Studijski program: **GRAĐEVINARSTVO**

Modul: **PŽA, HVE, MTI**

Godina/Semestar: **III godina / V semestar**

Naziv predmeta (šifra): **Betonske konstrukcije 1**

(B2S3BK, B2H3BK, B2M3BK, B1S3BK)

Nastavnik: **Jelena Dragaš**

Naslov predavanja: **Ploče u jednom pravcu - dimenzionisanje.**

Datum : 01.12.2022.

1. Ploče u jednom pravcu

- *Prenose opterećenje samo u jednom pravcu*

1. Ploče u jednom pravcu

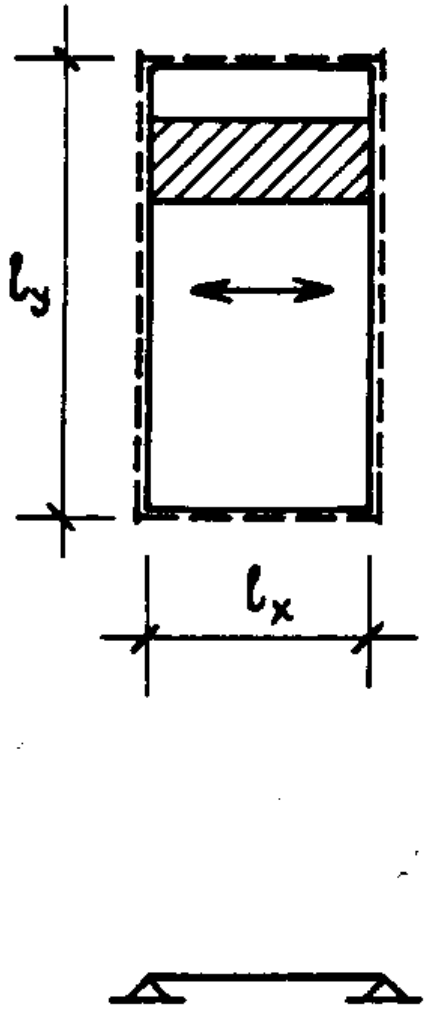
Ploče oslonjene na četiri strane proračunavaju se kao:

1. Ploče koje prenose opterećenje u jednom pravcu

$$l_y > 2l_x$$

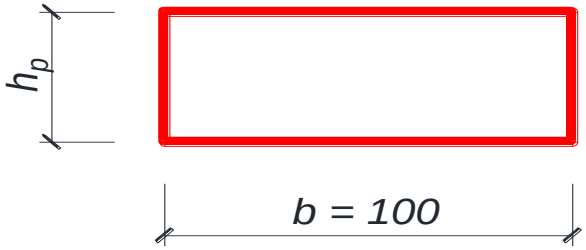
2. Ploče koje prenose opterećenje u oba pravca (krstasto armirane ploče)

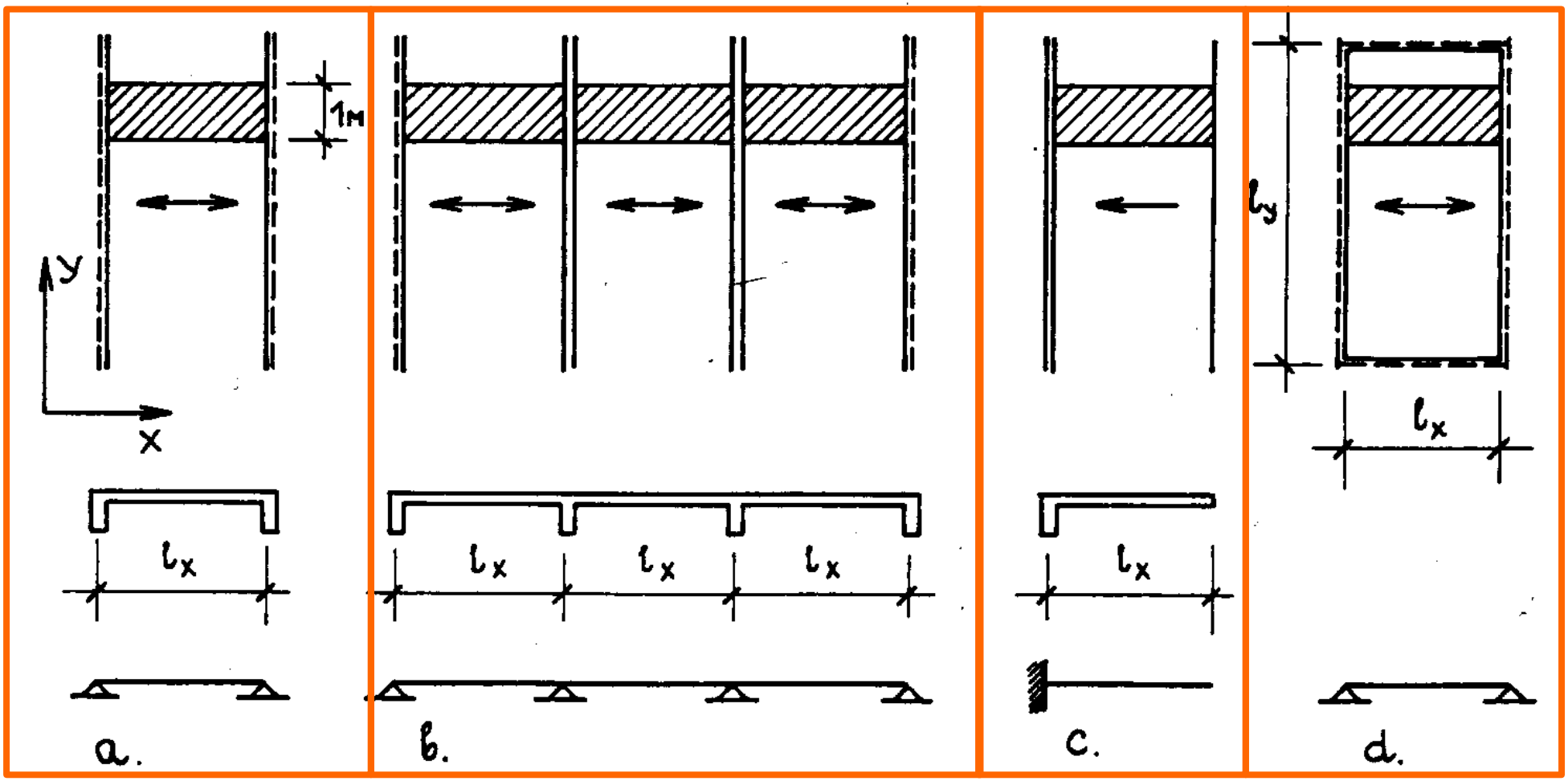
$$l_y \leq 2l_x$$



1. Ploče u jednom pravcu

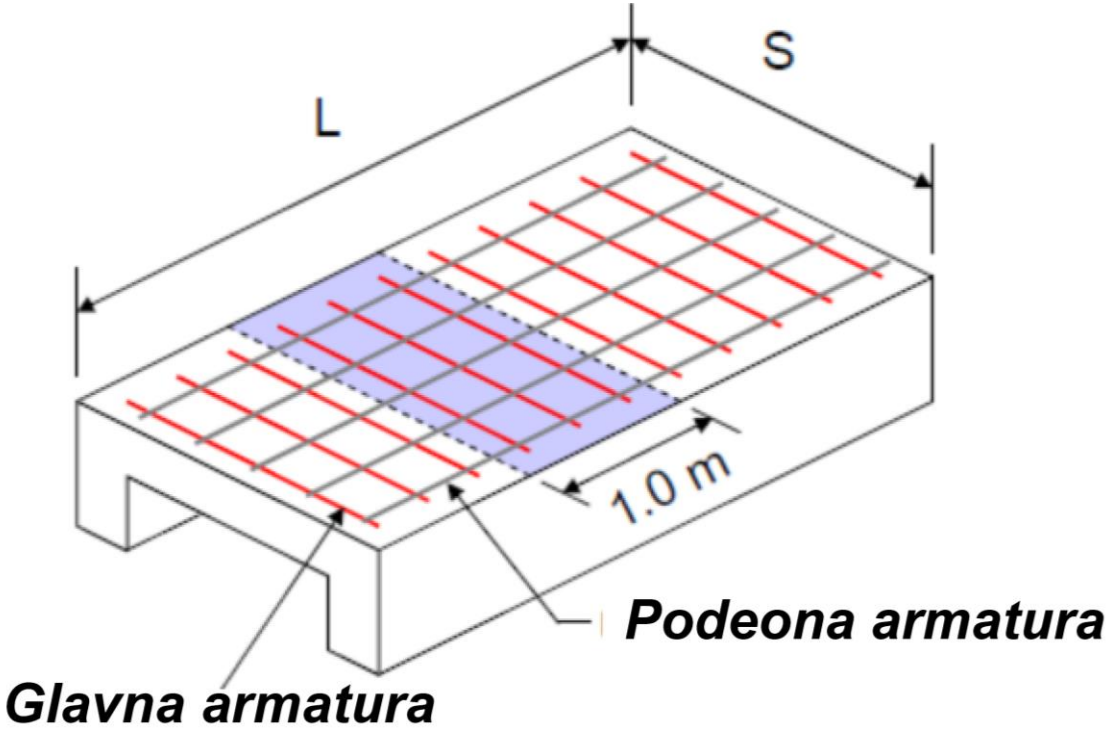
- *Proračunavaju se kao linijski elementi*

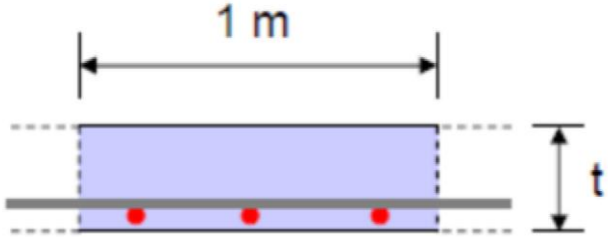


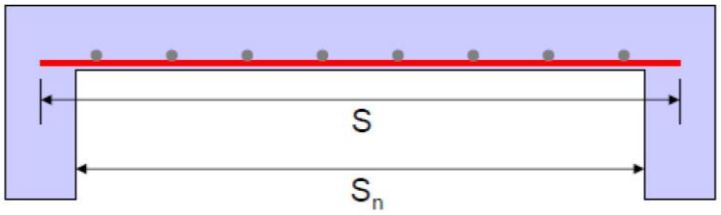


1. Ploče u jednom pravcu

- *Proračunavaju se kao linijski elementi*







1. Ploče u jednom pravcu

- *Ploče se **računaju** na dužni metar, **dimenzionišu** na dužni metar i **armatura** se dobija na dužni metar:*

100cm

$$k = \frac{d}{\sqrt{\frac{M_{Ed}}{b \times f_{cd}}}} \xrightarrow{TABLICE} \omega_1 \quad \Rightarrow \quad A_{s1} = \omega_1 \cdot \frac{b \cdot d}{100} \cdot \frac{f_{cd}}{f_{yd}}$$

100cm

$$A_{s1} = \omega_1 \cdot \frac{b \cdot d}{100} \cdot \frac{f_{cd}}{f_{yd}} = \omega_1 \cdot \frac{100 \cdot d}{100} \cdot \frac{f_{cd}}{f_{yd}} = \boxed{\omega_1 \cdot d \cdot \frac{f_{cd}}{f_{yd}}}$$

1. Ploče u jednom pravcu

- *Sračunata armatura* A_{s1} ***(cm²/m)*** *– umesto broja šipki na dužnom metru, određuje se razmak između šipki:*

- *broj šipki:* $n = \dfrac{A_{s1}}{a_s^{(1)}}$ ***kom /m'***

- *Razmak* ***s****, računski potrebnih n šipki na dužni metar:*

$$s = \frac{1m}{n} = \frac{100cm}{n} = \frac{100}{\frac{A_{s1}}{a_s^{(1)}}} = \frac{100 \cdot a_s^{(1)}}{A_{s1}} [cm]$$

- *Uobičajni razmak šipki glavne armature je 10÷20cm (7.5, 10, 12.5, 15, 20 cm)*
- *Uobičajni razmak šipki podeone armature je 20÷40cm (15, 20, 25, 30, 40 cm)*

1. Ploče u jednom pravcu
(specifični zahtevi SRPS EN1992)

- *Armatura za smicanje u ploči predviđa se za: h ≥ 20 cm*
- *Ukoliko je u pločama ispunjen uslov:*

$$\left|V_{Ed}\right| \le \frac{1}{3} V_{Rd,\max}$$

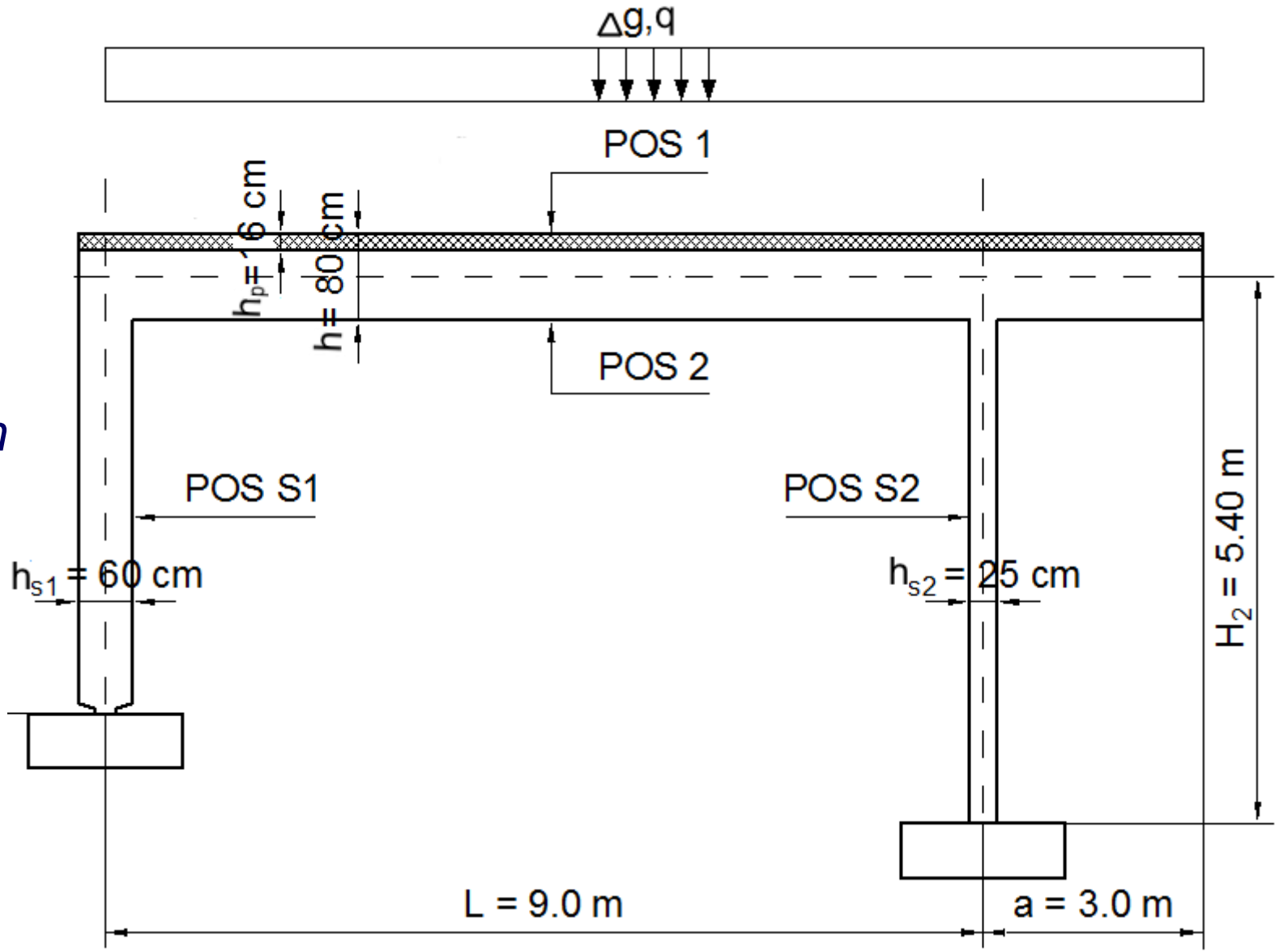
sva armatura za smicanje može da se sastoji od koso povijenih šipki ili od drugih oblika armature za smicanje

