CariCo

CariCo formwork beams

- safety concept
- distribution of forces in a formwork beam
- carrying capacity characteristics
- span table

CARICO formwork beams | theory | summary

1. SAFETY CONCEPT

1.1. SAFE WORKING STRESS DESIGN (Permissible stress design) $\sigma_{permissible}$

deterministic safety concept (old concept)

$$\sigma \leq \sigma_{perm} = \frac{\beta_F}{\nu}$$

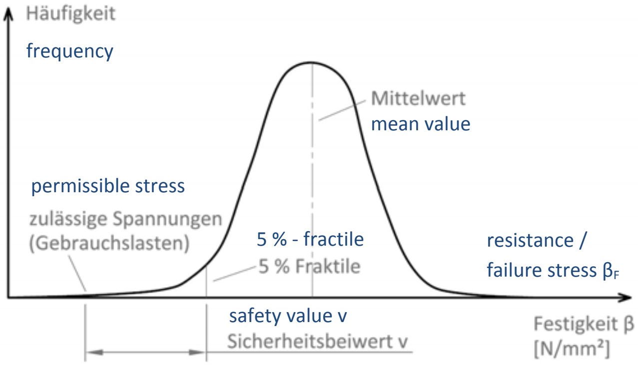


Fig.1: Frequency distribution of resistance and definition of the permissible stress (scheme)
Reference: [1] Neuhaus, 1994

The existing stress level σ (force, load) must be less or equal to the safe working (permissible) stress σ_{perm} (resistance, failure stress).

The safe working stress σ_{perm} bases on the 5 % fractile value of the failure stress β_F divided by the global safety value ν.

1.2. CONCEPT OF SEPERATED SAFETY VALUES

semi-probabilistic safety concept (current concept, Eurocodes)

$$\boxed{E_d \leq R_d}$$

$$\gamma_F \cdot E_k \leq k_{\mathrm{mod}} \cdot \frac{R_k}{\gamma_M}$$

S oder E	Stress; effect of actions
R	Resistance
k_{mod}	Modification factor for duration of load action and moisture content
γ_F	Partial factor for actions, also accounting for model uncertainties and dimensional variations
γ_M	Partial factor for material properties, also accounting for model uncertainties and dimensional variations

Indices

k	Characteristic value (normally 5 % fractile value without partial factors)
M	according to the material
d	Design value (with partial factors)
F	in terms of load (force)

This concept charges safety values to both sides of the equation. Especially the standard for timber structures extends the equation with the modification factor k_{mod}.

In general the failure probability in construction engineering is set to $1*10^{-6}$ (1/1.000.000). That means one of 1.000.000 identical construction components could fail by the same load conditions.

