

STRUCTURAL CALCULATIONS

FOR

REINFORCED CONCRETE SLEEPERS

AT

OUTBACK SLEEPERS AUSTRALIA PTY LTD

Prepared by:

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JOB NO: C060604

Outback Sleepers
AUSTRALIA PTY LTD

www.outbacksleepers.net.au
APPROVAL REGISTER

Rev	Date	Issue	Engineer	Checked	Approved
Ø	10/7/06	Construction	CL		
1	13/4/07	Construction Re-Issue	CL		

The following Australian Standards have been used in the preparation of this design:

AS 1170.0:2002	Structural Design Actions Part 0: General Principles
AS 1170.1:2002	Structural Design Actions Part 1: Permanent, Imposed & Other Actions
AS 3600	Concrete Structures
AS 3700	Masonry Structures

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INTRODUCTION

The following structural calculations concern the design of "standard" reinforced concrete sleepers manufactured by Outback Sleepers Australia PTY LTD. The required flexural reinforcement was calculated for wall heights ranging from 1.0m to 3.0m and two different lengths of sleepers (2.0m and 2.4m). Checks were also done on the end bearing zone which is assumed to have no reinforcement. All of the above was completed in accordance with AS3600-2001 "Concrete Structure".

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Sleeper Length = 2.0m

Maximum Sleeper Depth = 1.0m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 ⇒ B1 exposure class to exposed face
 ○ N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)
- 2) < 1km from coast Table 4.10.3.4 – AS3600
 ⇒ B2 exposure class to exposed face
 ○ N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600

Length of Sleeper	L = 2000 mm
Height of Wall	H = 1000 mm
Compressive Strength of Concrete	$F'_c = 32 \text{ MPa}$ (B1)
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500 \text{ MPa}$
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 80 mm
b = t / 2	b = 40 mm
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45 - \phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18 \text{ kN/m}^3$
Surcharge	Q = 5 kPa
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667 \text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d / 2$	$\eta_1 = 5.400 \text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 7.067 \text{ kPa}$
$w = \eta_t \times d$	w = 1.413 kN/m
$w^* = 1.5 \times w$	$w^* = 2.120 \text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 1.060 \text{ kNm}$

Flexural Strength of SleeperCapacity Reduction Factor of Bending $\phi_b = 0.8$ Table 2.3 – AS3600

$$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{(b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d))})$$
 $A_{st \text{ required}} = 72.39 \text{ mm}^2$

2 10mm diameter bars are required

Diameter of Bar	$d_b = 10 \text{ mm}$
$A_{st} = 2 \times \pi \times (d_b/2)^2$	$A_{st} = 157.08 \text{ mm}^2$
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 2.051 \text{ kNm}$

 $\phi M_u \geq M^*$ therefore OK**Shear Strength of Sleeper**

$$V^* = w^* \times L / 2$$
 $V^* = 2.120 \text{ kN}$

Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required cl 8.2.5 – AS3600


$$\beta_1 = 1.1 \times (1.6 - b)$$
 $\beta_1 = 1.716$ cl 8.2.7.1 – AS3600

$$\beta_2 = \beta_3 = 1.0$$

Shear Strength Reduction Factor; $\phi_v = 0.7$ Table 2.3 – AS3600

$$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$$
 $\frac{1}{2}\phi V_{uc} = 4.115 \text{ kN}$ cl 8.2.7.1 – AS3600

As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required

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Sleeper Length = 2.0m

Maximum Sleeper Depth = 1.6m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 - ⇒ B1 exposure class to exposed face
 - N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)
- 2) < 1km from coast Table 4.10.3.4 – AS3600
 - ⇒ B2 exposure class to exposed face
 - N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600


Length of Sleeper	L = 2000 mm
Height of Wall	H = 1600 mm
Compressive Strength of Concrete	$F'_c = 32 \text{ MPa}$ (B1)
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500 \text{ MPa}$
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 100 mm
$b = t / 2$	b = 50 mm
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45 - \phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18 \text{ kN/m}^3$
Surcharge	Q = 5 kPa
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667 \text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d / 2$	$\eta_1 = 9.000 \text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 10.667 \text{ kPa}$
$w = \eta_t \times d$	w = 2.133 kN/m
$w^* = 1.5 \times w$	$w^* = 3.200 \text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 1.600 \text{ kNm}$

Flexural Strength of Sleeper

Capacity Reduction Factor of Bending	$\phi_b = 0.8$	Table 2.3 – AS3600
$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d)})$	$A_{st \text{ required}} = 87.11 \text{ mm}^2$	
2 10mm diameter bars are required		
Diameter of Bar	$d_b = 10 \text{ mm}$	
$A_{st} = 2 \times \pi \times (d_b/2)^2$	$A_{st} = 157.08 \text{ mm}^2$	
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 2.679 \text{ kNm}$	
$\phi M_u \geq M^*$ therefore OK		

Shear Strength of Sleeper

$V^* = w^* \times L / 2$	$V^* = 3.200 \text{ kN}$	
Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required		cl 8.2.5 – AS3600
$\beta_1 = 1.1 \times (1.6 - b)$	$\beta_1 = 1.705$	cl 8.2.7.1 – AS3600
$\beta_2 = \beta_3 = 1.0$		
Shear Strength Reduction Factor;	$\phi_v = 0.7$	Table 2.3 – AS3600
$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$	$\frac{1}{2}\phi V_{uc} = 4.745 \text{ kN}$	cl 8.2.7.1 – AS3600
As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required		

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Sleeper Length = 2.0m

Maximum Sleeper Depth = 2.0m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 - ⇒ B1 exposure class to exposed face
 - N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)
- 2) < 1km from coast Table 4.10.3.4 – AS3600
 - ⇒ B2 exposure class to exposed face
 - N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600

