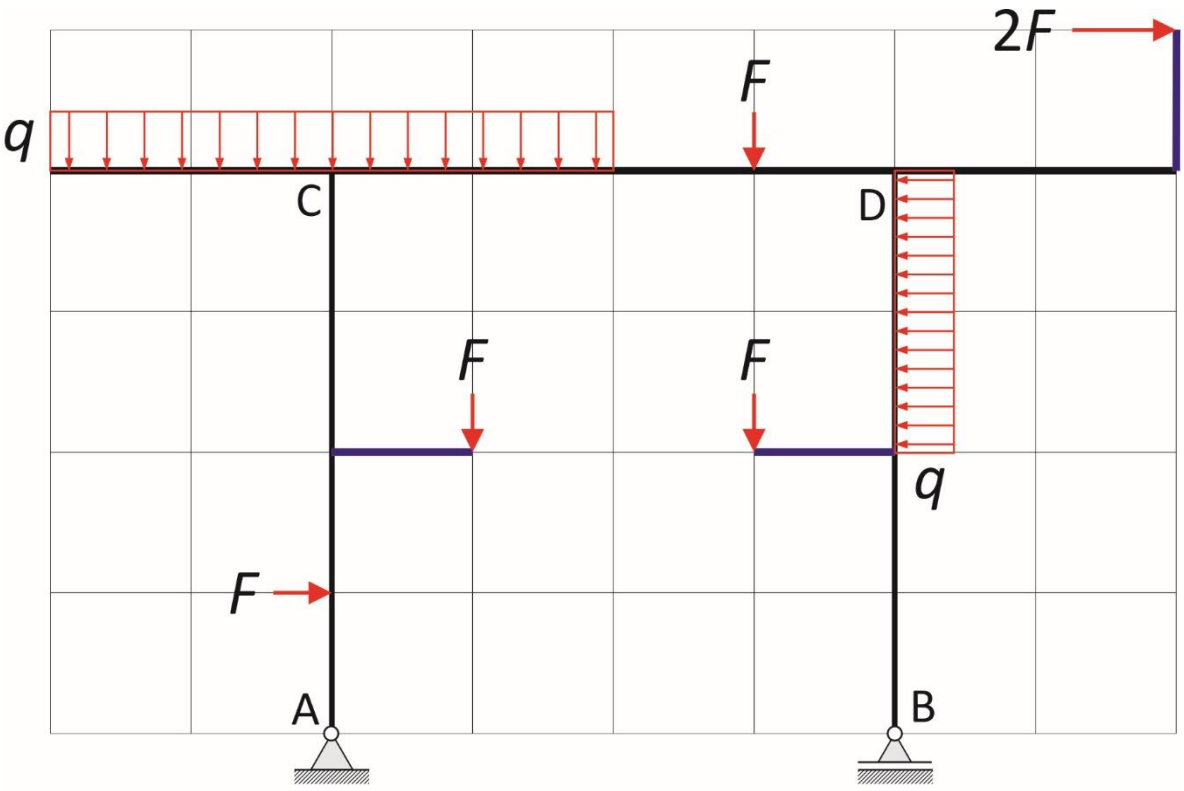
Student_____

- Projektni zadatak -

Laboratorijska vežba br.2

Na slici je prikazana skica ramovske konstrukcije koja se sastoji od horizontalnog nosača, vertikalnih/kosih nosača i kratkih nosača (dužine a). Struktura je opterećena silama, kontinualnim opterećenjima i momentom, sa intenzitetima prema podacima u prilogu. Karakteristike nosača su takođe date u prilogu. Kratke nosače tretirati kao "fiktivni" element.



F=10 kN

q=10 kN/m

Dimenzije su šematski zadate po "grid-linijama" sa kvadratima a x a.

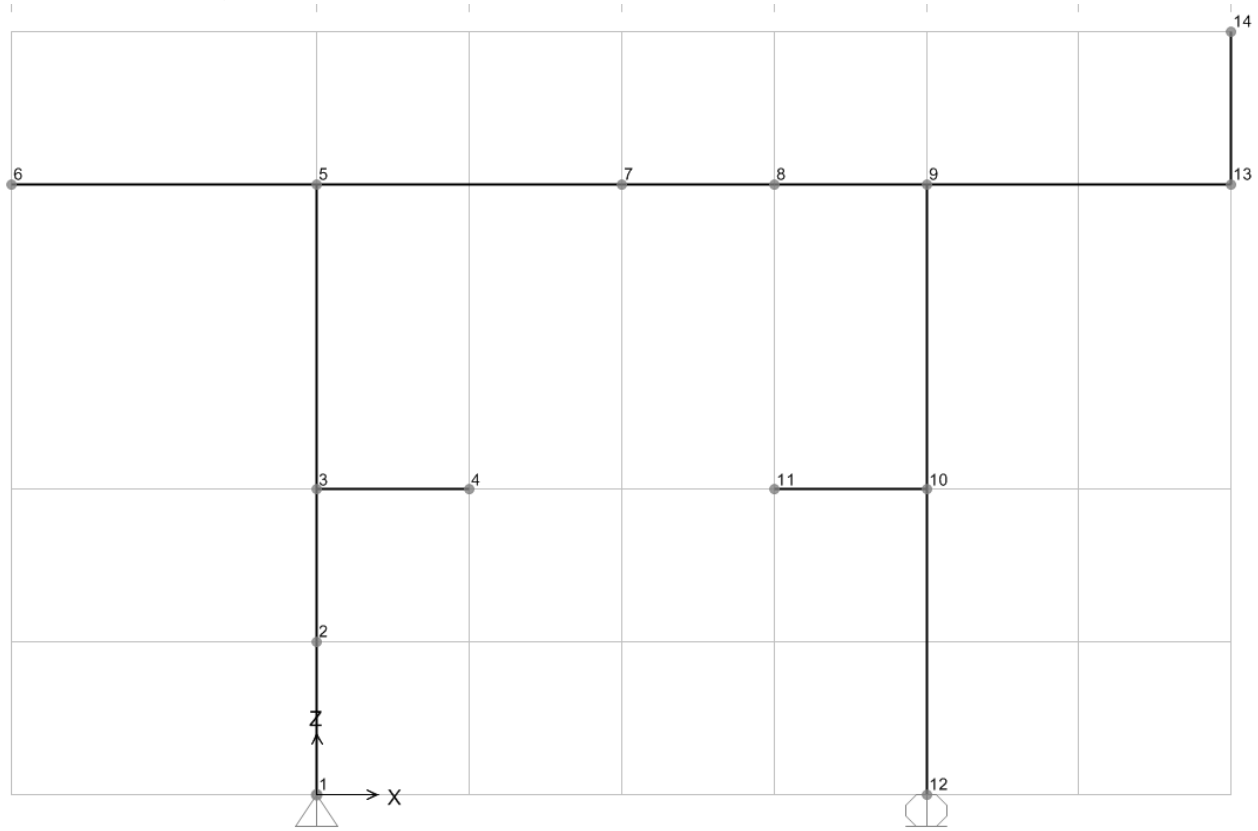
Potrebno je uraditi sledeće:

- Izvršiti statički proračun strukture primenom MKE u programu SAP 2000
- Izvršiti dokaz čvrstoće strukture
- Izraditi tehnički izveštaj i pripremiti u PDF-u

dr Vlada Gašić
Zadatak izdao

Statički proračun ramovske konstrukcije

1. Numeracija čvorova KE



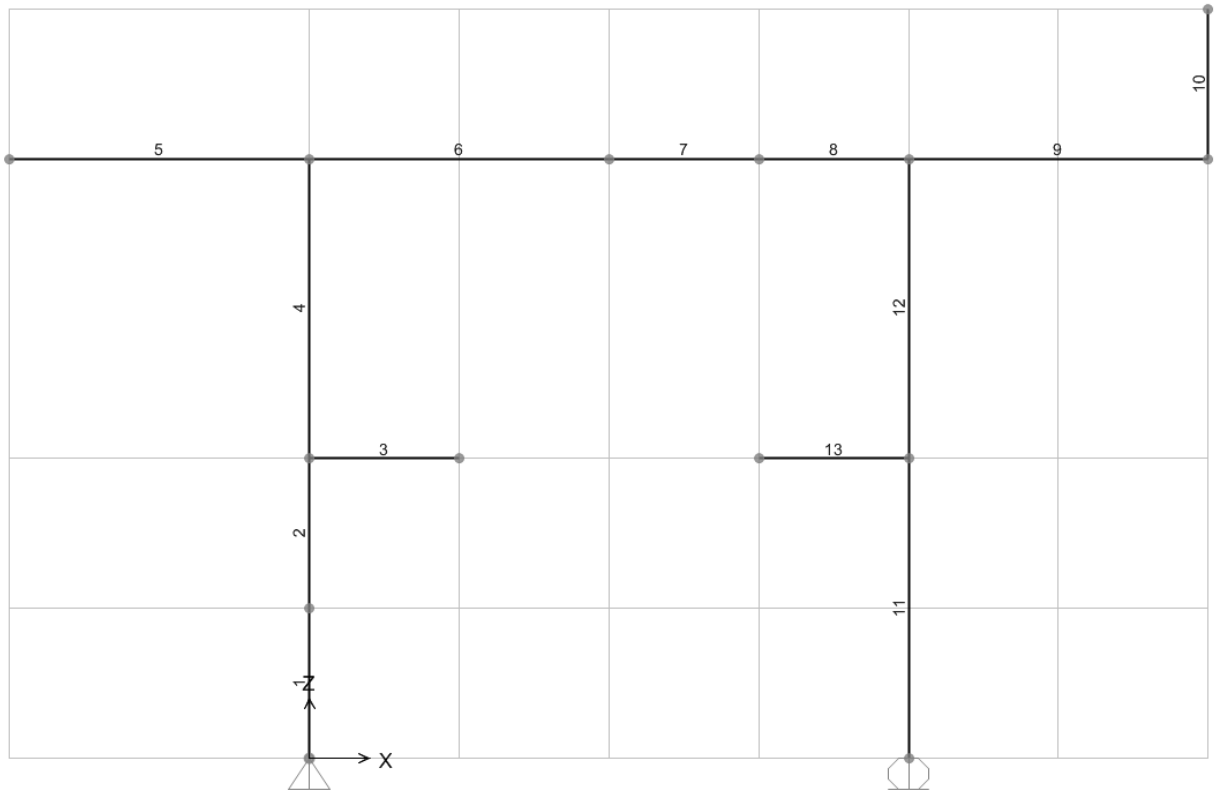
Slika 1 – *Numeracija čvorova KE modela*

2. Koordinate čvorova KE

Tabela 1 – *Koordinate čvorova*

TABLE: Joint Coordinates					
Joint	**CoordSys**	**CoordType**	**XorR**	**Y**	**Z**
Text	Text	Text	cm	cm	cm
1	GLOBAL	Cartesian	0	0	0
2	GLOBAL	Cartesian	0	0	100
3	GLOBAL	Cartesian	0	0	200
4	GLOBAL	Cartesian	100	0	200
5	GLOBAL	Cartesian	0	0	400
6	GLOBAL	Cartesian	-200	0	400
7	GLOBAL	Cartesian	200	0	400
8	GLOBAL	Cartesian	300	0	400
9	GLOBAL	Cartesian	400	0	400
10	GLOBAL	Cartesian	400	0	200
11	GLOBAL	Cartesian	300	0	200
12	GLOBAL	Cartesian	400	0	0
13	GLOBAL	Cartesian	600	0	400
14	GLOBAL	Cartesian	600	0	500

