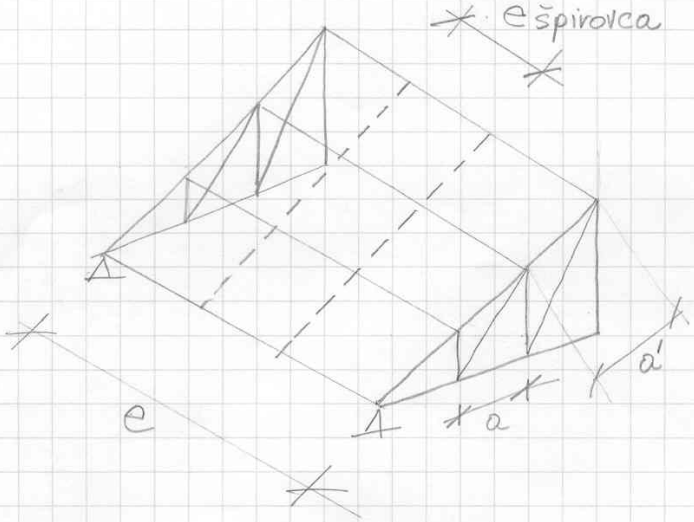
6. VAJA: DIMENZIONIRANJE UPOGIBNO OBREMENJENIH ELEMENTOV

6.1 DIMENZIONIRANJE ŠPIROVCA



DIM. ŠPIROVCEV
10/12, 12/14 cm, ...

→ pogoj: $e_š \leq 1{,}0\,m$ v mojem primeru $e_š = \frac{e}{3} = \frac{2{,}5}{3} = 0{,}833\,m$

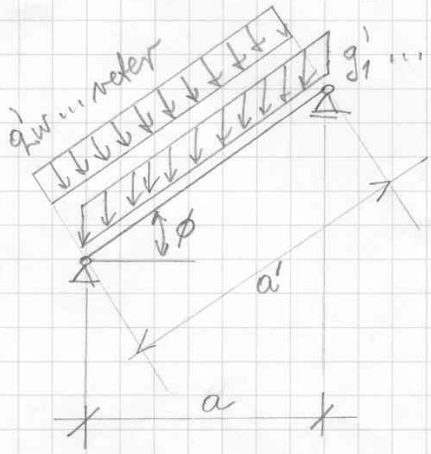
→ obtežba deluje na širini $e_š$ → površinsko obtežbo prevedemo na linijsko (na en špirovec)

→ špirovec pa obravnavamo kot kontinuiran nosilec zaradi oslobaciter (zaseki), ampak kot prostoležeči nosilec z obtežbo $\frac{q l^2}{8}$

q'_s ... sneg

q'_1 ... lastna teža

q'_w ... veter



→ na podlagi te obtežbe določimo upogibne momente in prečne sile.

14.4.03

• OBTEŽBA:

(* špirovcev, lege, letve, kritina)

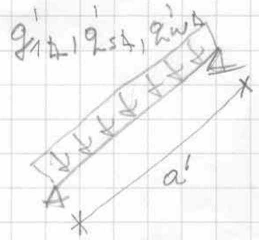
$g_1' = g_1 \cdot e_š = 0{,}45\ kN/m^2 \cdot 0{,}833\ m = 0{,}375\ kN/m$

$q_s' = q_s \cdot e_š = 1{,}25\ kN/m^2 \cdot 0{,}833\ m = 1{,}041\ kN/m$

$q_w' = q_w \cdot e_š = 0{,}24\ kN/m^2 \cdot 0{,}833\ m = 0{,}20\ kN/m$

→ (rabimo max. moment in max. prečno silo)

→ obtežba pravokotno na špirovec: $\phi = 13{,}65°$; $a' = 2{,}88\ m$



$g_{1⊥}' = g_1' \cdot \cos\phi = 0{,}375 \cdot \cos 13{,}65° = 0{,}364\ kN/m$ (*)

$q_{s⊥}' = q_s' \cdot \cos^2\phi = 1{,}041 \cdot \cos^2 13{,}65° = 0{,}983\ kN/m$

$q_{w⊥}' = q_w' = 0{,}20\ kN/m$

→ prečne sile rabimo pravokotno na nosilec!