Length of Sleeper	L = 2000 mm
Height of Wall	H = 2000 mm
Compressive Strength of Concrete	$F'_c = 32\text{ MPa}$ (B1)
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500\text{ MPa}$
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 100 mm
b = t / 2	b = 50 mm
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45 - \phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18\text{ kN/m}^3$
Surcharge	Q = 5 kPa
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667\text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d / 2$	$\eta_1 = 11.400\text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 13.067\text{ kPa}$
w = $\eta_t \times d$	w = 2.613 kN/m
$w^* = 1.5 \times w$	$w^* = 3.920\text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 1.960\text{ kNm}$

Flexural Strength of Sleeper

Capacity Reduction Factor of Bending $\phi_b = 0.8$ Table 2.3 – AS3600

$$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{(b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d))})$$
 $A_{st \text{ required}} = 109.17\text{ mm}^2$

2 10mm diameter bars are required

Diameter of Bar	$d_b = 10\text{ mm}$
$A_{st} = 2 \times \pi \times (d_b/2)^2$	$A_{st} = 157.08\text{ mm}^2$
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 2.679\text{ kNm}$

$\phi M_u \geq M^*$ therefore OK

Shear Strength of Sleeper

$$V^* = w^* \times L / 2$$
 $V^* = 3.920\text{ kN}$

Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required cl 8.2.5 – AS3600


$$\beta_1 = 1.1 \times (1.6 - b)$$
 $\beta_1 = 1.705$ cl 8.2.7.1 – AS3600

$$\beta_2 = \beta_3 = 1.0$$

Shear Strength Reduction Factor;

$$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$$
 $\frac{1}{2}\phi V_{uc} = 4.745\text{ kN}$ Table 2.3 – AS3600

As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required cl 8.2.7.1 – AS3600

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Sleeper Length = 2.0m

Maximum Sleeper Depth = 2.4m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 - ⇒ B1 exposure class to exposed face
 - N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)
- 2) < 1km from coast Table 4.10.3.4 – AS3600
 - ⇒ B2 exposure class to exposed face
 - N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600

Length of Sleeper	L = 2000 mm
Height of Wall	H = 2400 mm
Compressive Strength of Concrete	$F'_c = 32\text{ MPa}$ (B1)
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500\text{ MPa}$
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 100 mm
b = t / 2	b = 50 mm
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45 - \phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18\text{ kN/m}^3$
Surcharge	Q = 5 kPa
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667\text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d / 2$	$\eta_1 = 13.800\text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 15.467\text{ kPa}$
w = $\eta_t \times d$	w = 3.093 kN/m
$w^* = 1.5 \times w$	$w^* = 4.640\text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 2.320\text{ kNm}$

Flexural Strength of Sleeper

Capacity Reduction Factor of Bending $\phi_b = 0.8$ Table 2.3 – AS3600

$$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{(b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d))})$$

$A_{st \text{ required}} = 132.45\text{ mm}^2$

2 10mm diameter bars are required

Diameter of Bar	$d_b = 10\text{ mm}$
$A_{st} = 2 \times \pi \times (d_b/2)^2$	$A_{st} = 157.08\text{ mm}^2$
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 2.679\text{ kNm}$

$\phi M_u \geq M^*$ therefore OK

Shear Strength of Sleeper

$$V^* = w^* \times L / 2 \quad V^* = 4.640\text{ kN}$$

Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required cl 8.2.5 – AS3600


$$\beta_1 = 1.1 \times (1.6 - b) \quad \beta_1 = 1.705 \quad \text{cl 8.2.7.1 – AS3600}$$

$$\beta_2 = \beta_3 = 1.0$$

Shear Strength Reduction Factor; $\phi_v = 0.7$ Table 2.3 – AS3600

$$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3} \quad \frac{1}{2}\phi V_{uc} = 4.745\text{ kN} \quad \text{cl 8.2.7.1 – AS3600}$$

As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required

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Sleeper Length = 2.0m

Maximum Sleeper Depth = 3.0m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 - ⇒ B1 exposure class to exposed face
 - N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)
- 2) < 1km from coast Table 4.10.3.4 – AS3600
 - ⇒ B2 exposure class to exposed face
 - N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600

Length of Sleeper	L = 2000 mm
Height of Wall	H = 3000 mm
Compressive Strength of Concrete	$F'_c = 32 \text{ MPa}$ (B1)
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500 \text{ MPa}$
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 100 mm
$b = t / 2$	b = 50 mm
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45 - \phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18 \text{ kN/m}^3$
Surcharge	Q = 5 kPa
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667 \text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d / 2$	$\eta_1 = 17.400 \text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 19.067 \text{ kPa}$
$w = \eta_t \times d$	w = 3.813 kN/m
$w^* = 1.5 \times w$	$w^* = 5.720 \text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 2.860 \text{ kNm}$

Flexural Strength of Sleeper

Capacity Reduction Factor of Bending	$\phi_b = 0.8$	Table 2.3 – AS3600
$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{(b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d))})$	$A_{st \text{ required}} = 170.14 \text{ mm}^2$	
3 12mm diameter bars required		
Diameter of Bar	$d_b = 12 \text{ mm}$	
$A_{st} = 3 \times \pi \times (d_b/2)^2$	$A_{st} = 339.29 \text{ mm}^2$	
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 4.627 \text{ kNm}$	
$\phi M_u \geq M^*$ therefore OK		

Shear Strength of Sleeper

$V^* = w^* \times L / 2$	$V^* = 5.720 \text{ kN}$	
Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required		cl 8.2.5 – AS3600
$\beta_1 = 1.1 \times (1.6 - b)$	$\beta_1 = 1.705$	cl 8.2.7.1 – AS3600
$\beta_2 = \beta_3 = 1.0$		
Shear Strength Reduction Factor;	$\phi_v = 0.7$	Table 2.3 – AS3600
$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$	$\frac{1}{2}\phi V_{uc} = 6.133 \text{ kN}$	cl 8.2.7.1 – AS3600
As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required		

