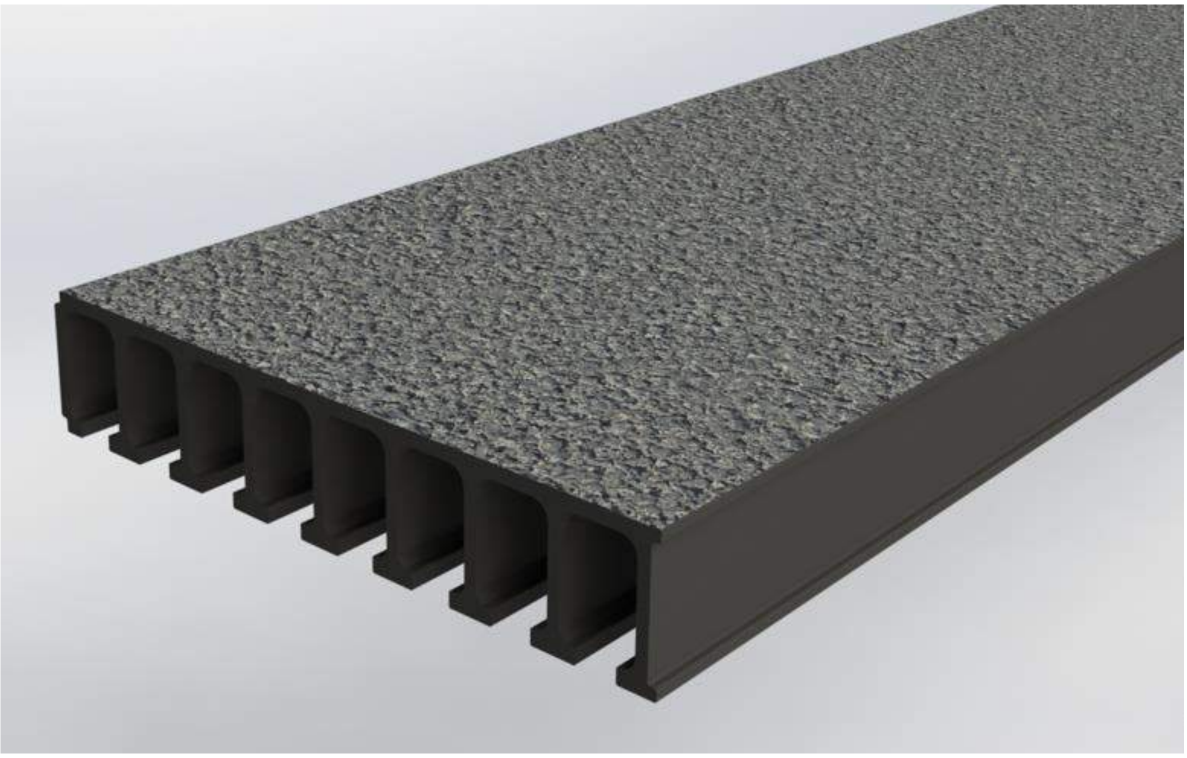
Solico Engineering B.V.
Innovatiepark 24
NL-4906 AA Oosterhout
Nederland
Tel.: +31-162-462280
E-mail: composites@solico.nl
Bankrelatie: Rabobank Oosterhout
Rek.nr. NL33 RABO 0311 2315 27
K.v.K. Breda nr. 66511291



krafton® bridge deck plank 400.80

Assessment acc. to Eurocode NL

Client	:	krafton®
Excecution	:	ing. M. Snoek
Authorized	:	ing. D.A. Mager
Report no.	:	R_10696-1
Issue	:	3
Date	:	24-11-2023

This report has been translated from Dutch

Table of contents

Issue management

Issue	Comments	Date
1	First issue	23-03-2023
2	Addition of alternative service vehicles	29-08-2023
3	Table in Chapter 1 corrected	24-11-2023

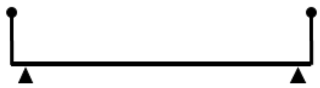
1 Summary

The mechanical properties were used to determine the maximum span of the bridge deck plank for loads from the Dutch National Annex of EN1991-2 and for multiple deflection requirements. The following situations were reported:

Multiple single spans:

One single span:

(Plank = entire bridge width)



(Multiple) multi-spans[1]:

The maximum span recommendations for plank 400.80 are:

	Multiple single spans	One single span	Multiple multi-spans
Without vehicles	3420 mm	3420 mm	4470 mm
Only service vehicle 50kN	2000 mm	2330 mm	2330 mm
Only service vehicle 100kN	1410 mm	2070 mm	1780 mm
Only service vehicle 160kN	1120 mm	1960 mm	1670 mm
Only service vehicle 200kN	1000 mm	1920 mm	1240 mm
Only accidental vehicle	2170 mm	2170 mm	2170 mm
Service (50kN) and accidental vehicle	2000 mm	2170 mm	2170 mm

On the following pages, the results of the maximum span recommendations are presented in graph form. When a span is chosen in combination with a deflection requirement below the relevant lines in the graph, the krafton® 400.80 meets the specified requirements for a bridge deck plank in accordance with Eurocode for use as a bicycle - pedestrian bridge deck in consequence class CC2.

The analysis for 3 or more supports assumes supports at equal distance from each other.

The maximum allowable cantilever for every situation is 350 mm.

Note:

- A minimum deflection requirement of L/200 has been used for the service vehicle
- Deflection analysis for service vehicles on multi-span planks is according to situation 1, as per figure 1. In case situation 2 can occur, an additional analysis needs to be performed.

[1] A multi-span is a situation where the bridge deck plank continues uninterrupted over at least 3 supports. A connection is made at the support that sufficiently fixes the plank in the vertical direction, both upwards and downwards.

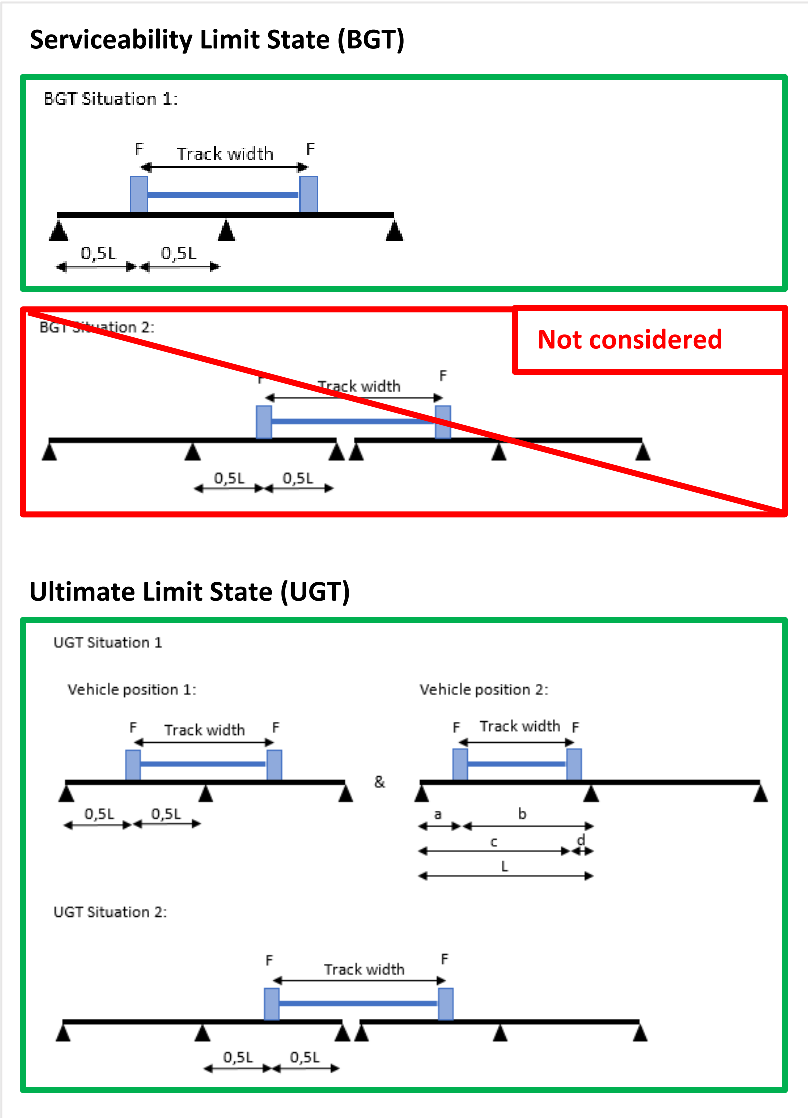


figure 1: Considered situations service- and accidental vehicle multi-span BGT and UGT

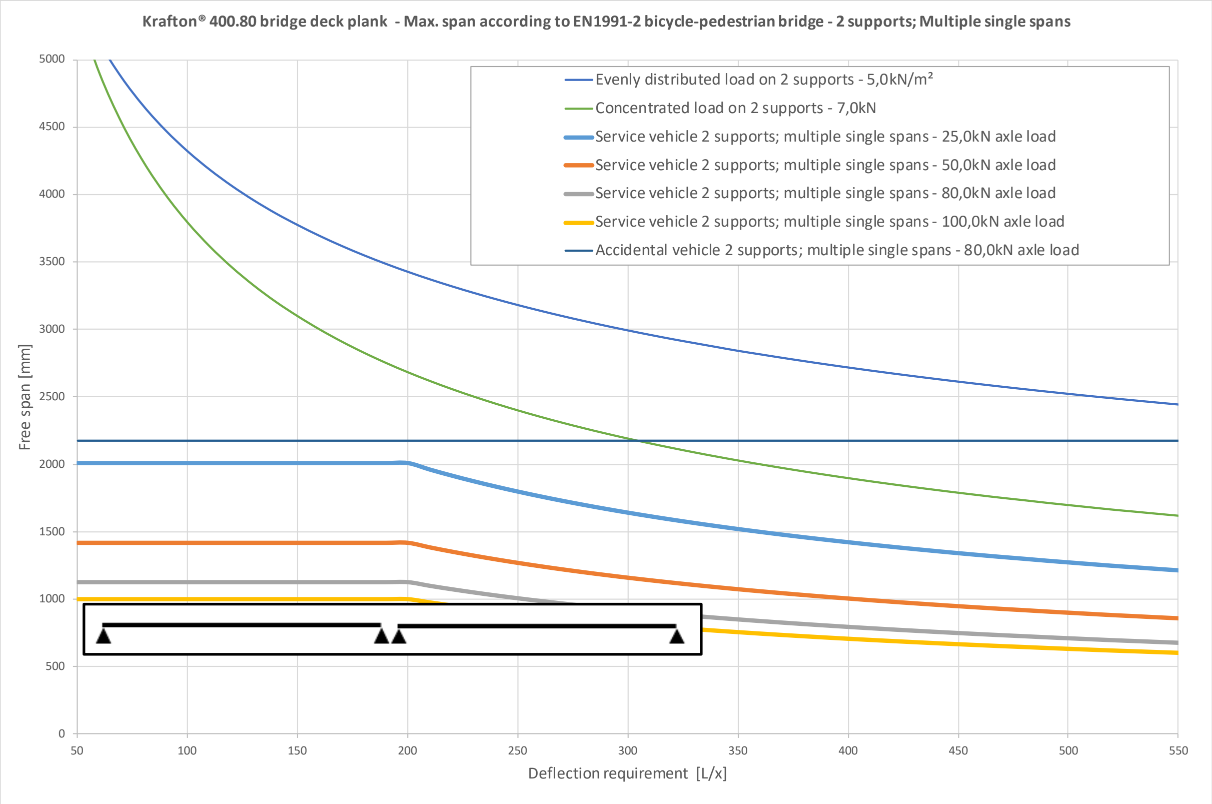


figure 2: Maximum span as a function of deflection requirements; 2 supports; multiple single spans

