ENGINEERING CALCULATION

Project: Northgate Bridge Replacement
Calc ID: STR-2024-047 Sheet 1 of 3
Subject: RC Edge Beam Flexural Design — Span 2 Revision B

Prepared:	J. Smith, Structural Engineer	**Date:**	2024-06-02
Checked:	M. Chen, Senior Engineer	**Date:**	2024-06-05
Approved:	R. Patel, Principal Engineer	**Date:**	2024-06-10

Revision History

Rev	Date	Author	Checked	Description
A	2024-03-15	J. Smith	M. Chen	Initial issue for client review.
B	2024-06-02	J. Smith	M. Chen	Revised dead loads per updated architectural drawings; updated reinforcement design.

Purpose & Scope

This calculation determines the flexural reinforcement required for the reinforced concrete edge beam at Span 2 of the Northgate Bridge Replacement. The beam is simply supported, spanning 9.2 m, and carries superimposed dead and traffic live loads as defined in the project loading schedule. All design checks are carried out to confirm compliance with the ultimate and serviceability limit-state requirements.

Design Standards & References

1. AS 3600:2018 — Concrete Structures.
2. AS/NZS 1170.0:2002 — Structural Design Actions — General Principles.
3. AS 5100.5:2017 — Bridge Design — Concrete.
4. Project Geotechnical Report No. GEO-2024-012 (Mason & Associates, Jan 2024).
5. Northgate Bridge Architectural Drawing Set, Rev D (Arup, Mar 2024).

Symbols & Notation

A_s	Area of tension reinforcement	mm^2
$A_{s,\mathbf{min}}$	Minimum area of tension reinforcement	mm^2
$A_{s,\mathbf{prov}}$	Area of tension reinforcement provided	mm^2
b	Width of rectangular section	mm
c_c	Concrete cover to outermost ligature	mm
d	Effective depth (extreme compression fibre to centroid of A_s)	mm
f'_c	Characteristic compressive strength of concrete	MPa
f_y	Yield strength of reinforcing steel	MPa
h	Overall depth of section	mm
k_u	Neutral axis parameter ($k_u d$)	—
k_{uo}	Ductility limit for neutral axis parameter	—
M^*	Design bending moment at ultimate limit state	kN·m
M_u	Ultimate moment capacity of section	kN·m
n	Modular ratio (E_s/E_c)	—
α_2	Stress-block parameter	—
γ	Stress-block parameter	—
ϕ	Capacity reduction factor for bending	—
ϕ_b	Diameter of longitudinal reinforcing bar	mm
ϕ_s	Diameter of ligature / stirrup	mm
ρ	Reinforcement ratio (A_s/bd)	—

Input Parameters & Material Properties

Parameter	Symbol	Value	Unit
Geometry			
Overall beam depth	h	700	mm
Beam width	b	400	mm
Clear span	L	9 200	mm
Concrete cover to ligatures	c_c	40	mm
Ligature diameter	ϕ_s	12	mm
Longitudinal bar diameter (assumed)	ϕ_b	25	mm
Material Properties			
Concrete compressive strength (Grade 35)	f'_c	35	MPa
Steel yield strength (Grade 500N)	f_y	500	MPa
Modulus of elasticity — concrete	E_c	30 100	MPa
Modulus of elasticity — steel	E_s	200 000	MPa
Density of reinforced concrete	ρ_c	25	kN/m^3
Loading (ULS)			
Self-weight (automated from section)	w_{sw}	7.00	kN/m
Superimposed dead load	w_G	12.5	kN/m
Traffic live load (T44 + L44 envelope)	w_Q	28.0	kN/m
Design ULS moment at mid-span	M^*	450	kN·m
Design ULS shear at support	V^*	215	kN

Design Calculations

Effective Depth

$$d = h - c_c - \phi_s - \frac{\phi_b}{2} = 700 - 40 - 12 - \frac{25}{2} = 635.5 \text{ mm} \quad \rightarrow \quad \text{adopt } d = 635 \text{ mm}$$

