TEMPORARY WORKS DESIGN GUIDE

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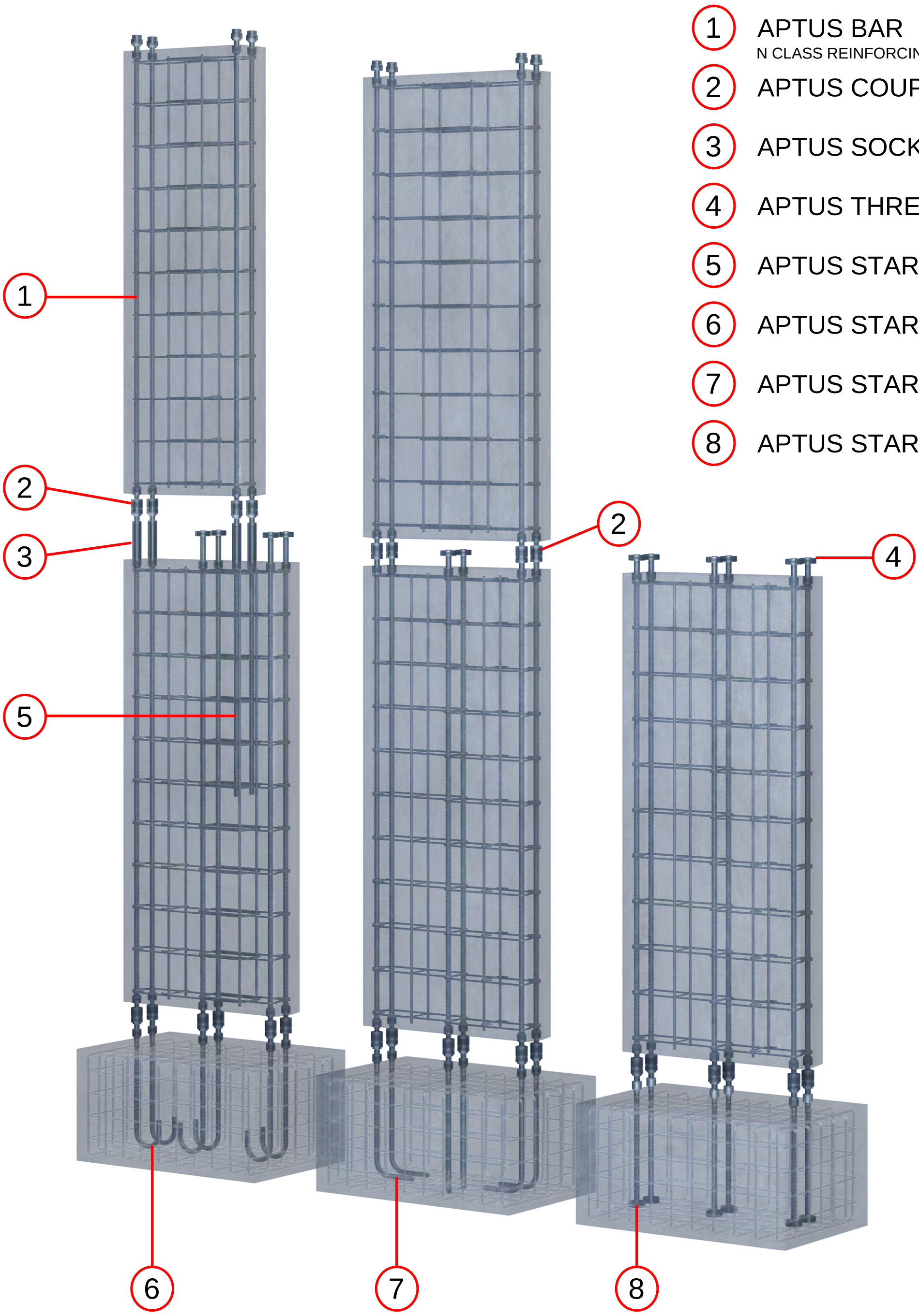
PURPOSE OF THIS DESIGN GUIDE

The purpose of this document is to outline a recommended temporary works design procedure for precast concrete elements utilising the APTUS coupler system.

Temporary works design takes into consideration the strength and stability of the APTUS couplers under temporary load conditions (typically governed by wind loading). This guide should only be used by a competent and experienced temporary works design engineer, in conjunction with established structural engineering design principles and sound engineering judgement.



1. APTUS BAR
   N CLASS REINFORCING BAR WITH FRICTION WELDED SOCKETS BOTH ENDS
2. APTUS COUPLER
3. APTUS SOCKET EXTENSION
4. APTUS THREADED ANCHOR HEAD
5. APTUS STARTER BAR - STRAIGHT
6. APTUS STARTER BAR - HOOK
7. APTUS STARTER BAR - COG
8. APTUS STARTER BAR - ANCHOR HEAD

<u>**VARIABLE DEFINITIONS**</u>

APTUS PRECAST ELEMENT 1

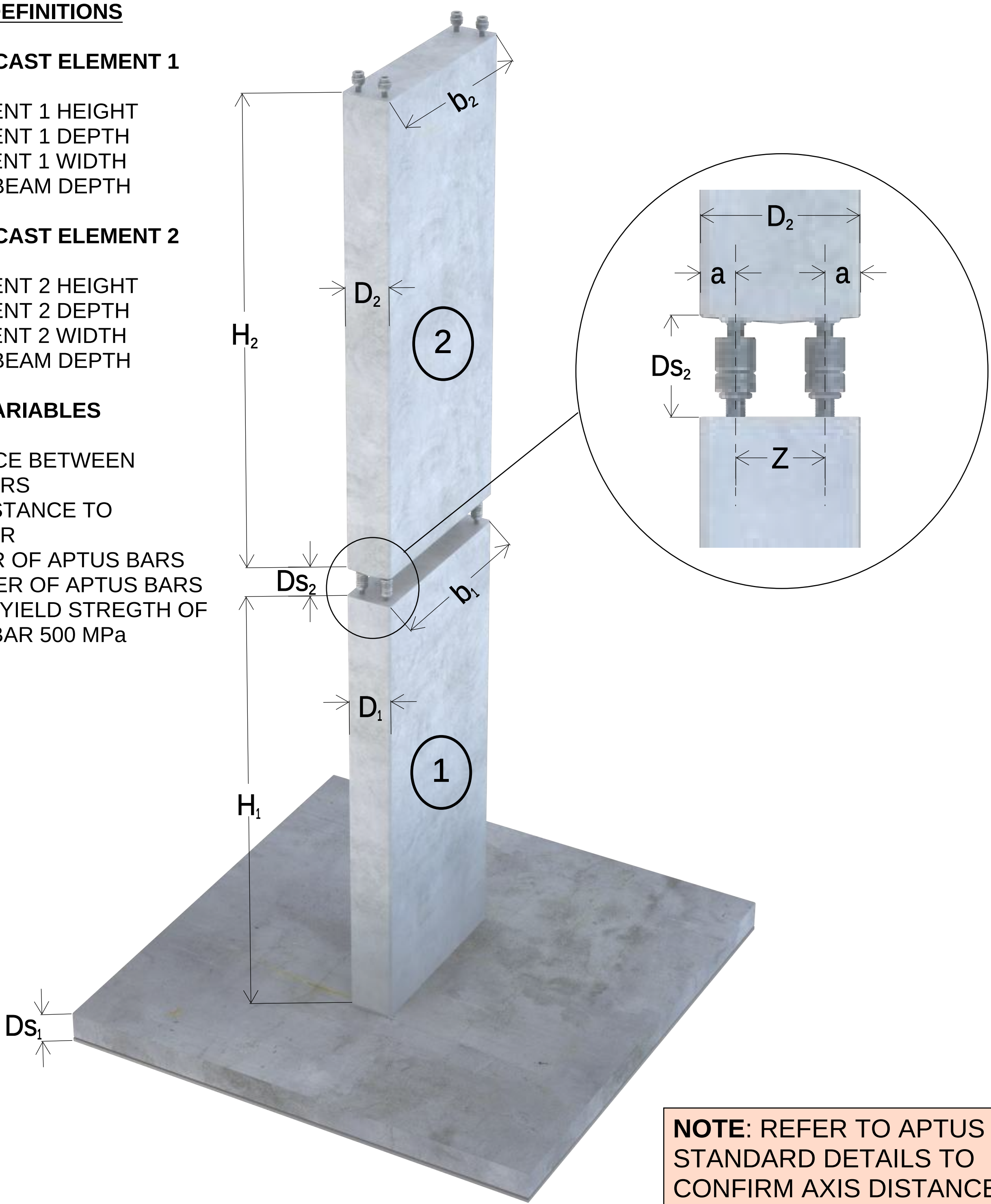
H_1 = ELEMENT 1 HEIGHT
D_1 = ELEMENT 1 DEPTH
b_1 = ELEMENT 1 WIDTH
Ds_1 = SLAB/BEAM DEPTH

