Middle East Technical University Civil Engineering Department

CE 484 PRESTRESSED CONCRETE

Term Project

<u>Team Members:</u>

2025880 - Umut Ekinci

2090496 - Mehmet Nuri Özışın

Submitted Date:06.01.2020

Table of Contents

1.Introduction

The aim of the assignment is perform the structural design of 26 m long simply supported prestressed concrete girder for major highway bridge in Ankara. The center of girder to center of girder is stated 170 cm which means that there is no gap between girders. Unshored construction process is accepted by making the girder desgin in order to lack of information(Length of viaduct and trafic laods). TS3233 is followed by making prestressed concrete girder.

2.Material and Cross-sectional Properties

Initially, Material properties are determined for girder, slab and strands as follow:

- Material factors are

$$\gamma_{mc} = 1{,}5 \; for \; cast \; in \; place \; concrete$$

$$\gamma_{mc} = 1{,}4 \; for \; pre - casted \; concrete$$

$$\gamma_{ms} = 1{,}15$$

- For grade-270 low relaxation steel strands:

$$f_{pk} = 18 \; t/cm^2$$

$$f_{pd} = \frac{f_{pk}}{\gamma_{ms}} = \frac{18}{1{,}15} 15{,}65 \; t/cm^2$$

- For concrete of girder:

$$f_{ck} = 400 \; kgf/cm^2$$

$$f_{cd} = \frac{f_{ck}}{\gamma_{mc}} = \frac{400}{1{,}4} = 281{,}71 \; kgf/cm^2$$

$$f_{cik} = 0{,}70 * 400 = 280 \; kgf/cm^2$$

$$E_{c,girder} = 10270\sqrt{400} + 140000 = 345400 \; kgf/cm^2$$

- For concrete of slab:

$$f_{ck} = 250 \; kgf/cm^2$$

$$f_{cd} = \frac{f_{ck}}{\gamma_{mc}} = \frac{250}{1{,}5} = 166{,}67 \; kgf/cm^2$$

$$E_{c,slab} = 10270\sqrt{250} + 140000 = 302383 \; kgf/cm^2$$

Secondly, the girder section is determined as figure 1.

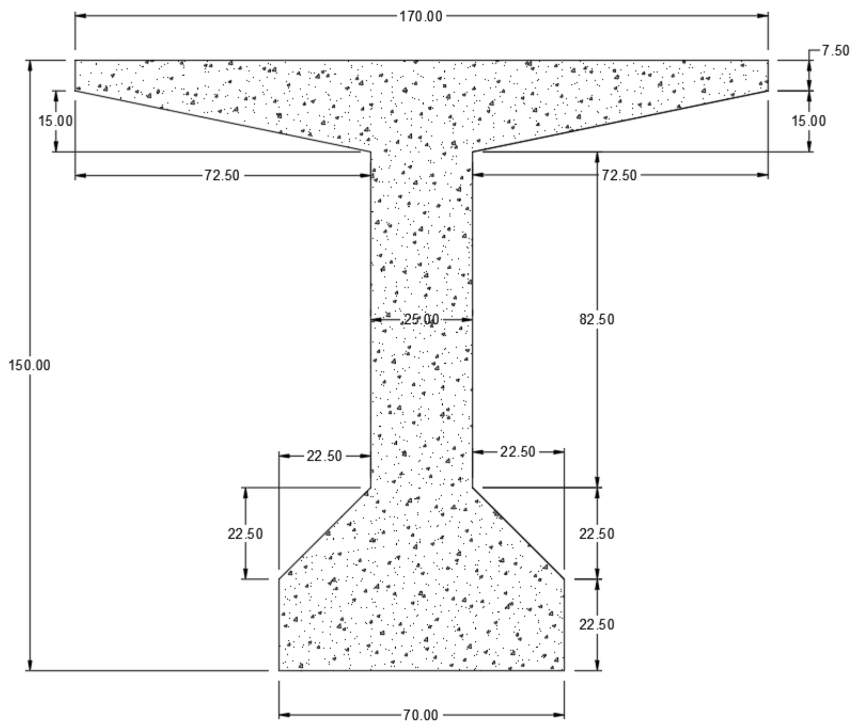

Figure 1: Prestressed Concrete Girder Cross-section

Cross-section in Figure 1. is converted to simple shape, which is can be seen in Figure 2., by keeping the area and centroid constant. The reason of using simple shape is to be able to calculate sectional properties such as inertia and area.

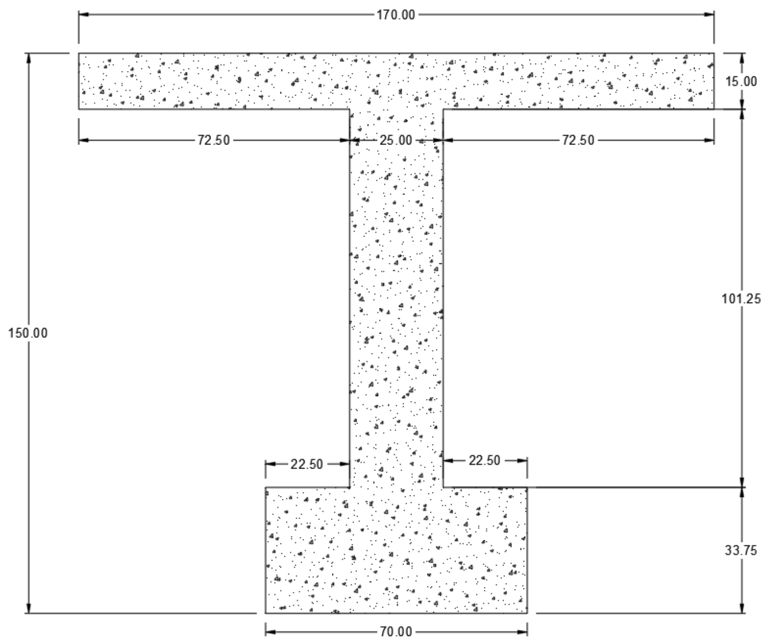

Figure 2: Simplified Prestressed Concrete Girder Cross-section

Simplified cross-sectional properties can be calculated as follows:

$$A_c = 170 * 15 + 101{,}25 * 25 + 33{,}75 * 70 = 7443{,}75\ cm^2$$

$$y_c = \frac{70 * \frac{33{,}75^2}{2} + 101{,}25 * 25 * \left(\frac{101{,}25}{2} + 33{,}75\right) + 15 * 170 * \left(\frac{15}{2} + 101{,}25 + 33{,}75\right)}{7443{,}75}$$

$$y_c = 82{,}86\ \ cm\ (measured\ from\ above)$$

$$I_c = \frac{1}{12} * (70 * 33{,}75^3 + 25 * 101{,}25^3 + 170 * 15^3) + 70 * 33{,}75 * \left(82{,}86 - \frac{33{,}75}{2}\right)^2 + 25 * 101{,}25 * \left(82{,}86 - \left(\frac{101{,}25}{2} + 37{,}5\right)\right)^2 + 170 * 15 * \left(82{,}86 - \left(\frac{15}{2} + 135\right)\right)^2$$

$$I_c = 2{,}18 * 10^7\ cm^4$$

A 20 cm deck(slab) will be placed on top of the girders 60 days later after the production of girders. Cross-section of prestressed concrete girder and slab can be seen in Figure 3.

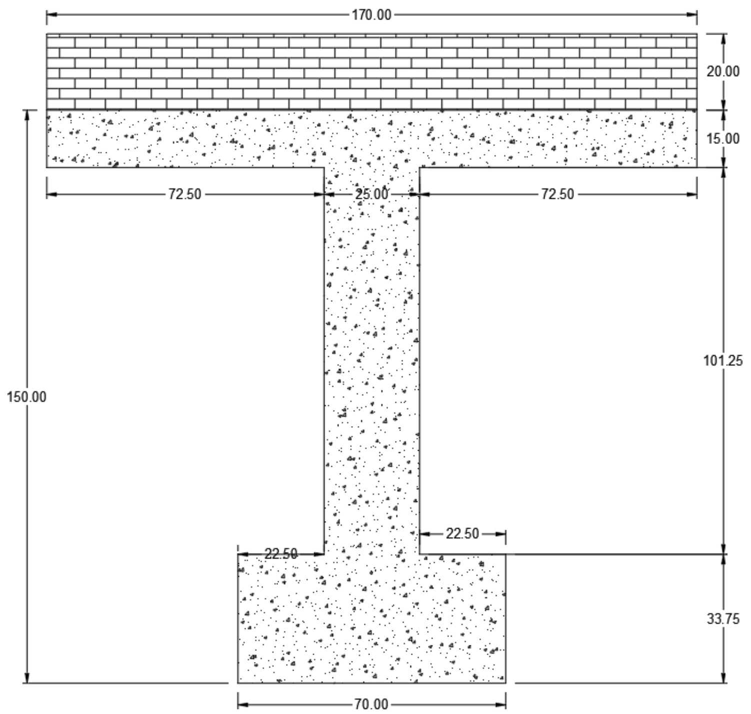

Figure 3: Cross-section of Prestressed Concrete Girder and Slab

Concrete of girder and slab has different features, so the cross section is converted to composite cross-section. Slab features are transferred to girder features by considering "n" value which is ratio of elastic modulus of slab and girder.

$$n = \frac{E_{c,slab}}{E_{c,girder}} = \frac{302383}{345400} = 0,875$$

Afterwards, the top-width of slab is found for composite section as follow:

$$w = 0,875 * 170 = 148,83\ cm$$

Lastly, cross-section of composite section is obtained like figure 4.