2. Primer 1

Ploča POS 1 je sistema kontinualnog nosača preko dva polja raspona λ=6.0 m

Δg = 2.0 kN/m²
q = 3.0 kN/m²

C25/30
B500B
XC2



2. Primer 1

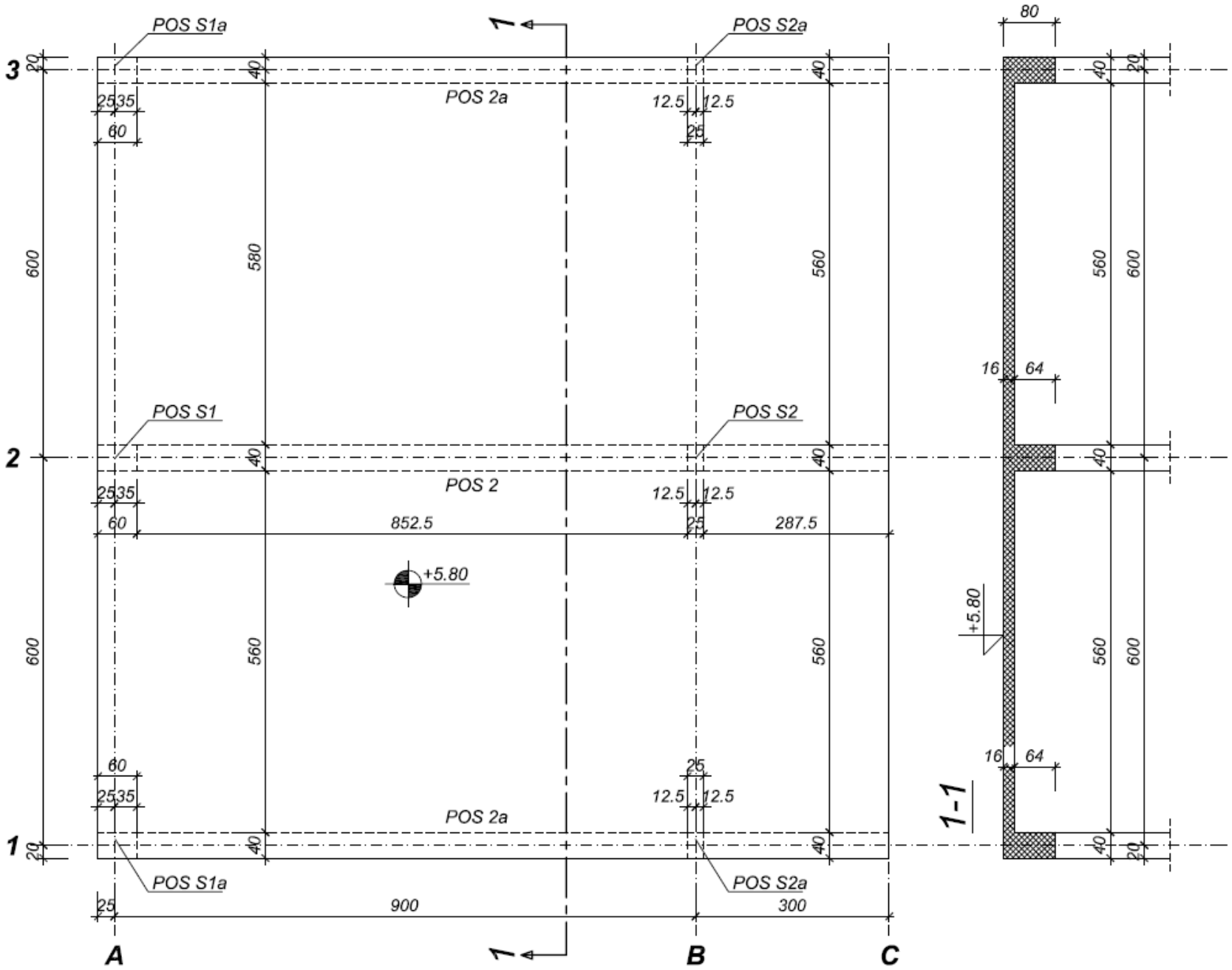
ANALIZA OPTEREĆENJA

a. stalno opterećenje

-	sopstvena težina ploče	0.16×25	= 4.0 kN/m^2
-	slojevi, izolacije	Δg	= 2.0 kN/m^2
	ukupno stalno opterećenje	g	= 6.0 kN/m^2

b. povremeno opterećenje

	ukupno povremeno opterećenje	q	= 3.0 kN/m^2


POS S1a
POS S2a
POS 2a
POS S1
POS S2
POS 2
POS 2a
POS S1a
POS S2a
1
1
3
2
1
A
B
C
20
40
25
35
60
600
580
560
12.5
25
852.5
287.5
+5.80
900
300
80
64
16
1-1

2. Primer 1

PRORAČUN STATIČKIH UTICAJA

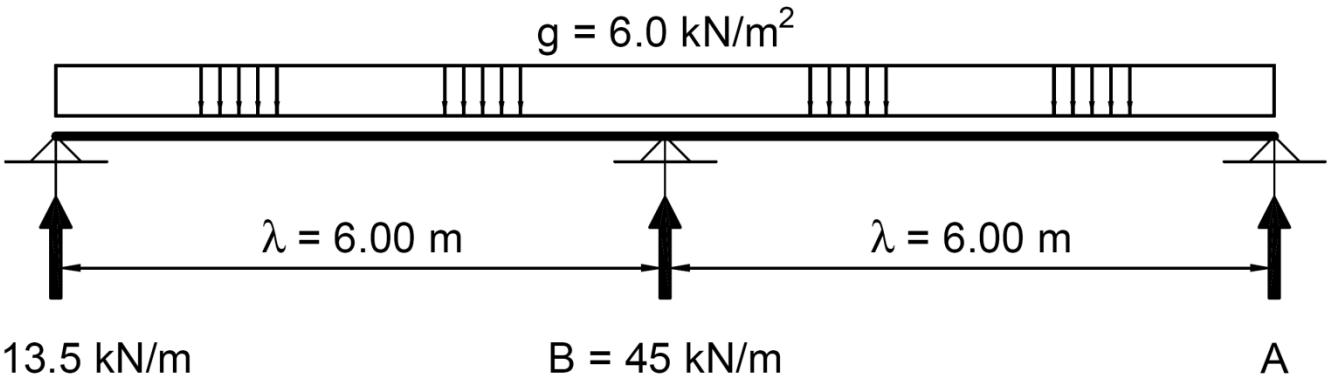
stalno opterećenje

$A_g = 0.375 \times 6.0 \times 6.0 = 13.5$ kN/m ;

$B_g = 1.25 \times 6.0 \times 6.0 = 45.0$ kN/m ;

$M_{g,osl} = 0.125 \times 6.0 \times 6.0^2 = 27.0$ kNm/m ;

$M_{g,polje} = 0.07 \times 6.0 \times 6.0^2 = 15.2$ kNm/m ;



2. Primer 1

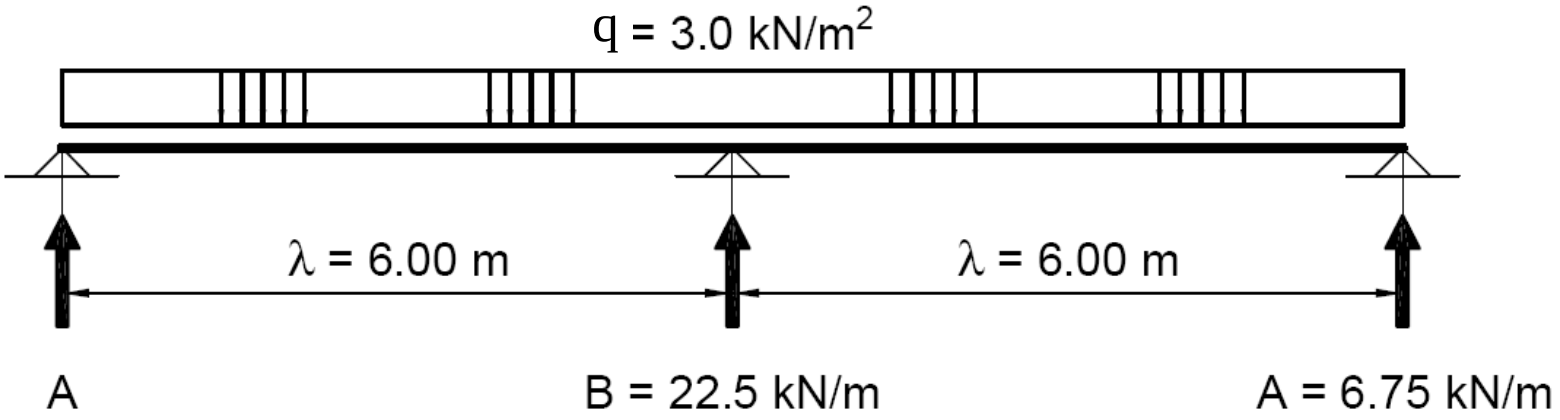
povremeno opterećenje

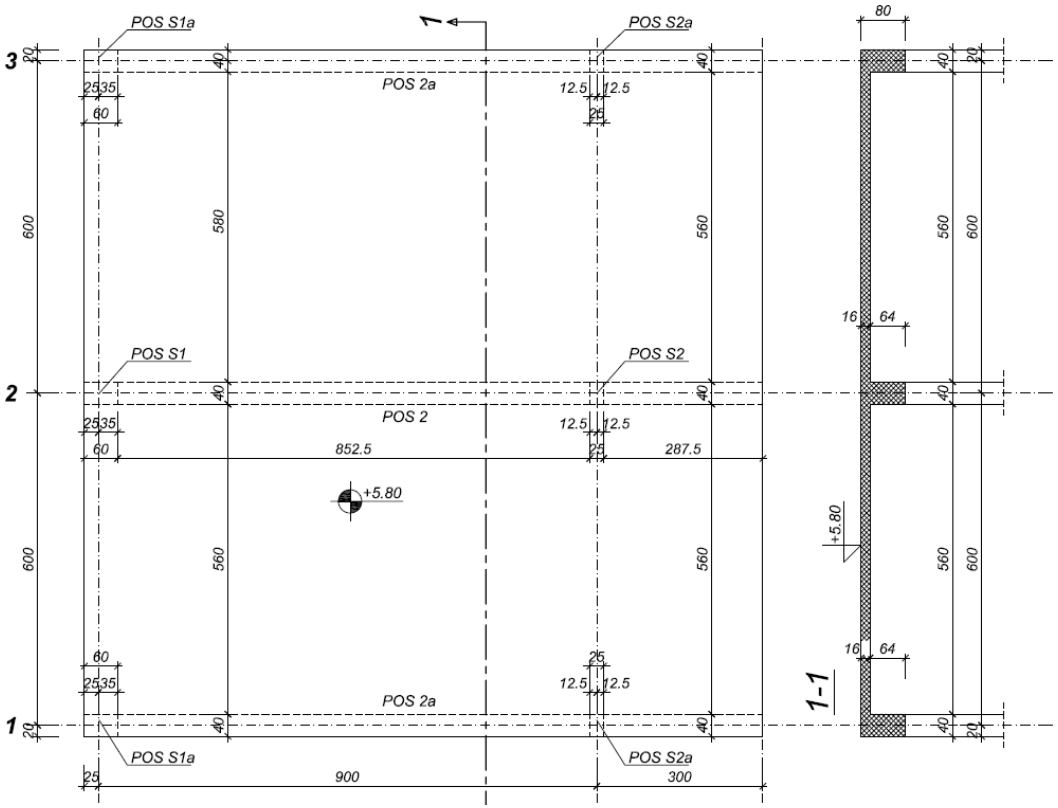
$$A_q = 0.375 \times 3.0 \times 6.0 = 6.75 \text{ kN/m}$$

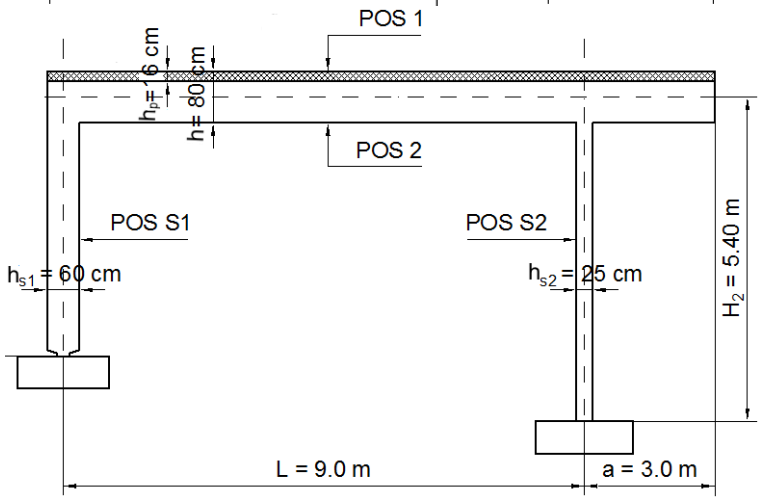
$$B_q = 1.25 \times 3.0 \times 6.0 = 22.5 \text{ kN/m}$$

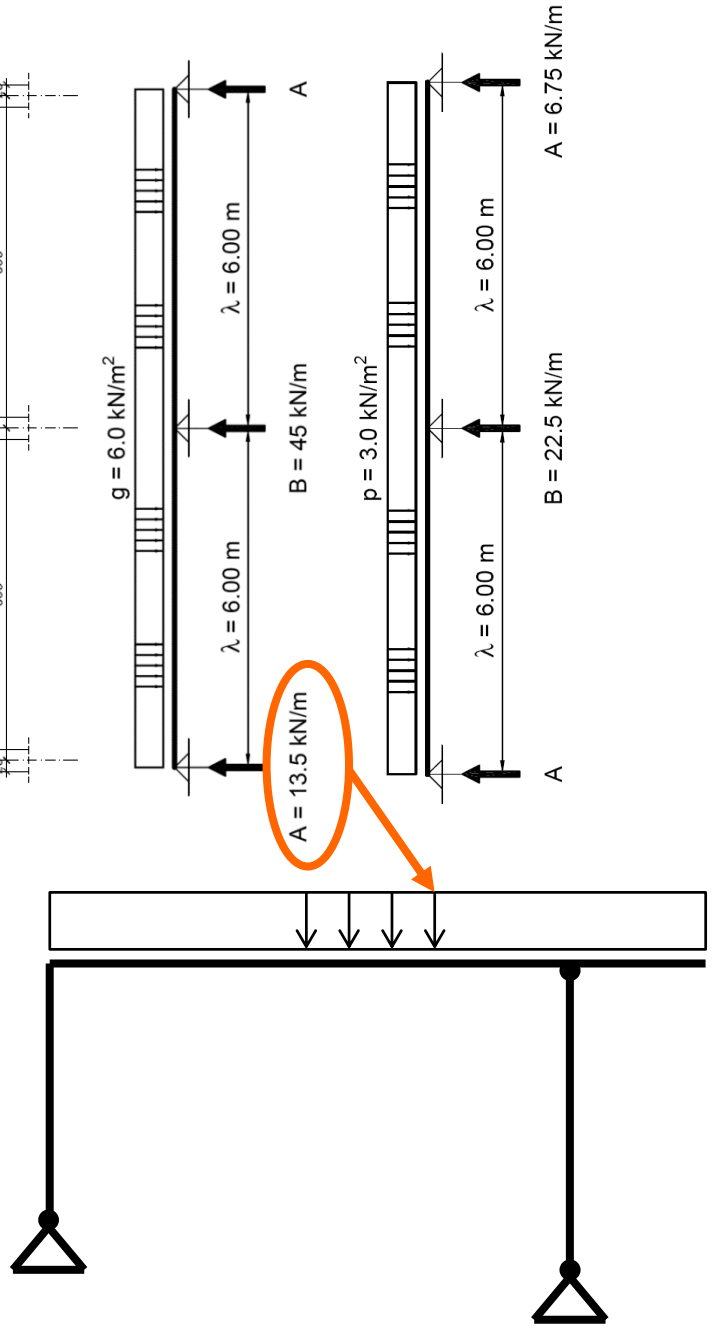
$$M_{q,osl} = 0.125 \times 3.0 \times 6.0^2 = 13.5 \text{ kNm/m}$$