APTUS PRECAST ELEMENT 2

H_2 = ELEMENT 2 HEIGHT
D_2 = ELEMENT 2 DEPTH
b_2 = ELEMENT 2 WIDTH
Ds_2 = SLAB/BEAM DEPTH

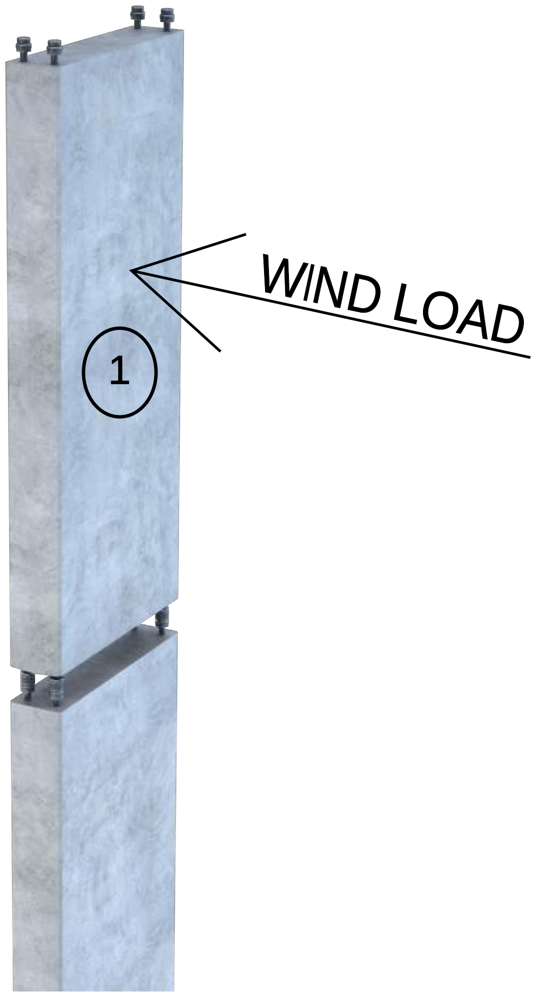
COMMON VARIABLES

Z = DISTANCE BETWEEN COUPLERS
a = AXIS DISTANCE TO COUPLER
n = NUMBER OF APTUS BARS
d_b = DIAMETER OF APTUS BARS
f_{sy} = DESIGN YIELD STREGTH OF APTUS BAR 500 MPa



NOTE: REFER TO APTUS STANDARD DETAILS TO CONFIRM AXIS DISTANCE. STANDARD AXIS DISTANCES BASED ON THE ELEMENT DEPTH SHOULD BE ADOPTED.

OVERVIEW STAGE 1

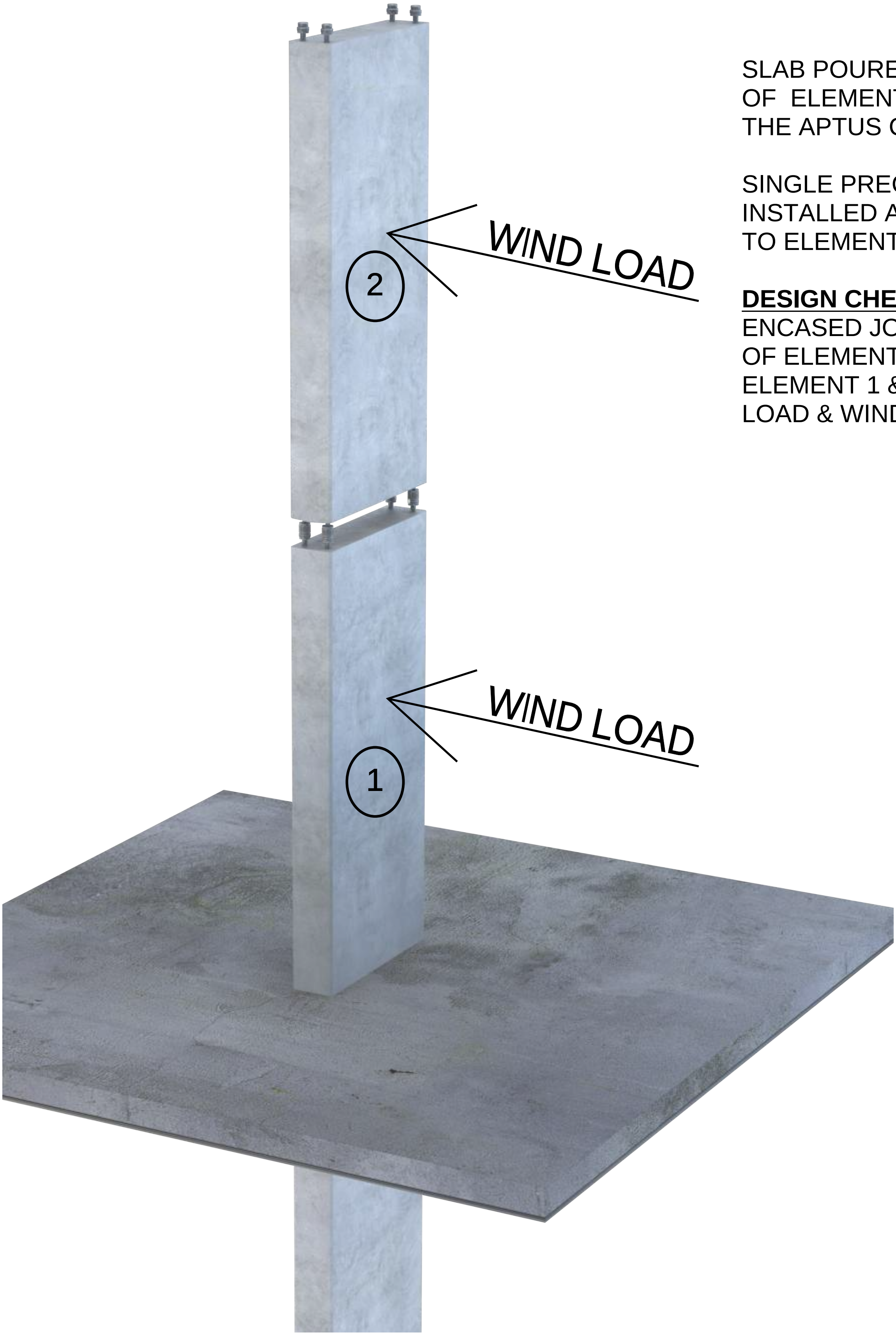


SINGLE PRECAST ELEMENT (1) INSTALLED AND CONNECTED TO ELEMENT BELOW. (COLUMN OR FOOTING)

