STATIČKI PRORAČUN HALE SA TRAPEZNIM NOSAČIMA

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TEHNIČKI OPIS KONSTRUKCIJE

OPIS PROJEKTNOG ZADATKA

Projektni zadatak prema kojem je izrađen projekt sadrži nekoliko bitnih dijelova. Izabran materijal je masivno i lamelirano lijepljeno drvo, maksimalna visina konstrukcije iznosi 11.50 metara, raspon 24.00 metara, a kao karakteristična djelovanja uzeta su 1.15 kN/m^2 (Stalno) i 1.60 kN/m^2 (Snijeg). Potrebno je projektirati halu sa jednostrešnim trepeznim nosačima koji naliježu na armirano betonske stupove.

DIMENZIJE OBJEKTA

Tlocrtne dimenzije objekta su 23.15 metara X 30.00 metara. Visina krovne konstrukcije je 11.37 metara.

SEKUNDARNA KONSTRUKCIJA

Sekundarna konstrukcija tj. podrožnice nalaze se na osnom razmaku 1.28 metara. Raspon sekundarne konstrukcije jednak je razmaku glavnih nosača te iznosi 3.75 metara. Poprečni presjek sekundarne konstrukcije je dimenzija 12 centimetara X 18 centimetara. Svi elementi su duljine 3.75 metara te se na svakom glavnom nosaču vrši spajanje čeličnim kutnicima, koji se za glavni nosač priključuju sa 4 čavla 34/90. Materijal koji je odabran za sekundarnu konstrukciju je KVH drvo klase S13, vlažnosti manje od 18 %.

GLAVNA NOSIVA KONSTRUKCIJA

Glavna nosiva konstrukcija sastoji od jednostrešnih trapeznih nosača čiji je osni raspon 23.15 metara. Materijal koji je izabran za izvedbu je lamelirano lijepljeno drvo klase BS16c, a dimenzije poprečnog presjeka su 20 centimetara X 90-171 centimetara. Lamelirano lijepljeno drvo mora biti vlažnosti manje od 18 % kako bi imalo projektirana svojstva. Osni razmak među glavnim nosača je 3.75 metara, a objekt je sačinjen od 9 glavnih nosača.

VJETROVNI SPREG

Vjetrovni spreg se nalazi između glavnih nosača, a ispod podrožnica. Na cijelom objektu postoje 2 vjetrovna sprega, koji su međusobno udaljeni 18.75 metara te tako stabiliziraju maksimalno 5 glavnih nosača. Spregovi su kružnog poprečnog presjeka promjera 20 milimetara, isti moraju biti od čelika S355, a pričvršćeni su na glavni nosač pomoću čeličnih ploča.

ZAŠTITA KONSTRUKCIJE

Drvene elemente konstrukcije potrebno je prije montaže zaštiti od nametnika te utjecaja vlage. Drvo je materijala kod kojeg se nosivost smanjuje povećanjem vlažnosti, te elemente ne smijemo prije montaže položiti izravno na zemlju, beton, ili ih ostaviti nezaštićene na kiši. Prije montaže drvene elemente je potrebno premazati impregnacijom tipa Belinka Belles kako bi se zaštitili od nametnika, nakon toga napraviti dva premaza tankoslojnom lazurom tipa Belinka Belton, te na kraju jedan finalni premaz debeloslojnom lazurom tipa Belinka Beltop. Moguće je koristiti i premaze drugih proizvođača koji imaju jednakovrijedna svojstva. Spajala moraju biti vruće pocinčana, te nisu potrebni naknadni premazi.

POZICIJA 101 PODROŽNICA 12cm/18cm GRAĐA S13

1. ANALIZA DJELOVANJA

stalno djelovanje	**G_k= 1.15 kN/m^2**
promjenjivo djelovanje (snijeg)	**$Q_{1,k}$= 1.60 kN/m^2**
građa sekundarne konstrukcije	**S 13**
razmak sekundarne konstrukcije	**e=1.28 m**
raspon sekundarne konstrukcije	**l_s=3.75 m**
nagib glavnog nosača	**α=8°**

1.1 GRANIČNO STANJE NOSIVOSTI

2.1.1 KOMBINACIJA DJELOVANJA STALNO+SNIJEG

$q_{y,d}$ = [(1.35 x G_k + 1.50 x $Q_{1,k}$ x cosα) x cosα] x e =

= [(1.35 x 1.15 + 1.50 x 1.60 x cos 8°) x cos 8°] x 1.28 =

$q_{y,d}$= 4.98 kN/m'

$q_{z,d}$ = [(1.35 x G_k + 1.50 x $Q_{1,k}$ x cosα) x sinα] x e =

= [(1.35 x 1.15 + 1.50 x 1.60 x cos 8°) x sin 8°] x 1.28 =

$q_{z,d}$= 0.70 kN/m'

2.1.2 PROJEKTIRANE VRIJEDNOSTI REZNIH SILA

Momenti savijanja:

$$M_{y,d} = \frac{q_{y,d} \times l^2}{8};$$

$$M_{z,d} = \frac{q_{z,d} \times l^2}{8};$$

$$M_{y,d} = \frac{4.98 \times 3.75^2}{8} = 8.75\ \text{kNm}$$

$$M_{z,d} = \frac{0.70 \times 3.75^2}{8} = 1.23\ \text{kNm}$$

Poprečna sila:

$$V_{y,d} = \frac{q_{y,d} \times l}{2};$$

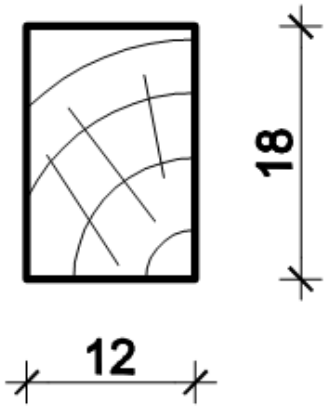
$$V_{z,d} = \frac{q_{z,d} \times l}{2}$$

