Design of Prototype frame structure

Design information

Design parameter	Value
Gravity	9.81 m/s^2
Superimposed dead load	1.5 kPa
Live load	4.0 kPa
Ultimate wind velocity	50 m/s
Region	A
Terrain category	2
Topographic multiplier	1.0
Shielding multiplier	1.0
Importance multiplier (for wind)	1.0
Earthquake acceleration coefficient	0.11g
Site factor	1.0
Structural response modification factor	4.0
Importance factor (for earthquakes)	1.0

Calculation of Loading on beam

Beam self-weight	= 0.733x 24	= 17.59	kN/m
Slab self-weight	= 0.17 x 24x3.6	= 14.69	kN/m
Super imposed dead load	= 1.5 x 6.0	= 9.00	kN/m
Total Dead Load		**= 41.28**	**kN/m**
Imposed Live Load	**= 4.0 x 6.0**	**= 24.00**	**kN/m**

Calculation of equivalent earthquake load on Proto type frame

The factored load per floor (1.0 G+ 0.4 Q+ EQ)- Load Case

G_g = (41.28 + 0.4 x 24) x (2x8.4+4x9.6) = 2808.576 kN/ floor/frame

Standards Australia (AS1170.4, 1993) Method

The equivalent base shear force is given by: $V = I[(CS)/R_f]G_g$

This should be within the limits of $V > 0.01G_g$ *and* $V < I[(2.5a)/R_f]G_g$
Where,

- I = *Occupancy important factor either 1.0 or 1.25*
- C = *Earthquake design coefficient given by* $(1.25a)/T^{2/3}$ *where T is the natural period of the structure.*
- S = *Site factor which is taken as:*
- R_f = *Structural response factor which is taken as :*
- a = *Acceleration coefficient depends on the geographical location and a map of Australia has been given to select the appropriate value of a.*

Structure natural period T= h/46 = (4.2+3x3.4)/46 = 0.313 sec

Earthquake design coefficient C = $(1.25a)/T^{2/3}$= $1.25\text{x}0.11/0.313^{2/3}$= 0.298

Calculate CS= 0.298 x1.0 = 0.298 > (2.5a)= 2.5x0.11=0.275

The equivalent base shear force $V < I[(2.5a)/R_f]G_g$

V=1.0x(2.5x0.11)x (2806.6x4)/4 = 772.36 kN > ($0.01G_g$)=0.01x(2806.6x4)= 112.3 kN

Therefore, the equivalent base shear force V= 772.36 kN

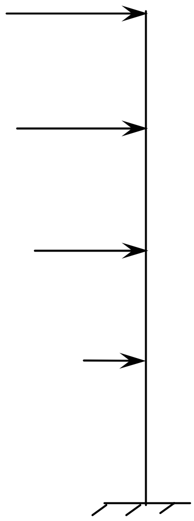
Vertical distribution of horizontal earthquake forces (As per cl. 6.3 of AS 1170.4)

14.4x772.36/(14.4+11+7.6+4.2)=**299 kN**

11.0x772.36/(14.4+11+7.6+4.2)=**229 kN**

7.60x772.36/(14.4+11+7.6+4.2)=**158 kN**

4.20x772.36/(14.4+11+7.6+4.2)=**87 kN**



Earthquake loads at floor levels

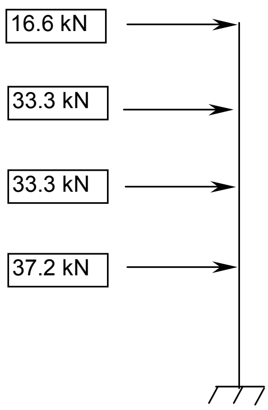
DATA

basic wind speed (V_u) =	50	m/s	Building		
Region =	A		Breadth (b) =	52	m
Terrain Category =	2.0		Depth (d) =	36	m
Shielding muiltiplier (M_s) =	1.0		Height (h) =	14.4	m
Topographical muiltiplier (M_t) =	1.0				
Structure Importance muiltiplier (M_i) =	1.0				
Wind Direction =	Assume West wind				