DESIGN CHECK: CAPACITY OF APTUS COUPLERS AT THE BASE OF ELEMENT 1 TO SUPPORT ELEMENT 1 UNDER DEAD LOAD & WIND LOAD.

NOTE: THE DESIGN CHECK IS UNDERTAKEN ABOUT THE WEAK AXIS OF THE ELEMENT. THE STRUCTURAL ENGINEER MUST CONSIDER ALL PROJECT SPECIFIC POTENTIAL DESIGN CASES.

OVERVIEW STAGE 2

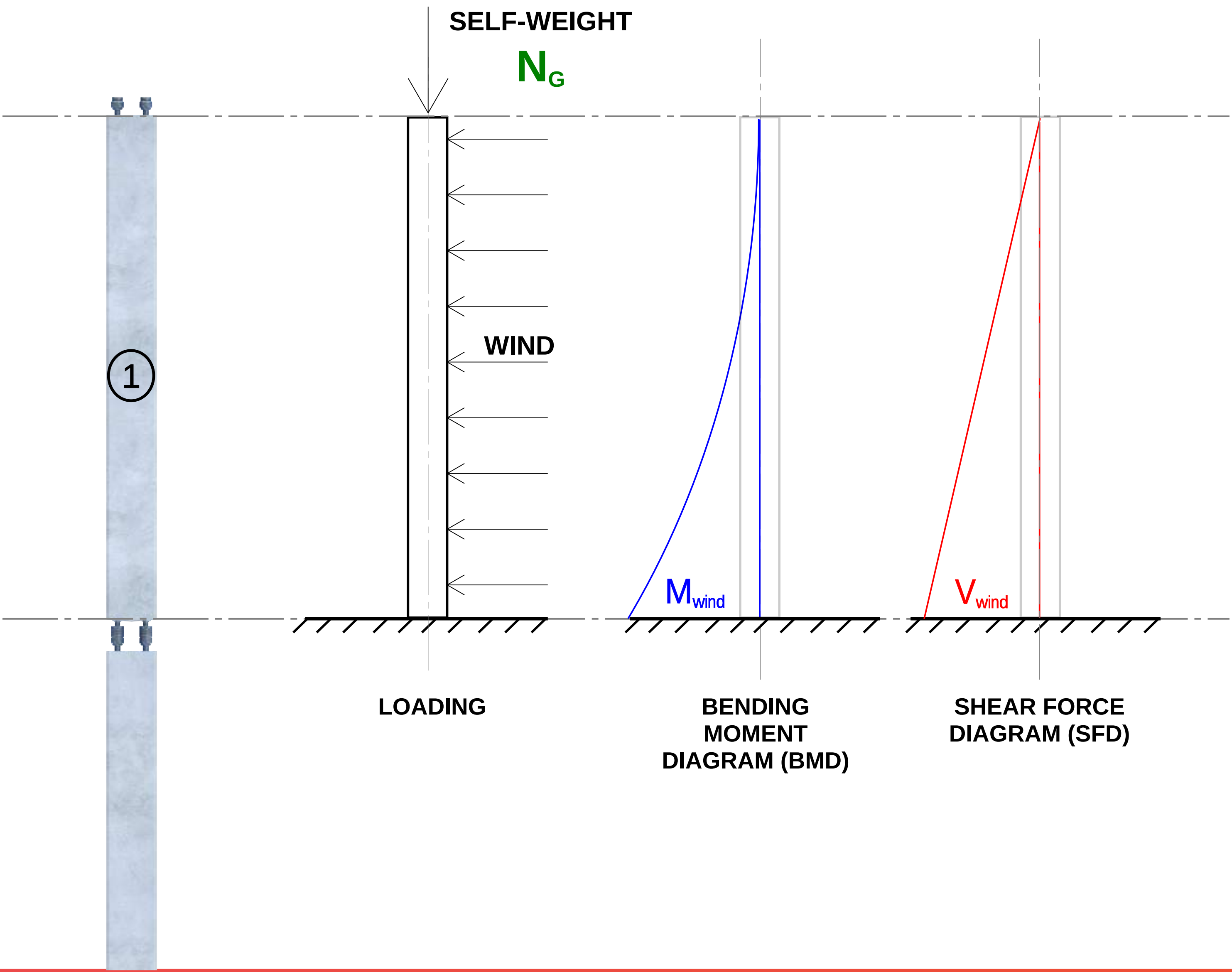


SLAB POURED AT THE BASE OF ELEMENT 1, ENCASING THE APTUS COUPLERS.