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CHECK PLAIN CONCRETE END-BEARING ZONES

To AS3600 clause 15.2

End Region Shear Strength

Bearing Capacity Reduction Factor

$\phi_r = 0.6$

Table 2.3 – AS3600

$\phi V_u = \phi_r \times 0.15 \times t \times d \times (F'_c)^{1/3}$

cl 15.4.1 – AS3600

for t = 80mm

$\phi V_u = 4.572$ kN

for t = 100mm

$\phi V_u = 5.715$ kN

for t = 120mm

$\phi V_u = 6.858$ kN

for t = 80mm

H = 1000mm

$V^* = 2.120$ kN

for t = 100mm

H = 1600mm

$V^* = 3.200$ kN

H = 2000mm

$V^* = 3.920$ kN

H = 2400mm

$V^* = 4.640$ kN

for t = 120mm

H = 3000mm

$V^* = 5.720$ kN

As $V^* \leq \phi V_u + 2\%$ End Bearing Shear Strength is Adequate

End Region Flexural Strength

$\phi M_{uo} = \phi_r \times F'_t \times I_g / (t/2)$ $\phi M_{uo} = \phi_r \times 0.6 \sqrt{F'_c} \times (b \times t^3 / 12) / (t/2)$

cl 8.1.4.1 – AS3600

for t = 80mm

$\phi M_{uo} = 0.434$ kNm

for t = 100mm

$\phi M_{uo} = 0.679$ kNm

for t = 120mm

$\phi M_{uo} = 0.978$ kNm

@ $x = L_{dt} = 12d_b$

cl 13.1.2.2 – AS3600

for $d_b = 10$ mm

$L_{dt1} = 120$ mm

for $d_b = 12$ mm

$L_{dt2} = 144$ mm

for $d_b = 16$ mm

$L_{dt3} = 192$ mm

$M^*_x = wx(L-x)/2$

for H = 1000mm

$M^* = 0.239$ kNm

for H = 1600mm

$M^* = 0.361$ kNm

for H = 2000mm

$M^* = 0.442$ kNm

for H = 2400mm

$M^* = 0.523$ kNm

for H = 3000mm

$M^* = 0.764$ kNm


As $M^* < \phi M_{uo}$ the flexural strength in the end zone is OK

< ϕM_{uo} , SEE

APPENDIX CALCS

SC3

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Sleeper Length = 2.4m

Maximum Sleeper Depth = 1.0m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 - ⇒ B1 exposure class to exposed face
 - N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)
- 2) < 1km from coast Table 4.10.3.4 – AS3600
 - ⇒ B2 exposure class to exposed face
 - N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600


Length of Sleeper	L = 2400 mm
Height of Wall	H = 1000 mm
Compressive Strength of Concrete	$F'_c = 32\text{ MPa}$ (B1)
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500\text{ MPa}$
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 100 mm
$b = t / 2$	b = 50 mm
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45 - \phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18\text{ kN/m}^3$
Surcharge	Q = 5 kPa
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667\text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d / 2$	$\eta_1 = 5.400\text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 7.067\text{ kPa}$
$w = \eta_t \times d$	w = 1.413 kN/m
$w^* = 1.5 \times w$	$w^* = 2.120\text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 1.526\text{ kNm}$

Flexural Strength of Sleeper

Capacity Reduction Factor of Bending	$\phi_b = 0.8$	Table 2.3 – AS3600
$A_{st\text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d)})$	$A_{st\text{ required}} = 82.74\text{ mm}^2$	
2 10mm diameter bars are required		
Diameter of Bar	$d_b = 10\text{ mm}$	
$A_{st} = 2 \times \pi \times (d_b/2)^2$	$A_{st} = 157.08\text{ mm}^2$	
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 2.679\text{ kNm}$	
$\phi M_u \geq M^*$ therefore OK		

Shear Strength of Sleeper

$V^* = w^* \times L / 2$	$V^* = 2.544\text{ kN}$	
Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required		cl 8.2.5 – AS3600
$\beta_1 = 1.1 \times (1.6 - b)$	$\beta_1 = 1.705$	cl 8.2.7.1 – AS3600
$\beta_2 = \beta_3 = 1.0$		
Shear Strength Reduction Factor;	$\phi_v = 0.7$	Table 2.3 – AS3600
$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$	$\frac{1}{2}\phi V_{uc} = 4.745\text{ kN}$	cl 8.2.7.1 – AS3600
As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required		

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Sleeper Length = 2.4m

Maximum Sleeper Depth = 1.6m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 - ⇒ B1 exposure class to exposed face
 - N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)
- 2) < 1km from coast Table 4.10.3.4 – AS3600
 - ⇒ B2 exposure class to exposed face
 - N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600


Length of Sleeper	L = 2400 mm
Height of Wall	H = 1600 mm
Compressive Strength of Concrete	$F'_c = 32 \text{ MPa}$ (B1)
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500 \text{ MPa}$
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 100 mm
$b = t/2$	b = 50 mm
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45-\phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18 \text{ kN/m}^3$
Surcharge	Q = 5 kPa
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667 \text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d/2$	$\eta_1 = 9.000 \text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 10.667 \text{ kPa}$
$w = \eta_t \times d$	w = 2.133 kN/m
$w^* = 1.5 \times w$	$w^* = 3.200 \text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 2.304 \text{ kNm}$