$$M_{q,polje} = 0.07 \times 3.0 \times 6.0^2 = 7.6 \text{ kNm/m}$$

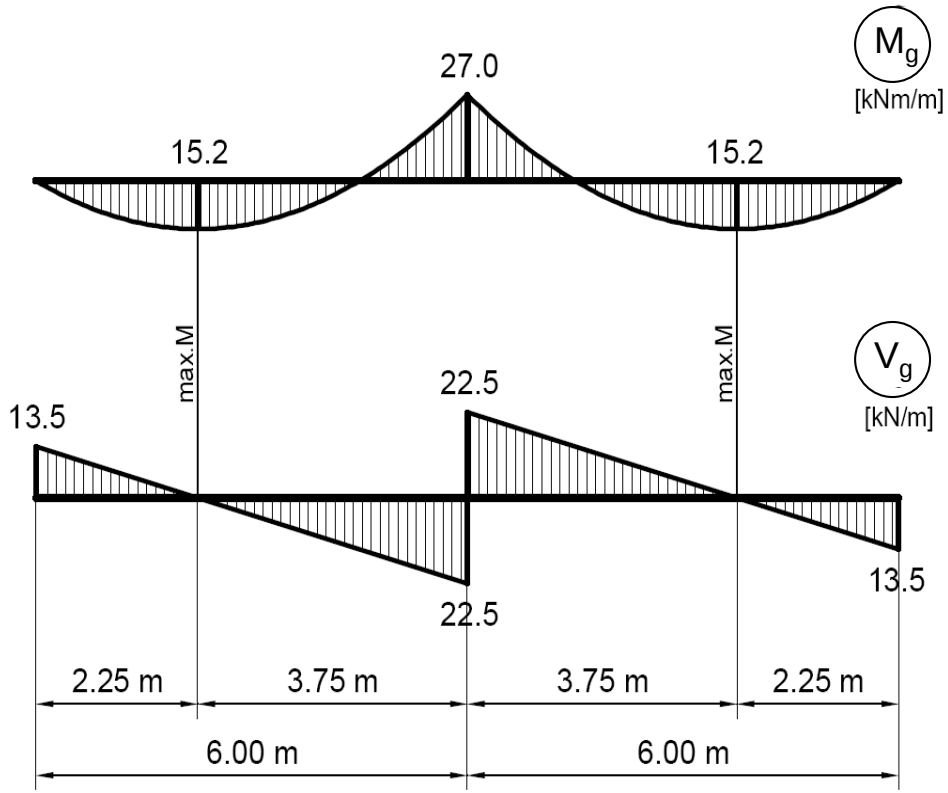


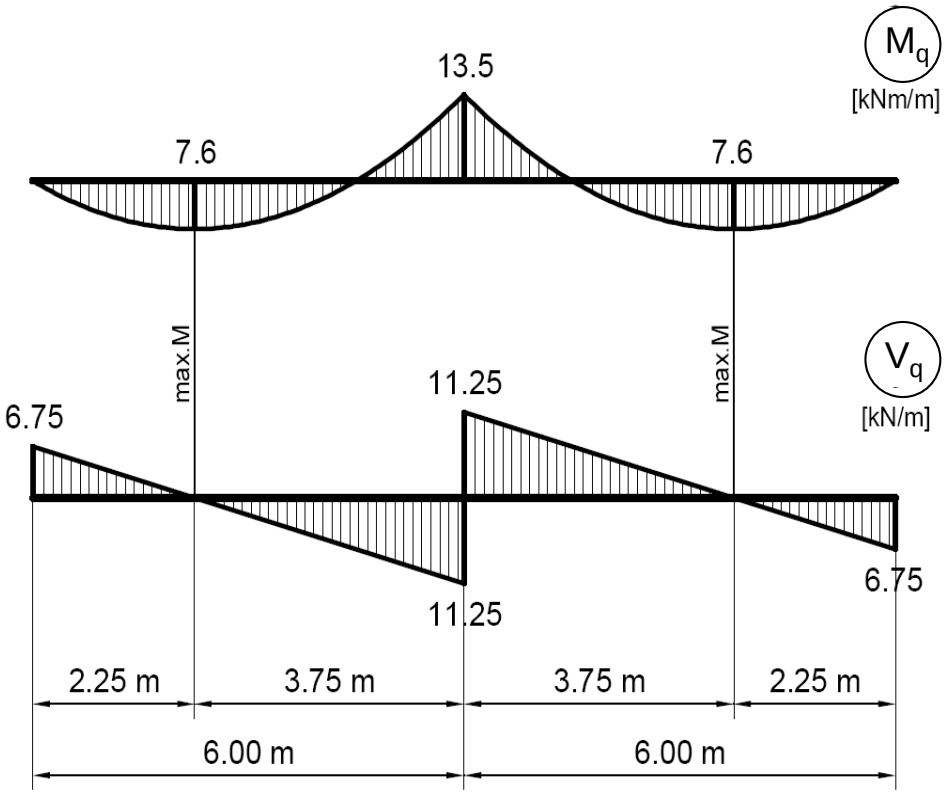

POS S1a
POS S2a
POS 2a
POS S1
POS S2
POS 2
+5.80
1-1
900
300
852.5
287.5


POS 1
POS 2
POS S1
POS S2
h = 80 cm
h_p = 16 cm
h_S1 = 60 cm
h_S2 = 25 cm
H_2 = 5.40 m
L = 9.0 m
a = 3.0 m


g = 6.0 kN/m²
p = 3.0 kN/m²
λ = 6.00 m
A
B = 45 kN/m
B = 22.5 kN/m
A = 6.75 kN/m
A = 13.5 kN/m

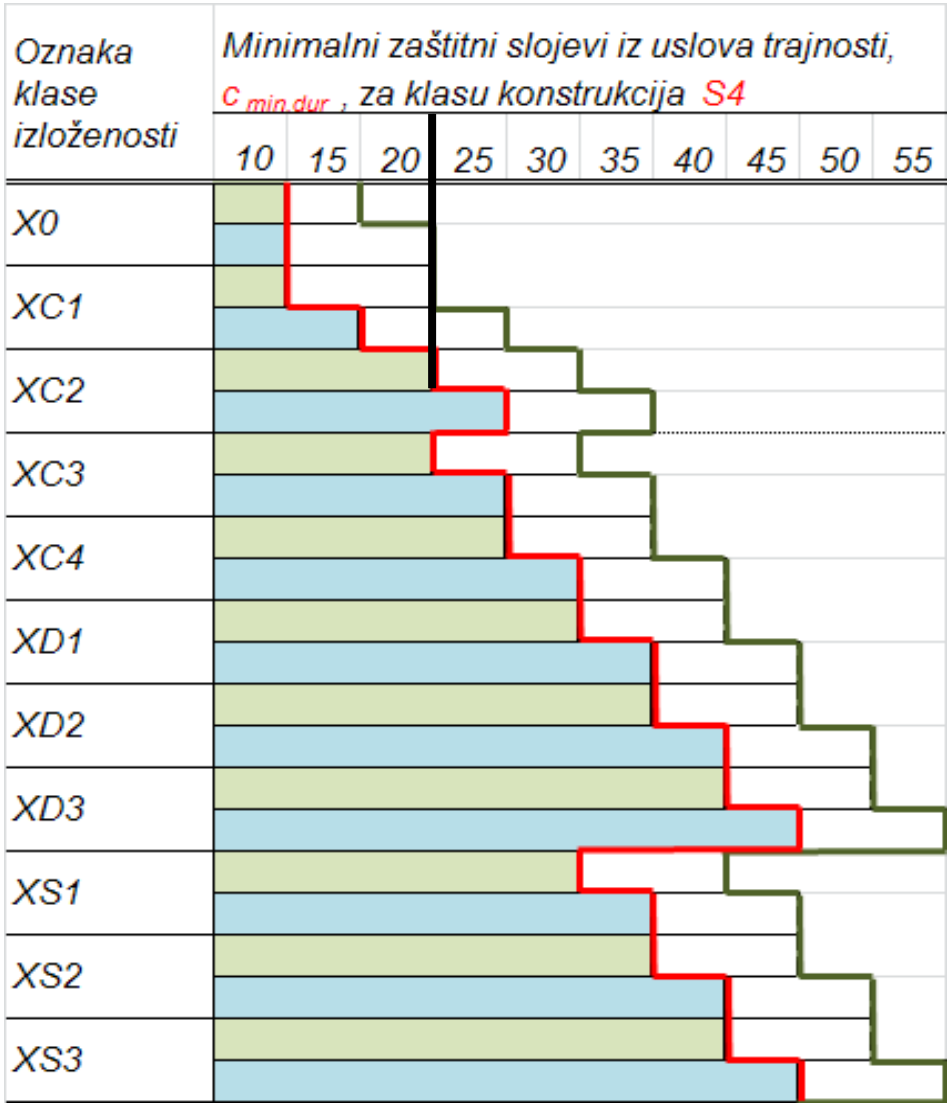
2. Primer 1

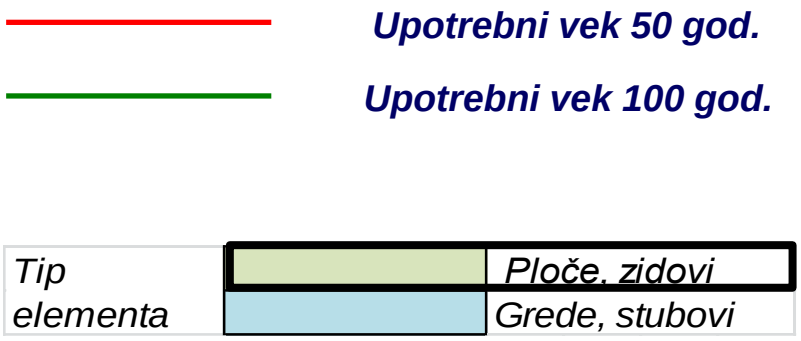

Mg
[kNm/m]
27.0
15.2
15.2
max.M
max.M
Vg
[kN/m]
22.5
13.5
13.5
22.5
2.25 m
3.75 m
3.75 m
2.25 m
6.00 m
6.00 m


Mq
[kNm/m]
13.5
7.6
7.6
max.M
max.M
Vq
[kN/m]
11.25
6.75
6.75
11.25
2.25 m
3.75 m
3.75 m
2.25 m
6.00 m
6.00 m

2. Primer 1

- Zaštitni sloj kod ploča:





XC2

2. Primer 1

- Zaštitni sloj kod ploča:

$$c_{nom} = c_{\min} + \Delta c_{dev}$$

c_{min}= max{$c_{min,b}$; $c_{min,dur}$; 10 mm} = max{16; 20; 10 mm}= 20 mm

Raspored šipki	Minimalni zaštitni sloj $c_{min,b}$*
Pojedinačne šipke	Prečnik šipke, Ø
Šipke u svežnju	Ekvivalentni prečnik ($Ø_n$)

Pretpostavljeno Ø =16mm

2.Primer 1

DIMENZIONISANJE

C25/30 => f_{cd} = 1.42 kN/cm^2;B500B =>f_{yd}= 43.5 kN/cm^2

XC2=>c_{nom} = 20 + 10 = 30 mm

Gornja zona

$$M_{Ed} = 1.35 \cdot 27 + 1.5 \cdot 13.5 = 56.7\ kNm/m$$

pretp. d_1 = 4 cm => d = 16 – 4 = 12 cm

$$k = \frac{12}{\sqrt{\frac{56.7}{1.42}}} = 1.897 \quad \Rightarrow \quad \zeta = 0.827$$

2.Primer 1

$$A_s = \frac{5670}{0.827 \cdot 12 \cdot 43.5} = 13.1\ cm^2/m$$

pretp. Ø16 ($a_s^{(1)}$ = 2.01 cm²) $s = \frac{100 \cdot a_s^{(1)}}{A_s} = \frac{201}{13.15} = 15.3\ cm$

usvojeno ***Ø16/15*** *(13.4 cm²/m)*

$$A_{sp} = 0.2 \cdot 13.1 = 2.62\ cm^2/m$$

pretp. Ø10 ($a_s^{(1)}$ = 0.785 cm²) $s_p = \frac{100 \cdot a_s^{(1)}}{A_{sp}} = \frac{78.5}{2.62} = 30.0\ cm$

usvojeno ***Ø10/30*** *(2.62 cm²/m)*

2.Primer 1

Donja zona

$$M_{Ed} = 1.35 \cdot 15.2 + 1.5 \cdot 7.6 = 31.9\ kNm/m$$

pretp. $d_1 = 4\ cm \Rightarrow d = 16 - 4 = 12\ cm$

$$k = \frac{12}{\sqrt{\frac{31.9}{1.42}}} = 2.528 \quad \Rightarrow \quad \zeta = 0.912$$

2.Primer 1

$$A_s = \frac{3190}{0.912 \cdot 12 \cdot 43.5} = 6.71\ cm^2/m$$

pretp. Ø12 ($a_s^{(1)}$ = 1.13 cm²) $s = \frac{100 \cdot a_s^{(1)}}{A_s} = \frac{113}{6.71} = 16.8\ cm$

usvojeno ***Ø12/15*** *(7.5 cm²/m)*

$$A_{sp} = 0.2 \cdot 6.71 = 1.34\ cm^2/m$$

pretp. Ø8 ($a_s^{(1)}$ = 0.503 cm²) $s_p = \frac{100 \cdot a_s^{(1)}}{A_{sp}} = \frac{50.3}{1.34} = 37.5\ cm$

usvojeno ***Ø8/30*** *(1.68 cm²/m)*

2. Primer 1

- Najveće rastojanje šipki **s – *glavne armature*** u pločama na mestima maksimalnih naprezanja:

Za jednako podeljeno opterećenje

$$s_{max,slabs} = min\begin{Bmatrix} 3h \\ 40cm \end{Bmatrix}$$

Preporuka
20 cm!

Za koncentrisano opterećenje, ili jednako podeljeno ali za zone sa max naprezanjima

$$s_{max,slabs} = min\begin{Bmatrix} 2h \\ 25cm \end{Bmatrix}$$

- Najveće rastojanje šipki $\mathbf{s_p}$ – ***podeone armature*** u pločama na mestima maksimalnih naprezanja:

Za jednako podeljeno opterećenje

$$s_{max,slabs} = min\begin{Bmatrix} 3.5h \\ 45cm \end{Bmatrix}$$

Preporuka
30 cm!

Za koncentrisano opterećenje, ili jednako podeljeno ali za zone sa max naprezanjima

$$s_{max,slabs} = min\begin{Bmatrix} 3h \\ 40cm \end{Bmatrix}$$

2. Primer 1

- *Standardom su propisani minimalni procenti armiranja glavne armature u odnosu na površinu betonskog preseka b,h*

$$A_{s,min} = max\left\{\begin{matrix} 0{,}26\dfrac{f_{ctm}}{f_{yk}} b_t d \\ 0{,}0013 b_t d \end{matrix}\right\}$$

f_{ck}	f_{ctm}	Minimum % ($0.26 f_{ctm}/f_{yk}$[a])
25	2.6	0.13%
28	2.8	0.14%
30	2.9	0.15%
32	3.0	0.16%
35	3.2	0.17%
40	3.5	0.18%
45	3.8	0.20%
50	4.1	0.21%

2. Primer 1

- *Maksimalno rastojanje glavne i podeone armature*

$$s_{\max,slabs} = \min\begin{Bmatrix} 2\cdot 16 = 32cm \\ 25cm \end{Bmatrix} = 25cm$$

$$s_{p,\max,slabs} = \min\begin{Bmatrix} 3\cdot 16 = 48cm \\ 40cm \end{Bmatrix} = 40cm$$

- *Minimalni procenat armiranja glavnom armaturom*

$$A_{s,\min} = 0.13\cdot d = 0.13\cdot 12 = 1.56cm^2/m$$

2. Primer 1

Transverzalne sile

$$V_{Ed} = 1.35 \cdot 22.5 + 1.5 \cdot 11.25 = 47.25 \frac{kN}{m}$$

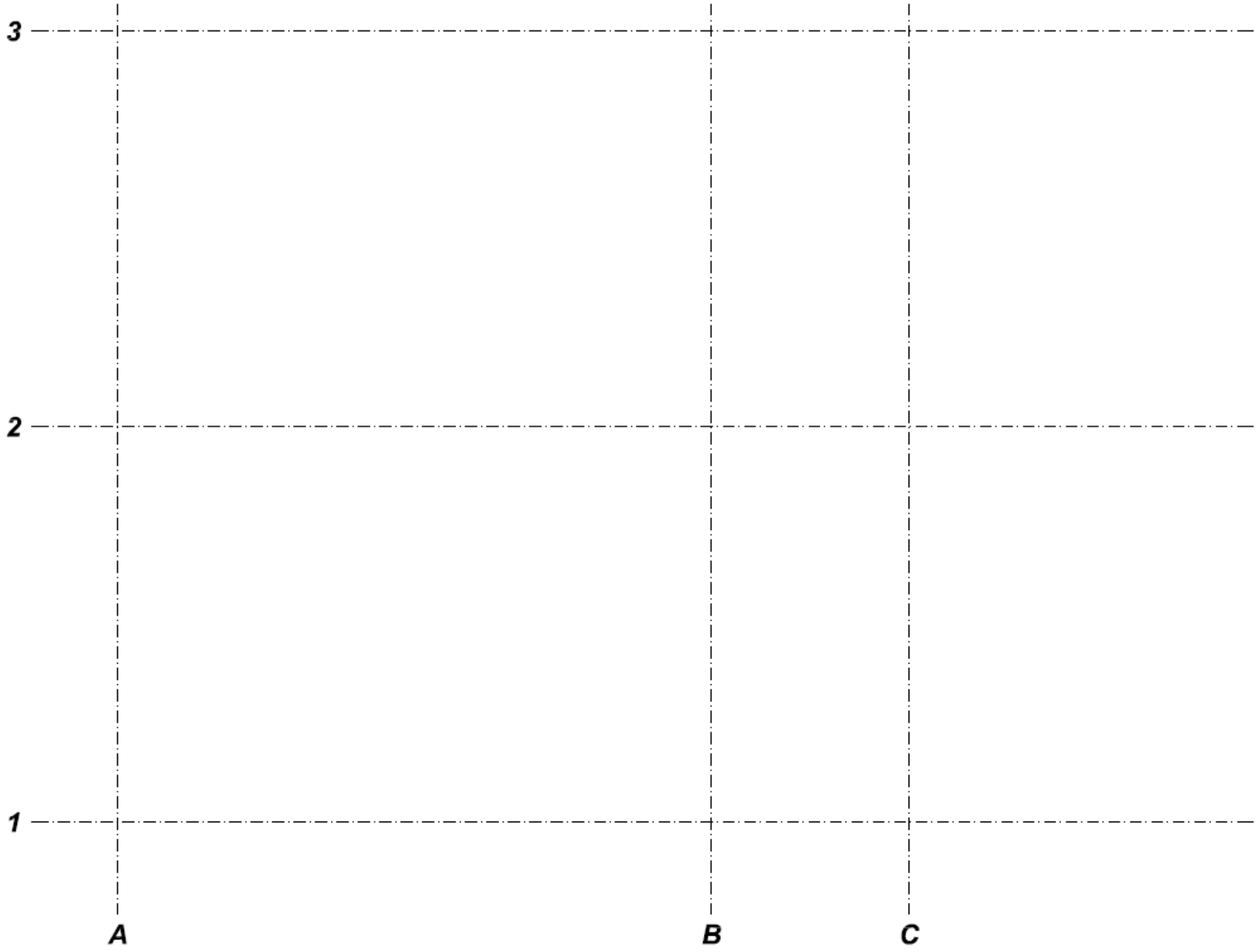
$$k = 1 + \sqrt{\frac{200}{120}} = 2.29 > 2! \Rightarrow \quad k = 2$$