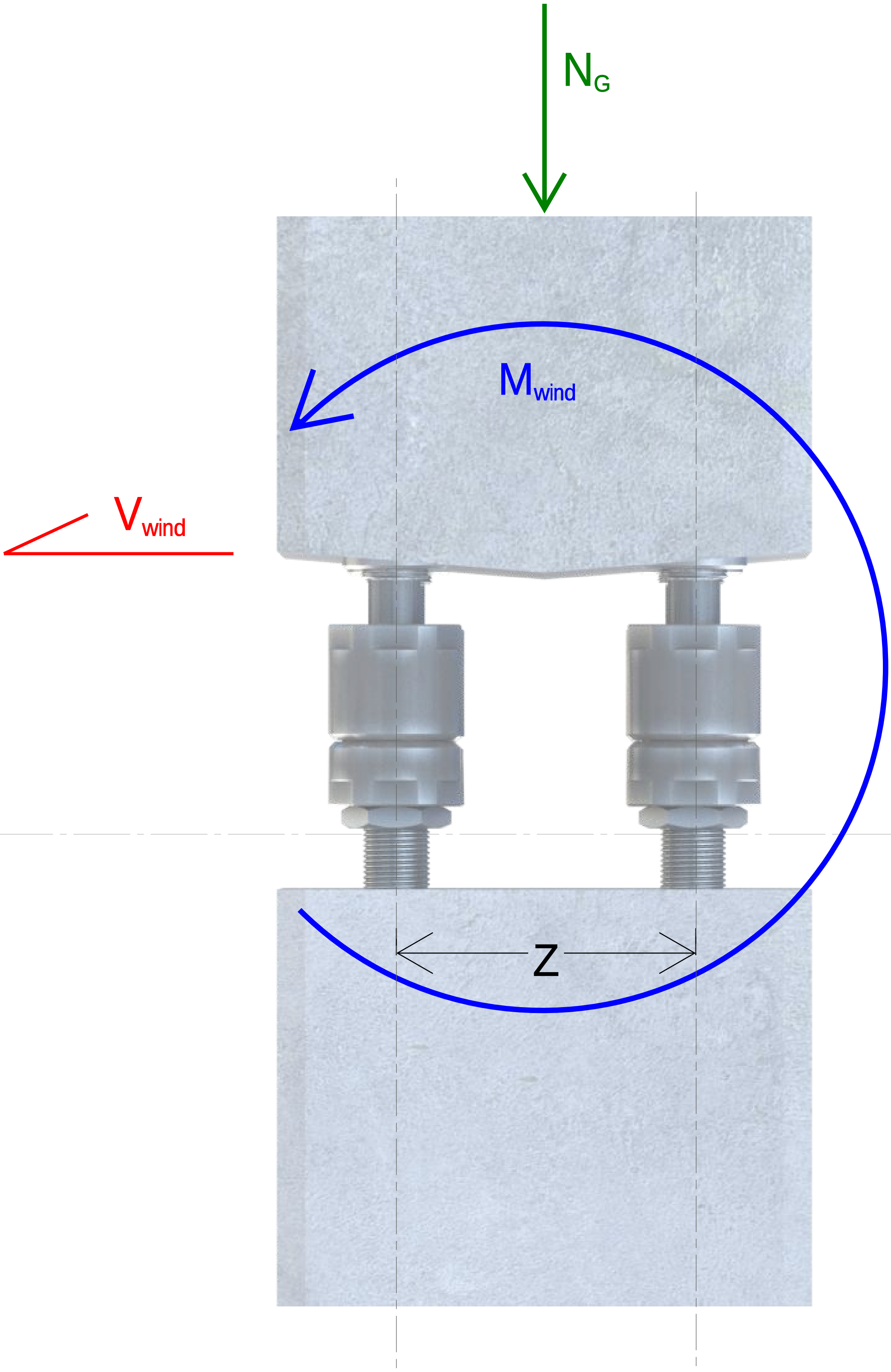
SINGLE PRECAST ELEMENT (2) INSTALLED AND CONNECTED TO ELEMENT BELOW (1).

DESIGN CHECK: CAPACITY OF ENCASED JOINT AT THE BASE OF ELEMENT 1 TO SUPPORT ELEMENT 1 & 2 UNDER DEAD LOAD & WIND LOAD.

GLOBAL DESIGN ACTION EFFECTS



GLOBAL DESIGN ACTION EFFECTS



LOCAL DESIGN ACTION EFFECTS

STAGE 1 DESIGN ASSUMPTIONS

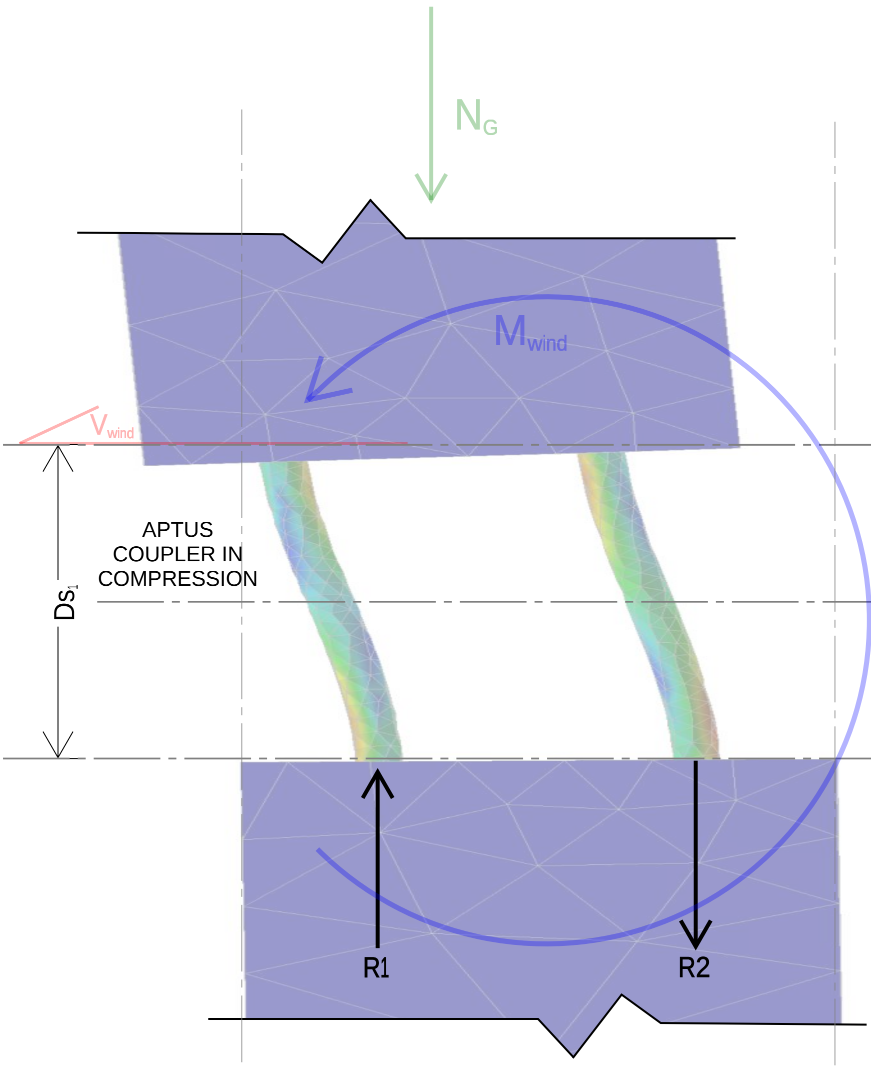
1. APTUS COUPLERS ARE TREATED AS STANDARD GR500 'N-CLASS' REINFORCEMENT BAR.

2. SHEAR FORCE IN THE APTUS ELEMENT IS RESISTED BY BENDING IN THE APTUS COUPLERS IN DOUBLE CURVATURE.

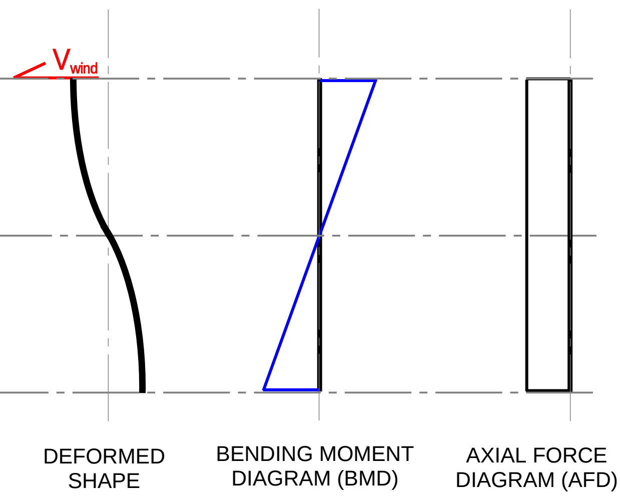
3. TOTAL SHEAR FORCE IS ASSUMED TO BE RESISTED BY ALL THE APTUS COUPLERS EQUALLY.