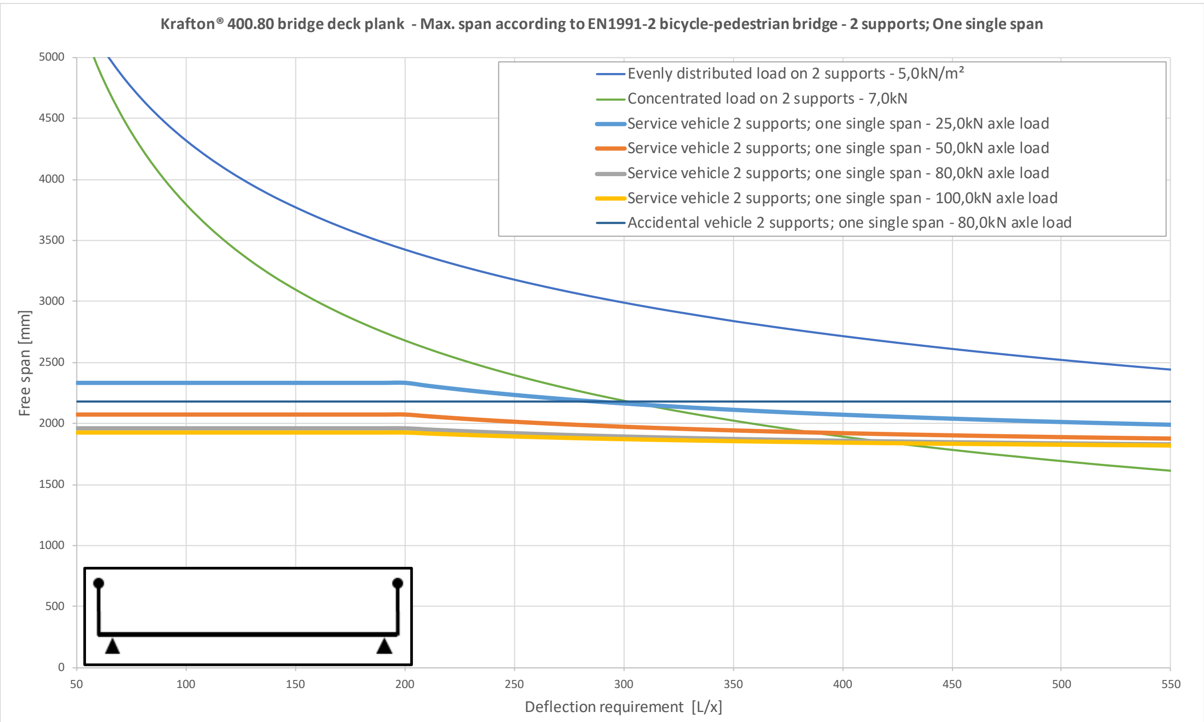


figure 3: Maximum span as a function of deflection requirements; 2 supports; one single span

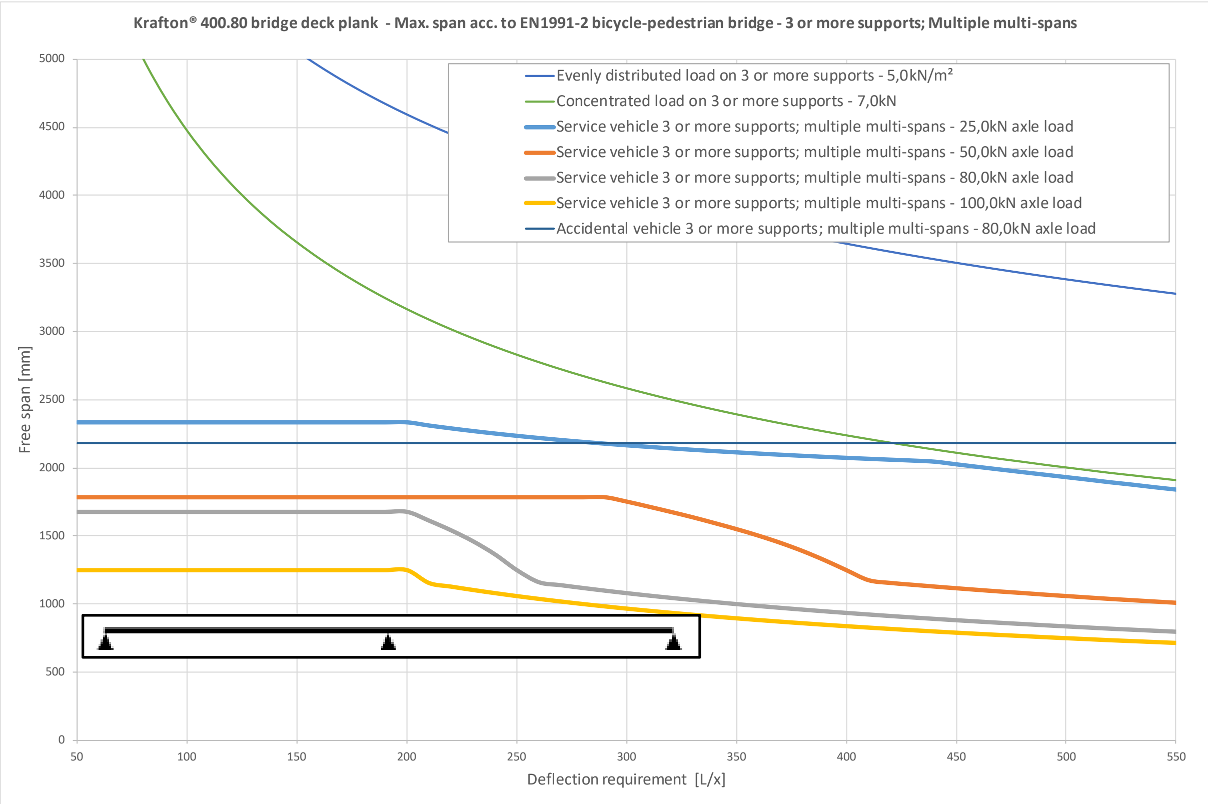


figure 4: Maximum span as a function of deflection requirements; 3 or more supports

For questions or special applications, please contact:

krafton®
Markweg Zuid 34
4794 SN Heijningen

T +31 (0) 168227510

E / info@krafton.nl

2 Product description

Pultruded, glass fibre reinforced polyester bridge deck plank.

A cross section of the plank is shown in figure 5.

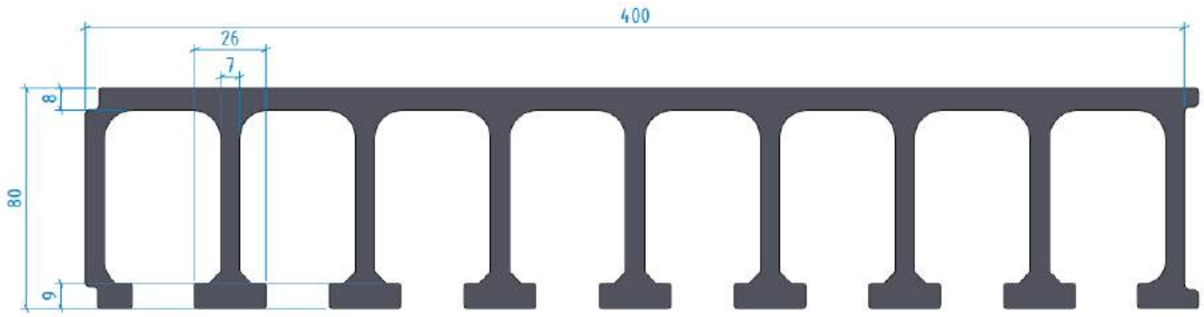


figure 5: Geometry plank 400.80

2.1 Geometric properties

Width	b	400	mm
Height	h	80	mm
Number of ribs	n	9	-
Rib spacing	d	42.125	mm
Sectional area	A	9586	mm^2
Shear area	A_s	4455	mm^2
Moment of inertia	I	8048641	mm^4
Section modulus	W	176245	mm^3
Weight of plank	G	47.9	kg/m^2

2.2 Mechanical properties

The characteristic mechanical properties are shown in table 1, complete mechanical properties can be found in Appendix A: Properties of the bridge deck plank.

table 1: Characteristic mechanical properties

		Unit	krafton® 400.80
Modulus of elasticity	($E_{b,kar}$)	N/mm²	32154
Flexural stress[2]	($\sigma_{b,kar}$)	N/mm²	293
Shear stress	(τ_{kar})	N/mm²	50.5
Shear force on 100x100mm	($D_{kar,100}$)	N	81138
Shear force on 200x200mm	($D_{kar,200}$)	N	120646

[2]Lowest value of single- and multispan tests.

3 Requirements

3.1 Standards and recommendations

The bridge deck plank has been assessed according to the following standards and recommendations.

Standard	Title	Issue
NEN-EN 1990	Eurocode - Basis of structural design	2011
NEN-EN 1991-2+C1	Traffic loads on bridges	2015
NEN-EN 1991-1-3	Actions on structures - Part 1-3: General actions - Snow loads	2011
CUR recommendation 96 (2019)	Fibre-Polymer Composite Structures in Civil Applications	2019
EN 13706-3	Specification for pultruded profiles – Part 3: Specific requirements	2002

3.2 National Annex Netherlands

Standard	Title	Issue
NEN-EN 1990+A1+A1/C2/NB	Dutch National Annex to Eurocode: Fundamentals of structural design	2011
NEN-EN 1991-2+C1/NB	Dutch National Annex to Eurocode: Traffic loads on bridges	2019
NEN-EN 1991-1-3/NB	Dutch National Annex to Eurocode: Part 1-3: General loads – Snow loads	2011

3.3 *Loads*

3.3.1 Permanent load (G)

The permanent load on the bridge deck is caused by the weight of the bridge deck planks and the protective abrasion layer. The following masses have been used.

GRP bridge deck planks	47.9 kg/m²		
Abrasion layer	13.0 kg/m²		
Total permanent load	60.9 kg/m²	=	0.609 kN/m² [G]

3.3.2 Variable load (Q)

3.3.2.1 Mobile load

Evenly distributed load		5.0 kN/m²	[Qf]
Concentrated load		7.0 kN	[Qf;w]
	Dimension concentrated load	100 x 100 mm²	
Service vehicle 50kN			
	Axle 1	25.0 kN	[Qd]
	Wheel print	250 x 250 mm²	
	Axle 2	25.0 kN	
	Wheel print	250 x 250 mm²	
	Track width	1750 mm	
	Wheelbase	3000 mm	
Service vehicle 100kN			
	Axle 1	50.0 kN	[Qd]
	Axle 2	50.0 kN	
Service vehicle 160kN			
	Axle 1	80.0 kN	[Qd]
	Axle 2	80.0 kN	
Service vehicle 200kN			
	Axle 1	100.0 kN	[Qd]
	Axle 2	100.0 kN	

Wheel print, track width and wheelbase of service vehicle 100kN, 160kN and 200kN is the same as service vehicle 50kN.

3.3.2.2 Snow

Maximum possible snow load	0.7 kN/m²	
Maximum form factor (closed railing)	2 -	
Maximum snow load	1.4 kN/m²	[Qs]

3.3.3 Special load (A)

Accidental vehicle with the following characteristics:

Accidental vehicle of 120 kN

Axle 1	80.0 kN	[Aov]
Wheel print	200 x 200 mm	
Axle 2	40.0 kN	
Wheelprint	200 x 200 mm	
Track width	1300 mm	
Wheelbase	3000 mm	

3.4 Requirements

3.4.1 Requirements serviceability limit state

The deflection requirement can be determined separately for each project.

The verification calculation is reported for a deflection recommendation.

The deflection requirements are set for deflection due to variable loadings.

All deflection requirements up to a requirement of L/550 are calculated and reported in figure 2, figure 3 and figure 4.

The following maximum deflection recommendations are used:

- L/200 Distributed mobile load
- L/100 Concentrated load
- L/200 Service vehicle
- No deflection recommendations for other loads considered

3.4.2 Comfort

The comfort requirement is in accordance with JRC document "JRC 53443 human induced vibrations".

Desired comfort level CL1.

Maximum allowable acceleration is 0,5 m/s^2. This is guaranteed when the Eigen frequency is above 5Hz. This report uses the stated Eigen frequency as a lower limit.

3.4.3 Requirements ultimate limit state

Strength requirement in accordance with CUR 96:

$$E_d \leq \frac{\eta_c \cdot R_k}{\gamma_m}$$

E_d Design load
R_k Characteristic resistance
η_c Conversion factor
γ_M Material factor

Since η_c is dependent on the duration of the load, it is included in the load combination.

$$\frac{E_d}{\eta_c} \leq \frac{R_k}{\gamma_m}$$

3.4.4 Material factor

The CUR “Recommendation 96” prescribes material factors with regard to the properties of fibre-reinforced plastics that must be taken into account when checking the ultimate limit state. These values are valid for post-cured laminates produced by pultrusion.

γ_{M1} is the partial material factor linked to geometrical deviations and modelling uncertainties in obtaining the correct material properties.

γ_{M2} is the partial material factor that takes into account uncertainties in the strength properties of the material and depends on the distribution in material properties.

$\gamma_M = \gamma_{M1} \times \gamma_{M2}$

γ_{M1}	=	1,15	For strength	
γ_{M2}	=	1,20	For pultrusion	

Resulting:

γ_M	=	1,38	For strength	(=1,15 x 1,20)

SOLICO
ENGINEERING IN COMPOSITES

3.5 *Load combinations*

3.5.1 Conversion factors

The CUR “Recommendation 96” 2017 prescribes conversion factors with regards to the properties of fibre-reinforced plastics that must be taken into account when checking the various limit states.