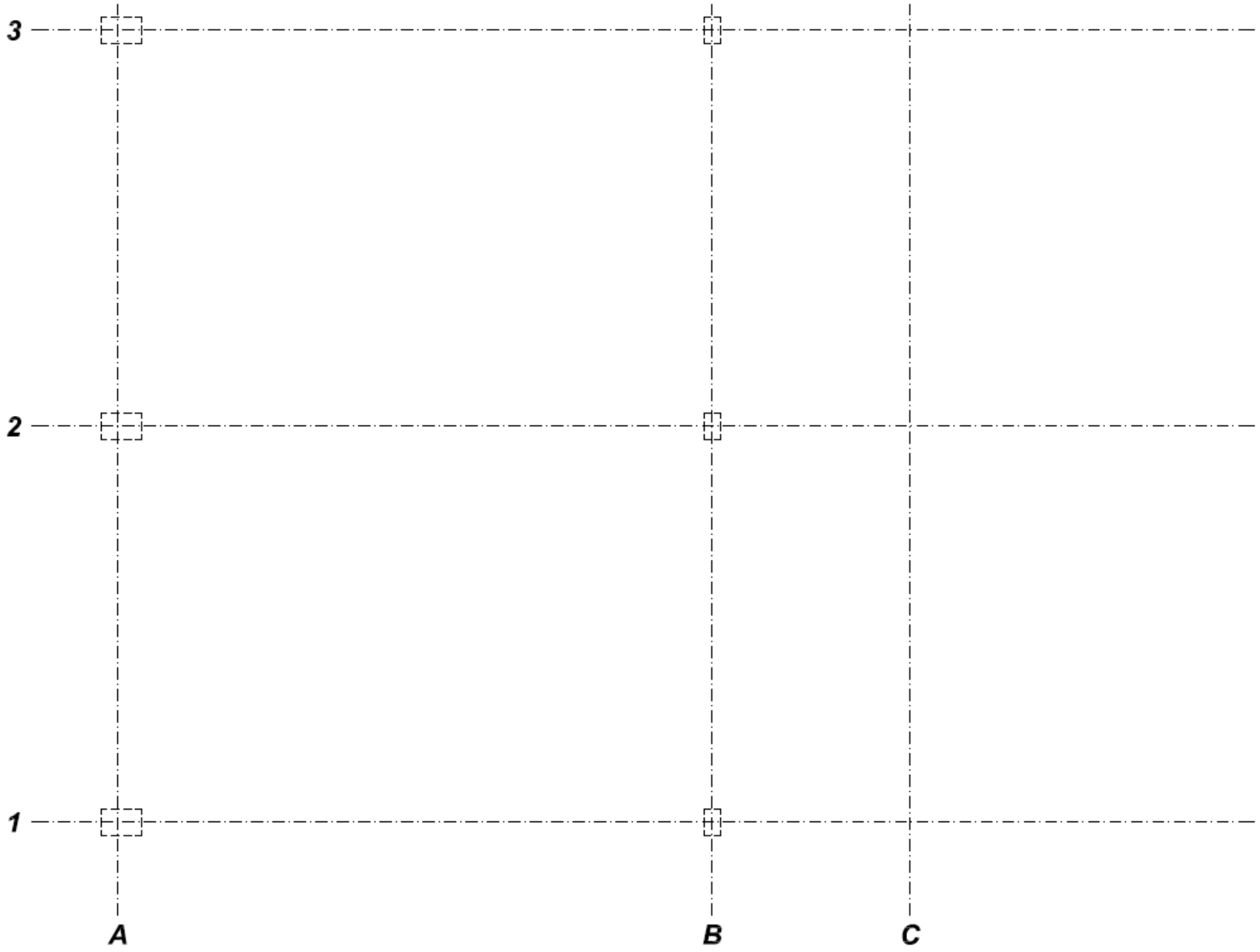
$$V_{Rd,c,min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} \cdot bd = 0.035 \cdot 2^{\frac{3}{2}} \cdot 25^{\frac{1}{2}} \cdot 100 \cdot 12/10 = 59.4 \frac{kN}{m}$$

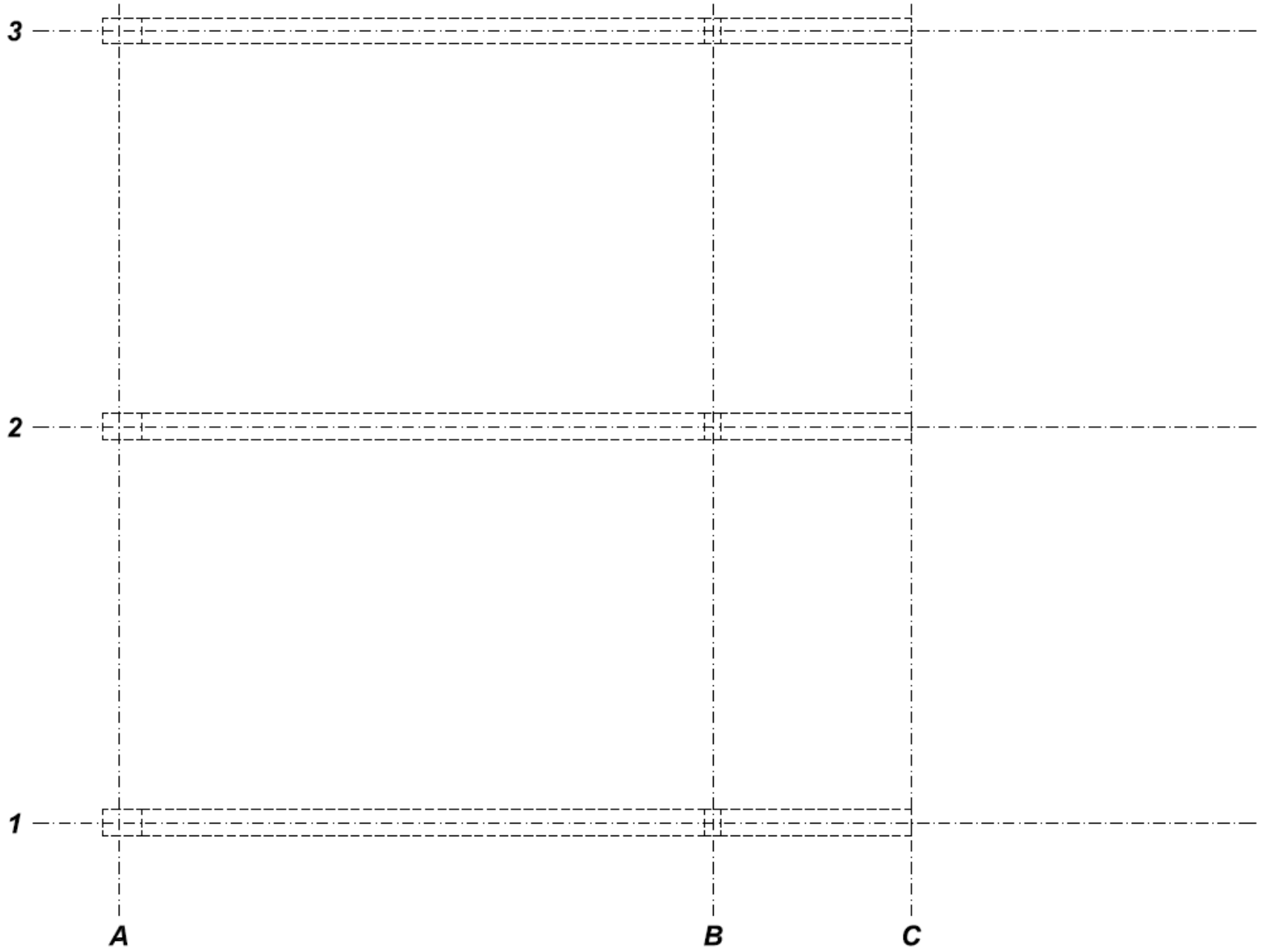
Ovo je najmanja vrednost koju $V_{Rd,c}$ može uzeti, prema tome na strani smo sigurnosti ukoliko proveru smicanja izvršimo na ovaj način.

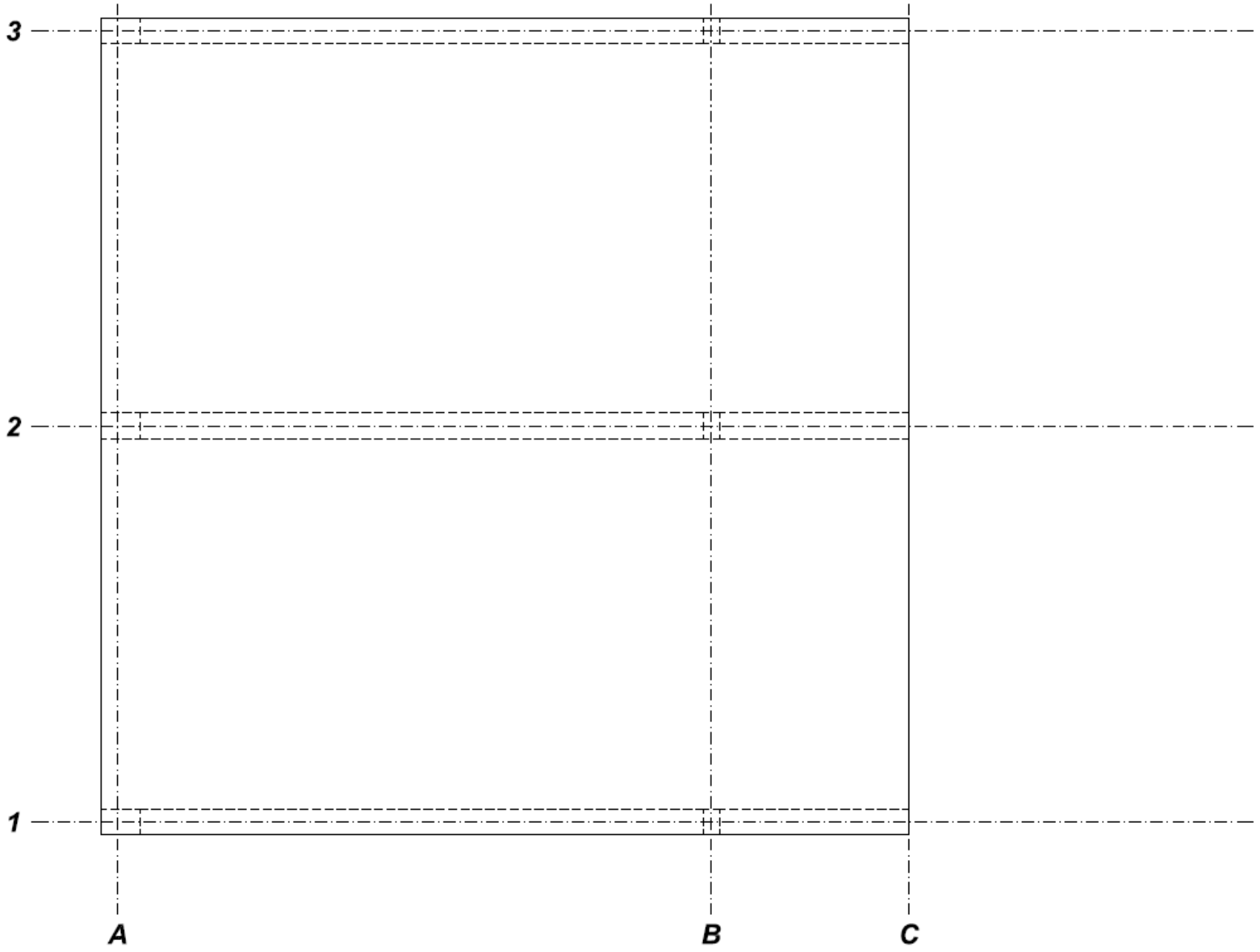
$$V_{Ed} = 47.25\ kN/m < V_{Rd,c} = 59.4\ kN/m$$

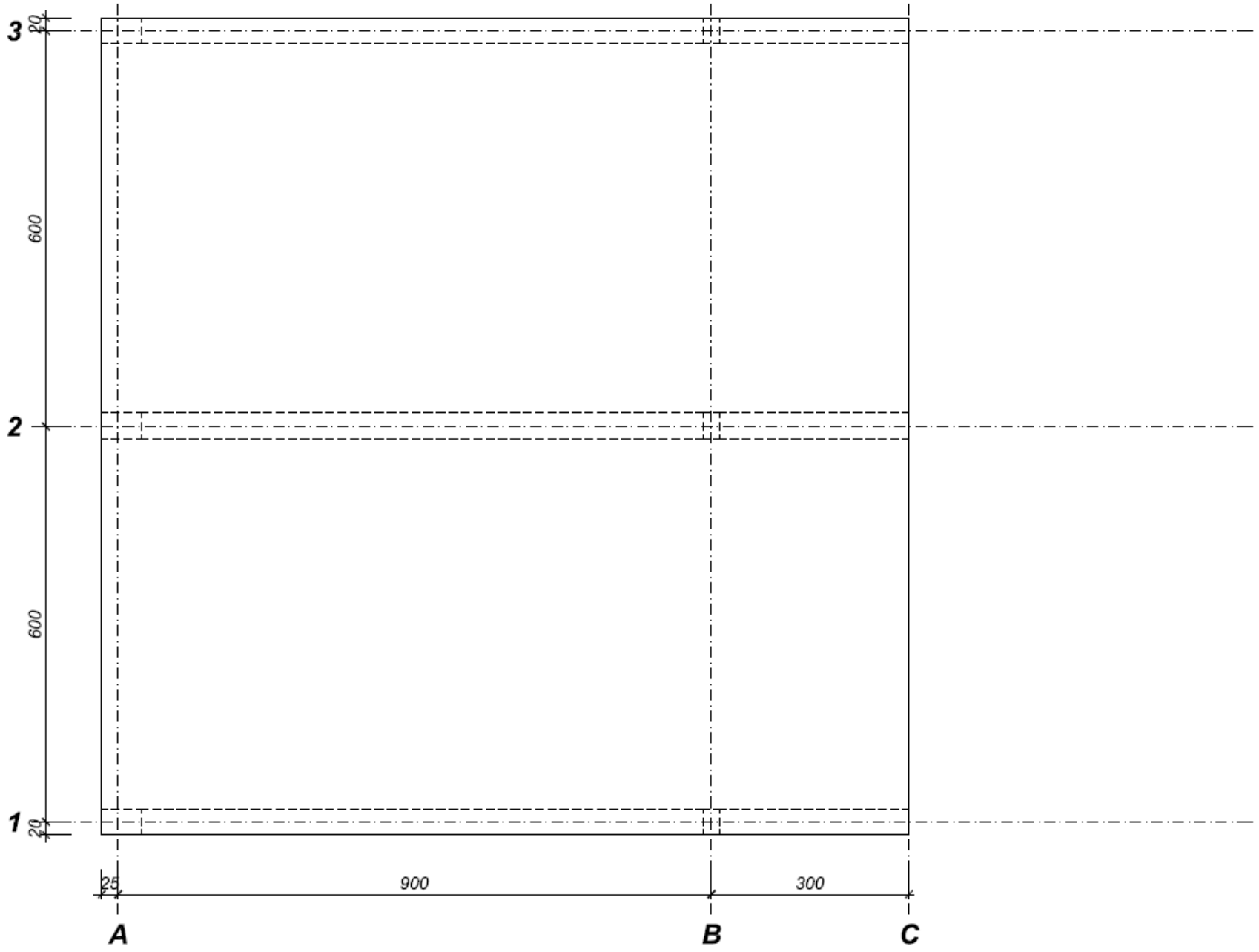
Nije potrebno osiguranje (niti dozvoljeno jer je h < 20 cm!)