$$V_{y,d} = \frac{4.98 \times 3.75}{2} = 9.34\ kN$$

$$V_{z,d} = \frac{0.70 \times 3.75}{2} = 1.31\ kN$$

$$V_d = \sqrt{V_{y,d}^{\ 2} + V_{z,d}^{\ 2}} = 9.43\ kN$$

2.1.3 DIMENZIONIRANJE PODROŽNICE



$$A = 12.0 \times 18.0 = 216\ cm^2$$

$$W_y = \frac{b \times h^2}{6} = \frac{12.0 \times 18.0^2}{6} = 648\ cm^3$$

$$W_z = \frac{b^2 \times h}{6} = \frac{12.0^2 \times 18.0}{6} = 432\ cm^3$$

$$I_y = \frac{b \times h^3}{12} = \frac{12.0 \times 18.0^3}{12} = 5832\ cm^4$$

$$I_z = \frac{b^3 \times h}{12} = \frac{12.0^3 \times 18.0}{12} = 2592\ cm^4$$

Parametri za proračun građa S13:

$F_{m,k}$= 30 N/mm^2 = 3 kN/cm^2

$f_{v,k}$= 2.5 N/mm^2 = 0.25 kN/cm^2

γ_M= 1.3

k_{mod}= 0.9

k_m= 0.7

$$f_{m,d} = k_{mod}\ x\ \frac{f_{m,k}}{y_m} = 0.90x\frac{3.0}{1.3} = 2.08\ kN/cm^2$$

Dokaz nosivosti presjeka na savijanje:

$$\sigma_{m,y,d} = \frac{M_{y,d}}{W_y} = \frac{8.75 \times 100}{648} = 1.35\ \text{kN/cm}^2$$

$$\sigma_{m,z,d} = \frac{M_{z,d}}{W_z} = \frac{1.23 \times 100}{432} = 0.29\ \text{kN/cm}^2$$

$$\frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} = \frac{1.35}{2.08} + 0.7 \times \frac{0.29}{2.08} = 0.75 < 1 \qquad \textbf{0.75 < 1.0}$$

$$k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} = 0.7 \times \frac{1.35}{2.08} + \frac{0.29}{2.08} = 0.59 < 1 \qquad \textbf{0.59 < 1.0}$$

PRESJEK ZADOVOLJAVA ISKORISTIVOST 75%

Grenzzustand der Tragfähigkeit

Nachweis der **Biegespannung** nach EC 5 Abschnitt 5.1.6

POZ 101 Sekundarna konstrukcija 120mm/180mm građa S13

Eingabedaten:

Baustoff	2
Vollholz	
S10/MS10	1
S 13	2
MS 13	3
MS 17	4
Brettschichtholz	
BS 11	5
BS 14k	6
BS 14h	7
BS 16k	8
BS 16h	9
BS 18k	10
BS 18h	11

Querschnittswerte:

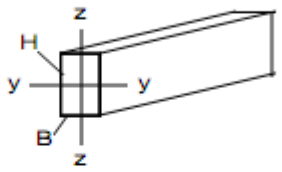
B =	120	mm
H =	180	mm
W_y =	6,48 E+5	mm^3
W_z =	4,32 E+5	mm^3

Querschnittsschwächung:

ΔW_y =	0,00 E+0	mm^3
ΔW_z =	0,00 E+0	mm3

Bemessungswerte der Schnittgrößen:

$M_{y,d}$ =	8,75	kNm
$M_{z,d}$ =	1,23	kNm



NKL =	2
u ≤ 12%	1
u ≤ 20%	2
20% < u	3
KLED =	4
ständig =	1
lang =	2
mittel =	3
kurz =	4

Nachweise:

Bedingung (1): $\frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \le 1$

Bedingung (2): $k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \le 1$

Bedingung (1):	0,65	+	0,10	=	0,75	<	1
Bedingung (2):	0,46	+	0,14	=	0,59	<	1

Rechenwerte:

k_{mod} = 0,90 γ_M = 1,3 k_m = 0,7 für Rechteckquerschnitte

Biegung um die y-Achse

$\sigma_{m,y,d} = M_{y,d} / W_{y,netto}$ =	13,5	N/mm^2
$f_{m,y,k}$ =	30,0	N/mm^2
$f_{m,y,d} = k_{mod} \cdot f_{m,y,k} / \gamma_M$ =	20,8	N/mm^2

Biegung um die z-Achse

$\sigma_{m,z,d} = M_{z,d} / W_{z,netto}$ =	2,8	N/mm^2
$f_{m,z,k}$ =	30,0	N/mm^2
$f_{m,z,d} = k_{mod} \cdot f_{m,z,k} / \gamma_M$ =	20,8	N/mm^2

Grenzzustand der Tragfähigkeit

Nachweis der **Biegespannung** (Kippen) nach EC 5 Abschnitt 5.2.2

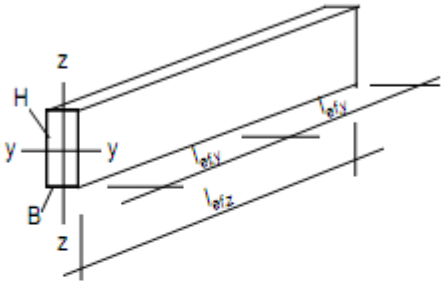
POZ 101 Sekundarna konstrukcija 120mm/180mm građa S13

Eingabedaten:

Baustoff	2
Vollholz	
S10/MS10	1
S 13	2
MS 13	3
MS 17	4
Brettschichtholz	
BS 11	5
BS 14k	6
BS 14h	7
BS 16k	8
BS 16h	9
BS 18k	10
BS 18h	11

Querschnittswerte:

B =	120	mm
H =	180	mm
A =	21600	mm^2
W_y =	6,48E+05	mm^3
W_z =	4,32E+05	mm^3



Systemwerte:

$l_{ef,y}$ =	3,75	m	Biegung um y-Achse
$l_{ef,z}$ =	3,75	m	um z-Achse

Bemessungswert der Schnittgrößen:

$M_{y,d}$ =	8,75	kNm
$M_{z,d}$ =	1,23	kNm

NKL =	2
u ≤ 12%	1
u ≤ 20%	2
20% < u	3
KLED =	4
ständig =	1
lang =	2
mittel =	3
kurz =	4

Nachweise:

$$(1)\quad \frac{\sigma_{m,y,d}}{k_{crit,y}\, f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{k_{crit,z}\, f_{m,z,d}} \le 1$$

$$(2)\quad k_m \frac{\sigma_{m,y,d}}{k_{crit,y}\, f_{m,y,d}} + \frac{\sigma_{m,z,d}}{k_{crit,z}\, f_{m,z,d}} \le 1$$

(1)	0,65	+	0,10	=	0,75	< 1
(2)	0,46	+	0,14	=	0,59	< 1

Rechenwerte:

$E_{0,05}$ = 8000 N/mm^2 k_{mod} = 0,90 γ_M = 1,3 k_m = 0,7

Biegung um die y-Achse

$\sigma_{m,y,d}$ =	13,5	N/mm^2
$f_{m,y,k}$ =	30,0	N/mm^2
$f_{m,y,d}$ =	20,8	N/mm^2
$\sigma_{m,crit,y}$ =	134,0	N/mm^2
$\lambda_{rel,m,y}$ =	0,47	
$k_{crit,y}$ =	1,00	

Biegung um die y-Achse

$\sigma_{m,z,d}$ =	2,8	N/mm^2
$f_{m,z,k}$ =	30,0	N/mm^2
$f_{m,z,d}$ =	20,8	N/mm^2
$\sigma_{m,crit,z}$ =	452,4	N/mm^2
$\lambda_{rel,m,z}$ =	0,26	
$k_{crit,z}$ =	1,00	

Dokaz nosivosti na posmik:

$\tau_{v,d} \le f_{v,d}$

$$f_{v,d} = k_{mod} \times \frac{f_{v,k}}{\gamma_M} = 0.90 \times \frac{2.5}{1.3} = 1.73\ N/mm^2$$

$$\tau_{v,d} = 1.5 \times \frac{V_d}{A} = 1.5 \times \frac{9430}{21600} = 0.65\ N/mm^2 < 1.73\ N/mm^2$$

PRESJEK ZADOVOLJAVA ISKORISTIVOST 38%

Grenzzustand der Tragfähigkeit

Nachweis der **Schubspannung** nach EC 5 Abschnitt 5.1.7

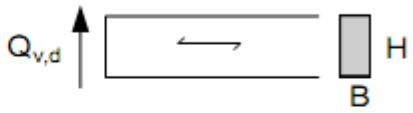
POZ 101 Sekundarna konstrukcija 120mm/180mm građa S13

Eingabedaten:

Baustoff	2
Vollholz	
S10/MS10	1
S 13	2
MS 13	3
MS 17	4
Brettschichtholz	
BS 11	5
BS 14k	6
BS 14h	7
BS 16k	8
BS 16h	9
BS 18k	10
BS 18h	11

Querschnittswerte:

B = 120 mm
H = 180 mm
A = 21600 mm²



NKL =	2
u ≤ 12%	1
u ≤ 20%	2
20% < u	3
KLED =	4
ständig =	1
lang =	2
mittel =	3
kurz =	4

Bemessungswert der Schnittgröße:

$Q_{v,d}$ = 9,43 kN

Nachweis: $\tau_d = 1{,}5 \frac{Q_{v,d}}{A} \le k_{mod} \cdot \frac{f_{v,k}}{\gamma_M} = f_{v,d}$

τ_d = 0,65 < 1,73 = $f_{v,d}$

Rechenwerte:

$f_{v,k}$ = 2,50 N/mm² k_{mod} = 0,90 γ_M = 1,3

1.2 GRANIČNO STANJE UPORABLJIVOSTI

Građa sekundarne konstrukcije S 13

$E_{o,\,mean}$= 12000 N/mm^2 = 1200 kN/cm^2

$G_{o,\,mean}$= 750 N/mm^2 = 75 kN/cm^2

$k_{def,\,G}$ = 0.8

$k_{def,\,Q}$= 0.0

2.2.1 STALNO DJELOVANJE

$$q_{y,d}^{G_{u,i}} = G_{k,i} \times \cos\alpha \times e = 1.15 \times \cos 8° \times 1.28 = 1.46\ \text{kN/m'}$$
$$q_{z,d}^{G_{u,i}} = G_{k,i} \times \sin\alpha \times e = 1.15 \times \sin 8° \times 1.28 = 0.20\ \text{kN/m'}$$

2.2.2 PROMJENJIVO DJELOVANJE

$$q_{y,d}^{Q_{u,i}} = Q_{k,s} \times \cos\alpha \times e = 1.60 \times \cos 8° \times 1.28 = 2.03\ \text{kN/m'}$$
$$q_{z,d}^{Q_{u,i}} = Q_{k,s} \times \sin\alpha \times e = 1.60 \times \sin 8° \times 1.28 = 0.29\ \text{kN/m'}$$

2.2.3 PROJEKTIRANE VRIJEDNOSTI UNUTARNJIH SILA

Stalno djelovanje:

$$M_{y,d}^{G_{k,i}} = \frac{q_{y,d} \times l^2}{8} = \frac{1.46 \times 3.75^2}{8} = 2.45\ \text{kNm}$$
$$M_{z,d}^{G_{k,i}} = \frac{q_{z,d} \times l^2}{8} = \frac{0.20 \times 3.75^2}{8} = 0.35\ \text{kNm}$$