Cl. 3.2	Gust wind Speed (V_z) =	$V_u M_{(z,cat)} M_s M_t M_i$		
T. 3.2.5.1	$M_{(z, cat)}$ =	1.044		
	V_z =	52.2	m/s	
Cl. 3.3	Dynamic Wind Pressure (q_z) =	$0.6V_z^2 \times 10^{-3}$		kPa
	q_z =	1.63	kPa	
Cl. 3.4.1.2	Force on Windward Wall (F) =	$Sum\ (p_z)A_z$		
	p_z =	$(p_e - p_i)$		
Cl. 3.4.2	p_e =	$(C_{p,e})K_a K_l K_p q_z$		
T. 3.4.3.1(A)	$(C_{p,e})$ =	0.7		for h < 25m & $q_z = q_h$
Cl. 3.4.4	K_a =	1.0		
Cl. 3.4.5	K_l =	1.0		
Cl. 3.4.6	K_p =	1.0		
	p_e =	1.14	kPa	
Cl. 3.4.7	p_i =	$(C_{p,i})\, q_z$		
T. 3.4.7	$(C_{p,i})$ =	-0.30 or 0.0		for All condition 3
	p_i =	-0.49	kPa	
	or	0	kPa	
	p_z =	**1.63**	kPa	*or* **1.14** kPa

Therefore, Total force on the frame (F)

Cl. 3.4.1.2	*F (max)* =	9.78	kN/m

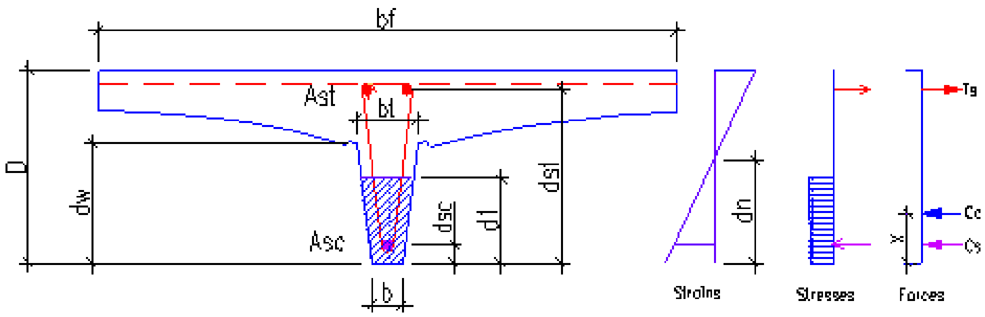


BEAM DESIGN [AS3600- Normal Strength Concrete]

PROJECT : CORCON PROTOTYPE FRAME BEAM

BEAM : RIB BEAM 894 mm deep

DESIGN DATA



$f_c = 40.6$	MPa		
$f_{sy} = 448$	MPa	$E_s := 200000$	MPa
$D := 894$	mm	$d_{sc} := 60$	mm
$b := 150$	mm	$d_{st} := 830$	mm
$A_{st} := 2512$	mm^2	$d_w := 576$	mm
$A_{sc} := 1256$	mm^2	$b_t := 360$	mm

DESIGN FOR BENDING

Compressive strain $\varepsilon_u := 0.003$

$\gamma := 0.85 - 0.007(f_c - 28)$ $\quad \gamma = 0.762 \quad 0.65 \le \gamma \le 0.85 \quad \alpha := 0.85$

Effective Depth of Compression Block "'d $_o$" is obtained from $C_c+C_s=T$

Initial Guess $d_o := 134.185$

Neutral Axis depth $d_n := \dfrac{d_o}{\gamma}$ $\quad d_n = 176.1$ mm

Width of the rib at a depth "do": $b_o := d_o \cdot \dfrac{(b_t - b)}{d_w} + b$ $\quad b_o = 198.922$ mm

Distance to C.G. of Compression concrete area "x"

$$x := \frac{\left[0.5 \cdot b \cdot d_o^{\,2} + d_o^{\,2} \cdot \dfrac{(b_o - b)}{3}\right]}{0.5 \cdot (b + b_o) \cdot d_o} \qquad x = 70.228 \text{ mm}$$

Lever arm distance $z := d_{st} - x$ $\quad z = 759.8$ mm

Check yield Assumptions

Yeild strain of steel $\varepsilon_{sy} := \frac{f_{sy}}{E_s}$ $\varepsilon_{sy} = 0.0022$