The conversion factor takes into account the anticipated effects of temperature, time, environmental influences (moisture, sunlight), duration of the load and cyclical loads on the material properties. The conversion factor can be different for each type of load (short or long term). The conversion factor η_c, is made up of:

$$\eta_c = \eta_{ct} \cdot \eta_{cm} \cdot \eta_{cv} \cdot \eta_{cf}$$

η_{ct}	=	1,0	Temperature effects (BGT[3])
η_{ct}	=	0,9	Temperature effects (UGT[4])
η_{cm}	=	0,9	Effects of water(vapour)
$\eta_{cv,short}$	=	1,0	Creep effects - short term (1 hour)
$\eta_{cv,middle}$	=	0,8	Creep effects - middle term (3 months)
$\eta_{cv,long}$	=	0,67	Creep effects - long term (100 years)
η_{cf}	=	0,9	Fatigue effects

Depending on the load duration and type of analysis, the conversion factors are combined, in accordance with CUR “Recommendation 96” 2019. These following conversion factors are combined with the load.

Deformation analysis (serviceability limit state):

$\eta_{c,short}$ = 0,81

$\eta_{c,middle}$ = 0,65

$\eta_{c,long}$ = 0,54

Analysis of strength (ultimate limit state):

$\eta_{c,short}$ = 0,81

$\eta_{c,middle}$ = 0,65

$\eta_{c,long}$ = 0,54

[3] BGT is the Dutch abbreviation for SLS (Serviceability Limit State)

[4] UGT is the Dutch abbreviation for ULS (Ultimate Limit State)

3.5.2 Load factors

The load factors in the serviceability limit state are equal to 1.0.

The load factors in the ultimate limit state are in accordance to consequence class **CC2**

table 2: Load factors in accordance to EN1991 NB

Gevolgklasse	β	G			Verkeer (met $\psi = 1$)	Overig veranderlijk (met $\psi = 1$)
		$\gamma_{G,j,sup}$		$\gamma_{G,j,inf}$		
		6.10a	6.10b (incl. ξ)	6.10a en 6.10b		
CC1	3,3	1,20	1,10	0,9	1,20	1,35
CC2	3,8	1,30	1,20	0,9	1,35	1,5
CC3	4,3	1,40	1,25	0,9	1,5	1,65

3.5.3 Combinations serviceability limit state (BGT)

$$BC = \frac{1}{\eta_c} \times G \ or \ \frac{1}{\eta_c} \times Q_i$$

Wherein:	η_c	conversion factor strength according to CUR 96; 2019
	G	permanent load (self-weight)
	Q_i	variable load i

BGT 1	1/001 x G
BGT 2	1/001 x Qf
BGT 3	1/001 x Qf;w
BGT 4	1/001 x Qd

3.5.4 Combinations ultimate limit state (UGT)

$$BC = \gamma_{G;sup} \frac{1}{\eta_c} \times G + \gamma_Q \frac{1}{\eta_c} \times Q_i$$

Wherein:	$\gamma_{G;sup}$	load factor permanent load according to N1990/NB
	η_c	conversion factor strength according to CUR 96; 2019
	γ_Q	load factor variable load according to N1990/NB
	G	permanent load (self-weight)
	Q_i	variable load i

UGT 1	,01 x 1/001 x G
UGT 2	,01 x 1/001 x G + ,01 x 1/001 x Qf
UGT 3	,01 x 1/001 x G + ,01 x 1/001 x Qf;w
UGT 4	,01 x 1/001 x G + ,01 x 1/001 x Qd
UGT 5	,01 x 1/001 x G + ,02 x 1/001 x Qs
UGT 6	,01 x 1/001 x G + ,01 x 1/001 x Aov

4 Symbols

y	=	vertical deflection [mm]
$y_{optr.}$	=	occurring deflection [mm]
$y_{toel.}$	=	allowable deflection [mm]
F	=	concentrated load [N]
q	=	distributed load [N/mm]
L	=	free span [mm]
E_b	=	flexural modulus [N/mm²]
I	=	moment of inertia [mm⁴]
$\sigma_{b,kar}$	=	characteristic bending strength [N/mm²]
$\sigma_{optr.}$	=	occurring flexural stress [N/mm²]
$\sigma_{toel.}$	=	allowable flexural stress [N/mm²]
W	=	section modulus [mm³]
γ_m	=	material reduction factor [-]
A_s	=	shear area [mm²]
b_o	=	width of concentrated load [mm]
L_o	=	length of concentrated load [mm]
L_s	=	track width [mm]
D	=	occurring shear force [N]
τ_{kar}	=	characteristic shear strength [N/mm²]
$\tau_{optr.}$	=	occurring shear stress [N/mm²]
$\tau_{toel.}$	=	allowable shear stress [N/mm²]
$D_{kar,i}$	=	characteristic resistance to shear due to a concentrated load [N]
BGT	=	serviceability limit state
UGT	=	ultimate limit state

5 Verification of allowable span on 2 supports

5.1 Self-weight

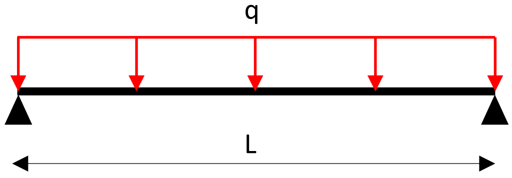
This load case is not a determining load case and has not been considered further.

5.2 *Distributed mobile load*

BGT 2	**1/001 x Qf**
UGT 2	**,01 x 1/001 x G + ,01 x 1/001 x Qf**

Plank width		0.400 m
Self-weight		0.609 kN/m²
Distributed mobile load		5.0 kN/m²
G		0.244 N/mm
Q_f		2.0 N/mm
Maximum span at L/200		3420 mm
	q_{BGT2}	2.47 N/mm
	q_{UGT2}	3.87 N/mm

The calculation uses the following situation:



5.2.1 BGT 2

Verification of deflection:

$$y = \frac{5 \times q \times L^4}{384 \times EI} \leq \frac{L}{200}$$

q	2.47 N/mm
L	3420 mm
E	32154 N/mm^2
I	8048641 mm^4
$y_{optr.}$	17.13 mm
$y_{toel.}$	17.13 mm
u.c.	1.00 OK

5.2.2 UGT 2

Verification of flexural stress:

$$\sigma_b = \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$

q	3.87	N/mm
L	3420	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr.}$	32	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.15	OK

Verification of shear stress:

$$\tau = \frac{q \times L}{2 \times A_s} \leq \frac{\tau_{kar}}{\gamma_m}$$

q	3.87	N/mm
L	3420	mm
A_s	4455	mm^2
$\tau_{kar.}$	50.5	N/mm^2
γ_m	1.38	-
$\tau_{optr.}$	1.5	N/mm^2
$\tau_{toel.}$	36.6	N/mm^2
u.c.	0.04	OK

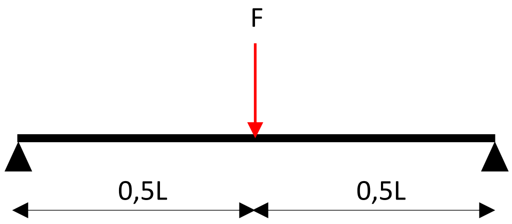
5.3 *Concentrated load*

BGT 3	**1/001 x Qf;w**
UGT 3	**,01 x 1/001 x G + ,01 x 1/001 x Qf;w**

Plank width	0.400	m
Self-weight	0.609	kN/m²
Concentrated load on 100 x 100 mm	7.0	kN
G	0.244	N/mm
Maximum span at L/100	3790	mm

Q_{BGT3}	8642	N
q_{UGT3}	0.541	N/mm
Q_{UGT3}	11667	N

The calculation uses the following situation:



5.3.1 BGT 3

Verification of deflection:

$$y = \frac{F \times L^3}{48 \times EI} \leq \frac{L}{100}$$

F	8642	N
L	3790	mm
E	32154	N/mm^2
I	8048641	mm^4
$y_{optr.}$	37.91	mm
$y_{toel.}$	37.91	mm
u.c.	1.00	OK

5.3.2 UGT 3

Verification of flexural stress:

$$\sigma_b = \frac{F \times L}{4 \times W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$

F	11667	N
q	0.541	N/mm
L	3790	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr.}$	68	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.32	**OK**

Verification of shear force:

$$D_{optr.} = F \leq \frac{D_{kar,100}}{\gamma_m}$$

F	11667	N
$D_{kar;100}$	81138	N
γ_m	1.38	-
$D_{optr.}$	11513	N
$D_{toel.}$	58795	N
u.c.	0.20	**OK**

5.4 Service vehicle 50kN

Calculations for service vehicle 100kN, 160kN and 200kN are conducted in accordance to the same calculation. For results, please refer to 1-Summary.

BGT 4	**1/001 x Qd**
UGT 4	**,01 x 1/001 x G + ,01 x 1/001 x Qd**

Plank width	0.400	m
Self-weight	0.609	kN/m²
Concentrated load on 250 x 250 mm	12.5	kN
G	0.244	N/mm
Track width	1750	mm
Maximum span situation 1 L/200	2000	mm
Maximum span situation 2 L/200	2330	mm

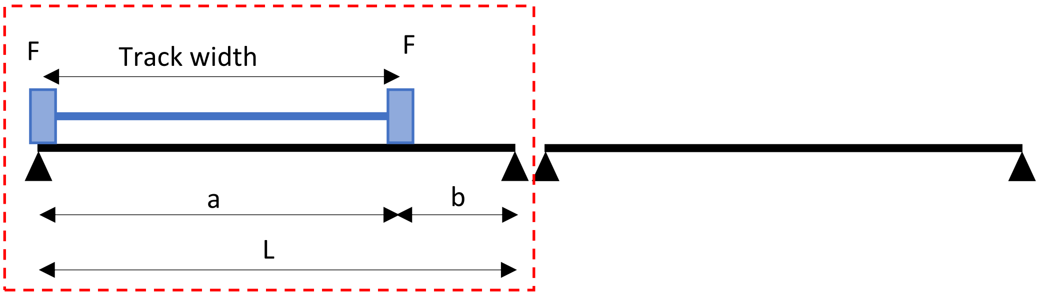
Q_{BGT4}	15432	N
q_{UGT4}	0.541	N/mm
Q_{UGT4}	20833	N

The calculation uses the following situations:

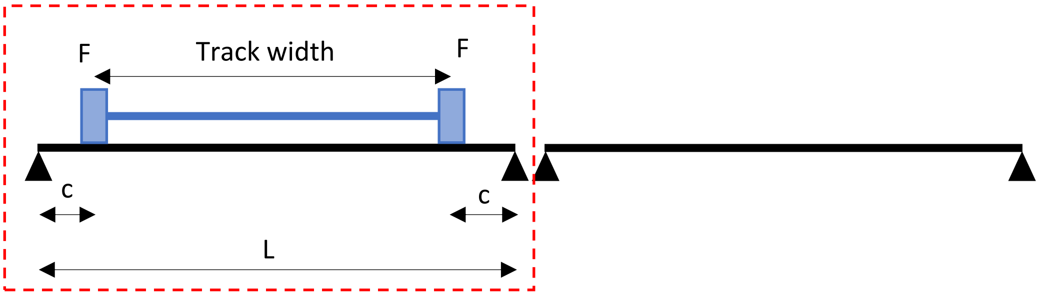
Situation 1: multiple single spans

Situation 1 describes the situation where the vehicle can stand on multiple planks. These planks are on two supports. The single spans within the red rectangles are considered.

