60
12.2	-10.924	0.000	27.60	0.181	0.81
-4.8	-10.924	0.000	27.60	0.181	0.81
-21.8	-10.924	2.596	27.60	0.181	4.60
-33.8	-7.255	4.025	27.60	0.120	4.60
-45.8	-2.003	0.000	27.60	0.033	0.81
-62.8	-2.003	0.000	27.60	0.033	0.81
-79.8	-2.003	9.504	27.60	0.033	4.60
-80.9	-1.008	9.638	27.60	0.017	4.60
-82.0	0.000	9.772	27.60	0.000	4.60

15.4. Resistance to fire at x = 1.92 m, maxV_d = 0.01 kN, minM_d = 3.94 kNm, maxM_d = 9.47 kNm



mechanical resistance and static terms: stiffness B_x = 831.287 Nmm

z mm	ESx Nmm	σm,d N/mm²	fm,d N/mm²	τv,d N/mm²	fv,d N/mm²
46.2	0.000	5.789	27.60	0.000	4.60
29.2	-7.051	3.659	27.60	0.000	4.60
12.2	-10.924	0.000	27.60	0.000	0.81
-4.8	-10.924	0.000	27.60	0.000	0.81
-21.8	-10.924	-2.730	27.60	0.000	4.60
-33.8	-7.255	-4.233	27.60	0.000	4.60
-45.8	-2.003	0.000	27.60	0.000	0.81
-62.8	-2.003	0.000	27.60	0.000	0.81

mechanical resistance and static terms: stiffness B_x = 831.287 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
-79.8	-2.003	-9.996	27.60	0.000	4.60
-80.9	-1.008	-10.137	27.60	0.000	4.60
-82.0	0.000	-10.278	27.60	0.000	4.60