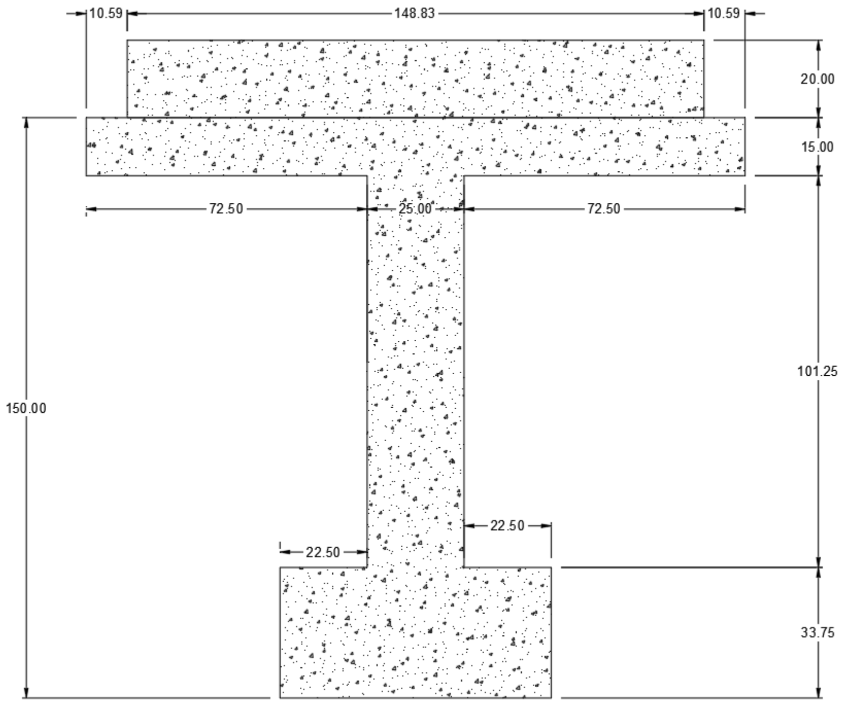

Figure 4:Cross-section of Composite Section

Composite cross-sectional properties are calculated as follows.

$$A_{c,composite} = A_c + 148,83 * 20 = 7443,75 + 2976,6 = 10420,35\ cm^2$$

$$y_{c,composite} = \frac{7443,75 * 82,86 + 148,83 * 20 * (150 + \frac{20}{2})}{10420,35} = 104,90\ cm$$

$$I_{c,composite} = 2,18 * 10^7 + 7443,75 * (104,90 - 82,86)^2 + \frac{1}{12} * 148,83 * 20^3 + 148,83 * 20 * (150 + \frac{20}{2} - 104,90)^2$$

$$I_{c,composite} = 3,45 * 10^7\ cm^4$$

Summary of Materials can be seen in Table 1.

Table 1: Material and Cross-sectional Properties

Steel Strand	
f_{pk} kgf/cm^2)	18000.00
f_{pd} (kgf/cm^2)	15652.17
E_c (kgf/cm^2)	2000000.00
Conrete of Girder	
f_{ck} (kgf/cm^2)	400.00
f_{cd} (kgf/cm^2)	285.71
f_{cik} (kgf/cm^2)	280.00
E_c (kgf/cm^2)	345400.00
Concrete of Slab	
f_{ck}(kgf/cm^2)	250.00
f_{cd}(kgf/cm^2)	166.67
E_c(kgf/cm^2)	302382.96
Cross Section of Girder	
A_c(cm^2)	7443.75
y_c(cm)	82.86
I_c (cm^4)	21796857.34
Cross section of Composite Section	
$A_{c.composite}$(cm^2)	10420.30
$y_{c.composite}$(cm)	104.90
$I_{c.composite}$(cm^4)	34547611.63

3.Allowable Stresses

- **Allowable Concrete Stresses**

  @Transfer

  <u>*In compression;*</u>

$$\sigma_{all} = 0{,}60 * f_{cik} = 0{,}60 * 280 = 168\ kgf/cm^2\ for\ girder$$

<u>*In tension;*</u>

$$\sigma_{all} = 1{,}6\sqrt{f_{cik}} = 1{,}6\sqrt{280} = 26{,}77\ kgf/cm^2\ @\ the\ member\ ends$$

$$\sigma_{all} = 0{,}8\sqrt{f_{cik}} = 0{,}8\sqrt{280} = 13{,}39\ kgf/cm^2\ @\ other\ locations$$

@ Under service loads

<u>*In compression;*</u>

$$\sigma_{all} = 0{,}4 * f_{ck} = 0{,}4 * 400 = 160\ kgf/cm^2\ for\ bridge\ beams$$

$$\sigma_{all} = 0{,}4 * f_{ck} = 0{,}4 * 250 = 100\ kgf/cm^2\ for\ slab$$

<u>In tension;</u>

<u>Girder:</u>

$$\sigma_{all} = 1{,}6\sqrt{f_{ck}}\ (if\ no\ additional\ reinforcent\ in\ tension\ zone)$$

$$\sigma_{all} = 1{,}6\sqrt{400} = 32\ kgf/cm^2$$

$$\sigma_{all} = 3{,}2\sqrt{f_{ck}}\ \ (if\ additional\ reinforcement\ is\ provided)$$

$$\sigma_{all} = 3{,}2\sqrt{400} = 64\ kgf/cm^2$$

<u>Slab:</u>

$$\sigma_{all} = 1{,}6\sqrt{f_{ck}}\ (if\ no\ additional\ reinforcent\ in\ tension\ zone)$$

$$\sigma_{all} = 1{,}6\sqrt{250} = 25{,}30 kgf/cm^2$$

$$\sigma_{all} = 3{,}2\sqrt{f_{ck}}\ \ (if\ additional\ reinforcement\ is\ provided)$$

$$\sigma_{all} = 3{,}2\sqrt{250} = 50{,}6\ kgf/cm^2$$

- **Allowable Strands Stresses**

  @ Initial Stressing, f_{pj}

$$\sigma_{all} = 0{,}8 * f_{pk} = 0{,}80 * 18000 = 14400\ kgf/cm^2$$

@ Right after the release, f_{pi}

$$\sigma_{all} = 0{,}7 * f_{pk} = 0{,}70 * 18000 = 12600\ kgf/cm^2$$

4.Determination of Dead Load and Live Load

4.1.Dead Load

For dead load of girder and slab found by following formulation:

$$w = A * \gamma_c$$

If $\gamma_c = 2.4\ t/m^3$ is taken:

$$w_{deadload} = A_c * \gamma_c = 7443{,}75 * 10^{-4} * 2{,}4 = 1{,}7865\ t/m$$

$$w_{slab} = A_s * \gamma_c = 170 * 20 * 10^{-4} * 2{,}4 = 0{,}816$$

Given superimposed dead load is converted to line load by multiplying top width of cross-section of slab.

$$w_{superimposed} = 250 * 1{,}7 = 425\ kgf/m = 0{,}45\ t/m$$

4.2.Live Load

A truck is considered for live load. Truck can be seen in Figure 5.

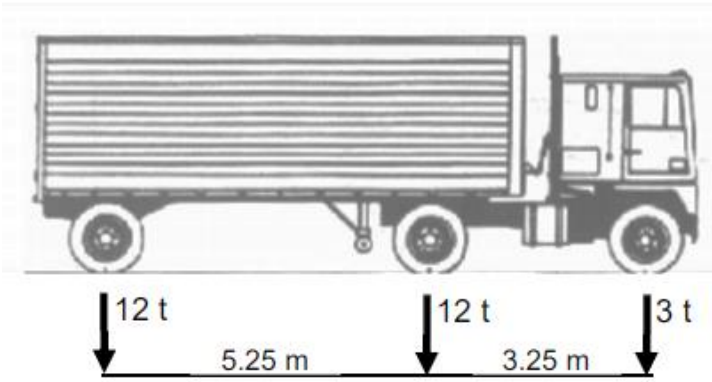

Figure 5: Truck as Live Load

Live load is found by moving truck 0,5 m from right to left steadily. While finding live load, superposition method is used, and calculations are made by MS Excel.

5.Determining Shear Force and Moment

5.1. Shear Force and Moment for Dead Load

For distributed loads, shear values and moment can be calculated by using following formulation;

$$V_x = \frac{wL}{2} - wx$$

$$M_x = \frac{wL}{2}x - \frac{wx^2}{2}$$

Shear and moment values for dead load (girder dead load, slab dead load and superimposed dead load) are calculated by using above formulations in MS Excell. Results of Shear and Moment for different sections can be seen in Table 2. and Table 3.

Table 2: Shear Values for Dead Load

Sections @m	$V_{deadload}$ (ton)	V_{slab} (ton)	$V_{superimposed}$ (ton)
0	23.22	10.61	5.53
0.5715	22.20	10.14	5.28
1.143	21.18	9.68	5.04
2.6	18.58	8.49	4.42
5.2	13.93	6.36	3.32
7.8	9.29	4.24	2.21
10.4	4.64	2.12	1.11

13	0.00	0.00	0.00
15.6	-4.64	-2.12	-1.11
18.2	-9.29	-4.24	-2.21
20.8	-13.93	-6.36	-3.32
23.4	-18.58	-8.49	-4.42
24.857	-21.18	-9.68	-5.04
25.4285	-22.20	-10.14	-5.28
26	-23.22	-10.61	-5.53

Table 3:Moment Values for Dead Loads

Sections @m	$M_{deadload}$ (ton*m)	M_{slab} (ton*m)	$M_{superimposed}$ (ton*m)
0	0.00	0.00	0.00
0.5715	12.98	5.93	3.09
1.143	25.38	11.59	6.04
2.6	54.35	24.82	12.93
5.2	96.61	44.13	22.98
7.8	126.81	57.92	30.17
10.4	144.92	66.19	34.48
13	150.96	68.95	35.91
15.6	144.92	66.19	34.48
18.2	126.81	57.92	30.17
20.8	96.61	44.13	22.98
23.4	54.35	24.82	12.93
24.857	25.38	11.59	6.04
25.4285	12.98	5.93	3.09
26	0.00	0.00	0.00

5.2. Shear Force and Moment for Live Load

For the live load, the truck should be placed for various places for both shear and moment values. Live load arrangement can be seen in Figure 6.

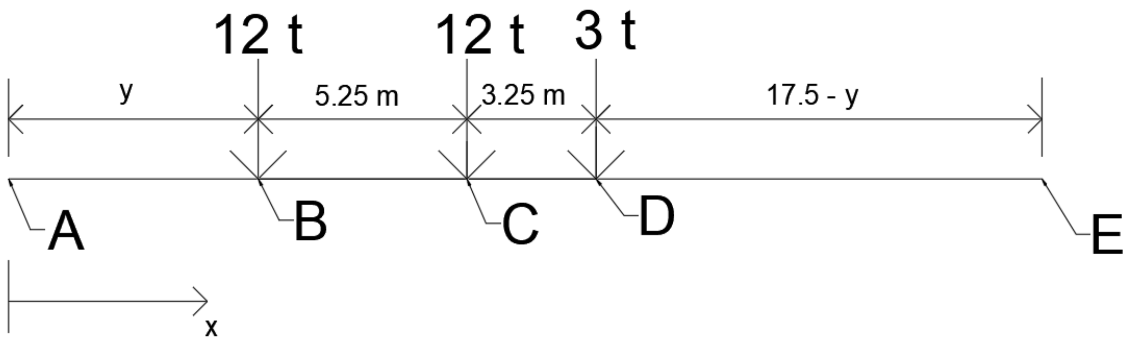

Figure 6: Live Load Arrangement of Truck

Truck is moved 0,5 m from starting from left side of beam to right of beam. While doing that, shear values are initially obtained for A, B, C, D and E points. Shear values are constant between A-B, B-C, C-D and D-E. By using MS excel code, shear values are obtained for desired sections. Result of maximum and minimum shear values can be seen in Table 4.