Flexural Strength of Sleeper

Capacity Reduction Factor of Bending	$\phi_b = 0.8$	Table 2.3 – AS3600
$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{(b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d))})$	$A_{st \text{ required}} = 131.38 \text{ mm}^2$	
2 10mm diameter bars are required		
Diameter of Bar	$d_b = 12 \text{ mm}$	
$A_{st} = 2 \times \pi \times (d_b/2)^2$	$A_{st} = 226.19 \text{ mm}^2$	
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 3.565 \text{ kNm}$	
$\phi M_u \geq M^*$ therefore OK		

Shear Strength of Sleeper

$V^* = w^* \times L / 2$	$V^* = 3.840 \text{ kN}$	
Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required		cl 8.2.5 – AS3600
$\beta_1 = 1.1 \times (1.6 - b)$	$\beta_1 = 1.705$	cl 8.2.7.1 – AS3600
$\beta_2 = \beta_3 = 1.0$		
Shear Strength Reduction Factor;	$\phi_v = 0.7$	Table 2.3 – AS3600
$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$	$\frac{1}{2}\phi V_{uc} = 5.358 \text{ kN}$	cl 8.2.7.1 – AS3600
As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required		

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Sleeper Length = 2.4m

Maximum Sleeper Depth = 2.0m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 - ⇒ B1 exposure class to exposed face
 - N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)

- 2) < 1km from coast Table 4.10.3.4 – AS3600
 - ⇒ B2 exposure class to exposed face
 - N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600

Length of Sleeper	$L = 2400 \text{ mm}$
Height of Wall	$H = 2000 \text{ mm}$
Compressive Strength of Concrete	$F'_c = 32 \text{ MPa (B1)}$
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500 \text{ MPa}$
Depth of Sleeper	$d = 200 \text{ mm}$
Thickness of Sleeper	$t = 100 \text{ mm}$
$b = t / 2$	$b = 50 \text{ mm}$
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45 - \phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18 \text{ kN/m}^3$
Surcharge	$Q = 5 \text{ kPa}$
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667 \text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d / 2$	$\eta_1 = 11.400 \text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 13.067 \text{ kPa}$
$w = \eta_t \times d$	$w = 2.613 \text{ kN/m}$
$w^* = 1.5 \times w$	$w^* = 3.920 \text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 2.822 \text{ kNm}$

Flexural Strength of Sleeper

Capacity Reduction Factor of Bending $\phi_b = 0.8$ Table 2.3 – AS3600

$$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{(b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d))})$$
 $A_{st \text{ required}} = 167.39 \text{ mm}^2$

2 12mm diameter bars required

Diameter of Bar	$d_b = 12 \text{ mm}$
$A_{st} = 2 \times \pi \times (d_b/2)^2$	$A_{st} = 226.19 \text{ mm}^2$
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 3.565 \text{ kNm}$

$\phi M_u \geq M^*$ therefore OK

Shear Strength of Sleeper

$$V^* = w^* \times L / 2$$
 $V^* = 4.704 \text{ kN}$

Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required cl 8.2.5 – AS3600

$$\beta_1 = 1.1 \times (1.6 - b)$$
 $\beta_1 = 1.705$ cl 8.2.7.1 – AS3600


$$\beta_2 = \beta_3 = 1.0$$

Shear Strength Reduction Factor;

$$\phi_v = 0.7$$
Table 2.3 – AS3600

$$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$$
 $\frac{1}{2}\phi V_{uc} = 5.358 \text{ kN}$ cl 8.2.7.1 – AS3600

As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required

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Sleeper Length = 2.4m

Maximum Sleeper Depth = 2.4m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 - ⇒ B1 exposure class to exposed face
 - N32 concrete $c \geq 30\text{mm}$ (for rigid formwork and intense compaction, 40mm otherwise)

- 2) < 1km from coast Table 4.10.3.4 – AS3600
 - ⇒ B2 exposure class to exposed face
 - N40 concrete $c \geq 35\text{mm}$ (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600

Length of Sleeper	L = 2400 mm
Height of Wall	H = 2400 mm
Compressive Strength of Concrete	$F'_c = 32 \text{ MPa}$ (B1)
Yield Strength of Steel Reinforcement (N grade)	$f_{sy} = 500 \text{ MPa}$
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 100 mm
b = t / 2	b = 50 mm
Friction Angle of Soil	$\phi = 30$
$K_a = (\tan(45 - \phi/2))^2$	$K_a = 0.333$
Unit Weight of Backfill Soil	$\gamma_s = 18 \text{ kN/m}^3$
Surcharge	Q = 5 kPa
$\eta_0 = K_a \times Q$	$\eta_0 = 1.667 \text{ kPa}$
$\eta_1 = K_a \times \gamma_s \times H - K_a \times \gamma_s \times d / 2$	$\eta_1 = 13.800 \text{ kPa}$
$\eta_t = \eta_0 + \eta_1$	$\eta_t = 15.467 \text{ kPa}$
w = $\eta_t \times d$	w = 3.093 kN/m
$w^* = 1.5 \times w$	$w^* = 4.640 \text{ kN/m}$
$M^* = w^* \times L^2 / 8$	$M^* = 3.341 \text{ kNm}$

Flexural Strength of Sleeper

Capacity Reduction Factor of Bending $\phi_b = 0.8$ Table 2.3 – AS3600

$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{(b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d))})$ $A_{st \text{ required}} = 207.34 \text{ mm}^2$

3 12mm diameter bars required

Diameter of Bar	$d_b = 12 \text{ mm}$
$A_{st} = 3 \times \pi \times (d_b/2)^2$	$A_{st} = 339.29 \text{ mm}^2$
$\phi M_u = \phi_b \times f_{sy} \times A_{st} \times b \times (1 - 0.6 \times (A_{st} \times f_{sy}) / (b \times d \times F'_c))$	$\phi M_u = 4.627 \text{ kNm}$