4. TOTAL DEAD WEIGHT IS ASSUMED TO BE RESISTED BY ALL THE COUPLERS EQUALLY.

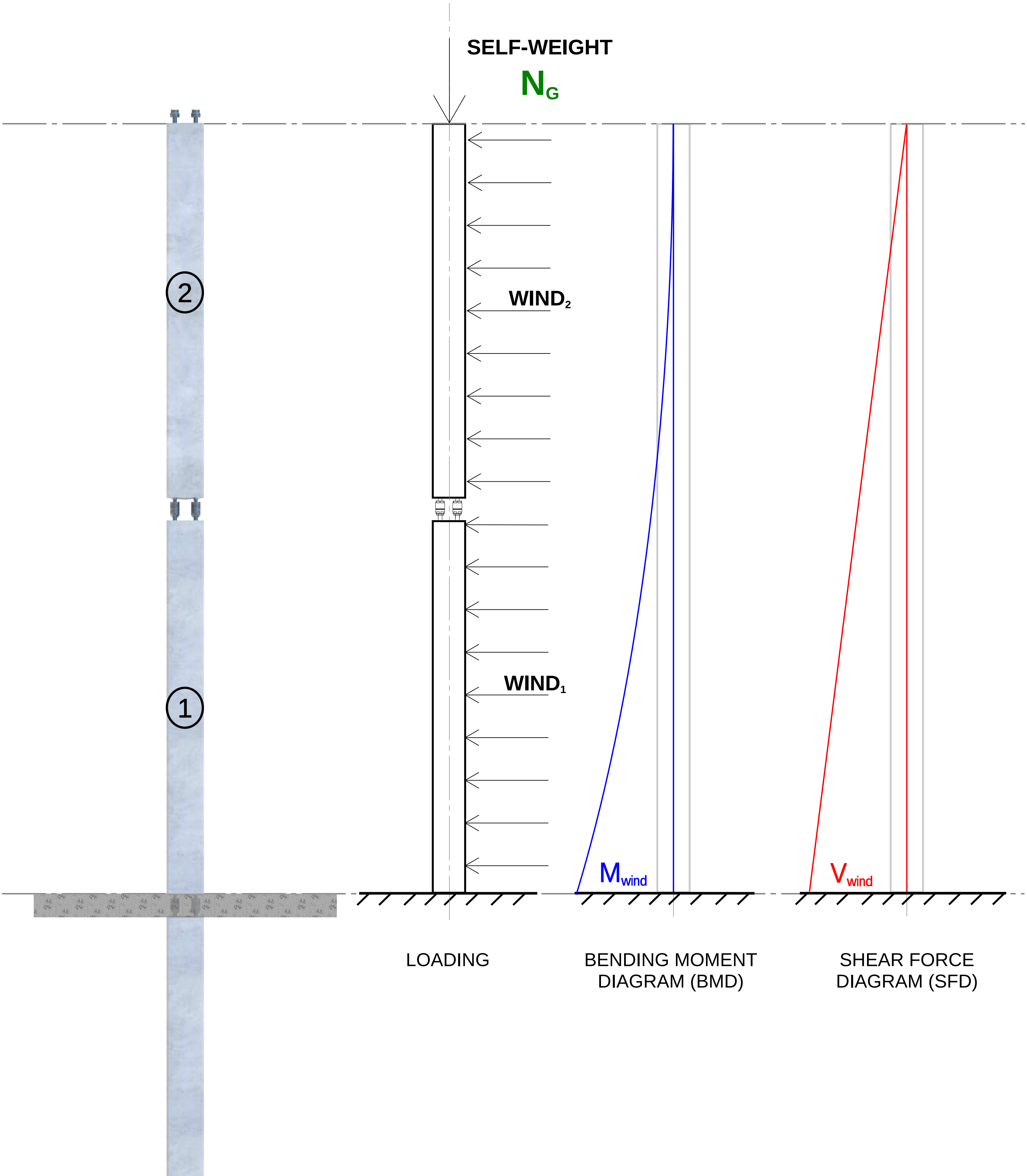
5. THE OVERTURNING MOMENT IS RESISTED BY A PUSH-PULL IN THE APTUS COUPLERS



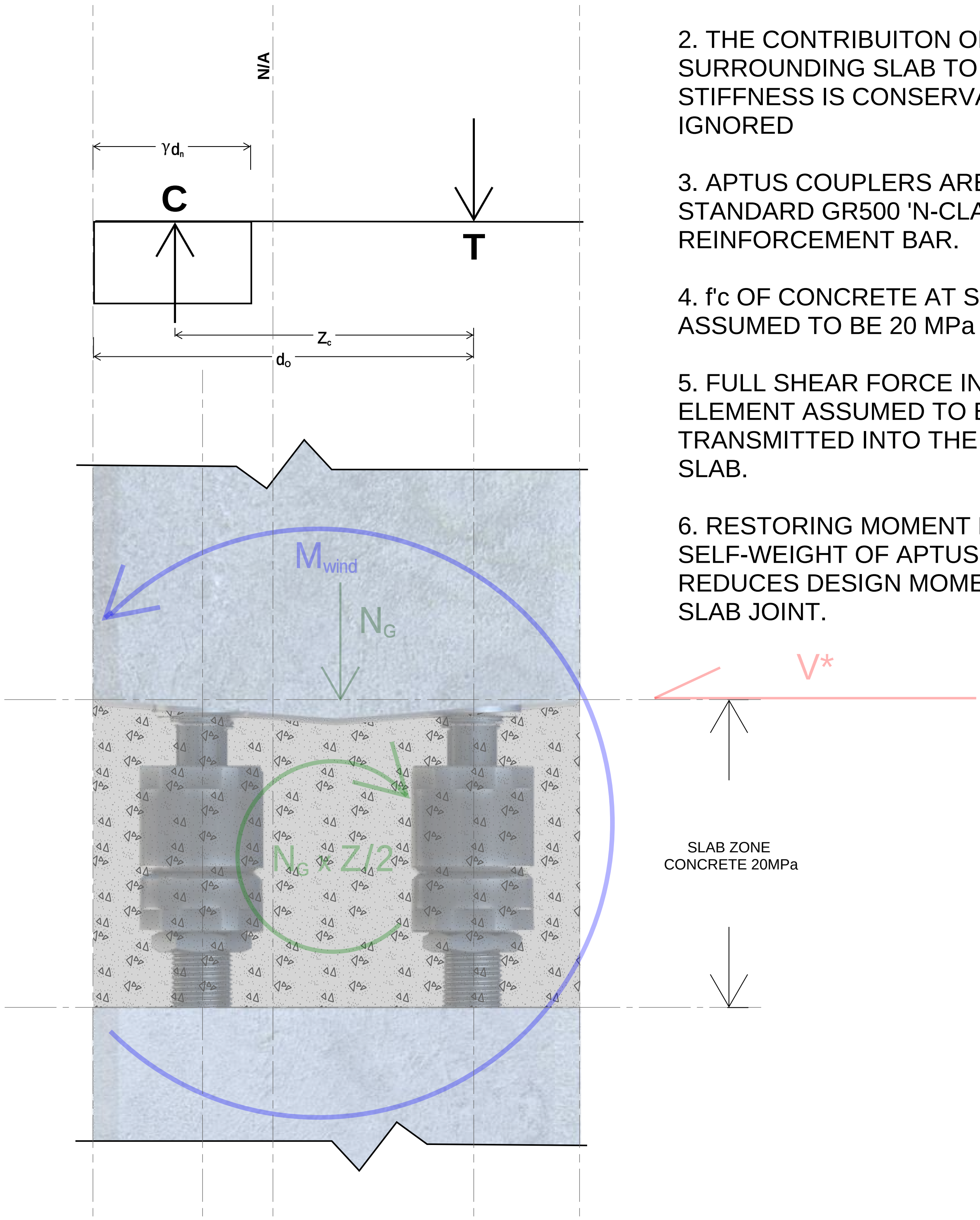
DESIGN ACTION EFFECTS ON APTUS COMPRESSION IN COUPLER



GLOBAL DESIGN ACTION EFFECTS



LOCAL DESIGN ACTION EFFECTS



STAGE 2 DESIGN ASSUMPTIONS

1. THE COLUMN CROSS-SECTION IS CHECKED AS A REINFORCED CONCRETE SECTION IN BENDING.

2. THE CONTRIBUITON OF THE SURROUNDING SLAB TO THE JOINT STIFFNESS IS CONSERVATIVELY IGNORED

3. APTUS COUPLERS ARE TREATED AS STANDARD GR500 'N-CLASS' REINFORCEMENT BAR.

4. f'c OF CONCRETE AT STAGE 2 ASSUMED TO BE 20 MPa

5. FULL SHEAR FORCE IN APTUS ELEMENT ASSUMED TO BE TRANSMITTED INTO THE CONCRETE SLAB.

6. RESTORING MOMENT DUE SELF-WEIGHT OF APTUS ELEMENT REDUCES DESIGN MOMENT AT THE SLAB JOINT.

