DIMENSJONERING AV STØTTEBJELKE - BRUKSGRENSETILSTAND (SLS)

Egenskaper

Valgt betongklasse		$B45$
Valgt armeringsklasse		$B500NC$
E-modul betong	EC 2, Tabell 3.1	$E_c := 34\ kN \div mm^2$
E-modul for stål	EC 2, 3.2.7(4)	$E_s := 200\ kN \div mm^2$

Dimensjoner

Lengde	$L := 3.15\ m$
Bredde	$b := 550\ mm$
Høyde	$h := 500\ mm$
Betongtverrsnitt	$A_c := b \cdot h = 275000\ mm^2$
Senteravstand (z):	$S_z := 128.7\ mm$
Senteravstand (y):	$S_y := 100\ mm$
Nominell overdekning	$c_{nom} := 70\ mm$
Minimumsoverdekning (Tabell NA.4.5N)	$c_{min;dur} := 60\ mm$
Effektiv høyde:	$d := 386\ mm$

Armeringsareal

Armeringsdiameter lengdearmering: $\phi := 32\ mm$

$$A_{s.z} := \pi \cdot \left(\frac{\phi}{2}\right)^2 \frac{1\ m}{S_z} = 6249\ mm^2$$

$$A_{s.y} := \pi \cdot \left(\frac{\phi}{2}\right)^2 \frac{1\ m}{S_y} = 8042\ mm^2$$

Krefter:

Dimensjonerende moment z-retning (SLS): $M_{Ed;z} := 29.13\ kN \cdot m$

Dimensjonerende moment y-retning (SLS): $M_{Ed;y} := 67.56\ kN \cdot m$

Tabell over krefter:

Member/Node/Case	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)	Definition
15/ 12/ SLS/29	**38,67>>**	16,58	-366,04	29,10	-67,21	-1,22	1*1.00 + 9/29*1.00 + 8/1*1.00 + 78*1.00
15/ 2/ SLS/307	**-1,52<<**	-14,11	248,64	-14,12	13,66	-1,40	1*1.00 + 9/19*1.00 + 8/9*1.00 + 78*1.00
15/ 12/ SLS/29	38,67	**16,58>>**	-366,04	29,10	-67,21	-1,22	1*1.00 + 9/29*1.00 + 8/1*1.00 + 78*1.00
15/ 2/ SLS/37	14,00	**-21,79<<**	337,44	-26,23	9,17	-1,52	1*1.00 + 9/1*1.00 + 8/2*1.00 + 78*1.00
15/ 2/ SLS/289	12,54	-21,46	**340,22>>**	-26,47	8,96	-1,80	1*1.00 + 9/1*1.00 + 8/9*1.00 + 78*1.00
15/ 12/ SLS/29	38,67	16,58	**-366,04<<**	29,10	-67,21	-1,22	1*1.00 + 9/29*1.00 + 8/1*1.00 + 78*1.00
15/ 12/ SLS/28	38,08	16,43	-365,18	**29,13>>**	-67,56	-1,14	1*1.00 + 9/28*1.00 + 8/1*1.00 + 78*1.00
15/ 2/ SLS/289	12,54	-21,46	340,22	**-26,47<<**	8,96	-1,80	1*1.00 + 9/1*1.00 + 8/9*1.00 + 78*1.00
15/ 2/ SLS/90	-1,15	-14,26	266,90	-15,50	**15,51>>**	-1,46	1*1.00 + 7/90*1.00 + 78*1.00
15/ 12/ SLS/28	38,08	16,43	-365,18	29,13	**-67,56<<**	-1,14	1*1.00 + 9/28*1.00 + 8/1*1.00 + 78*1.00
15/ 12/ SLS/289	26,45	7,20	-278,39	16,26	-63,85	**0,10>>**	1*1.00 + 9/1*1.00 + 8/9*1.00 + 78*1.00
15/ 2/ SLS/289	12,54	-21,46	340,22	-26,47	8,96	**-1,80<<**	1*1.00 + 9/1*1.00 + 8/9*1.00 + 78*1.00