3. Numeracija elemenata KE



Slika 2 – *Numeracija elemenata KE modela*

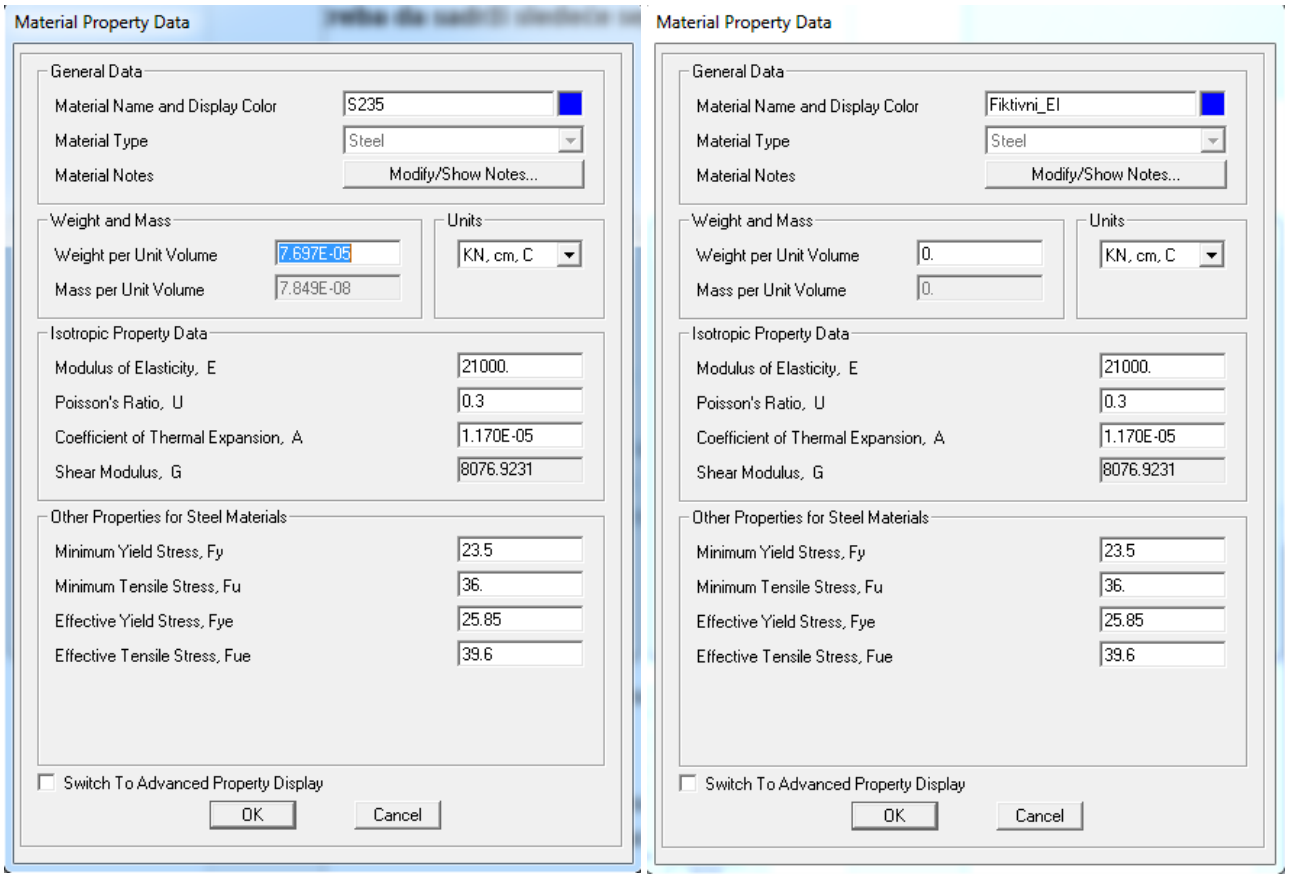
4. Postavka elemenata

Tabela 2 *Postavka elemenata*

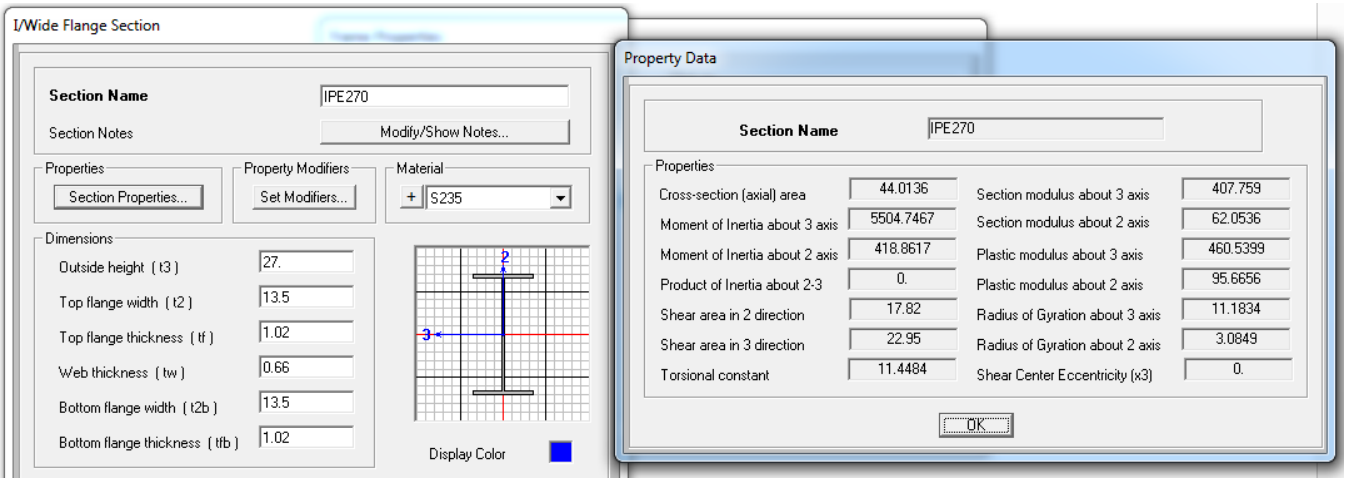
TABLE: Connectivity - Frame						
Frame	**JointI**	**JointJ**	**Length**	**CentroidX**	**CentroidY**	**CentroidZ**
Text	Text	Text	cm	cm	cm	cm
1	1	2	100	0	0	50
2	2	3	100	0	0	150
3	3	4	100	50	0	200
4	3	5	200	0	0	300
5	6	5	200	-100	0	400
6	5	7	200	100	0	400
7	7	8	100	250	0	400
8	8	9	100	350	0	400
9	9	13	200	500	0	400
10	13	14	100	600	0	450
11	12	10	200	400	0	100
12	10	9	200	400	0	300
13	10	11	100	350	0	200

5. Karakteristike poprečnih preseka

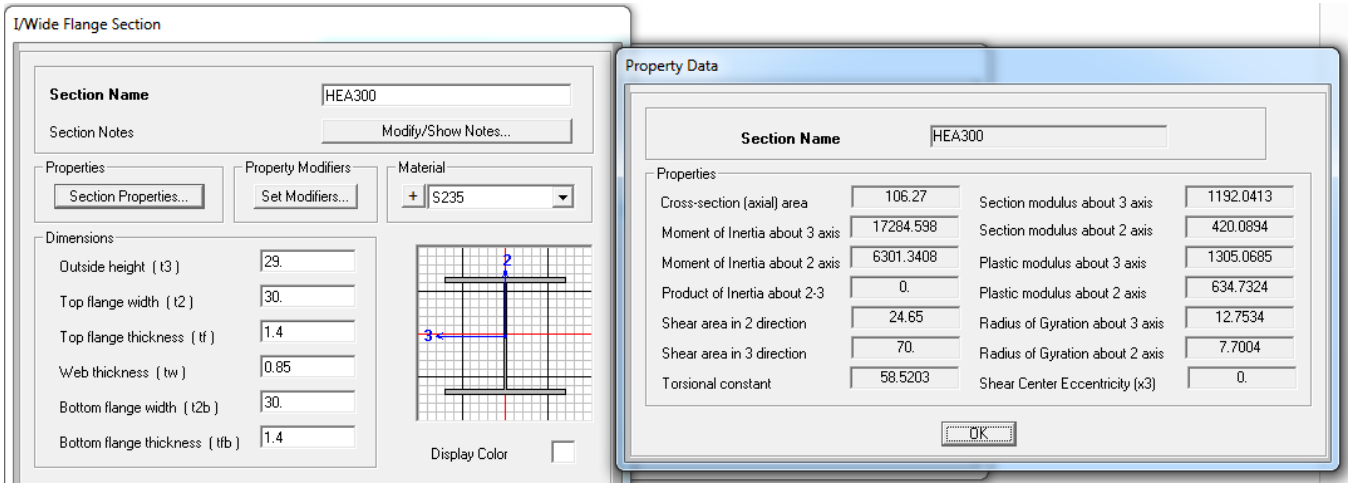
Na narednim slikama date su karakteristike poprečnih preseka korišćenih za ovu ramovsku konstrukciju, kao i karakteristike čelika od kojeg je konstrukcija izrađena.



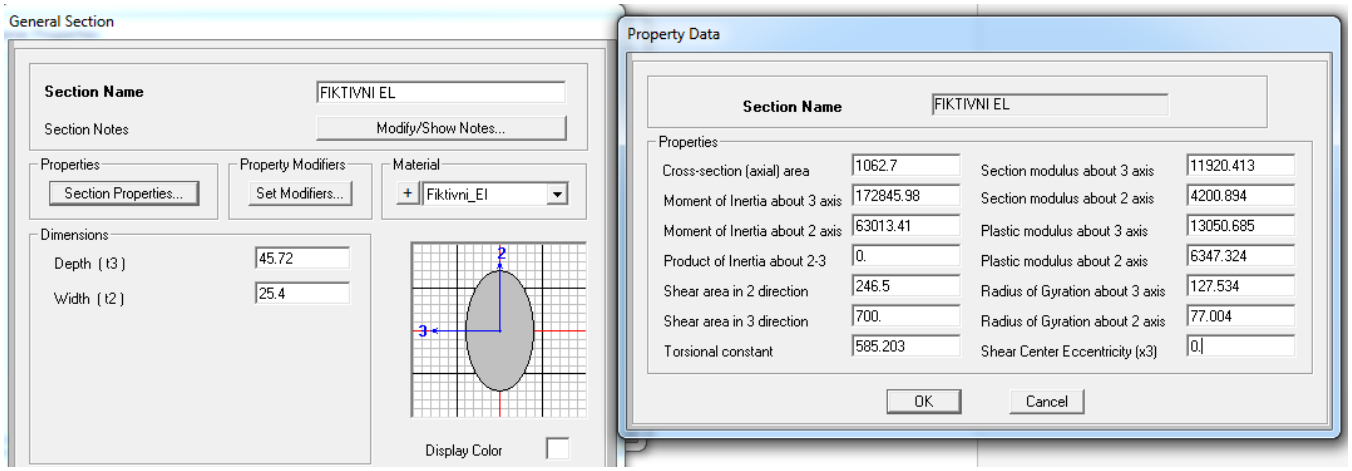
Slika 3 – *Karakteristike čelika S235 kao i materijala korišćenog za fiktivne elemente u konstrukciji*