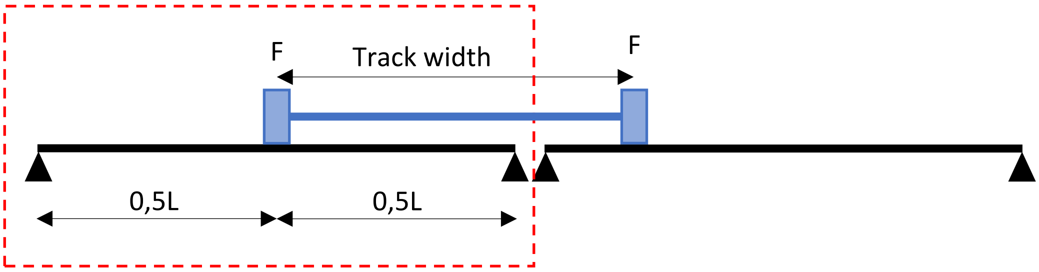
Vehicle position 1:



Vehicle position 2:



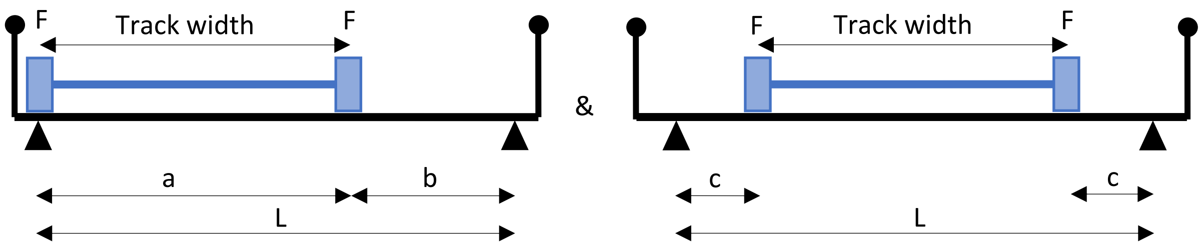
Vehicle position 3:



Situation 2: one single span L > Ls

Situation 2 describes the situation where one plank is equal to the entire width of the bridge. Two positions are considered here; these are shown below. The most critical position is reported, this depends on the total length L, track width Ls and the allowable deflection.

Vehicle position 1: Vehicle position 2:

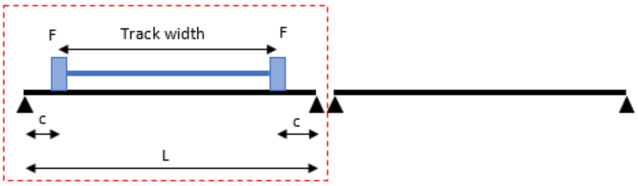


5.4.1 BGT 4 situation 1

Verification of deflection:

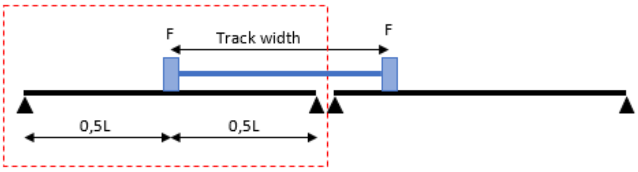
The maximum deflection for service vehicle position 2 is:

$$y_{pos2} = \frac{F \times c}{24 \times EI} \times (3L^2 - 4c^2) \leq \frac{L}{200}$$



The maximum deflection for service vehicle position 3 is:

$$y_{pos3} = \frac{F \times L^3}{48 \times EI} \leq \frac{\mathrm{L}}{200}$$



The maximum occurring deflection for situation 1:

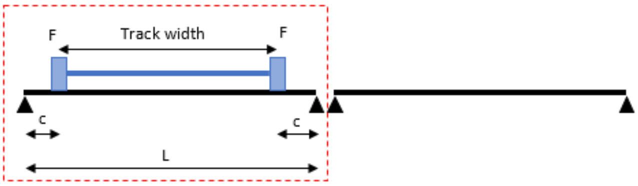
F	15432	N
L	2000	mm
c	128.107778	mm
E	32154	N/mm^2
I	8048641	mm^4
$y_{optr;pos2}$	3.8224007	mm
$y_{optr;pos3}$	10.03	mm
$y_{optr;max}$	10.03	mm
$y_{toel.}$	10.03	mm
u.c.	1.00	**NOT OK**

5.4.2 UGT 4 situation 1

Verification of flexural stress:

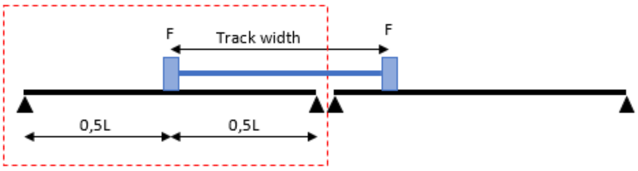
The maximum flexural stress for service vehicle position 2 is:

$$\sigma_{b;pos2} = \frac{F \times c}{W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



The maximum flexural stress for service vehicle position 3 is:

$$\sigma_{b;pos3} = \frac{F \times L}{4 \times W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



The maximum occurring flexural stress for situation 1:

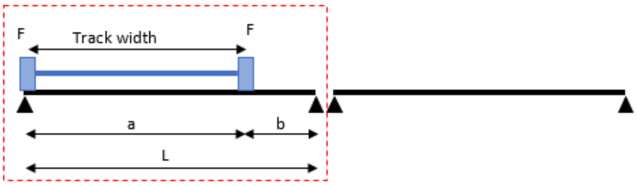
F	20833	N
q	0.541	N/mm
L	2000	mm
c	128.107778	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr;pos2}$	16.6884942	N/mm^2
$\sigma_{optr;pos3}$	61	N/mm^2
$\sigma_{optr;max}$	61	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.29	**OK**

Verification of shear force:

$$D_{kar;250} > D_{kar;200}$$

$$D_{optr.} = \left(F \times \frac{L - \frac{1}{2} \times L_0}{L}\right) + \left(F \times \frac{b - \frac{1}{2} \times L_0}{L}\right) \leq \frac{D_{kar;250}}{\gamma_m}$$

The second term in the equation above is used only when L > L_S + L_0 (when the span is greater than the track width + wheel width). When L < L_S + L_0, the second term in the equation above is set equal to 0.

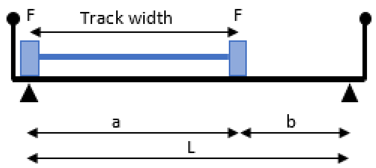


F	20833	N
L	2000	mm
L_0	250	mm
b	256	mm
$D_{kar;250}$	120646	N
γ_m	1.38	-
$D_{optr.}$	20898	N
$D_{toel.}$	87425	N
u.c.	0.24	OK

5.4.3 BGT 4 situation 2

Verification of deflection:

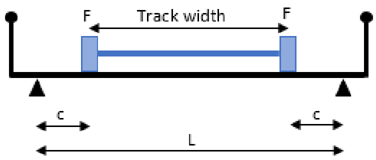
The maximum deflection for service vehicle position 1 is:



$$y_{pos1} = \frac{F \times a \times b}{27 \times EI \times L} \times (a + 2b) \times \sqrt{3a \times (a + 2b)} \leq \frac{L}{200}$$

Maximum deflection at: $x = \sqrt{\frac{a}{3} \times (a + 2b)}$ when $a > b$

The maximum deflection for service vehicle position 2 is:



$$y_{pos2} = \frac{F \times c}{24 \times EI} \times (3L^2 - 4c^2) \leq \frac{L}{200}$$

The maximum occurring deflection for situation 2:

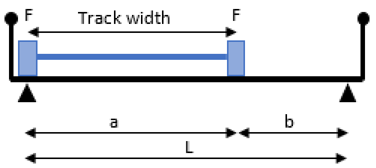
F	15432	N
a	1750	mm
b	587	mm
c	293	mm
L	2330	mm
E	32154	N/mm^2
I	8048641	mm^4
$y_{optr;pos1}$	11.11	mm
$y_{optr;pos2}$	11.68	mm
$y_{optr.max}$	11.68	mm
$y_{toel.}$	11.68	mm
u.c.	1.00	OK

5.4.4 UGT 4 situation 2

Verification of flexural stress:

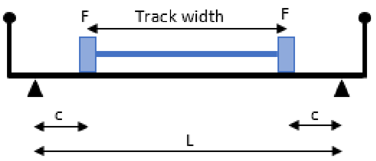
The maximum flexural stress for service vehicle position 1 is:

$$\sigma_{b;pos1} = \frac{F \times a \times b}{L \times W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



The maximum flexural stress for service vehicle position 2 is:

$$\sigma_{b;pos2} = \frac{F \times c}{W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



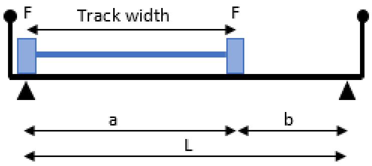
The maximum occurring flexural stress for situation 2:

F	20833	N
q	0.541	N/mm
a	1750	mm
b	587	mm
c	293	mm
L	2330	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr.pos1}$	54	N/mm^2
$\sigma_{optr.pos2}$	37	N/mm^2
$\sigma_{optr.max}$	54	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.25	**OK**

Verification of shear force:

$D_{kar;250} > D_{kar;200}$

$$D_{optr.} = \left(F \times \frac{L - \frac{1}{2} \times L_0}{L}\right) + \left(F \times \frac{b - \frac{1}{2} \times L_0}{L}\right) \leq \frac{D_{kar,250}}{\gamma_m}$$



F	20833	N
L	2330	mm
L_0	250	mm
b	587	mm
$D_{kar;250}$	120646	N
γ_m	1.38	-
$D_{optr.}$	24039	N
$D_{toel.}$	87425	N
u.c.	0.27	OK

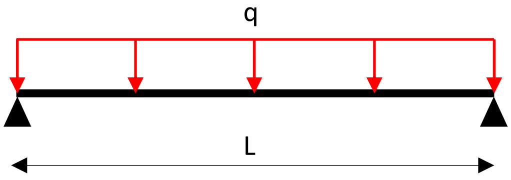
5.5 *Snow*

The maximum allowable span is limited to 5000 mm.

UGT 5 **,01 x 1/001 x G + ,02 x 1/001 x Qs**

Plank width	0.400 m
Self-weight	0.609 kN/m²
Distributed load	1.4 kN/m²
G	0.244 N/mm
Q_s	0.6 N/mm
Maximum span	5000 mm
q_{UGT5}	1.83 N/mm

The calculation uses the following situation:



5.5.1 UGT 5

Verification of flexural stress:

$$\sigma_b = \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$

q	1.83 N/mm
L	5000 mm
W	176245 mm^3
$\sigma_{kar.}$	293 N/mm^2
γ_m	1.38 -
$\sigma_{optr.}$	33 N/mm^2
$\sigma_{toel.}$	212 N/mm^2
u.c.	0.15 OK

Verification of shear stress:

$$\tau = \frac{q \times L}{2 \times A_s} \leq \frac{\tau_{kar}}{\gamma_m}$$

q	1.83	N/mm
L	5000	mm
A_s	4455	mm^2
$\tau_{kar.}$	50.5	N/mm^2
γ_m	1.38	-
$\tau_{optr.}$	0.5	N/mm^2
$\tau_{toel.}$	36.6	N/mm^2
u.c.	0.01	**OK**

5.6 Accidental vehicle

UGT 6 **,01 x 1/001 x G + ,01 x 1/001 x Aov**

Plank width	0.400 m
Self-weight	0.609 kN/m²
Concentrated load on 200 x 200 mm	40.0 kN
G	0.244 N/mm
Track width	1300 mm
Maximum span situation 1	2170 mm
Maximum span situation 2	2170 mm

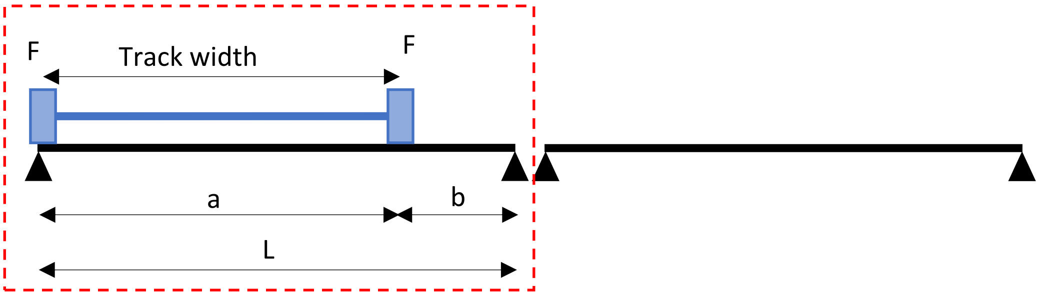
q_{UGT6}	0.541 N/mm
Q_{UGT6}	66667 N

The calculation uses the following situations:

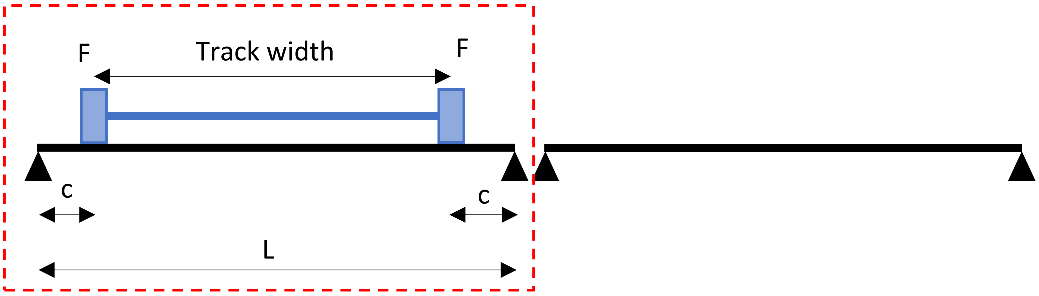
Situation 1: multiple single spans

Situation 1 describes the situation where the vehicle can stand on multiple planks. These planks are on two supports. The single spans within the red rectangles are considered.