Promjenjivo djelovanje:

$$M_{y,d}^{Q_{k,s}} = \frac{q_{y,d} \times l^2}{8} = \frac{2.03 \times 3.75^2}{8} = 3.57\ \text{kNm}$$
$$M_{z,d}^{Q_{k,s}} = \frac{q_{z,d} \times l^2}{8} = \frac{0.29 \times 3.75^2}{8} = 0.51\ \text{kNm}$$

2.2.4 KOMBINACIJA DJELOVANJA STALNO+SNIJEG

Stalno djelovanje:

$$u_{inst,y}^{G_{k,i}} = \frac{5}{48} \times \frac{M_y \times l^2}{E_{o,mean} \times I_y} + 1.2 \times \frac{M_y}{G_{o,mean} \times A}$$

$$u_{inst,y}^{G_{k,i}} = \frac{5}{48} \times \frac{2.45 \times 100 \times 375^2}{1200 \times 5832} + 1.2 \times \frac{2.45 \times 100}{75 \times 216}$$

$$u_{inst,y}^{G_{k,i}} = 0.53 \text{ cm}$$

$$u_{inst,z}^{G_{k,i}} = \frac{5}{48} \times \frac{M_z \times l^2}{E_{o,mean} \times I_z} + 1.2 \times \frac{M_z}{G_{o,mean} \times A}$$

$$u_{inst,z}^{G_{k,i}} = \frac{5}{48} \times \frac{0.35 \times 100 \times 375^2}{1200 \times 2592} + 1.2 \times \frac{0.35 \times 100}{75 \times 216}$$

$$u_{inst,z}^{G_{k,i}} = 0.17 \text{cm}$$

$$u_{inst}^{G_{k,i}} = \sqrt{u_{inst,y}^{G_{k,i}\,2} + u_{inst,z}^{G_{k,i}\,2}} = \sqrt{0.53^2 + 0.17^2} = 0.56 \text{ cm}$$

$$k_{def,G} = 0.8$$

$$u_{fin}^{G_{k,i}} = u_{inst}^{G_{k,i}} \times (1 + k_{def,G}) = 0.56 \times (1 + 0.8) = 1.01 \text{cm}$$

Progib od stalnog djelovanja

$$u_{fin}^{G} = 1.01 \text{ cm} < l/200 = 1.88 \text{ cm}$$

Promjenjivo djelovanje:

$$u_{inst,y}^{Q_{1,k}} = \frac{5}{48} \times \frac{M_y \times l^2}{E_{o,mean} \times I_y} + 1.2 \times \frac{M_y}{G_{o,mean} \times A}$$

$$u_{inst,y}^{Q_{1,k}} = \frac{5}{48} \times \frac{3.57 \times 100 \times 375^2}{1200 \times 5832} + 1.2 \times \frac{3.57 \times 100}{75 \times 216}$$

$$u_{inst,y}^{Q_{1,k}} = 0.77 \text{ cm}$$

$$u_{inst,z}^{Q_{1,k}} = \frac{5}{48} \times \frac{M_z \times l^2}{E_{o,mean} \times I_z} + 1.2 \times \frac{M_z}{G_{o,mean} \times A}$$

$$u_{inst,z}^{Q_{1,k}} = \frac{5}{48} \times \frac{0.51 \times 100 \times 375^2}{1200 \times 2592} + 1.2 \times \frac{0.51 \times 100}{75 \times 216}$$

$$u_{inst,z}^{Q_{1,k}} = 0.24 \text{ cm}$$

$$u_{inst,z}^{Q\ 1,k} = \sqrt{u_{inst,y}^{Q_{k,s}\ 2} + u_{inst,z}^{Q_{k,s}\ 2}} = \sqrt{0.77^2 + 0.24^2} = 0.80 \text{ cm}$$

$$k_{def,Q} = 0.0$$

$$u_{fin}^{Q\ 1,k} = u_{inst,z}^{Q\ 1,k} \times (1 + k_{def,Q}) = 0.80 \times (1 + 0.0) = 0.80 \text{ cm}$$

Progib od promjenjivog djelovanja

$$u_{fin}^{Q\ 1,K} = 0.80 \text{ cm} < l/300 = 1.25 \text{ cm}$$

Konačna vrijednost progiba:

$$u_{fin} = 1.01 + 0.80 = 1.81 \text{ cm} < l/200 = 1.88 \text{ cm}$$

PRESJEK ZADOVOLJAVA

Nachweis der Gebrauchstauglichkeit

Nachweis der Durchbiegung nach EC5 Abschnitt 4.1 und 4.3

POZ 101 Sekundarna konstrukcija 120/180 mm građa S 13

		KLED 1=ständig 2=lang 3=mittel 4=kurz		
Überhöhung u_0 [mm] =				
Durchbiegung auf der Grundlage von DIN 1055	u_k mm		ψ_1	k_{def}
ständige Einwirkungen				
aus Eigengewicht u_g (G_k)	5,6	1	1,0	0,80
veränderliche Einwirkungen				
aus Schnee u_s ($Q_{1,k}$)	8,0	4	0,2	0,00
aus Wind u_w ($Q_{2,k}$)	0,0	4	0,5	-
aus Verkehrslast u_p ($Q_{3,k}$)	0,0	3	0,8	-
$u_{k,ges}$ =	13,6			

Spannweite l in m =	3,75
Kragträger (0 = nein, 1 = ja) =	0

NKL =	2
u ≤ 12%	1
u ≤ 20%	2
20% < u	3

Ergebnis:

$u_{2,inst}$ [mm] =	8,0	<	12,5	= l/300
$u_{2,fin}$ [mm] =	8,0	<	18,8	= l/200
$u_{net,fin}$ [mm] =	18,1	<	18,8	= l/200

Einzelergebnisse:

Lastfall-Kombination	Grundgleichungen zur Kombination der ständigen und veränderlichen Einwirkungen	$u_{1,inst}$ / $u_{2,inst}$	$u_{net,inst}$ mm	$u_{2,fin}$ mm	$u_{net,fin}$ mm
LFK '0'	G_k	5,6	5,6	-	10,1
LFK '1a'	$G_k + Q_{1,k}$	8,0	13,6	8,0	18,1
LFK '1b'	$G_k + Q_{2,k}$	-	-	-	-
LFK '1c'	$G_k + Q_{3,k}$	-	-	-	-
LFK '2a'	$G_k + Q_{1,k} + \psi_1 \cdot Q_{2,k}$	-	-	-	-
LFK '2b'	$G_k + \psi_1 \cdot Q_{1,k} + Q_{2,k}$	-	-	-	-
LFK '2c'	$G_k + Q_{1,k} + \psi_1 \cdot Q_{3,k}$	-	-	-	-
LFK '2d'	$G_k + \psi_1 \cdot Q_{1,k} + Q_{3,k}$	-	-	-	-
LFK '2e'	$G_k + Q_{2,k} + \psi_1 \cdot Q_{3,k}$	-	-	-	-
LFK '2f'	$G_k + \psi_1 \cdot Q_{2,k} + Q_{3,k}$	-	-	-	-
LFK '3a'	$G_k + Q_{1,k} + \psi_1 \cdot Q_{2,k} + \psi_1 \cdot Q_{3,k}$	-	-	-	-
LFK '3b'	$G_k + \psi_1 \cdot Q_{1,k} + Q_{2,k} + \psi_1 \cdot Q_{3,k}$	-	-	-	-
LFK '3c'	$G_k + \psi_1 \cdot Q_{1,k} + \psi_1 \cdot Q_{2,k} + Q_{3,k}$	-	-	-	-
max u [mm] =		**8,0**	13,6	**8,0**	**18,1**
bei		LFK '1a'	LFK '1a'	LFK '1a'	LFK '1a'

Erläuterung von Begriffen		
	Durchbiegung infolge ständiger Einwirkungen	$u_1 = u_G$
	Durchbiegung infolge veränderlicher Einwirkungen	$u_2 = \Sigma u_Q$
	Gesamte Durchbiegung	$u_{net} = u_1 + u_2 - u_0$
	Elastische Anfangsdurchbiegung	u_{inst}
	Enddurchbiegung (einschl. Kriechen)	$u_{fin} = u_{inst}(1 + k_{def})$
	(hierbei sind die Verformungswerte für jede anteilige Einwirkung mit dem zugehörigen k_{def} - Wert getrennt zu ermitteln)	
NKL =	Nutzungsklasse (vgl. EC5: Abschnitt 3.1.5)	
KLED =	Klasse der Lasteinwirkungsdauer (vgl. NAD: Tabelle 3.1-1)	
ψ_1 =	Kombinationsbeiwerte für Grenzzustand der Gebrauchstauglichkeit (vgl. NAD: Tabelle 2.2-1)	
k_{def} =	Deformationsbeiwert (vgl. EC5 Tabelle 4.1)	

POZICIJA 102 LAMELIRANI NOSAČ 90cm/171cm GRAĐA BS16c

2. ANALIZA DJELOVANJA

stalno djelovanje	**G_k= 1.15 kN/m²**
promjenjivo djelovanje (snijeg)	**$Q_{1,k}$= 1.60 kN/m²**
građa glavne nosive konstrukcije	**BS 16c**
razmak glavnih nosača	**e=3.75 m**
raspon glavne nosive konstrukcije	**L=23.15 m**
nagib glavnog nosača	**α=8°**

2.1 GRANIČNO STANJE NOSIVOSTI

2.1.1 STALNO DJELOVANJE

OD POZICIJE 101

$$\frac{G_k \times e}{\cos\alpha} = \frac{1.15 \times 3.75}{\cos 8} = 4.36 \text{kN/m}$$ =4.36 kN/m

OD VLASTITE TEŽINE

$$b \times \frac{(h_a + h_{ap})}{2} \times \rho_k = 0.20 \times \frac{(0.9 + 1.71)}{2} \times 4.1 = 1.07 \text{kN/m}$$ =1.07 kN/m

UKUPNO STALNO 5.43 kN/m

2.1.2 PROMJENJIVO DJELOVANJE (SNIJEG)

$Q_{1,k}$ x e= 1.60 x 3.75= 6.00 kN/m' =6.00 kN/m

UKUPNO PROMJENJIVO 6.00 kN/m

2.1.3 KOMBINACIJA DJELOVANJA STALNO+SNIJEG

$$q_{y,d} = 1.35 \times G_{k,j} + 1.50 \times Q_{k,s} = 1.35 \times 5.43 + 1.50 \times 6.00 = 16.33 \text{ kN/m}$$

2.1.4 PROJEKTIRANE VRIJEDNOSTI REZNIH SILA

$$M_{y,d} = \frac{q_{y,d} \times L^2}{8} = \frac{16.33 \times 23.15^2}{8} = 1093.95 \text{ kNm}$$

$$V_{y,d} = \frac{q_{y,d} \times L}{2} = \frac{16.33 \times 23.15}{2} = 189.01 \text{ kN}$$

2.1.5 DIMENZIONIRANJE LAMELIRANOG LIJEPLJENOG NOSAČA

Parametri za proračun građa BS 16c:

$f_{m,k} = 32$ N/mm^2

$f_{v,k} = 2.7$ N/mm^2

$f_{c,90,k} = 5.5$ N/mm^2

$f_{c,0,k} = 28$ N/mm^2

$E_{0,05} = 10800$ N/mm^2

$E_{0,mean} = 13500$ N/mm^2

$G_{0,mean} = 840$ N/mm^2

$k_{mod} = 0.9$

$\gamma_M = 1.3$

$$f_{m,d} = k_{mod} \times \frac{f_{m,k}}{\gamma_M} = 0.9 \times \frac{32}{1.3} = 22.15 \text{ N/mm}^2$$

$$f_{v,d} = k_{mod} \times \frac{f_{v,k}}{\gamma_M} = 0.9 \times \frac{2.7}{1.3} = 1.87 \text{ N/mm}^2$$

$$f_{c,90,d} = k_{mod} \times \frac{f_{c,90,k}}{\gamma_M} = 0.9 \times \frac{5.5}{1.3} = 3.81 \text{N/mm}^2$$