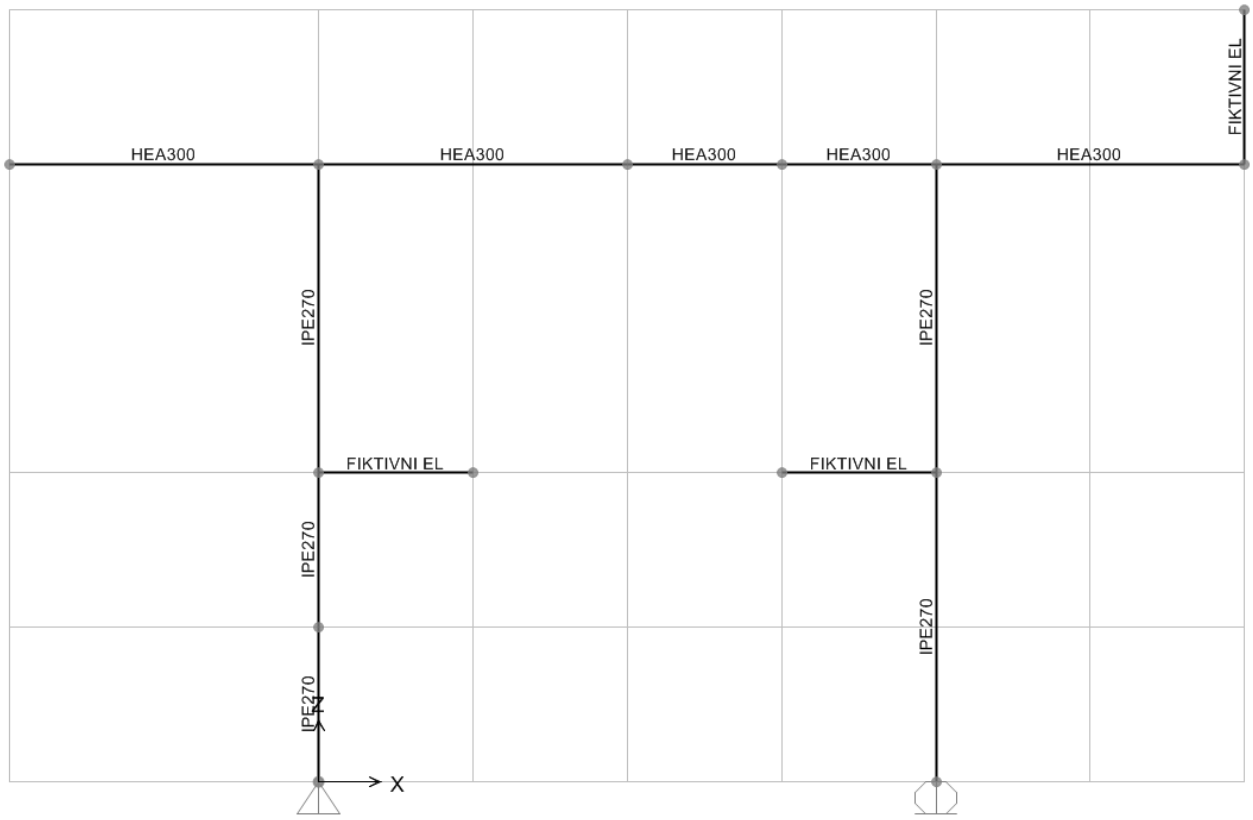
Slika 4 – *Presek profila IPE 270 sa njegovim karakteristikama*



