**CIV 313S 2022 Guided Design**

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Angela Abdullahi, 1006031642

*By our signatures below this statement, we confirm that:*

1. *The work we performed in connection with the Guided Design was in full accordance with the University of Toronto's academic integrity policies as defined in the Code of Behaviour on Academic Matters.*
2. *The documents we are submitting (drawings and report), as well as the underlying design work and calculations, were produced by our group alone.*

Signatures:
Mahzabin Karim, Adneen Mir, Angela Abdullahi

## 1.0 Introduction

The following report summarizes the demand and capacity checks that were carried out to design a pedestrian bridge. The drawings detailing the bridge can be found at the end of this report.

## 2.0 Design for Transverse Bending

The live and dead load factored moment diagram is shown in Figure 1. This diagram has the maximum factored moments from all load combinations, as well as the capacity of the reinforcement. 5 – 10M transverse bars were placed in each 1-meter span on the top and bottom of the deck slab to resist positive and negative transverse moment. The design includes 5 bars to ensure that minimum reinforcement requirements were met (Mcr).

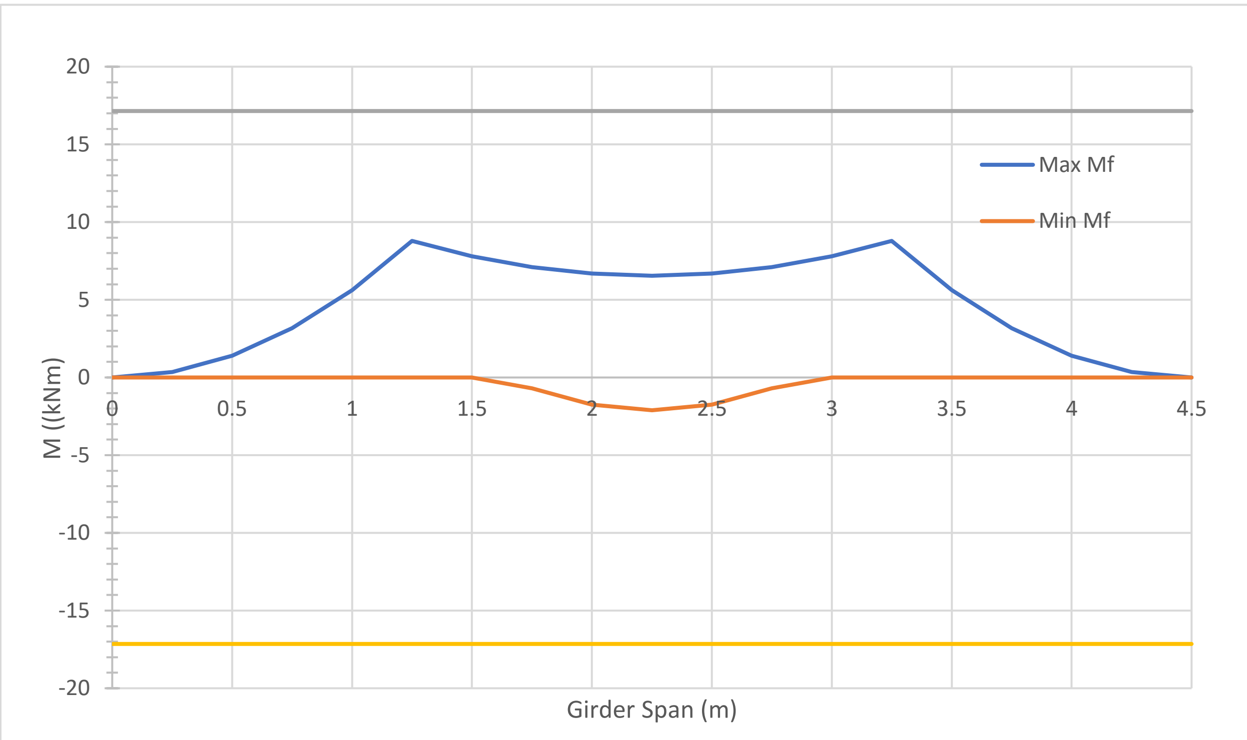



Figure 1: Factored transverse bending demand and capacity (grey and yellow) in the deck slab.

## 2.1 Crack Control of Transverse Design

Transverse Negative Steel Design:

Calculations for Negative Moment (Flange):

$$d_c = MIN(50, clear\ cover\ to\ stirrup + stirrup\ size) + \frac{size\ of\ bars}{2}$$

$$d_c = MIN(50, 40 + 0) + \frac{10}{2} = 40 + 5$$

$$d_c = 45mm = a$$

$$To\ calculate\ A_o:$$

If $(stirrup\ size + clear\ cover\ to\ stirrup) > 50\ then\ A_o = b * \left((2 * centroid) - \left((stirrup\ size + clear\ cover\ to\ stirrup) - 50\right)\right)$, or else $A_o = b * 2 * centroid$

$$stirrup\ size + clear\ cover\ to\ stirrup = 0 + 40 = 40 < 50$$
$$A_o = b * 2 * centroid = 1000 * 2 * 45 = 90000\ mm^2$$

$$A = \frac{A_o}{Number\ of\ bars} = \frac{90000}{5} = 18000\ mm^2$$

$$f_s = 240\ MPa$$

$$z = f_s * (d_c * A)^{\frac{1}{3}}$$
$$z = 240 * (45 * 18000)^{\frac{1}{3}} = 22372.1\frac{N}{mm}$$
$$z = 22372.1\frac{N}{mm} < 25000\ so\ PASS\ CRACK\ CONTROL$$

The number of bars provided to resist negative moment is 5 – 10M bars in each 1000 mm span to pass crack control. Less than this would fail minimum reinforcement requirements.

<u>Transverse Positive Steel Design (symmetrical to negative):</u>

Calculations for Flange:

$$d_c = MIN(50, 40 + 0) + \frac{10}{2} = 40 + 5$$
$$d_c = 45mm = a$$

$$A_o = b * 2 * a = 1000 * 2 * 45 = 90000\ mm^2$$

$$A = \frac{90000}{5} = 18000\ mm^2$$

$$f_s = 240\ MPa$$

$$z = 240 * (45 * 18000)^{\frac{1}{3}} = 22372.1\frac{N}{mm}$$
$$z = 22372.1\frac{N}{mm} < 25000\ so\ PASS\ CRACK\ CONTROL$$

The number of bars provided is 5 – 10M bars in each 1000 mm span to pass crack control. Less than this would fail minimum reinforcement requirements.

## 3.0 Demand for Longitudinal Bending

The live load envelope was obtained by applying three live load cases individually, one being load on the left span only, the second as load only on the right span and the third as load on both spans. The maximum positive and minimum negative values for eight, equally spaced intervals on each span were plotted, this became the live lead envelope.

Load combinations of 1.4D and 1.25D+1.5L, using the unfactored dead and live load envelope, were calculated and once again, the maximum positive and minimum negative values were taken. The 1.25D + 1.5L load case governed. This became the factored moment envelope. The unfactored dead, unfactored live envelope and factored envelope due to dead and live load can be seen in Figure 2, Figure 3 and Figure 4, respectively.

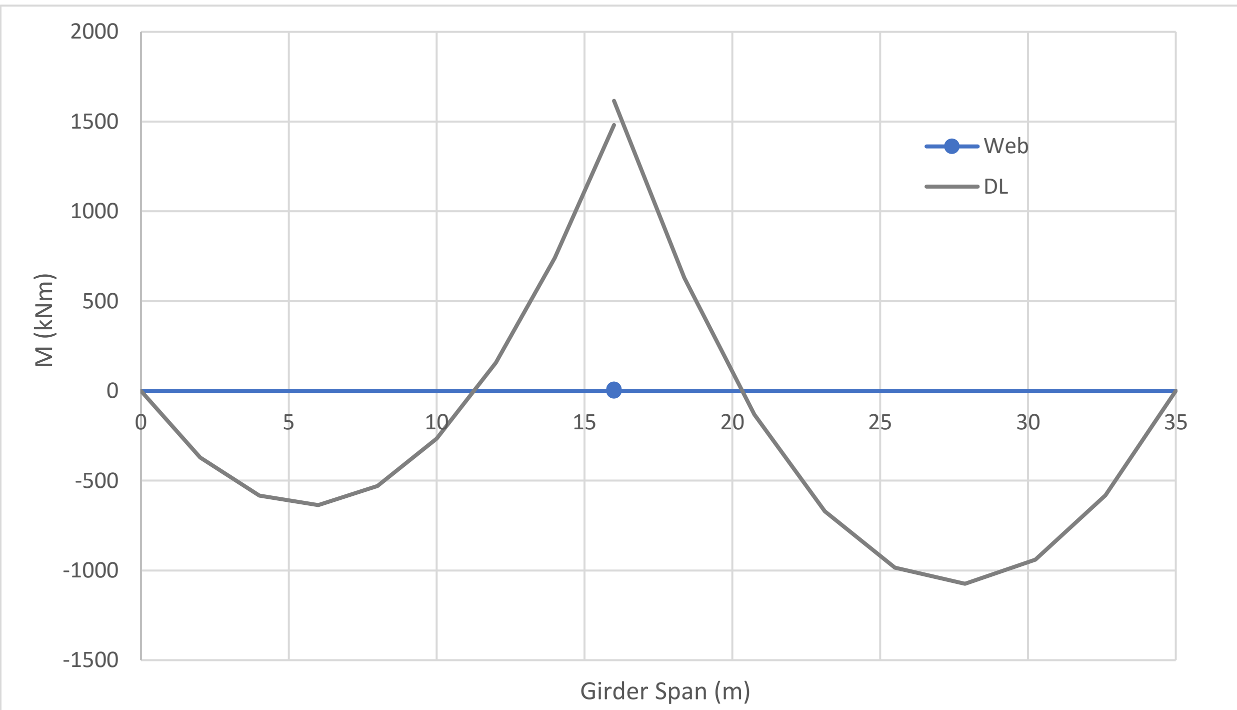



Figure 2: Unfactored dead load moment demand.

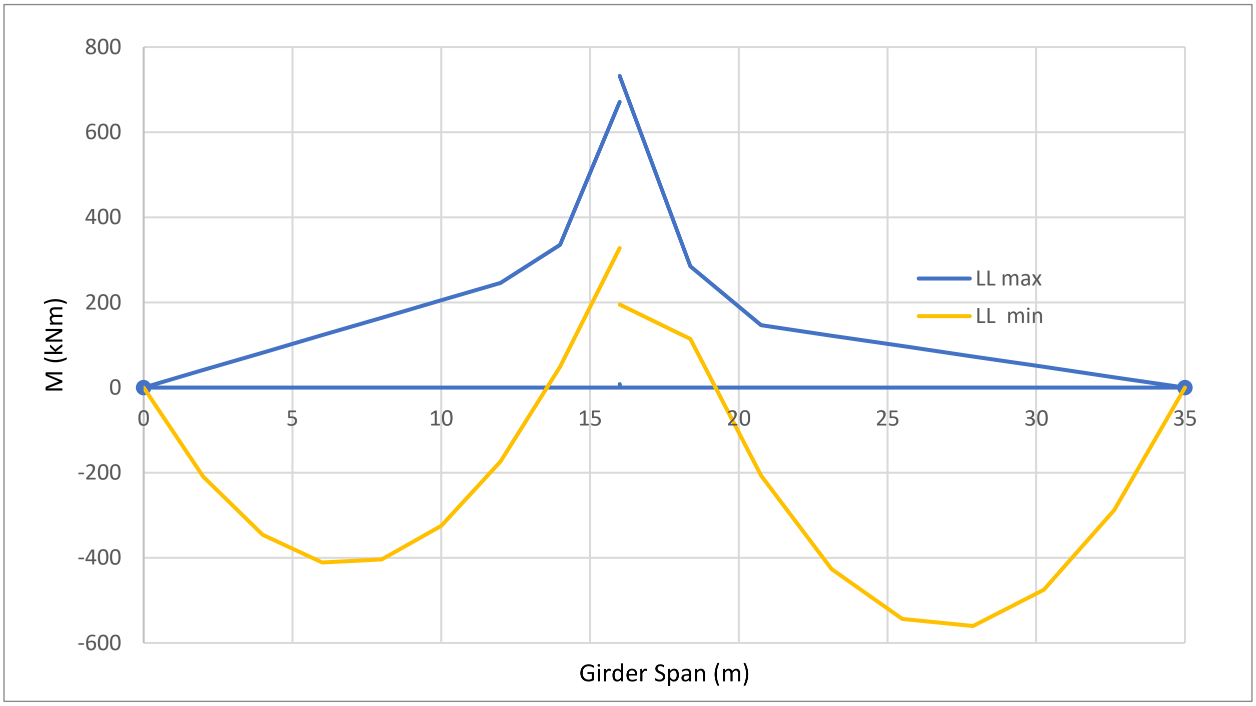



Figure 3: Unfactored live load moment envelope.