• Projektna obtežba:

(M) $q_{d⊥} = 1{,}35 \cdot g_{1⊥}' + 1{,}5 \cdot q_{s⊥}' = 1{,}966\ kN/m$

(S) $q_{d⊥} = 1{,}35 (g_{1⊥}' + q_{s⊥}' + q_{w⊥}') = 2{,}088$

MSU: $q_d = g_{1⊥}' + q_{s⊥}' + q_{w⊥}' = 1{,}547\ kN/m$

$$\frac{q_{d⊥}^M}{q_{d⊥}^S} = \frac{1{,}966}{2{,}088} = 0{,}94 > 0{,}89 \Longrightarrow$$ merodajen "M" obtežni primer

• OBREMENITEV:

$$M_{d\,max} = \frac{q_{d⊥}^M \cdot a'^2}{8} = \frac{1{,}966 \cdot 2{,}88^2}{8} = \underline{2{,}04\ kNm}$$

$$V_{d\,max} = \frac{q_{d⊥}^M \cdot a'}{2} = \frac{1{,}966 \cdot 2{,}88}{2} = \underline{2{,}83\ kN}$$

• DIMENZIONIRANJE: (les C 30)

$$\sigma_{md} = \frac{M_{d,max}}{W} \leq f_{md}$$

$$W = \frac{J}{z_{rob}} \rightarrow \text{pravokotni prerez } W_{\square} = \frac{b h^2}{6}$$

Razmerje med b in h:

$W_{max}: \frac{h}{b} = \sqrt{2}$

$J_{max}: \frac{h}{b} = \sqrt{3}$

VSAMEMO $\rightarrow \frac{h}{b} = \sqrt{2} \rightarrow h = b \cdot \sqrt{2}$; $h > b$ ... mož pogoj

$W = \frac{b h^2}{6} = \frac{b^3}{3} \rightarrow$ ... vstavim v pogoj za nosilnost

$$b \geq \sqrt[3]{\frac{3 \cdot M_{max,d}}{f_{m,d}}} = \sqrt[3]{\frac{3 \cdot 2{,}04 \cdot 100}{1{,}846}} = 6{,}92 \text{ cm}$$

$h = b \cdot \sqrt{2} = 6{,}92 \cdot \sqrt{2} = 9{,}79$ cm | IZBEREM ŠPIROVEC

$b/h = 8/10$ cm

• KONTROLA STRIŽNIH NAPETOSTI:

$$\tau_{vd} = \frac{V_{d\,max} \cdot S}{J \cdot b} \leq f_{v,d}$$

(S: STATIČNI MOMENT)

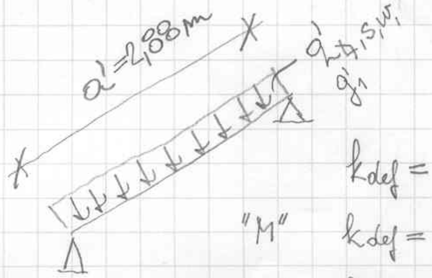
$\rightarrow$ pravokotni prerez: $\tau_{vd} = \frac{V_d}{\frac{2}{3} b \cdot h} = \frac{2{,}83 \text{ kN}}{\frac{2}{3} \cdot 8 \text{ cm} \cdot 10 \text{ cm}} =$

STRIŽNI PREREZ $\rightarrow A_s = \frac{2}{3} A$

$\tau_{vd} = 0{,}053 \frac{kN}{cm^2} < f_{vd} = 0{,}185 \frac{kN}{cm^2}$ ✓ PREREZ USTREZA

OP: Minimalne dimenzije za lesnate prereze je 6/6 cm.