Table 4: Shear Values for Live Load

Sections @m	Maximum $V_{liveload}$ (ton)	Minimum $V_{liveload}$ (ton)
0	23.60	5.42
0.5715	22.56	5.42
1.143	22.04	5.42
2.6	20.48	5.42
5.2	17.88	5.42
7.8	15.29	-3.00
10.4	12.69	-5.60
13	10.10	-8.19
15.6	6.98	-10.79
18.2	-1.90	-13.38
20.8	-3.40	-16.50
23.4	-3.40	-18.58
24.857	-3.40	-20.02
25.4285	-3.40	-20.54
26.00	-3.40	-21.06

After finding shear values for live load, Moment values for A, B, C, D and E points are found by integration of shear values (using by area method because finding moment values is easy so that shear values are constant between points). Afterwards, moment values are found by making interpolation between points. MS Excell codes are used to find moment values for desired sections. Result of Maximum moment values can be seen in Table 5.

Table 5: Moment Values for Live Load

Sections @ m	Maximum $M_{liveload}$ (tom*m)
0	0.00
0.5715	12.89
1.143	25.19
2.6	53.40
5.2	93.30
7.8	119.70
10.4	132.60
13	138.75
15.6	136.80
18.2	121.35
20.8	91.80
23.4	49.05
24.857	25.19
25.4285	12.89
26	0.00

Lastly, Design Shear and Moment Values are found by 1,4G + 1,6Q load combination. Result can be seen in Table 6.

Sections @ m	V_{design} (ton)	M_{design}(ton*m)
0	92.85	0.00
0.5715	88.77	51.42
1.143	85.52	100.52
2.6	76.85	214.38
5.2	61.68	378.50
7.8	46.50	492.37
10.4	31.33	555.99
13	16.15	580.15
15.6	0.15	562.71
18.2	-25.09	495.01
20.8	-38.51	376.10
23.4	-49.53	207.42
24.857	-55.70	100.52
25.4285	-58.12	51.42
26	-60.55	0.00

6.Determination of Strand Type and Quantity

Initially, strand type and eccentricity are determined. Strand type is determined as 0,6∅ inch 7 wires strand. It has following properties:

$$A_s = 140\ mm^2\ and\ d = 15{,}24\ mm$$

After that, location of strand is determined as 12 cm above the bottom of cross section of girder. Eccentricity is found as following:

$$e = 82{,}86 - 12 = 70{,}86\ cm$$

Determining how many strands are required is very hard part of the project. Allowable Stress analysis is decided to find how many strands is required. By considering unshored construction technique, the long-term stress expression at the bottom of the span can be written as:

$$\sigma_{bottom} = -\frac{P_e}{A_c} - \frac{P_e * e * c_b}{I_c} + \frac{(M_{dl} + M_{sl}) * c_b}{I_c} + \frac{\left(M_{sp} + M_{ll}\right) * c_{b,composite}}{I_{c,composite}}$$

$$\sigma_{bottom} = -\frac{P_e}{7443{,}75} - \frac{P_e * 70{,}86 * 82{,}86}{2{,}18 * 10^7} + \frac{(150{,}96 + 68{,}95) * 10^5 * 82{,}86}{2{,}18 * 10^7} + \frac{(35{,}91 + 138{,}75) * 10^5 * 104{,}90}{3{,}45 * 10^7}$$

$$\sigma_{bottom} = -\frac{P_e}{7443{,}75} - \frac{P_e * 70{,}86 * 82{,}86}{2{,}18 * 10^7} + 83{,}58 + 53{,}11 < 32\ kgf/cm^2$$

$$P_{e_{min}} > 301392{,}99 kgf$$

If f_{pj} and f_{pe} are taken from lectures notes. Following equation can be written:

$$f_{pj} = 0{,}75 * f_{pk} = 0{,}75 * 18000 = 13500\ kgf/cm^2$$

$$f_{pe} = 0{,}70 * f_{pj} = 0{,}70 * 13500 = 9450\ kgf/cm^2$$

Afterwards, by using the stress- force relationship, the required area of strands can be found as follows:

$$P_{e_{min}} = f_{pe} * A_{min}$$

$$A_{min} = \frac{301392{,}99}{9450} = 31{,}89\ cm^2$$

Area of 0,6∅ inch 7 wires strand is 140 mm^2.

$$A_{ps} = N * A_s$$

$$N = \frac{A_{ps}}{A_s} = \frac{3189}{140} = 22{,}78$$

To be make conservative side, we choose strand number as 24. The location of strands can be seen in Figure 7.

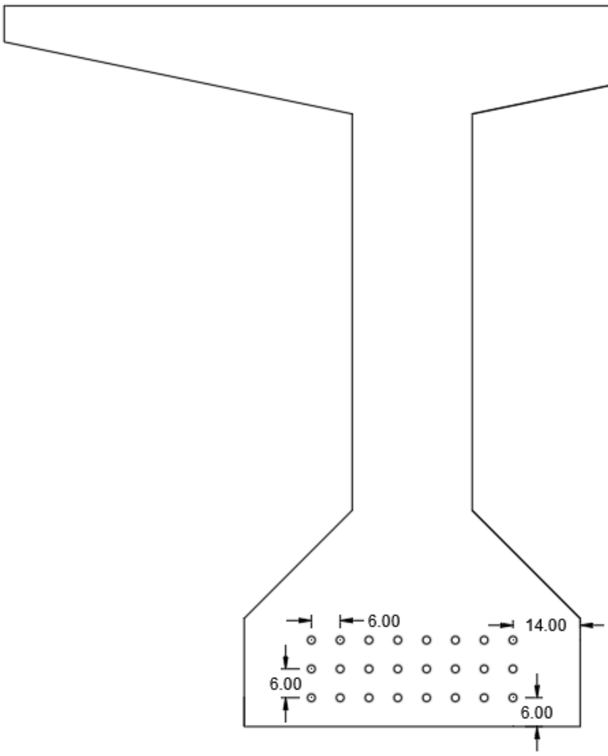

Figure 7: Strands Location

Total Area of strand and eccentricity are as follows:

$$A_{ps} = 24 * 140 = 3360\ mm^2 = 33.60\ cm^2$$

$$e = 82{,}86 - 12 = 70{,}86\ cm$$

7.Determination of Prestresses Losses

After release of prestress, strand has some losses at transfer and following time, and these losses are found by TS3233 specifications. Losses are like follows:

- Relaxation Loss (RE)

Relaxation loss is stated in TS3233 like following:

$$if\ f_{pj} \geq 0{,}70 * f_{pk} \rightarrow Relaxation\ Loss\ RE = 8\ \%\ of\ f_{pj}$$
$$if\ f_{pj} \leq 0{,}50 * f_{pk} \rightarrow Relaxation\ Loss\ RE = 1\ \%\ of\ f_{pj}$$

$$f_{pj} = 0{,}75 * f_{pk}$$

$$f_{pj} = 0,75 * 18000 = 13500\ kgf/cm^2$$

Therefore, since

$$f_{pj} \geq 0,70 * f_{pk} \rightarrow Relaxation\ Loss\ RE = 8\ \%\ of\ f_{pj}$$

$$RE = 0,08 * 13500 = 1080\ kgf/cm^2$$

$50\ \%\ of\ RE\ occurs\ @\ the\ initial\ state = 0,50 * 1080 = 540\ \ kgf/cm^2$
$Full\ relaxation\ occurs\ @\ the\ long\ term\ (lets\ say\ after\ 1\ month) = 1080\ kgf/cm^2$

- Elastic Shortening (ES)

There are two procedures in TS3233. The first approach is based on iteration. Second one is based on making nearly estimation for stresses. Second approach is used.

$$P_j = 13500 * 33,60 = 453600\ kgf\ = 453,6\ tons$$

$$P = 0,9 * 453,6 = 408,24\ tons$$

The elastic loss,$\Delta\sigma$, then can be calculated by using the formula below:

$$\Delta\sigma = E_s * \Delta\varepsilon_s = n * \left(\frac{P}{A_c} + \frac{P * e^2}{I_c} - \frac{M_{dl} * e}{I_c}\right)$$

Where;

$$n = \frac{E_s}{E_{cik}}$$

$$E_c = 345400\ kgf/cm^2$$

$$E_s = 2000000\ kgf/cm^2$$

$$n = \frac{2000000}{354400} = 5,64$$

$$\Delta\sigma = 5,64 * \left(\frac{408240}{7443,75} + \frac{408240 * 70,86^2}{2,18 * 10^7} - \frac{150,96 * 10^5 * 70,86}{2,18 * 10^7}\right)$$

$$\Delta\sigma = 5,64 * (54,84 + 94,03 - 49,07) = 562,87\ kgf/cm^2$$

Elastic Shortening loss occurs only at transfer.

- Shrinkage Loss (SH)

The humidity rate is stated as “low” for the Ankara in the design assignment. For this condition, the shrinkage coefficient can be taken from the code TS3233 as;

$$C_{shrinkage} = 500 * 10^{-6}$$

Then shrinkage loss can be calculated by using:

$$SH = C_{shrinkage} * E_s$$

$$SH = 500 * 10^{-6} * 2000000 = 1000\ kgf/cm^2$$

$$During\ transfer\ \&\ 1^{st}\ month \rightarrow 50\ \%\ of\ the\ total\ shrinkage = 0{,}50 * 1000 = 500\ kgf/cm^2$$

$$During\ transfer\ \&\ 6^{st}\ month \rightarrow 75\ \%\ of\ the\ total\ shrinkage = 0{,}75 * 1000 = 750\ kgf/cm^2$$

$$During\ transfer\ \&\ 2^{nd}\ month \rightarrow 600\ kgf/cm^2 (By\ linear\ interpolation\ between\ 1^{st} and\ 6^{st})$$

$$Shrinkage\ loss\ at\ the\ long\ term \rightarrow 1000\ kgf/cm^2$$

- Creep Loss (CR)

Creep coefficient was taken from TS3233 for pre-tensioned members and it is as follows:

$$C_{creep} = 48 * 10^{-7}$$

The creep loss can be calculated by:

$$\varepsilon_{creep} = C_{creep} * \sigma_{c-cgs}$$

$$CR = \varepsilon_{creep} * E_s$$

However, there should be some modifications which should be applied to the coefficient above if:

If concrete compressive strength @ transfer, $f_{cik} \leq 350\ kgf/cm^2$; then increase C_{creep} by:

$$C_{creep} = 48 * 10^{-7} \frac{350}{f_{cik}}$$

If the concrete stress at cgs at transfer is larger than concrete compressive strength f_{ck}; then increase creep by 25 %.