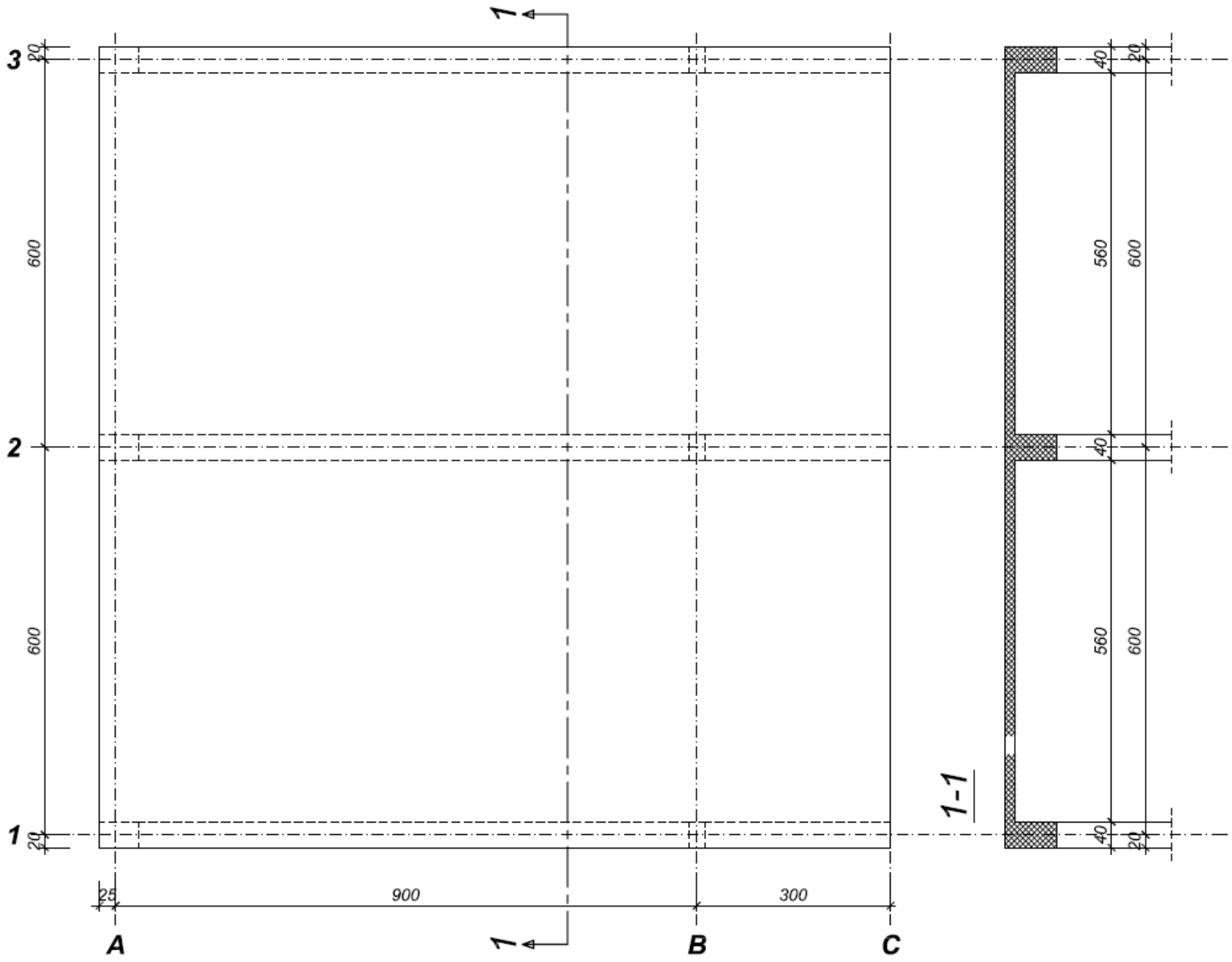

3
2
1
A
B
C

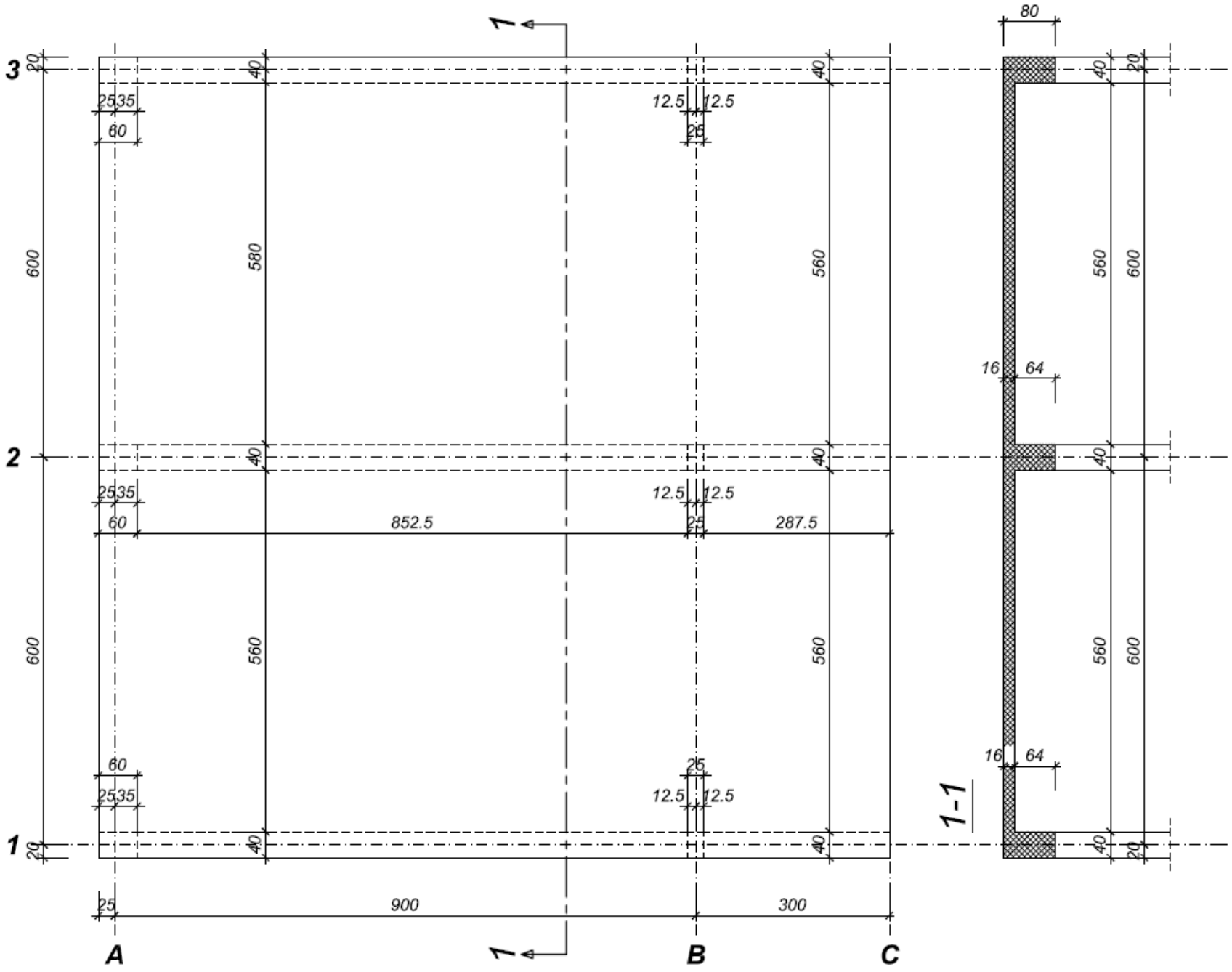

3
2
1
A
B
C

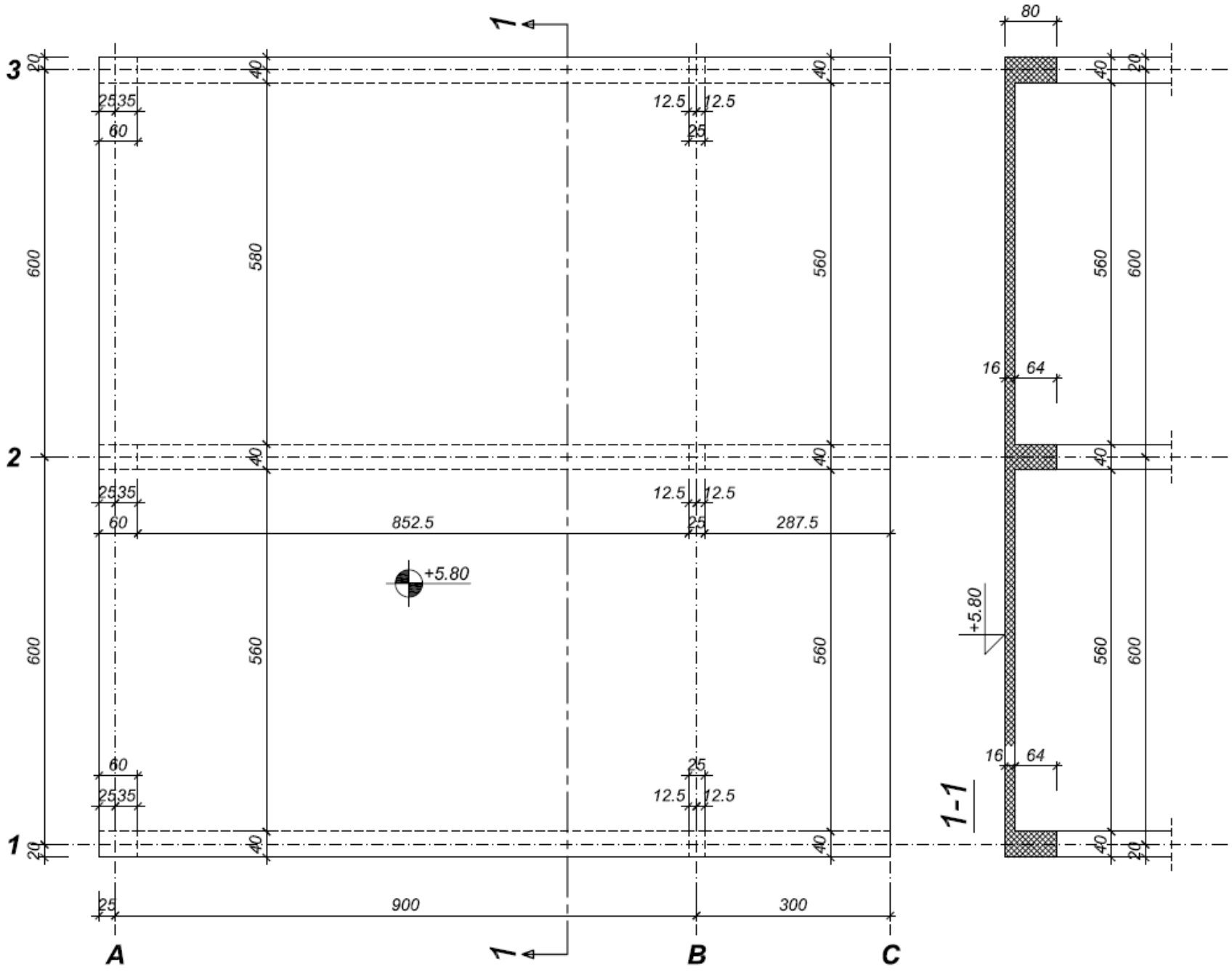

3
2
1
A
B
C

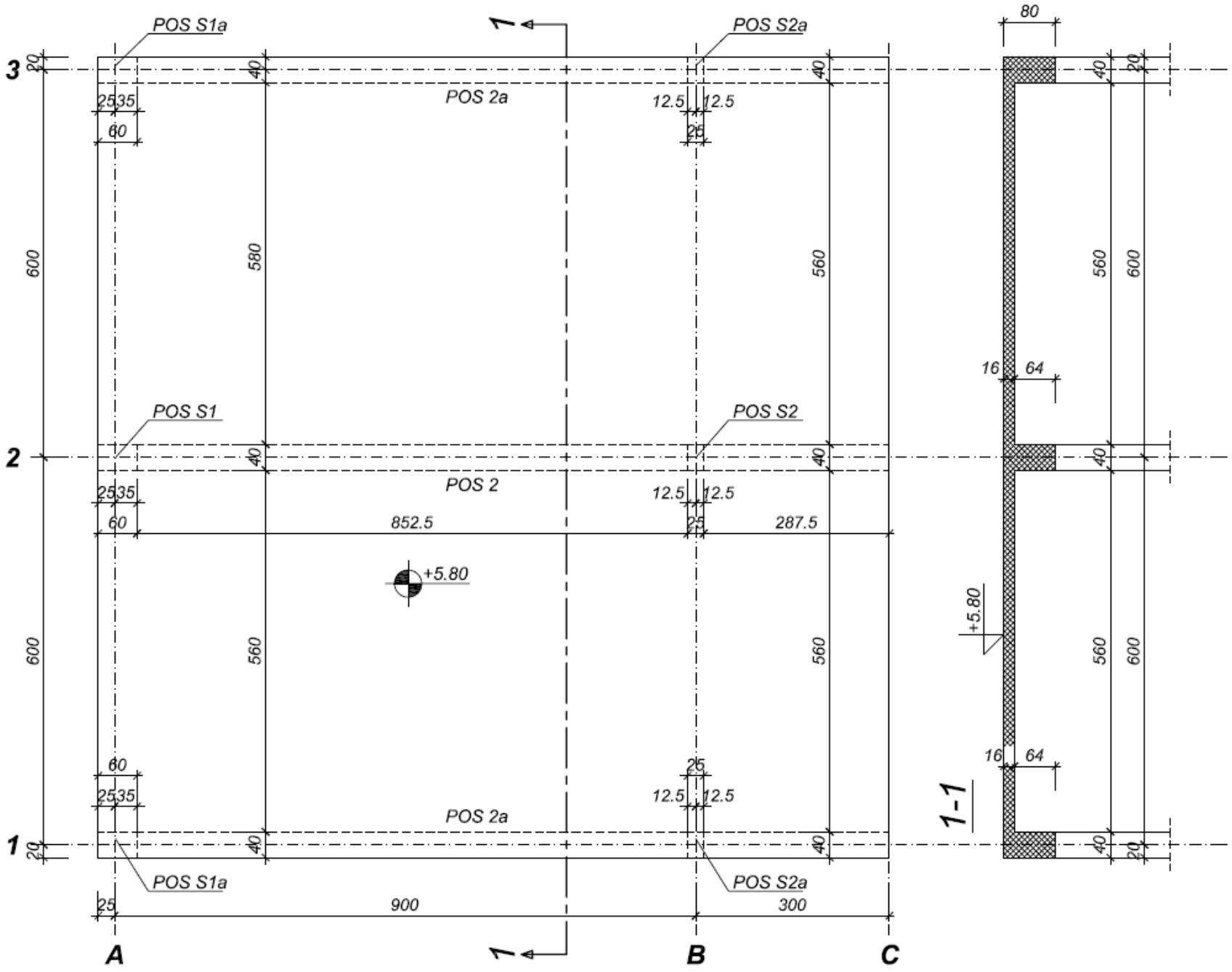

3
2
1
A
B
C


3
2
1
20
600
600
20
25
900
300
A
B
C


1
3
2
1
20
600
600
20
25
900
300
A
1
B
C
40
20
560
600
40
560
600
40
20
1-1

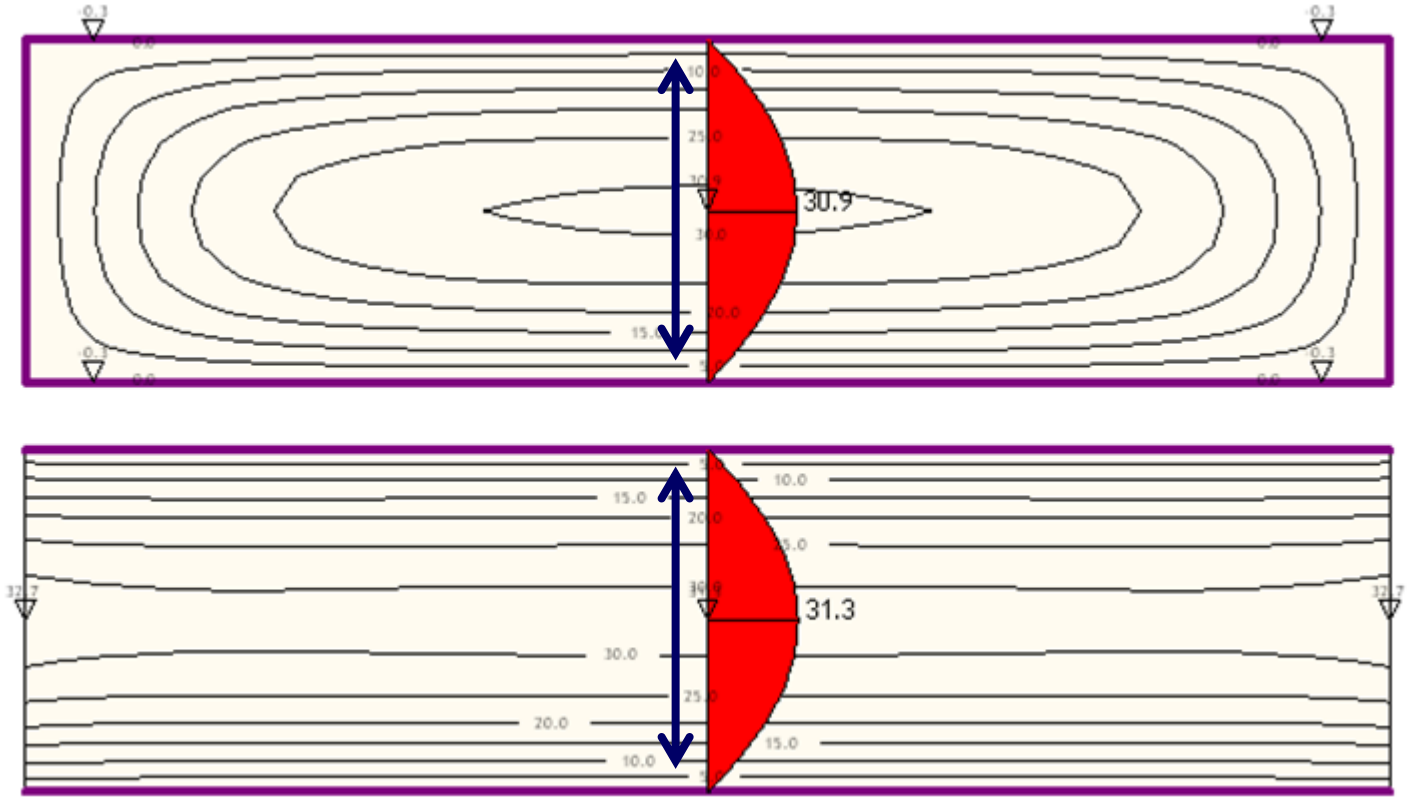

1
3
2
1
A
B
C
1
1-1
80
20
40
25
35
60
12.5
25
600
580
560
852.5
287.5
900
300
16
64


1
3
2
1
A
B
C
20
40
25
35
60
12.5
12.5
25
600
580
560
852.5
287.5
+5.80
900
300
80
16
64
1-1


POS S1a
POS S2a
POS 2a
POS S1
POS S2
POS 2
POS 2a
POS S1a
POS S2a
+5.80
+5.80
1-1
1
1
3
2
1
A
B
C
20
40
25
35
60
12.5
12.5
25
600
580
560
852.5
287.5
900
300
80
16
64