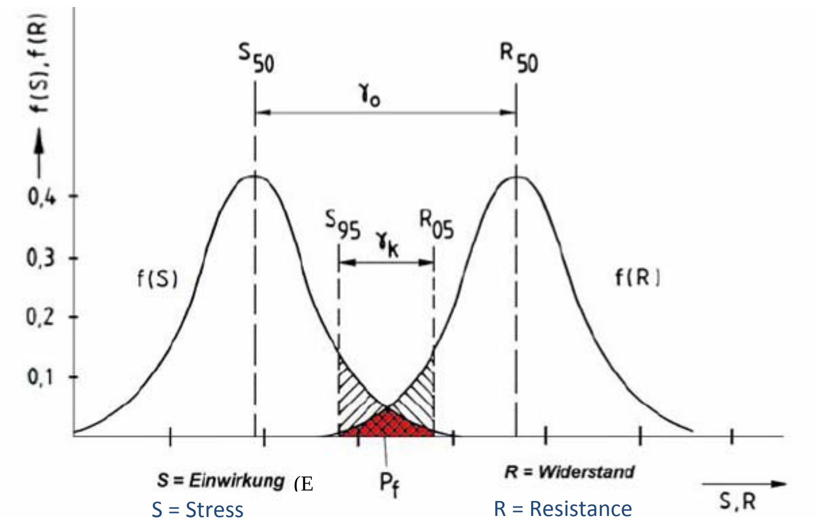
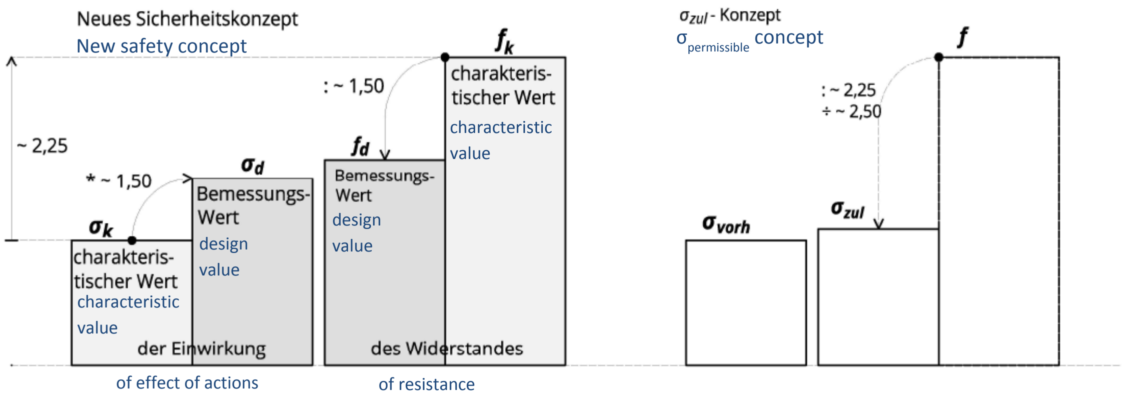


Fig. 2: Probability density function of resistance R and stress S; failure probability P_f
Reference: [2] Steinbrecher, 2011

1.3. COMPARISION OF THE CONCEPTS



$$\sigma_d \leq f_d$$

$$(\gamma_G ; \gamma_Q)\sigma_k \leq \frac{f_k}{\gamma_M} * k_{mod} * k$$

$$\sigma_{vorh} \leq \sigma_{zul}$$

Fig. 3: Characteristic values and design values with rounded partial factors
Reference: [3] Wallner, 2013

Comparing the different safety concepts the rate of safety is between 2,15 - 2,5. The key aspect is that the resistance is equal or higher than the stress values.

2. DISTRIBUTION OF FORCES IN A FORMWORK BEAM

2.1. INTERNAL FORCES | normal force [N] shear force [V] bending moment [M]

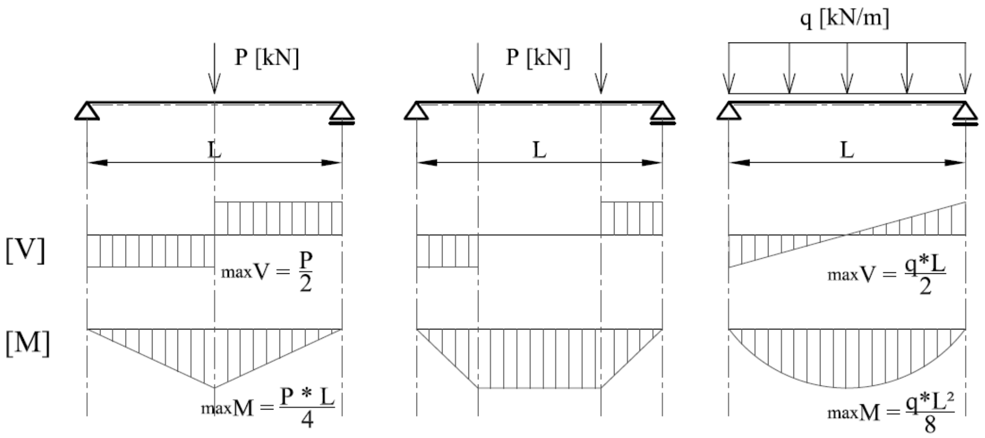


Fig. 4: Sketches of the internal forces in a girder according to a single and a distributed load case (there are no normal forces)

2.2. Distribution of internal forces (simplified)

The formwork beams is an optimized building element consisting of the web and flanges. The upper and the lower flange are stressed by the bending moments divided to tension and pressure forces. The distance between the center lines of the flanges stands for the lever arm. The web holds the distance of the flanges and takes the shear-forces. The function of the web can be compared with the diagonal of a framework (lattice beam).