$\phi M_u \geq M^*$ therefore OK

Shear Strength of Sleeper

$V^* = w^* \times L / 2$ $V^* = 5.568 \text{ kN}$

Calculate $0.5\phi_v V_{uc}$ and check it is larger than $V^* \Rightarrow$ no shear reinforcement is required cl 8.2.5 – AS3600

$\beta_1 = 1.1 \times (1.6 - b)$ $\beta_1 = 1.705$ cl 8.2.7.1 – AS3600

$\beta_2 = \beta_3 = 1.0$

Shear Strength Reduction Factor; $\phi_v = 0.7$ Table 2.3 – AS3600

$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$ $\frac{1}{2}\phi V_{uc} = 6.133 \text{ kN}$ cl 8.2.7.1 – AS3600

As $0.5\phi V_{uc} \geq V^*$ no shear reinforcement is required

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Sleeper Length = 2.4m

Maximum Sleeper Depth = 3.0m

GENERAL SLEEPER COVER REQUIREMENTS

- 1) 1km → 50km from coast Table 4.10.3.4 – AS3600
 ⇒ B1 exposure class to exposed face
 ○ N32 concrete c ≥ 30mm (for rigid formwork and intense compaction, 40mm otherwise)
- 2) < 1km from coast Table 4.10.3.4 – AS3600
 ⇒ B2 exposure class to exposed face
 ○ N40 concrete c ≥ 35mm (for rigid formwork and intense compaction, 45mm otherwise)

SLEEPER REINFORCEMENT TO AS3600

Length of Sleeper	L = 2400 mm
Height of Wall	H = 3000 mm
Compressive Strength of Concrete	F _c ' = 32 MPa (B1)
Yield Strength of Steel Reinforcement (N grade)	f _{sy} = 500 MPa
Depth of Sleeper	d = 200 mm
Thickness of Sleeper	t = 120 mm
b = t / 2	b = 60 mm
Friction Angle of Soil	φ = 30
K _a = (tan(45-φ/2)) ²	K _a = 0.333
Unit Weight of Backfill Soil	γ _s = 18 kN/m ³
Surcharge	Q = 5 kPa
η ₀ = K _a × Q	η ₀ = 1.667 kPa
η ₁ = K _a × γ _s × H - K _a × γ _s × d / 2	η ₁ = 17.400 kPa
η _t = η ₀ + η ₁	η _t = 19.067 kPa
w = η _t × d	w = 3.813 kN/m
w* = 1.5 × w	w* = 5.720 kN/m
M* = w* × L ² / 8	M* = 4.118 kNm

Flexural Strength of SleeperCapacity Reduction Factor of Bending φ_b = 0.8 Table 2.3 – AS3600

$$A_{st \text{ required}} = F'_c \times d / (1.2 \times f_{sy}) \times (b - \sqrt{(b^2 - (2.4 \times M^*) / (\phi_b \times F'_c \times d))})$$
A_{st required} = 204.17 mm²

3 16mm diameter bars required

Diameter of Bar	d _b = 16 mm
A _{st} = 3 × π × (d _b /2) ²	A _{st} = 603.19 mm ²
φM _u = φ _b × f _{sy} × A _{st} × b × (1 - 0.6 × (A _{st} × f _{sy}) / (b × d × F'_c))	φM _u = 7.655 kNm

φM_u ≥ M* therefore OK**Shear Strength of Sleeper**

$$V^* = w^* \times L / 2$$
V* = 6.864 kN

Calculate 0.5φ_vV_{uc} and check it is larger than V* => no shear reinforcement is required cl 8.2.5 – AS3600

$$\beta_1 = 1.1 \times (1.6 - b)$$
β₁ = 1.694 cl 8.2.7.1 – AS3600

$$\beta_2 = \beta_3 = 1.0$$

Shear Strength Reduction Factor;

$$\frac{1}{2}\phi V_{uc} = 0.5 \times \phi_v \times \beta_1 \times \beta_2 \times \beta_3 \times b \times d \times (A_{st} \times F'_c / (b \times d))^{1/3}$$
φ_v = 0.7 Table 2.3 – AS3600
 ½φV_{uc} = 8.336 kN cl 8.2.7.1 – AS3600

As 0.5φV_{uc} ≥ V* no shear reinforcement is required

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CHECK PLAIN CONCRETE END-BEARING ZONES

To AS3600 clause 15.2

End Region Shear Strength

Bearing Capacity Reduction Factor

$\phi_r = 0.6$

Table 2.3 – AS3600

$\phi V_u = \phi_r \times 0.15 \times t \times d \times (F'_c)^{1/3}$

cl 15.4.1 – AS3600

for t = 80mm

$\phi V_u = 4.572 \text{ kN}$

for t = 100mm

$\phi V_u = 5.715 \text{ kN}$

for t = 120mm

$\phi V_u = 6.858 \text{ kN}$

for t = 80mm

H = 1000mm

$V^* = 2.554 \text{ kN}$

for t = 100mm

H = 1600mm

$V^* = 3.840 \text{ kN}$

H = 2000mm

$V^* = 4.704 \text{ kN}$

H = 2400mm

$V^* = 5.568 \text{ kN}$

H = 3000mm

$V^* = 6.864 \text{ kN}$

As $V^* \leq \phi V_u + 2\%$ End Bearing Shear Strength is Adequate

End Region Flexural Strength

$\phi M_{uo} = \phi_r \times F'_t \times I_g / (t/2)$ $\phi M_{uo} = \phi_r \times 0.6 \sqrt{F'_c} \times (b \times t^3 / 12) / (t/2)$

