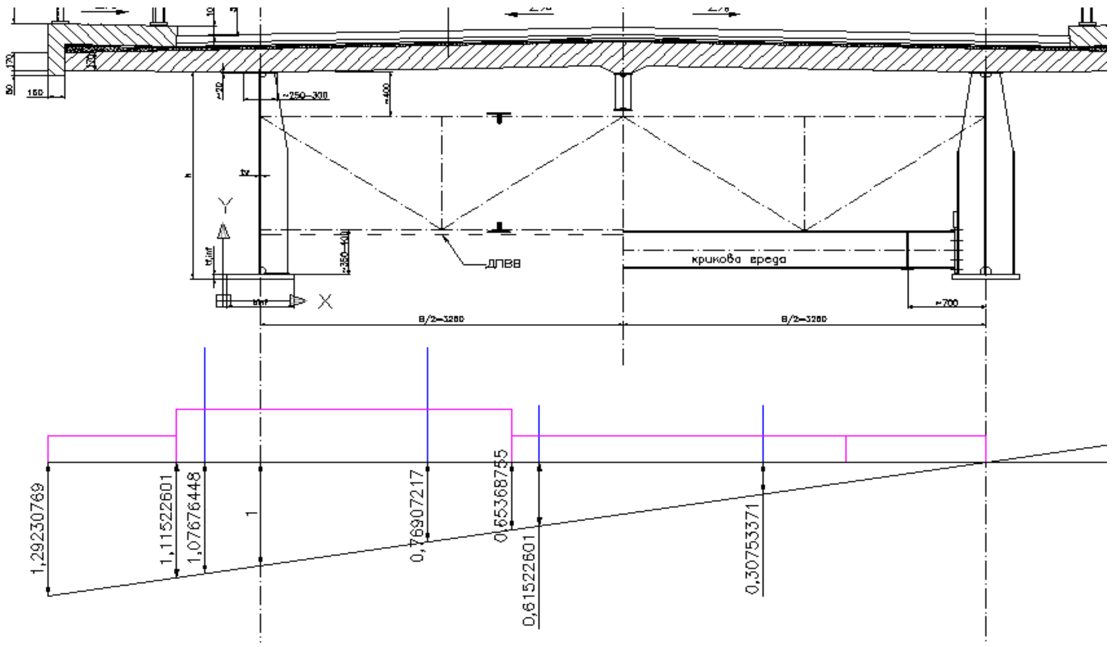
Катедра Транспортни съоръжения, ФТС на УАСГ
ЧИСЛЕН ПРИМЕР ЗА ПРОВЕРКИ НА НАПРЕЖЕНИЯТА В СРЕДНОТО СЕЧЕНИЕ НА ЕДНООТВОРЕН КОМБИНИРАН СТОМАНОСТОМАНОБЕТОНОВ МОСТ.
Разработил: гл. ас. д-р инж. Лазар Димитров Георгиев

LOAD MODEL 1 - EN1991-2



γ_Q= 1.500

Q_{1k}=	300.00	kN	Q_{2k}=	200.00	kN	q_{RAk}=	2.50	kN/m^2
α_{1Q}=	1.00		α_{2Q}=	1.00		α_{RA}=	1.00	
Q_1=	450.00	kN	Q_2=	300.00	kN	q_{RA}=	3.75	kN/m^2
q_{1k}=	9.00	kN/m^2	q_{2k}=	2.50	kN/m^2			
α_{1q}=	1.00		α_{2q}=	1.00				
q_1=	13.50	kN/m^2	q_2=	3.75	kN/m^2			

Q [kN]	η	R(Q)
225.00	1.07676	242.27
225.00	0.76907	173.04
150.00	0.61523	92.28
150.00	0.30753	46.13
	R_{TL}[kN]=	553.73
	q_{TL}[kN/m']=	922.88

q [kN]	Ω	R(Q)
13.50	2.65337	35.82
3.75	1.38875	5.21
3.75	1.38557	5.20
	R_{UDL}[kN/m']=	46.22

Натоварване от G2 за втори етап на работа - за една главна греда

	b[m]	h[m]	A $[m^2]$	$\gamma[kN/m^3]$	g_{2k} [kN/m]	g_2 [kN/m]
Асфалтобетон + предп. Бетон	4.000	0.110	0.44000	24.000	10.560	14.256
Хидроизолация	4.000	-	-	-	1.200	1.620
Тротоарен блок	-	-	0.27563	25.000	6.891	9.302
Еластична ограда	-	-	-	-	0.700	0.945
Парапет					1.000	1.350
					g_2 [kN/m']=	27.473

1. МАТЕРИАЛИ / MATERIALS:

1.1. Стомана / Steel: S355J2

E_s= 210000 N/mm^2

t_{max}= 40 mm - дебелина / thickness

f_y= 345.00 N/mm^2 f_{yd}= 328.57 N/mm^2 γ_M= 1.050

f_u= 450.00 N/mm^2

Designation		Minimum yield strength R_{eH} [a] MPa[b] Nominal thickness mm									Tensile strength R_m [a] MPa[b] Nominal thickness mm				
According EN 10027-1 and CR 10260	According EN 10027-2	≤ 16	> 16 ≤ 40	> 40 ≤ 63	> 63 ≤ 80	> 80 ≤ 100	> 100 ≤ 150	> 150 ≤ 200	> 200 ≤ 250	> 250 ≤ 400[c]	< 3	≥ 3 ≤ 100	> 100 ≤ 150	> 150 ≤ 250	> 250 ≤ 400[c]
S235JR	1.0038	235	225	215	215	215	195	185	175	-	360 to 510	360 to 510	350 to 500	340 to 490	-
S235J0	1.0114	235	225	215	215	215	195	185	175	-	360 to 510	360 to 510	350 to 500	340 to 490	-
S235J2	1.0117	235	225	215	215	215	195	185	175	165	360 to 510	360 to 510	350 to 500	340 to 490	330 to 480
S275JR	1.0044	275	265	255	245	235	225	215	205	-	430 to 580	410 to 560	400 to 540	380 to 540	-
S275J0	1.0143	275	265	255	245	235	225	215	205	-	430 to 580	410 to 560	400 to 540	380 to 540	-
S275J2	1.0145	275	265	255	245	235	225	215	205	195	430 to 580	410 to 560	400 to 540	380 to 540	380 to 540
S355JR	1.0045	355	345	335	325	315	295	285	275	-	510 to 680	470 to 630	450 to 600	450 to 600	-
S355J0	1.0553	355	345	335	325	315	295	285	275	-	510 to 680	470 to 630	450 to 600	450 to 600	-
S355J2	1.0577	355	345	335	325	315	295	285	275	265	510 to 680	470 to 630	450 to 600	450 to 600	450 to 600
S355K2	1.0596	355	345	335	325	315	295	285	275	265	510 to 680	470 to 630	450 to 600	450 to 600	450 to 600
S450J0[d]	1.0590	450	430	410	390	380	380	-	-	-	-	550 to 720	530 to 700	-	-

[a] For plate, strip and wide flats with widths ≥ 600 mm the direction transverse (t) to the rolling direction applies. For all other products the values apply for the direction parallel (l) to the rolling direction.

[b] 1 MPa = 1 N/mm^2.

[c] The values apply to flat products.

1.2. Бетон / Concrete: C35/45

f_{ck}=	35.00	N/mm^2	$f_{cm} = f_{ck}+8$(MPa)
f_{cm}=	43.00	N/mm^2	$f_{ctm}=0{,}30\times f_{ck}^{(2/3)} \leq$C50/60 $f_{ctm}=2{,}12\cdot\ln(1+(f_{cm}/10))$ > C50/60
f_{ctm}=	3.21	N/mm^2	$f_{ctk;0,05} = 0{,}7\times f_{ctm}$ 5% fractile
$f_{ctk,0.05}$=	2.25	N/mm^2	$f_{ctk;0,95} = 1{,}3\times f_{ctm}$ 95% fractile
$f_{ctk,0.95}$=	2.92	N/mm^2	$E_{cm} = 22[(f_{cm})/10]^{0,3}$ (f_{cm} in MPa)
E_{cm}=	34077	N/mm^2	

3. Геометрични характеристики на напречното сечение / geometric characteristics of cross section:

3.1. Стоманено сечение / Steel cross section

b_{fsup}= 280 mm b_{finf}= 700 mm

t_{fsup}= 20 mm t_{finf}= 35 mm

h_w= 2200 mm

t_w= 18 mm λ_w= 122.22

3.2. Стоманобетонно сечение / Reinforced concrete cross section

$L=$ 33.000 m - отвор на моста

$k_e=$ 1.000

$L_e=$ 33.000 m - ефективна дължина

$b_{os}=$ 0.160 m - разстояние между крайните дюбели в напречна посока

	b_o [m]	$1/8L_e$ [m]	b_e [m]
Лява страна	1.670	4.125	1.670
Дясна страна	3.170	4.125	3.170
		Σ=	4.840

$b_{eff}=$ 5000 mm

$h_c=$ 250 mm

4. Характеристики за съсхване и пълзене / shrinkage and creep characteristics:

$A_c=$ 1.250 m^2

$u=$ 10.220 m

$2A_c/u=$ 244.62 mm

RH= 80.000 % relative humidity

TIME	t_o [days]	t [days]
съсхване / shringage	1	36500
пълзене / creep - g_2+R_{op}	90	36500