NEDBØYNINGSBEREGNING:

Materialstivhetsforhold:

$$\eta := \frac{E_s}{E_c} = 5.9$$

Armeringsforhold:

$$\rho_z := \frac{A_{s.z}}{(b \cdot d)} = 0.029$$ Sørensen (s. 116)

$$\rho_y := \frac{A_{s.y}}{(b \cdot d)} = 0.038$$ Sørensen (s. 116)

$$\eta\rho_z := \eta \cdot \rho_z = 0.173$$

$$\alpha_z := \sqrt{(\eta\rho_z)^2 + 2 \cdot \eta\rho_z} - \eta\rho_z = 0.4$$ Sørensen (lign. 5.5)

$$\eta\rho_y := \eta \cdot \rho_y = 0.223$$

$$\alpha_y := \sqrt{(\eta\rho_y)^2 + 2 \cdot \eta\rho_y} - \eta\rho_y = 0.5$$ Sørensen (lign. 5.5)

Betongtrykksonen:

$$I_{c.z} := 0.5 \cdot {\alpha_z}^2 \left(1 - \frac{\alpha_z}{3}\right) \cdot b \cdot d^3 = (2.616 \cdot 10^9)\ mm^4$$ Sørensen (lign. 5.9)

$$I_{c.y} := 0.5 \cdot {\alpha_y}^2 \left(1 - \frac{\alpha_y}{3}\right) \cdot b \cdot d^3 = (3.072 \cdot 10^9)\ mm^4$$ Sørensen (Lign. 5.9)

Elastisitets modul:

$$EI_z := E_c \cdot I_{c.z} = (8.894 \cdot 10^{13})\ N \cdot mm^2$$ Sørensen (lign. 5.10)

$$EI_y := E_c \cdot I_{c.y} = (1.044 \cdot 10^{14})\ N \cdot mm^2$$ Sørensen (lign. 5.10)

Nedbøyning:

$$\delta_{robot} := 1.58\ mm$$ (Fra Autodesk Robot)

$$\frac{L}{250} = 12.6\ mm$$ EC2, 7.4.1(4)

Konstruksjonen er godkjent for nedbøyning

RISSVIDDEKONTROLL:

$\alpha_z = 0.44$

$\alpha_y = 0.481$

$k_c := c_{nom} \div c_{min;dur} = 1.167$ (EC2 NA. 7.3.1(5)

$W_{maz} := 0.30 \cdot k_c = 0.35$ (EC2 NA, Tabell 7.1N – Grenseverdier wmaz)

$\sigma_{s.z} := E_s \cdot \frac{M_{Ed;z} \cdot (1-\alpha_z) \cdot d}{EI_z} = 14\ \boldsymbol{MPa}$ Sørensen (lign. 5.5)

$\sigma_{s.y} := E_s \cdot \frac{M_{Ed;y} \cdot (1-\alpha_y) \cdot d}{EI_y} = 26\ \boldsymbol{MPa}$ Sørensen (lign. 5.5)

Forenklet rissviddekontroll etter EC2, 7.3.3(2):

Tabell 5.3 med armeringsdiameter 12 mm gir; $\sigma_{s;tillatt1} := 280\ \boldsymbol{MPa}$

Tabell 5.4 med senteravstand 200 mm gir; $\sigma_{s;tillatt2} := 240\ \boldsymbol{MPa}$

Rissviddekrav ikke tilfredsstilt!

Gjør da en risskontroll ved beregning av rissvidde:

Tillatt rissvidde: $W_{maz} = 0.35$

$EI_z = (8.894 \cdot 10^{13})\ \boldsymbol{N \cdot mm^2}$

$EI_y = (1.044 \cdot 10^{14})\ \boldsymbol{N \cdot mm^2}$

$f_{ct;eff} := 3.8\ \boldsymbol{MPa}$ (EC2, Tabell 3.1 for B45)

$h_{c;eff.z} := min\left(2.5\ (h-d), \left(\frac{h-\alpha_z \cdot d}{3}\right), \frac{h}{2}\right) = 110\ \boldsymbol{mm}$ EC2, 7.3.2(3)