VARIABLE DEFINITIONS

APTUS PRECAST ELEMENT 1

H_1 = 2900 mm
D_1 = 300 mm
b_1 = 1000 mm
Ds_1 = 200 mm

APTUS PRECAST ELEMENT 2

H_2 = 2900 mm
D_2 = 300 mm
b_2 = 1000 mm
Ds_2 = 200 mm

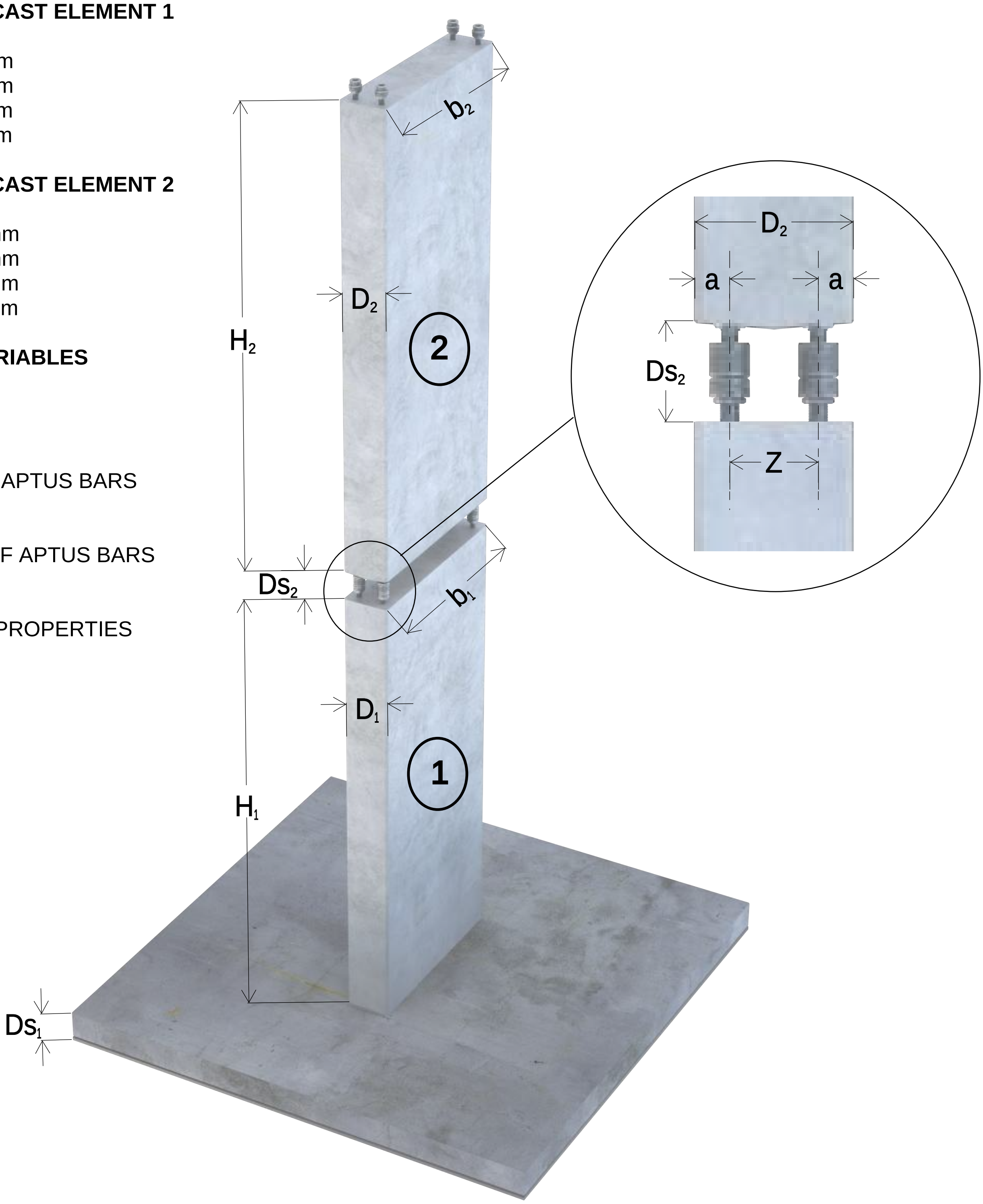
TYPICAL VARIABLES

Z = 168 mm
a = 66 mm

NUMBER OF APTUS BARS
n = 4

DIAMETER OF APTUS BARS
d_b = 32mm

APTUS BAR PROPERTIES
f_{sy} = 500 MPa
f_u = 540 MPa



Wind Loading – in accordance with AS1170.2

Design Wind Speed

Wind Region (Brisbane)	B
Terrain Category	TC3
Project Ground Level	RL10.000
RL at Top of Element	RL40.000
Importance Level	2 (AS3850.2:2015 CL2.5.6)
Annual Probability of Exceedance	$1/100$ (AS1170.0: 2002 Table 3.3)
Regional Wind Speed	$V_{100} = 48$ m/s (AS1170.2 Table 3.1)
Site Wind Speed	$V_{sit} = V_R M_{z,cat} = 48 \times 1.00 = 48$ m/s
Where	$M_{z,cat} = 1.0$ (TC3, H = 30m) AS1170.2 Table 4.1