cl 8.1.4.1 – AS3600

for t = 80mm

$\phi M_{uo} = 0.434 \text{ kNm}$

for t = 100mm

$\phi M_{uo} = 0.679 \text{ kNm}$

for t = 120mm

$\phi M_{uo} = 0.978 \text{ kNm}$

@ $x = L_{dt} = 12d_b$

cl 13.1.2.2 – AS3600

for $d_b = 10\text{mm}$

$L_{dt1} = 120 \text{ mm}$

for $d_b = 12\text{mm}$

$L_{dt2} = 144 \text{ mm}$

for $d_b = 16\text{mm}$

$L_{dt3} = 192 \text{ mm}$

$M^*_x = wx(L-x)/2$

for H = 1000mm

$M^* = 0.290 \text{ kNm}$

for H = 1600mm

$M^* = 0.520 \text{ kNm}$

for H = 2000mm

$M^* = 0.637 \text{ kNm}$

for H = 2400mm

$M^* = 0.754 \text{ kNm}$

for H = 3000mm

$M^* = 1.212 \text{ kNm}$

$M^* < \phi M_{uo}$, SEE APPENDIX
CALCS SC6

As $M^* < \phi M_{uo}$ the flexural strength in the end zone is OK

↑
NOT USED SO
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www.outbacksleepers.net

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Sleepers 2000mm long

H	t	d	w*	A _{st} required	number of bars	bar dia	A _{st}	M*	φM _u
m	mm	mm	kN/m	mm ²		mm	mm ²	kNm	kNm
1.00	80	40	2.120	72	2	10	157	1.060	2.051
1.60	100	50	3.200	87	2	10	157	1.600	2.679
2.00	100	50	3.920	109	2	10	157	1.960	2.679
2.40	100	50	4.640	132	2	10	157	2.320	2.679
3.00	100	50	5.720	170	3	12	339	2.860	4.627

End Bearing Zone							
V*	p'	β ₁	0.5φV _{uc}	V*	φ _r V _u +2%	M*	φM
kN			kN	kN	kN	kNm	kNm
2.120	0.0098	1.716	4.115	2.120	4.663	0.239	0.434
3.200	0.0079	1.705	4.745	3.200	5.829	0.361	0.679
3.920	0.0079	1.705	4.745	3.920	5.829	0.442	0.679
4.640	0.0079	1.705	4.745	4.640	5.829	0.523	0.679
5.720	0.0170	1.705	6.113	5.720	5.829	0.764	0.679

Sleepers 2400mm long

H	t	d	w*	A _{st} required	number of bars	bar dia	A _{st}	M*	φM _u
m	mm	mm	kN/m	mm ²		mm	mm ²	kNm	kNm
1.00	100	50	2.120	83	2	10	157	1.526	2.679
1.60	100	50	3.200	131	2	12	226	2.304	3.565
2.00	100	50	3.920	167	2	12	226	2.822	3.565
2.40	100	50	4.640	207	3	12	339	3.341	4.627
3.00	120	60	5.720	204	3	16	603	4.118	6.619

End Bearing Zone							
V*	p'	β ₁	0.5φV _{uc}	V*	φ _r V _u	M*	φM
kN			kN	kN	kN	kNm	kNm
2.544	0.0079	1.705	4.745	2.544	4.663	0.290	0.434
3.840	0.0113	1.705	5.358	3.840	5.829	0.520	0.679
4.704	0.0113	1.705	5.358	4.704	5.829	0.637	0.679
5.568	0.0170	1.705	6.133	5.568	5.829	0.754	0.679
6.864	0.0251	1.694	7.282	6.864	6.995	1.212	0.978

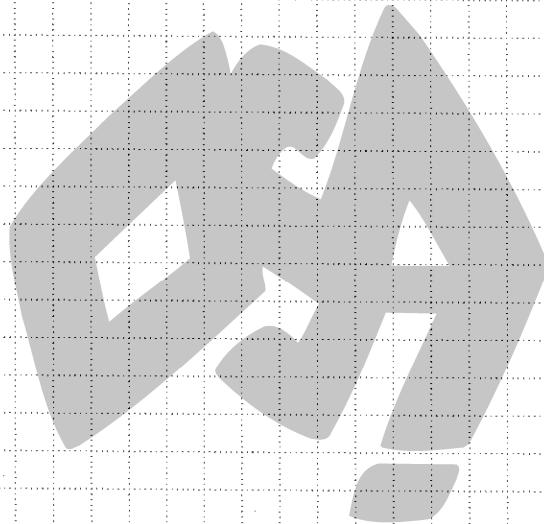


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APPENDIX A



Outback Sleepers
A U S T R A L I A P T Y L T D
www.outbacksleepers.net.au

SLEEPER LENGTH = 2.4m width = 200mm
SLEEPER HEIGHT = 2.4m

$$k_n > 0.4$$

LINEAR ANALYSIS

FIND M_{ud} WITH k_n LIMITED TO 0.4

$$d = 50\text{mm}$$

$$k_{ud} = 20\text{mm}$$

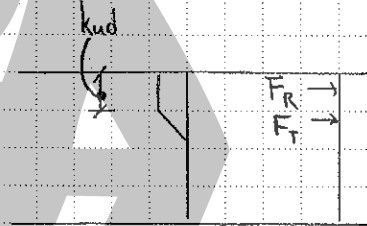
$$\gamma = 0.85 - 0.007 (5'c - 28)$$

$$= 0.822$$

$$Y_{kud} = 16.44\text{mm}$$

$$\sigma_c = 0.855'c$$

$$= 27.2\text{MPa}$$



FORCE IN CONCRETE

RECTANGLE

$$= Y_{kud} \times \sigma_c \times \text{width} / 1000$$

$$= 16.44\text{mm} \times 27.2\text{MPa} \times 200 / 1000$$

$$F_R = 89.43\text{kN}$$

REACTION FROM TOP COMPRESSIVE FIBRE

$$y_R = \frac{\gamma k_{ud}}{2}$$

$$= 8.22\text{mm}$$

TRIANGLE

$$= 0.5 \sigma_c (k_{ud} - \gamma k_{ud}) \times \text{width} / 1000$$

$$= 0.5 \times 27.2\text{MPa} \times (20 - 16.44) \times 200 / 1000$$

$$F_T = 9.68\text{kN}$$

$$y_T = \frac{\gamma k_{ud}}{3} + \frac{1}{3} (k_{ud} - \gamma k_{ud})$$

$$= 17.63\text{mm}$$

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$$\text{TOTAL FORCE} = 99.11\text{kN}$$