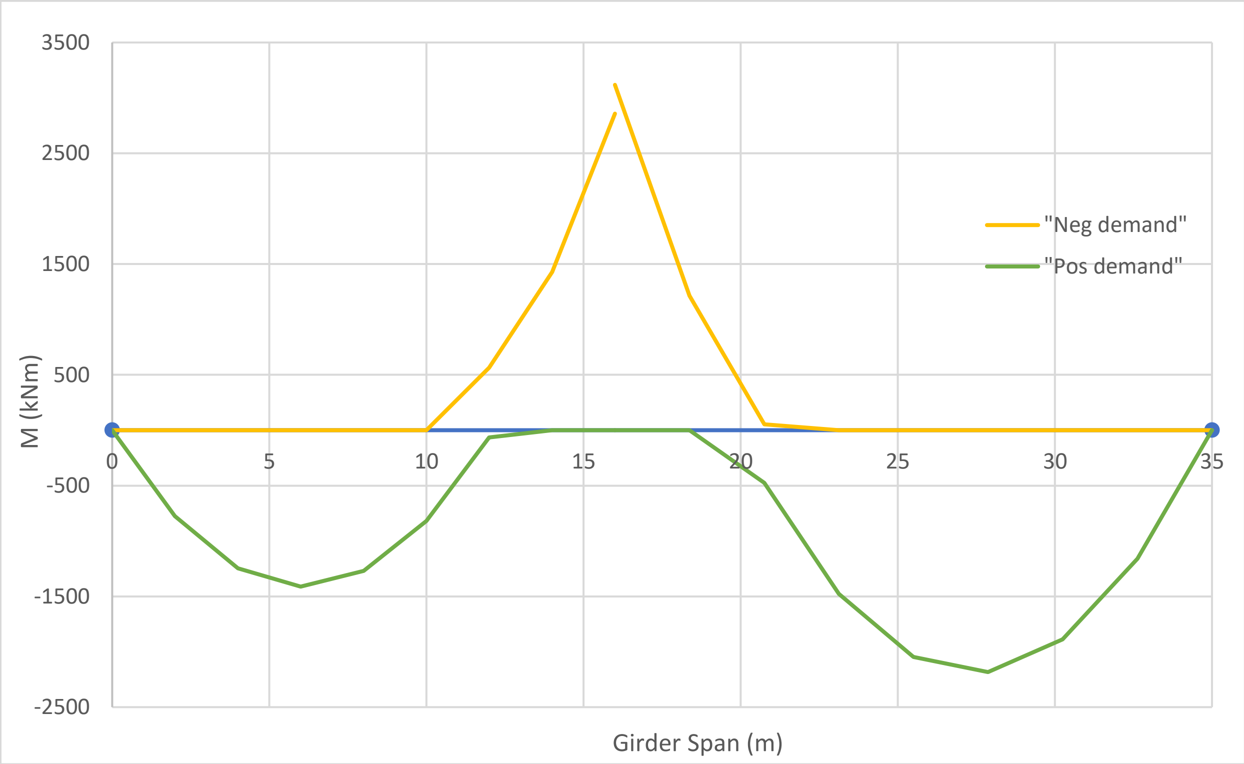



Figure 4: Factored moment envelope at ULS.

## 3.1 Crack Control for Longitudinal Steel in Girder

Longitudinal, negative moment resisting steel crack control can be seen in Figure 5, including the curtailed bar arrangement case. In both cases crack control is met. The z parameter is checked here.

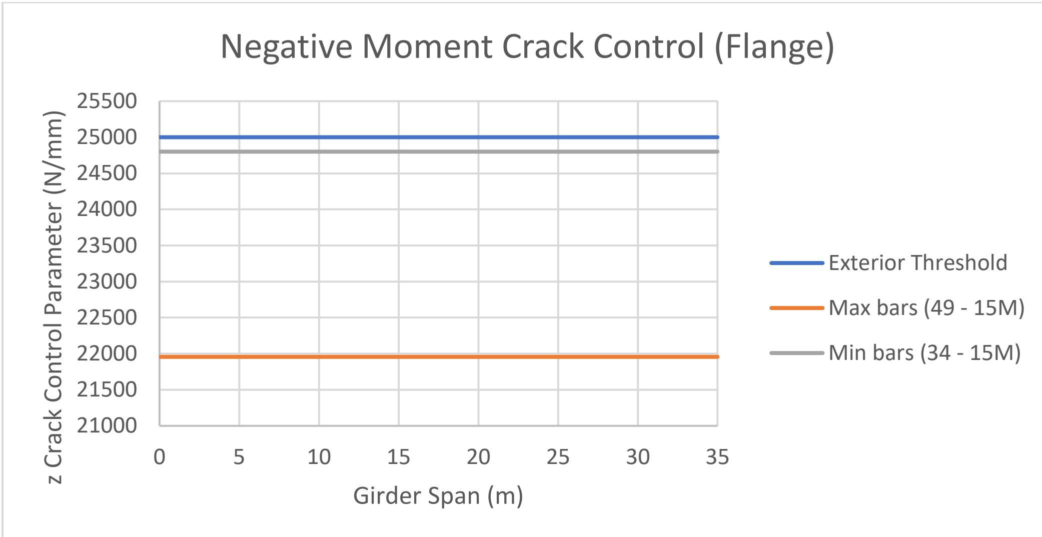



Figure 5: Z parameter for crack control in flange.

Longitudinal, positive moment resisting steel crack control can be seen in Figure 6, including the curtailed bar arrangement. In both cases crack control is met. The z parameter is checked here.

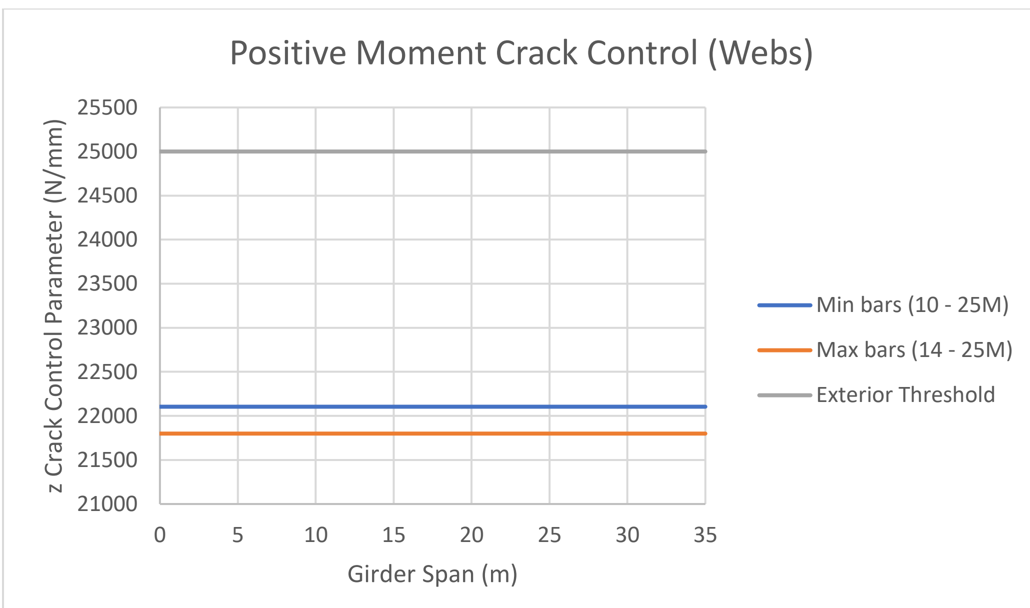



Figure 6: Z parameter for crack control in webs.

## 4.0 Design for Shear Demand

The shear for each of the cases discussed in section 3.0 was plotted. The respective shear demand diagrams can be found in the figures below. This includes unfactored dead, unfactored live shear envelope and the factored dead and live shear envelope. The 1.25D + 1.5L case governed.

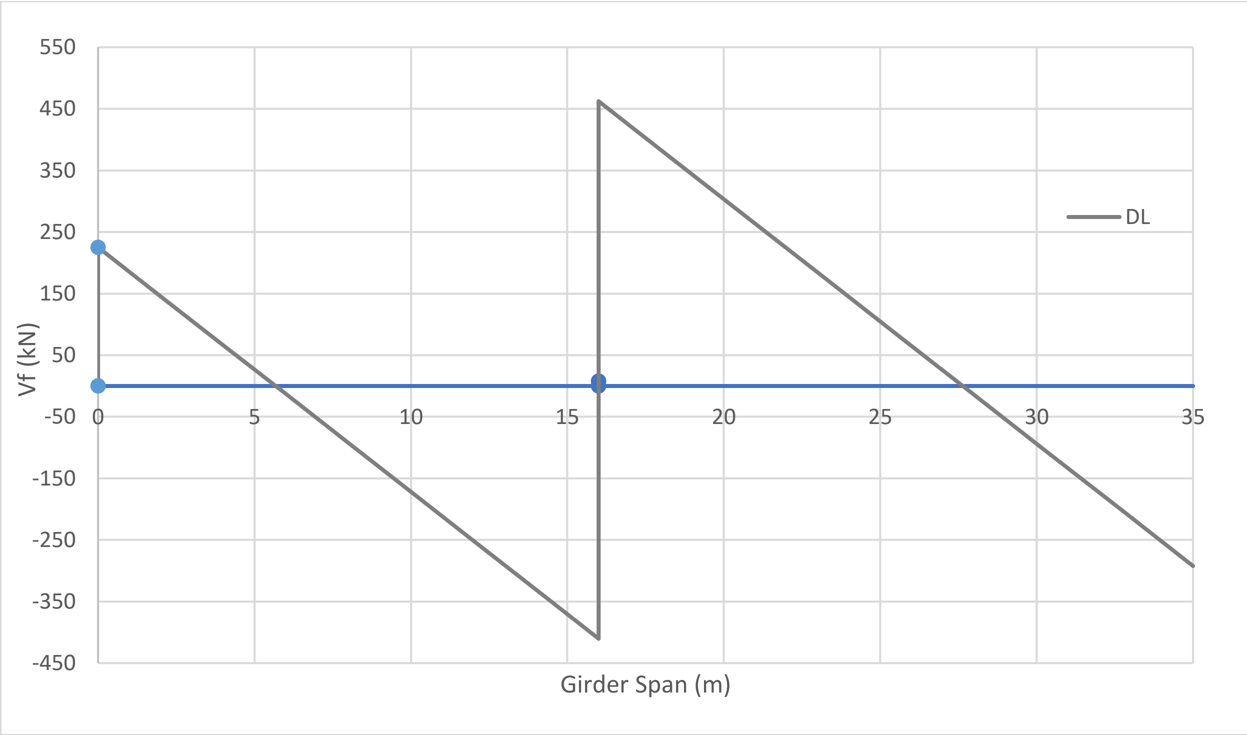



Figure 7: Unfactored shear demand due to dead load.

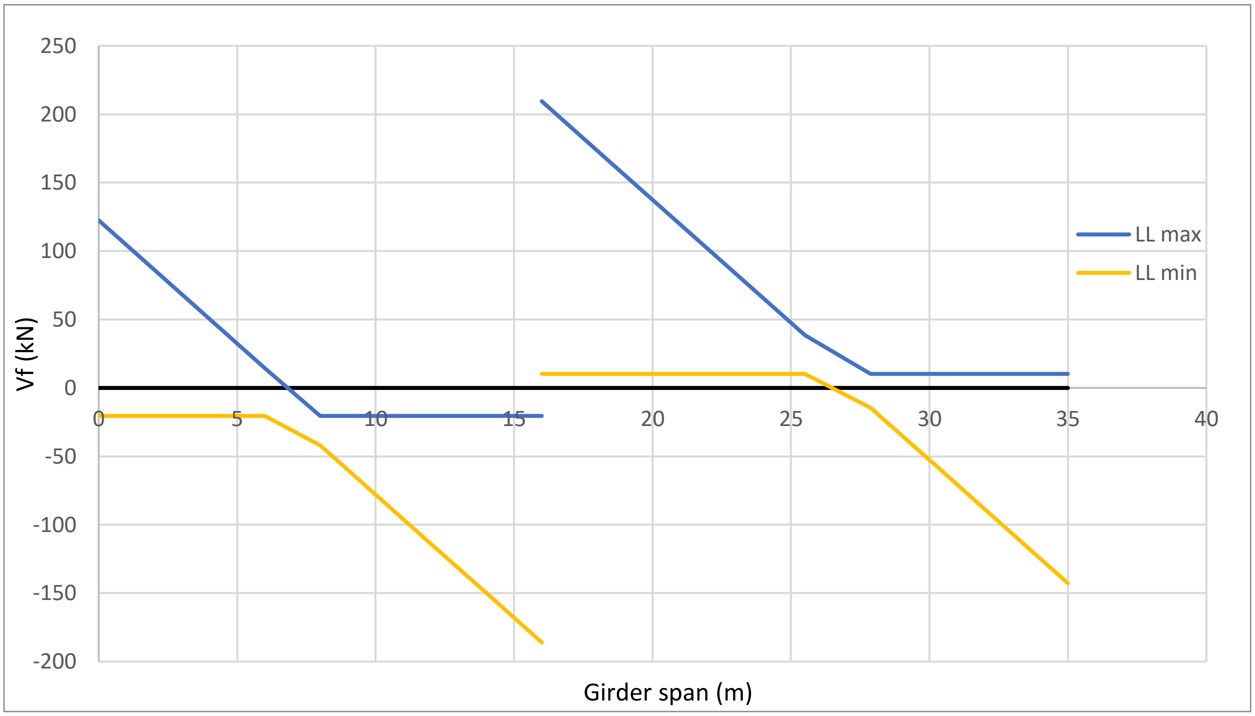



Figure 8: Unfactored shear demand live load envelope.

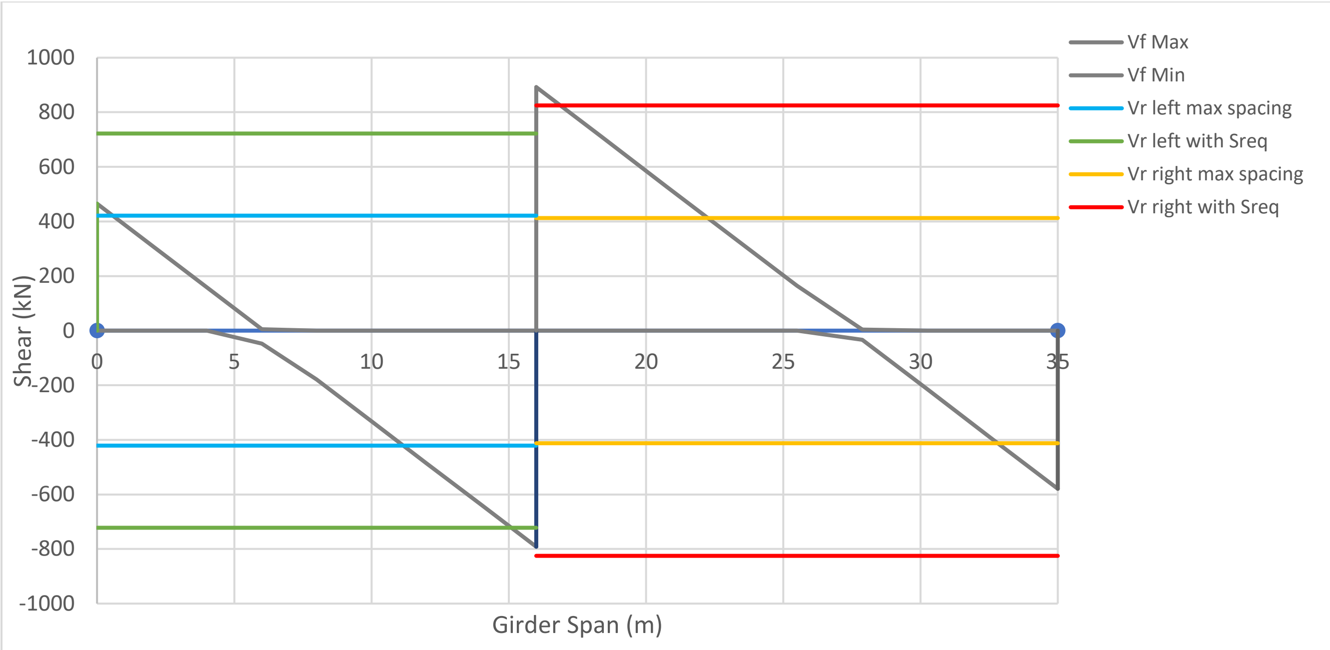



Figure 9: Factored shear demand envelope with capacities.