• KONTROLA POVESA: ⟶ kontroliramo na MSU ($\gamma_G, \gamma_Q = 1{,}0$)



prerez: $b/h = 8/10$ cm

$k_{def} = 0{,}80$ $\quad g'_{1\perp} = 0{,}364$ kN/m $= q'_{d1\perp}$

"M" $\quad k_{def} = 0{,}25$ $\quad q'_{s\perp} = 0{,}983$ kN/m $= q'_{ds\perp}$

"S" $\quad k_{def} = 0{,}00$ $\quad q'_{w\perp} = 0{,}20$ kN/m $= q'_{dw\perp}$

začetni pomiki: $\frac{5}{384} \cdot \frac{a'^4}{E_{0,mean} J} = \frac{5}{384} \cdot \frac{288^4}{1200 \cdot 666{,}67} = 111{,}97 \ \frac{cm^2}{kN}$

$J = \frac{b \cdot h^3}{12} = \frac{8 \cdot 10^3}{12} = 666{,}67 \ cm^4$

u_g : $u_{1,inst} = q'_{d1\perp} \cdot 111{,}97 = 0{,}00364 \cdot 111{,}97 = 0{,}408$ cm

$u_{1,fin} = u_{1,inst}(1 + k_{def,1}) = 0{,}408 \cdot (1 + 0{,}80) = 0{,}734$ cm

u_q : $u_{2,inst_s} = q'_{s\perp} \cdot 111{,}97 = 0{,}00983 \cdot 111{,}97 = 1{,}10$ cm

$u_{2,fin_s} = u_{2,inst_s}(1 + k_{def,2}) = 1{,}10\,(1 + 0{,}25) = 1{,}38$ cm

$u_{2,inst_w} = q'_{w\perp} \cdot 111{,}97 = 0{,}0020 \cdot 111{,}97 = 0{,}224$ cm

$u_{2,fin_w} = u_{2,inst_w}(1 + k_{def,2}) = 0{,}224\,(1 + 0) = 0{,}224$ cm

kontrole: (samo zaradi koristne obt.)

$u_{2,inst} = u_{2,inst_s} + u_{2,inst_w} = 1{,}10 + 0{,}224 = 1{,}324$ cm

$u_{2,inst} = 1{,}324 \text{ cm} \nless \frac{a'}{300} = \frac{288}{300} = 0{,}96$ cm

⟶ povečati prerez

$u_0 = 0 \rightarrow u_{net} = u_1 + u_2$

$u_{net,fin} = 0{,}734 + (1{,}38 + 0{,}224) = 2{,}34 \text{ cm} \nless \frac{a'}{200} = \frac{288}{200} = 1{,}44$ cm

Obema pogojema mora biti zadovoljeno, ⟶ Povečati prerez
dasije prerez v MSU OK ✓

→ povečam presek: $\boxed{b/h = 10/12\ cm}$

$$J = \frac{b\cdot h^3}{12} = \frac{10\cdot 12^3}{12} = 1440\ cm^4$$

začetni pomiki: $\frac{5}{384}\cdot\frac{288^4}{1200\cdot 1440} = 51{,}84$

u_g: $u_{1,inst} = 0{,}00364\cdot 51{,}84 = 0{,}189\ cm$

$u_{1,fin} = 0{,}189\,(1+0{,}8) = 0{,}340\ cm$

u_q: $u_{2,inst,s} = 0{,}00983\cdot 51{,}84 = 0{,}509\ cm$

$u_{2,fin,s} = 0{,}509\cdot(1+0{,}25) = 0{,}636\ cm$

$u_{2,inst,w} = 0{,}0020\cdot 51{,}84 = 0{,}104\ cm$

$u_{2,fin,w} = 0{,}104\,(1+0) = 0{,}104\ cm$

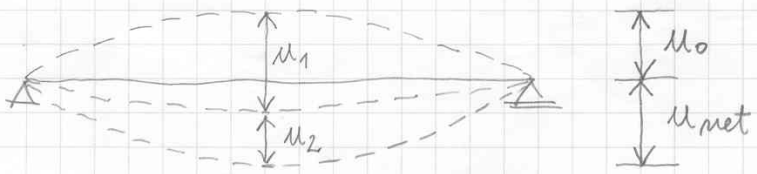
kontrole:

$u_{2,inst} = 0{,}509 + 0{,}104 = 0{,}613\ cm < \frac{a'}{300} = 0{,}96\ cm$ ✓

$u_{net,fin} = u_{1,fin} + u_{2,fin,s} + u_{2,fin,w} =$

$= 0{,}340 + 0{,}636 + 0{,}104 = 1{,}08\ cm < \frac{a'}{200} = 1{,}44\ cm$ ✓

pomiki so ustrezni ✓



$u_{net} = u_1 + u_2 - u_0$

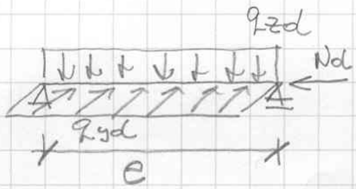
u_1 ... pomik zaradi stalne obtežbe (g)

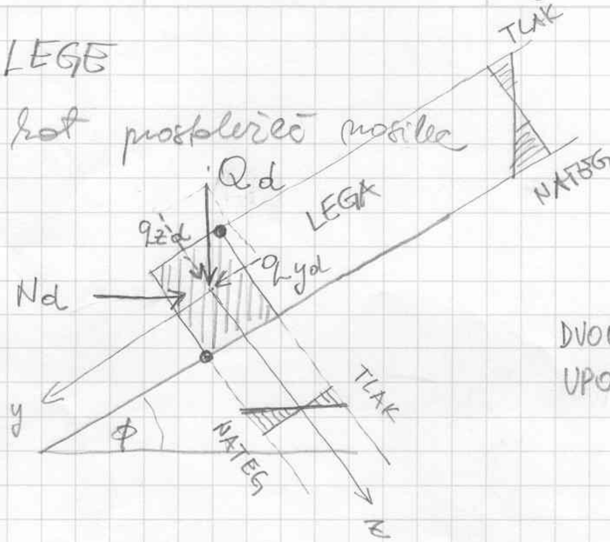
u_2 ... pomik zaradi spremenljive obtežbe (q)

ŠOL. L.:	LETNIK:	IME IN PRIIMEK:	PREDMET: LKI	VAJA ŠT.: 6	LIST ŠT.: 40

6.2. DIMENZIONIRANJE LEGE

→ lego obravnavamo kot prostoležeč nosilec





DVOOSNI UPOGIB

N_d ... osna sila zaradi izbočitve tlačenega pasu.
(lega preprečuje izbočitev)

→ 5.1 (nadomestna zv. obtežba)

$$N_d = \frac{2\, q_d \cdot a}{n=3} = \frac{2 \cdot 1{,}01 \cdot 2{,}88\ kN/m \cdot m}{3} = \underline{1{,}94\ kN}$$

↘ 5.1 — $\frac{\text{ŠT. PALIC(?)}}{\text{ŠT. BAV. KONSTR.}}$

9.5.03

→ VNAPREJ IZBEREMO LEGO $b/h = 14/18\ cm$

→ določitev lastne teže lege:

$$g_l = 0{,}14 \cdot 0{,}18 \cdot \rho_{MEAN} \cdot g$$

(ρ_{MEAN} ← TABELA (povprečna gostota); g ← pospešek)

$$= 0{,}14 \cdot 0{,}18 \cdot 460 \cdot 9{,}81 = \underline{\underline{0{,}114\ kN/m}}$$

DO TU
13.12.2001

OBTEŽBA:

špirovci/strehe, lege

$e = 2{,}5\ m$ $\phi = 13{,}65°$

$$q_{yd}^{\text{"M"}} = 1{,}35 \cdot (0{,}45 \cdot 2{,}88 + 0{,}114) \cdot \sin 13{,}65° + 1{,}5\,(1{,}25 \cdot 2{,}8) \cdot \sin 13{,}65° = 1{,}69\ \frac{kN}{m}$$

$$q_{zd}^{\text{"M"}} = 1{,}35 \cdot (0{,}45 \cdot 2{,}88 + 0{,}114) \cdot \cos 13{,}65° + 1{,}5 \cdot (1{,}25 \cdot 2{,}8) \cdot \cos 13{,}65° = 6{,}95\ \frac{kN}{m}$$

(↑ a) (↑ a)

$q_{y,d}^{\text{"S"}} =$

$q_{z,d}^{\text{"S"}} =$

→ primerjaj ... → MERODAJEN OBT. PRIM. "M"

• OBREMENITEV: (rozd. med. polja)

$$M_{y,d}^{"M"} = \frac{q_{z,d} \cdot e^2}{8} = \frac{6,95 \cdot 2,5^2}{8} = 5,43\ kNm$$

$$M_{z,d}^{"M"} = \frac{q_{y,d} \cdot e^2}{8} = \frac{1,69 \cdot 2,5^2}{8} = 1,32\ kNm$$

$$V_{y,d}^{"M"} = \frac{q_{y,d} \cdot e}{2} = \frac{1,69 \cdot 2,5}{2} = 2,11\ kN$$

$$V_{z,d}^{"M"} = \frac{q_{z,d} \cdot e}{2} = \frac{6,95 \cdot 2,5}{2} = 8,69\ kN$$

→ ker imamo dimenzije že izbrane, moramo kontrole:

• KONTROLA NORMALNIH NAPETOSTI:

- okoli osi z

$$\frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + k_M \frac{\sigma_{m,y,d}}{f_{m,d}} + \frac{\sigma_{m,z,d}}{f_{m,d}} \leq 1,0$$

↘ KOEFICIENT OBLIKE PRI UPOGIBU

k_M (pravokotni prerez) = 1,70

- okoli osi y

$$\frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + k_M \cdot \frac{\sigma_{m,z,d}}{f_{m,d}} + \frac{\sigma_{m,y,d}}{f_{m,d}} \leq 1,0$$

- oba zgornja pogoja morata biti izpolnjena

$k_{c,y}$; $k_{c,z}$ ... uklonska koeficienta (V#1#4)

$$\sigma_{m,y,d} = \frac{M_{y,d}}{W_y} = \frac{\frac{M_{y,d}}{b \cdot h^2}}{6} = \frac{\frac{5,43 \cdot 100}{14 \cdot 18^2}}{6} = 0,718\ \frac{kN}{cm^2}$$

$$\sigma_{m,z,d} = \frac{M_{z,d}}{W_z} = \frac{\frac{M_{z,d}}{h \cdot b^2}}{6} = \frac{\frac{1,32 \cdot 100}{18 \cdot 14^2}}{6} = 0,224\ \frac{kN}{cm^2}$$

$$\sigma_{c,0,d} = \frac{N_d}{b \cdot h} = \frac{1,94}{14 \cdot 18} = 0,0077\ kN/cm^2$$

• IZRAČUN VITKOSTI

k_{cy}: $\rightarrow i_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{6804}{252}} = 5,196\,cm$

$I_y = \frac{b \cdot h^3}{12} = \frac{14 \cdot 18^3}{12} = 6804\ cm^4$; $A = 14 \cdot 18 = 252\,cm$

$\rightarrow \lambda_y = \frac{l_{w,y}}{i_y} = \frac{250\,cm}{5,196\,cm} = 48,11$