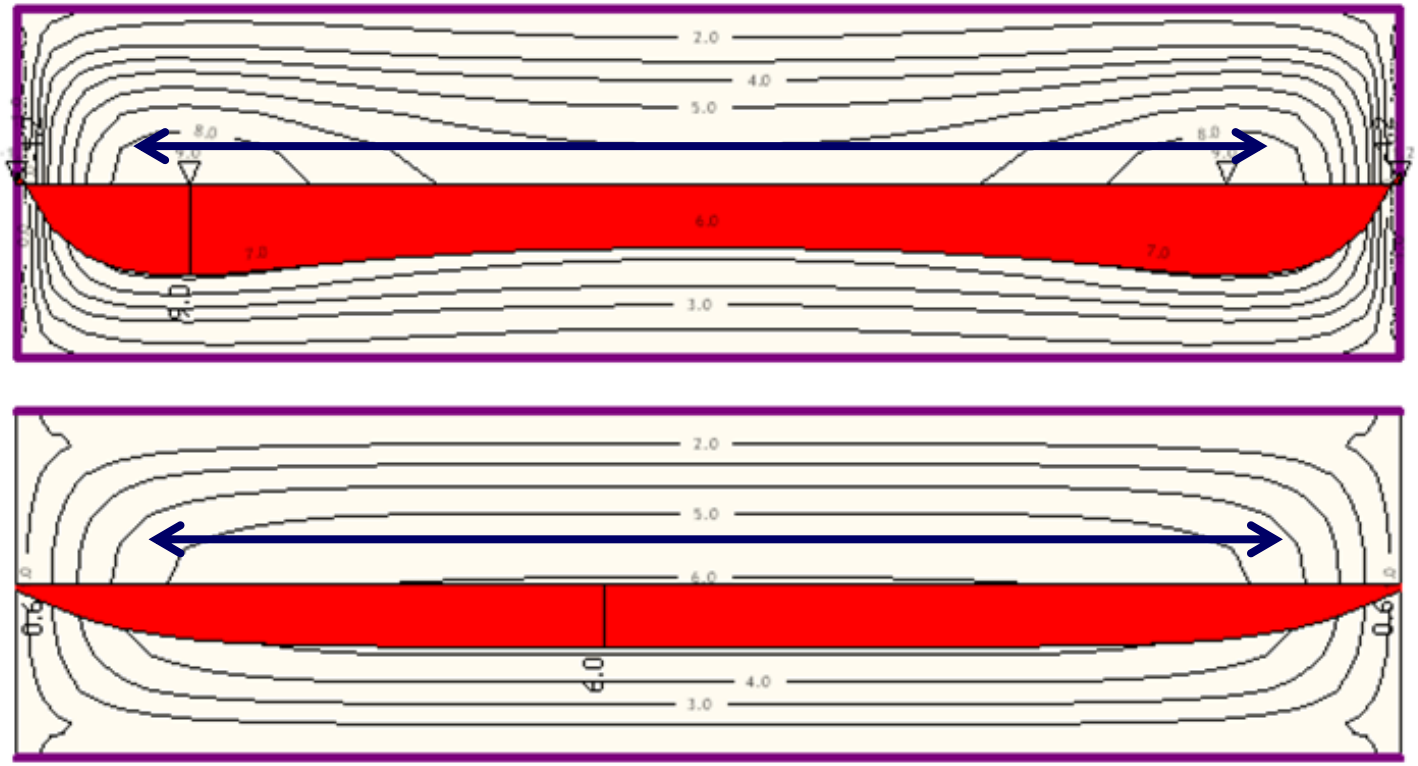
1. Ploče u jednom pravcu

- *U kraćem pravcu l_x postavlja se glavna armatura A_s sračunata iz momenta M_x sa većom statičkom visinom na rastojanju s*



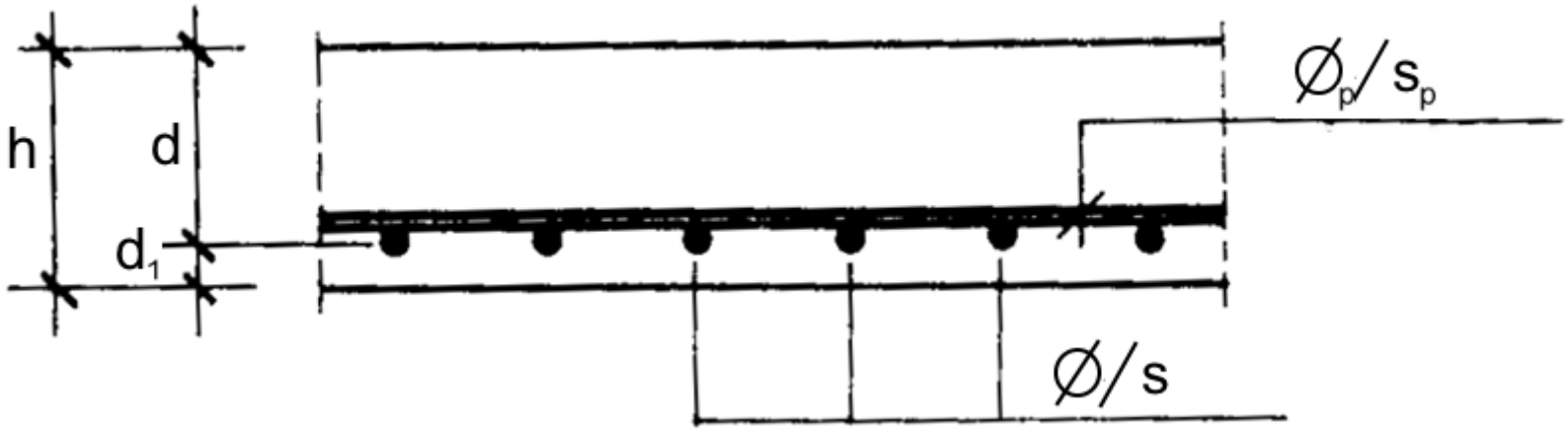
1. Ploče u jednom pravcu

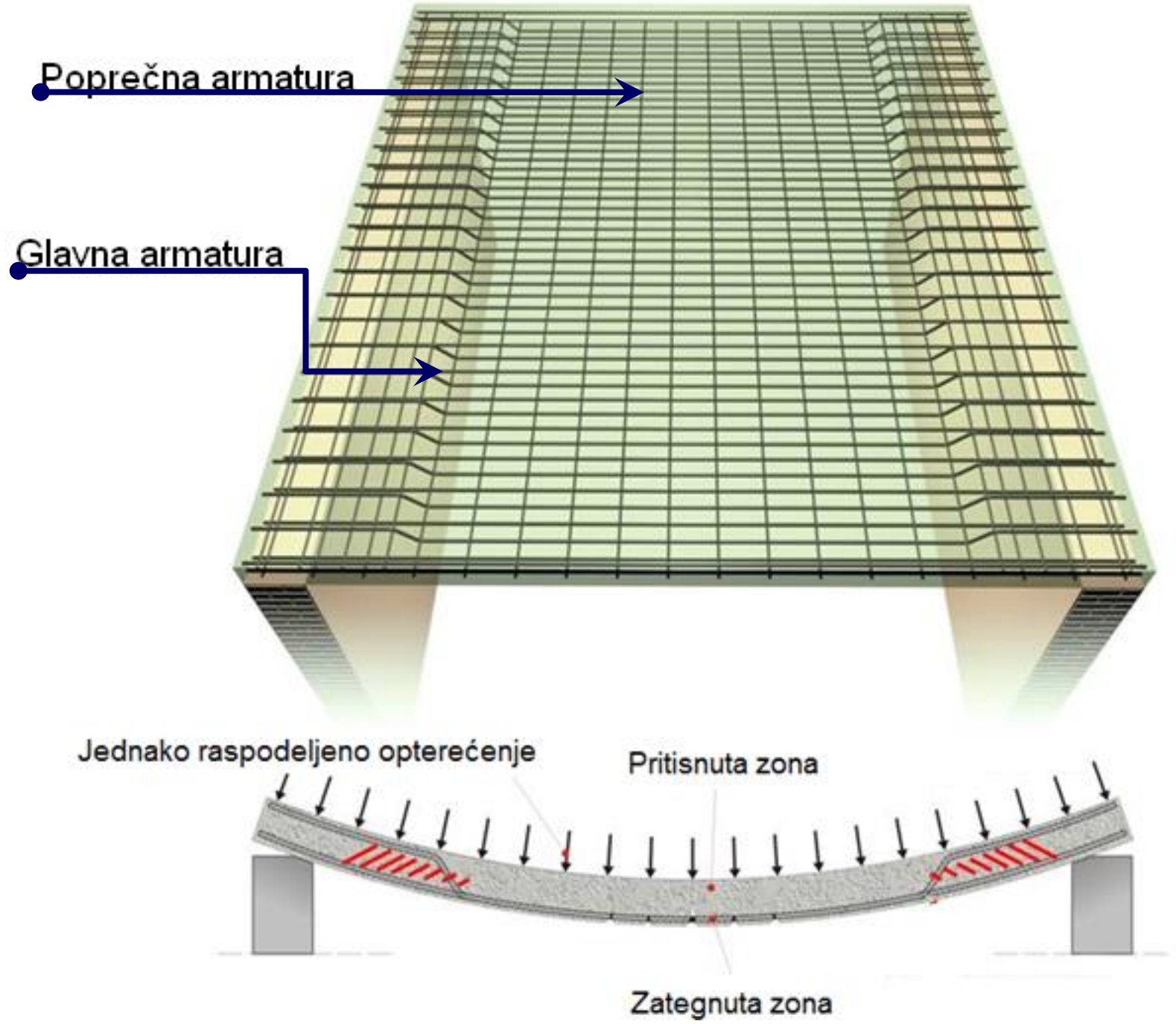
- *U kraćem pravcu l_x postavlja se glavna armatura **A_s** sračunata iz momenta M_x sa većom statičkom visinom na rastojanju s*
- *U dužem pravcu l_y postavlja se poprečna armatura **$A_{sp}=0.2A_s$** sračunata iz momenta M_y sa manjom statičkom visinom na rastojanju s_p*

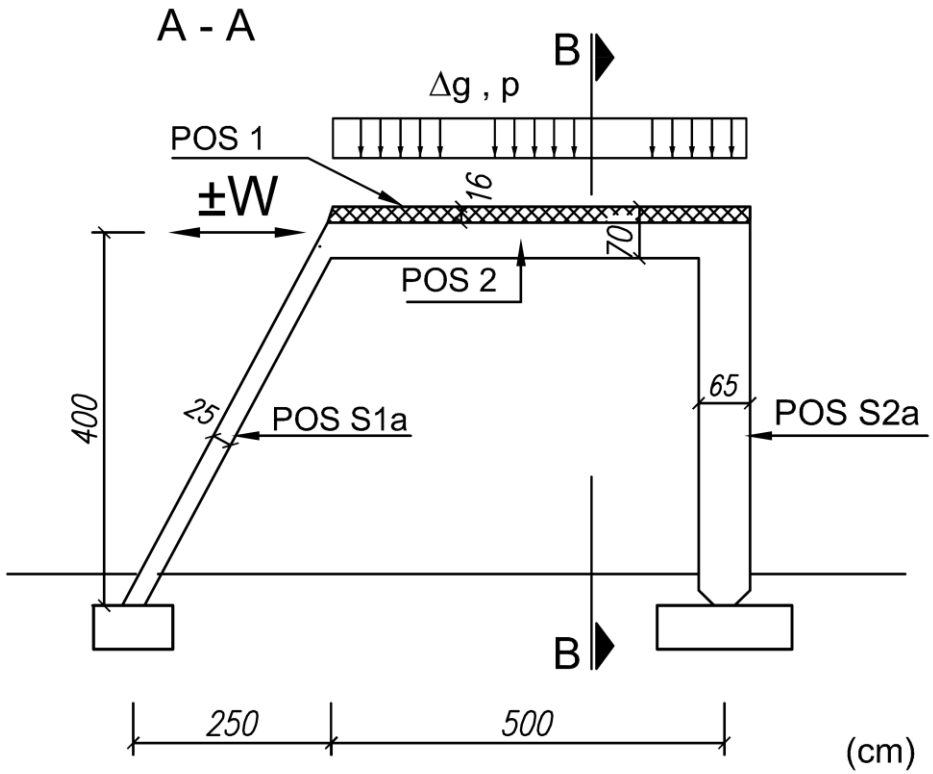


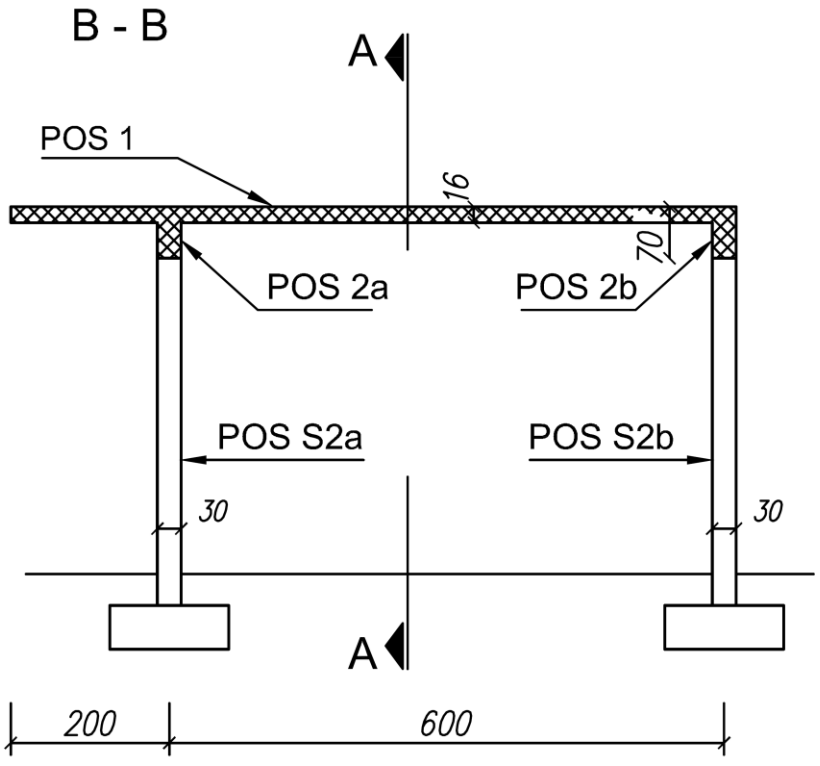
1. Ploče u jednom pravcu

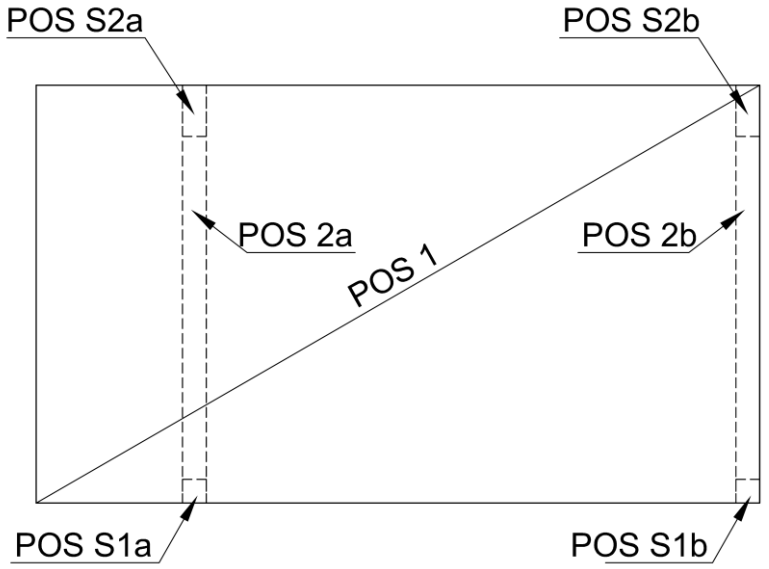
- *U kraćem pravcu l_x postavlja se glavna armatura **A_s** sračunata iz momenta M_x sa većom statičkom visinom na rastojanju s*
- *U dužem pravcu l_y postavlja se poprečna armatura **$A_{sp}=0.2A_s$** sračunata iz momenta M_y sa manjom statičkom visinom na rastojanju s_p*