$\Psi_{AS}=$ 0.550

$\Psi_{AL}=$ 1.100

$(1+\Psi_{AS}\varphi_t)^{-1}=$ 0.383

$(1+\Psi_{AL}\varphi_t)^{-1}=$ 0.419

Разработил: гл. ас. д-р инж. Лазар Димитров Георгиев

ОПРЕДЕЛЯНЕ НА ПРЕВОДНОТО ЧИСЛО ЗА СЪСЪХВАНЕ n_{AS}

Concrete C35/45		
f_{cm}=	43.00	N/mm^2
f_{ck}=	35.00	N/mm^2
E_{cm}=	34077	N/mm^2
Steel S235		
f_y=	345.00	N/mm^2
E_s=	210000	N/mm^2

$$\varphi(t,t_0) = \varphi_0 \cdot \beta_c(t,t_0)$$

where:
φ_0 is the notional creep coefficient and may be estimated from:

$$\varphi_0 = \varphi_{RH} \cdot \beta(f_{cm}) \cdot \beta(t_0)$$

$$\beta(f_{cm}) = \frac{16{,}8}{\sqrt{f_{cm}}} \qquad \beta(t_0) = \frac{1}{(0{,}1 + t_0^{0{,}20})}$$

$n_o=E_s/E_{cm}$= 6.162 Short-term modular ratio

t= 36500 days - considered time

t_o= 1 days - time of load application (after concreting)

RH= 80 % - relative humidity

A_c= 1.250 m^2 - concrete area

u= 10.220 m - concrete perimeter exposed to drying

$h_o=2A_c/u$= 244.62 mm

α_1= 0.8658

α_2= 0.9597

α_3= 0.9022

$$\beta_H = 1{,}5\,[1 + (0{,}012\,RH)^{18}]\,h_0 + 250 \leq 1500 \qquad \text{for } f_{cm} \leq 35$$

$$\beta_H = 1{,}5\,[1 + (0{,}012\,RH)^{18}]\,h_0 + 250\,\alpha_3 \leq 1500\,\alpha_3 \qquad \text{for } f_{cm} \geq 35$$

$\alpha_{1/2/3}$ are coefficients to consider the influence of the concrete strength:

$$\alpha_1 = \left[\frac{35}{f_{cm}}\right]^{0{,}7} \quad \alpha_2 = \left[\frac{35}{f_{cm}}\right]^{0{,}2} \quad \alpha_3 = \left[\frac{35}{f_{cm}}\right]^{0{,}5}$$

β_H= 768.45571o

$\beta_C(t-t_o)$= 0.9938

$$\varphi_{RH} = 1 + \frac{1 - RH/100}{0{,}1 \cdot \sqrt[3]{h_0}} \qquad \text{for } f_{cm} \leq 35 \text{ MPa}$$

$$\varphi_{RH} = \left[1 + \frac{1 - RH/100}{0{,}1 \cdot \sqrt[3]{h_0}} \cdot \alpha_1\right] \cdot \alpha_2 \qquad \text{for } f_{cm} > 35 \text{ MPa}$$

φ_{RH}= 1.2657

β_{fcm}= 2.5620

β_{to}= 0.90909

$$\beta_c(t,t_0)\ldots = \left[\frac{(t - t_0)}{(\beta_H + t - t_0)}\right]^{0{,}3}$$

φ_t= 2.9296

Ψ_{AS}= 0.55

Permanent loads	1.1
Shrinkage	0.55
Imposed deformations	1.5

n_o= 6.162	**Short-term modular ratio**	$1+\Psi_L\varphi_t$= 2.6113
$n_{AS}= n_o(1+\Psi_{AS}\varphi_t)$ = 16.092	**Shrikage modular ratio**	$(1+\Psi_{AS}\varphi_t)^{-1}$= 0.3830

$E_{c,AS}=E_s/n$=	13050.10	N/mm^2	=	13050101	kN/m^2

Determining the drying shrinkage

f_{cm}= 43.00 N/mm^2

f_{cmo}= 10.00 N/mm^2

α_{ds1}= 4

α_{ds2}= 0.12

RH= 80.00 %

RH_o= 100 %

β_{RH}= -0.7564

$\varepsilon_{cd,infinite}$= -0.000253

$$\varepsilon_{cd,\infty} = 0{,}85\left[\left(220 + 110\cdot\alpha_{ds1}\right)\cdot \exp\left(-\alpha_{ds2}\cdot\frac{f_{cm}}{f_{cmo}}\right)\right]\cdot 10^{-6}\cdot\beta_{RH}$$

$$\beta_{RH} = -1{,}55\left[1-\left(\frac{RH}{RH_0}\right)^3\right]$$

where:
- f_{cm} is the mean compressive strength (MPa)
- f_{cmo} = 10 Mpa
- α_{ds1} is a coefficient which depends on the type of cement
  - = 3 for slowly hardening cements (*S*)
  - = 4 for normal or rapid hardening cements (*N*)
  - = 6 for rapid hardening high-strength cements (*R*)
- α_{ds2} is a coefficient which depends on the type of cement
  - = 0,13 for slowly hardening cements (*S*)
  - = 0,12for normal or rapid hardening cements (*N*)
  - = 0,11 for rapid hardening high-strength cements (*R*)
- *RH* is the ambient relative humidity (%)
- RH_0 = 100%.

Autogenius shrinkage

$\varepsilon_{ca,infinite}$= -0.000063

t= 36500 days

t_s= 1 days

h_o= 244.62 mm

k_h= 0.8000

β_{ds}= 0.99582462

h_0	k_h
100	1.0
200	0.85
300	0.75
≥ 500	0.70

ε_{ct}= -0.000202

$\varepsilon_{sh,tot}$= -0.000316 = -0.3158 *10^{-3} - total shrinkage

α_{tc}= 1.000E-05 K^{-1} coefficient of termal expansion for concrete

ΔT_{sh}= -31.5790 K - equivallent temperature change for shrinkage

E_{sh}= 13050101 kN/m^2 - notional modulus of elasticity for shrinkage

$\Delta T_{sh,design}$= -31.5790 K

ОПРЕДЕЛЯНЕ НА ПРЕВОДНОТО ЧИСЛО ЗА ПЪЛЗЕНЕ n_{AL}

Concrete C35/45		
f_{cm}=	43.00	N/mm^2
f_{ck}=	35.00	N/mm^2
E_{cm}=	34077	N/mm^2
Steel S355J2		
f_y=	345.00	N/mm^2
E_s=	210000	N/mm^2

$\varphi(t,t_0) = \varphi_0 \cdot \beta_c(t,t_0)$

where:

φ_0 is the notional creep coefficient and may be estimated from:

$\varphi_0 = \varphi_{RH} \cdot \beta(f_{cm}) \cdot \beta(t_0)$

$$\beta(f_{cm}) = \frac{16{,}8}{\sqrt{f_{cm}}} \qquad \beta(t_0) = \frac{1}{(0{,}1 + t_0^{0{,}20})}$$

$n_o=E_s/E_{cm}$= 6.162 Short-term modular ratio

t= 36500 days - considered time

t_o= 90 days - time of load application (after concreting)

RH= 80 % - relative humidity

A_c= 1.250 m^2 - concrete area

u= 10.220 m - concrete perimeter exposed to drying

$h_o=2A_c/u$= 244.62 mm

α_1= 0.8658

α_2= 0.9597

α_3= 0.9022

$\beta_H = 1{,}5\,[1 + (0{,}012\,RH)^{18}]\,h_0 + 250 \le 1500$ for $f_{cm} \le 35$

$\beta_H = 1{,}5\,[1 + (0{,}012\,RH)^{18}]\,h_0 + 250\,\alpha_3 \le 1500\,\alpha_3$ for $f_{cm} \ge 35$

$\alpha_{1/2/3}$ are coefficients to consider the influence of the concrete strength:

$$\alpha_1 = \left[\frac{35}{f_{cm}}\right]^{0{,}7} \quad \alpha_2 = \left[\frac{35}{f_{cm}}\right]^{0{,}2} \quad \alpha_3 = \left[\frac{35}{f_{cm}}\right]^{0{,}5}$$

β_H= 768.455718

$\beta_C(t-t_o)$= 0.9938

$$\varphi_{RH} = 1 + \frac{1 - RH/100}{0{,}1 \cdot \sqrt[3]{h_0}} \quad \text{for } f_{cm} \le 35 \text{ MPa}$$

$$\varphi_{RH} = \left[1 + \frac{1 - RH/100}{0{,}1 \cdot \sqrt[3]{h_0}} \cdot \alpha_1\right] \cdot \alpha_2 \quad \text{for } f_{cm} > 35 \text{ MPa}$$

φ_{RH}= 1.2657

β_{fcm}= 2.5620

β_{to}= 0.39070

$$\beta_c(t,t_0)\ldots = \left[\frac{(t - t_0)}{(\beta_H + t - t_0)}\right]^{0{,}3}$$

φ_t= 1.2590

Ψ_L= 1.10

Permanent loads	1.1
Shrinkage	0.55
Imposed deformations	1.5

n_o= 6.162	**Short-term modular ratio**	$1+\Psi_L\varphi_t$= 2.3849
$n_{AL}= n_o(1+\Psi_L\varphi_t)$ = 14.697	**Creep modular ratio**	$(1+\Psi_{AL}\varphi_t)^{-1}$= 0.4193