Aerodynamic Shape Factor

where $b/H \geq 0.5$ Procedure 1 – Freestanding Wall in accordance with AS1170.2 Appendix D

$$C_{fig} = C_{p,n} \text{ (Refer Table D2)}$$

where $b/H < 0.5$ Procedure 2 – Rectangular Prism in accordance with AS1170.2 Appendix E

$$C_{fig} = K_{ar} C_{F,x} \text{ (Clause E2.1)}$$

$$\text{Aspect Ratio} = \frac{H_1}{b_1} = \frac{2900}{1000} = 2.9$$

$$K_{ar} = 0.7 \text{ (Table E1)}$$

$$C_{F,x} \text{ (Clause E3.2) with Aspect Ratio} = \frac{D_1}{b_1} = \frac{300}{1000} = 0.3$$

$$\frac{C_{F,x} - 2.2}{0.3 - 0.1} = \frac{3.0 - 2.2}{0.65 - 0.1}$$

$$C_{F,x} = 2.49$$

$$C_{fig} = K_{ar} C_{F,x} = 0.7 \times 2.49 = 1.74$$

Repeat to find C_{fig} for Element 2 if the geometry is different; in this example $C_{fig.1} = C_{fig.2}$

Design Wind Pressure

$$p^* = 0.5 \times \rho_{air} {V_{des}}^2 C_{fig}$$

$$p^* = 0.5 \times 1.2 \times 48^2 \times 1.74 / 1000 = 2.4 \text{ kPa}$$

Stage 1 Design Check

Capacity of the APTUS couplers at the base of element 1 to support element 1 under dead load and wind load. Refer to page 7 – 9. In some cases the element supporting element 1 may have different dimensions. The design engineer should confirm that the lever arm used in this calculation is correct.

Design Action Effects

Global Design Action Effects on Precast Element

$$w^*_{wind} = p \times b_2 = 2.4 \times 1.0 = 2.4\ kN/m$$

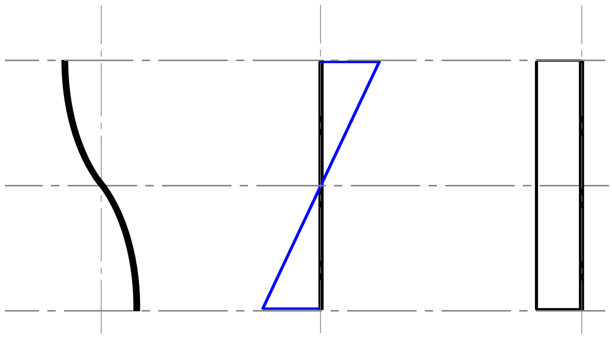
$$M^*_{wind} = \frac{w^*{}_{wind}(H_2)^2}{2} = \frac{2.4 \times 2.9^2}{2} = 10.1\ kNm$$

$$V^*_{wind} = w^*{}_{wind} \times H_2 = 2.4 \times 2.9 = 6.96\ kN$$

$$N_G = H_2 \times b_2 \times D_2 \times \rho_{conc}$$

$$N_G = 2.9 \times 0.3 \times 1.0 \times 25 = 21.8\ kN$$

Local Design Action Effects on Critical APTUS Coupler in Compression



$$N^*_{comp} = \frac{1.2 \times N_G}{n} + \frac{\frac{M_{wind}}{Z}}{\frac{n}{2}}$$

$$N^*_{comp} = \frac{1.2 \times 21.8}{4} + \frac{\frac{10.1}{0.168}}{\frac{4}{2}} = 36.6\ kN$$

$$M^* = \frac{M_{local}}{n} + M_{ecc}$$

$$M^* = \frac{\left(V^*{}_{wind} \times \frac{Ds_1}{2}\right)}{n} + \left(N^*_{comp} \times e_{nom}\right)$$

where $e_{nom} = 3\text{mm lateral tolerance in coupler}$

$$M^* = \frac{\left(6.96 \times \frac{0.2}{2}\right)}{4} + (36.6 \times 0.003) = 0.28\ kNm$$

ΔP effects have been not been assessed due to small displacement theory

Local Design Action Effects on APTUS Coupler in Tension

$$N^*_{tension} = \frac{\frac{M^*{}_{wind}}{Z}}{\frac{n}{2}} - \frac{0.9 \times N_G}{n}$$

$$N^*_{tension} = \frac{\frac{10.1}{0.168}}{\frac{4}{2}} - \frac{0.9 \times 21.8}{4} = 25.2 \text{ kN}$$

Capacity Calculations AS4100:1998

The below information outlines design ultimate capacity calculations for an N32 APTUS Bar.

Axial Section Capacity – Compression (AS4100:1998 Section 6)

$$\phi N_s = \phi k_f A_{bar} f_y$$

$$k_f = 1.0 \text{ (No local buckling behaviour present)}$$

$$\phi N_s = 0.9 \times 1.0 \times 804 \times 500 = 362 \text{ kN}$$

Axial Member Capacity – Compression (AS4100:1998 Section 6)

$$l_e = k_e \times L; \text{ where } L = Ds_1$$

$$k_e = 1.2$$

$$l_e = k_e \times Ds_1$$

(as per AS4100:1998 Figure 4.6.3.2 for base fully fixed/top moment fixed with no lateral restraint)

$$l_e = 1.2 \times 200 = 240 \text{ mm}$$

$$\phi N_c = \alpha_c \phi N_s \leq \phi N_s$$

$$\lambda_n = \left(\frac{l_e}{r}\right)\sqrt{k_f}\sqrt{\frac{f_y}{250}}$$

$$r = \sqrt{\frac{I}{A_{bar}}} = \sqrt{\frac{51{,}446}{804}} = 8$$

$$\lambda_n = \left(\frac{240}{8}\right)\sqrt{1}\sqrt{\left(\frac{500}{250}\right)} = 42.42$$

$$\alpha_a = \frac{2100(\lambda_n - 13.5)}{\lambda_n^2 - 15.3\lambda_n + 2050}$$

$$\alpha_a = \frac{2100(42.42 - 13.5)}{42.42^2 - 15.3 \times 42.42 + 2050} = 18.98$$

$$\alpha_b = -1 \text{ (Refer AS4100 Table 6.3.3(1))}$$

$$\lambda = \lambda_n + \alpha_a \alpha_b = 42.42 + 18.98 \times -1$$

$$\lambda = 23.44$$

$$\eta = 0.00326(\lambda - 13.5) \geq 0$$

$$\eta = 0.00326(23.44 - 13.5) = 0.0324$$

$$\xi = \frac{\left(\frac{\lambda}{90}\right)^2 + 1 + \eta}{2\left(\frac{\lambda}{90}\right)^2}$$

$$\xi = \frac{\left(\frac{23.44}{90}\right)^2 + 1 + 0.0324}{2\left(\frac{23.44}{90}\right)^2} = 8.11$$

$$\alpha_c = \xi\left(1 - \sqrt{\left[1 - \left(\frac{90}{\xi\lambda}\right)^2\right]}\right)$$

$$\alpha_c = 8.11\left(1 - \sqrt{\left[1 - \left(\frac{90}{8.11 \times 23.44}\right)^2\right]}\right) = 0.966$$

$$\phi N_c = 0.966 \times \phi N_s = 0.966 \times 362 \text{ kN} = 350 \text{ kN}$$

$$\phi N_c = 350 \text{ kN} > 36.6 \text{ kN} = N^*$$

∴ APTUS bar has sufficient axial compression capacity.