Određivanje položaja karakterističnog presjeka x-x:

$$x = \frac{l}{\frac{h_{ap}}{h_a} + 1} = \frac{2315}{\frac{171}{90} + 1} = 798.28 \text{cm}$$

Visina poprečnog presjeka na mjestu karakterističnog presjeka x-x:

$$h_x = \frac{2 \times h_{ap}}{\frac{h_{ap}}{h_a} + 1} = \frac{2 \times 171}{\frac{171}{90} + 1} = 117.93 \text{cm}$$

Vrijednosti reznih sila, naprezanja savijanja i karakteristike poprečnog presjeka na mjestu karakterističnog presjeka x-x:

$$M_{y,d,(x1)} = \frac{q_{y,d} \times x_1}{2} \times (l - x_1) = \frac{16.33 \times 7.98}{2} \times (23.15 - 7.98) = 988.43\ \text{kNm}$$

$$W_{y,(x1)} = \frac{b \times h_{x1}^{\ 2}}{6} = \frac{200 \times 1179^2}{6} = 46334700\ \text{mm}^3$$

$$\sigma_{m,y,d,(x1)} = \frac{M_{y,d,(x1)}}{W_{y,(x1)}} = \frac{988430000}{46334700} = 21.33\ \text{kNm/mm}^2$$

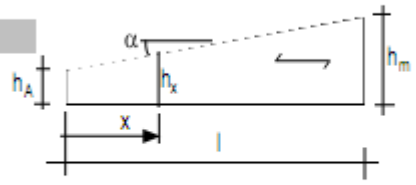
POZ 102 Lamelirani lijepljeni nosač 90cm/171cm BS16c

Eingabedaten:

Baustoff	8
Brettschichtholz	
BS 11	5
BS 14k	6
BS 14h	7
BS 16k	8
BS 16h	9
BS 18k	10
BS 18h	11

Systemwerte :

B =	200	mm
h_A =	900	mm
h_m =	1710	mm
l =	23,15	m
α =	2,00	°
x =	7,98	m
H_x =	1179	mm
W_x =	4,64E+07	mm^3



0	Z/D
0	Druck am angeschnittenen Rand
1	Zug am angeschnittenen Rand

NKL =	2
u ≤ 12%	1
u ≤ 20%	2
20% < u	3
KLED =	4
ständig =	1
lang =	2
mittel =	3
kurz =	4

Bemessungswert der Schnittgröße:

max M_d = 1093,95 kNm = $ql^2/8$

$M_{x,d}$ = 988,59 kNm

Nachweise:

$$(1)\ \sigma_{m,0,d} = (1+4\tan^2\alpha)\frac{M_{x,d}}{W_x} \le k_{mod}\frac{f_{m,k}}{\gamma_M}$$

$$(2)\ \sigma_{m,\alpha,d} = (1-4\tan^2\alpha)\frac{M_{x,d}}{W_x} \le k_{m\alpha}\,k_{mod}\frac{f_{m,k}}{\gamma_M}$$

(1) $\sigma_{m,0,d}$ =	21,43	<	22,15
(2) $\sigma_{m,\alpha,d}$ =	21,22	<	22,02

Rechenwerte:

$f_{m,k}$ =	32,00	N/mm^2
$f_{m,d}$ =	22,15	N/mm^2
$f_{t,90,k}$ =	0,45	N/mm^2
$f_{t,90,d}$ =	0,31	N/mm^2
$f_{c,90,k}$ =	5,50	N/mm^2
$f_{c,90,d}$ =	3,81	N/mm^2

M/W =	21,32	N/mm^2
$1+4\tan^2\alpha$ =	1,00	
$1-4\tan^2\alpha$ =	1,00	
$k_{m,\alpha}$ =	0,99	

k_{mod} =	0,9
γ_M =	1,3

3.2 GRANIČNO STANJE UPORABLJIVOSTI

Građa glavne nosive konstrukcije BS 16c

$E_{o,\,mean}$= 13500 N/mm^2 = 1350 kN/cm^2

$G_{o,\,mean}$= 840 N/mm^2 = 84 kN/cm^2

$k_{def,\,G}$ = 0.8

$k_{def,\,Q}$= 0.0

3.2.1 PRORAČUNSKA VRIJEDNOST MOMENATA SAVIJANJA PRI KONTROLI PROGIBA PRESJEKA U SREDINI RASPONA

$$_{max}M_G = \frac{G_{k,j} \times l^2}{8} = \frac{5{,}43 \times 23{,}15^2}{8} = 363.76\text{kNm}$$

$$_{max}M_Q = \frac{Q_{k,s} \times l^2}{8} = \frac{6.00 \times 23{,}15^2}{8} = 401.94\text{kNm}$$

3.2.2 POPREČNI PRESJEK NA LEŽAJU NOSAČA MJERODAVAN ZA UTVRĐIVANJA KRUTOSTI NOSAČA

$$I_a = \frac{b \times h_a^3}{12} = \frac{20 \times 90^3}{12} = 1215000\text{cm}^4$$

$$A_a = b \times h_a = 20 \times 90 = 1800\text{cm}^2$$

3.2.3 KOEFICJENTI UTJECAJA PROMJENE VISINE IZMEĐU PRSJEKA NA LEŽAJU I PRESJEKA U SREDINI RASPONA

$$k_\sigma = \frac{\left(\frac{h_a}{h_{ap}}\right)^{2.4}}{0.15 + 0.85 \times \frac{h_a}{h_{ap}}} = \frac{\left(\frac{90}{171}\right)^{2.4}}{0.15 + 0.85 \times \frac{90}{171}} = 0.36$$

$$k_\tau = \frac{2}{1.0 + \left(\frac{h_{ap}}{h_a}\right)^{0.74}} = \frac{2}{1.0 + \left(\frac{171}{90}\right)^{0.74}} = 0.77$$