Required Tensile Reinforcement — Flexure

Strength reduction factor for flexure with Class N reinforcement (AS 3600 Table 2.2.2):

$$\phi = 0.85$$

Required ultimate moment capacity:

$$M_u \geq \frac{M^*}{\phi} = \frac{450}{0.85} = 529.4 \text{ kN·m}$$

Stress-block parameters (AS 3600 Clause 8.1.3):

$$\alpha_2 = 0.85 - 0.0015\,f'_c = 0.85 - 0.0015 \times 35 = 0.7975 \quad (\geq 0.67\,\checkmark)$$
$$\gamma = 0.97 - 0.0025\,f'_c = 0.97 - 0.0025 \times 35 = 0.8825 \quad (\geq 0.67\,\checkmark)$$

Design flexural parameter:

$$R_n = \frac{M^*}{\phi\, b\, d^2} = \frac{450 \times 10^6}{0.85 \times 400 \times 635^2} = 3.270\ \text{MPa}$$

Required reinforcement ratio:

$$\begin{aligned}\rho &= \frac{0.85\,f'_c}{f_y}\left(1 - \sqrt{1 - \frac{2\,R_n}{0.85\,f'_c}}\right)\\ &= \frac{0.85 \times 35}{500}\left(1 - \sqrt{1 - \frac{2 \times 3.270}{0.85 \times 35}}\right)\\ &= 0.05950 \times \left(1 - \sqrt{1 - 0.2198}\right)\\ &= 0.05950 \times (1 - 0.8833) = 0.00694\end{aligned}$$

Required steel area:

$$A_{s,\text{req}} = \rho\, b\, d = 0.00694 \times 400 \times 635 = 1\,763\ \text{mm}^2$$

Bar Selection

Provide 4-N25 bars in a single layer (bottom):

$$A_{s,\text{prov}} = 4 \times 491 = 1\,964\ \text{mm}^2 \ > \ 1\,763\ \text{mm}^2 \quad \checkmark$$

Check bar spacing (AS 3600 Clause 8.2.1):

$$s_{\min} = \max(1.5\,\phi_b,\ \phi_b + 5\ \text{mm},\ 25\ \text{mm}) = \max(37.5,\ 30,\ 25) = 37.5\ \text{mm}$$

Available clear spacing:

$$s = \frac{b - 2\,c_c - 2\,\phi_s - 4\,\phi_b}{3} = \frac{400 - 80 - 24 - 100}{3} = 65.3\ \text{mm} \ > \ 37.5\ \text{mm} \quad \checkmark$$

Ultimate Moment Capacity Check

Depth of equivalent rectangular stress block:

$$a = \frac{A_{s,\text{prov}}\,f_y}{0.85\,f'_c\,b} = \frac{1\,964 \times 500}{0.85 \times 35 \times 400} = 82.5\ \text{mm}$$

Ultimate moment capacity:

$$M_u = A_{s,\text{prov}}\,f_y\left(d - \frac{a}{2}\right) = 1\,964 \times 500 \times \left(635 - \frac{82.5}{2}\right) \times 10^{-6} = 1\,964 \times 500 \times 593.75 \times 10^{-6} = 582.7\ \text{kN·m}$$

Design capacity:

$$\phi M_u = 0.85 \times 582.7 = 495.3\ \text{kN·m} \ > \ M^* = 450\ \text{kN·m} \quad \checkmark$$

Minimum Reinforcement Check

Characteristic flexural tensile strength (AS 3600 Clause 3.1.1.3):

$$f'_{ct,f} = 0.6\sqrt{f'_c} = 0.6\sqrt{35} = 3.55 \text{ MPa}$$

Minimum reinforcement (AS 3600 Clause 8.1.6.1):

$$\begin{aligned} A_{s,\text{min}} &= 0.22 \left(\frac{D}{d}\right)^2 \frac{f'_{ct,f}}{f_y}\, b\, d \\ &= 0.22 \times \left(\frac{700}{635}\right)^2 \times \frac{3.55}{500} \times 400 \times 635 \\ &= 0.22 \times 1.215 \times 0.00710 \times 254\,000 \\ &= 482 \text{ mm}^2 \end{aligned}$$

$$A_{s,\text{prov}} = 1\,964 \text{ mm}^2 \;>\; 482 \text{ mm}^2 \quad \checkmark$$