$l_{w,y} = e = 2,5\,m$

$\rightarrow \lambda_{REL,y} = \frac{\lambda_y}{\pi}\sqrt{\frac{f_{c,0,k}}{E_{,005}}} = \frac{48,11}{\pi}\sqrt{\frac{2,3}{800}} = 0,82$

$\rightarrow$ $k_{cy}(\lambda_{REL}) = 0,867$

k_{cz}: $\rightarrow i_z = \sqrt{\frac{I_z}{A}} = \sqrt{\frac{4116}{252}} = 4,04\,cm$

$I_z = \frac{h \cdot b^3}{12} = \frac{18 \cdot 14^3}{12} = 4116,0\ cm^4$

$\lambda_z = \frac{l_{w,z}}{i_z} = \frac{250}{4,04} = 61,88$

$\lambda_{REL,z} = \frac{61,88}{\pi}\sqrt{\frac{2,3}{800}} = 1,06 \rightarrow k_{c,z}(\lambda_{REL}) = 0,679$

• $f_{c,0,d} = 1,415\ kN/cm^2$ • $f_{m,d} = 1,846\ kN/cm^2$

$k_M = 0,7$

• okoli osi z:

$$\frac{0,0077}{0,679 \cdot 1,415} + 0,7 \cdot \frac{0,718}{1,846} + \frac{0,224}{1,846} = 0,402 < 1,0$$ ✓

• okoli osi y:

$$\frac{0,0077}{0,867 \cdot 1,415} + 0,7\,\frac{0,224}{1,846} + \frac{0,718}{1,846} = 0,480 < 1,0$$ ✓

• KONTROLA STRIŽNIH NAPETOSTI $A_s = 2/3\,A = \frac{2 \cdot 18 \cdot 14}{3} = 168\,cm^2$

• smer osi y: $\tau_{y,d} = \frac{V_{y,d}}{A_s} = \frac{2,11}{168} = 0,013\,\frac{kN}{cm^2}$

• smer osi z: $\tau_{z,d} = \frac{V_{z,d}}{A_s} = \frac{8,69}{168} = 0,052\,\frac{kN}{cm^2}$

$\tau_{d,max} = \sqrt{\tau_{y,d}^2 + \tau_{z,d}^2} \leq f_{v,d} \Rightarrow \sqrt{0,013^2 + 0,052^2} = 0,054\,\frac{kN}{cm^2} < 0,185\,\frac{kN}{cm^2}$ ✓

FAGG

• KONTROLA POVESA!

• KONTROLA POVESA ; $\gamma_g = \gamma_q = 1{,}0$ (MSU)

g ; $q_{y,d}(g) = 1{,}0\,(0{,}45 \cdot a' + 0{,}114) \cdot \sin\phi = 1{,}0(0{,}45 \cdot 2{,}88 + 0{,}114) \cdot \sin 13{,}65° = 0{,}33\ \frac{kN}{m}$

(0,45 ↑ špirovci, letvice; 0,114 ↑ lega)

$q_{z,d}(g) = 1{,}0\,(0{,}45 \cdot 2{,}88 + 0{,}114) \cdot \cos 13{,}65° = 1{,}37\ \frac{kN}{m}$

q_{SNEG} ; $q_{y,d}(q_s) = 1{,}0 \cdot (1{,}25 \cdot a) \cdot \sin\phi = 1{,}0\,(1{,}25 \cdot 2{,}8) \cdot \sin 13{,}65° = 0{,}83\ \frac{kN}{m}$

(1,25 ↑ obt. snega)

$q_{z,d}(q_s) = 1{,}0\,(1{,}25 \cdot 2{,}8) \cdot \cos 13{,}65° = 3{,}40\ kN/m$

q_{VETER} ; $q_{y,d}(q_w) = \emptyset$

$q_{z,d}(q_w) = 1{,}0\left(0{,}24\ \frac{kN}{m^2} \cdot a'\right) = 1{,}0\,(0{,}24 \cdot 2{,}88) = 0{,}69\ \frac{kN}{m}$

x ZAČETNI POMIK ;