$$= \frac{(F_R y_R + F_T y_T)}{(F_R + F_T)}$$

$$= 9.14\text{mm}$$

$$\text{SO ASSUME } F_{\text{STEEL}} = F_{\text{CONC}} = 99.11\text{kN}$$

$$\text{lever arm} = 50 - 9.14\text{mm}$$

$$= 40.86\text{mm}$$

$$M_{ud} = F_{\text{CONC}} \times \text{lever arm}$$

$$= 99.11\text{kN} \times 40.86\text{mm} / 1000$$

$$= 4.05\text{kN.m}$$

$$\phi = 0.8 M_{ud} / M_{uo} \geq 0.6$$

$$M_{uo} = 4.627 / 0.8$$

$$= 5.784\text{kN.m}$$

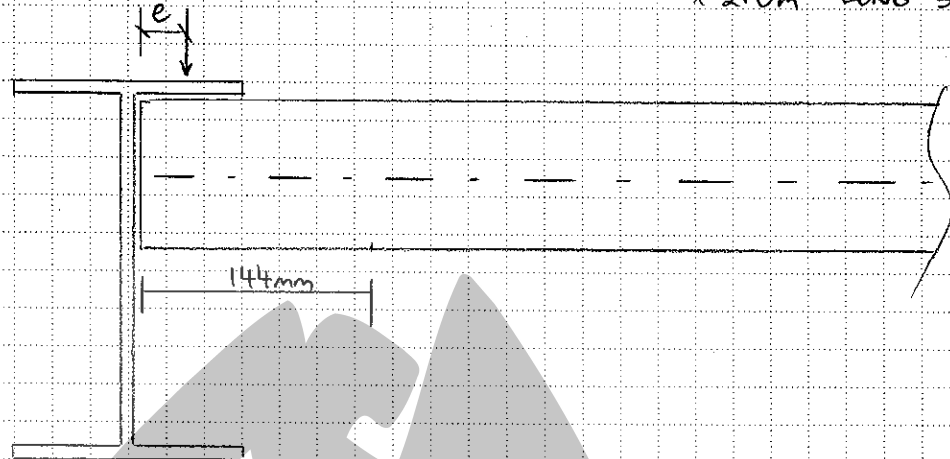
$$\begin{aligned}\phi &= 0.8 \times 4.05 \text{ kN}\cdot\text{m} / 5.784 \text{ kN}\cdot\text{m} \\ &= 0.56 < 0.6 \\ \Rightarrow \phi &= 0.6\end{aligned}$$

$$\begin{aligned}\phi M_{uo} &= 0.6 \times 5.784 \text{ kN}\cdot\text{m} \\ &= 3.47 \text{ kN}\cdot\text{m} > M^* (3.341 \text{ kN}\cdot\text{m})\end{aligned}$$

→ OK


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FROM ATTACHED SPREADSHEET USE 250UB31 TO SUPPORT 3.0m HIGH
x 2.0m LONG SLEEPERS.



AS SHOW ABOVE CONCRETE SLEEPER LENGTH < 2.0m

$$e = (146 - 6.1) / 2 \div 2$$

$$= 35.0 \text{ mm ALLOW FOR } 5 \text{ mm TOLERANCE}$$

$$\therefore \text{LENGTH OF BEAM} = 2000 - [(35 - 5) \times 2] \text{ EACH END}$$

$$= 1940 \text{ mm}$$

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SO NOW MEASURING M^* AT DIFFERENT LOCATION x

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$$x = 144 - (35 - 5)$$

$$= 114 \text{ mm}$$

$$M^* = wx(L-x)/2$$

$$= 5.720 \text{ kN/m} \times 0.114 \text{ m} \times (1.94 \text{ m} - 0.114 \text{ m}) / 2$$

$$= 0.60 \text{ kN.m} < \phi M_{uo} \Rightarrow \text{OK}$$

$$(0.679 \text{ kN.m})$$



Date: 11/04/2007
Job number: C060604
Designer: CL

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Consulting Engineers

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SLEEPER RETAINING WALL STRUCTURAL CALCULATIONS FOR CUT RETAINING WALL

INPUT DATA

Design Height, H	3000 mm
Angle of Surcharge of the Retained Material, β	0 degrees
Surcharge Loading, Q	5 kPa
Density of the Retained Material, γ	18 kN/m ³
Angle of Internal Friction of the Retained Material, ϕ	30 degrees
Sleeper Length, L_1	2 m
Allowable Soil Bearing Pressure	100 kPa
Concrete Pier Footing Diameter, B_1	600 mm
Steel Upright Spacing, L_2	2 m

CONSTANTS

Angle of Inclination of the Wall, α	90 degrees
Friction Angle Between the Retained Material and the Wall, δ	0 degrees
Rankine Coefficient of Active Earth Pressure, K_a	0.3333
Sleeper Breadth, B_2	200 mm
Sleeper Depth, D_1	100 mm



CALCULATIONS

Horizontal Sleepers

HORIZONTAL PRECAST CONCRETE SLEEPERS TO MANUFACTURERS SPECIFICATIONS.