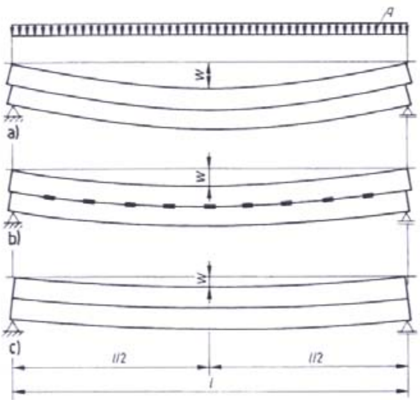


Fig. 5: Composite beam with different joining elements:

- a) no compound
- b) with mechanical fasteners (flexible)
- c) glued stiff connection (H20 beam)

Reference: [4] Neuhaus, 2011

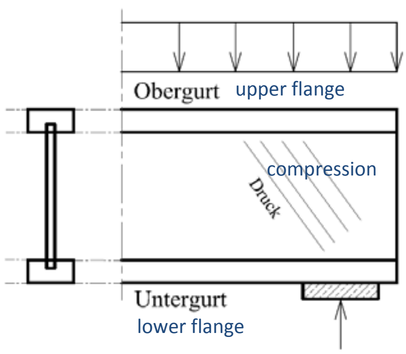


Fig. 6: The load transfer of loads located close to the supports is also managed by the web of the beam.

3. H20 BEAM | CARRYING CAPACITY CHARACTERISTICS

The load carrying characteristics of the beam are described in EN 13377 [6]. The values are given in the standard are minimum requirements that in general are exceeded by values determined by tests.

3.1. SAFE WORKING LOADS (Permissible stress) | H20 beam

(old concept, partially still in use)

Table E.1: Safe working loads for panel web beams (nominal beam depth H, minimum flange width b, bending stiffness EI, safe working value of shear force Q, safe working value of bearing force A, safe working value of bending moment M), [6] EN 13377:2002

1	2	3	4	5	6	7
class	depth H (mm)	minimum flange width b (mm)	E_I (kNm²)	Q (kN)	A (kN)	M (kNm)
P16	160	65	200	8,5	17	2,7
P20	200	80	450	11,0	22	5,0
P24	240	80	700	13,0	26	6,5

3.2. CHARACTERISTIC VALUES | H20 beam

(current concept, Eurocode)

Table 1: Classification, dimensions and structural properties of panel web beams (beam depth H, minimum flange width b, bending stiffness EI, charact. shear resistance V_k, charact. bearing resistance $R_{b,k}$, charact. bending resistance M_k), [6] EN 13377:2002

1	2	3	4	5	6	7
Class	beam depth H [mm]	minimum flange width b [mm]	E_I [kNm²]	V_k [kN]	$R_{b,k}$ [kN]	M_k [kNm]
P16	160	65	200	18,4	36,8	5.9
P20	200	80	450	23,9	47,8	10.9
P24	240	80	700	28,2	56,4	14.1
NOTE 1 For explanation of symbols, see 3.2.						
NOTE 2 For calculation of "safe working loads", see annex E.						