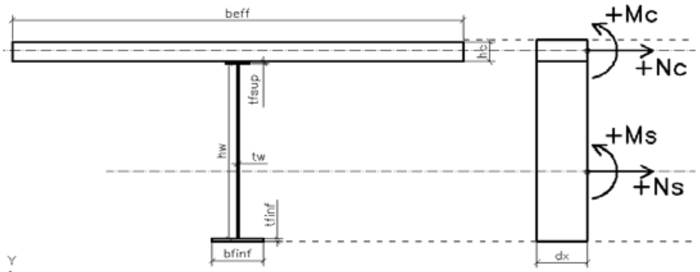
$E_{c,AS}=E_s/n$=	14288.61	N/mm^2	=	14288609	kN/m^2

SECTION x= 16.500 m

ИЗЧИСЛЕНИЕ ЗА СЪСЪХВАНЕ / SHRINKAGE CALCULATIONS

ε_{sh}=	-0.00031579	shrinkage deformation			
E_s=	210000000	kN/m^2	=	21000.00	kN/cm^2
E_c=	13050101	kN/m^2	=	1305.01	kN/cm^2
n_{AS}=	16.09183				
beff=	500.0	cm			
hc=	25.0	cm			
bfsup=	28.0	cm	bfinf=	70.0	cm
tfsup=	2.0	cm	tfinf=	3.5	cm
hw=	220.0	cm	h_{out}=	2.255	m
tw=	1.8	cm			

As=	697.0	cm^2
Js=	4704463.4	cm^4
zs=	83.1	cm
Ac=	12500.0	cm^2
Jc=	651041.7	cm^4
zc=	238.0	cm



z_c-z_s= 1.5486 m

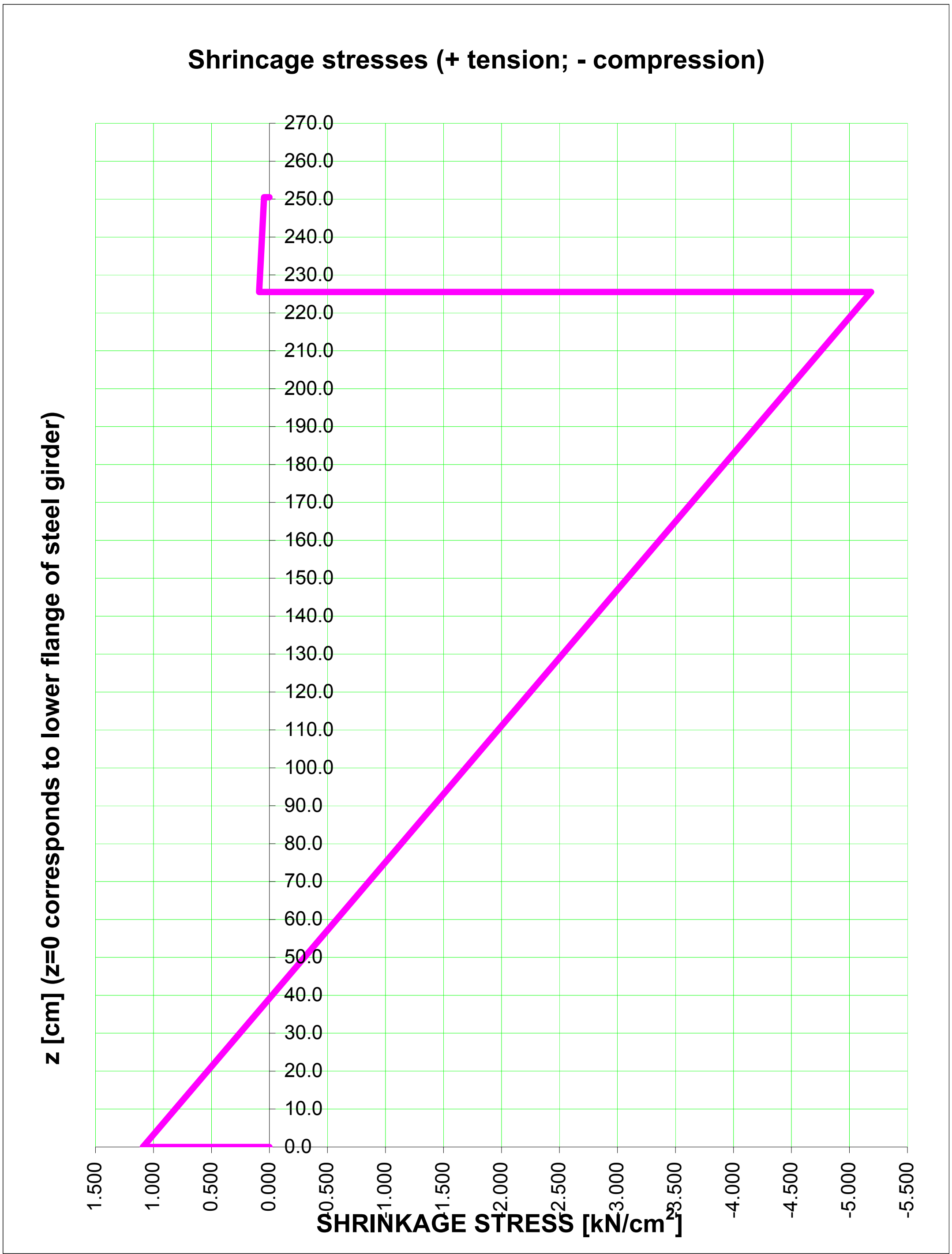
zi=	164.7609	cm
Ai=	1473.7917	cm^2
Ji=	13555298.39	cm^4

$N_{s,sh}$=	-852.78	kN	**Partial internal forces for steel section /**
$M_{s,sh}$=	1309.38	kNm	**Частни разрезни усилия за стоманеното сечение**

$N_{c,sh}$=	852.78	kN	**Partial internal forces for RC section /**
$M_{c,sh}$=	11.26	kNm	**Частни разрезни усилия за ст.б. сечение**

F1=	0.00000000E+00	=0;	$N_c+N_s=0$
F2=	0.00000000E+00	=0;	$M_s+M_c+N_s(z_i-z_s)-N_c(z_c-z_i)=0$
F3=	1.00000000E-10	=0;	$[\varepsilon_{sh}+N_c/(E_cA_c)+M_cz_c/(E_cJ_c)]-[N_s/(E_sA_s)-M_sz_s/(E_sJ_s)]=0$
F4=	-2.36963366E-11	=0;	$(M_c/M_s)-((J_c/n_{sh})/J_s)=0$

z [cm]	σ_{sh} [kN/cm^2]	z_s [cm]	σ_{sh}(N)	σ_{sh}(M)
0.00	1.09044	83.137	-1.224	2.314
225.50	-5.18586	-142.363	-1.224	-3.962
225.50	0.08984	12.500	0.068	0.022
250.50	0.04660	-12.500	0.068	-0.022



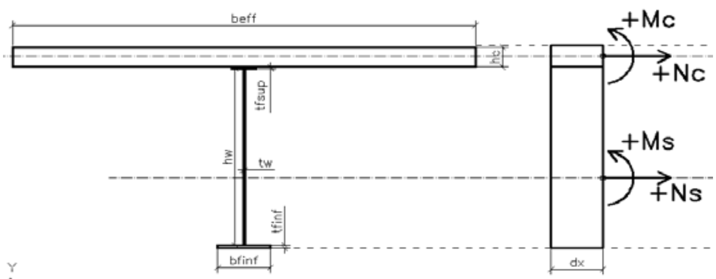
Катедра Транспортни съоръжения, ФТС на УАСГ
ЧИСЛЕН ПРИМЕР ЗА ПРОВЕРКИ НА НАПРЕЖЕНИЯТА В СРЕДНОТО СЕЧЕНИЕ НА ЕДНООТВОРЕН КОМБИНИРАН СТОМАНОСТОМАНОБЕТОНОВ МОСТ.
Разработил: гл. ас. д-р инж. Лазар Димитров Георгиев

SECTION x= 16.500 m

CREEP CALCULATIONS

g_2=	27.473	kN/m	R=	637.77	kN
L=	33.000	m	L_1=	11.000	m
M_m=	10755.29	kNm			
Es=	210000000	kN/m^2	=	21000.00	kN/cm^2
Ec=	14288609	kN/m^2	=	1428.86	kN/cm^2
n_{AL}=	14.69702				
beff=	500.0	cm			
hc=	25.0	cm			
bfsup=	28.0	cm	bfinf=	70.0	cm
tfsup=	2.0	cm	tfinf=	3.5	cm
hw=	220.0	cm			
tw=	1.8	cm			