## 5.0 Elastic Girder Deflections due to Dead Load

Figure 10 shows the deflections in the spans due to dead load.

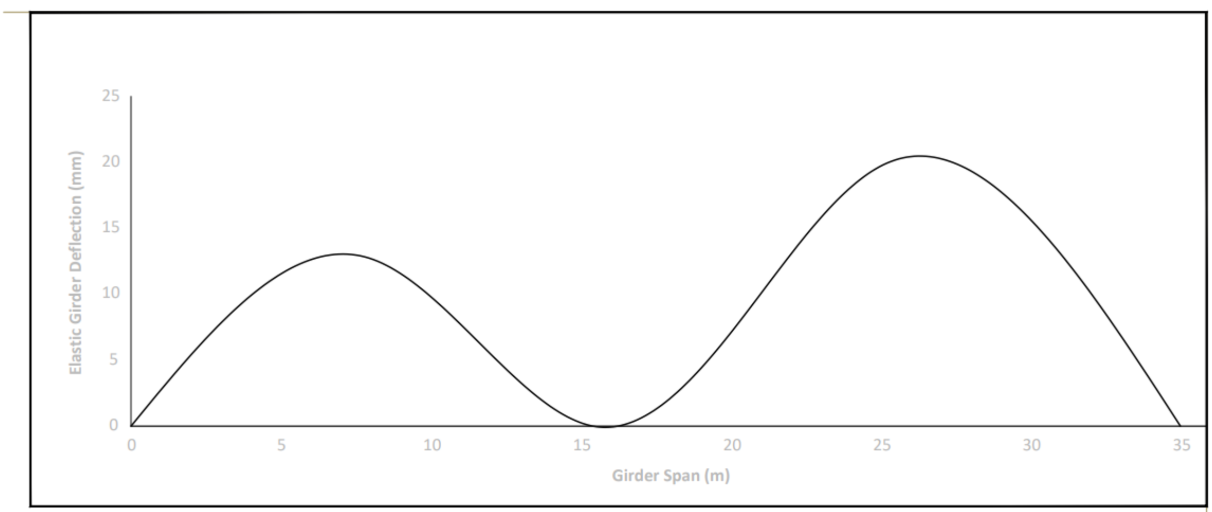



Figure 10: Elastic girder deflection due to dead load.

## 6.0 Interaction Diagram for Pier

Three points were plotted to get the interaction diagram as shown in Figure 11. This included the pure tension and pure compression limit states. A total of 10 points (combinations of factored M,N pairs) were then plotted. Each load case was tested at two points, the top and bottom of the pier. The results can be seen in Figure 11. All points remained within the interaction diagram.

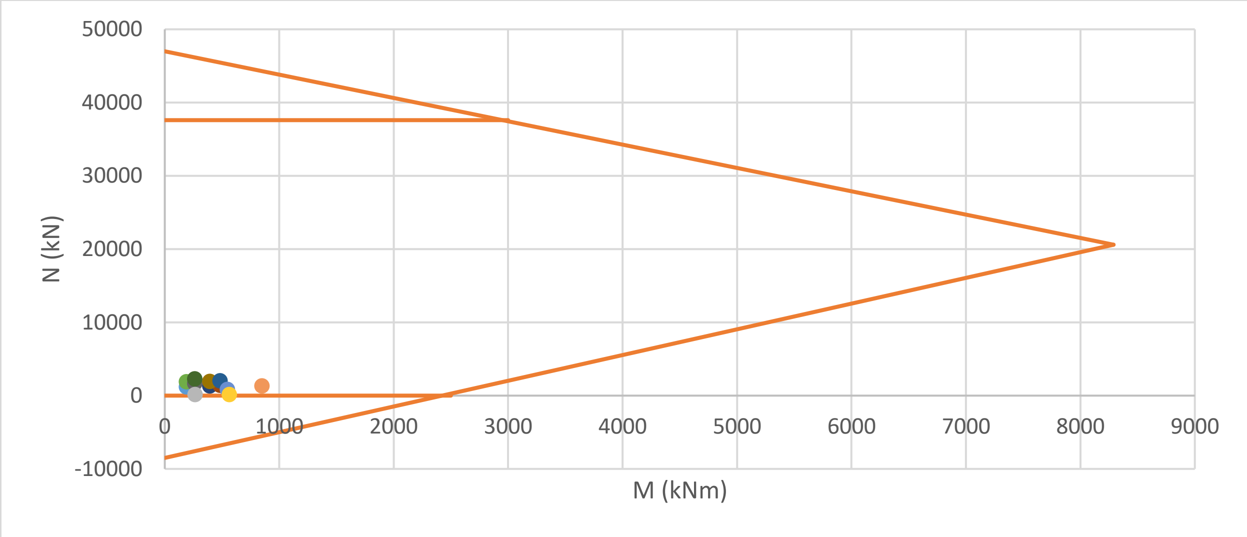



Figure 11: Interaction diagram with factored demand at ULS.

## 7.0 Foundation Design

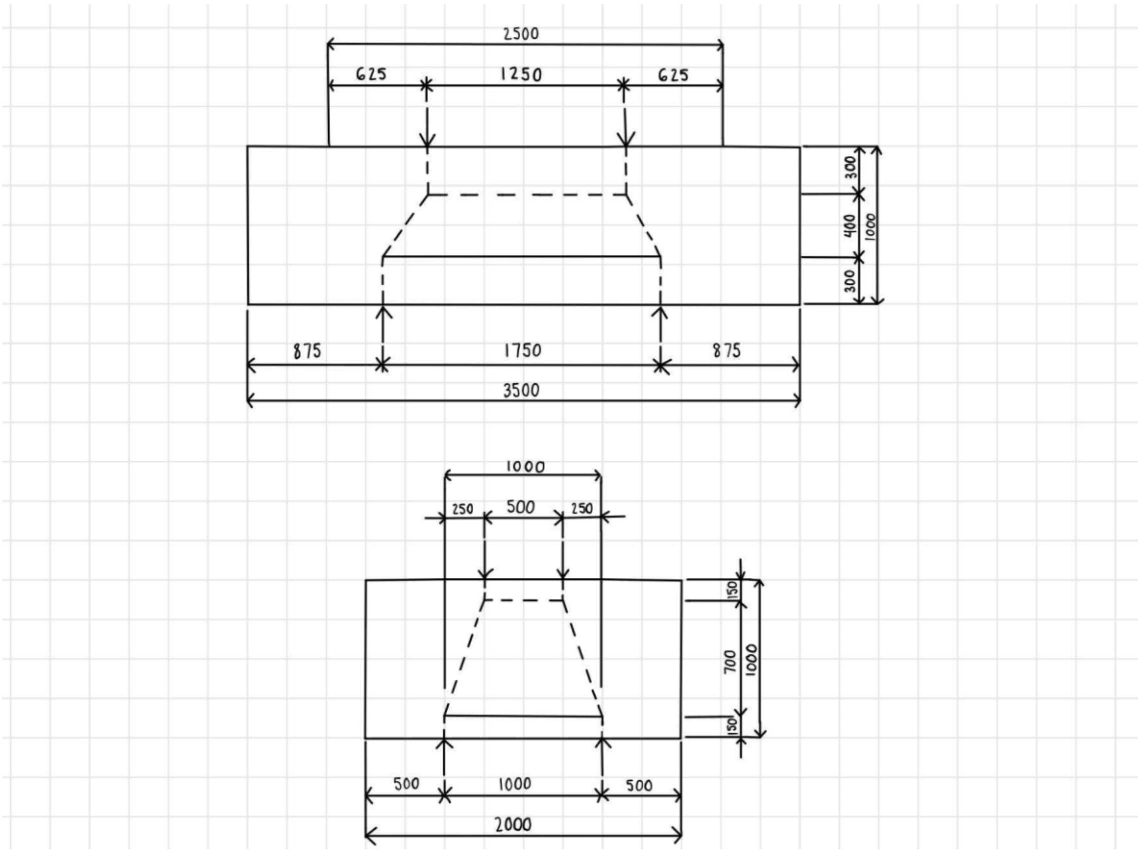



Figure 12: Truss model used for the design of the foundation.

The pure axial case governed, and the corresponding moment was set to 0 to be conservative. The cases tested were the pairs with maximum moment and its corresponding axial load, and the one with the maximum axial load with its corresponding moment set to 0. The truss model shown was used to design the longitudinal bars at the bottom of the footing.

## 8.0 Pier to Girder Connection Design

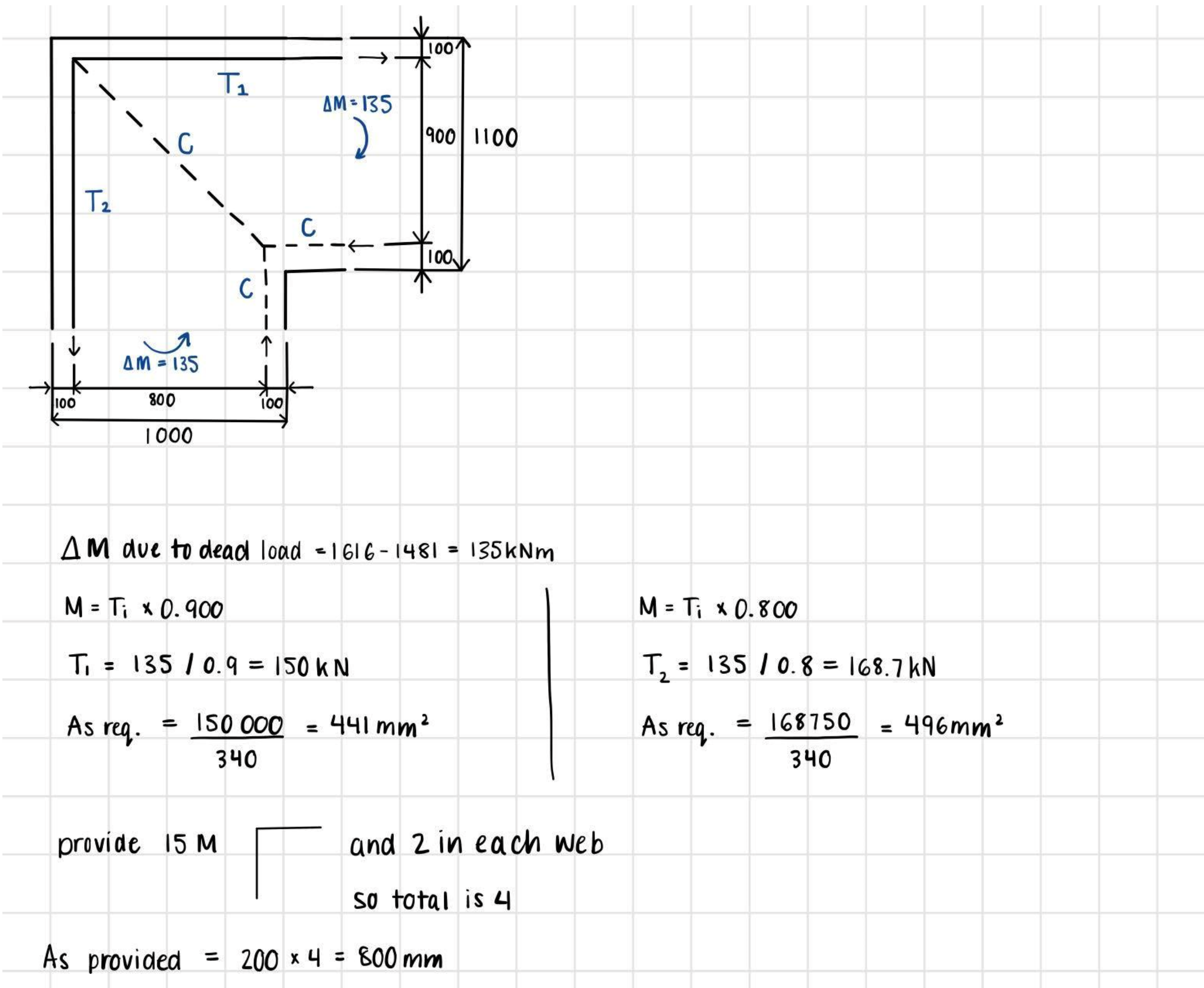


Figure 13: Truss model fused for the design of the pier to girder connection.

The change in moment is taken from the jump in moment from the unfactored dead load case. This truss model helped design bar group P1506 in the Pier Details (Drawing No. 4).

## 9.0 Peak Tensile Demand Graph at ULS with Curtailment

The tensile capacity and curtailing arrangement of the negative longitudinal bars in the flange are shown in Figure 14. 34-15M bars are to be used throughout the entire span with an additional 15 – 15M bars (total of 49) from 14 – 18 meters of the 35-meter girder.

The positive curtailment arrangement and tensile demand and capacity for each bar arrangement can be seen in Figure 15. A total of 10 – 25M bars (five in each web) span throughout the girder. An additional 4 bars (two in each web) are provided from 22 to 33 meters from left to right, where demand is the greatest.