Steel Uprights*Active Earth Force,*

$$P_a = 0.5 \cdot K_a \cdot \gamma \cdot H \cdot \sec(\Delta) \cdot L^2 \quad 54 \text{ kN}$$

Surcharge Force,

$$P_q = K_a \cdot \gamma \cdot H \cdot L^2 \quad 10 \text{ kN}$$

Cantilever Bending Moment,

$$M^* (\text{ult}) = (P_a \cdot (H/3) + P_q \cdot (H/2)) \cdot 1.5 \quad 103.5 \text{ kNm}$$

USE **250 UB 31** OR **200 UC 46** STEEL UPRIGHTS AT **2000 mm CENTRES**

USE 2 - **200 PFC** STEEL UPRIGHTS FOR CORNER DETAIL

NB: STEEL UPRIGHT SECTIONS CHOSEN ASSUMING FULLY RESTRAINT COMPRESSION FLANGE!

Concrete Pier Footing*Total Horizontal Force on a Steel Upright,*

$$P = P_a + P_q \quad 64 \text{ kN}$$

Lever Arm,

$$h = M/P \quad 1.0781 \text{ m}$$

Soil Bearing Pressure,

$$S_1 = P \cdot (2.37 \cdot D + 2.64 \cdot h) / B_1 \cdot D \cdot D \quad 98.783 \text{ kPa}$$

Concrete Pier Footing Depth, D

$$\mathbf{3450} \text{ mm}$$

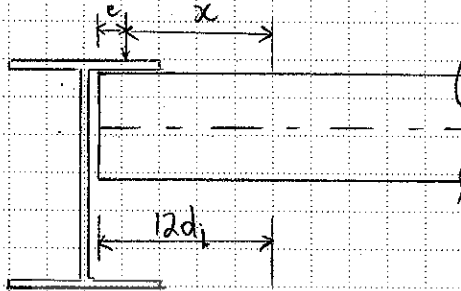
Soil Bearing Pressure < Allowable Soil Bearing Pressure

TRUE

USE **600** mm DIAMETER x **3450** mm DEEP CONCRETE PIER FOOTING
 DEPTH OF EMBEDMENT OF STEEL UPRIGHT INTO PIER FOOTING = **3250** mm

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FROM ATTACHED SPREADSHEET USE 200UB25 FOR SUPPORTS



$$e = (103 - 8.8) / 2 \approx 24.3 \text{ mm}$$

ALLOW FOR 5mm TOLERANCE

$$e = 19.3 \text{ mm}$$

$$\text{EFFECTIVE LENGTH} = 2361.4 \text{ mm}$$

$$x = 144 - 19.3 = 124.7 \text{ mm}$$

$$M^* = wx(L-x)/2 = 4.640 \times 0.1247 \times (2.3614 - 0.1247) / 2 = 0.647 \text{ kN.m}$$

$$0.647 \text{ kN.m} < \phi M_{ubT} (0.679 \text{ kN.m}) \Rightarrow \text{OK}$$

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SLEEPER RETAINING WALL STRUCTURAL CALCULATIONS FOR CUT RETAINING WALL

INPUT DATA

Design Height, H	2400 mm
Angle of Surcharge of the Retained Material, β	0 degrees
Surcharge Loading, Q	5 kPa
Density of the Retained Material, γ	18 kN/m ³
Angle of Internal Friction of the Retained Material, ϕ	30 degrees
Sleeper Length, L_1	2.4 m
Allowable Soil Bearing Pressure	100 kPa
Concrete Pier Footing Diameter, B_1	600 mm
Steel Upright Spacing, L_2	2.4 m

CONSTANTS

Angle of Inclination of the Wall, α	90 degrees
Friction Angle Between the Retained Material and the Wall, δ	0 degrees
Rankine Coefficient of Active Earth Pressure, K_a	0.3333
Sleeper Breadth, B_2	200 mm
Sleeper Depth, D_1	100 mm



CALCULATIONS

Horizontal Sleepers

HORIZONTAL PRECAST CONCRETE SLEEPERS TO MANUFACTURERS SPECIFICATIONS.

Steel Uprights

Active Earth Force,

$$P_a = 0.5 \cdot K_a \cdot \gamma \cdot H \cdot \sec(\Delta) \cdot L_2 \quad 41.472 \text{ kN}$$

Surcharge Force,

$$P_q = K_a \cdot h_e \cdot \gamma \cdot H \cdot L_2 \quad 9.6 \text{ kN}$$

Cantilever Bending Moment,

$$M^* (\text{ult}) = (P_a \cdot (H/3) + P_q \cdot (H/2)) \cdot 1.5 \quad 67.046 \text{ kNm}$$

USE **200 UB 25** OR **150 UC 30** STEEL UPRIGHTS AT **2400 mm CENTRES**

USE 2 - **150 PFC** STEEL UPRIGHTS FOR CORNER DETAIL

NB: STEEL UPRIGHT SECTIONS CHOSEN ASSUMING FULLY RESTRAINT COMPRESSION FLANGE!

Concrete Pier Footing

Total Horizontal Force on a Steel Upright,

$$P = P_a + P_q \quad 51.072 \text{ kN}$$

Lever Arm,

$$h = M/P \quad 0.8752 \text{ m}$$

Soil Bearing Pressure,

$$S_1 = P \cdot (2.37 \cdot D + 2.64 \cdot h) / B_1 \cdot D \cdot D \quad 99.364 \text{ kPa}$$

Concrete Pier Footing Depth, D

2750 mm

Soil Bearing Pressure < Allowable Soil Bearing Pressure

TRUE

USE **600** mm DIAMETER x **2750** mm DEEP CONCRETE PIER FOOTING
 DEPTH OF EMBEDMENT OF STEEL UPRIGHT INTO PIER FOOTING = **2550** mm

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