Axial Member Capacity – Tension (AS4100 Section 7)

$$\phi N_t = \min(\phi A_g f_y; \phi 0.85 A_n f_u)$$

where: $f_u = 540$ MPa

$$A_g = A_n = 803 \text{ mm}^2$$

$\phi = 0.9$ (AS4100 Table 3.4)

$$\phi A_g f_y = \frac{0.9 \times 804 \times 500}{1000} = 361 \text{ kN}$$

$$\phi 0.85 A_n f_u = \frac{0.9 \times 0.85 \times 804 \times 540}{1000} = 331 \text{ kN}$$

$$\phi N_t = 331 \text{ kN} > 25.2 \text{ kN} = N^*$$

∴ APTUS bar has sufficient tension capacity.

Bending Moment Capacity - Section and Member (AS4100 Section 5)

$$\phi M_s = \phi f_y Z_{e,bar} = 0.9 \times 500 \times 4825/1000^2 = 2.17\ \mathrm{kNm}$$

$$\text{where } Z_{e,bar} = \min(1.5 Z_{bar}; S_{bar})$$

$$1.5\ Z_{bar} = 1.5 \times \frac{\pi d_b^3}{32} = 4825\ \mathrm{mm}^3$$

$$S_{bar} = \frac{d_b^3}{6} = 5461\ \mathrm{mm}^3$$

$$Z_{e,bar} = 4825\ \mathrm{mm}^3$$

$$\phi M_b = \phi \alpha_m \alpha_s M_s \leq \phi M_s$$

$$l_e = 240\ \mathrm{mm}$$

$$M_o = \sqrt{\left[\left(\frac{\pi^2 EI}{l_e^2}\right) GJ\right]}$$

$$M_o = \sqrt{\left[\left(\frac{\pi^2 \times 200{,}000 \times 51{,}446}{240^2}\right)[80{,}000 \times 102{,}944]\right]}$$

$$M_o = 120\ \mathrm{kNm}$$

$$\alpha_s = 0.6\left[\sqrt{\left[\left(\frac{M_s}{M_o}\right)^2 + 3\right]} - \left(\frac{M_s}{M_o}\right)\right]$$

$$\alpha_s = 0.6\left[\sqrt{\left[\left(\frac{2.17}{120}\right)^2 + 3\right]} - \left(\frac{2.17}{120}\right)\right] = 1.03$$

$$\alpha_m = \frac{1.7 M_m^*}{\sqrt{[(M_2^*)^2 + (M_3^*)^2 + (M_4^*)^2]}} \leq 2.5$$

$$\alpha_m = \frac{1.7 M^*}{\sqrt{\left[\left(\frac{M^*}{2}\right)^2 + (0)^2 + \left(\frac{M^*}{2}\right)^2\right]}} = \frac{1.7 M^*}{\sqrt{2} \times \frac{M^*}{2}} = 2.40 \leq 2.5$$

$$\phi M_b = \alpha_m \alpha_s \phi M_s = 0.9 \times 2.40 \times 1.03 \times 2.17 = 4.82\ \mathrm{kNm} > 2.17\ \mathrm{kNm} = \phi M_s$$

$$\therefore \phi M_b = 2.17\ \mathrm{kNm}$$

Combined Actions - reduced bending capacity due to compression (AS4100:1998 Cl 8.4.2)

$$M^* \leq \phi M_i$$

$$\phi M_i = \phi M_s\left(1 - \frac{N^*}{\phi N_c}\right)$$

$$\phi M_i = 2.17\left(1 - \frac{36.6}{350}\right) = 1.94\ \mathrm{kNm}$$

$$\phi M_i = 1.94\ \mathrm{kNm} > 0.28\ \mathrm{kNm} = M^*$$

$\therefore$ APTUS bar has sufficient moment capacity allowing for combined bending and compression.

Stage 2 Design Check

Capacity of encased joint at the base of element 1 to support element 1 & 2 under dead load and wind load. Refer to page 10 and 11. Note in this example calculation, both precast elements are the same dimensions. In some cases the APTUS elements stacking on top of each other may have different dimensions and the design engineer should calculate the wind loading on each element individually.

Design Action Effects

$$M^* = {M^*}_{wind.1} + {M^*}_{wind.2} - \left(N_G \times \frac{D}{2}\right)$$

$${w^*}_{wind.1} = p^* \times b_1 = 2.4 \times 1.0 = 2.4\ \mathrm{kN/m}$$

$${w^*}_{wind.2} = p^* \times b_2 = 2.4 \times 1.0 = 2.4\ \mathrm{kN/m}$$

$${M^*}_{wind.1} = {w^*}_{wind.1} \times H_1 \times \frac{H_1}{2} = 2.4 \times 2.9 \times \frac{2.9}{2} = 10.1\mathrm{kN.m}$$

$${M^*}_{wind.2} = {w^*}_{wind.2} \times H_2 \times \left(H_1 + Ds_2 + \frac{H_2}{2}\right) = 2.4 \times 2.9 \times \left(2.9 + 0.2 + \frac{2.9}{2}\right) = 31.7\ \mathrm{kN.m}$$

$$N_G = \left((H_2 \times b_2 \times D_2) + (H_1 \times b_1 \times D_1)\right) \times \rho_{conc}$$

$$N_G = \left((2.9 \times 0.3 \times 1.0) + (2.9 \times 0.3 \times 1.0)\right) \times 25 = 43.6\ \mathrm{kN}$$

$$M^* = 10.1 + 31.7 - \left(43.6 \times \frac{0.3}{2}\right) = 35.2\ \mathrm{kNm}$$

Capacity Calculation AS3600:2018

Variables

A_{st} = Steel area of couplers in tension

$f_{sy} = 500$ MPa

$f'_c = 20$ MPa

α_2 & γ in accordance with AS3600: 2018 Cl 8.1.3

Concrete joint is treated as a singly reinforced concrete section in bending.

$$T = C$$

$$A_{st} \times f_{sy} = \alpha_2 \times \gamma \times d_n \times b \times f'_c$$

$$d_n = \frac{A_{st} \times f_{sy}}{\alpha_2 \times \gamma \times b \times f'_c}$$

$$d_n = \frac{2 \times 804 \times 500}{0.82 \times 0.92 \times 1000 \times 20} = 53.2 \text{ mm} \ \ \text{(2 bars in tension)}$$

$$\text{where } \alpha_2 = 0.85 - 0.0015 \times f'_c = 0.82$$

$$\text{where } \gamma = 0.97 - 0.0025 \times f'_c = 0.92$$

$$\phi M_{uo} = \phi T Z_c$$

$$\text{where } Z_c = d_0 - \frac{\gamma d_n}{2} = (0.3 - 0.066) - \frac{0.92 \times 0.0532}{2} = 0.209 \text{ m}$$

$$\text{and } T = A_{st} \times f_{sy} = 2 \times 804 \times 500 = 804 \text{ kN}$$

$$\phi M_{uo} = \phi T Z_c = 0.85 \times 804 \times 0.209 = 143 \text{ kNm}$$

$$k_{uo} = 0.227; \therefore \phi = 0.85$$

$$\phi M_{uo} = 143 \text{ kNm} > 35.2 \text{ kNm} = M^*$$

$\therefore$ Encased joint between elements 1 & 2 has sufficent capacity.

Reference – Reinforcement Bar Section Properties

	N20	N24	N28	N32	N36	N40
I (mm^4)	7850	16278	30157	51446	82406	125600
J (mm^4)	15708	32572	60344	102944	164896	251327
Z (mm^3)	785	1356	2154	3215	4578	6280
Area (mm^2)	314.2	452.4	615.8	804.2	1020	1260

APTUS®
concrete connections

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