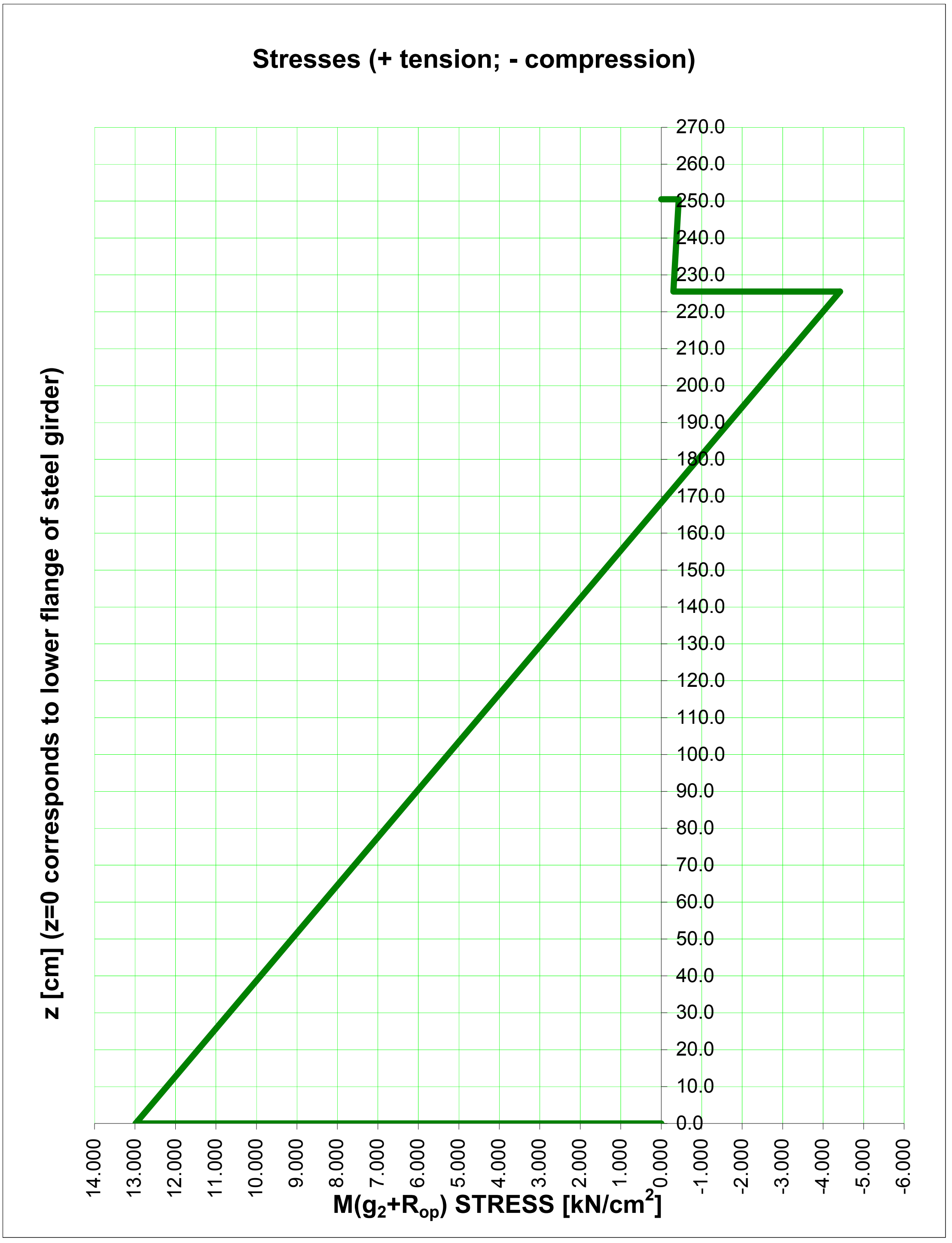
As=	697.0	cm^2
Js=	4704463.4	cm^4
zs=	83.1	cm
Ac=	12500.0	cm^2
Jc=	651041.7	cm^4
zc=	238.0	cm
zi=	168.2498	cm
Ai=	1547.5124	cm^2
Ji=	13935736.02	cm^4



N_s=	4578.45	kN	**Partial internal forces for steel section /**
M_s=	3630.80	kNm	**Частни разрезни усилия за стоманеното сечение**

N_c=	-4578.45	kN	**Partial internal forces for RC section /**
M_c=	34.19	kNm	**Частни разрезни усилия за ст.б. сечение**

z [cm]	σ_{sh} [kN/cm^2]	z_s [cm]	$\sigma_{sh}(N)$	$\sigma_{sh}(M)$
0.00	12.985	83.137	6.569	6.416
225.50	-4.418	-142.363	6.569	-10.987
225.50	-0.301	12.500	-0.366	0.066
250.50	-0.432	-12.500	-0.366	-0.066



SECTION x= 16.500 m

CALCULATIONS - no

g_2=	27.473	kN/m	R=	637.77	kN
L=	33.000	m	L_1=	11.00	m
M_m=	10755.29	kNm			
Es=	210000000	kN/m^2	=	21000.00	kN/cm^2
Ec=	34077146	kN/m^2	=	3407.71	kN/cm^2
n_o=	6.16249				
beff=	500.0	cm			
hc=	25.0	cm			
bfsup=	28.0	cm	bfinf=	70.0	cm
tfsup=	2.0	cm	tfinf=	3.5	cm
hw=	220.0	cm			
tw=	1.8	cm			

As= 697.0 cm^2

Js= 4704463.4 cm^4

zs= 83.1 cm

Ac= 12500.0 cm^2

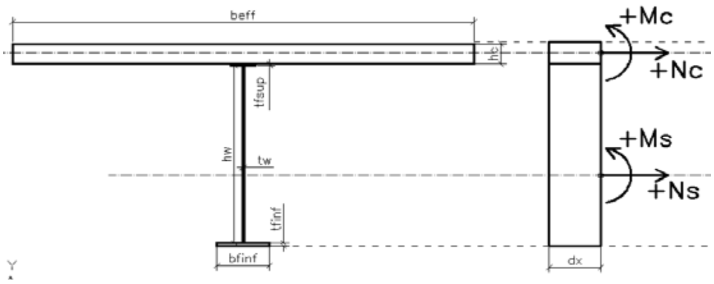
Jc= 651041.7 cm^4

zc= 238.0 cm

zi= 198.3951 cm

Ai= 2725.4016 cm^2

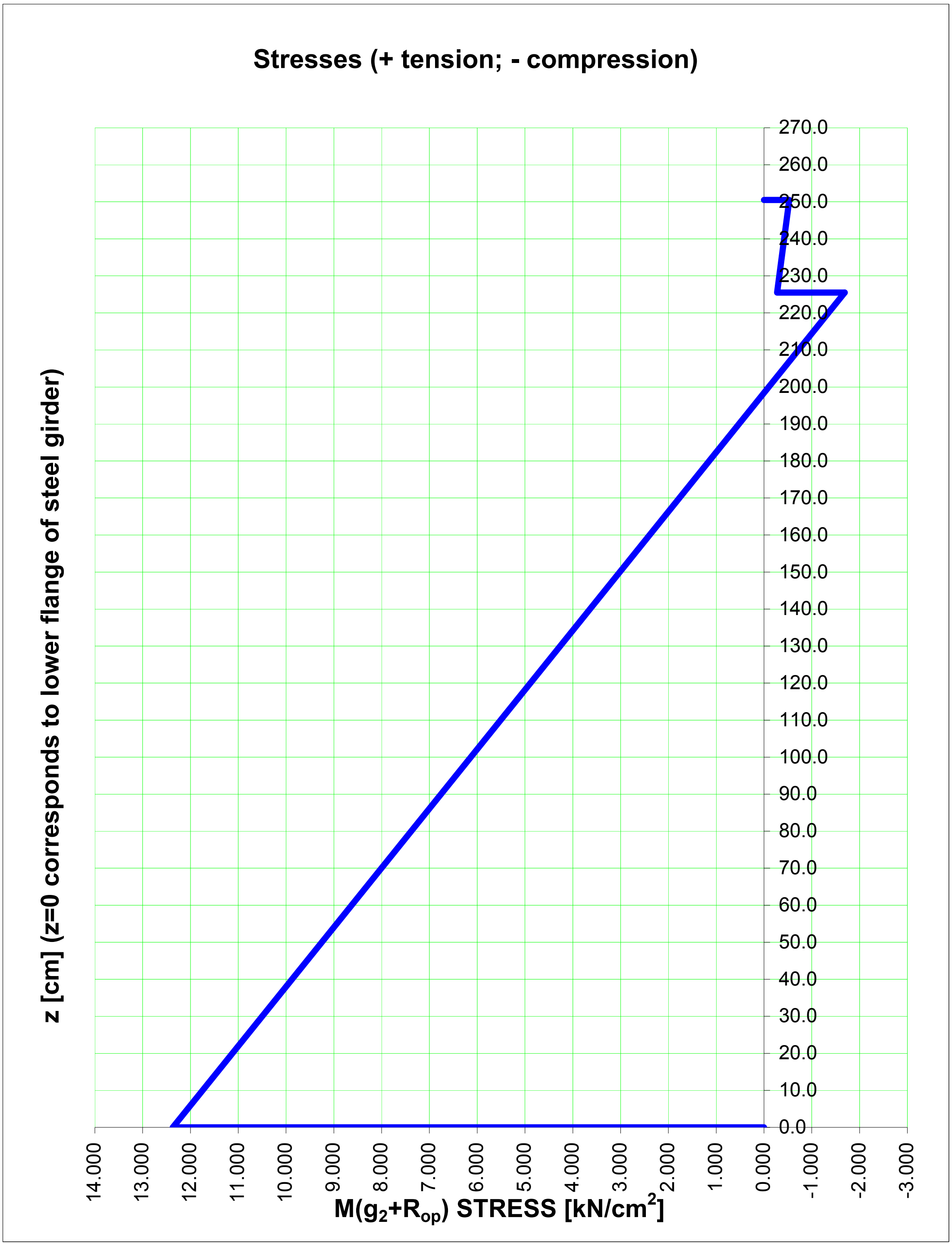
Ji= 17250942.04 cm^4



N_s=	5008.55	kN	**Partial internal forces for steel section /**
M_s=	2933.05	kNm	**Частни разрезни усилия за стоманеното сечение**

N_c=	-5008.55	kN	**Partial internal forces for RC section /**
M_c=	65.87	kNm	**Частни разрезни усилия за ст.б. сечение**

z [cm]	σ_{sh} [kN/cm^2]	z_s [cm]	$\sigma_{sh}(N)$	$\sigma_{sh}(M)$
0.00	12.369	83.137	7.186	5.183
225.50	-1.690	-142.363	7.186	-8.876
225.50	-0.274	12.500	-0.401	0.126
250.50	-0.527	-12.500	-0.401	-0.126