Slika 5 – *Presek profila HEA 300 sa njegovim karakteristikama*

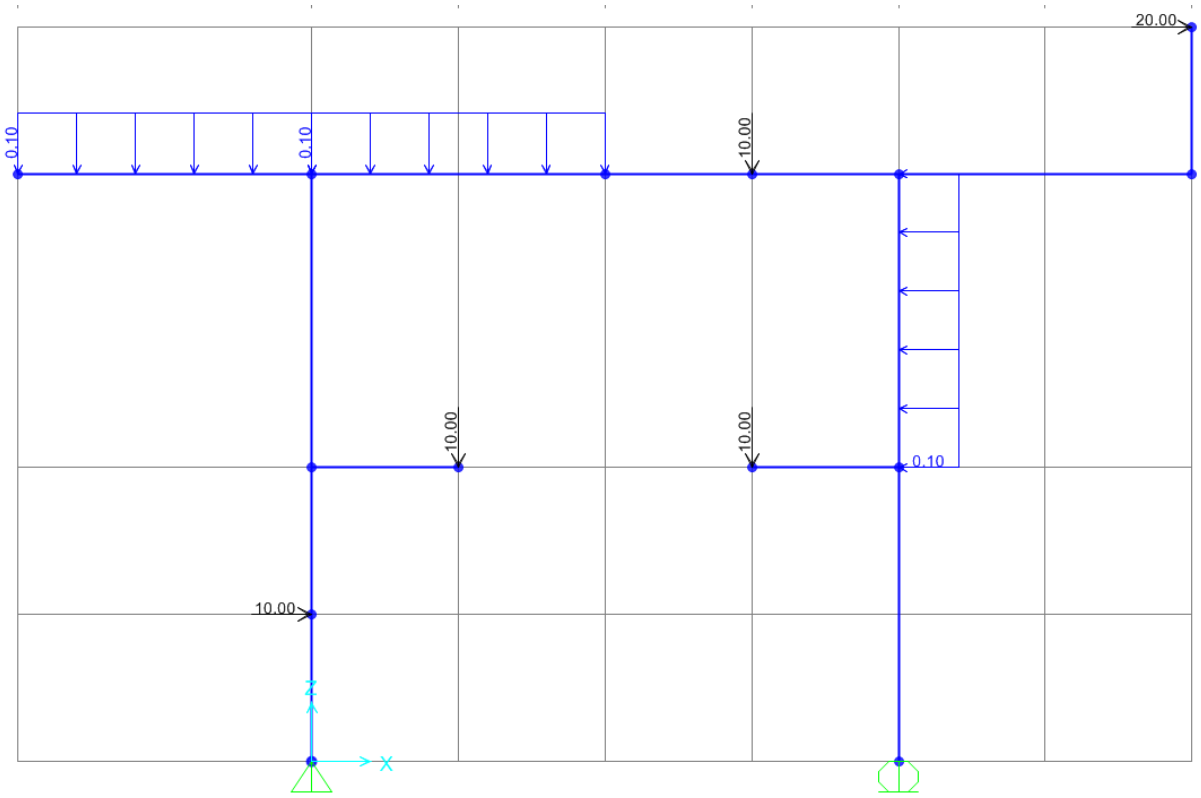


Slika 6 – *Presek fiktivnog poprečnog preseka sa njegovima karakteristikama*

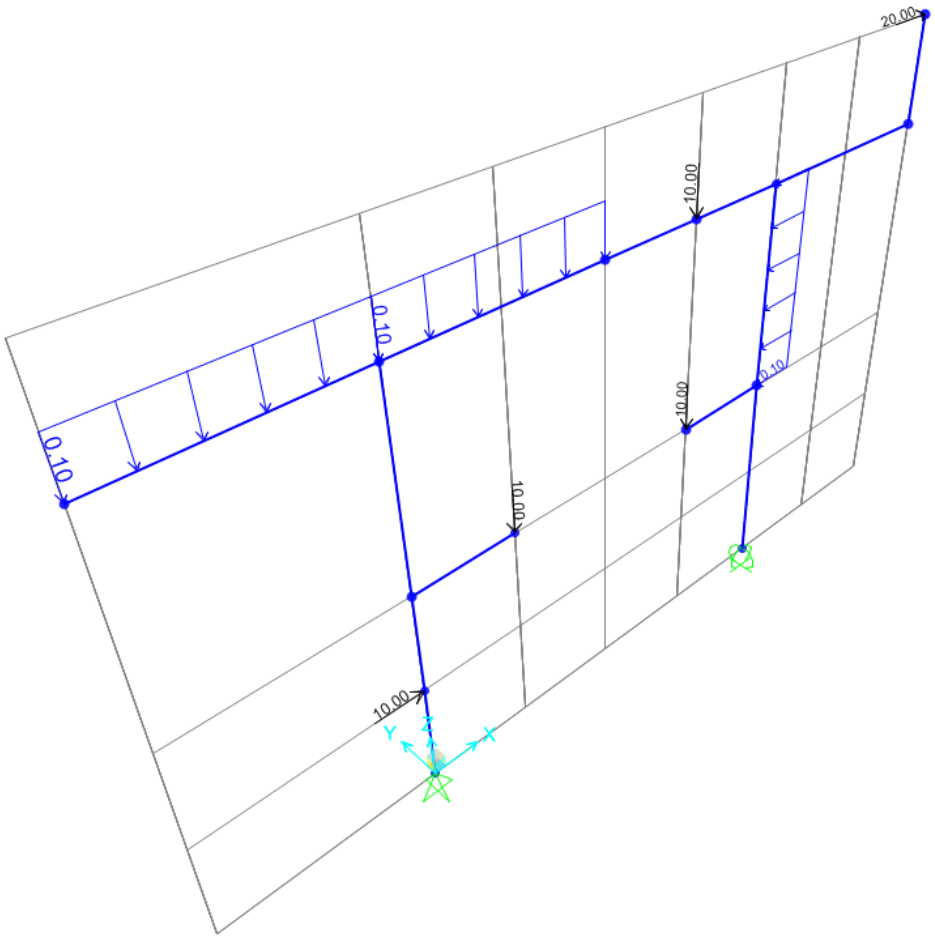


Slika 7 – *Prikaz dodeljenih poprečnih preseka konstrukcije*

6. Prikaz spoljašnjih opterećenja ramovske konstrukcije



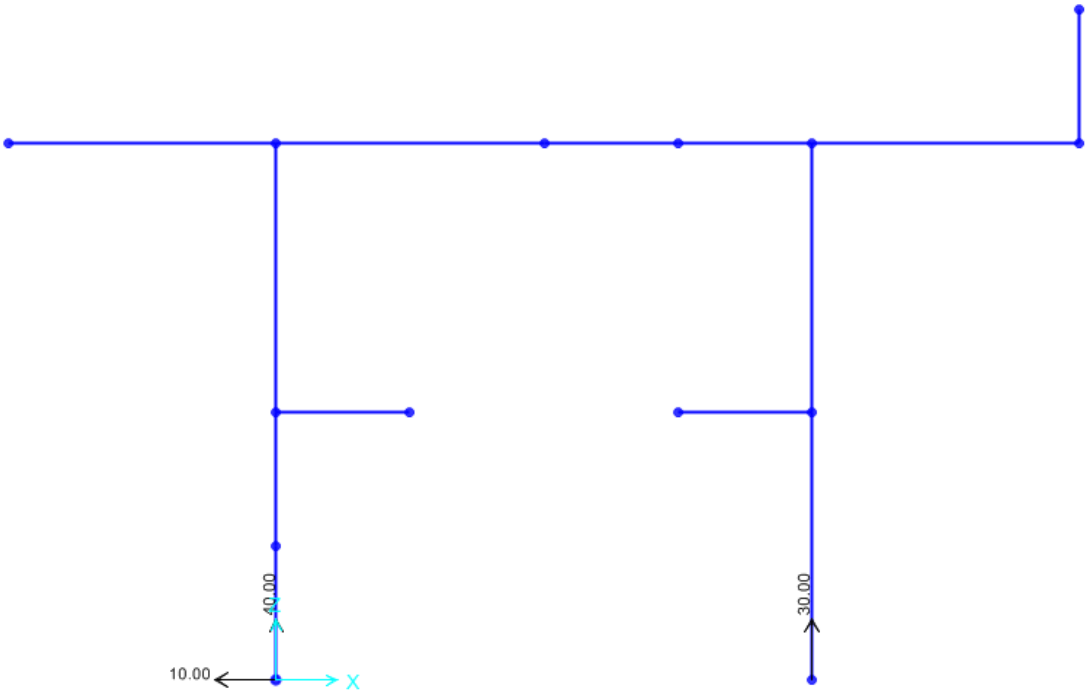
Slika 8 – *Prikaz spoljašnjih opterećenja u xz-ravni*



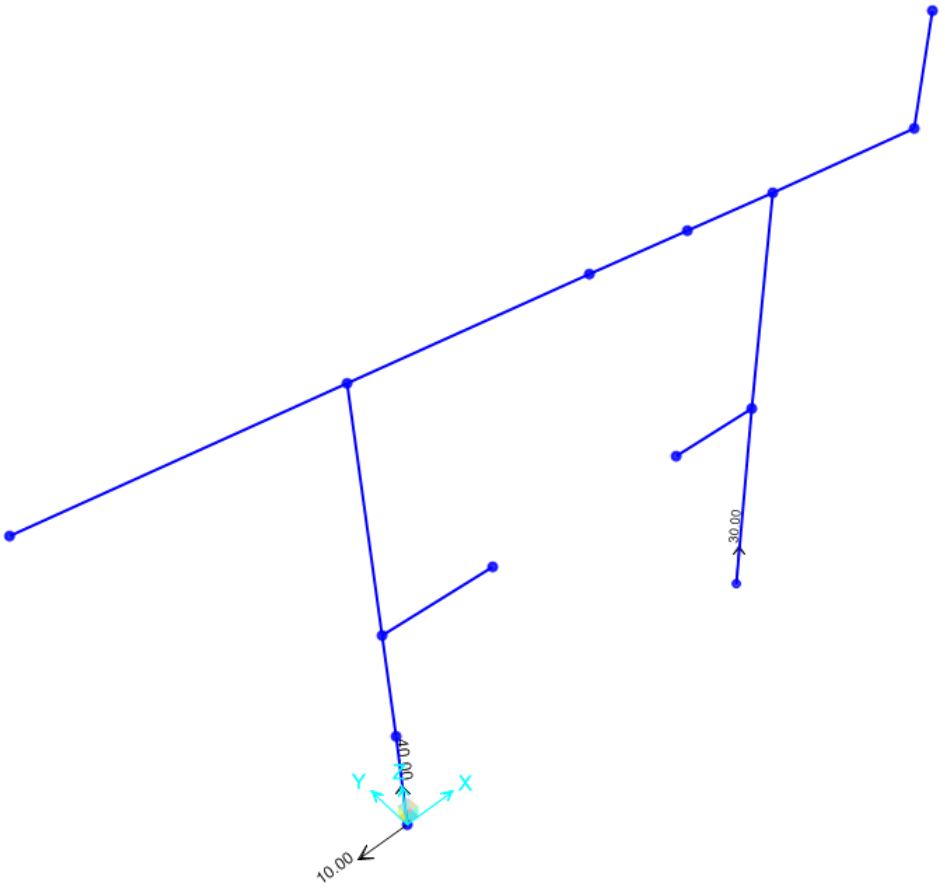
Slika 9 – *Prikaz spoljašnjih opterećenja u 3D*

7. Rezultati proračuna

Prikaz reakcija oslonaca



Slika 10 -*Prikaz reakcija oslonaca u xz-ravni*

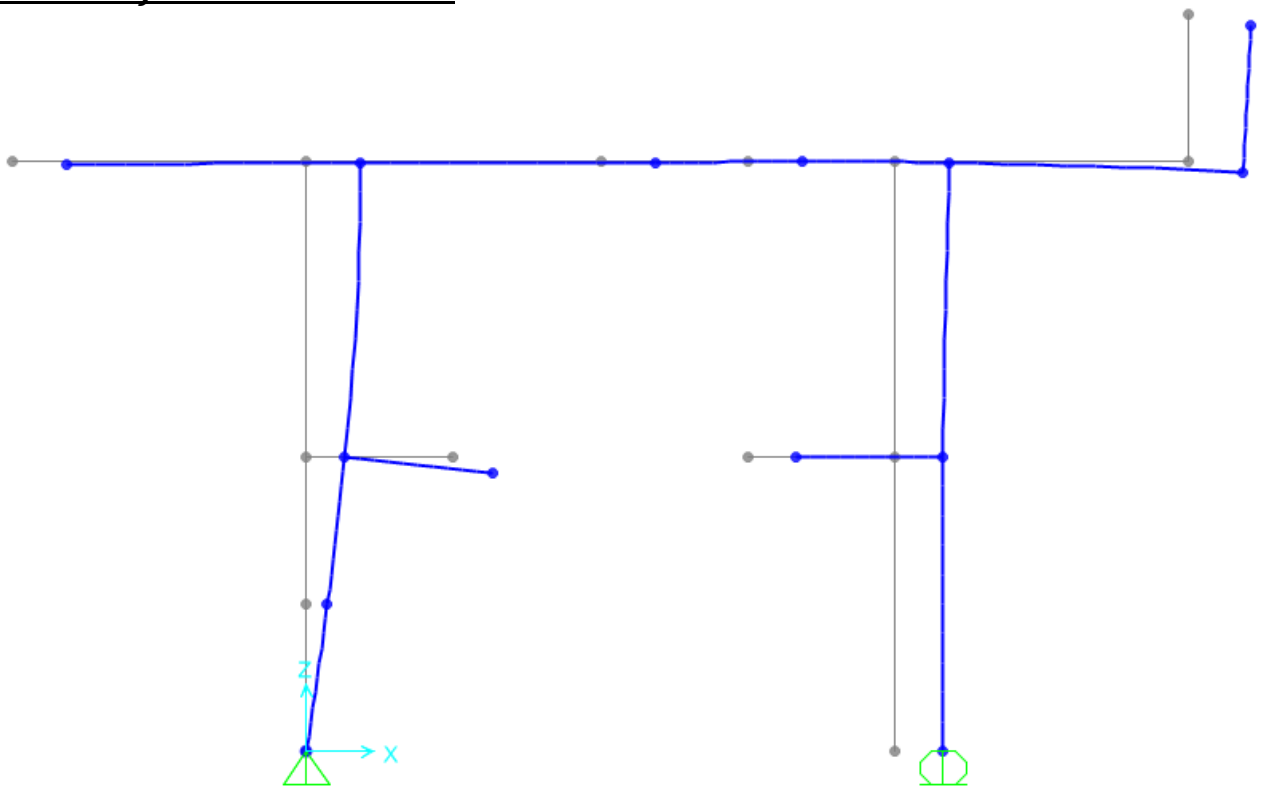


Slika 11 – *Prikaz reakcija oslonaca u 3D*

Tabela 3 *Reakcije oslonaca*

TABLE: Joint Reactions								
Joint	**OutputCase**	**CaseType**	**F1**	**F2**	**F3**	**M1**	**M2**	**M3**
Text	Text	Text	KN	KN	KN	KN-cm	KN-cm	KN-cm
1	DEAD	LinStatic	-10	0	40	0	0	0
12	DEAD	LinStatic	0	0	30	0	0	0