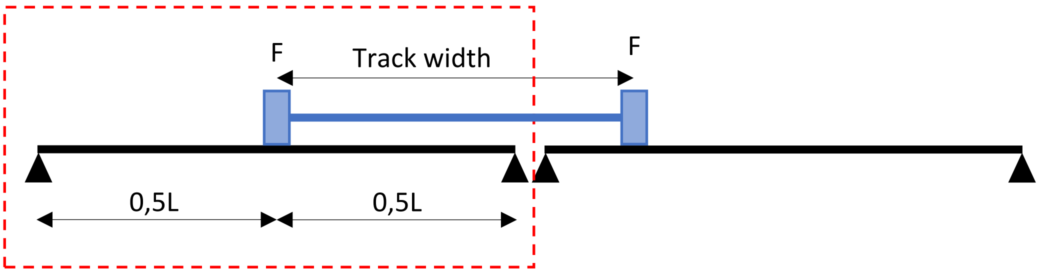
Vehicle position 1:



Vehicle position 2:



Vehicle position 3:

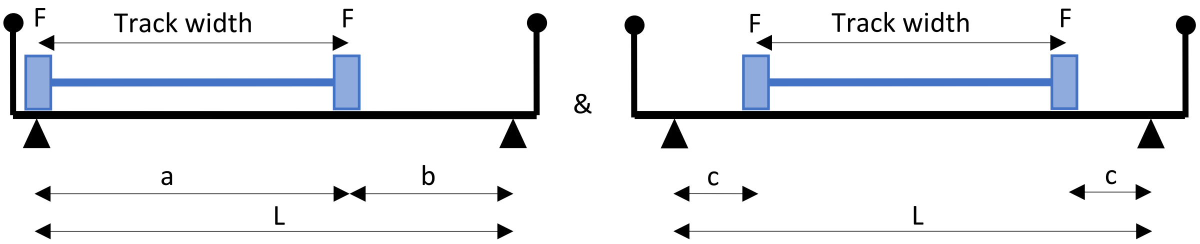


Situation 2: one single span L > Ls

Situation 2 describes the situation where one plank is equal to the entire width of the bridge. Two positions are considered here; these are shown below. The most critical position is reported, this depends on the total length L, track width Ls and the allowable deflection.

Vehicle position 1:

Vehicle position 2:

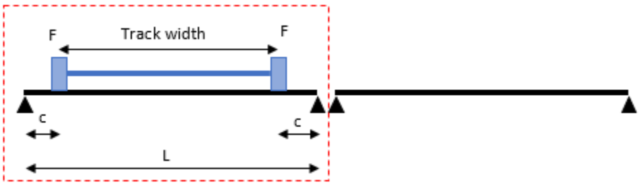


5.6.1 UGT 6 situation 1

Verification of flexural stress:

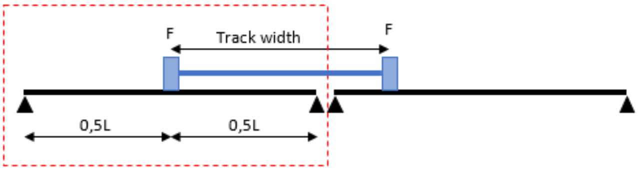
The maximum flexural stress for accidental vehicle position 2 is:

$$\sigma_{b;pos2} = \frac{F \times c}{W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



The maximum flexural stress for service vehicle position 3 is:

$$\sigma_{b;pos3} = \frac{F \times L}{4 \times W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$

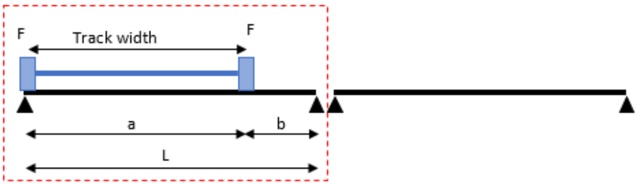


The maximum occurring flexural stress for situation 1:

F	66667	N
q	0.541	N/mm
L	2170	mm
c	439.142032	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr;pos2}$	168	N/mm^2
$\sigma_{optr;pos3}$	208	N/mm^2
$\sigma_{optr;max}$	208	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.98	**OK**

Verification of shear force:

$$D_{optr.} = \left(F \times \frac{L - \frac{1}{2} \times L_0}{L}\right) + \left(F \times \frac{b - \frac{1}{2} \times L_0}{L}\right) \leq \frac{D_{kar;200}}{\gamma_m}$$



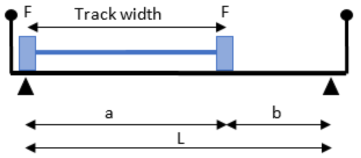
F	66667	N
L	2170	mm
L_0	200	mm
$D_{kar;200}$	120646	N
γ_m	1.38	-
$D_{optr.}$	87426	N
$D_{toel.}$	87425	N
u.c.	1.00	**NOT OK**

5.6.2 UGT 6 situation 2

Verification of flexural stress:

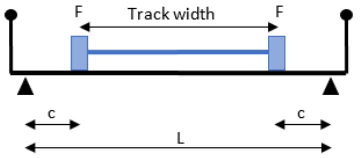
The maximum flexural stress for accidental vehicle position 1 is:

$$\sigma_{b;pos1} = \frac{F \times a \times b}{L \times W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



The maximum flexural stress for accidental vehicle position 2 is:

$$\sigma_{b;pos2} = \frac{F \times c}{W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$

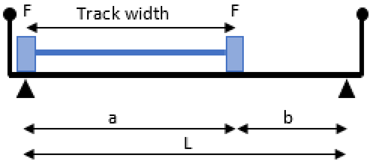


The maximum occurring flexural stress for situation 2:

F	66667	N
q	0.541	N/mm
a	1300	mm
b	878	mm
c	439	mm
L	2170	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr.pos1}$	200	N/mm^2
$\sigma_{optr.pos2}$	168	N/mm^2
$\sigma_{optr.max}$	200	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.94	**OK**

Verification of shear force:

$$D_{optr.} = \left(F \times \frac{L - \frac{1}{2} \times L_0}{L}\right) + \left(F \times \frac{b - \frac{1}{2} \times L_0}{L}\right) \leq \frac{D_{kar,200}}{\gamma_m}$$



F	66667	N
L	2170	mm
L_0	200	mm
b	878	mm
$D_{kar;200}$	120646	N
γ_m	1.38	-
$D_{optr.}$	87426	N
$D_{toel.}$	87425	N
u.c.	1.00	**NOT OK**

5.7 Summary

The plank has been verified for each load case. The maximum span was determined using the aforementioned strength requirements and deflection requirements up to L/550. For each case, the maximum span is shown in figure 6 and figure 7.

Unless otherwise stated, the calculation was made for a simply supported beam on two supports.

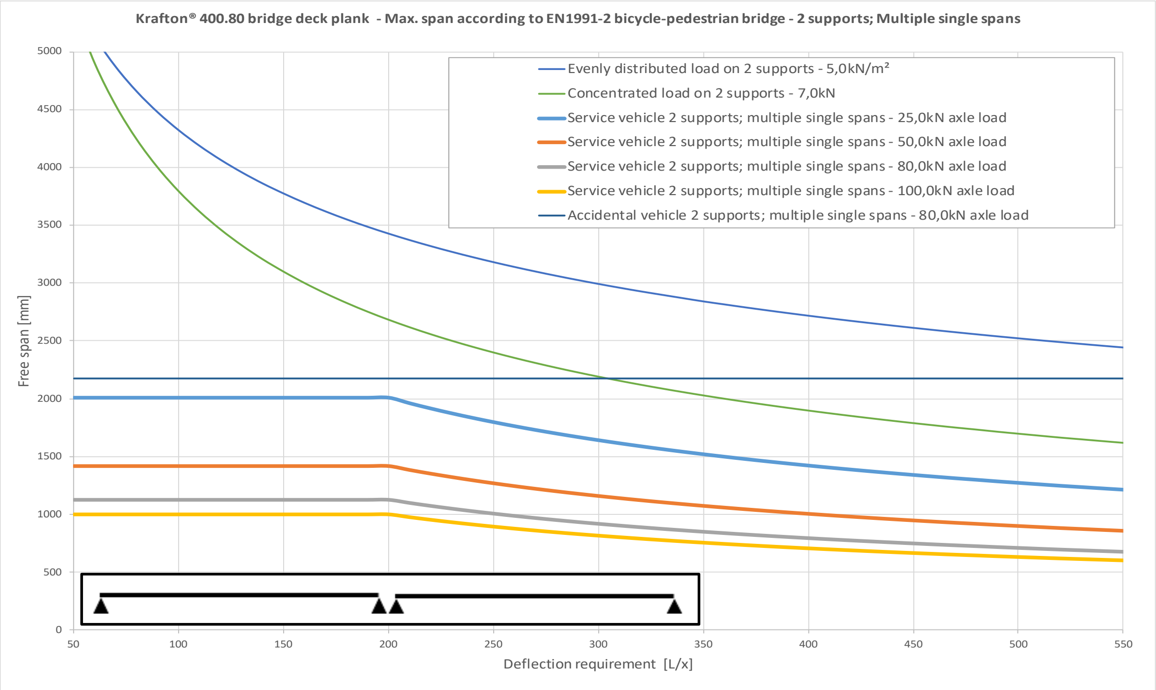


figure 6: Maximum span as a function of deflection requirements; 2 supports; multiple single spans

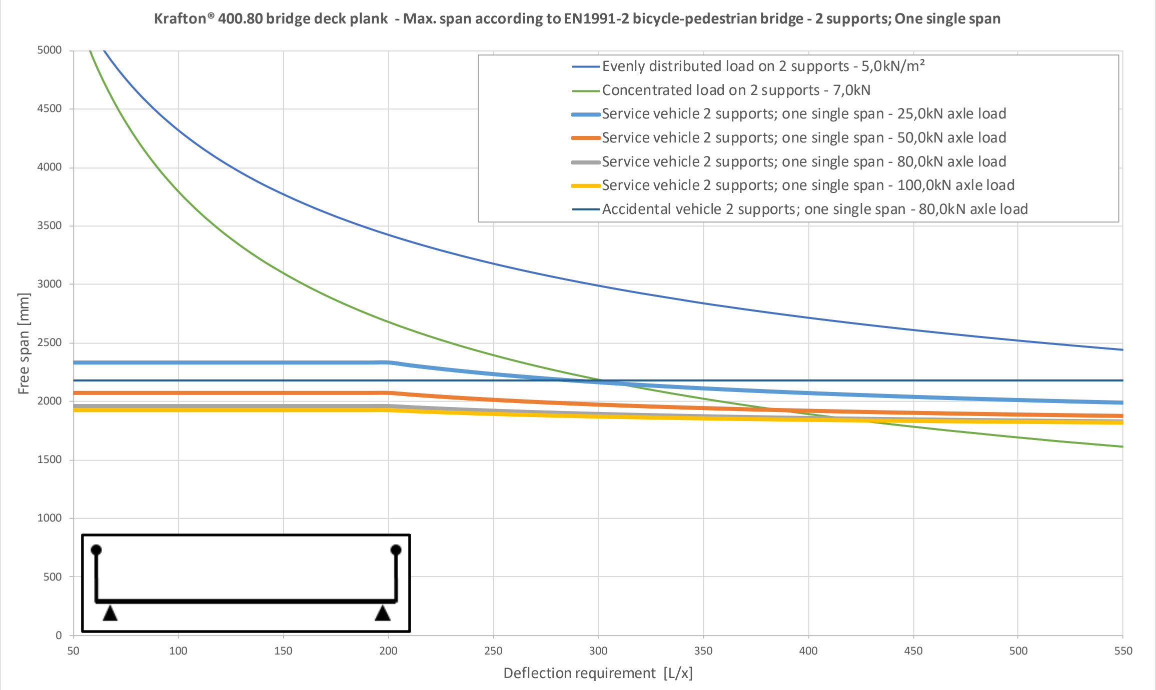


figure 7: Maximum span as a function of deflection requirements; 2 supports; one single span

The spans were calculated with the following loads:

- Evenly distributed load 5,0 kN/m²
- Concentrated load 7,0 kN
- Service vehicle 50 kN, 100 kN, 160 kN, 200 kN
- Accidental vehicle 120 kN

Note:
A minimum deflection requirement of L/200 has been considered for the service vehicle

6 Verification of allowable span on 3 or more supports

6.1 Self-weight

This load case is not a determining load case and has not been considered further.