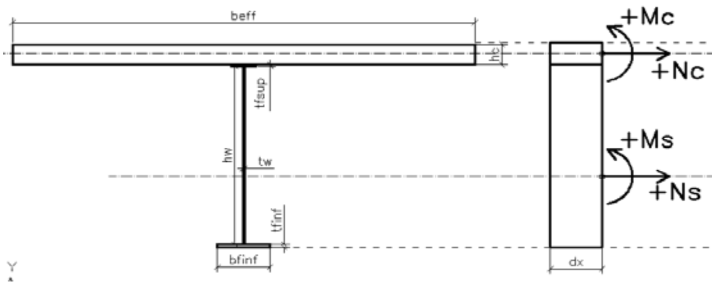


SECTION x= 16.500 m

Напрежения от товарен модел 1 LM1 - CALCULATIONS - no

q_{LM1_UDL}=	46.224	kN/m	F_{LM1_TL}=	553.73	kN	x=	16.5
L=	33.000	m	η1+η2=	15.9			
M_m=	15096.53	kNm					
Es=	210000000	kN/m^2	=	21000.00	kN/cm^2		
Ec=	34077146	kN/m^2	=	3407.71	kN/cm^2		
n_o=	6.16249						
beff=	525.0	cm					
hc=	25.0	cm					
bfsup=	28.0	cm	bfinf=	70.0	cm		
tfsup=	2.0	cm	tfinf=	3.5	cm		
hw=	220.0	cm					
tw=	1.8	cm					

As=	697.0	cm^2
Js=	4704463.4	cm^4
zs=	83.1	cm
Ac=	13125.0	cm^2
Jc=	683593.8	cm^4
zc=	238.0	cm
zi=	199.8160	cm
Ai=	2826.8216	cm^2
Ji=	17409599.07	cm^4



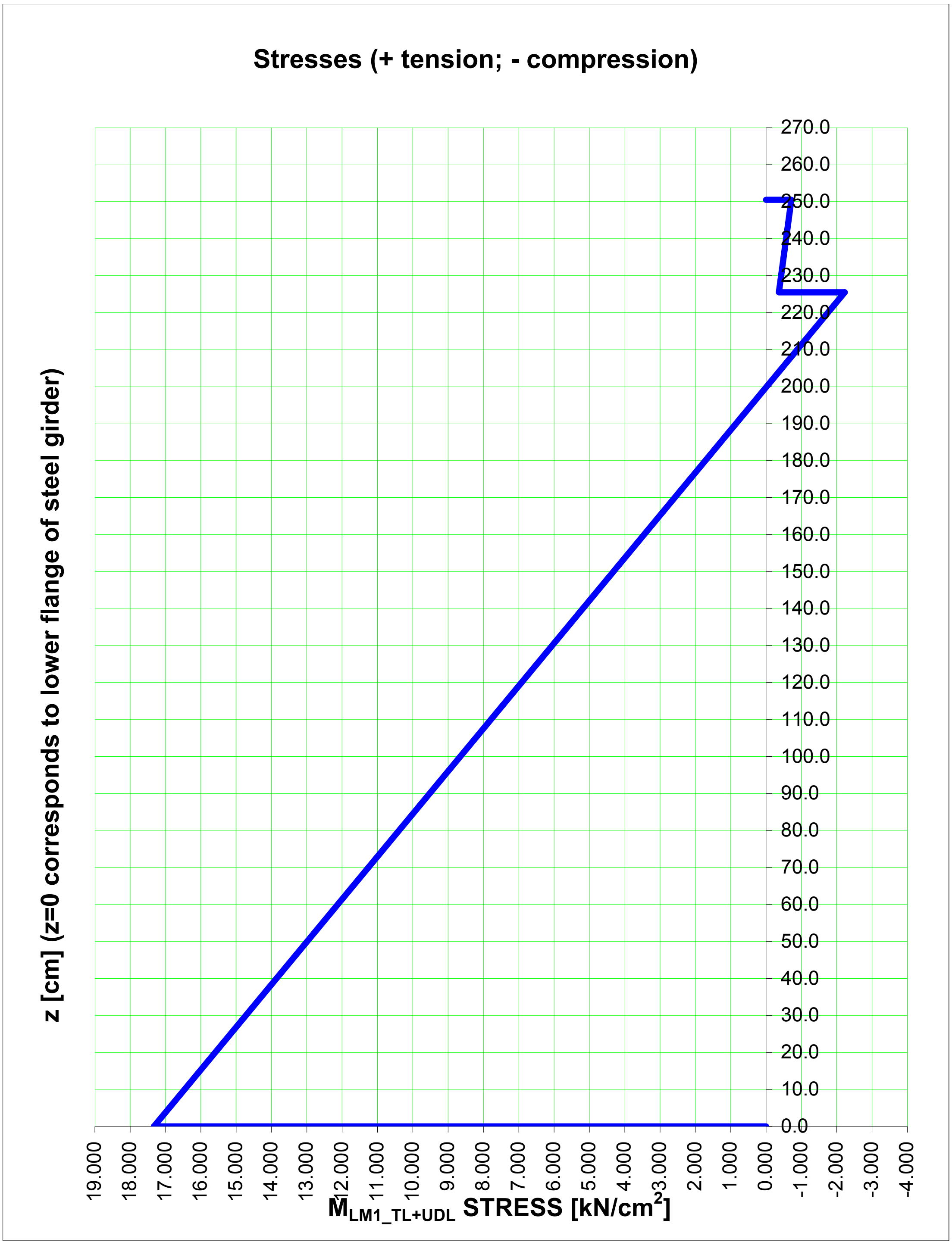
N_s=	7052.01	kN
M_s=	4079.42	kNm

Partial internal forces for steel section /
Частни разрезни усилия за стоманеното сечение

N_c=	-7052.01	kN
M_c=	96.19	kNm

Partial internal forces for RC section /
Частни разрезни усилия за ст.б. сечение

z [cm]	σ_{sh} [kN/cm^2]	z_s [cm]	$\sigma_{sh}(N)$	$\sigma_{sh}(M)$
0.00	17.327	83.137	10.118	7.209
225.50	-2.227	-142.363	10.118	-12.345
225.50	-0.361	12.500	-0.537	0.176
250.50	-0.713	-12.500	-0.537	-0.176