3.2.4 TRENUTNE VRIJEDNOSTI DEFORMACIJA (PROGIBA) ZA POJEDINAČNA DJELOVANJA

Početni progib od stalnog djelovanja:

$$u_{inst,\sigma}^{G} = k_{\sigma} \times \frac{5}{48} \times \frac{\max M_G \times l^2}{E_{o,mean} \times I_a} = 0.36 \times \frac{5}{48} \times \frac{36376 \times 2315^2}{1350 \times 1215000} = 4.46cm$$

$$u_{inst,\tau}^{G} = k_{\tau} \times 1.2 \times \frac{\max M_G}{G_{o,mean} \times A_a} = 0.77 \times 1{,}2 \times \frac{36376}{84 \times 1800} = 0.22cm$$

$$u_{inst}^{G} = u_{inst,\sigma}^{G} + u_{inst,\tau}^{G} = 4.46 + 0.22 = 4.68cm$$

Početni progib od promjenjivog djelovanja:

$$u_{inst,\sigma}^{Q} = k_{\sigma} \times \frac{5}{48} \times \frac{\max M_Q \times l^2}{E_{o,mean} \times I_a} = 0.36 \times \frac{5}{48} \times \frac{40194 \times 2315^2}{1350 \times 1215000} = 4.93cm$$

$$u_{inst,\tau}^{Q} = k_{\tau} \times 1.2 \times \frac{\max M_Q}{G_{o,mean} \times A_a} = 0.77 \times 1{,}2 \times \frac{40194}{84 \times 1800} = 0.25cm$$

$$u_{inst}^{Q} = u_{inst,\sigma}^{Q} + u_{inst,\tau}^{Q} = 4.93 + 0.25 = 5.18cm$$

Konačne vrijednosti progiba nosača od pojedinačnih vertikalnih djelovanja:

$$u_{1,fin} = u_{net,fin}^{G} = u_{inst}^{G} \times (1 + k_{def,G}) = 4.68 \times (1 + 0{,}8) = 8.42cm$$

$$8.42cm < l/200 = 11.58cm$$

$$u_{2,fin} = u_{net,fin}^{Q} = u_{inst}^{Q} \times (1 + k_{def,Q}) = 5.18 \times (1 + 0) = 5.18cm$$

$$5.18 < l/300 = 7.72cm$$

PRESJEK ZADOVOLJAVA

Konačna vrijednost progiba za kombinaciju stalnog i kratkotrajnog promjenjivog djelovanja – dokaz uporabljivosti nosača za ukupno djelovanje:

$$u_0 = u_{net,fin}^{G} + 0{,}5 \times u_{net,fin}^{Q} = 8.42 + 0.5 \times 5.18 = 11.01cm$$

$$u_{net,fin} = u_{1,fin} + u_{2,fin} - u_0 = 8.42 + 5.18 - 11.01 = 2.59cm$$

$$2.59 < l/200 = 11.58cm$$

PRESJEK ZADOVOLJAVA

Nachweis der Gebrauchstauglichkeit

Nachweis der Durchbiegung nach EC5 Abschnitt 4.1 und 4.3

POZ 102 Lamelirani lijepljeni nosač 90cm/171cm BS 16c

		KLED 1=ständig 2=lang 3=mittel 4=kurz		
Überhöhung u_0 [mm] =	110,1			
Durchbiegung auf der Grundlage von DIN 1055	u_k mm		ψ_1	k_{def}
ständige Einwirkungen				
aus Eigengewicht $u_g(G_k)$	46,8	1	1,0	0,80
veränderliche Einwirkungen				
aus Schnee $u_s(Q_{1,k})$	51,8	4	0,2	0,00
aus Wind $u_w(Q_{2,k})$	0,0	4	0,5	-
aus Verkehrslast $u_p(Q_{3,k})$	0,0	3	0,8	-
$u_{k,ges}$ =	98,6			

Spannweite l in m =	23,15
Kragträger (0 = nein, 1 = ja) =	0

NKL =	2
u ≤ 12%	1
u ≤ 20%	2
20% < u	3

Ergebnis:

$u_{2,inst}$ [mm] =	51,8	<	77,2	= l/300
$u_{2,fin}$ [mm] =	51,8	<	115,8	= l/200
$u_{net,fin}$ [mm] =	25,9	<	115,8	= l/200

Einzelergebnisse:

Lastfall-Kombination	Grundgleichungen zur Kombination der ständigen und veränderlichen Einwirkungen	$u_{1,inst}$ / $u_{2,inst}$ mm	$u_{net,inst}$ mm	$u_{2,fin}$ mm	$u_{net,fin}$ mm
LFK '0'	G_k	46,8	-63,3	-	-25,9
LFK '1a'	$G_k + Q_{1,k}$	51,8	-11,5	51,8	25,9
LFK '1b'	$G_k + Q_{2,k}$	-	-	-	-
LFK '1c'	$G_k + Q_{3,k}$	-	-	-	-
LFK '2a'	$G_k + Q_{1,k} + \psi_1 \cdot Q_{2,k}$	-	-	-	-
LFK '2b'	$G_k + \psi_1 \cdot Q_{1,k} + Q_{2,k}$	-	-	-	-
LFK '2c'	$G_k + Q_{1,k} + \psi_1 \cdot Q_{3,k}$	-	-	-	-
LFK '2d'	$G_k + \psi_1 \cdot Q_{1,k} + Q_{3,k}$	-	-	-	-
LFK '2e'	$G_k + Q_{2,k} + \psi_1 \cdot Q_{3,k}$	-	-	-	-
LFK '2f'	$G_k + \psi_1 \cdot Q_{2,k} + Q_{3,k}$	-	-	-	-
LFK '3a'	$G_k + Q_{1,k} + \psi_1 \cdot Q_{2,k} + \psi_1 \cdot Q_{3,k}$	-	-	-	-
LFK '3b'	$G_k + \psi_1 \cdot Q_{1,k} + Q_{2,k} + \psi_1 \cdot Q_{3,k}$	-	-	-	-
LFK '3c'	$G_k + \psi_1 \cdot Q_{1,k} + \psi_1 \cdot Q_{2,k} + Q_{3,k}$	-	-	-	-
max u [mm] =		**51,8**	-11,5	**51,8**	**25,9**
bei		LFK '1a'	LFK '1a'	LFK '1a'	LFK '1a'