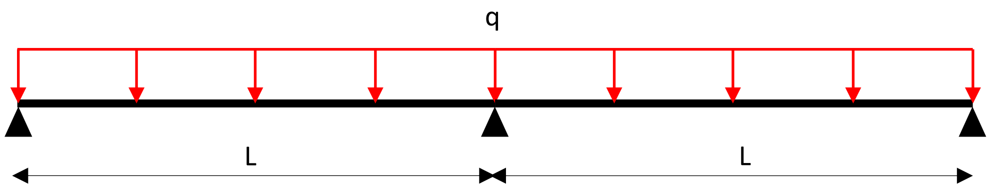
6.2 Distributed mobile load

BGT 2	**1/001 x Qf**
UGT 2	**,01 x 1/001 x G + ,01 x 1/001 x Qf**

Plank width	0.400 m
Self-weight	0.609 kN/m²
Distributed load	5.0 kN/m²
G	0.244 N/mm
Q_f	2.0 N/mm
Maximum span L/200	4590 mm

q_{BGT2}	2.47 N/mm
q_{UGT2}	3.87 N/mm

The calculation uses the following situation:



6.2.1 BGT 2

Verification of deflection:

$$y = \frac{q \times L^4}{185 \times EI} \leq \frac{L}{200}$$

q	2.47 N/mm
L	4590 mm
E	32154 N/mm^2
I	8048641 mm^4
$y_{optr.}$	22.96 mm
$y_{toel.}$	22.97 mm
u.c.	1.00 **OK**

6.2.2 UGT 2

Strength verification is conservatively simplified to a single span situation.

Verification of flexural stress:

$$\sigma_b = \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$

q	3.87	N/mm
L	4590	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr.}$	58	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.27	OK

Verification of shear stress:

$$\tau = \frac{q \times L}{2 \times A_s} \leq \frac{\tau_{kar}}{\gamma_m}$$

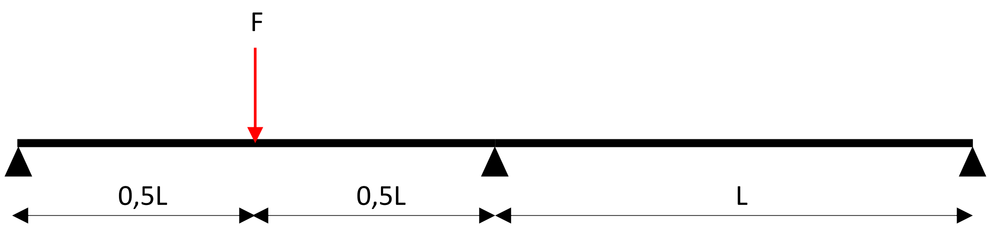
q	3.87	N/mm
L	4590	mm
A_s	4455	mm^2
$\tau_{kar.}$	50.5	N/mm^2
γ_m	1.38	-
$\tau_{optr.}$	2.0	N/mm^2
$\tau_{toel.}$	36.6	N/mm^2
u.c.	0.05	OK

6.3 Concentrated load

BGT 3	**1/001 x Qf;w**
UGT 3	**,01 x 1/001 x G + ,01 x 1/001 x Qf;w**

Plank width		0.400 m
Self-weight		0.609 kN/m²
Concentrated load on 100 x 100 mm		7.0 kN
G		0.244 N/mm
Maximum span L/100		4470 mm
	Q_{BGT3}	8642 N
	q_{UGT3}	0.541 N/mm
	Q_{UGT3}	11667 N

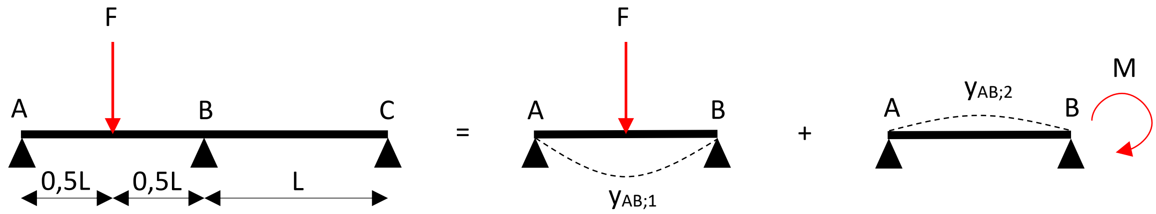
The calculation uses the following situation:



6.3.1 BGT 3

Verification of deflection:

Deflection at x=0.5L is representative for the maximum deflection[5].



$$y_{AB} = \frac{F \times L^3}{48 \times EI} + \frac{M}{6 \times EI}\left(-\frac{3}{8}L^2\right)$$

$$M = \frac{3 \times F \times L}{32}$$

$$y = \frac{23 \times F \times L^3}{1536 \times EI} < \frac{L}{100}$$

F	8642	N
L	4470	mm
E	32154	N/mm²
I	8048641	mm⁴
$y_{optr.}$	44.71	mm
$y_{toel.}$	44.72	mm
u.c.	1.00	**OK**

[5] In reality, the location of maximum deflection is not at x=0.5L. This assumption introduces a maximum error of 2%. Considering deflection has no effect on safety, this simplification is acceptable.

6.3.2 UGT 3

Strength verification is conservatively simplified to a single span situation.

Verification of flexural stress:

$$\sigma_b = \frac{F \times L}{4 \times W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$

F	11667	N
q	0.541	N/mm
L	4470	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr.}$	82	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.39	**OK**

Verification of shear stress:

$$D_{optr.} = F \leq \frac{D_{kar,100}}{\gamma_m}$$

F	11667	N
$D_{kar;100}$	81138	N
γ_m	1.38	-
$D_{optr.}$	11513	N
$D_{toel.}$	58795	N
u.c.	0.20	**OK**

6.4 *Service vehicle 50kN*

Calculations for service vehicle 100kN, 160kN and 200kN are conducted in accordance to the same calculation. For results, please refer to 1-Summary.

BGT 4	**1/001 x Qd**
UGT 4	**,01 x 1/001 x G + ,01 x 1/001 x Qd**

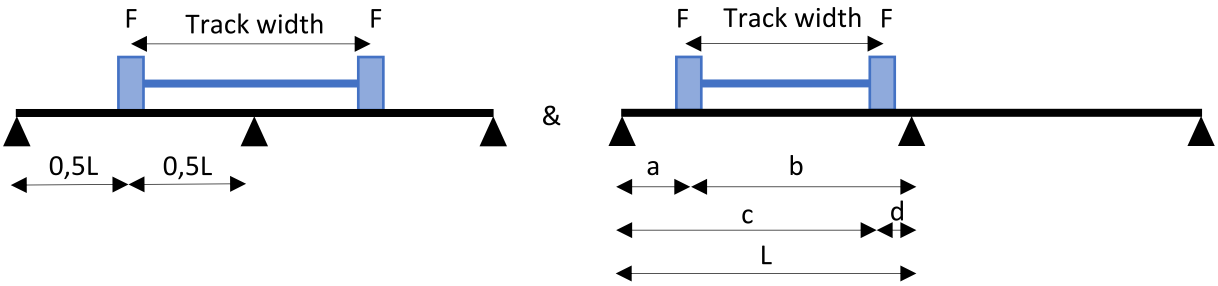
Plank width	0.400 m
Self-weight	0.609 kN/m²
Concentrated load on 250 x 250 mm	12.5 kN
G	0.244 N/mm
Track width	1750 mm
Maximum span L/200	2336 mm

Q_{BGT4}	15432 N
q_{UGT4}	0.541 N/mm
Q_{UGT4}	20833 N

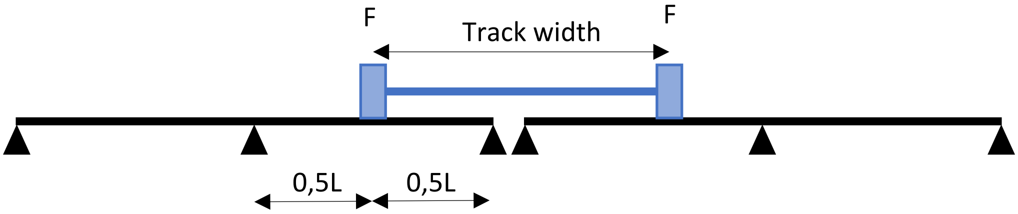
The calculation uses the following situations:

Situation 1:

Vehicle position 1: Vehicle position 2:



Situation 2:

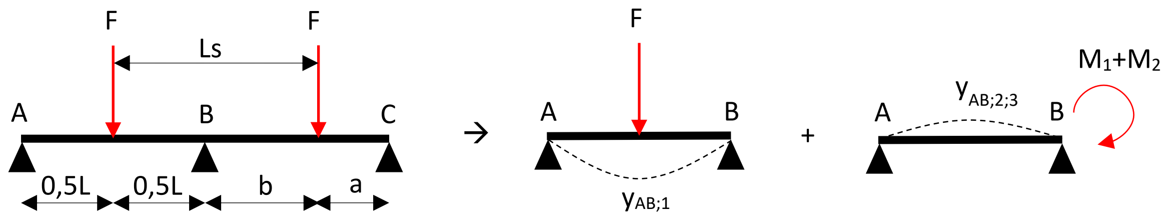


6.4.1 BGT 4

Verification of deflection:

The maximum deflection for service vehicle situation 1 is:

Deflection at x=0.5L is representative for the maximum deflection [6].



$$y_{pos1} = \frac{F \times L^3}{48 \times EI} + \frac{M_1}{6 \times EI}\left(-\frac{3}{8}L^2\right) + \frac{M_2}{6 \times EI}\left(-\frac{3}{8}L^2\right) \leq \frac{\mathrm{L}}{200}$$

$$M_1 = \frac{3 \times F \times L}{32} \qquad M_2 = \frac{F \times a \times b}{4L^2} \times (L + a) \qquad a = \frac{3}{2}L - L_s \qquad b = L - a$$

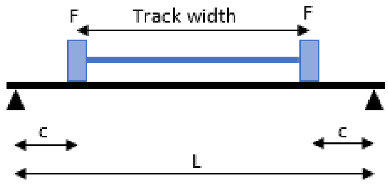
$$y_{pos1} = \frac{F \times L^3}{48 \times EI} - \frac{3 \times F \times L^3}{512 \times EI} - \frac{M_2 \times L^2}{16 \times EI} \leq \frac{\mathrm{L}}{200}$$

M_2 is only available when a > 0, or L > 2/3L_s. In the situation where a < 0 is true, F in M_2 is considered to be 0kN.

[6] In reality, the location of maximum deflection is not at x=0.5L. This assumption introduces a maximum error of 2%. Considering deflection has no effect on safety, this simplification is acceptable.

The maximum deflection for service vehicle situation 1 position 2 is:

This calculation is conservatively simplified to a single span.



$$y_{pos2} = \frac{F \times c}{24 \times EI} \times (3L^2 - 4c^2) \leq \frac{L}{200}$$

The maximum occurring deflection for situation 1:

F	15432	N
L	2336	mm
Ls	1750	mm
a	1755	mm
b	582	mm
c	293.246851	mm
E	32154	N/mm^2
I	8048641	mm^4
$y_{optr.pos1}$	7.50	mm
$y_{optr.pos2}$	12	mm
$y_{optr.max}$	11.68	mm
$y_{toel.}$	11.68	mm
u.c.	1.00	OK

To verify deflection, situation 2 **DEFLECTS MORE** than situation 1, it is infrequent and therefore not considered. Should it be required, a separate analysis should be conducted.

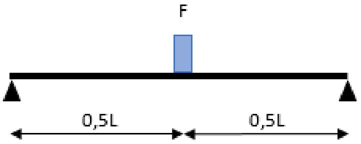
6.4.2 UGT 4

Strength verification is conservatively simplified to a single span and applies to all considered situations.