❖ Creep loss after transfer

$$P_i = P_j - SH - ES - RE - CR$$

$$f_{pi} = 13500 - 0 - 562{,}87 - 540 - 0 = 12397{,}13\ kgf/cm^2$$

$$P_i = f_{pi} * A_{ps}$$

$$P_i = 12397{,}13 * 33{,}60 = 416543{,}57\ kgf = 416{,}54\ tons$$

$$\sigma_{c-cgs} = \left(\frac{P_i}{A_c} + \frac{P_i * e^2}{I_c} - \frac{M_{dl} * e}{I_c}\right)$$

$$\sigma_{c-cgs} = \left(\frac{416543,57}{7443,75} + \frac{416543,57 * 70,86^2}{2,18 * 10^7} - \frac{150,96 * 10^5 * 70,86}{2,18 * 10^7}\right)$$

$$\sigma_{c-cgs} = 55,96 + 95,94 - 49,07 = 102,83\ kgf/cm^2$$

- Corrections:

$$102,83\ kgf/cm^2 < \frac{3}{8} * 315 = 118\ kgf/cm^2$$

So, don't need correction.

$$f_{cik} = 280\ kgf/cm^2 < 350\ kgf/cm^2$$

So, factor the creep coefficient as stated above

$$C'_{creep} = 48 * 10^{-7} * \frac{350}{280} * 1,00 = 6 * 10^{-6}$$

$$\varepsilon_{creep} = 6 * 10^{-6} * 102,83 = 6,1698 * 10^{-4}$$

$$CR = 6,1698 * 10^{-4} * 2 * 10^6 = 1233,96\ kgf/cm^2$$

$$Between\ transfer\ \&\ 1^{st}\ month \rightarrow\ 0,50 * 1233,96 = 616,98\ kgf/cm^2$$

$$Between\ 1^{st}\ month\ \&\ 6^{th}\ month \rightarrow\ 0,75 * 1233,96 = 925,47\ kgf/cm^2$$

$$Between\ transfer\ \&\ 2^{nd}\ month (from\ interpolation) = 678,68\ kgf/cm^2$$

$$Creep\ loss\ at\ the\ long\ term = 1233,96\ kgf/cm^2$$

Since the slab is poured at the 2^{nd} month after the prestressing effect is initiated, the creep loss should be recalculated.

- Creep loss at 2^{nd} month

$$f_p = 13500 - 600 - 562,87 - 1080 - 678,68 = 10578,45 kgf/cm^2$$

$$P = 10578,45 * 33,60 = 355435,92\ kgf = 355,43\ tons$$

$$\sigma_{c-cgs} = \left(\frac{355435,92}{7443,75} + \frac{355435,92 * 70,86^2}{2,18 * 10^7} - \frac{(150,96 + 68,95) * 10^5 * 70,86}{2,18 * 10^7}\right)$$

$$\sigma_{c-cgs} = 47,75 + 81,87 - 71,48 = 58,14\ kgf/cm^2$$

Since at the 2nd month concrete reaches its full capacity, there should not be any correction for concrete strength anymore.

$$\varepsilon_{creep} = 4{,}8 * 10^{-6} * 58{,}14 = 2{,}79072 * 10^{-4}$$

$$CR = 2{,}79072 * 10^{-4} * 2 * 10^{6} = 558{,}14\ kgf/cm^2$$

After the 2nd month, the creep loss is:

$$Between\ the\ beginning\ of\ 2^{nd} month\ and, 3^{rd} month \rightarrow\ 0{,}50 * 558{,}14 = 279{,}07\ kgf/cm^2$$

$$Between\ the\ beginning\ of\ 2^{nd}\ month\ \&\ 8^{th}\ month \rightarrow\ 0{,}75 * 558{,}14 = 418{,}605\ kgf/cm^2$$

$$Between\ the\ beginning\ of\ 2^{nd}\ month\ \&\ 6^{th}\ month (from\ interpolation) \rightarrow\ 362{,}79\ kgf/cm^2$$

Since the superimposed dead load is acting at the 6th month after the prestressing effect is initiated, the creep loss should be recalculated again.

- ❖ Creep loss at the 6th month

$$f_p = 13500 - 750 - 562{,}87 - 1080 - (678{,}38 + 362{,}79) = 10065{,}96\ kgf/cm^2$$

$$P = 10065{,}96 * 33{,}60 = 338216{,}26\ kgf = 338{,}22\ tons$$

Apart from different creep calculations, now the superimposed dead load is carried by not girder only but by composite section. Therefore, the eccentricity and inertia values should be arranged accordingly.

$$e_{c,composite} = 104{,}90 - 12 = 92{,}90\ cm$$

$$\sigma_{c-cgs} = \left(\frac{338216{,}26}{7443{,}75} + \frac{338216{,}26 * 70{,}86^2}{2{,}18 * 10^7} - \frac{(150{,}96 + 68{,}95) * 10^5 * 70{,}86}{2{,}18 * 10^7} - \frac{35{,}91 * 10^5 * 92{,}90}{3{,}45 * 10^7}\right)$$

$$\sigma_{c-cgs} = 45{,}44 + 77{,}90 - 71{,}48 - 9{,}67 = 42{,}19\ kgf/cm^2$$

Since at the 6th month, concrete reaches its full capacity, there should not be any correction for concrete strength anymore.

$$\varepsilon_{creep} = 4{,}8 * 10^{-6} * 42{,}19 = 2{,}02512 * 10^{-4}$$

$$CR = 2{,}02512 * 10^{-4} * 2 * 10^{6} = 405{,}02\ kgf/cm^2$$

Since there is no additional dead load on the girder, no need to make time interval analysis.

Summary of prestress loss can be seen in Table 6.

Table 6: Summary of Prestress Losses

Time	RE (kgf/cm^2)	ES (kgf/cm^2)	SH (kgf/cm^2)	CR (kgf/cm^2)	Total Loss (kgf/cm^2)	f_p (kgf/cm^2)	P (kgf)
At transfer	540	562.87	0	0	1102.87	12397.13	416544
At 1st month	1080	562.87	500	616.98	2759.85	10740.15	360869
At 2nd month	1080	562.87	600	678.68	2921.55	10578.45	355436
At 6th month	1080	562.87	750	1041.47	3434.34	10065.66	338206
At long-term	1080	562.87	1000	1446.49	4089.36	9410.64	316197

8.Allowable Stress Check

8.1. Allowable Stress Check without Draping

While finding sectional stresses, following parameters are used.

Table 7: Parameters

f_{pi} (kgf/cm^2)	12397
P_i (kgf)	**416544**
I (cm^4)	**21800000**
e (cm)	**70.86**
C_{top} (cm)	**67.14**
C_{bottom} (cm)	**82.86**
S_{top} (cm^3)	**324695**
S_{bottom} (cm^3)	**263094**
Concrete (cm^2)	**7443.75**
I_{comp} (cm^4)	**34500000**
$y_{,comp}$ (cm)	**104.9**
$e_{,composite}$ (cm)	**92.9**
$C_{,bottom,compotsite}$ (cm)	**104.9**
$C_{,top\ of\ girder,compostie}$	**45.1**
$C_{,top\ of\ slab,compostie}$	**65.1**
$S_{bottom,comp}$ (cm^3)	**328885**
$S_{bottomofslab,comp}$ (cm^3)	**764967**
$S_{,topofgirder,comp}$ (cm^3)	**764967**
$S_{,topofslab,comp}$ (cm^3)	**529954**
n	**0.875**
P @ 1st month (kgf)	**360869**
P @ 2nd month (kgf)	**355436**
P @ 6th month (kgf)	**338206**
P @ long term (kgf)	**316198**