$h_{c;eff.y} := min\left(2.5\ (h-d), \left(\frac{h-\alpha_y \cdot d}{3}\right), \frac{h}{2}\right) = 105\ \boldsymbol{mm}$ EC2, 7.3.2(3)

$A_{c;eff.z} := b \cdot h_{c;eff.z} = (6.051 \cdot 10^4)\ \boldsymbol{mm^2}$ EC2, 7.3.2 (3)

$A_{c;eff.y} := b \cdot h_{c;eff.y} = (5.763 \cdot 10^4)\ \boldsymbol{mm^2}$ EC2, 7.3.2 (3)

$\rho_{p;eff.z} := \frac{A_{s.z}}{A_{c;eff.z}} = 0.103$ EC2, 7.3.4 (2)

$\rho_{p;eff.y} := \frac{A_{s.y}}{A_{c;eff.y}} = 0.14$ EC2, 7.3.4 (2)

$\eta = 5.882$ EC2, 7.3.4 (2)

Tøyningsdifferens:

Tøyningsdifferens etter Sørensen (lign 5.59):

$k_1 := 0.4$ (for langvarig last)

$(\varepsilon sm - \varepsilon cm)$:

$$\varepsilon_{1.z} := \frac{\sigma_{s.z} - k_1 \cdot \left(f_{ct;eff} \div \rho_{p;eff.z}\right)\ \left(1 + \eta \cdot \rho_{p;eff.z}\right)}{E_s} = -0.00005$$ EC2, 7.3.4(2)

$$\varepsilon_{1.y} := \frac{\sigma_{s.y} - k_1 \cdot \left(f_{ct;eff} \div \rho_{p;eff.y}\right)\ \left(1 + \eta \cdot \rho_{p;eff.y}\right)}{E_s} = 0.00003$$

$\varepsilon_{2.z} := 0.6 \cdot \sigma_{s.z} \div E_s = 0.00004246$

$\varepsilon_{2.y} := 0.6 \cdot \sigma_{s.y} \div E_s = 0.00007775$

$\varepsilon_z := \max\left(\varepsilon_{1.z}, \varepsilon_{2.z}\right) = 0.000042461$

$\varepsilon_y := \max\left(\varepsilon_{1.y}, \varepsilon_{2.y}\right) = 0.000077754$

Største endelige rissavstand:

$k_1 := 0.8$ (EC2, 4.3.4(3))

$k_2 := 0.5$ (EC2, 4.3.4(3))

$k_3 := 3.4$ (NA. 7.3.4(3))

$k_4 := 0.425$ (NA. 7.3.4(3))

$S_z = 128.7\ mm$

$S_y = 100\ mm$

$S_{z;krav} := 5 \cdot \left(c_{nom} + \phi \div 2\right) = 430\ mm$

$S_{y;krav} := 5 \cdot \left(c_{nom} + \phi \div 2\right) = 430\ mm$

Senteravstand < 430 mm = benytter likning (5.60) til Sr.max:

$S_{r;max.z} := k_3 \cdot c_{nom} + k_1 \cdot k_2 \cdot k_4 \cdot \phi \div \rho_{p;eff.z} = 291\ mm$ EC2, 7.3.4(3) lign (7.11)

$S_{r;max.y} := k_3 \cdot c_{nom} + k_1 \cdot k_2 \cdot k_4 \cdot \phi \div \rho_{p;eff.y} = 277\ mm$ EC2, 7.3.4(3) lign (7.11)

Beregnet rissvidde:

$W_{k.z} := S_{r;max.z} \cdot \varepsilon_z = 0.012\ mm$ EC2, 7.3.4 (1) lign (7.8)

$W_{k.y} := S_{r;max.y} \cdot \varepsilon_y = 0.022\ mm$ EC2, 7.3.4 (1) lign (7.8)

$W_{maz} = 0.35$

Dvs.

$W_k < W_{max}$ = **krav til rissvidde på z og y er tilfredsstilt.**