Verification of flexural stress:

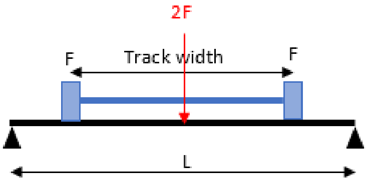
The maximum flexural stress for service vehicle position 1 is:

$$\sigma_b = \frac{F \times L}{4 \times W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



The maximum flexural stress for service vehicle position 2 is:

$$\sigma_b = \frac{2 \times F \times L}{4 \times W} + \frac{q \times L^2}{8 \times W} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



Both concentrated loads are conservatively merged to one concentrated load. This position occurs only if: track width > L

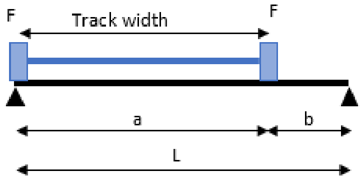
The maximum occurring flexural stress:

F	20833	N
q	0.541	N/mm
L	2336	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr.pos1}$	71	N/mm^2
$\sigma_{optr.pos2}$	140	N/mm^2
$\sigma_{optr.max}$	140	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.66	**OK**

Verification of shear force:

$D_{250} > D_{200}$

$$D_{optr.} = \left(F \times \frac{L - \frac{1}{2} \times L_0}{L}\right) + \left(F \times \frac{b - \frac{1}{2} \times L_0}{L}\right) \leq \frac{D_{kar;250}}{\gamma_m}$$



F	20833	N
L	2336	mm
b	586	mm
L_0	250	mm
$D_{kar;250}$	120646	N
γ_m	1.38	-
$D_{optr.}$	23834	N
$D_{toel.}$	87425	N
u.c.	0.27	**OK**

6.5 Snow

Strength verification is conservatively simplified to a single span. Verification is described in the single span chapter of this report. Chapter 5.5.

6.6 *Accidental vehicle*

UGT 6 **,01 x 1/001 x G + ,01 x 1/001 x Aov**

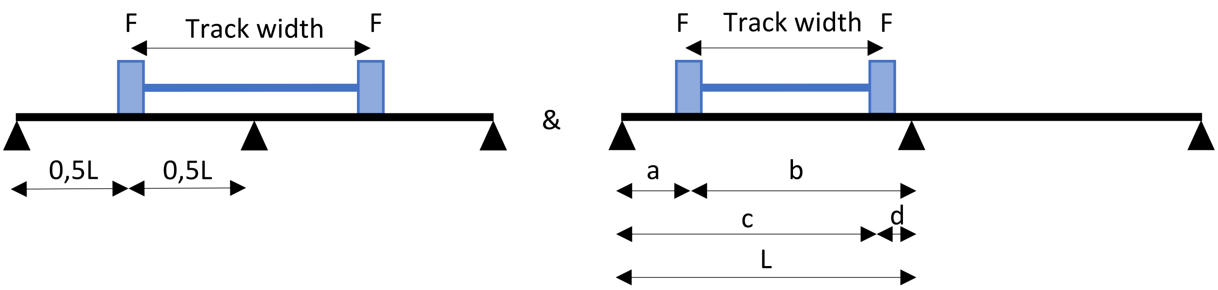
Plank width	0.400 m
Self-weight	0.609 kN/m²
Concentrated load on 200 x 200 mm	40.0 kN
G	0.244 N/mm
Track width	1300 mm
Maximum span	2178 mm

q_{UGT6}	0.541 N/mm
Q_{UGT6}	66667 N

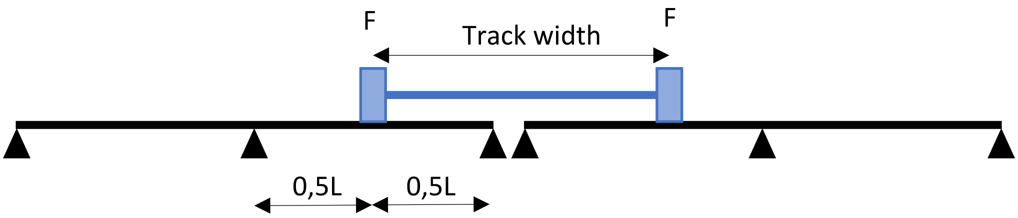
The calculation uses the following situations:

Situation 1:

Vehicle position 1: Vehicle position 2:



Situation 2:



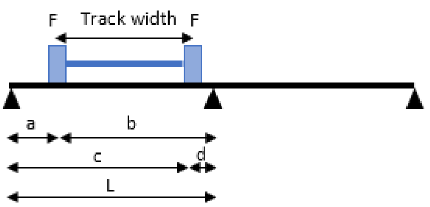
6.6.1 UGT 6

Verification of flexural stress:

The maximum flexural stress for the accidental vehicle situation 1 position 1 is more favourable than situation 2 and is therefore not considered.

The maximum flexural stress for accidental vehicle situation 1 position 2 is:

$$\sigma_b = \sigma_{b;1} + \sigma_{b;2} + \sigma_{b;3} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$



Flexural stress at location as a result of wheel 1:

$$\sigma_{b;1} = \frac{F \times a \times b}{4 \times L^2 \times W} \times \left(4 \times L^2 - a \times (L + a)\right)$$

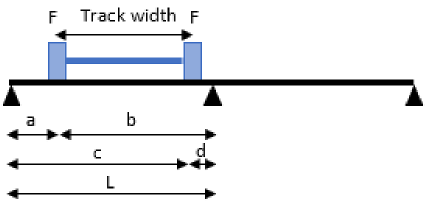
Flexural stress at location as a result of wheel 2:

$$\sigma_{b;2} = \frac{F \times c \times d}{4 \times L^2 \times W} \times \left(4 \times L^2 - c \times (L + c)\right) \times \frac{c - L_s}{c}$$

Flexural stress at location as a result of self-weight:

$$\sigma_{b;3} = \frac{3 \times q \times L \times a - 4 \times q \times a^2}{8 \times W}$$

$$\sigma_b = \sigma_{b;1} + \sigma_{b;2} + \sigma_{b;3} \leq \frac{\sigma_{b,kar}}{\gamma_m}$$

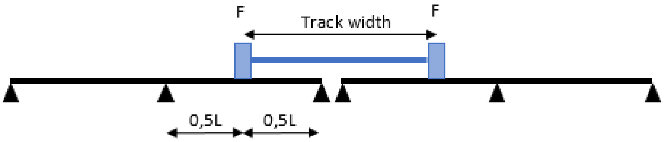


F	66667	N
q	0.541	N/mm
L	2178	mm
Ls	1300	mm
a	762	mm
b	1416	mm
c	2062	mm
d	116	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{b;1}$	165	N/mm^2
$\sigma_{b;2}$	0	N/mm^2
$\sigma_{b;3}$	1	N/mm^2
$\sigma_{optr.}$	166.33	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.78	**OK**

The maximum flexural stress for accidental vehicle situation 2 is:

The flexural stress at x=0.5L is representative of the maximum flexural stress [7].

$$\sigma_b = \frac{13 \times F \times L}{64 \times W} + \frac{q \times L^2}{16 \times W}$$



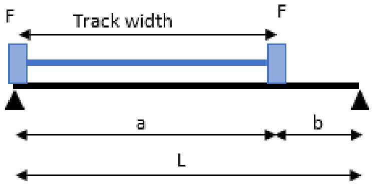
F	66667	N
q	0.541	N/mm
L	2178	mm
W	176245	mm^3
$\sigma_{kar.}$	293	N/mm^2
γ_m	1.38	-
$\sigma_{optr.}$	168	N/mm^2
$\sigma_{toel.}$	212	N/mm^2
u.c.	0.79	**OK**

[7] In reality, the location of maximum flexural stress is not at x=0.5L. This assumption introduces an error of 2%. To compensate for this margin of error, a maximum u.c. of 0.98 is allowed.

Verification of shear force:

Shear verification is conservatively simplified to a single span.

$$D_{optr.} = \left(F \times \frac{L - \frac{1}{2} \times L_0}{L}\right) + \left(F \times \frac{b - \frac{1}{2} \times L_0}{L}\right) \leq \frac{D_{kar;200}}{\gamma_m}$$



F	66667	N
L	2178	mm
b	878	mm
L_0	200	mm
$D_{kar;200}$	120646	N
γ_m	1.38	-
$D_{optr.}$	87426	N
$D_{toel.}$	87425	N
u.c.	1.00	**NOT OK**

6.7 Summary

The plank has been verified for each load case. The maximum span was determined using the aforementioned strength requirements and deflection requirements up to L/550. For each case, the maximum span is shown in figure 8.

Unless otherwise stated, the calculation was made for a continuous beam on three supports.

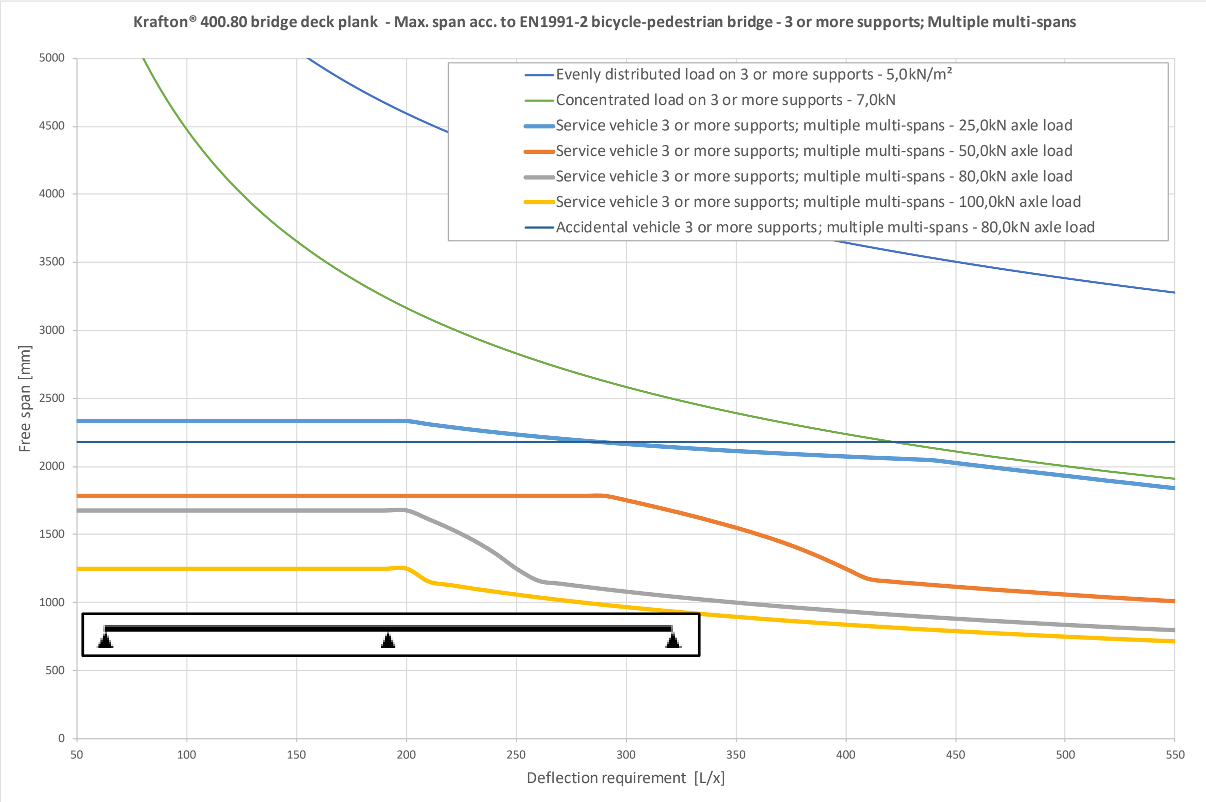


figure 8: Maximum span as a function of deflection requirements; 3 or more supports

The spans were calculated with the following loads:

- Evenly distributed load 5,0 kN/m²
- Concentrated load 7,0 kN
- Service vehicle 50 kN, 100 kN, 160 kN, 200 kN
- Accidental vehicle 120 kN

Note:

- A minimum deflection requirement of L/200 has been considered for the service vehicle
- Deflection analysis for service vehicles on multi-span planks is according to situation 1, as per figure 9. In case situation 2 can occur, an additional analysis needs to be performed.