Prikaz deformisane strukture

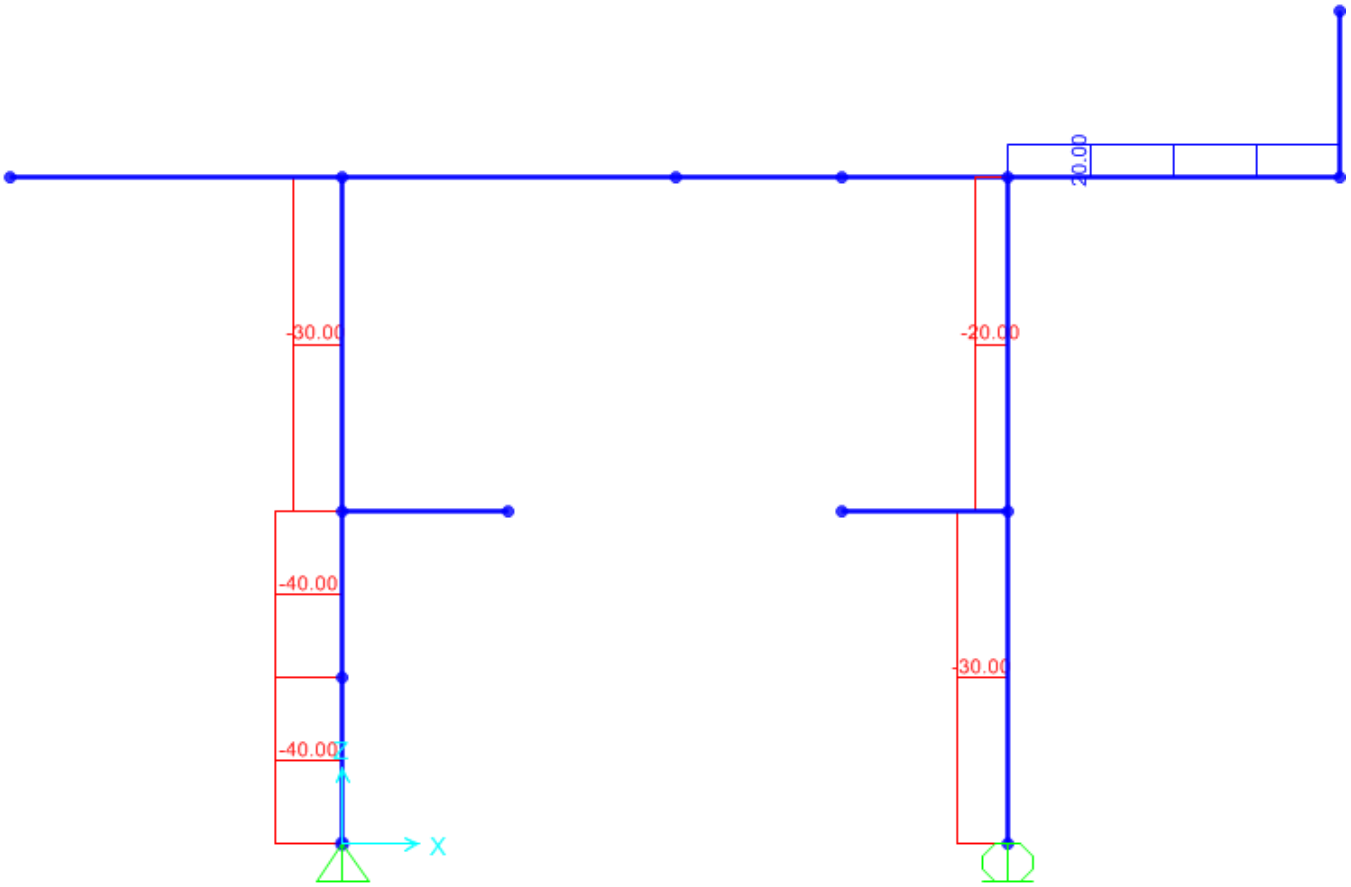


Slika 12 – *Prikaz deformisane strukture*

Tabela 4 *Pomeranja čvorova KE modela*

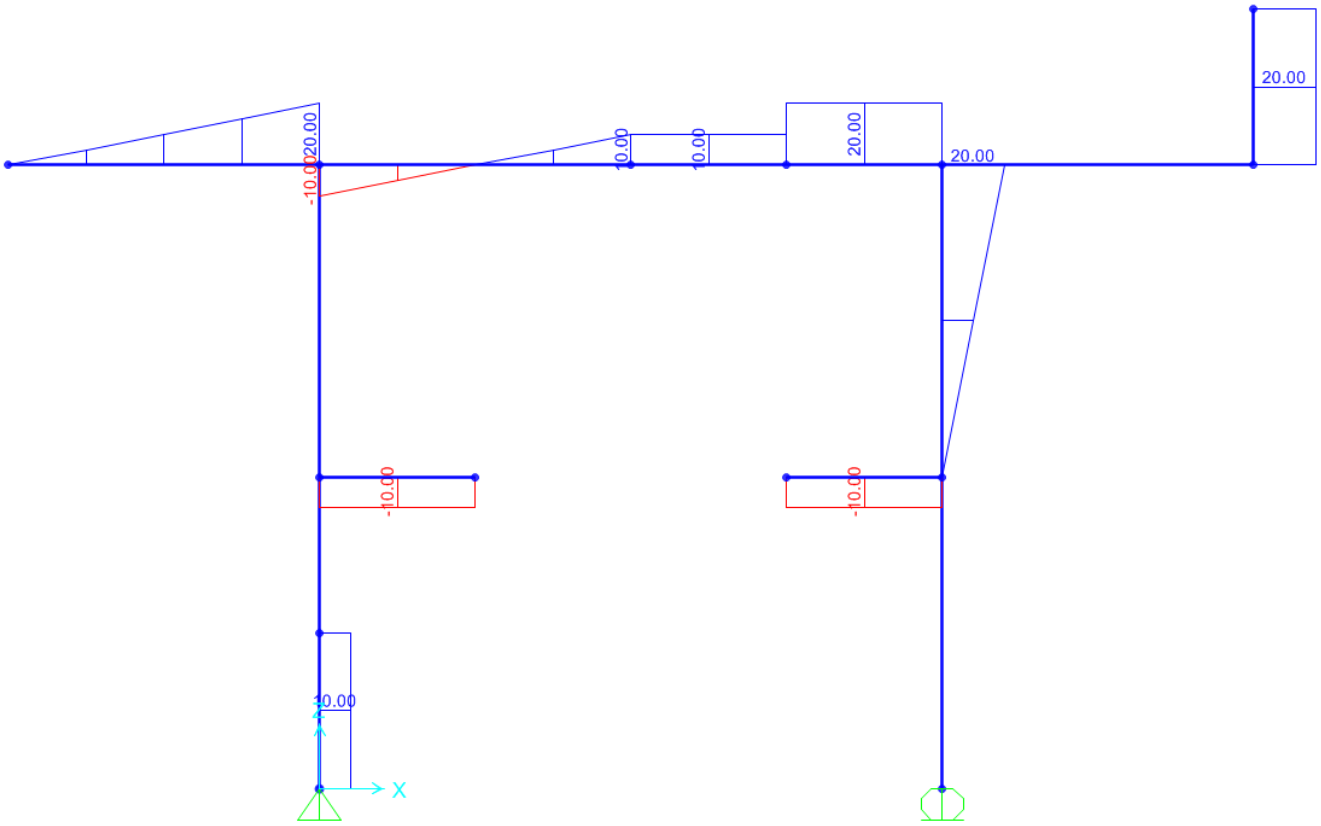
TABLE: Joint Displacements								
Joint	**OutputCase**	**CaseType**	**U1**	**U2**	**U3**	**R1**	**R2**	**R3**
Text	Text	Text	cm	cm	cm	Radians	Radians	Radians
1	DEAD	LinStatic	0	0	0	0	0.004819	0
2	DEAD	LinStatic	0.474439	0	-0.004328	0	0.004387	0
3	DEAD	LinStatic	0.869842	0	-0.008655	0	0.003522	0
4	DEAD	LinStatic	0.869842	0	-0.362227	0	0.003535	0
5	DEAD	LinStatic	1.228122	0	-0.015147	0	0.000061	0
6	DEAD	LinStatic	1.228122	0	-0.068034	0	-0.000306	0
7	DEAD	LinStatic	1.228122	0	-0.009038	0	-0.000122	0
8	DEAD	LinStatic	1.228122	0	0.003631	0	0.000015	0
9	DEAD	LinStatic	1.228122	0	-0.010819	0	0.000566	0
10	DEAD	LinStatic	1.100952	0	-0.006492	0	-0.00001	0
11	DEAD	LinStatic	1.100952	0	-0.008945	0	-0.000024	0
12	DEAD	LinStatic	1.103018	0	0	0	-0.00001	0
13	DEAD	LinStatic	1.229914	0	-0.234293	0	0.001668	0
14	DEAD	LinStatic	1.399592	0	-0.234293	0	0.001696	0