At Transfer Stage								
			Top			Bottom		
Sections @ (m)	M_{dl}	P/A	$P*e/S_{top}$	M_{dl}/S_{top}	Total	$P*e/S_{bottom}$	M_{dl}/S_{bottom}	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5715	12.98	-27.98	45.45	-4.00	13.48	-56.09	4.93	-79.14
1.143	25.38	-55.96	90.90	-7.82	27.13	-112.19	9.65	-158.50
2.6	54.35	-55.96	90.90	-16.74	18.21	-112.19	20.66	-147.49
5.2	96.61	-55.96	90.90	-29.76	5.19	-112.19	36.72	-131.43
7.8	126.81	-55.96	90.90	-39.05	-4.11	-112.19	48.20	-119.95
10.4	144.92	-55.96	90.90	-44.63	-9.69	-112.19	55.08	-113.06
13	150.96	-55.96	90.90	-46.49	-11.55	-112.19	57.38	-110.77
15.6	144.92	-55.96	90.90	-44.63	-9.69	-112.19	55.08	-113.06
18.2	126.81	-55.96	90.90	-39.05	-4.11	-112.19	48.20	-119.95
20.8	96.61	-55.96	90.90	-29.76	5.19	-112.19	36.72	-131.43
23.4	54.35	-55.96	90.90	-16.74	18.21	-112.19	20.66	-147.49
24.857	25.38	-55.96	90.90	-7.82	27.13	-112.19	9.65	-158.50
25.4285	12.98	-27.98	45.45	-4.00	13.48	-56.09	4.93	-79.14
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 1st Month								
			Top			Bottom		
Sections @ (m)	M_{dl}	P/A	$P*e/S_{top}$	M_{dl}/S_{top}	Total	$P*e/S_{bottom}$	M_{dl}/S_{bottom}	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5715	12.98	-24.24	39.38	-4.00	11.14	-48.60	4.93	-67.90
1.143	25.38	-48.48	78.75	-7.82	22.46	-97.19	9.65	-136.03
2.6	54.35	-48.48	78.75	-16.74	13.54	-97.19	20.66	-125.02
5.2	96.61	-48.48	78.75	-29.76	0.52	-97.19	36.72	-108.95
7.8	126.81	-48.48	78.75	-39.05	-8.78	-97.19	48.20	-97.48
10.4	144.92	-48.48	78.75	-44.63	-14.36	-97.19	55.08	-90.59
13	150.96	-48.48	78.75	-46.49	-16.22	-97.19	57.38	-88.30
15.6	144.92	-48.48	78.75	-44.63	-14.36	-97.19	55.08	-90.59
18.2	126.81	-48.48	78.75	-39.05	-8.78	-97.19	48.20	-97.48
20.8	96.61	-48.48	78.75	-29.76	0.52	-97.19	36.72	-108.95
23.4	54.35	-48.48	78.75	-16.74	13.54	-97.19	20.66	-125.02
24.857	25.38	-48.48	78.75	-7.82	22.46	-97.19	9.65	-136.03
25.4285	12.98	-24.24	39.38	-4.00	11.14	-48.60	4.93	-67.90
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 2nd Month (After poured slab)											
				Top				Bottom			
Sections @ (m)	M_{dl}	M_{sl}	P/A	$P*e/S_{top}$	M_{dl}/S_{top}	M_{sl}/S_{top}	Total	$P*e/S_{bottom}$	M_{dl}/S_{bottom}	M_{sl}/S_{bottom}	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5715	12.98	5.93	-23.87	38.78	-4.00	-1.83	9.09	-47.87	4.93	2.25	-64.55
1.143	25.38	11.59	-47.75	77.57	-7.82	-3.57	18.43	-95.73	9.65	4.41	-129.43
2.6	54.35	24.82	-47.75	77.57	-16.74	-7.64	5.44	-95.73	20.66	9.43	-113.39
5.2	96.61	44.13	-47.75	77.57	-29.76	-13.59	-13.53	-95.73	36.72	16.77	-89.98
7.8	126.81	57.92	-47.75	77.57	-39.05	-17.84	-27.07	-95.73	48.20	22.01	-73.27
10.4	144.92	66.19	-47.75	77.57	-44.63	-20.39	-35.20	-95.73	55.08	25.16	-63.24
13	150.96	68.95	-47.75	77.57	-46.49	-21.24	-37.91	-95.73	57.38	26.21	-59.89
15.6	144.92	66.19	-47.75	77.57	-44.63	-20.39	-35.20	-95.73	55.08	25.16	-63.24
18.2	126.81	57.92	-47.75	77.57	-39.05	-17.84	-27.07	-95.73	48.20	22.01	-73.27
20.8	96.61	44.13	-47.75	77.57	-29.76	-13.59	-13.53	-95.73	36.72	16.77	-89.98
23.4	54.35	24.82	-47.75	77.57	-16.74	-7.64	5.44	-95.73	20.66	9.43	-113.39
24.857	25.38	11.59	-47.75	77.57	-7.82	-3.57	18.43	-95.73	9.65	4.41	-129.43
25.4285	12.98	5.93	-23.87	38.78	-4.00	-1.83	9.09	-47.87	4.93	2.25	-64.55
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 6th Month (After loaded superimposed)											
					Top						
Sections @ (m)	M_{dl}	M_{sl}	M_{sdl}	P/A	$P*e/S_{top}$	M_{dl}/S_{top}	M_{sl}/S_{top}	$M_{sdl}/S_{top.gir}$	$M_{sdl}/S_{top.slab}$	Total for slab	Total for girder
0	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5715	12.98	5.93	3.09	-22.72	36.90	-4.00	-1.83	-0.40	-0.58	-0.51	7.96
1.143	25.38	11.59	6.04	-45.43	73.81	-7.82	-3.57	-0.79	-1.14	-1.00	16.20
2.6	54.35	24.82	12.93	-45.43	73.81	-16.74	-7.64	-1.69	-2.44	-2.13	2.30
5.2	96.61	44.13	22.98	-45.43	73.81	-29.76	-13.59	-3.00	-4.34	-3.79	-17.98
7.8	126.81	57.92	30.17	-45.43	73.81	-39.05	-17.84	-3.94	-5.69	-4.98	-32.46
10.4	144.92	66.19	34.48	-45.43	73.81	-44.63	-20.39	-4.51	-6.51	-5.69	-41.15
13	150.96	68.95	35.91	-45.43	73.81	-46.49	-21.24	-4.69	-6.78	-5.93	-44.05
15.6	144.92	66.19	34.48	-45.43	73.81	-44.63	-20.39	-4.51	-6.51	-5.69	-41.15
18.2	126.81	57.92	30.17	-45.43	73.81	-39.05	-17.84	-3.94	-5.69	-4.98	-32.46
20.8	96.61	44.13	22.98	-45.43	73.81	-29.76	-13.59	-3.00	-4.34	-3.79	-17.98
23.4	54.35	24.82	12.93	-45.43	73.81	-16.74	-7.64	-1.69	-2.44	-2.13	2.30
24.857	25.38	11.59	6.04	-45.43	73.81	-7.82	-3.57	-0.79	-1.14	-1.00	16.20
25.4285	12.98	5.93	3.09	-22.72	36.90	-4.00	-1.83	-0.40	-0.58	-0.51	7.96
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 6th Month (After loaded superimposed) (following Part)						
Bottom						
$P*e/S_{bottom}$	M_{dl}/S_{bottom}	M_{sl}/S_{bottom}	$M_{sdl}/S_{bottom.comp}$	$M_{sdl}/S_{bottom.comp.slab}$	Total for Slab	Total for girder
0.00	0.00	0.00	0.00	0.00	0.00	0.00
-45.55	2.25	1.17	0.94	0.40	0.35	-63.90
-91.09	4.41	2.29	1.84	0.79	0.69	-127.99
-91.09	9.43	4.91	3.93	1.69	1.48	-118.25
-91.09	16.77	8.74	6.99	3.00	2.63	-104.03
-91.09	22.01	11.47	9.17	3.94	3.45	-93.87
-91.09	25.16	13.10	10.48	4.51	3.94	-87.78
-91.09	26.21	13.65	10.92	4.69	4.11	-85.75
-91.09	25.16	13.10	10.48	4.51	3.94	-87.78
-91.09	22.01	11.47	9.17	3.94	3.45	-93.87
-91.09	16.77	8.74	6.99	3.00	2.63	-104.03
-91.09	9.43	4.91	3.93	1.69	1.48	-118.25
-91.09	4.41	2.29	1.84	0.79	0.69	-127.99
-45.55	2.25	1.17	0.94	0.40	0.35	-63.90
0.00	0.00	0.00	0.00	0.00	0.00	0.00

Long Term					
Sections @ (m)	M_{dl}	M_{sl}	M_{sdl}	M_{ll}	P/A
0	0.00	0.00	0	0.00	0.00
0.5715	12.98	5.93	3.09	12.89	-21.24
1.143	25.38	11.59	6.04	25.19	-42.48
2.6	54.35	24.82	12.93	53.40	-42.48
5.2	96.61	44.13	22.98	93.30	-42.48
7.8	126.81	57.92	30.17	119.70	-42.48
10.4	144.92	66.19	34.48	132.60	-42.48
13	150.96	68.95	35.91	138.75	-42.48
15.6	144.92	66.19	34.48	136.80	-42.48
18.2	126.81	57.92	30.17	121.35	-42.48
20.8	96.61	44.13	22.98	91.80	-42.48
23.4	54.35	24.82	12.93	49.05	-42.48
24.857	25.38	11.59	6.04	25.19	-42.48
25.4285	12.98	5.93	3.09	12.89	-21.24
26	0.00	0.00	0.00	0.00	0.00

Long Term (following part)								
Top								
P*e/Stop	M_{dl}/S_{top}	M_{sl}/S_{top}	$M_{sdl}/S_{top.gir}$	$M_{sdl}/S_{top.slab}$	$M_{ll}/S_{top.comp.gir}$	$M_{ll}/S_{top.comp.slab}$	Total for slab	Total for girder
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34.50	-4.00	-1.83	-0.40	-0.58	-1.69	-2.43	-2.64	5.35
69.01	-7.82	-3.57	-0.79	-1.14	-3.29	-4.75	-5.16	11.06
69.01	-16.74	-7.64	-1.69	-2.44	-6.98	-10.08	-10.95	-6.53
69.01	-29.76	-13.59	-3.00	-4.34	-12.20	-17.61	-19.20	-32.02
69.01	-39.05	-17.84	-3.94	-5.69	-15.65	-22.59	-24.74	-49.96
69.01	-44.63	-20.39	-4.51	-6.51	-17.33	-25.02	-27.59	-60.33
69.01	-46.49	-21.24	-4.69	-6.78	-18.14	-26.18	-28.84	-64.03
69.01	-44.63	-20.39	-4.51	-6.51	-17.88	-25.81	-28.28	-60.88
69.01	-39.05	-17.84	-3.94	-5.69	-15.86	-22.90	-25.02	-50.17
69.01	-29.76	-13.59	-3.00	-4.34	-12.00	-17.32	-18.95	-31.82
69.01	-16.74	-7.64	-1.69	-2.44	-6.41	-9.26	-10.23	-5.96
69.01	-7.82	-3.57	-0.79	-1.14	-3.29	-4.75	-5.16	11.06
34.50	-4.00	-1.83	-0.40	-0.58	-1.69	-2.43	-2.64	5.35
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Long Term (following part)								
Bottom								
$P*e/S_{bottom}$	M_{dl}/S_{bottom}	M_{sl}/S_{bottom}	$M_{sdl}/S_{bottom.comp}$	$M_{sdl}/S_{bottom.comp.slab}$	$M_{ll}/S_{bottom.comp}$	$M_{ll}/S_{bottom.comp.slab}$	Total for Slab	Total for girder
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-42.58	4.93	2.25	0.94	0.40	3.92	1.69	1.83	-51.77
-85.16	9.65	4.41	1.84	0.79	7.66	3.29	3.57	-104.09
-85.16	20.66	9.43	3.93	1.69	16.24	6.98	7.59	-77.38
-85.16	36.72	16.77	6.99	3.00	28.37	12.20	13.30	-38.79
-85.16	48.20	22.01	9.17	3.94	36.40	15.65	17.14	-11.86
-85.16	55.08	25.16	10.48	4.51	40.32	17.33	19.11	3.40
-85.16	57.38	26.21	10.92	4.69	42.19	18.14	19.98	9.05
-85.16	55.08	25.16	10.48	4.51	41.60	17.88	19.59	4.68
-85.16	48.20	22.01	9.17	3.94	36.90	15.86	17.33	-11.36
-85.16	36.72	16.77	6.99	3.00	27.91	12.00	13.13	-39.24
-85.16	20.66	9.43	3.93	1.69	14.91	6.41	7.09	-78.70
-85.16	9.65	4.41	1.84	0.79	7.66	3.29	3.57	-104.09
-42.58	4.93	2.25	0.94	0.40	3.92	1.69	1.83	-51.77
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

8.2. Allowable Stress Check with Draping

When observed allowable stress check without draping, tensional stress at edge of member exceed allowable stress. Therefore, draping method is used to get rid of this situation. Draping is in the edge of the beam between 0 m - 5,2 m and 20,8m - 26 m.