Strain in the tensile steel $\varepsilon_{st} := \varepsilon_u \cdot \frac{d_{st} - d_n}{d_n}$ $\varepsilon_{st} = 0.0111$

Strain in the compressive steel $\varepsilon_{sc} := \varepsilon_u \cdot \frac{d_n - d_{sc}}{d_n}$ $\varepsilon_{sc} = 0.002$

Steel stress $\sigma_{st} := \mathrm{if}\left(\left|\varepsilon_{st}\right| < \varepsilon_{sy}, E_s \cdot \varepsilon_{st}, f_{sy}\right)$

$\sigma_{sc} := \mathrm{if}\left(\left|\varepsilon_{sc}\right| < \varepsilon_{sy}, E_s \cdot \varepsilon_{sc}, f_{sy}\right)$

Steel stress is corrected for sign :

$\sigma_{st} := \mathrm{if}\left(\varepsilon_{st} < 0 + \left|\varepsilon_{st}\right| > \varepsilon_{sy}, -f_{sy}, \sigma_{st}\right)$ $\sigma_{st} = 448$ MPa

$\sigma_{sc} := \mathrm{if}\left(\varepsilon_{st} < 0 + \left|\varepsilon_{st}\right| > \varepsilon_{sy}, -f_{sy}, \sigma_{sc}\right)$ $\sigma_{sc} = 395.6$ MPa

Concrete Compressive Force $C_c := \alpha \cdot f_c \cdot d_o \cdot \frac{(b + b_o) \cdot 10^{-3}}{2}$ $C_c = 807.9$ kN

Compressive steel force $C_s := A_{sc} \cdot \sigma_{sc} \cdot \frac{(d_n - d_{sc})}{d_n} \cdot 10^{-3}$ $C_s = 327.6$ kN

Tensile steel force $T := A_{st} \cdot \sigma_{st} \cdot 10^{-3}$ $T = 1125.4$ kN

Out of balance force $F_{out} := C_c + C_s - T$ $F_{out} = 10$ kN

$$d_o := \mathrm{root}\left[0.5 \cdot \alpha \cdot f_c \cdot d_o \cdot \left[2 \cdot b + d_o \cdot \frac{(b_t - b)}{d_w}\right] + \sigma_{sc} \cdot \frac{(d_o - \alpha \cdot d_{sc}) \cdot A_{sc}}{d_o} - \sigma_{st} \cdot A_{st}, d_o\right]$$

Change the initial guess d_o until F_{out} close to zero $d_o = 135.329$ mm

Moment Capacity $M_u := \left[C_s \cdot (d_{st} - d_{sc}) + C_c \cdot z\right] \cdot 10^{-3}$ $M_u = 866.1$ kNm

$\phi := 0.8$ $\phi \cdot M_u = 692.9$ kNm

Therefore, Negative Moment Capcity of Prototype Beam $\phi \cdot M_u = 692.9$ kNm

BEAM DESIGN [AS3600- Normal Strength Concrete]

PROJECT : CORCON PROTOTYPE BEAM

**BEAM : ** RIB BEAM 894 mm deep

DESIGN DATA

$f_c = 40.6$	MPa				
$f_{sy} = 448$	MPa	$E_s := 200000$	MPa	$f_{syf} = 345$	MPa
$D := 894$	mm	$d_{sc} := 60$	mm	$b_t := 360$	mm
$b := 150$	mm	$d_o := 830$	mm	$s := 200$	mm
$A_{st} := 2512$	mm^2	$d_w := 576$	mm	$A_g := 453 \cdot 10^3$	mm^2
$A_{sc} := 1256$	mm^2	$N := 0$		$A_{sv} := 226$	mm^2

Design for Shear

(a) Calculation of Vuc

$$\beta_1 := 1.1 \cdot \left(1.6 - \frac{d_o}{1000}\right) \qquad \beta_1 = 0.847$$

$$\beta_2 := 1 - \frac{N}{3.5A_g}$$ For members with tensile axial force

$$\beta_2 := 1 + \frac{N}{14 \cdot A_g}$$ For members with Compressive axial force

$$\beta_2 = 1$$

$$\beta_3 := 1$$ (As there is no Concentrated load near the support)

$$b_v := 0.5 \cdot (b + b_t)$$

$$V_{uc} := \beta_1 \cdot \beta_2 \cdot \beta_3 \cdot b_v \cdot d_o \left(\frac{A_{st} \cdot f_c}{b_v \cdot d_o}\right)^{\frac{1}{3}} \cdot 10^{-3} \qquad V_{uc} = 140.5 \quad \text{kN}$$