Prikaz dijagrama aksijalnih sila



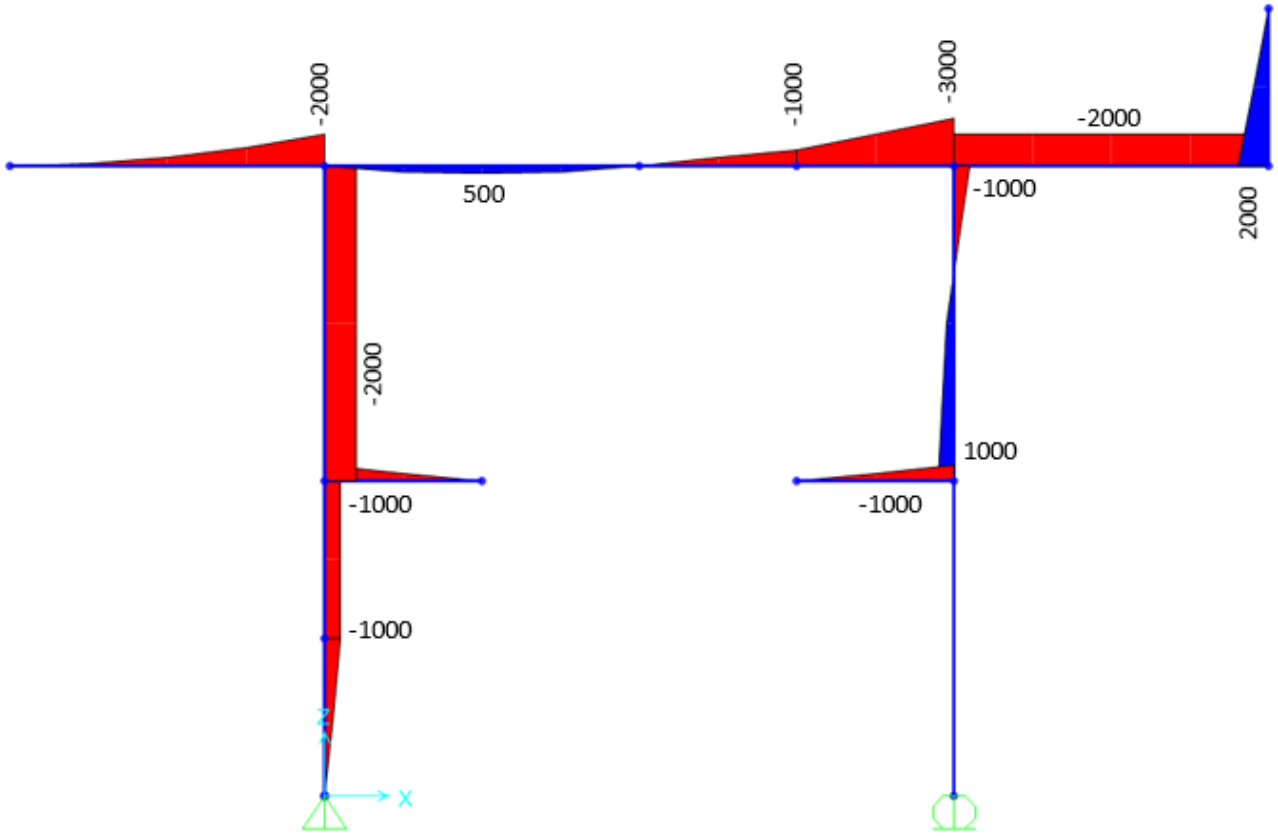
Slika 13 – *Prikaz dijagrama aksijalnih sila*

Prikaz dijagrama transferzalnih sila



Slika 14 – *Prikaz dijagrama transferzalnih sila*

Prikaz dijagrama momenata savijanja



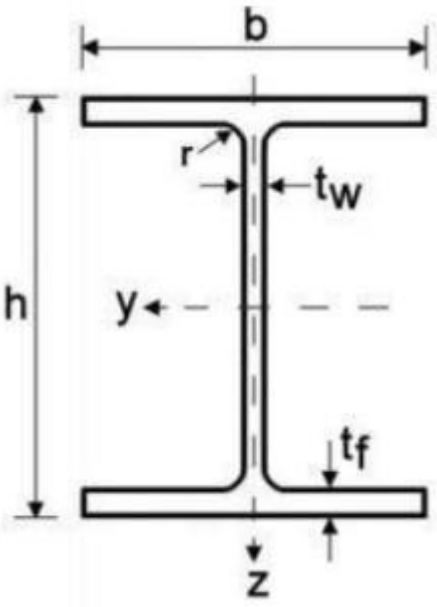
Slika 15 – *Prikaz dijagrama momenata savijanja*

Dokaz čvrstoće

Dokaz čvrstoće horizontalnog nosača

Horizontalni nosač izrađen je od profila HEA 300 čije su karakteristike poprečnog preseka date u nastavku teksta, a preuzete iz priloga F (priručnik za Osnove metalnih konstrukcija u mašinogradnji) na strani P-16.

$h = 29$ cm
$b = 30$ cm
$t_w = 0{,}85$ cm
$t_f = 1{,}4$ cm
$A = 112{,}5$ cm^2
$I_y = 18260$ cm^4
$S_y = 692$ cm^3
$W_{el,y} = 1260$ cm^3



Materijal koji se koristio za izradu profila je S235 , a koeficijent sigurnosti se uzima za prvi slučaj opterećenja pa je:

$f_y = 23{,}5\ {}^{kN}/_{cm^2}$ napon na granici tečenja

$\nu = 1{,}5$ koeficijent sigurnosti za prvi slučaj opterećenja

$\sigma_{dop} = \frac{f_y}{\nu} = 15{,}67\ {}^{kN}/_{cm^2}$ dopušteni normalni napon

$\tau_{dop} = \frac{\sigma_{dop}}{\sqrt{3}} = 9{,}045\ {}^{kN}/_{cm^2}$ dopušteni tangencijalni napon

Maksimalne vrednosti opterećenja u horizontalnom nosaču

$N_{max} = 20$ kN aksijalna sila
$V_{max} = 20$ kN transferzalna sila
$M_{max} = 3000$ kNcm moment savijanja

Maksimalne vrednosti napona u horizontalnom nosaču biće

$$\sigma_{N,max} = \frac{N_{max}}{A} = \frac{20}{112{,}5} = 0{,}18\,\frac{\text{kN}}{\text{cm}^2} < \sigma_{dop}$$

$$\sigma_{M,max} = \frac{M_{max}}{W_{el,y}} = \frac{3000}{1260} = 2{,}38\,\frac{\text{kN}}{\text{cm}^2} < \sigma_{dop}$$

$$\tau_{max} = \frac{V_{max} \cdot S_y}{I_y \cdot t_w} = \frac{20 \cdot 692}{18260 \cdot 0{,}85} = 0{,}9\,\frac{\text{kN}}{\text{cm}^2} < \tau_{dop}$$

Parcijalni i dovoljni uslovi dokaza čvrstoće su zadovoljeni

Dokaz čvrstoće vertikalnih nosača

Vertikalni nosači izrađeni su od profila IPE 270 čije su karakteristike poprečnog preseka date u nastavku teksta, a preuzete iz priloga F (priručnik za Osnove metalnih konstrukcija u mašinogradnji) na strani P-12.