SECTION x= 16.500 m

TEMPERATURE CHANGE +15°C

T= 15.000 °C

α_{tc}= 0.00001

ε_t= 0.00015000

Es= 210000000 kN/m^2 = 21000.00 kN/cm^2

Ec= 34077146 kN/m^2 = 3407.71 kN/cm^2

n_{sh}= 6.16249

beff= 500.0 cm

hc= 25.0 cm

bfsup=	28.0	cm	bfinf=	70.0	cm
tfsup=	2.0	cm	tfinf=	3.5	cm

hw= 220.0 cm

tw= 1.8 cm

As= 697.0 cm^2

Js= 4704463.4 cm^4

zs= 83.1 cm

Ac= 12500.0 cm^2

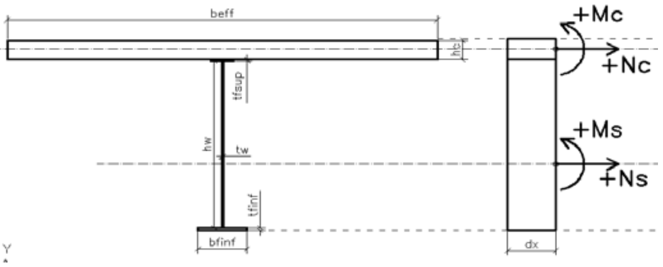
Jc= 651041.7 cm^4

zc= 238.0 cm

zi= 198.3951 cm

Ai= 2725.4016 cm^2

Ji= 17250942.04 cm^4

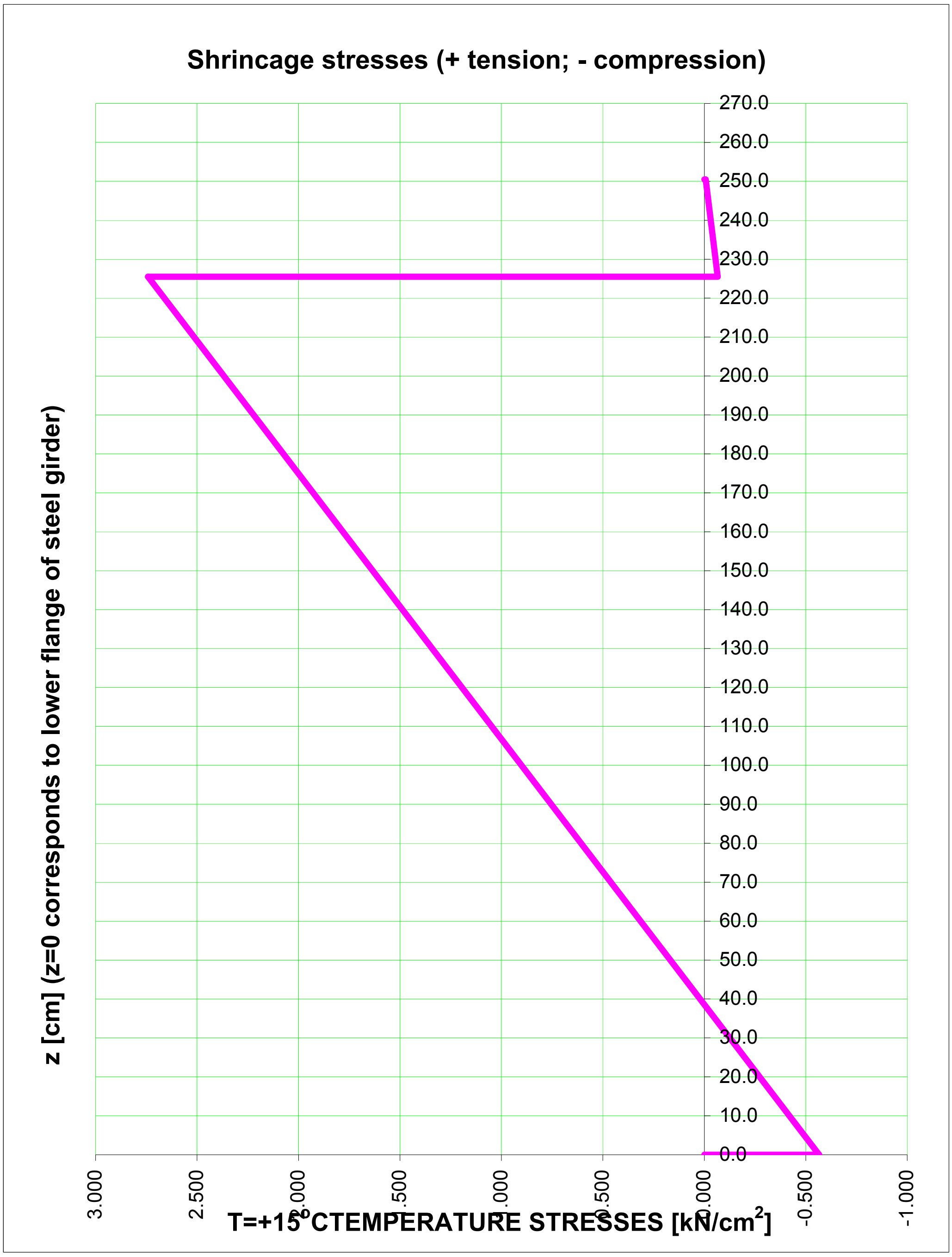


N_s=	455.63 kN	**Partial internal forces for steel section /**
M_s=	-690.10 kNm	**Частни разрезни усилия за стоманеното сечение**

N_c=	-455.63 kN	**Partial internal forces for RC section /**
M_c=	-15.50 kNm	**Частни разрезни усилия за ст.б. сечение**

F1=	0.00000000E+00 =0;	$N_c+N_s=0$
F2=	0.00000000E+00 =0;	$M_s+M_c+N_s(z_i-z_s)-N_c(z_c-z_i)=0$
F3=	0.00000000E+00 =0;	$[\varepsilon_{sh}+N_c/(E_cA_c)+M_cz_c/(E_cJ_c)]-[N_s/(E_sA_s)-M_sz_s/(E_sJ_s)]=0$
F4=	2.49800181E-16 =0;	$(M_c/M_s)-((J_c/n_{sh})/J_s)=0$

z [cm]	σ_t [kN/cm^2]	z_s [cm]	$\sigma_{sh}(N)$	$\sigma_{sh}(M)$
0.00	-0.56585	83.137	0.654	-1.220
225.50	2.74201	-142.363	0.654	2.088
225.50	-0.06620	12.500	-0.036	-0.030
250.50	-0.00670	-12.500	-0.036	0.030



SECTION x= 16.500 m

TEMPERATURE CHANGE -15°C

T_{Ed}= -15.000 °C

α_{tc}= 0.00001

ε_t= -0.00015000

Es= 210000000 kN/m² = 21000.00 kN/cm²

Ec= 34077146 kN/m² = 3407.71 kN/cm²

n_{sh}= 6.16249

beff= 500.0 cm

hc= 25.0 cm

bfsup= 28.0 cm bfinf= 70.0 cm

tfsup= 2.0 cm tfinf= 3.5 cm

hw= 220.0 cm

tw= 1.8 cm

As= 697.0 cm²

Js= 4704463.4 cm⁴

zs= 83.1 cm

Ac= 12500.0 cm²

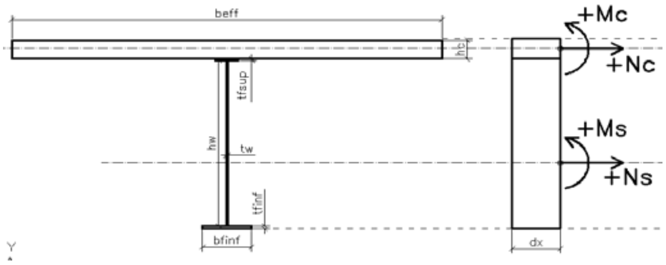
Jc= 651041.7 cm⁴

zc= 238.0 cm

zi= 198.3951 cm

Ai= 2725.4016 cm²

Ji= 17250942.04 cm⁴

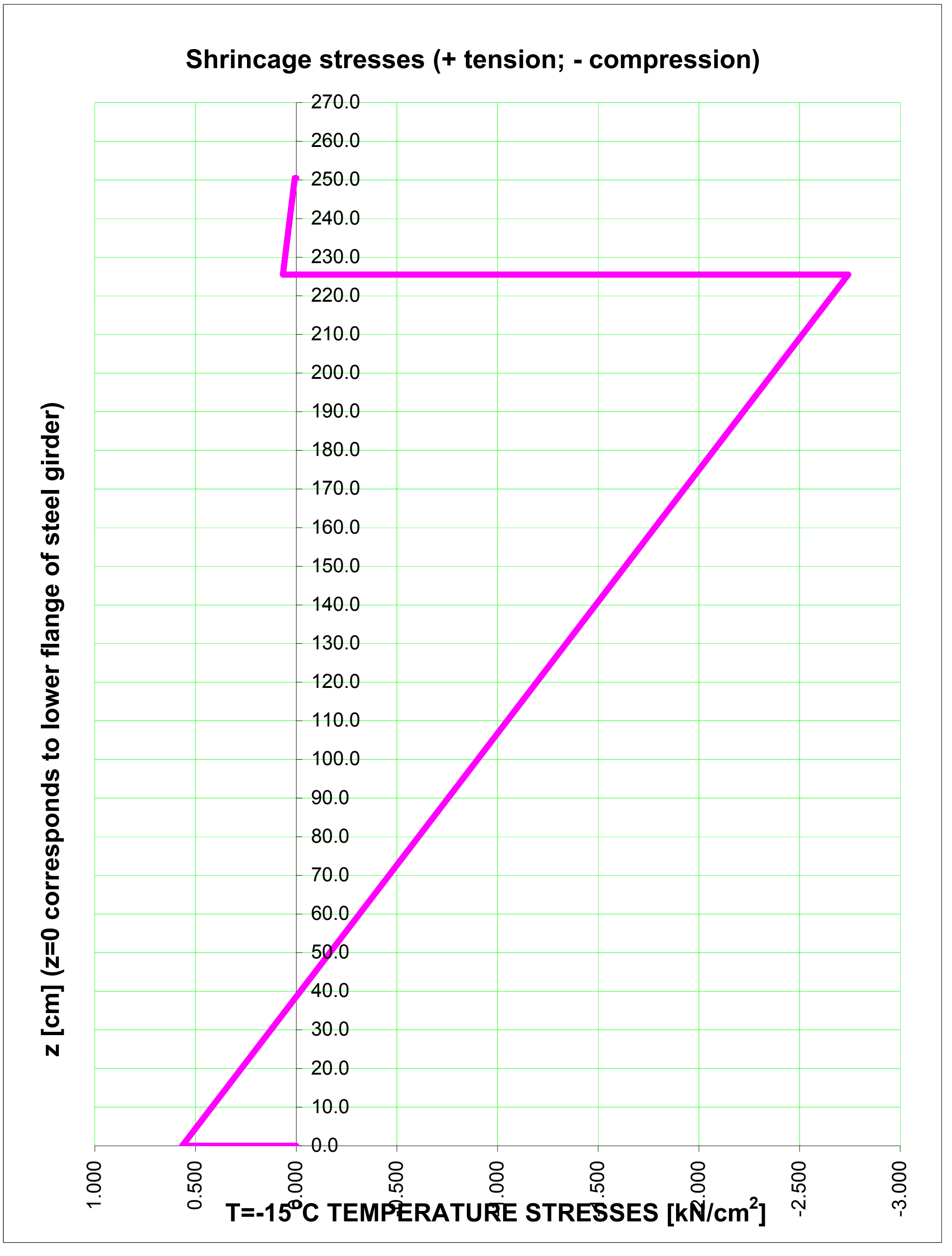


N_s= -455.63 kN	**Partial internal forces for steel section /**
M_s= 690.10 kNm	**Частни разрезни усилия за стоманеното сечение**

N_c= 455.63 kN	**Partial internal forces for RC section /**
M_c= 15.50 kNm	**Частни разрезни усилия за ст.б. сечение**

F1=	0.00000000E+00 =0;	$N_c+N_s=0$
F2=	0.00000000E+00 =0;	$M_s+M_c+N_s(z_i-z_s)-N_c(z_c-z_i)=0$
F3=	0.00000000E+00 =0;	$[\varepsilon_{sh}+N_c/(E_cA_c)+M_cz_c/(E_cJ_c)]-[N_s/(E_sA_s)-M_sz_s/(E_sJ_s)]=0$
F4=	2.15105711E-16 =0;	$(M_c/M_s)-((J_c/n_{sh})/J_s)=0$

z [cm]	σ_t [kN/cm^2]	z_s [cm]	$\sigma_{sh}(N)$	$\sigma_{sh}(M)$
0.00	0.56585	83.137	-0.654	1.220
225.50	-2.74201	-142.363	-0.654	-2.088
225.50	0.06620	12.500	0.036	0.030
250.50	0.00670	-12.500	0.036	-0.030