3.3. MATHEMATICAL CORRELATION BETWEEN THE CONCEPTS

The translation of characteristic values (table 1) to safe working values (table E.1) bases on the following formula:

$$_{zul}R = \frac{k_{\text{mod}}}{\gamma_{M,timber}} \cdot \frac{1}{\gamma_F} \cdot R_k$$

$\gamma_F = 1{,}5$

$\gamma_{M,timber} = 1{,}3$

$k_{\text{mod}} = 0{,}9$

Example:
bending moment M_k = 10,9 kNm> $_{\text{permissible}}$M = 5,0 kNm

$$_{perm}M = \frac{0{,}9}{1{,}3} \cdot \frac{1}{1{,}5} \cdot 10.9 = 5{,}03 kNm$$

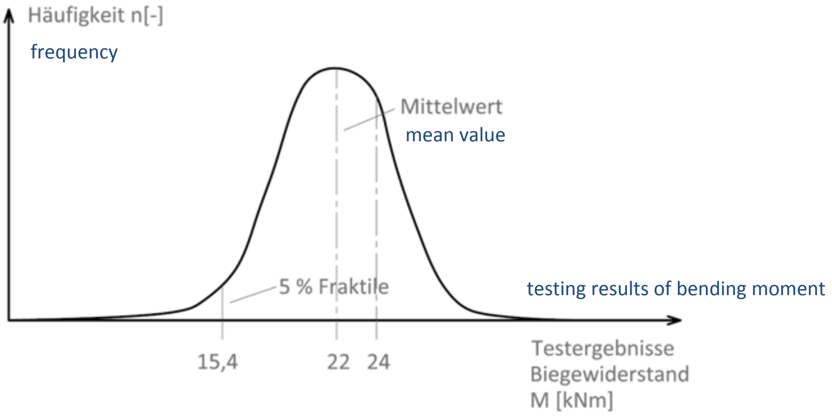


Fig. 7: Illustration of the results of experiments for the authorization of H20 beams

The test results (5 % fractile) is about 15,4 kNm, the maximum bending resistance according to the standard is 10,9 kNm, independent from the product.

Additional to the safety factors according to the standard	1,3*1,5/0,9 = 2,16	
the tested beams include following factors		
Bending resistance	15,4/10,9 = 1,41	(+ 41 %)
Shear resistance	26,5/23,9 = 1,11	(+ 11 %)

4. SPAN TABLE | H20 beam

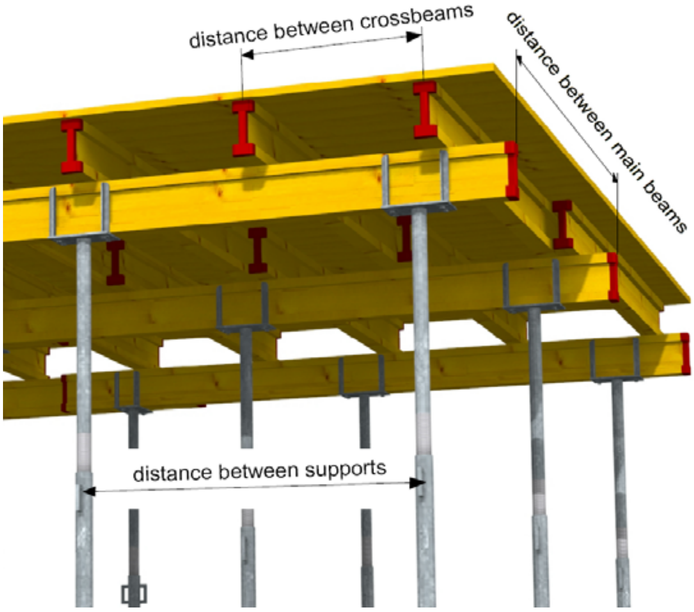


Fig. 8: Explanation of the components

PERMISSIBLE DISTANCES BETWEEN MAIN BEAMS AND SUPPORTS

Max. deflection:	*l/500*
Live load:	*1,5 kN/m² or 20 % of concrete weight*
Load-bearing capacity of the supports:	*at least 22 kN*
Technical specifications:	*- permissible moment (M) = 5,0 kNm* *- permissible shear force (Q) = 11,0 kN* *- characteristic bending resistance (M_k) = 10,9 kNm* *- characteristic shear resistance (V_k) = 23,9 kN*