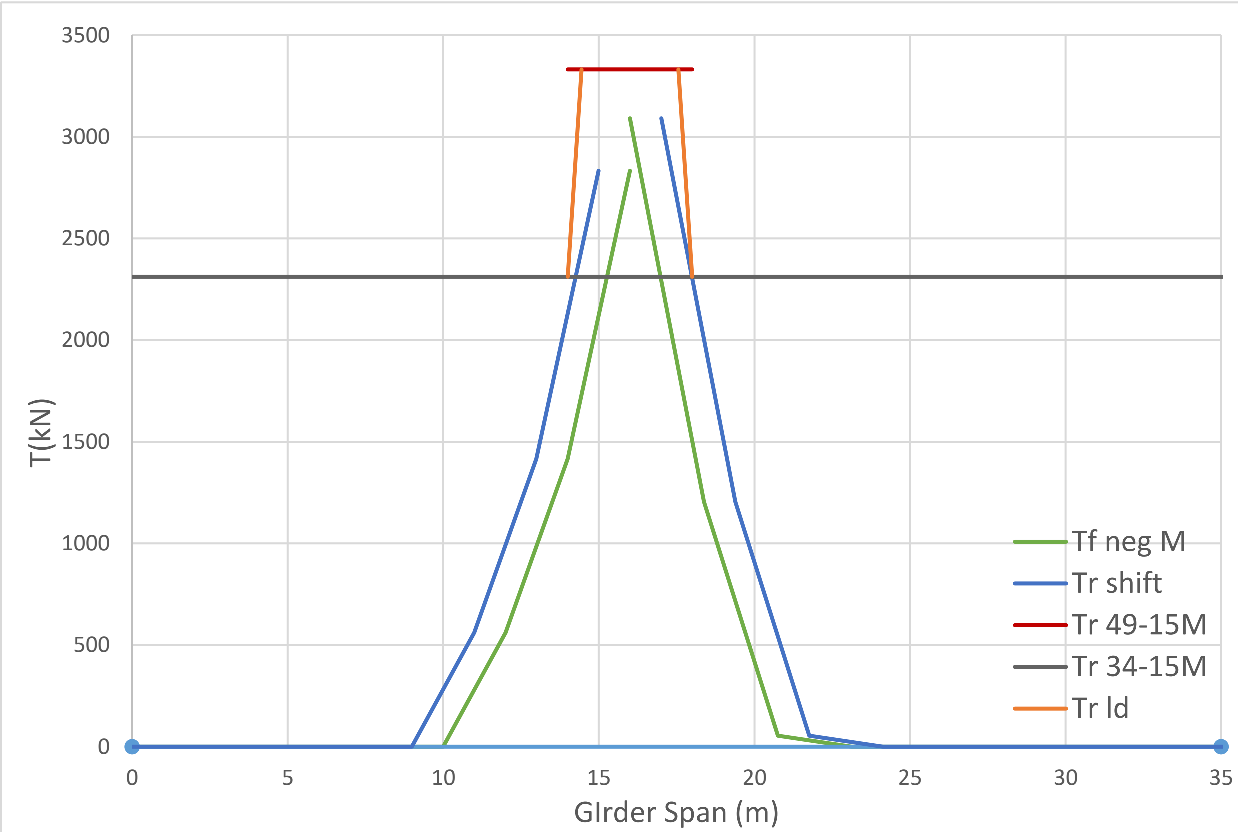



Figure 14: Peak tensile demand at ULS in the top longitudinal reinforcement in the girder and capacity provided by curtailed reinforcement.

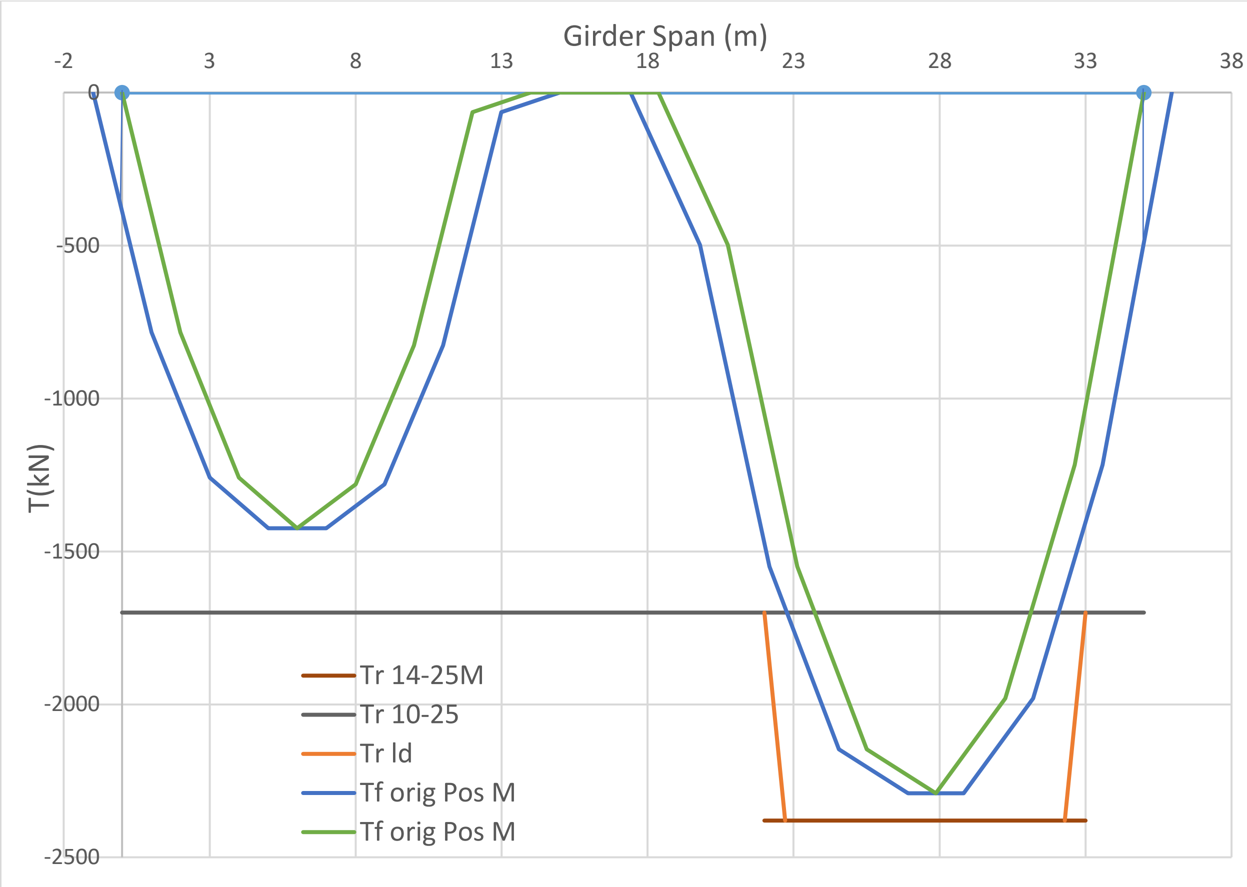


Figure 15: Peak tensile demand at ULS in the bottom longitudinal reinforcement in the girder and capacity provided by curtailed reinforcement.

## 10.0 Abutment Reactions

Table 1: Reactions at abutments for all factored and unfactored load cases.

| Load / Load Case | Reaction Abutment 1 (kN) | Reaction Abutment 3 (kN) |
|---|---|---|
| Dead | 225 | 292 |
| LL1 | 122 | -10 |
| LL2 | -20 | 143 |
| LL3 | 102 | 132 |
| EQ | -14.6 | 9.4 |
| 1.4D | 315 | 409 |
| 1.0D + 1.0EQ | 211 | 302 |
| 1.0D + 1.0EQ (opposite direction) | 302 | 211 |
| 1.25D + 1.5LL1 | 464 | 350 |
| 1.25D + 1.5LL2 | 251 | 580 |
| 1.25D + 1.5LL3 | 434 | 563 |

## 11. Concrete and Reinforcement Tables

Steel volumes were obtained by taking the total mass from the schedules in drawing No.6 and dividing by the density. Mass in kg for steel can be found in Drawing No.6.

Table 2: Quantity of reinforcing steel in each section.

| Section | Volume ($m^3$) |
|---|---|
| Girder | 6499 kg / 7850 kg/$m^3$ = 0.828 |
| Pier | 0.0273 |
| Footing | 0.271 |
| Total | **1.13** |

Table 3: Quantity of concrete in each section.

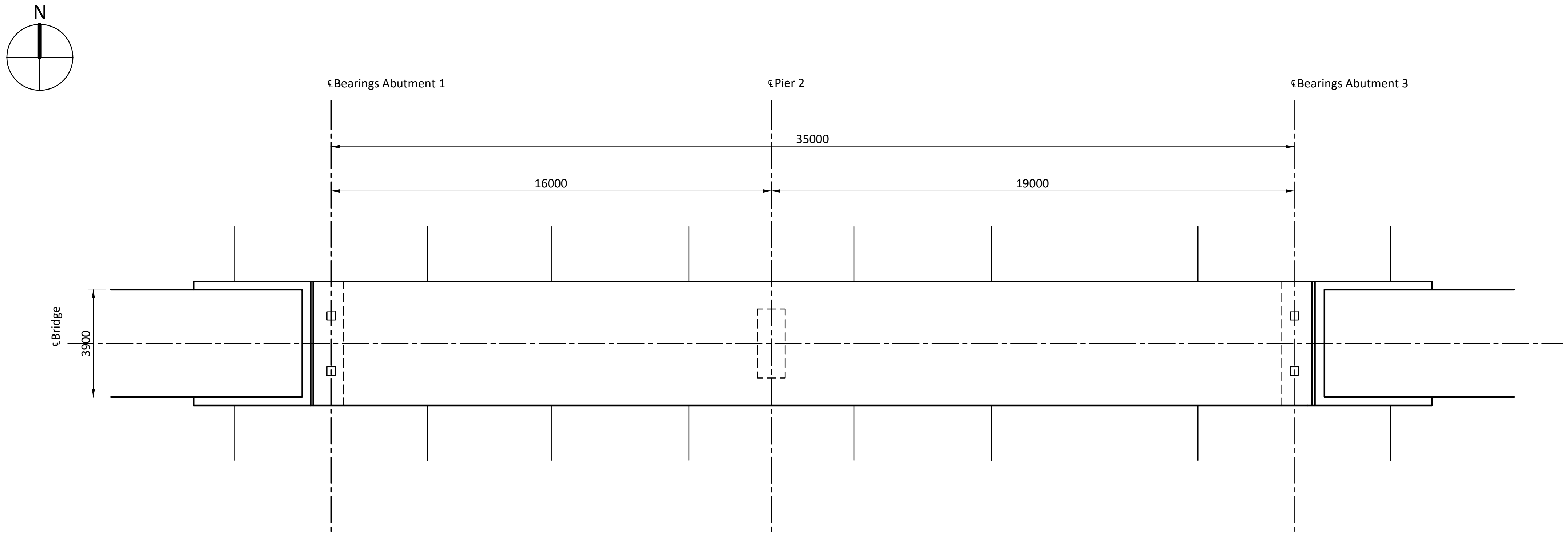
| Section | Volume ($m^3$) |
|---|---|
| Girder | 60.1 - 0.828 = 59.3 |
| Pier | 20.3 |
| Footing | 6.73 |
| Total | **86.3** |

All reinforcement volumes were subtracted from concrete volumes. Prior to this the volumes for the concrete were found as follows:

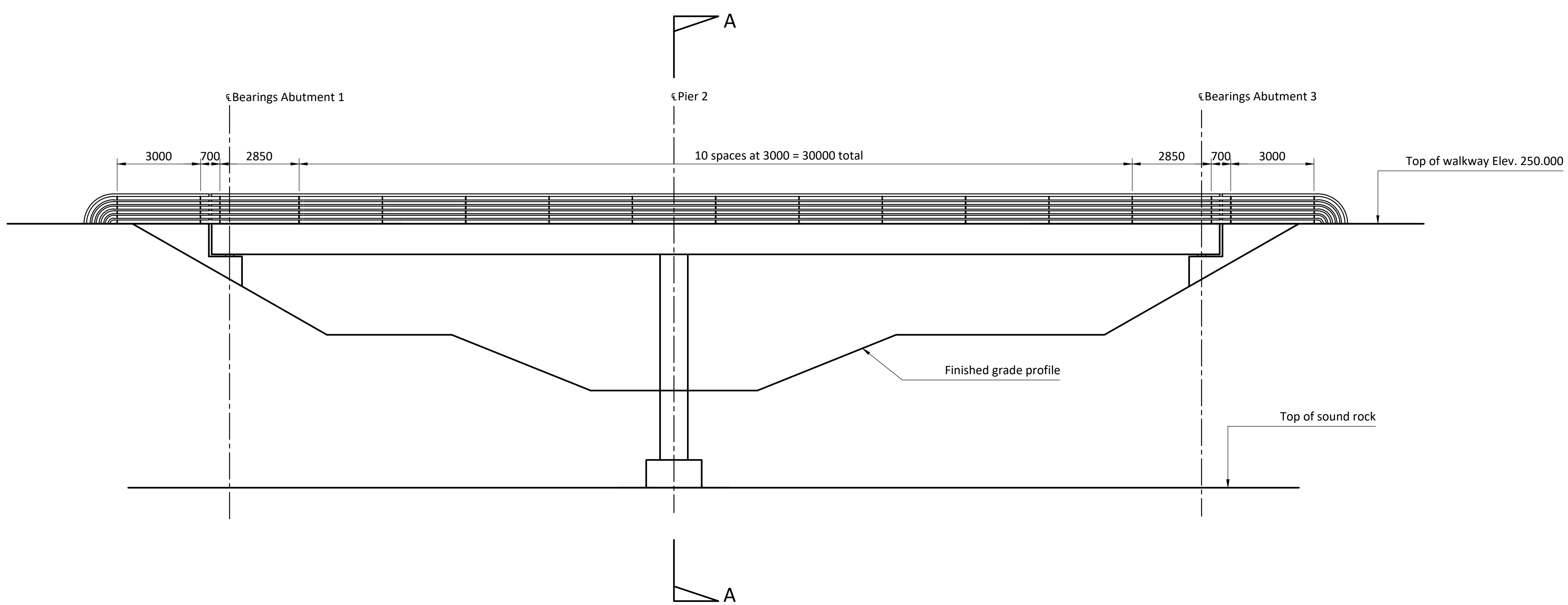
Girder:
Area = 1.655 m^2
Length = 36.300 m (including extension beyond abutments)
Volume = 36.3*1.655 = 60.1 m^3