$h = 27$ cm
$b = 13{,}5$ cm
$t_w = 0{,}66$ cm
$t_f = 1{,}02$ cm
$A = 45{,}9$ cm^2
$I_y = 5790$ cm^4
$S_y = 242$ cm^3
$W_{el,y} = 429$ cm^3

<u>Maksimalne vrednosti opterećenja u vertikalnim nosačima</u>

$N_{max} = 40$ kN aksijalna sila
$V_{max} = 20$ kN transferzalna sila
$M_{max} = 2000$ kNcm moment savijanja

<u>Maksimalne vrednosti napona u vertikalnim nosačima biće</u>

$$\sigma_{N,max} = \frac{N_{max}}{A} = \frac{40}{45{,}9} = 0{,}87\,\frac{\text{kN}}{\text{cm}^2} < \sigma_{dop}$$

$$\sigma_{M,max} = \frac{M_{max}}{W_{el,y}} = \frac{2000}{429} = 4{,}66\,\frac{\text{kN}}{\text{cm}^2} < \sigma_{dop}$$

$$\tau_{max} = \frac{V_{max} \cdot S_y}{I_y \cdot t_w} = \frac{20 \cdot 242}{5790 \cdot 0{,}66} = 1{,}27\,\frac{\text{kN}}{\text{cm}^2} < \tau_{dop}$$

Parcijalni i dovoljni uslovi dokaza čvrstoće su zadovoljeni

Prilog

Tabela 5 *Opterećenja elemenata*

TABLE: Element Forces - Frames						
Frame	**Station**	**OutputCase**	**CaseType**	**P**	**V2**	**M3**
Text	cm	Text	Text	KN	KN	KN-cm
1	0	DEAD	LinStatic	-40	10	3.638E-12
1	50	DEAD	LinStatic	-40	10	-500
1	100	DEAD	LinStatic	-40	10	-1000
2	0	DEAD	LinStatic	-40	5.684E-12	-1000
2	50	DEAD	LinStatic	-40	5.684E-12	-1000
2	100	DEAD	LinStatic	-40	5.684E-12	-1000
3	0	DEAD	LinStatic	0	-10	-1000
3	50	DEAD	LinStatic	0	-10	-500
3	100	DEAD	LinStatic	0	-10	1.273E-11
4	0	DEAD	LinStatic	-30	3.126E-12	-2000
4	100	DEAD	LinStatic	-30	3.126E-12	-2000
4	200	DEAD	LinStatic	-30	3.126E-12	-2000
5	0	DEAD	LinStatic	0	3.109E-15	2.274E-13
5	50	DEAD	LinStatic	0	5	-125
5	100	DEAD	LinStatic	0	10	-500
5	150	DEAD	LinStatic	0	15	-1125
5	200	DEAD	LinStatic	0	20	-2000
6	0	DEAD	LinStatic	1.819E-12	-10	1.649E-09
6	50	DEAD	LinStatic	1.819E-12	-5	375
6	100	DEAD	LinStatic	1.819E-12	1.489E-11	500
6	150	DEAD	LinStatic	1.819E-12	5	375
6	200	DEAD	LinStatic	1.819E-12	10	-1.328E-09
7	0	DEAD	LinStatic	0	10	-1.328E-09
7	50	DEAD	LinStatic	0	10	-500
7	100	DEAD	LinStatic	0	10	-1000
8	0	DEAD	LinStatic	-7.276E-12	20	-1000
8	50	DEAD	LinStatic	-7.276E-12	20	-2000
8	100	DEAD	LinStatic	-7.276E-12	20	-3000
9	0	DEAD	LinStatic	20	-1.453E-12	-2000
9	50	DEAD	LinStatic	20	-1.453E-12	-2000
9	100	DEAD	LinStatic	20	-1.453E-12	-2000
9	150	DEAD	LinStatic	20	-1.453E-12	-2000
9	200	DEAD	LinStatic	20	-1.453E-12	-2000
10	0	DEAD	LinStatic	0	20	2000
10	50	DEAD	LinStatic	0	20	1000
10	100	DEAD	LinStatic	0	20	-2.328E-10
11	0	DEAD	LinStatic	-30	0	-1.819E-12
11	100	DEAD	LinStatic	-30	0	-1.819E-12
11	200	DEAD	LinStatic	-30	0	-1.819E-12
12	0	DEAD	LinStatic	-20	2.194E-11	1000
12	100	DEAD	LinStatic	-20	10	500
12	200	DEAD	LinStatic	-20	20	-1000
13	0	DEAD	LinStatic	0	-10	-1000
13	50	DEAD	LinStatic	0	-10	-500
13	100	DEAD	LinStatic	0	-10	9.095E-13

Tabela 6 *Sile i momenti u čvorovima elemenata*

TABLE: Element Joint Forces - Frames							
Frame	**Joint**	**OutputCase**	**CaseType**	**F1**	**F2**	**F3**	**M2**
Text	Text	Text	Text	KN	KN	KN	KN-cm
1	1	DEAD	LinStatic	-10	0	40	-3.638E-12
1	2	DEAD	LinStatic	10	0	-40	-1000
2	2	DEAD	LinStatic	-5.67E-12	0	40	1000
2	3	DEAD	LinStatic	5.67E-12	0	-40	-1000
3	3	DEAD	LinStatic	0	0	10	-1000
3	4	DEAD	LinStatic	0	0	-10	2.91E-11
4	3	DEAD	LinStatic	-3.133E-12	0	30	2000
4	5	DEAD	LinStatic	3.133E-12	0	-30	-2000
5	6	DEAD	LinStatic	0	0	-3.553E-15	2.274E-13
5	5	DEAD	LinStatic	0	0	20	2000
6	5	DEAD	LinStatic	-1.819E-12	0	10	1.649E-09
6	7	DEAD	LinStatic	1.819E-12	0	10	1.328E-09
7	7	DEAD	LinStatic	0	0	-10	-1.328E-09
7	8	DEAD	LinStatic	0	0	10	1000
8	8	DEAD	LinStatic	7.276E-12	0	-20	-1000
8	9	DEAD	LinStatic	-7.276E-12	0	20	3000
9	9	DEAD	LinStatic	-20	0	1.45E-12	-2000
9	13	DEAD	LinStatic	20	0	-1.45E-12	2000
10	13	DEAD	LinStatic	-20	0	0	-2000
10	14	DEAD	LinStatic	20	0	0	0
11	12	DEAD	LinStatic	-4.607E-15	0	30	1.281E-12
11	10	DEAD	LinStatic	4.607E-15	0	-30	9.805E-13
12	10	DEAD	LinStatic	-2.194E-11	0	20	-1000
12	9	DEAD	LinStatic	20	0	-20	-1000
13	10	DEAD	LinStatic	0	0	10	1000
13	11	DEAD	LinStatic	0	0	-10	0

Tabela 7 *Reakcije u osloncima*

TABLE: Joint Reactions								
Joint	**OutputCase**	**CaseType**	**F1**	**F2**	**F3**	**M1**	**M2**	**M3**
Text	Text	Text	KN	KN	KN	KN-cm	KN-cm	KN-cm
1	DEAD	LinStatic	-10	0	40	0	0	0
12	DEAD	LinStatic	0	0	30	0	0	0