thickness (cm)	② total load (kN/m²)	Table 1: permissible distance between crossbeams (m)				Table 2: permissible distance between main beam (m)								
		0,50	0,625	0,667	0,75	1,00	1,25	1,50	1,75	2,00	2,25	2,50	3,00	3,50
		max. distance between main beam (m)				④ max. distance between supports (m)								
10	4,38	3,70	3,43	3,35	3,22	2,93	2,72	2,50	2,31	2,16	2,04	1,93	1,70	1,45
12	4,91	3,50	3,24	3,17	3,05	2,77	2,57	2,36	2,19	2,05	1,92	1,82	1,52	1,30
14	5,43	3,32	3,09	3,02	③ 2,91	2,64	2,45	2,24	2,08	1,94	1,82	⑤ 1,64	1,37	1,18
16	5,95	3,19	2,96	2,90	2,79	2,54	2,35	2,14	1,98	1,85	1,66	1,50	1,25	1,07
18	6,48	3,07	2,85	2,79	2,69	2,44	2,25	2,06	1,90	1,72	1,53	1,38	1,15	0,99
① 20	7,00	2,97	2,76	2,70	2,60	2,36	2,17	1,97	1,82	1,59	1,42	1,28	1,07	0,91
22	7,53	2,88	2,68	2,62	2,52	2,29	2,09	1,90	1,69	1,48	1,32	1,19	0,99	0,85
24	8,05	2,81	2,61	2,55	2,45	2,23	2,02	1,84	1,58	1,39	1,23	1,11	0,93	0,80
26	8,57	2,74	2,54	2,49	2,39	2,18	1,95	1,73	1,49	1,30	1,16	1,04	0,87	0,75
28	9,10	2,67	2,48	2,43	2,34	2,12	1,89	1,63	1,40	1,23	1,09	0,98	0,82	0,71
30	9,68	2,61	2,43	2,38	2,29	2,06	1,83	1,54	1,32	1,15	1,03	0,93	0,77	0,65
35	11,2	2,49	2,31	2,26	2,18	1,90	1,59	1,32	1,14	0,99	0,89	0,80	0,66	0,56
40	12,8	2,38	2,21	2,17	2,07	1,74	1,39	1,16	1,00	0,87	0,78	0,70	0,58	0,49
45	14,4	2,29	2,13	2,07	1,94	1,55	1,24	1,04	0,89	0,78	0,69	0,62	0,51	0,44
50	15,9	2,22	2,03	1,96	1,84	1,40	1,12	0,94	0,80	0,70	0,62	0,56	0,46	0,40
55	17,5	2,15	1,93	1,87	1,69	1,27	1,02	0,85	0,73	0,63	0,56	0,51	0,42	0,36

Example of calculation: Ceiling thickness 20 cm, distance between crossbeams 75 cm, we are looking for the distance between main beams and supports: permissible distance between main beams according to table 1 = 2,60 m. The identical or next smaller distance between main beams in table 2 = 2,5 m. Look for the permissible distance between supports in table 2, in column 2,5 m depending on the ceiling thickness (20 cm) = 1,28 m.

But examine the load-bearing capacity of the supports! These tables can be used for a preliminary estimate.

5. References

[1] Neuhaus H., Lehrbuch des Ingenieurholzbaus, B.G. Teubner Stuttgart, 1994

[2] Steinbrecher D, Vorlesungsskript Holzbau Grundlagen – Allgemeiner Teil, Brandenburgische Technische Universität Cottbus, 2011

[3] Wallner M., Koppelhuber S., Pock K., Brettsperrholz Bemessung, 2013

[4] Neuhaus H., Lehrbuch des Ingenieurholzbaus, Vieweg + Teubner Verlag, Wiesbaden, 2011

[6] ÖNORM EN 13377, Industriell gefertigte Schalungsträger aus Holz - Anforderungen, Klassifizierung und Nachweis, 2002-11-01