Pier:
Volume = 2.50*1.00*7.4 + 2.5*1*0.95 = 20.9 m^3 (accounts for monolithic connection from pier to girder)

Footing:
Volume = 3.5*2*1 = 7 m^3



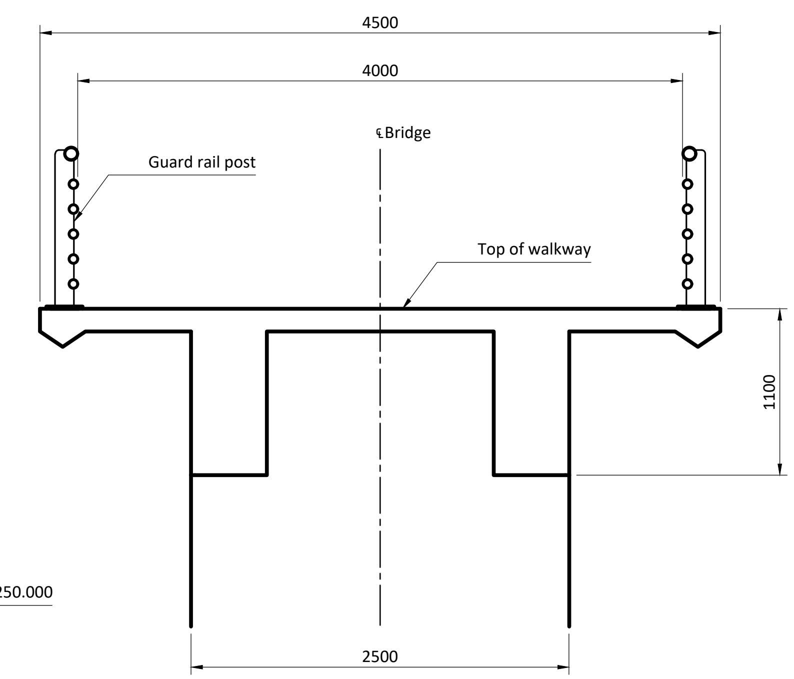

PLAN 1:200




ELEVATION 1:200

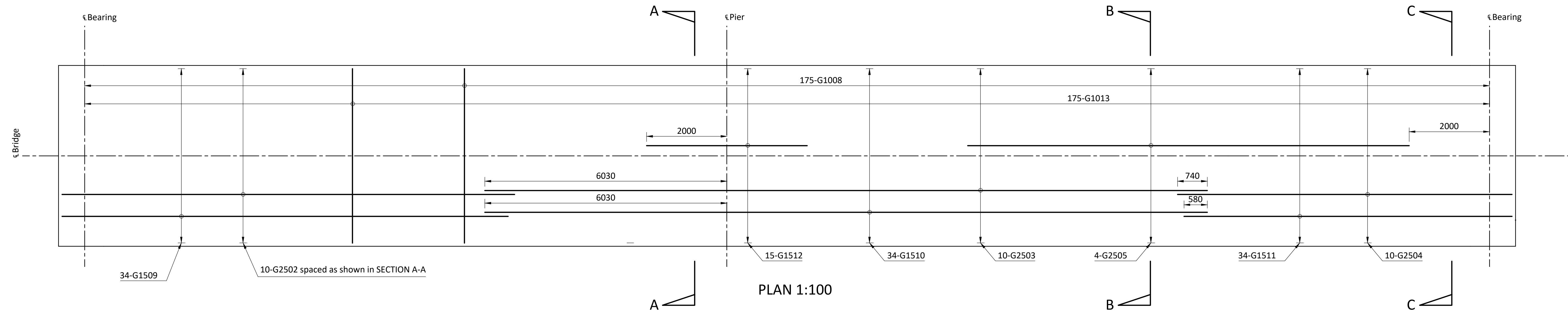
## Notes

1. Dimensions are in millimeters unless otherwise noted.
2. Elevation are in meters unless otherwise noted.
3. List of views on this drawing is as follows:
   - Plan view of entire bridge (guard rail hidden from plan view for clarity)
   - Elevation view of entire bridge
   - Section A-A through girder
4. Profile of sound bedrock assumed horizontal for this design. Top of sound rock located at elevation 240.500.
5. All foundations shall be placed on sound rock with an Ultimate Limit State (ULS) capacity of 1000 kPa.
6. Girder concrete shall have a minimum compressive strength of 40 MPa at 28 days.
7. Pier concrete shall have a minimum compressive strength of 35 MPa at 28 days.
8. Foundation concrete shall have a minimum compressive strength of 35 MPa at 28 days.
9. Reinforcing steel shall have a minimum yield strength of 400 MPa.
10. Minimum clear cover of 40 mm shall be maintained between reinforcing steel and concrete surface unless otherwise noted.

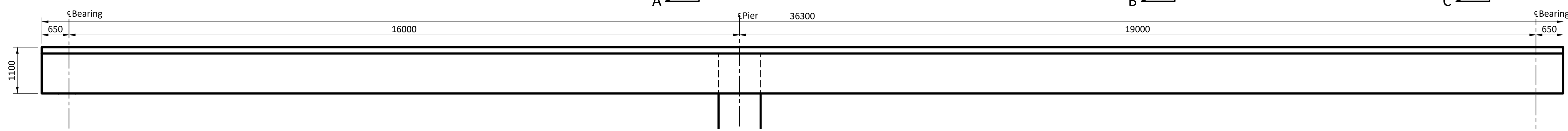



SECTION A-A 1:50

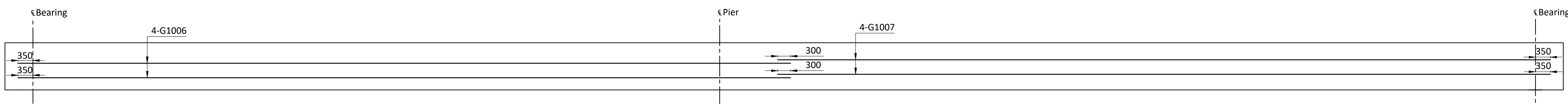
U of T CIV 313S Reinforced Concrete 1
Pedestrian Bridge
GENERAL ARRANGEMENT DRAWING — Dwg. No. R1
April 18, 2022
Mahzabin Karim, Adneen Mir, Angela Abdullahi



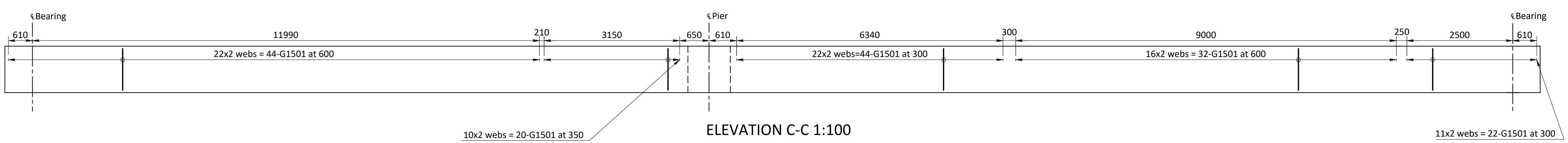

PLAN 1:100



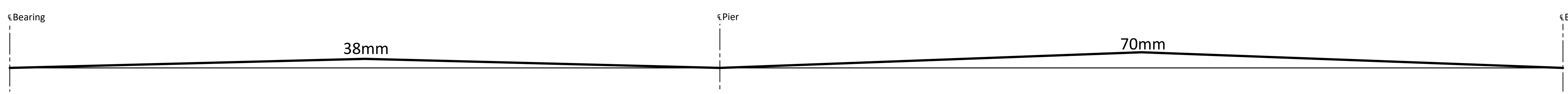

ELEVATION A-A 1:100




ELEVATION B-B 1:100

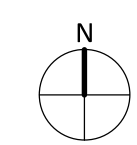



ELEVATION C-C 1:100




CAMBER 1:100

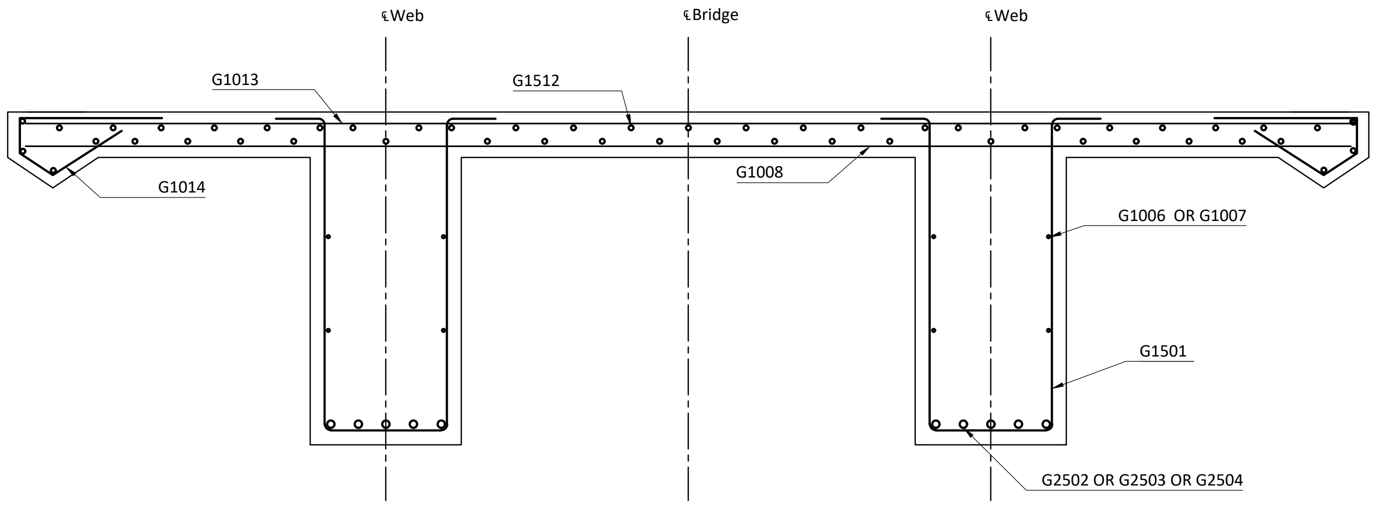
Notes:
1. List of views on this drawing are as follows:
   1.1 Plan view shows the longitudinal and transverse reinforcement in the flange and webs.
   1.2 Elevation A-A shows the overall concrete girder dimensions.
   1.3 Elevation B-B shows the minimum reinforcement in the webs as shown Section A-A of Drawing R3.
   1.4 Elevation C-C shows the stirrup arrangement.
   1.5 CAMBER drawing shows the camber required for the girder at each span.
2. Sections shown in the plan view are in Drawing R3.
3. Adjacent longitudinal bars that are spliced will alternate arrangement to prevent lap splices from overlapping.
4. Refer to drawing No.R6 for Footing Schedule.



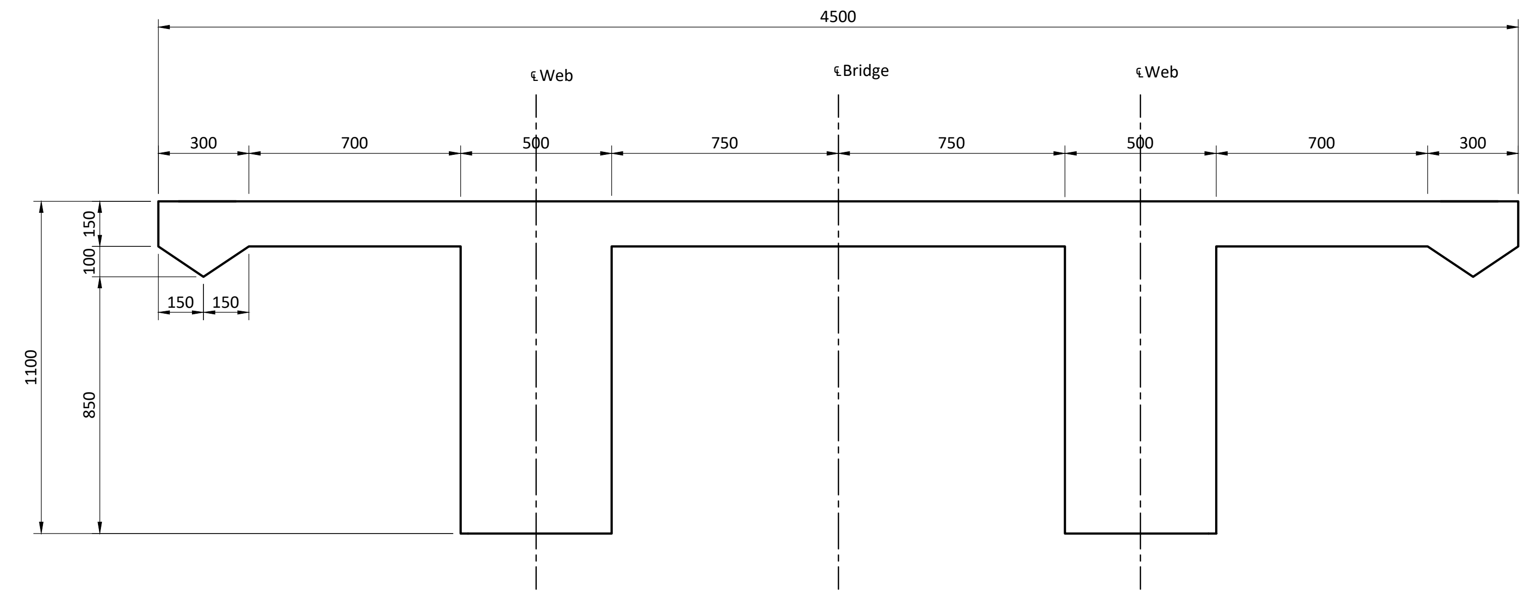

U of T CIV 313S Reinforced Concrete 1
Pedestrian Bridge
GIRDER DETAILS
Dwg. No. R2
April 18, 2022
Mahzabin Karim, Adneen Mir, Angela Abdullahi