SECTION x= 16.500 m

		НАПРЕЖЕНИЯ - ВТОРИ ЕТАП/STRESSES - STAGE 2 [kN/cm^2]						STAGE1 [kN/cm^2]
LOAD		LM1	G2no	G2nal	SH	TP15	TM15	
ratio n		6.162	6.162	14.697	16.092	6.162	6.162	-
0	1	2	3	4	5	6	7	8
z [cm]	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.00	17.327	12.369	12.985	1.090	-0.566	0.566	0.283
	225.50	-2.227	-1.690	-4.418	-5.186	2.742	-2.742	-0.485
	225.50	-0.361	-0.274	-0.301	0.090	-0.066	0.066	0.000
	250.50	-0.713	-0.527	-0.432	0.047	-0.007	0.007	0.000
	250.50	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESSES - STAGE 1 + STAGE 2

	COMB	1	2	3	4	5	6	7	8
	Description	"LM1"+"G2no"+"SH"	"LM1"+"G2nal"+"SH"	"LM1"+"G2nal"+"SH"+"TM15"	"LM1"+"G2nal"+"SH"+"TP15"	"LM1"+"G2no"+"SH"+"TM15"	"LM1"+"G2no"+"SH"+"TP15"	"LM1"+"G2no"	"LM1"+"G2nal"
z [cm]	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.00	31.069	31.685	32.251	31.120	31.635	30.504	29.696	30.595
	225.50	-9.588	-12.316	-15.058	-9.574	-12.330	-6.846	-3.917	-7.130
	225.50	-0.546	-0.572	-0.506	-0.638	-0.480	-0.612	-0.636	-0.662
	250.50	-1.194	-1.099	-1.092	-1.105	-1.187	-1.200	-1.240	-1.145
	250.50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Stage 1: Section x=L/2 "m"

M_1= 160.15 kNm - with relevant sign + or -

$W_{s,inf}$= 56586.6 cm^3 $\sigma_{1,inf}$= 0.283 kN/cm^2

$W_{s,sup}$= -33045.6 cm^3 $\sigma_{1,sup}$= -0.485 kN/cm^2

f_y= 35.500 kN/cm^2 - for t<=16mm

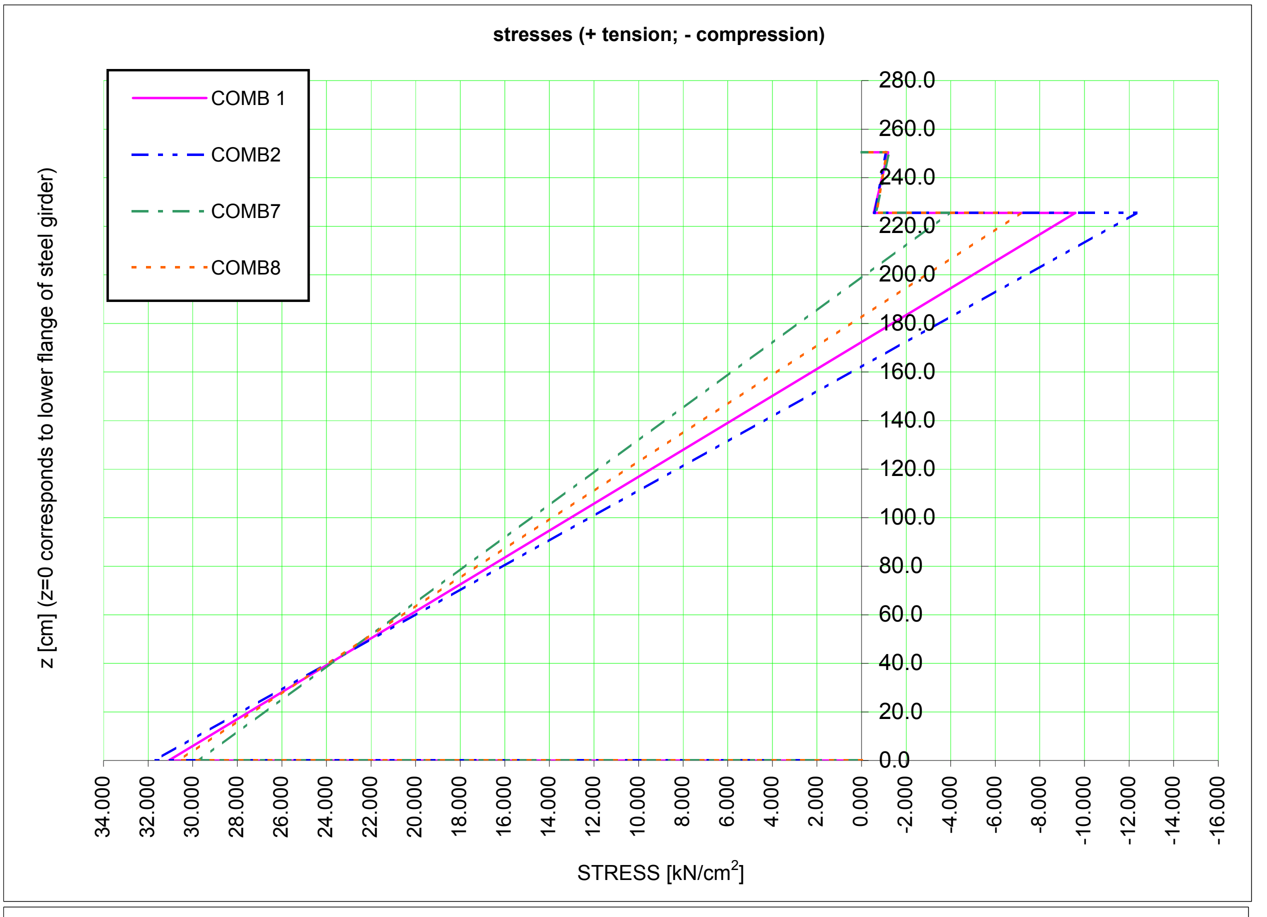
f_y= 34.500 kN/cm^2 - for 16< t<=40mm γ_{M0}= 1.05 f_{yd}= 32.857 kN/cm^2

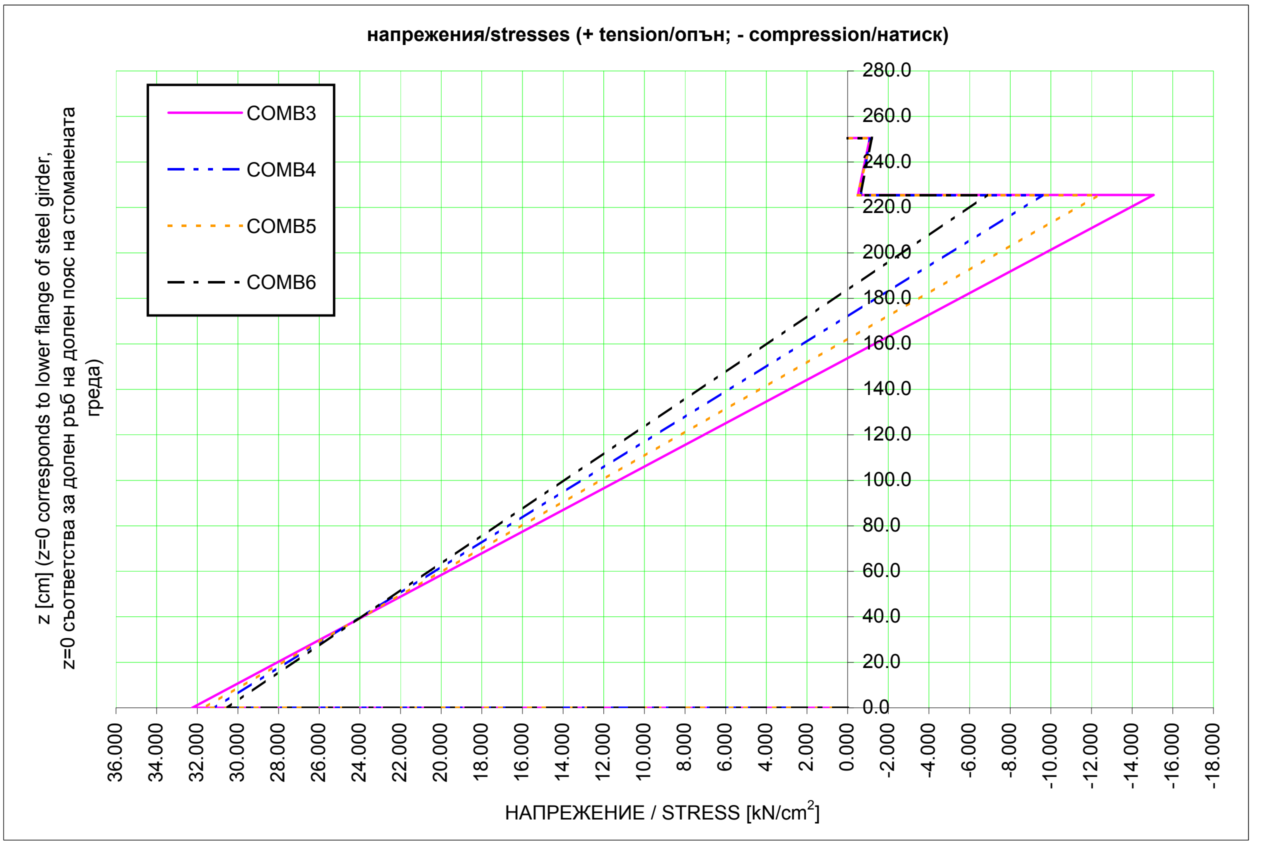
$\sigma_{1,inf}$= 0.283 kN/cm^2 $\sigma_{sh,inf}$= 1.090 kN/cm^2