FAKTOR Z (pomik v smeri y) $= \frac{5}{384} \cdot \frac{e^4}{E_{0,MEAN} \cdot J_z} = \frac{5 \cdot 250^4}{384 \cdot 1200 \cdot 4116} = 10{,}3\ \frac{cm^2}{kN}$

FAKTOR y (pomik v smeri z) $= \frac{5}{384} \cdot \frac{e^4}{E_{0,MEAN} \cdot J_y} = \frac{5 \cdot 250^4}{384 \cdot 1200 \cdot 6804} = 6{,}2\ \frac{cm^2}{kN}$

u_g ; $u_{1,inst,y}$ = FAKTOR Z $\cdot\, q_{y,d}(g) = \frac{1}{100} \cdot 10{,}3 \cdot 0{,}33 = 0{,}034$ cm

"P" $u_{1,inst,z}$ = FAKTOR y $\cdot\, q_{z,d}(g) = 6{,}2 \cdot 1{,}37 \cdot \frac{1}{100} = 0{,}085$ cm

$k_{def} = 0{,}8$ $u_{1,fin,y} = u_{1,inst,y}\,(1 + k_{def}) = 0{,}034 \cdot (1 + 0{,}8) = 0{,}061$ cm

$u_{1,fin,z} = u_{1,inst,z}\,(1 + k_{def}) = 0{,}085 \cdot (1 + 0{,}8) = 0{,}153$ cm

u_q (SNEG) ; $u_{2,inst,y}$ = FAKTOR Z $\cdot\, q_{y,d}(q_s) = 10{,}3 \cdot 0{,}83 \cdot \frac{1}{100} = 0{,}085$ cm

"M" $u_{2,inst,z}$ = FAKTOR y $\cdot\, q_{z,d}(q_s) = 6{,}2 \cdot 3{,}40 \cdot \frac{1}{100} = 0{,}211$ cm

$k_{def} = 0{,}25$ $u_{2,fin,y} = u_{2,inst,y} \cdot (1 + k_{def}) = 0{,}085\,(1 + 0{,}25) = 0{,}106$ cm

$u_{2,fin,z} = u_{2,inst,z} \cdot (1 + k_{def}) = 0{,}211\,(1 + 0{,}25) = 0{,}264$ cm

u_q (VETER) ; $u_{2,inst,y} = \emptyset$

"S" $u_{2,inst,z}$ = FAKTOR y $\cdot\, q_{z,d}(q_w) = 6{,}2 \cdot 0{,}69 \cdot \frac{1}{100} = 0{,}043$ cm

$k_{def} = 0$ $= u_{2,fin,z}$

· KONTROLE :

$$u_{2,inst} = \sqrt{\left(u_{2,inst,y(SNEG)} + u_{2,inst,y(VETER)}\right)^2 + \left(u_{2,inst,z(SNEG)} + u_{2,inst,z(VETER)}\right)^2}$$

$$= \sqrt{(0{,}085 + 0)^2 + (0{,}211 + 0{,}043)^2} = 0{,}268\,cm < \frac{e}{300} = \frac{250}{300} = 0{,}83\,cm \quad \checkmark$$

$$u_{net} = u_1 + u_2$$

$$u_{net,fin} = \sqrt{\left(u_{1,fin,y(g)} + u_{2,fin,y(g_S)} + u_{2,fin,y(g_W)}\right)^2 + \left(u_{1,fin,z(g)} + u_{2,fin,z(g_S)} + u_{2,fin,z(g_W)}\right)^2}$$

$$= \sqrt{(0{,}061 + 0{,}106 + 0)^2 + (0{,}153 + 0{,}264 + 0{,}043)^2} = 0{,}489\,cm < \frac{e}{200} = \frac{250}{200}$$

$$= 1{,}25\,cm \quad \checkmark$$