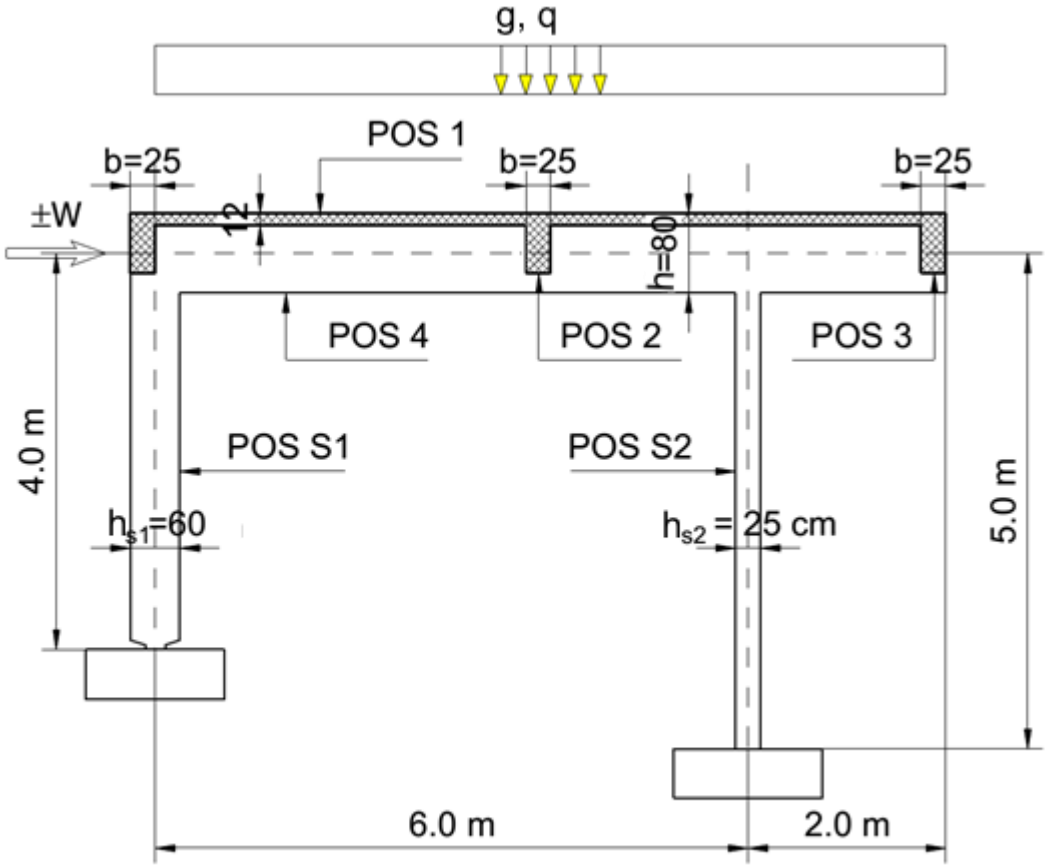


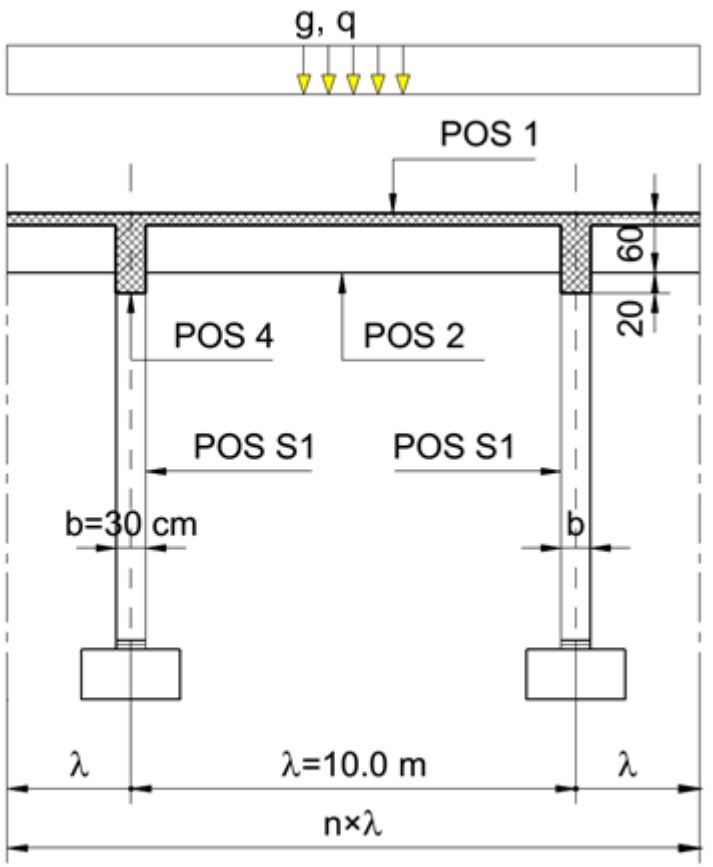

Poprečna armatura
Glavna armatura
Jednako raspodeljeno opterećenje
Pritisnuta zona
Zategnuta zona

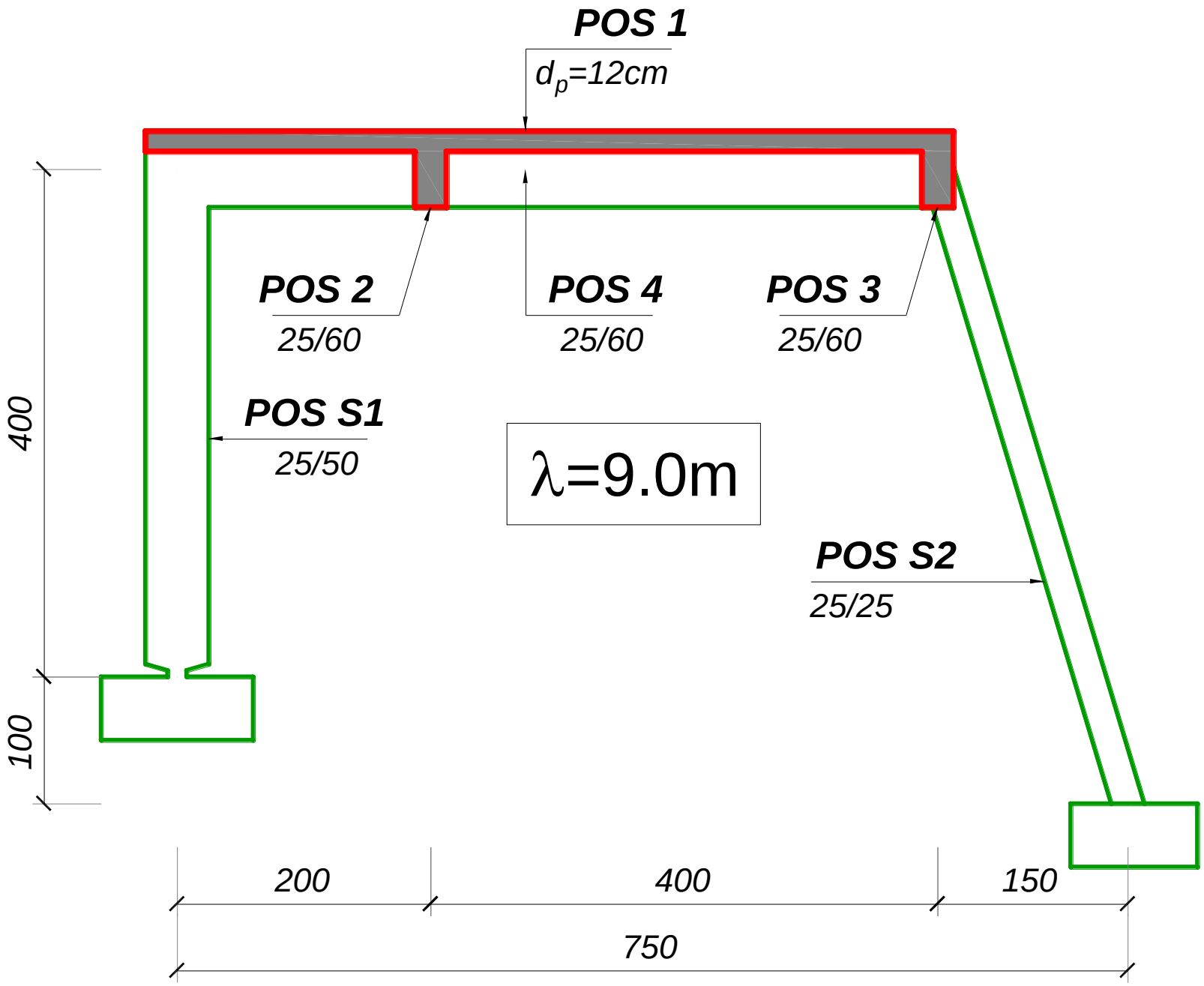

A - A
B
Δg , p
POS 1
±W
16
70
POS 2
400
25
POS S1a
65
POS S2a
B
250
500
(cm)

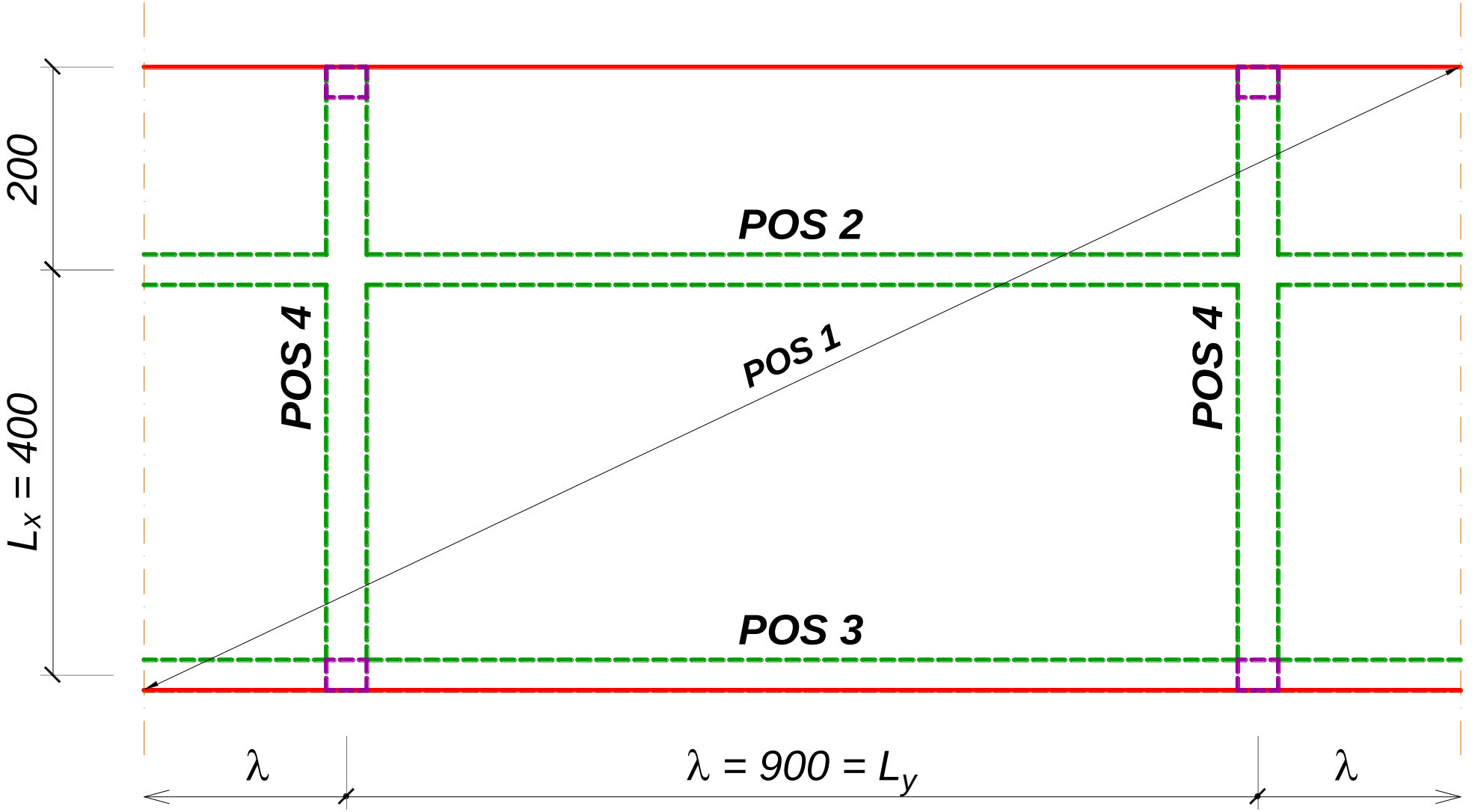

B - B
A
POS 1
16
70
POS 2a
POS 2b
POS S2a
POS S2b
30
30
A
200
600

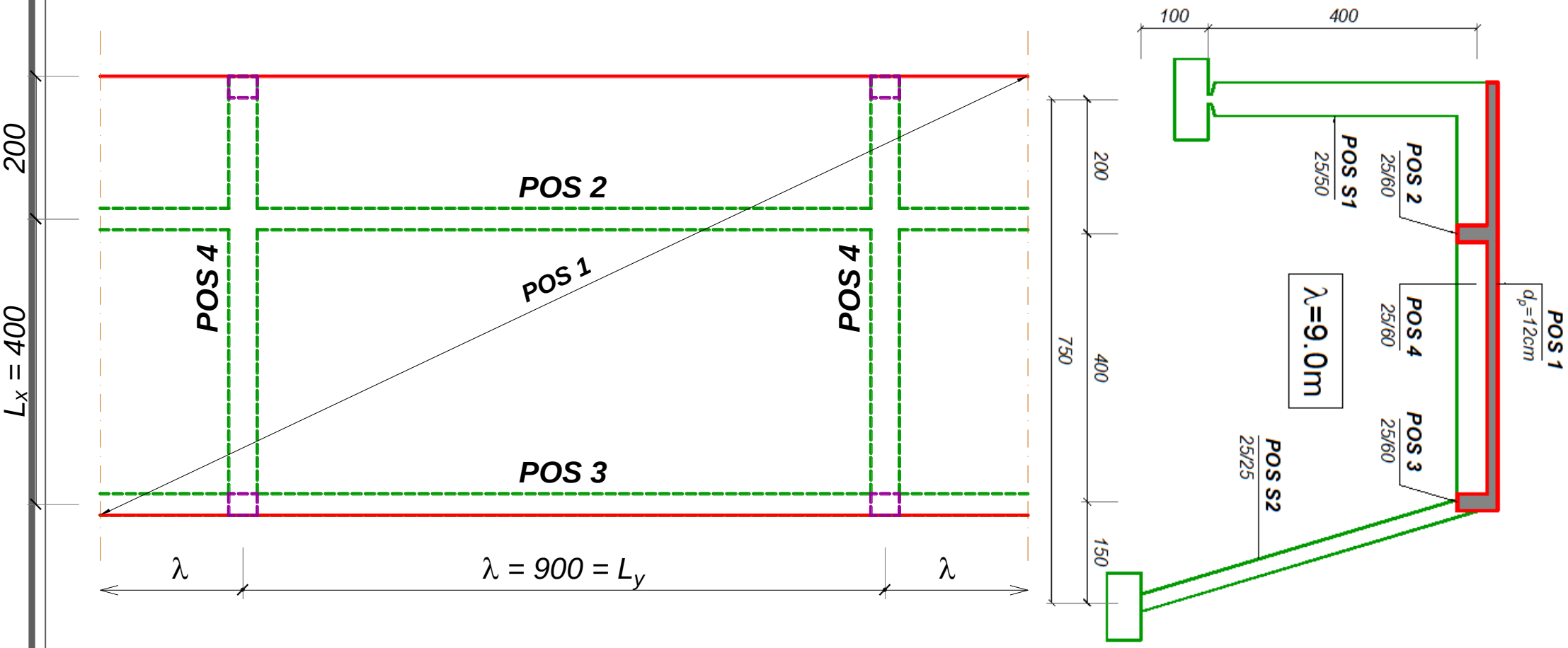

POS S2a
POS S2b
POS 2a
POS 2b
POS 1
POS S1a
POS S1b

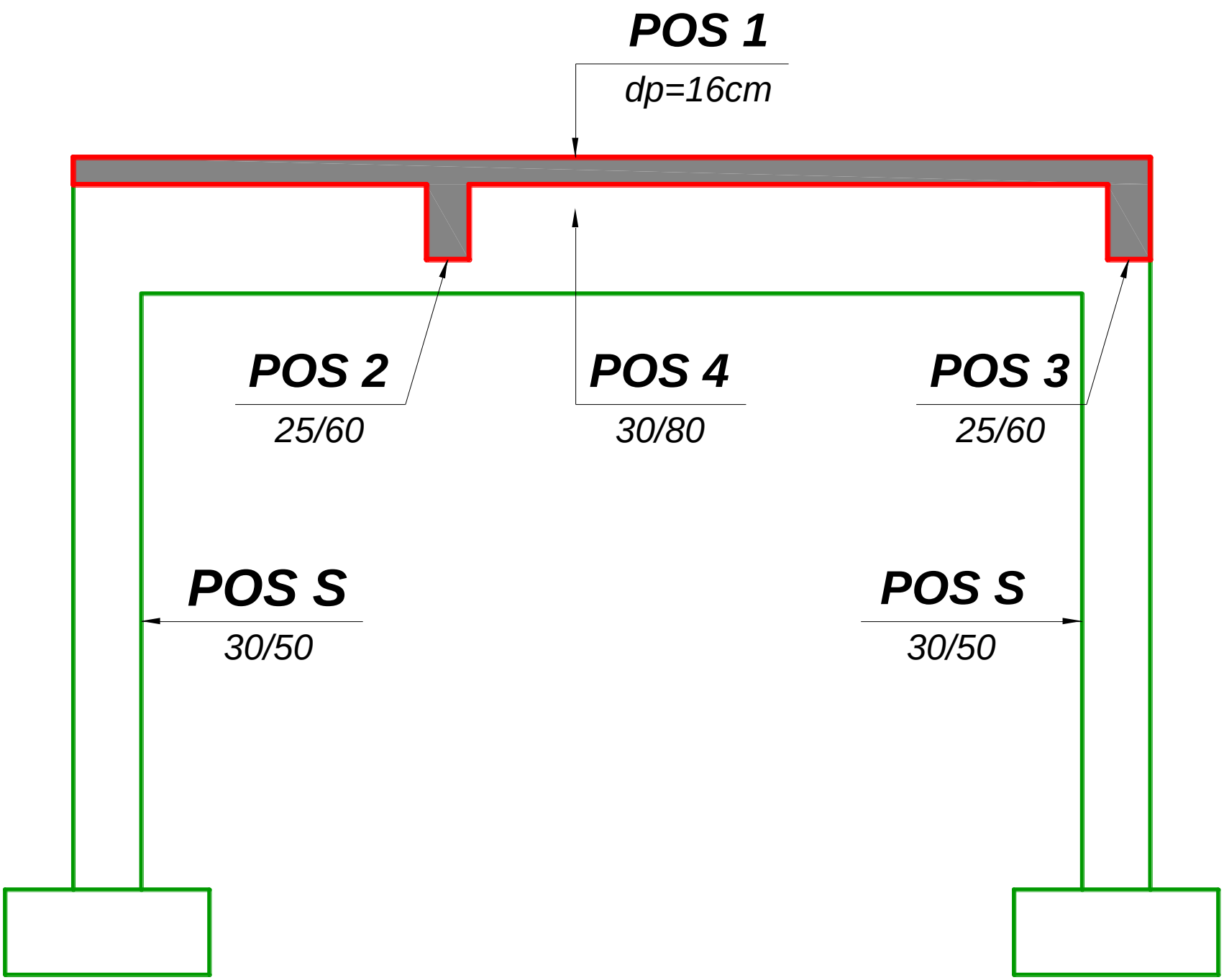

g, q
POS 1
b=25
b=25
b=25
±W
12
h=80
POS 4
POS 2
POS 3
4.0 m
POS S1
POS S2
h_{s1}=60
h_{s2} = 25 cm
5.0 m
6.0 m
2.0 m