Ductility Check

Neutral axis depth:

$$k_u = \frac{a}{\gamma\, d} = \frac{82.5}{0.8825 \times 635} = \frac{82.5}{560.4} = 0.147$$

Ductility limit for Class N reinforcement (AS 3600 Clause 8.1.5):

$$k_{uo} = 0.36 > k_u = 0.147 \quad \checkmark \quad \text{(ductile section)}$$

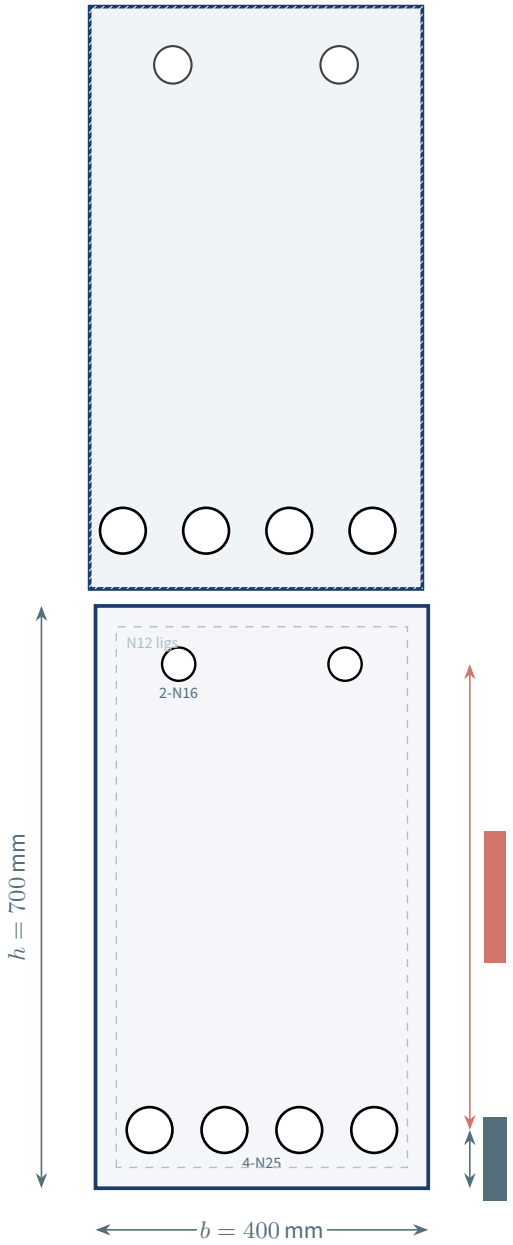

Figure 1: Reinforced concrete beam cross-section — Span 2 edge beam.

Results Summary

Parameter	Required	Provided	Status
Tension reinforcement area	$1\,763$ mm^2	$1\,964$ mm^2	✓
Minimum reinforcement area	482 mm^2	$1\,964$ mm^2	✓
Design moment capacity ϕM_u	—	495.3 kN·m	$> M^*$
Neutral axis parameter k_u	< 0.36	0.147	✓
Bar clear spacing	≥ 37.5 mm	65.3 mm	✓

All ultimate limit-state requirements are satisfied. The section is ductile and reinforcement detailing complies with AS 3600 requirements for minimum spacing and cover.

Sign-Off

Prepared by: ..... Date:

J. Smith, Structural Engineer

Checked by: ..... Date:

M. Chen, Senior Structural Engineer

Approved by: ..... Date:

R. Patel, Principal Engineer

⚠ This calculation is valid only for the loading conditions and material properties stated herein. Any deviation requires re-assessment by a qualified structural engineer.