$\sigma_{2,inf}$= 31.484 kN/cm^2 ($\sigma_{2inf}=f_{yd}-\sigma_{1,inf}-\sigma_{sh,inf}$)

M_u= 27375.84 kNm $M_{Ed,2,no}$= 25851.83 kNm x= 16.500 m

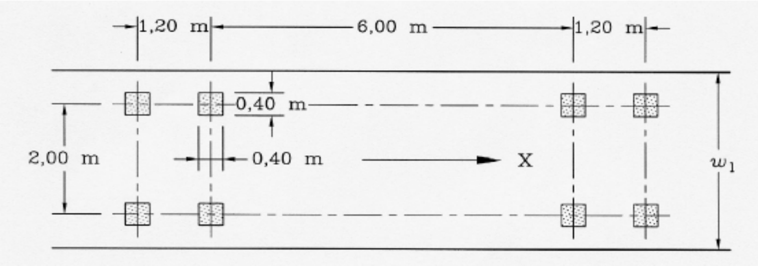
M_u/M_{Ed}= 1.0590


stresses (+ tension; - compression)
COMB 1
COMB2
COMB7
COMB8
z [cm] (z=0 corresponds to lower flange of steel girder)
STRESS [kN/cm^2]
280.0
260.0
240.0
220.0
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
34.000
32.000
30.000
28.000
26.000
24.000
22.000
20.000
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
-4.000
-6.000
-8.000
-10.000
-12.000
-14.000
-16.000


напрежения/stresses (+ tension/опън; - compression/натиск)
COMB3
COMB4
COMB5
COMB6
z [cm] (z=0 corresponds to lower flange of steel girder,
z=0 съответства за долен ръб на долен пояс на стоманената
греда)
НАПРЕЖЕНИЕ / STRESS [kN/cm^2]
280.0
260.0
240.0
220.0
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
36.000
34.000
32.000
30.000
28.000
26.000
24.000
22.000
20.000
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
-4.000
-6.000
-8.000
-10.000
-12.000
-14.000
-16.000
-18.000

В: Проверки на умора за дюбелната връзка между стоманобетонна плоча и стоманена греда за средата на отвора: разработил: гл. ас. д-р инж. Лазар Димитров Георгиев

1. EN1991-2: FLM3 и честота $0,5*10^6$возила/година



$Q_{FLM3,k}$=	120.00	kN/ос

Параметри на мостовата конструкция

B=	6.500	m - разстояние между осите на гл.н.
l_k=	1.750	m - конзолно издаване
G=	10.000	m - габарит на пътната конструкция
L=	33.000	m - отвор на мостовата конструкция

2. Статическо решение

2.1. Решение в напречна посока

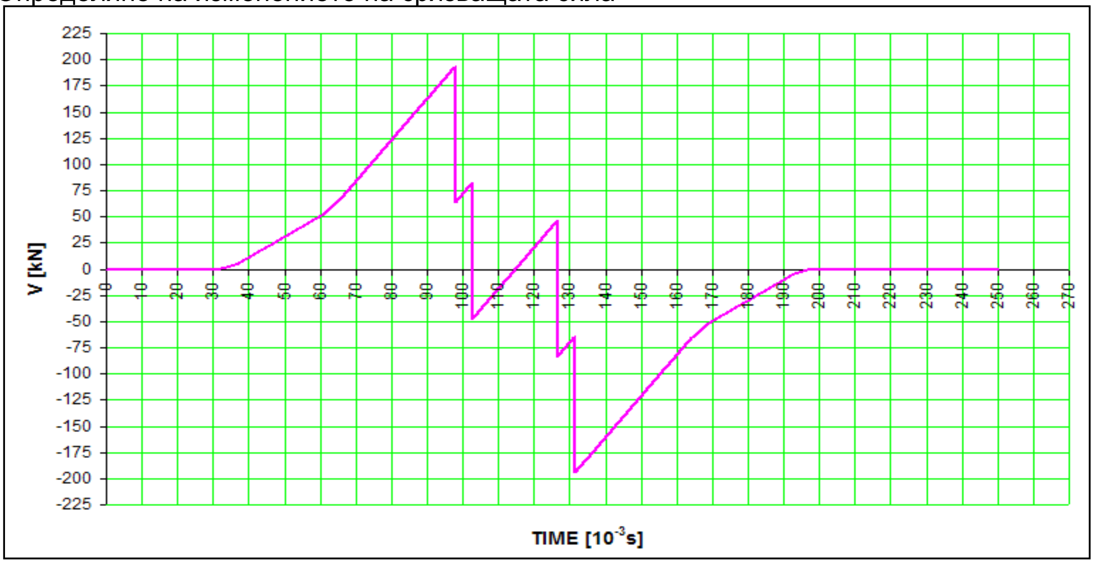
η_1= 1.23846

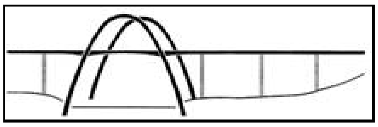
η_2= 0.93077

$\Sigma\eta_i$= 2.16923

P_{FLM3}=	130.15	kN	за едната главна греда

2.2. Определяне на изменението на срязващата сила

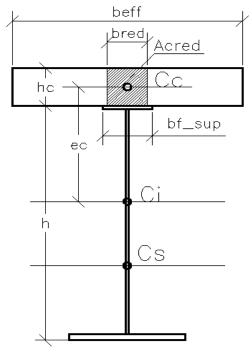




УАСГ – София
Факултет по ТРАНСПОРТНО СТРОИТЕЛСТВО
Катедра “ТРАНСПОРТНИ СЪОРЪЖЕНИЯ”
Специалност СТС4

ЧИСЛЕН ПРИМЕР: Проверки на умора за дюбелната връзка между стоманобетонна плоча и стоманена греда за средата на отвора: разработил: гл. ас. д-р инж. Лазар Димитров Георгиев

E_s=	210000000	kN/m^2	=		21000.00	kN/cm^2
E_c=	34077146	kN/m^2	=		3407.71	kN/cm^2
n=	6.16249	=n_o				
b_{eff}=	500.0	cm		b_{cred}=	81.1	cm
h_c=	25.0	cm				
b_{fsup}=	40.0	cm		b_{finf}=	85.0	cm
t_{fsup}=	2.0	cm		t_{finf}=	4.0	cm
h_w=	300.0	cm				m
t_w=	2.0	cm				
A_s=	1020.0	cm^2				
J_s=	12642508.2	cm^4				
z_s=	115.2	cm				
S_{si}=	137997.0	cm^3				
A_c=	12500.0	cm^2		A_{cred}=	2028.4	cm^2
J_c=	651041.7	cm^4		J_{cred}=	105645.9	cm^4
z_c=	318.5	cm		z_c-z_s=	2.0332	m
$S_{s,ci}$=	-137997.0	cm^3				
z_i=	250.5	cm				
A_i=	3048.4016	cm^2				
J_i=	40806186.5	cm^4				
$S_{cred,ci}$=	137997.0	cm^3		$S_{cred,ci}/J_i$=	0.0033818	cm^{-1}



d=	19	mm - диаметър на дюбелите	5d=	95	mm
n_p=	2	брой дюбели в напречен ред			
l_s=	180	mm - надлъжно разстояние между дюбелите			
n_1=	11.111	броя / m'			

ЧИСЛЕН ПРИМЕР: Проверки на умора за дюбелната връзка между стоманобетонна плоча и стоманена греда за средата на отвора:

A_d= 2.8353 cm^2

$\Delta\tau=K_V.\Delta V$

K_v= 107.34677 m^{-2}

$$K_V = \frac{S_{c,red,Ci}}{I_i.n_1.A_d}\gamma_{F,f} = \frac{4.S_{c,red,Ci}}{I_i.n_1.\pi.d^2}\gamma_{F,f}$$

$\Delta\tau_C$= 90.000 N/mm²= 90000 kN/m²

m= 8.00

$\Delta\tau_{FL}$= 55.191 N/mm²

γ_{Ff}= 1.150

γ_{Mf}= 1.350

DAMAGE TOLERANT	SAFE LIFE	-
1.000	1.150	γ_{Ff}
1.150	1.350	γ_{Mf}

ΔV [kN]	387.70	94.26	18.54	18.54
$\Delta\tau$ [kN/cm²]	4.162	1.012	0.199	0.199
$\Delta\tau_c$ [kN/cm²]	6.667	6.667	6.667	6.667
$\Delta\tau_{c,FL}$ [kN/cm²]	4.088	4.088	4.088	4.088
$n_{i,1}$ [цикли/год]	5.000E+05	5.000E+05	5.000E+05	5.000E+05
N_i [цикли]	8.670E+07	1.000E+40	1.000E+40	1.000E+40
D_{i1}	0.005767	0.000000	0.000000	0.000000
			D_1=	0.005767
			Експлоатационен срок T [год] =	173.40