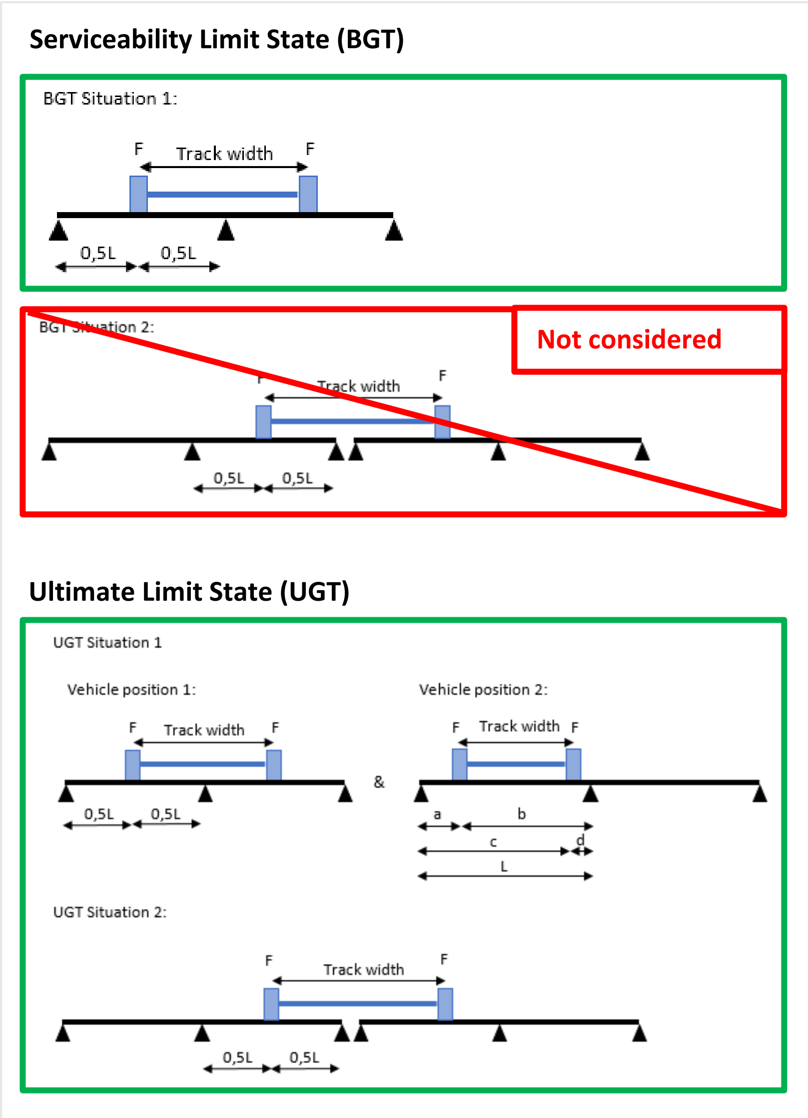


figure 9: Considered situations service- and accidental vehicle multi-span BGT and UGT

7 Comfort

$$f = \frac{1}{2\pi} * C * \sqrt{\frac{EI * g}{\eta_c * q * L^4}}$$

$$f \geq 5\ Hz$$

Plank width	w	0.400	mm
Self-weight	q	0.609	N/mm
Gravitational acceleration	g	9.81	m/s^2
Free span	L	5300	mm
Flexural stiffness	EI	2.59E+11	Nmm^2
Conversion factor comfort	η_c	0.81	-
Factor for support	C	9.87	-
	$f_{optr.}$	5.14	Hz
	$f_{toel.}$	5.00	Hz
	u.c.	0.97	**OK**

The maximum span of the plank at the 5Hz limit is 5300 mm, which is higher than the maximum spans in the other load situations.

The comfort requirement does not determine the maximum allowable span.

8 Conclusion

The krafton® 400.80 mm bridge deck plank complies with the Eurocode when a span and deflection requirement is chosen according to the charts shown.

For questions or special applications, please contact:

krafton®
Markweg Zuid 34
4794 SN Heijningen

T +31 (0) 168227510

E / info@krafton.nl

Appendix A: Properties of the bridge deck plank

A.1 Summary

This appendix reports the mechanical properties of the pultruded glass fibre reinforced krafton® 400.80 bridge deck plank. The mechanical properties of the bridge deck plank were determined through testing. The properties are summarised in table 3.

table 3: Mechanical properties

		Unit	Krafton® 400.80
Dimensions	(b x h)	mm	400 x 80
Surface	(A)	mm²	9586
Shear area	(A_s)	mm²	4455
Moment of inertia	(I)	mm^4	8048641
Section modulus	(W)	mm³	176245
Weight	(G)	kg/m²	47.9
Modulus of elasticity	(E_{gem})	N/mm²	32154
Flexural stress	($\sigma_{b,kar}$)	N/mm²	293
Shear stress	(τ_{kar})	N/mm²	50.5
Profile properties			
Flexural stiffness	(EI)	Nmm²/mm	6.47E+08
Flexural strength	(M_b)	Nmm/mm	128983
Shear strength	(D)	N/mm	563
Shear force on 100x100mm	($D_{kar,100}$)	N	81138
Shear force on 200x200mm	($D_{kar,200}$)	N	120646

A.2 Tests

A.2.1 Description of tests

The following tests were carried out:

- Determination of flexural stiffness and flexural strength according to EN ISO 14125
- Determination of shear strength by means of a 3-point bending test with line load immediately adjacent to the support.
- Determination of allowable shear force due to a concentrated load of 200mm x 200mm corresponding to the wheel print of an accidental vehicle according to EN1991-2 NB – Traffic loads on bridges.
- Determination of allowable shear force due to a concentrated load of 100mm x 100mm

A.3 Test results

According to EN1990:2002 appendix D, the characteristic strength value is calculated from the average strength value minus k_n times the standard deviation.

The values for k_n are used according to table D1 in EN1990:2002.

The characteristic stiffness value is equal to the average measured stiffness value.

table 4 EN1990:2002 appendix D Table D1

Tabel D1 — Waarden van k_n voor de 5 % karakteristieke waarde

n	1	2	3	4	5	6	8	10	20	30	∞
V_x bekend	2,31	2,01	1,89	1,83	1,80	1,77	1,74	1,72	1,68	1,67	1,64
V_x niet bekend	–	–	3,37	2,63	2,33	2,18	2,00	1,92	1,76	1,73	1,64

A.3.1 Flexural modulus

The mechanical properties were tested by krafton®, the tests were performed on 01-07-2021.

The flexural modulus was determined by determining the slope of the force-displacement curve. The slope was determined by taking two points on the graph and drawing a line between them. The points were chosen in the linear part of the curve. The E-modulus is calculated using the following formula:

$$\Delta y = \frac{\Delta F \times L^3}{48 \times E_b I} \quad \rightarrow \quad E_b = \frac{\Delta F \times L^3}{48 \times I \times \Delta y}$$

Wherin:

Δy	=	Displacement [mm]
ΔF	=	Force [N]
L	=	Span [mm]
E_b	=	Flexural modulus [N/mm^2]
I	=	Moment of inertia [mm^4]

table 5: Test results flexural modulus

Sample nr.	L [mm]	ΔF [N]	Δy [mm]	E_b [N/mm²]
1	2000	171200	113.66	31190
2	2000	162590	107.50	31319
3	2000	163100	108.09	31246
4	2000	156710	105.09	30879
5	2000	171980	115.57	30815
6	2000	175570	115.96	31352
7	2000	167570	110.85	31303
			Average value [$E_{b,gem}$]	31158

A.3.2 Flexural strength single span

The flexural strength is determined based on the test performed by krafton® on 01-07-2021.

The test values ($F_{failure}$) are used to determine the flexural strength (σ_b) using the following formula:

$$\sigma_b = \frac{F_{failure} \times L}{4 \times W}$$

Wherein	L	=	span	see table 6
	W	=	section modulus	176245 mm³

table 6: Test results flexural strength single span

Sample nr.	L [mm]	$F_{failure}$ [N]	$\sigma_{b,min}$ [N/mm²]
1	2000	171200	486
2	2000	162590	461
3	2000	163100	463
4	2000	156710	445
5	2000	171980	488
6	2000	175570	498
		Average [$\sigma_{b,gem}$]	474
		Standard deviation [s]	19
		Characteristic value [$\sigma_{b,kar}$]	435

The characteristic value is determined from the average value minus 2.09 x the standard deviation.

A.3.3 Flexural strength multi-span

The flexural strength is determined based on the test performed by SKZ on 03-02-2022.

The test values ($F_{failure}$) are used to determine the flexural strength (σ_b) using the following formula:

$$\sigma_{b;mv} = \frac{6 \times F_{failure} \times L}{32 \times W}$$

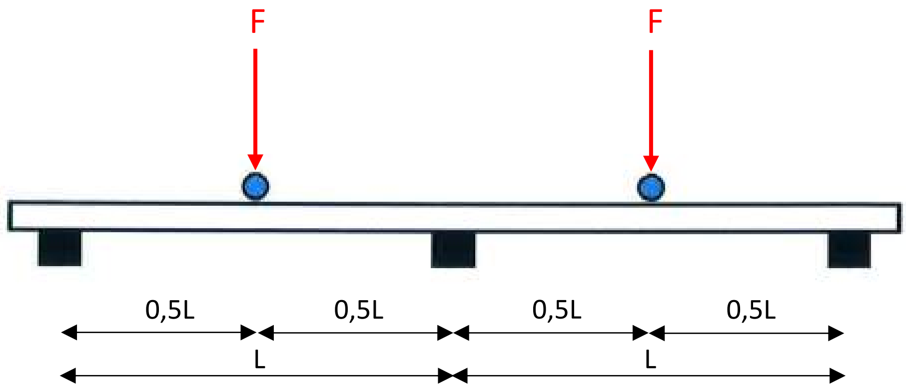


figure 10: Test setup multi-span

Wherein: L = span see table 7

W = section modulus mm^3

table 7: Test results flexural strength multi-span

Sample nr.	L [mm]	$F_{failure}$ [N]	$\sigma_{b,min}$ [N/mm²]
1	2000	177000	377
2	2000	159000	338
3	2000	154500	329
4	2000	168750	359
5	2000	145000	309
6	2000	161000	343
7	2000	160500	341
		Average [$\sigma_{b,gem}$]	342
		Standard deviation [s]	24
		Characteristic value [$\sigma_{b,kar}$]	293

The characteristic value is determined from the average value minus 2.09 x the standard deviation.

A.3.4 Shear strength

The shear strength is determined based on the test performed by krafton® on 26-11-2021.

The test values ($F_{failure}$) are used to determine the shear strength (τ) using the following formula:

$$\tau = \frac{F_{failure} \times (L - a)}{L \times A_s}$$

The test was performed at a span of L = 1000mm. The press forms a line load on the sample and has a diameter of 100mm. The distance between the press and the support was a = 80mm.

Table 8: Test results shear strength

Sample nr.	$F_{failure}$ [N]	τ [N/mm²]
1	246570	50.9
2	249960	51.6
3	249970	51.6
4	249940	51.6
5		
6		
	Average [τ_{gem}]	51.4
	Standard deviation [s]	0.3
	Characteristic value [τ_{kar}]	50.5

The characteristic value is determined from the average value minus 2.63 x the standard deviation.

SOLICO
ENGINEERING IN COMPOSITES

A.3.5 Shear strength for a concentrated load on 200x200 mm

The shear strength for a concentrated load on 200x200 mm is determined based on the test performed by krafton® on 13-09-2022.

The test values ($F_{failure}$) are used to determine the shear strength (D_{200}) using the following formula:

$$D_{200} = \frac{F_{failure} \times (L - L_0)}{L}$$

This only applies to a load on 200x200 mm. The value L_0 is equal to half the length of the concentrated load surface, plus the distance between the support and the edge of the concentrated load.

Table 9: Test results shear strength concentrated load on 200x200mm

Sample nr.	L [mm]	L_0 [mm]	$F_{failure}$ [N]	D_{200} [N]
1	2000	185	137100	124418
2	2000	185	144500	131134
3	2000	185	141900	128774
4	2000	185	149000	135218
5	2000	185	142500	129319
6				
			Average [$D_{gem,200}$]	129773
			Standard deviation [s]	3917
			Characteristic value [$D_{kar,200}$]	120646

The characteristic value is determined from the average value minus 2.33 x the standard deviation.

A.3.6 Shear strength for a concentrated load on 100x100 mm

The shear strength for a concentrated load on 100x100 mm is determined based on the test performed by krafton® on 12-09-2022.

The test values ($F_{failure}$) are used to determine the shear strength (D_{100}) using the following formula:

$$D_{100} = \frac{F_{failure} \times (L - L_0)}{L}$$

This only applies to a load on 100x100 mm. The value L_0 is equal to half the length of the concentrated load surface, plus the distance between the support and the edge of the concentrated load.

Table 10: Test results shear strength concentrated load on 100x100mm

Sample nr.	L [mm]	L_0 [mm]	$F_{failure}$ [N]	D_{100} [N]
1	2000	135	89310	83282
2	2000	135	91980	85771
3	2000	135	90150	84065
4	2000	135	88860	82862
5	2000	135	92050	85837
6				
			Average [$D_{gem,200}$]	84363
			Standard deviation [s]	1384
			Characteristic value [$D_{kar,200}$]	81138

The characteristic value is determined from the average value minus 2.33 x the standard deviation.