NOTES:

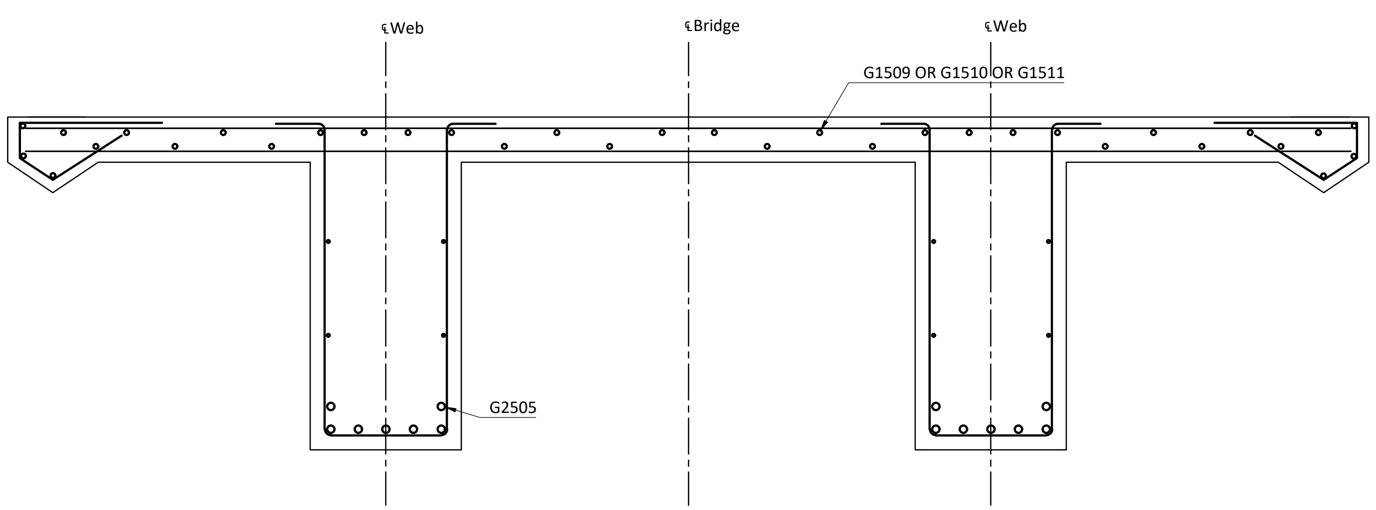
1. List of views on this drawing are as follows:
   1.1. Section A-A includes the maximum number of bars in the flange.
   1.2. Section B-B includes the maximum number of bars in web.
   1.3. Section C-C demonstrates concrete dimensions.
   1.4. Detail of custom stirrup on ends of drip nose.
2. Bar groups with "OR" are spliced and collectively span the entire girder (See Drawing No. R2)
3. Quantity of each bar type is shown in Drawing No. R2 and all bars are equally spaced unless noted otherwise.
4. Refer to Drawing No. R6 for Girder Reinforcement Schedule.
5. Refer to Notes on General Arrangement Drawing for material strengths and concrete cover.



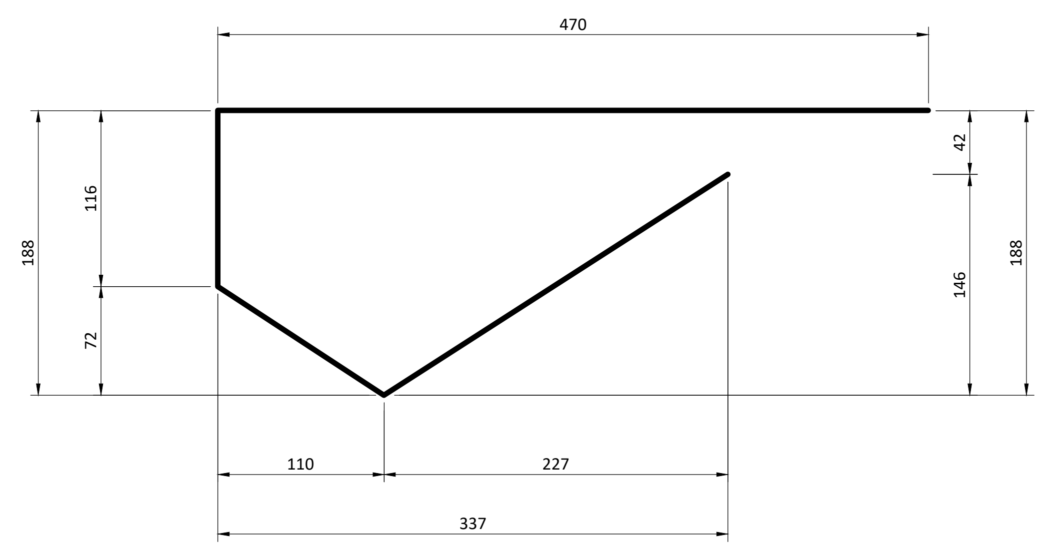

SECTION A-A 1:25




SECTION C-C 1:25




SECTION B-B 1:25

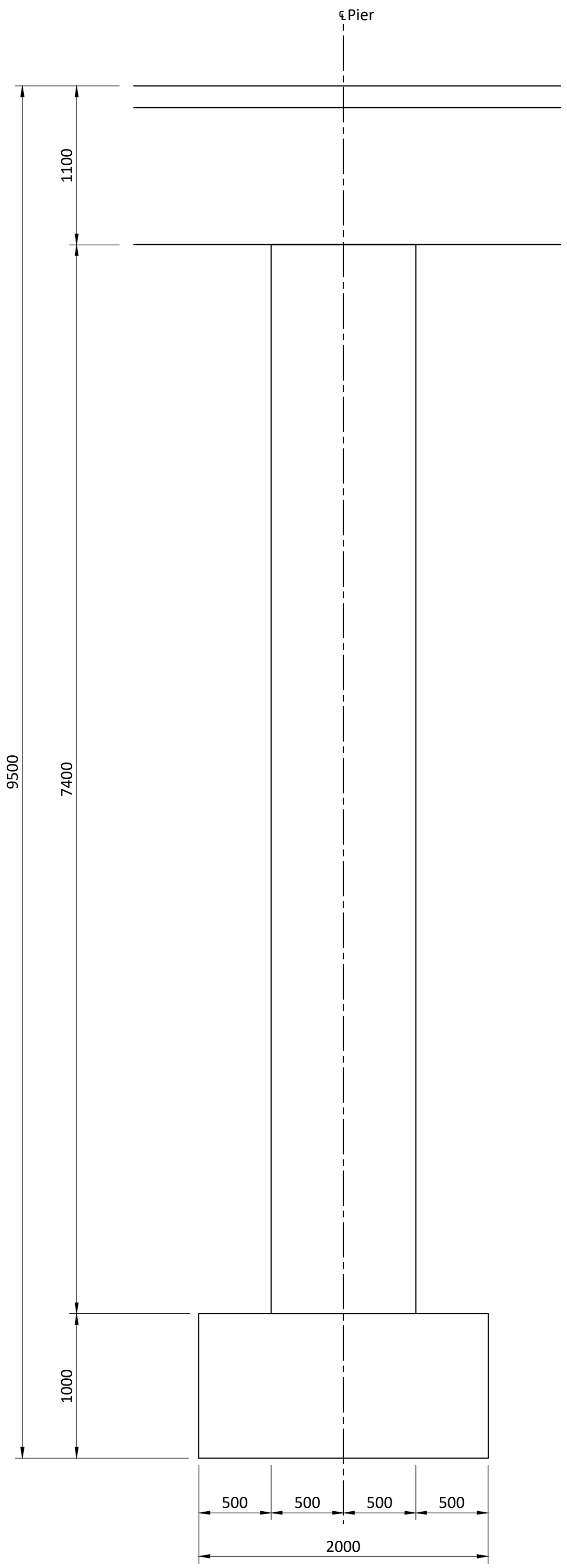



CUSTOM STIRRUP G1014 1 1:5

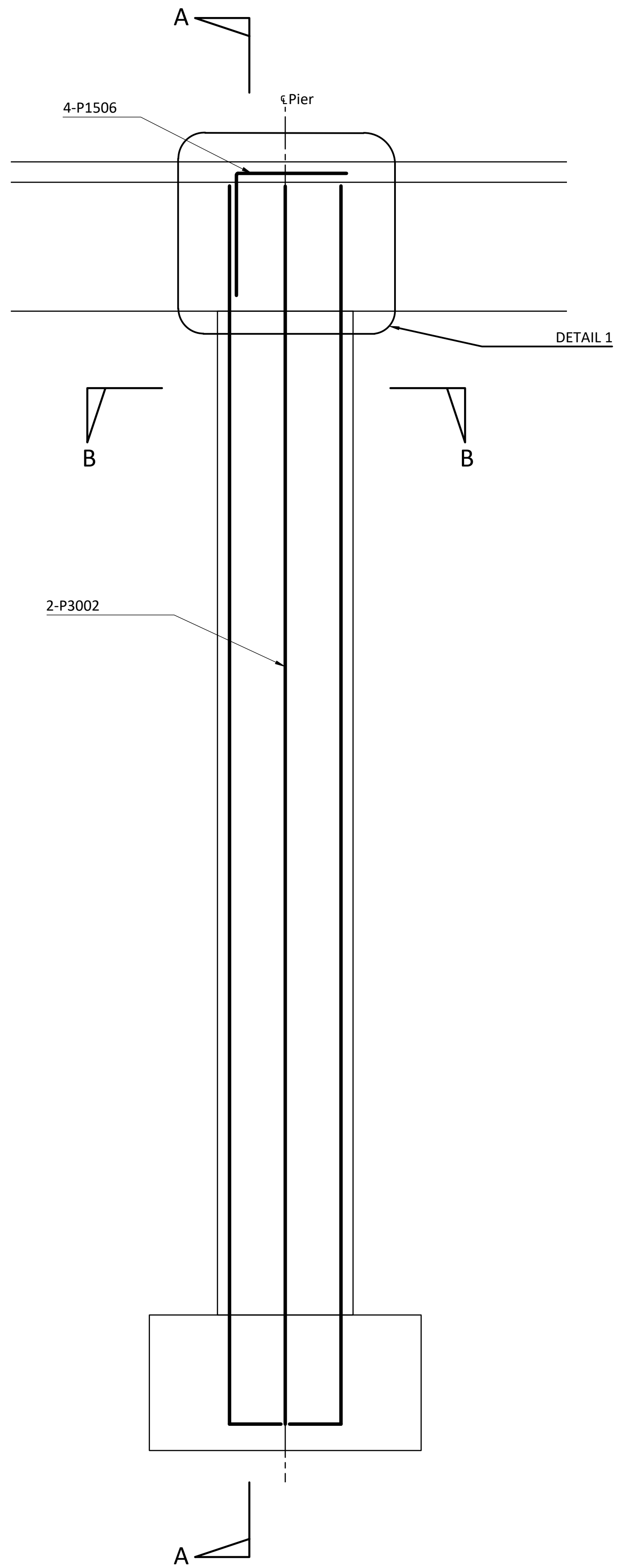
U of T CIV 313S Reinforced Concrete 1
Pedestrian Bridge
GIRDER CROSS-SECTIONS
Dwg. No. R3
April 18, 2022
Angela Abdullahi, Mahzabin Karim, Adneen Mir

# NOTES:

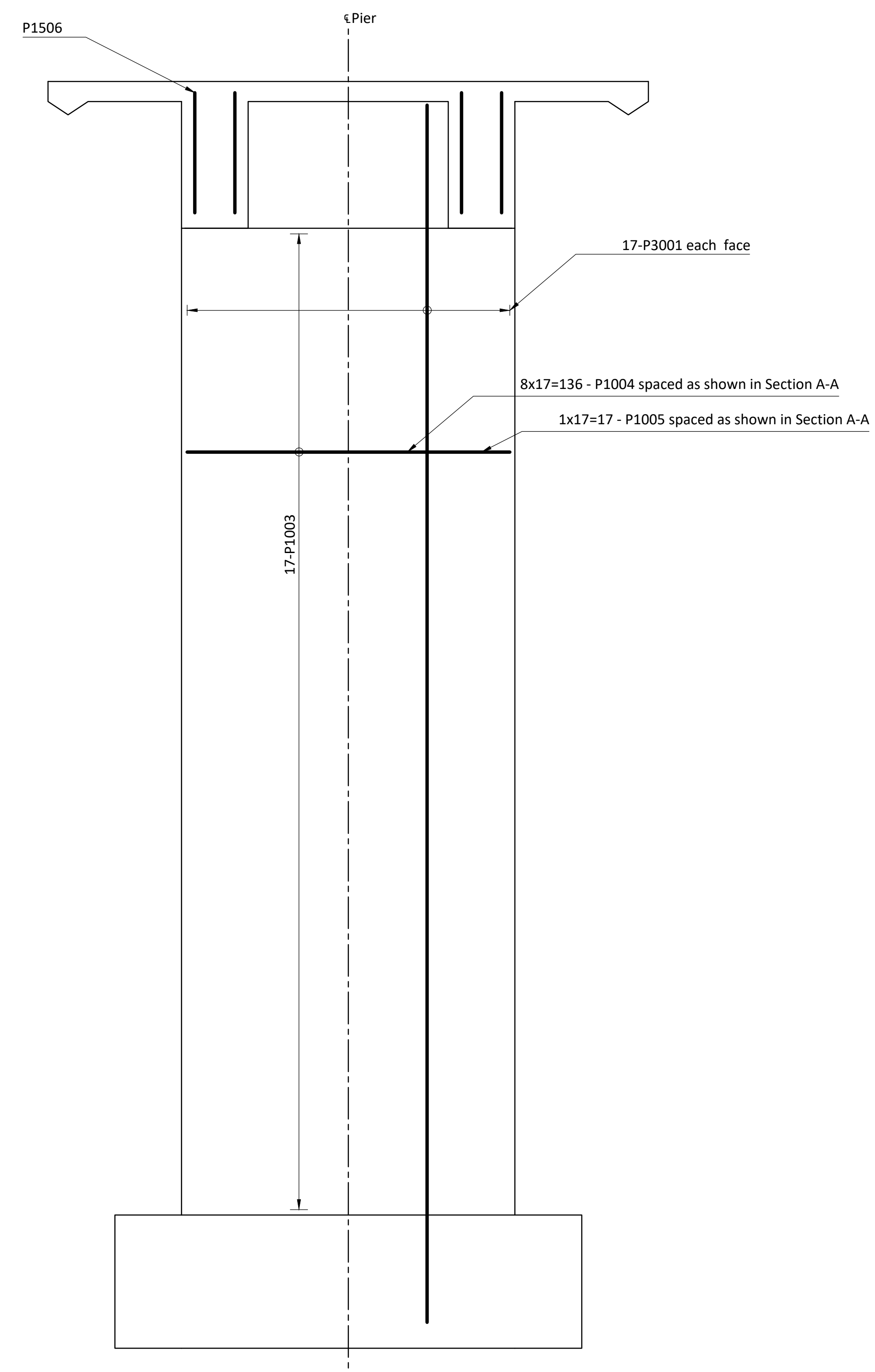
1. List of views on this drawing are as follows:
   - 1.1. Elevation of pier with concrete dimensions.
   - 1.2. Elevation of pier with reinforcement.
   - 1.3. Section A-A showing longitudinal bar and tie spacing along pier.
   - 1.4. Section B-B shows the arrangement of bars in each tie.
   - 1.5. Detail of girder to pier connection bars P1506.
2. P1004 and P1005 bars shall be aligned with each P1003 tie .
3. P1005 bars shall be mirrored for adjacent ties along the pier.
4. Refer to drawing R6 for Pier Reinforcement Schedule.
5. Refer to notes in General Arrangement Drawing for material strengths and concrete cover.