Table 8: Eccentiricities

Sections @ (m)	Eccenricity (cm)
0	40.86
0.5715	44.16
1.143	47.45
2.6	55.86
5.2	70.86
7.8	70.86
10.4	70.86
13	70.86
15.6	70.86
18.2	70.86
20.8	70.86
23.4	55.86
24.857	47.45
25.4285	44.16
26	40.86

The sectional stresses can be seen above tables.

At Transfer Stage								
			Top			bottom		
Sections @ (m)	Mdl	P/A	P*e/Stop	Mdl/Stop	Total	P*e/Sbottom	Mdl/Sbottom	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5715	12.98	-27.98	28.32	-4.00	-3.65	-34.96	4.93	-58.00
1.143	25.38	-55.96	60.88	-7.82	-2.90	-75.13	9.65	-121.44
2.6	54.35	-55.96	71.66	-16.74	-1.03	-88.44	20.66	-123.74
5.2	96.61	-55.96	90.90	-29.76	5.19	-112.19	36.72	-131.43
7.8	126.81	-55.96	90.90	-39.05	-4.11	-112.19	48.20	-119.95
10.4	144.92	-55.96	90.90	-44.63	-9.69	-112.19	55.08	-113.06
13	150.96	-55.96	90.90	-46.49	-11.55	-112.19	57.38	-110.77
15.6	144.92	-55.96	90.90	-44.63	-9.69	-112.19	55.08	-113.06
18.2	126.81	-55.96	90.90	-39.05	-4.11	-112.19	48.20	-119.95
20.8	96.61	-55.96	90.90	-29.76	5.19	-112.19	36.72	-131.43
23.4	54.35	-55.96	90.90	-16.74	18.21	-88.44	20.66	-123.74
24.857	25.38	-55.96	90.90	-7.82	27.13	-75.13	9.65	-121.44
25.4285	12.98	-27.98	45.45	-4.00	13.48	-34.96	4.93	-58.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 1st Month								
			Top			bottom		
Sections @ (m)	Mdl	P/A	P*e/Stop	Mdl/Stop	Total	P*e/Sbottom	Mdl/Sbottom	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5715	12.98	-24.24	24.54	-4.00	-3.70	-30.28	4.93	-49.59
1.143	25.38	-48.48	52.74	-7.82	-3.55	-65.09	9.65	-103.92
2.6	54.35	-48.48	62.08	-16.74	-3.13	-76.62	20.66	-104.44
5.2	96.61	-48.48	78.75	-29.76	0.52	-97.19	36.72	-108.95
7.8	126.81	-48.48	78.75	-39.05	-8.78	-97.19	48.20	-97.48
10.4	144.92	-48.48	78.75	-44.63	-14.36	-97.19	55.08	-90.59
13	150.96	-48.48	78.75	-46.49	-16.22	-97.19	57.38	-88.30
15.6	144.92	-48.48	78.75	-44.63	-14.36	-97.19	55.08	-90.59
18.2	126.81	-48.48	78.75	-39.05	-8.78	-97.19	48.20	-97.48
20.8	96.61	-48.48	78.75	-29.76	0.52	-97.19	36.72	-108.95
23.4	54.35	-48.48	62.08	-16.74	-3.13	-76.62	20.66	-104.44
24.857	25.38	-48.48	52.74	-7.82	-3.55	-65.09	9.65	-103.92
25.4285	12.98	-24.24	24.54	-4.00	-3.70	-30.28	4.93	-49.59
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 2nd Month (After poured slab)											
				Top				Bottom			
Sections @ (m)	Mdl	Msl	P/A	P*e/Stop	Mdl/Stop	Msl/Stop	Total	P*e/Sbottom	Mdl/Sbottom	Msl/Sbottom	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5715	12.98	5.93	-23.87	24.17	-4.00	-1.83	-5.53	-29.83	4.93	2.25	-46.51
1.143	25.38	11.59	-47.75	51.95	-7.82	-3.57	-7.19	-64.11	9.65	4.41	-97.81
2.6	54.35	24.82	-47.75	61.15	-16.74	-7.64	-10.98	-75.47	20.66	9.43	-93.12
5.2	96.61	44.13	-47.75	77.57	-29.76	-13.59	-13.53	-95.73	36.72	16.77	-89.98
7.8	126.81	57.92	-47.75	77.57	-39.05	-17.84	-27.07	-95.73	48.20	22.01	-73.27
10.4	144.92	66.19	-47.75	77.57	-44.63	-20.39	-35.20	-95.73	55.08	25.16	-63.24
13	150.96	68.95	-47.75	77.57	-46.49	-21.24	-37.91	-95.73	57.38	26.21	-59.89
15.6	144.92	66.19	-47.75	77.57	-44.63	-20.39	-35.20	-95.73	55.08	25.16	-63.24
18.2	126.81	57.92	-47.75	77.57	-39.05	-17.84	-27.07	-95.73	48.20	22.01	-73.27
20.8	96.61	44.13	-47.75	77.57	-29.76	-13.59	-13.53	-95.73	36.72	16.77	-89.98
23.4	54.35	24.82	-47.75	61.15	-16.74	-7.64	-10.98	-75.47	20.66	9.43	-93.12
24.857	25.38	11.59	-47.75	51.95	-7.82	-3.57	-7.19	-64.11	9.65	4.41	-97.81
25.4285	12.98	5.93	-23.87	24.17	-4.00	-1.83	-5.53	-29.83	4.93	2.25	-46.51
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 6th Month (After loaded superimposed)											
					Top						
Sections @ (m)	Mdl	Msl	Msdl	P/A	P*e/Stop	Mdl/Stop	Msl/Stop	Msdl/Stop.gir	Msdl/Stop.slab	Total for slab	Total for girder
0	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5715	12.98	5.93	3.09	-22.72	23.00	-4.00	-1.83	-0.40	-0.58	-0.51	-5.95
1.143	25.38	11.59	6.04	-45.43	49.43	-7.82	-3.57	-0.79	-1.14	-1.00	-8.18
2.6	54.35	24.82	12.93	-45.43	58.18	-16.74	-7.64	-1.69	-2.44	-2.13	-13.32
5.2	96.61	44.13	22.98	-45.43	73.81	-29.76	-13.59	-3.00	-4.34	-3.79	-17.98
7.8	126.81	57.92	30.17	-45.43	73.81	-39.05	-17.84	-3.94	-5.69	-4.98	-32.46
10.4	144.92	66.19	34.48	-45.43	73.81	-44.63	-20.39	-4.51	-6.51	-5.69	-41.15
13	150.96	68.95	35.91	-45.43	73.81	-46.49	-21.24	-4.69	-6.78	-5.93	-44.05
15.6	144.92	66.19	34.48	-45.43	73.81	-44.63	-20.39	-4.51	-6.51	-5.69	-41.15
18.2	126.81	57.92	30.17	-45.43	73.81	-39.05	-17.84	-3.94	-5.69	-4.98	-32.46
20.8	96.61	44.13	22.98	-45.43	73.81	-29.76	-13.59	-3.00	-4.34	-3.79	-17.98
23.4	54.35	24.82	12.93	-45.43	58.18	-16.74	-7.64	-1.69	-2.44	-2.13	-13.32
24.857	25.38	11.59	6.04	-45.43	49.43	-7.82	-3.57	-0.79	-1.14	-1.00	-8.18
25.4285	12.98	5.93	3.09	-22.72	23.00	-4.00	-1.83	-0.40	-0.58	-0.51	-5.95
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 6th Month (After loaded superimposed) (following part)						
Bottom						
P*e/Sbottom	Mdl/Sbottom	Msl/Sbottom	Msdl/Sbottom.comp	Msdl/Sbottom.comp.slab	Total for Slab	Total for girder
0.00	0.00	0.00	0.00	0.00	0.00	0.00
-28.38	2.25	1.17	0.94	0.40	0.35	-46.73
-61.00	4.41	2.29	1.84	0.79	0.69	-97.90
-71.81	9.43	4.91	3.93	1.69	1.48	-98.96
-91.09	16.77	8.74	6.99	3.00	2.63	-104.03
-91.09	22.01	11.47	9.17	3.94	3.45	-93.87
-91.09	25.16	13.10	10.48	4.51	3.94	-87.78
-91.09	26.21	13.65	10.92	4.69	4.11	-85.75
-91.09	25.16	13.10	10.48	4.51	3.94	-87.78
-91.09	22.01	11.47	9.17	3.94	3.45	-93.87
-91.09	16.77	8.74	6.99	3.00	2.63	-104.03
-71.81	9.43	4.91	3.93	1.69	1.48	-98.96
-61.00	4.41	2.29	1.84	0.79	0.69	-97.90
-28.38	2.25	1.17	0.94	0.40	0.35	-46.73
0.00	0.00	0.00	0.00	0.00	0.00	0.00

Long Term					
Sections @ (m)	Mdl	Msl	Msdl	Mll	P/A
0	0.00	0.00	0	0.00	0.00
0.5715	12.98	5.93	3.09	12.89	-21.24
1.143	25.38	11.59	6.04	25.19	-42.48
2.6	54.35	24.82	12.93	53.40	-42.48
5.2	96.61	44.13	22.98	93.30	-42.48
7.8	126.81	57.92	30.17	119.70	-42.48
10.4	144.92	66.19	34.48	132.60	-42.48
13	150.96	68.95	35.91	138.75	-42.48
15.6	144.92	66.19	34.48	136.80	-42.48
18.2	126.81	57.92	30.17	121.35	-42.48
20.8	96.61	44.13	22.98	91.80	-42.48
23.4	54.35	24.82	12.93	49.05	-42.48
24.857	25.38	11.59	6.04	25.19	-42.48
25.4285	12.98	5.93	3.09	12.89	-21.24
26	0.00	0.00	0.00	0.00	0.00