Erläuterung von Begriffen		
	Durchbiegung infolge ständiger Einwirkungen	$u_1 = u_G$
	Durchbiegung infolge veränderlicher Einwirkungen	$u_2 = \Sigma u_Q$
	Gesamte Durchbiegung	$u_{net} = u_1 + u_2 - u_0$
	Elastische Anfangsdurchbiegung	u_{inst}
	Enddurchbiegung (einschl. Kriechen)	$u_{fin} = u_{inst}(1+k_{def})$
	(hierbei sind die Verformungswerte für jede anteilige Einwirkung mit dem zugehörigen k_{def} - Wert getrennt zu ermitteln)	
NKL =	Nutzungsklasse (vgl. EC5: Abschnitt 3.1.5)	
KLED =	Klasse der Lasteinwirkungsdauer (vgl. NAD: Tabelle 3.1-1)	
ψ_1 =	Kombinationsbeiwerte für Grenzzustand der Gebrauchstauglichkeit (vgl. NAD: Tabelle 2.2-1)	
k_{def} =	Deformationsbeiwert (vgl. EC5 Tabelle 4.1)	

3. PRIKLJUČAK SEKUNDARNE KONSTRUKCIJE (POZ 101) NA GLAVNU KONSTRUKCIJU (POZ 102)

Građa glavne nosive konstrukcije	BS 16c
Vrsta spajala	čavli glatki
Način ugradnje	bušenjem
d×l čavla:	3.4×90 mm
Veza	čelična papuča
Debljina lima:	8 (mm)
Projektirana vrijednost nosivosti čavla na odrez:	R_d = 1.165 kN
Računska vrijednost poprečne sile:	V_d = 2.62 kN

Proračun potrebnog broja čavala

$$n_1 \geq \frac{V_d}{R_d} = \frac{2.62}{1.165} \geq 2.25 \text{kom}$$

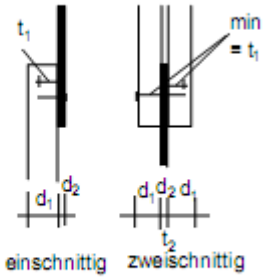
Odabrano 4 čavla 34/90mm

Priključak podrožnice na glavnu nosivu konstrukciju čavlima 34/90

Eingabedaten:

Stahl	0
Vollholz	
S10/MS10	1
S 13	2
MS 13	3
MS 17	4
Brettschichtholz	
BS 11	5
BS 14k	6
BS 14h	7
BS 16k	8
BS 16h	9
BS 18k	10
BS 18h	11
Holzwerkstoff	
BFU-NH	-
BFU-Bu	-
FP	-
HFH	-

Angaben zu den Nägeln:	
∅ =	3,4 mm
l =	90 mm
Typ	1
glattsch. =	0
Sonder-Nagel	
Kl. I =	1
Kl. II =	2
Kl. III =	3
Schnitt.	1
1-schn. =	1
2-schn. =	2
vorgebohrt	1
nein =	0
ja =	1



NKL =	2
u ≤ 12%	1
u ≤ 20%	2
20% < u	3
KLED =	4
ständig =	1
lang =	2
mittel =	3
kurz =	4

Angaben zu Holz		
Baustoff =	8	
d_1 =	900	mm
ρ_k =	410	kg/m³

Angaben zu Stahl		
Baustoff =	0	
d_2 =	8	mm

Beanspruchung auf Abscheren: Einschnittige Verbindung

R_d = 1,165 kN maßgebend: Gl.(6.2.2 d) nach EC5

Dickes Stahlblech			
Gl.(6.2.2 c)	Rd =	2,931	kN
Gl.(6.2.2 d)	Rd =	1,165	kN

Rechenwerte:

k_{mod} = 0,90 $\gamma_{M,Holz}$ = 1,3 $\gamma_{M,Stahl}$ = 1,1

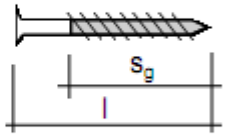
Holz:			Verbindungsmittel:		
t_1 =	82	mm	$M_{y,k}$ =	4336	Nmm
$f_{h,1,k}$ =	32,48	N/mm²	$M_{y,d}$ =	3942	Nmm
$f_{h,1,d}$ =	22,48	N/mm²			

Beanspruchung auf Herausziehen:

Herausziehen: R_{aus} = 0,584 kN Sondernagel, Tragfähigkeitsklasse I

Rechenwerte:

glattschaftiger Nagel:			Sondernagel:		
l_{ef} =	82	mm	$f_{1,k}$ =	4,71	N/mm²
$f_{1,k}$ =	3,03	N/mm²	$f_{1,d}$ =	3,26	N/mm²
$f_{1,d}$ =	2,09	N/mm²	$f_{2,k}$ =	100,86	N/mm²
			$f_{2,d}$ =	69,83	N/mm²



s_g = 90 mm

l_{ef} = 82 mm

R_{aus} =	0,584	Gl.(6.3.2 a)	$R_{aus,1}$ =	0,908	Gl.(6.3.2 a)
			$R_{aus,2}$ =	0,807	Gl.(6.3.2 c)