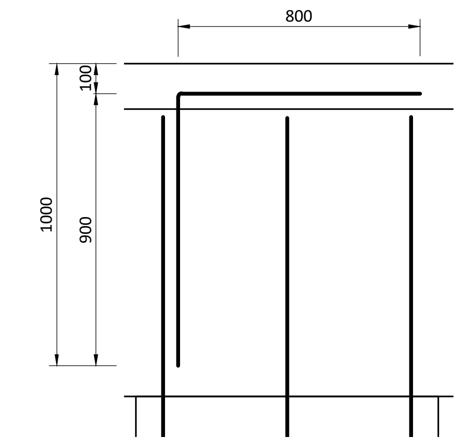

ELEVATION A-A 1:50



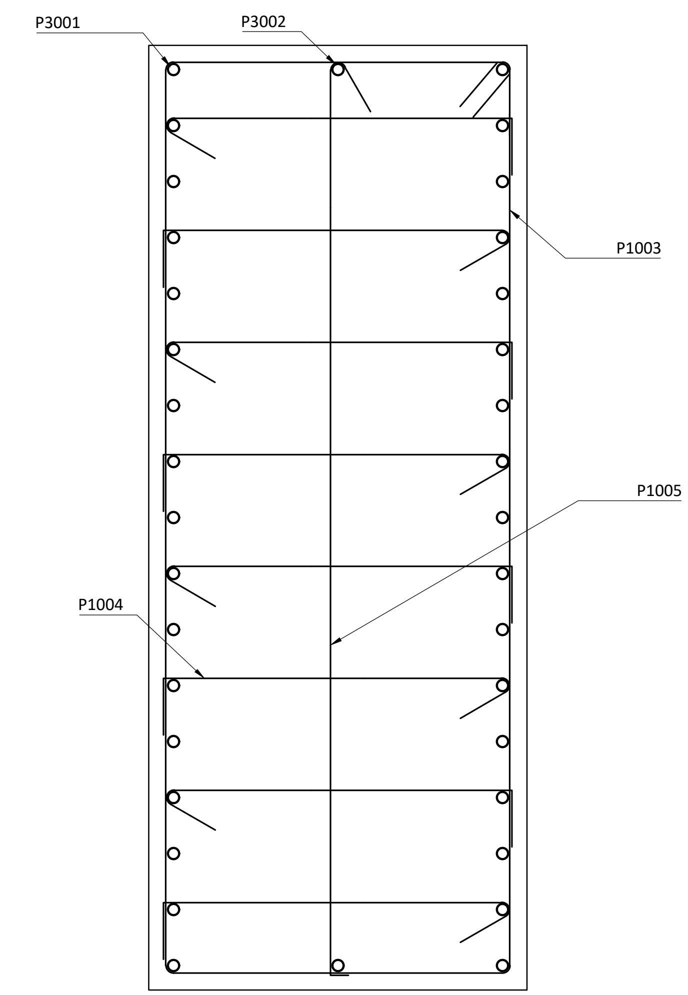

ELEVATION B-B 1:50




SECTION A-A 1:50

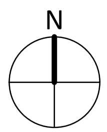



DETAIL 1 1:25



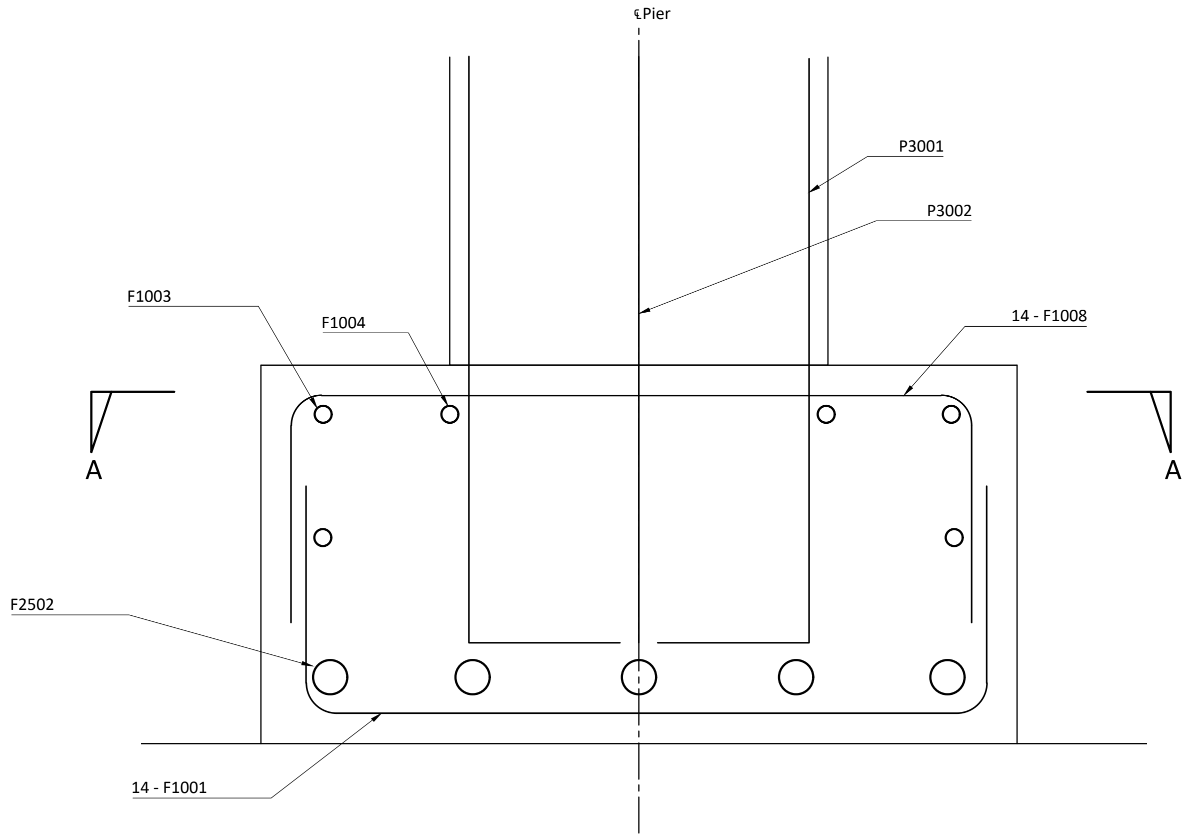

Section B-B 1:20

U of T CIV 313S Reinforced Concrete 1
Pedestrian Bridge
PIER DETAILS
Dwg. No. R4
April 18, 2022
Adneen Mir, Angela Abdullahi, Mahzabin Karim

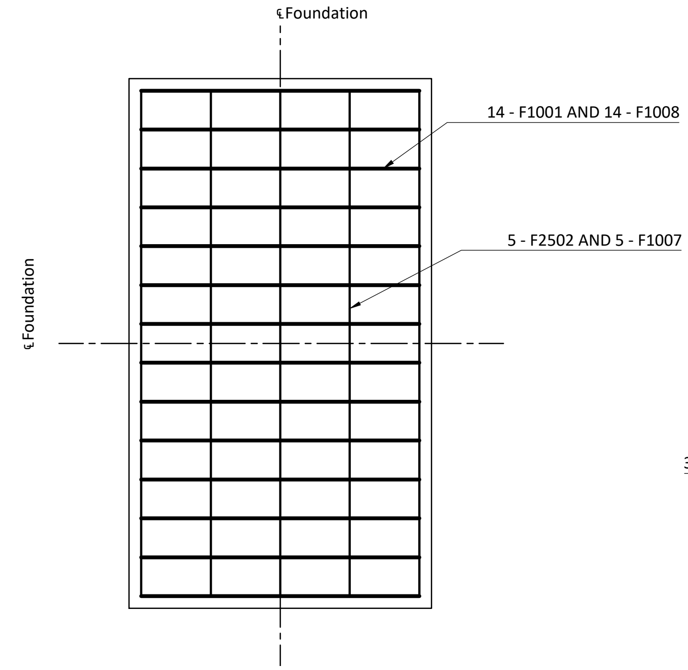


NOTES:

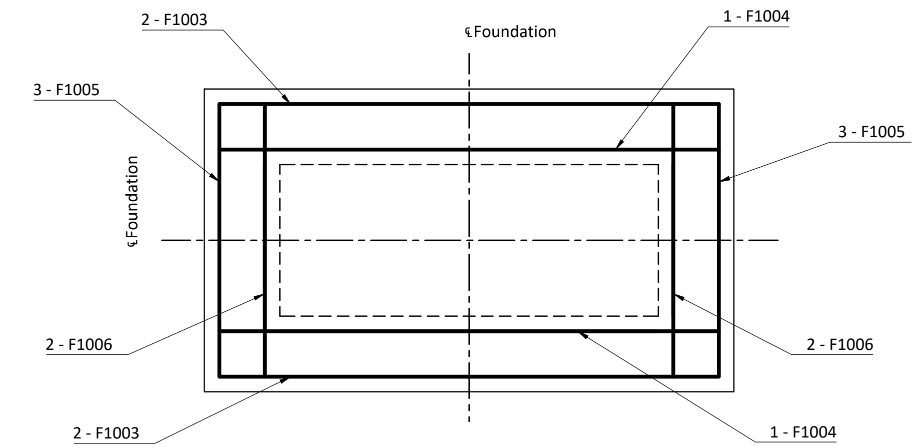
1. List of views are as follows:
   1.1. Elevation A-A of foundation facing north.
   1.2. Elevation B-B of foundation facing west.
   1.3. Section A-A showing rebar arrangement along base of footing.
   1.4. Section B-B shows the arrangement of the minimum bars for spacing requirements and other bars are omitted for clarity.
2. Pier rebar cage shall be installed after F2502 bars.
3. Refer to drawing R6 for Footing Reinforcement Schedule.
4. Refer to General Arrangement Drawing for material strengths and concrete cover.