Long Term (following part)								
Top								
P*e/Stop	Mdl/Stop	Msl/Stop	Msdl/Stop.gir	Msdl/Stop.slab	Mll/Stop.comp.gir	Mll/Stop.comp.slab	Total for slab	Total for girder
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21.50	-4.00	-1.83	-0.40	-0.58	-1.69	-2.43	-2.64	-7.65
46.21	-7.82	-3.57	-0.79	-1.14	-3.29	-4.75	-5.16	-11.73
54.40	-16.74	-7.64	-1.69	-2.44	-6.98	-10.08	-10.95	-21.13
69.01	-29.76	-13.59	-3.00	-4.34	-12.20	-17.61	-19.20	-32.02
69.01	-39.05	-17.84	-3.94	-5.69	-15.65	-22.59	-24.74	-49.96
69.01	-44.63	-20.39	-4.51	-6.51	-17.33	-25.02	-27.59	-60.33
69.01	-46.49	-21.24	-4.69	-6.78	-18.14	-26.18	-28.84	-64.03
69.01	-44.63	-20.39	-4.51	-6.51	-17.88	-25.81	-28.28	-60.88
69.01	-39.05	-17.84	-3.94	-5.69	-15.86	-22.90	-25.02	-50.17
69.01	-29.76	-13.59	-3.00	-4.34	-12.00	-17.32	-18.95	-31.82
54.40	-16.74	-7.64	-1.69	-2.44	-6.41	-9.26	-10.23	-20.56
46.21	-7.82	-3.57	-0.79	-1.14	-3.29	-4.75	-5.16	-11.73
21.50	-4.00	-1.83	-0.40	-0.58	-1.69	-2.43	-2.64	-7.65
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Long Term (following part)								
Bottom								
P*e/Sbottom	Mdl/Sbottom	Msl/Sbottom	Msdl/Sbottom.comp	Msdl/Sbottom.comp.slab	Mll/Sbottom.comp	Mll/Sbottom.comp.slab	Total for Slab	Total for girder
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-26.53	4.93	2.25	0.94	0.40	3.92	1.69	1.83	-35.73
-57.03	9.65	4.41	1.84	0.79	7.66	3.29	3.57	-75.96
-67.13	20.66	9.43	3.93	1.69	16.24	6.98	7.59	-59.35
-85.16	36.72	16.77	6.99	3.00	28.37	12.20	13.30	-38.79
-85.16	48.20	22.01	9.17	3.94	36.40	15.65	17.14	-11.86
-85.16	55.08	25.16	10.48	4.51	40.32	17.33	19.11	3.40
-85.16	57.38	26.21	10.92	4.69	42.19	18.14	19.98	9.05
-85.16	55.08	25.16	10.48	4.51	41.60	17.88	19.59	4.68
-85.16	48.20	22.01	9.17	3.94	36.90	15.86	17.33	-11.36
-85.16	36.72	16.77	6.99	3.00	27.91	12.00	13.13	-39.24
-67.13	20.66	9.43	3.93	1.69	14.91	6.41	7.09	-60.68
-57.03	9.65	4.41	1.84	0.79	7.66	3.29	3.57	-75.96
-26.53	4.93	2.25	0.94	0.40	3.92	1.69	1.83	-35.73
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

9. Ultimate Stress Check

The design moment at the span has been found as:

$$M_d = 580{,}15\ ton.m$$

To be on the safe side, the following criteria should be satisfied:

$$M_r \geq M_d$$

The resisting moment can be found by using:

$$M_r = f'_{pd} * A_{ps} * (jd)$$

$$f'_{pd} = f_{pd} * \left(1 - 0{,}4 * \rho_p * \frac{f_{pd}}{f_{cd}}\right)$$

$$\rho_p = \frac{A_{ps}}{b * d}$$

$$d_{girder} = 138\ cm\ \&\ d_{composite} = 158\ cm\ @\ the\ span$$

$$\rho_p = \frac{33{,}60}{170 * 138} = 1{,}43 * 10^{-3}$$

$$f'_{pd} = 15562{,}17 * \left(1 - 0{,}4 * 1{,}43 * 10^{-3} * \frac{15562{,}17}{166{,}67}\right) = 14731{,}02\ kgf/cm^2$$

Now, assume the $k_1 c$ value is bigger than 20 cm but smaller than 35 cm.

$$20\ cm \leq k_1 c \leq 35\ cm$$

$$F_t = f'_{pd} * A_{ps}$$

$$F_c = 0{,}85 * f_{cd} * b * d$$

$$F_t = 14731{,}02 * 33{,}60 = 494962{,}3\ kgf$$

$$F_{c1} = 0{,}85 * 166{,}67 * 170 * 20 = 481676{,}3\ kgf$$

$$F_t > F_{c1}\ so\ our\ assumption\ is\ correct$$

Now, name the compression zone for the girder flange height as "a" . Then, "a" can be calculated by equating the forces to each other.

$$F_{c1} + F_{c2} = F_t$$

$$F_{c2} = 0{,}85 * 285{,}71 * 170 * a = 41285{,}095 * a$$

$$41285{,}095 * a + 481676{,}3 = 494962{,}3$$

$$a = 0{,}32\ cm$$

herefore, a is so small that is almost slab exerts all the compressive forces at the ultimate state. The centroid of the compression force from above can be calculated as follows:

$$c' = \frac{(481676{,}3\ * 10) + (494962{,}3 - 481676{,}3\ ) * \left(20 + \frac{0{,}32}{2}\right)}{494962{,}3} = 10{,}27\ cm$$

Then the moment arm, jd, can be calculated as follows:

$$jd = 158 - 10{,}27 = 147{,}73\ cm$$

Then M_r can be computed as:

$$M_r = F_t * jd$$

$$M_r = 494962{,}3 * 147{,}73 = 73120780{,}58\ kgf * cm = 731{,}21\ ton/m$$

$$M_r > M_d$$

Therefore, we have sufficient capacity even in the worst scenario. As a result, there is no problem about the ultimate state.

10.Lightly Reinforced Section Check

The section should be controlled if it has sufficient lightly reinforcement or strand. The equation in below should be satisfactory.

$$M_r \geq 1{,}2 * M_{cr}$$

$$f_{ct} = 2 * \sqrt{f_{ct}}$$

$$f_{ct} = 2 * \sqrt{400} = 40\ kgf/cm^2$$

Iterative solution should be followed.

Assume $f_{ps} = 10{,}5\ t/cm^2$ & $P_s = 33{,}60 * 10{,}5 = 352{,}8\ tons = 352800kgf$

The stresses at the bottom and top can be computed by using simple formulas:

$$\sigma_{bottom} = -\frac{P_s}{A_c} - \frac{P_s * e * c_{bottom}}{I_c} + \frac{M_{dl} * c_{bottom}}{I_c}$$

$$\sigma_{top} = -\frac{P_s}{A_c} + \frac{P_s * e * c_{top}}{I_c} - \frac{M_{dl} * c_{top}}{I_c}$$

$$\sigma_{bottom} = -\frac{352,8 * 10^3}{7443,75} - \frac{352,8 * 10^3 * 70,86 * 82,86}{2,18 * 10^7} + \frac{150,95 * 10^5 * 82,86}{2,18 * 10^7}$$

$$\sigma_{bottom} = -47,39 - 95 + 57,37 = -85,02\ kgf/cm^2$$

$$\sigma_{top} = -\frac{352,8 * 10^3}{7443,75} + \frac{420 * 10^3 * 70,86 * 67,14}{2,18 * 10^7} - \frac{150,95 * 10^5 * 67,14}{2,18 * 10^7}$$

$$\sigma_{top} = -47,39 + 76,99 - 46,49 = -6,89\ kgf/cm^2$$

Now, for the stress-strain relationship for the strands, Henderson formula can be used:

$$f_{ps} = 2000 * \varepsilon_p * \left(0,025 + \frac{0,975}{\left(1 + \left(118 * \varepsilon_p\right)^{10}\right)^{0,1}}\right) \leq 18\ t/cm^2$$

Firstly, the initial strand strain by assuming the long-term effective stress exists on the strands:

$$9,41 = 2000 * \varepsilon_{prestress} * \left(0,025 + \frac{0,975}{\left(1 + \left(118 * \varepsilon_{prestress}\right)^{10}\right)^{0,1}}\right) \leq 18\ t/cm^2$$

$$\varepsilon_{prestress} = 4,706 * 10^{-3}$$

The additional strain coming from the load applied above:

$$\sigma_{cgs} = 40 + 85,02 = 125,02\ kgf/cm^2$$

$$\sigma_{cgs} = 125,02 * \frac{70,86}{82,86} = 106,91\ kgf/cm^2$$

$$\varepsilon_{loading} = \frac{\sigma_{cgs}}{E_c}$$

$$\varepsilon_{loading} = \frac{106,91}{345400} = 3,095 * 10^{-4}$$

$$\varepsilon_p = \varepsilon_{loading} + \varepsilon_{prestress}$$

$$\varepsilon_p = 4,706 * 10^{-3} + 3,095 * 10^{-4} = 5,0155 * 10^{-3}$$

Check the assumed strand stress at the cracking time:

$$f_{ps} = 2000 * 5,0155 * 10^{-3} * \left(0,025 + \frac{0,975}{(1 + (118 * 5,0155 * 10^{-3})^{10})^{0,1}}\right) \leq 18\ t/cm^2$$

$$f_{ps} = 10{,}02\ t/cm^2 \cong 10{,}50\ t/cm^2$$

Therefore, we can say that our assumption is correct. Then the cracking moment can be calculated as:

$$M_{cr} = \frac{\sigma_{cr} * I_c}{c_{bottom}}$$

$$M_{cr} = \frac{125{,}02 * 2{,}18 * 10^7}{82{,}86} * 10^{-5} = 32892058\ kgf/cm^2 = 328{,}92\ t.m$$

Then;

$$\frac{M_r}{M_{cr}} = \frac{731{,}21}{328{,}92} = 2{,}22 \gg 1{,}20$$

So, the amount of reinforcement seems quite satisfaction for the lightly reinforcement check.

11. Heavily Reinforced Section Check

The heavily reinforcement is unwanted condition for a beam because heavily reinforcement cause to brittle failure. The equation in below should be sufficient.

$$\psi_p = \frac{A_{ps}}{b * d} * \frac{f_{pd}}{f_{cd}} \leq 0{,}25$$

- **Check for Composite Section**

  Total compressive force is taken from ultimate check analysis,

$$F_c = 494{,}96\ tons$$

$$A_{ps} = \frac{F_c}{f'_{pd}}$$

$$A_{ps} = \frac{494{,}96}{14{,}7} = 33{,}67 cm^2$$

$$\psi_p = \frac{33{,}67}{170 * 158} * \frac{15652}{166{,}67} = 0{,}118 \leq 0{,}25$$

- **Check for Girder Section**

$$F_c = F_t$$

$$0{,}85 * 170 * a * 285{,}71 = 494962{,}3$$

$$a = 11{,}99\ cm < 15\ cm$$

$$\psi_p = \frac{33,67}{170 * 138} * \frac{15652}{285,71} = 0,079 \leq 0,25$$

The amount of reinforcement is sufficient for heavily reinforcement.