(b) Calculation of θv

$$\frac{b_v \cdot s}{f_{syf}} = 147.826$$

$$A_{svmin} := 0.35 \cdot b_v \cdot \frac{s}{f_{syf}} \qquad A_{svmin} = 51.739 \quad mm^2$$

$$A_{svmax} := b_v \cdot \frac{s}{f_{syf}} \left(0.2 \cdot f_c - \frac{V_{uc} \cdot 10^3}{b_v \cdot d_o} \right) \qquad A_{svmax} = 1.1 \times 10^3 \quad mm^2$$

$$\theta_v := 30 + 15 \cdot \left(\frac{A_{sv} - A_{svmin}}{A_{svmax} - A_{svmin}} \right) \qquad \theta_v = 32.5 \quad deg$$

$$\theta_{vr} := \theta_v \cdot \frac{\pi}{180}$$

(c) Calculation of ϕVu when stirrups are at yield

$$V_{us} := \frac{A_{sv}}{s} \cdot f_{syf} \cdot d_o \cdot \cot(\theta_{vr}) \cdot 10^{-3} \qquad V_{us} = 508.139$$

$$V_u := V_{uc} + V_{us} \qquad V_u = 648.7 \quad kN$$

$\phi := 0.7$ Therefore Shear Strength $\phi \cdot V_u = 454.1$ kN

BEAM DESIGN [AS3600- Normal Strength Concrete]

PROJECT : CORCON PROTOTYPE BEAM

BEAM : Corcon 894 mm deep

DESIGN DATA

$f_c = 40.6$	MPa		
$f_{sy} = 448$	MPa	$E_s := 200000$	MPa
$D := 894$	mm	$d_{sc} := 64$	mm
$b := 2100$	mm	$d_{st} := 834$	mm
$A_{st} := 1256$	mm^2		
$A_{sc} := 0$	mm^2		

DESIGN FOR BENDING (Positive)

Compressive strain $\varepsilon_u := 0.003$

Stress block parameter $\gamma := 0.85 - 0.007(f_c - 28)$ $\gamma = 0.762$ $0.65 \le \gamma \le 0.85$

Neutral axis depth $d_n := f_{sy} \cdot (A_{st} - A_{sc}) \cdot \left(\frac{1}{0.85 f_c \cdot b \cdot \gamma} \right)$ $d_n = 10.2$ mm

Lever arm distance $z := d_{st} - 0.5 \cdot \gamma \cdot d_n$ $z = 830.1$ mm

$k_u := \frac{d_n}{d_{st}}$ $k_u = 0.012$

Check yield Assumptions

Yeild strain of steel $\varepsilon_{sy} := \frac{f_{sy}}{E_s}$ $\varepsilon_{sy} = 0.0022$

Strain in the tensile steel $\varepsilon_{st} := \varepsilon_u \cdot \frac{d_{st} - d_n}{d_n}$ $\varepsilon_{st} = 0.2425$

Strain in the compressive steel $\varepsilon_{sc} := \varepsilon_u \cdot \frac{d_n - d_{sc}}{d_n}$ $\varepsilon_{sc} = -0.0158$

Concrete Compressive Force $C_c := 0.85 \cdot f_c \cdot \gamma \cdot b \cdot d_n \cdot 10^{-3}$ $C_c = 562.688$ kN

Compressive steel force $C_s := A_{sc} \cdot f_{sy} \cdot 10^{-3}$ $C_s = 0$ kN

Tensile steel force $T := A_{st} \cdot f_{sy} \cdot 10^{-3}$ $T = 562.688$ kN

Moment Capacity $M_u := \left[f_{sy} \cdot A_{sc} \cdot (d_{st} - d_{sc}) + 0.85 \cdot f_c \cdot b \cdot \gamma \cdot d_n \cdot z \right] \cdot 10^{-6}$ $M_u = 467.1$ kNm

$\phi := 0.8$

Design Bending strength (Positive) $\phi \cdot M_u = 373.7$ kNm