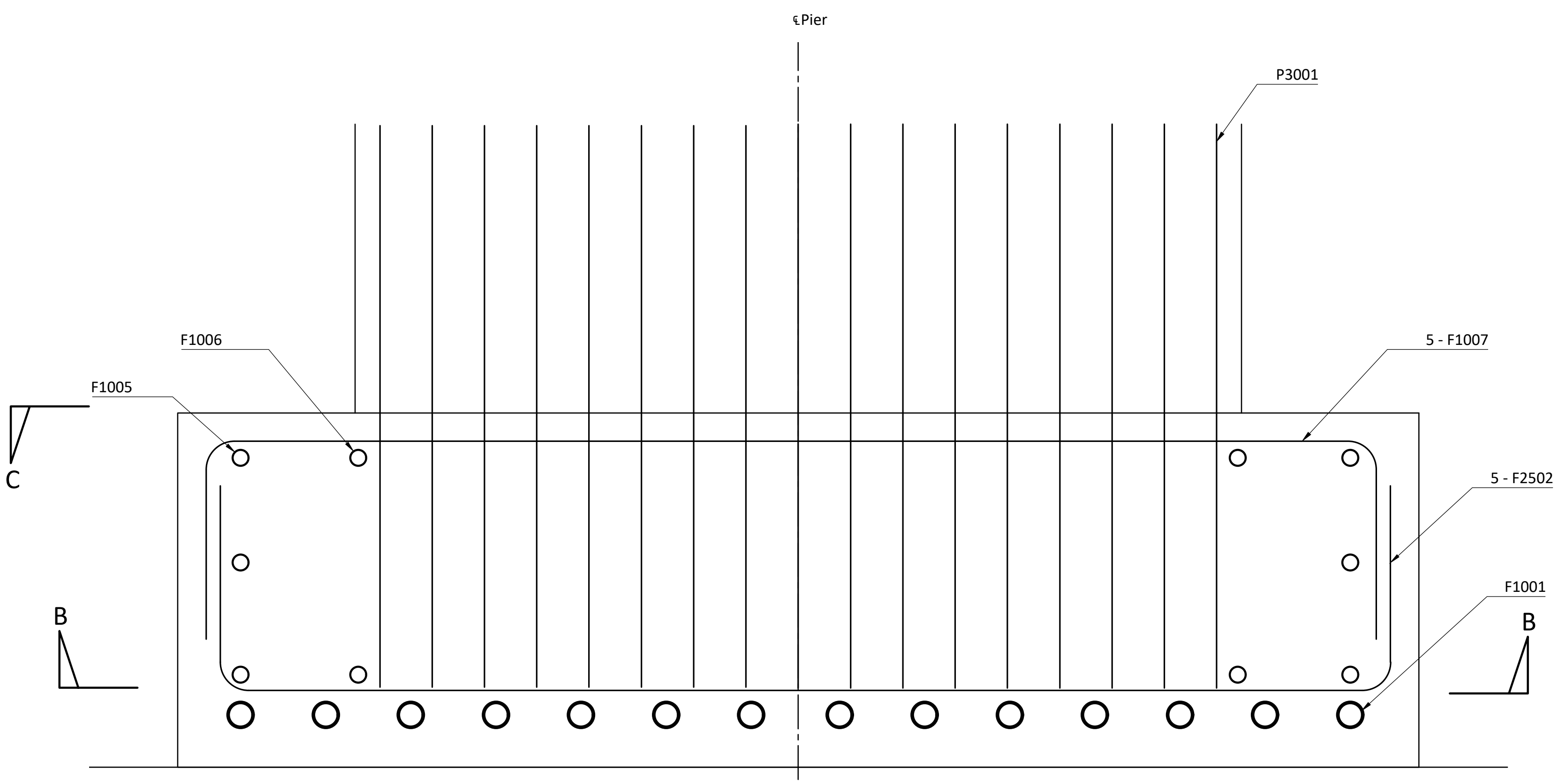

ELEVATION A-A 1:20



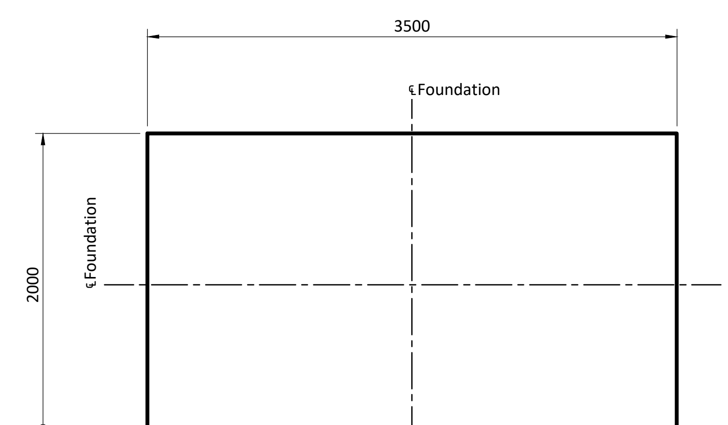

SECTION A-A 1:50




SECTION B-B 1:50

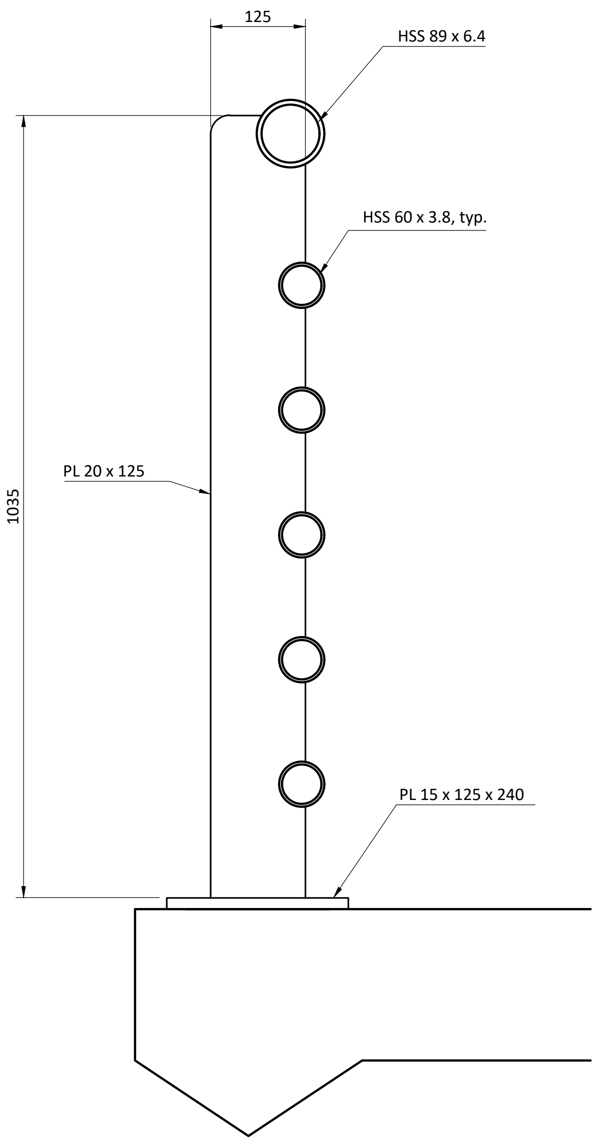



ELEVATION B-B 1:20

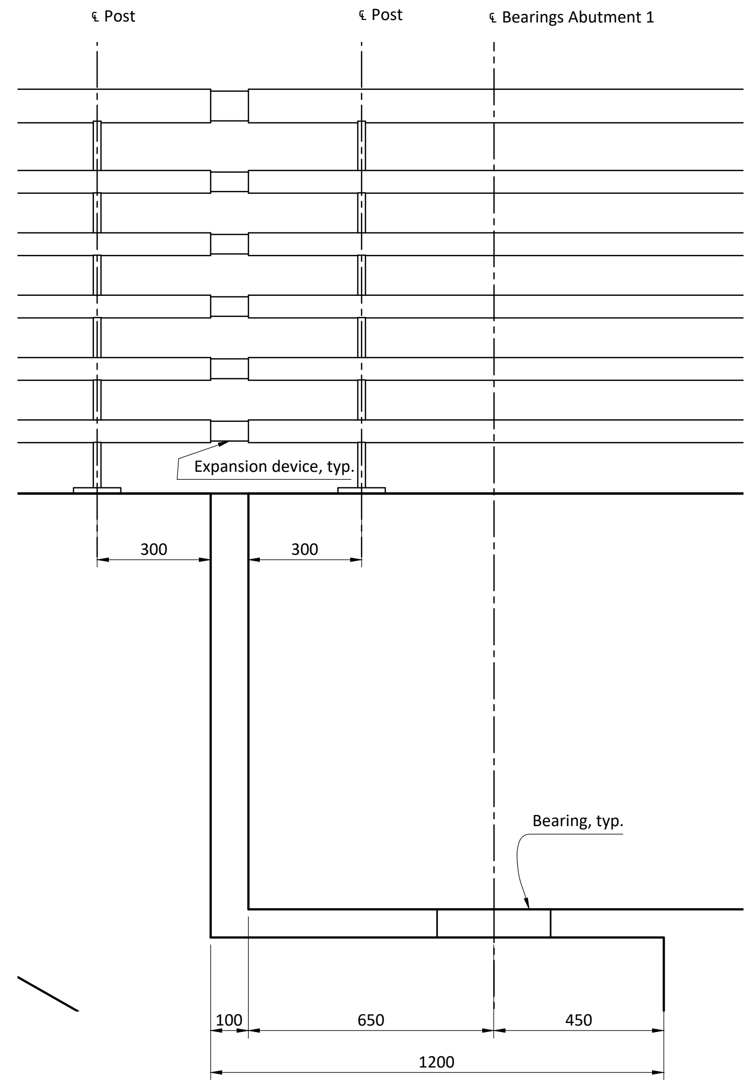



SECTION C-C 1:50

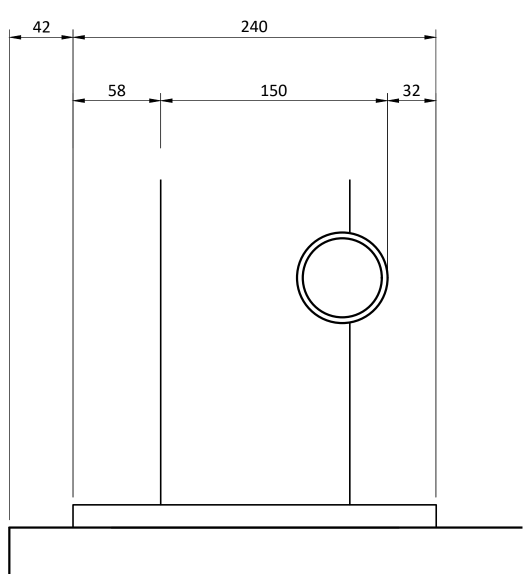
U of T CIV 313S Reinforced Concrete 1
Pedestrian Bridge
FOUNDATION DETAILS
Dwg. No. R5
April 18, 2022
Mahzabin Karim, Adneen Mir, Angela Abdullahi



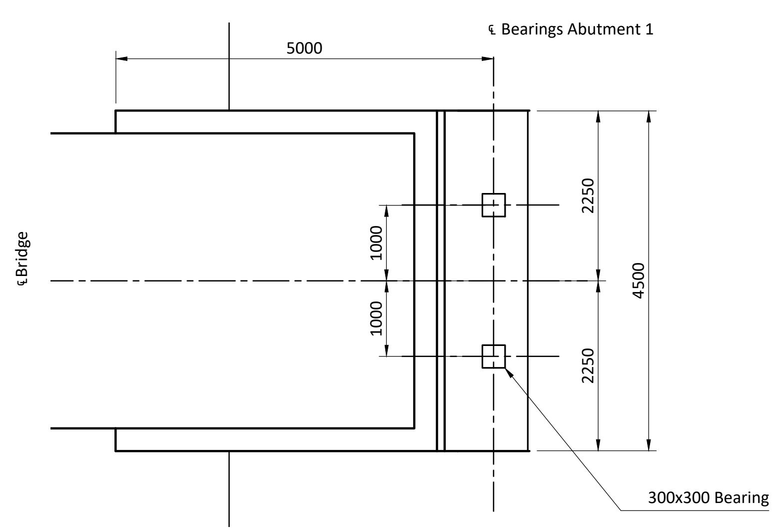

DETAIL OF RAIL 1:10




END OF GIRDER DETAIL 1:20
(Abutment 1 shown, Abutment 3 opposite hand)




DETAIL AT EDGE OF DECK SLAB 1:5




ABUTMENT PLAN DETAIL 1:100
(Abutment 1 shown, Abutment 3 opposite hand)

NOTES:

1. Additional details of the rail and abutments are shown in this drawing.
2. The reinforcement schedules for the girder, pier and footing are provided in this drawing.

## GIRDER REINFORCING STEEL SCHEDULE

| MARK | SIZE | NO. OF BARS | TYPE | A (mm) | B (mm) | C (mm) | D (mm) | E (mm) | F (mm) | G (mm) | LENGTH (mm) | UNIT MASS (kg/m) | MASS (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G1501 | 15M | 162 | S4 | 140 | 1020 | 420 | 1020 | | | 140 | 2740 | 2.358 | 1047 |
| G2502 | 25M | 10 | | | | | | | | | 11311 | 3.925 | 444 |
| G2503 | 25M | 10 | | | | | | | | | 18000 | 3.925 | 706 |
| G2504 | 25M | 10 | | | | | | | | | 8371 | 3.925 | 329 |
| G2505 | 25M | 4 | | | | | | | | | 11000 | 3.925 | 173 |
| G1006 | 10M | 8 | | | | | | | | | 18000 | 0.785 | 113 |
| G1007 | 10M | 8 | | | | | | | | | 18000 | 0.785 | 113 |
| G1008 | 10M | 175 | | | | | | | | | 4420 | 0.785 | 607 |
| G1509 | 15M | 34 | | | | | | | | | 11151 | 1.570 | 595 |
| G1510 | 15M | 34 | | | | | | | | | 18000 | 1.570 | 961 |
| G1511 | 15M | 34 | | | | | | | | | 8211 | 1.570 | 438 |
| G1512 | 15M | 15 | | | | | | | | | 4000 | 1.570 | 94 |
| G1013 | 10M | 175 | | | | | | | | | 4420 | 0.785 | 607 |
| G1014 | 10M | 350 | | 470 | 116 | 132 | 270 | | | | 988 | 0.785 | 271 |
| | | | | | | | | | | | | TOTAL MASS (kg) | 5620 |

## PIER REINFORCING STEEL SCHEDULE

| MARK | SIZE | NO. OF BARS | TYPE | A (mm) | B (mm) | C (mm) | D (mm) | E (mm) | F (mm) | G (mm) | LENGTH (mm) | UNIT MASS (kg/m) | MASS (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1001 | 10M | 14 | 17 | | 640 | 1890 | 640 | | | | 3170 | 0.785 | 35 |
| F2502 | 25M | 5 | 17 | | 700 | 3410 | 700 | | | | 4810 | 3.925 | 94 |
| F1003 | 10M | 4 | | | | | | | | | 3420 | 0.785 | 11 |
| F1004 | 10M | 2 | | | | | | | | | 3420 | 0.785 | 5 |
| F1005 | 10M | 6 | | | | | | | | | 1920 | 0.785 | 9 |
| F1006 | 10M | 4 | | | | | | | | | 1920 | 0.785 | 6 |
| F1007 | 10M | 5 | 17 | | 700 | 3410 | 700 | | | | 4810 | 0.785 | 19 |
| F1008 | 10M | 14 | 17 | | 640 | 1890 | 640 | | | | 3170 | 0.785 | 35 |
| | | | | | | | | | | | | TOTAL MASS (kg) | 214 |

## FOOTING REINFORCING STEEL SCHEDULE

| MARK | SIZE | NO. OF BARS | TYPE | A (mm) | B (mm) | C (mm) | D (mm) | E (mm) | F (mm) | G (mm) | LENGTH (mm) | UNIT MASS (kg/m) | MASS (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P3001 | 30M | 34 | | 490 | 9000 | | | | | | 9490 | 5.495 | 1773 |
| P3002 | 30M | 2 | | | | | | | | | 9000 | 5.495 | 99 |
| P1003 | 10M | 17 | T1 | 100 | 920 | 2420 | 920 | 2420 | | 100 | 6880 | 0.785 | 92 |
| P1004 | 10M | 136 | T9 | 100 | 900 | | | | | 100 | 1100 | 0.785 | 117 |
| P1005 | 10M | 17 | T9 | 100 | 2400 | | | | | 100 | 2600 | 0.785 | 35 |
| P1506 | 15M | 4 | | | 900 | 800 | | | | | 1700 | 1.570 | 11 |
| | | | | | | | | | | | | TOTAL MASS (kg) | 2127 |

U of T CIV 313S Reinforced Concrete 1
Pedestrian Bridge
SCHEDULE AND ADDITIONAL DETAILS — Dwg. No. R6
April 18, 2022
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