12.Shear Check

- **Vertical Shear Check**

Our purpose is to provide above equation:

$$V_r \leq V_d$$

$$V_r \leq \tau_{max} * b_w * d$$

Where;

τ_{max} values are given in TS3233: *Table 27.*

If;

$$V_d > \tau_{max} * b_w * d$$

$$V_{d,max} = 92,85\ tons$$

$$\tau_{max} = 53\ kgf/cm^2 (this\ data\ is\ taken\ from\ TS3233$$

$$V_d = 92,85\ tons \leq 50 * 20 * \left(150 - (82,86 - 40,86)\right) * 10^3 = 108\ tons$$

$$V_r = V_c + V_w$$

$$V_c = min \begin{cases} V_{cw}: Web\ shear\ cracking\ strength \\ V_{cr}: Flexural\ shear\ cracking\ strenght \end{cases}$$

$$V_{cw} = 0,67 * b_w * h * \sqrt{(f_{ct})^2 + \left(0,8 * f_{pc} * f_{ct}\right)} + V_p$$

$$f_{pc} = \frac{f_{pe} * A_{ps}}{A_c} = \frac{9,41 * 33,60 * 1000}{7443,75} = 42,47\ kgf/cm^2$$

$$f_{ct} = 0,8 * \sqrt{f_{ck}} = 0,8 * \sqrt{400} = 16\ kgf/cm^2$$

$$f_{cdt} = \frac{22}{1.4} = 15,71 kgf/cm^2 (22\ was\ taken\ from\ TS3233)$$

$$f_{ywd} = \frac{f_{ywk}}{\gamma_{ms}} = \frac{4200}{1,15} = 3652,2\ kgf/cm^2$$

$$V_p = f_{pe} * \tan\theta$$

$$\theta = \tan^{-1}\left(\frac{30}{520}\right) = 3{,}3019^{\circ}$$

$$V_{cr} = \left(1 - 0{,}55 * \frac{\sigma_{pef}}{f_{pk}}\right) * \tau_c * b_w * d + M_0 * \frac{V_d}{M_d}$$

$$M_0 = 0{,}8 * \sigma_{cpd} * \frac{I}{y}$$

$$\sigma_{cpd} = \frac{P_e}{A_c} + \frac{P_e * e^2}{I_c} = \frac{316{,}18 * 1000}{7443{,}75} + \frac{316{,}18 * 1000 * 70{,}86^2}{2{,}18 * 10^7} = 115{,}30 \ \ kgf/cm^2$$

$$\sigma_{pef} = f_{pe} \leq 0{,}6 * f_{pk}$$

$$V_{cr} \geq 0{,}38 * b_w * d * \sqrt{f_{ck}}$$

To be able to determine the τ_c value, first, the following expression should be computed:

$$\frac{100 * A_{ps}}{b_w * d}$$

Rquried parameters can be seen in above table.

Table 9: Parameters

Tmax (kgf/cm2)	**50.00**
bw (cm)	**20.00**
h (cm)	**150.00**
fpe (t/cm2)	**9.41**
fct (kgf/cm2)	**16.00**
Aps (cm2)	**33.60**
Ac (cm2)	**7443.75**
fpc (kgf/cm2)	**42.48**
Pe (tons)	**316.18**
Igirder (cm4)	**2.18E+07**
e,girder (cm)	**70.86**
Sigma(cpd) (kgf/cm2)	**115.30**
Sigma(pef)max(t/cm2)	**10.80**
As (mm2)	**78.54**
Asw (cm2)	**1.57**
fctd (kgf/cm2)	**15.71**
fywd (kgf/cm2)	**3652.17**
s (cm)	**73.01**
yc (cm)	**82.86**

teta (radian)	0.06

For the stirrup, we have decided to use Ø10 with two legs: $n = 2$.

$$A_s = \frac{\pi * 10^2}{4} = 78{,}54\ mm^2$$

$$A_{sw} = A_s * n = 2 * 78{,}54 = 157{,}1\ mm^2$$

Calculations are made by MS Excel. Result of calculation can be seen in above table and graph.

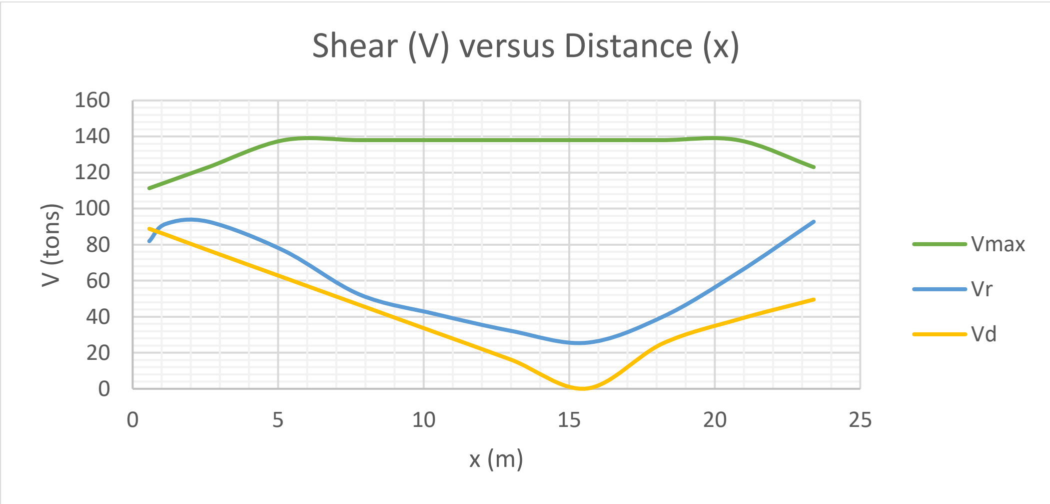

Figure 8: Shear - Distance Curve

Sections @ (m)	Vd (t)	Md (t-m)	Eccentricity (cm)	d (cm)	Vmax,allowable (t)	Vp (t)	Vcw (t)	M0 (t-m)	For Tau(c)	Tau(c) (kgf/cm2)	Vcr (t)	Vcr,min (t)	Vc (t)	smax (cm)	s (cm)	Vw (t)	Vr (t)	Check P.
0	92.85	0.00	40.86	108.00	108.00	0.00	56.84	492.12	1.56	8.61	-	17.41	-	81.00	40.00	15.49	-	-
0.5715	88.77	51.42	44.16	111.30	111.30	9.12	65.96	455.38	1.51	8.52	799.60	17.94	65.96	83.47	40.00	15.96	81.92	0.00
1.143	85.52	100.52	47.45	114.59	114.59	18.24	75.08	423.74	1.47	8.43	374.28	18.47	75.08	85.95	40.00	16.44	91.52	1.00
2.6	76.85	214.38	55.86	123.00	123.00	18.24	75.08	359.98	1.37	8.23	143.47	19.83	75.08	92.25	40.00	17.64	92.72	1.00
5.2	61.68	378.50	70.86	138.00	138.00	0.00	56.84	283.77	1.22	7.93	61.84	22.25	56.84	103.50	40.00	19.79	76.63	1.00
7.8	46.50	492.37	70.86	138.00	138.00	0.00	56.84	283.77	1.22	7.93	42.40	22.25	42.40	103.50	80.00	9.90	52.30	1.00
10.4	31.33	555.99	70.86	138.00	138.00	0.00	56.84	283.77	1.22	7.93	31.59	22.25	31.59	103.50	80.00	9.90	41.49	1.00
13	16.15	580.15	70.86	138.00	138.00	0.00	56.84	283.77	1.22	7.93	23.50	22.25	22.25	103.50	80.00	9.90	32.14	1.00
15.6	0.15	562.71	70.86	138.00	138.00	0.00	56.84	283.77	1.22	7.93	15.68	22.25	15.68	103.50	80.00	9.90	25.57	1.00
18.2	25.09	495.01	70.86	138.00	138.00	0.00	56.84	283.77	1.22	7.93	29.98	22.25	29.98	103.50	80.00	9.90	39.88	1.00
20.8	38.51	376.10	70.86	138.00	138.00	0.00	56.84	283.77	1.22	7.93	44.66	22.25	44.66	103.50	40.00	19.79	64.45	1.00
23.4	49.53	207.42	55.86	123.00	123.00	18.24	75.08	359.98	1.37	8.23	100.38	19.83	75.08	92.25	40.00	17.64	92.72	1.00
24.857	55.70	100.52	47.45	114.59	114.59	18.24	75.08	423.74	1.47	8.43	248.59	18.47	75.08	85.95	70.30	9.35	84.43	1.00
25.4285	58.12	51.42	44.16	111.30	111.30	18.24	75.08	455.38	1.51	8.52	528.22	17.94	75.08	83.47	72.40	8.82	83.90	1.00
26	60.55	0.00	40.86	108.00	108.00	0.00	56.84	492.12	1.56	8.61	-	17.41	56.84	81.00	40.00	15.49	72.33	1.00

- **Horizontal Shear Check**

We have a design shear force of $V_d = 92{,}85\ tons$. To have fully composite action, the following requirement should be satisfied:

$$V_h \geq V_d$$

$$V_h = b' * d_{composite} * f_{ht}$$

Now, assume that no shear reinforcement is provided but only the surface is roughened. Then, $f_{ht} = 5\ kgf/cm^2$.

$$V_h = 170 * 158 * 5 * 10^{-3} = 134{,}3\ tons$$

$$V_h \geq V_d$$

13.Conclusion

For the term project, we have design a girder with given material properties and initial section properties. At the initial state, the design moments at the required sections have been found. Then by making assumption, the area of the prestressed strand has been estimated. In the following calculation steps, to be precise about the stress on the strands, the prestressing losses have been determined by considering different time intervals due to application of additional loads. As a result, of these the prestressing forces for various time interval have been found.

After determining the prestressing effect, by following the allowable stress limits, stress checks at the required sections have been performed. During this checking period, half of the prestressing effect at the $\frac{L_t}{2}$ has been considered.

Having checked the allowable stressed, the ductility checks for both heavily and lightly reinforced section have been performed. During the calculation period, the worst scenario has been considered and it has been found that the section is properly reinforced. After, the ultimate stress analysis has been done. Our section has sufficient capacity to resist the ultimate design moment. Moreover, a shear control for both horizontal and vertical situation have been performed. It is important to notify using the design values for these checks, both for ultimate analysis and shear analysis. By considering the outcomes obtained above, the necessary stirrups have been provided. All in all, a prestressed girder has been designed by considering the code TS 3233. **NOTE: If you have any missing data and information. We can send MS Excel file to you.**