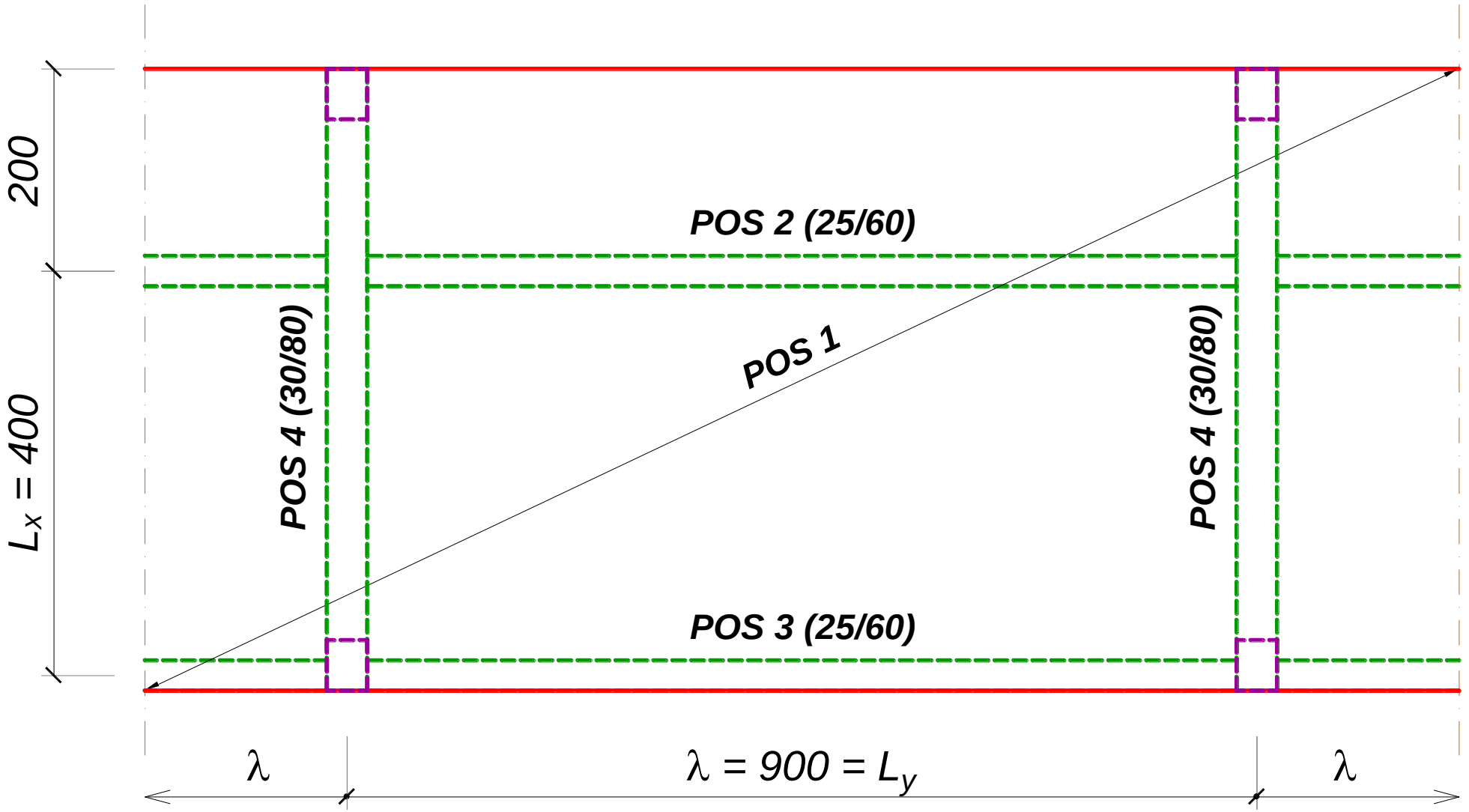

g, q
POS 1
60
20
POS 4
POS 2
POS S1
POS S1
b=30 cm
b
λ
λ=10.0 m
λ
n×λ

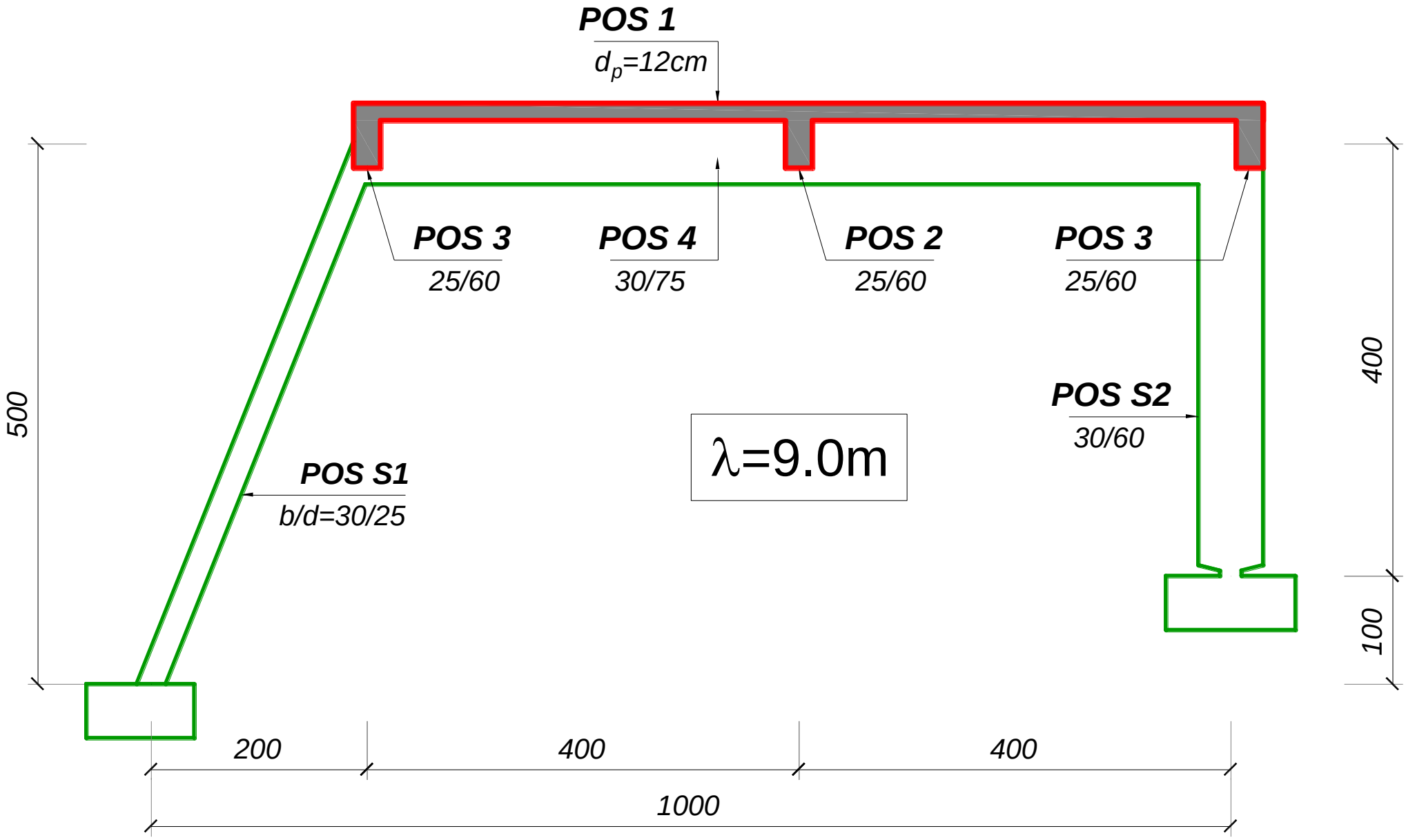

POS 1
d_p=12cm
POS 2
25/60
POS 4
25/60
POS 3
25/60
POS S1
25/50
λ=9.0m
POS S2
25/25
400
100
200
400
150
750

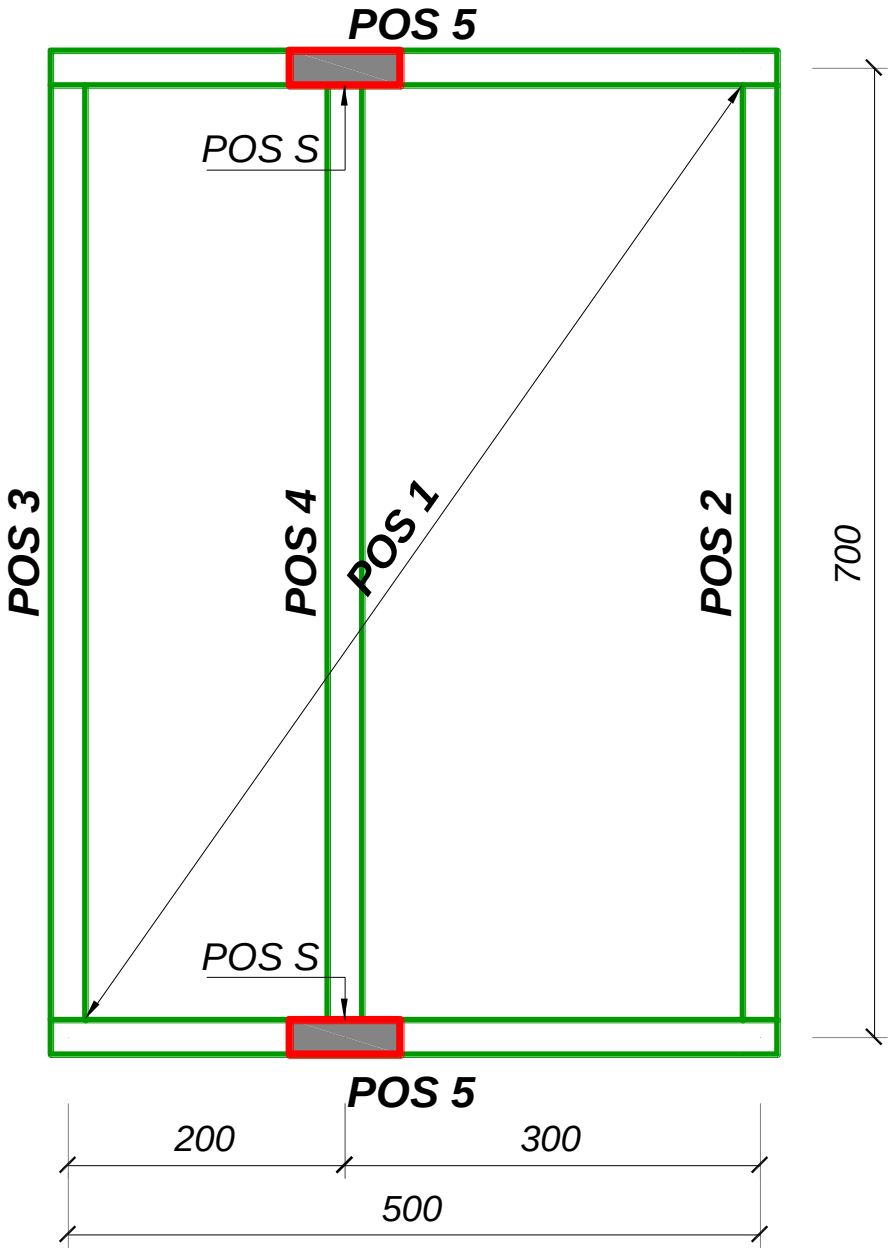

200
L_x = 400
POS 2
POS 4
POS 1
POS 4
POS 3
λ
λ = 900 = L_y
λ

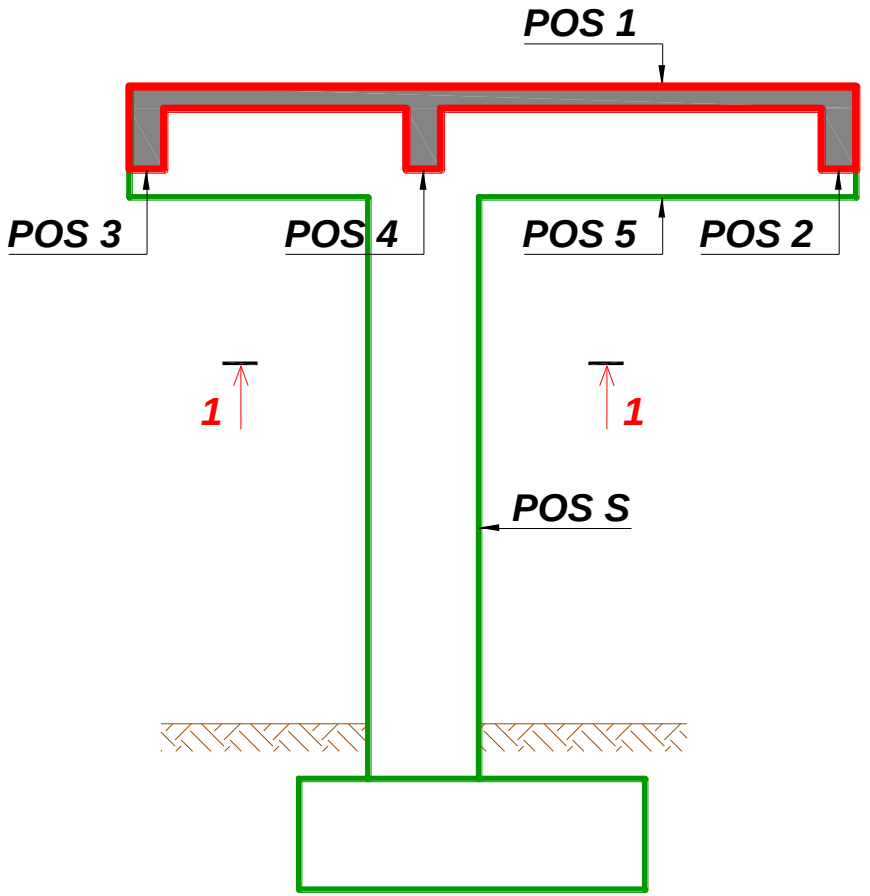

200
L_x = 400
POS 2
POS 4
POS 1
POS 4
POS 3
λ
λ = 900 = L_y
λ
100
400
200
400
150
750
POS S1
25/50
POS 2
25/60
POS 4
25/60
POS 3
25/60
POS S2
25/25
λ=9.0m
POS 1
d_p=12cm


POS 1
dp=16cm
POS 2
25/60
POS 4
30/80
POS 3
25/60
POS S
30/50
POS S
30/50


200
L_x = 400
POS 2 (25/60)
POS 1
POS 4 (30/80)
POS 4 (30/80)
POS 3 (25/60)
λ
λ = 900 = L_y
λ


POS 1
d_p=12cm
POS 3
25/60
POS 4
30/75
POS 2
25/60
POS 3
25/60
POS S2
30/60
POS S1
b/d=30/25
λ=9.0m
500
400
100
200
400
400
1000


POS 5
POS S
POS 3
POS 4
POS 1
POS 2
700
POS S
POS 5
200
300
500


POS 1
POS 3
POS 4
POS 5
POS 2
1
1
POS S