

STRUCTURAL CALCULATIONS

FOR

CONCRETE SLEEPER AND PANEL

Prepared by:

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PROJECT NO. 150933

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Rev	Date	Issue	Engineer	Checked			
Α	09/05/2019	Client Issue	RS	CL			
В	24/05/2019	Client Reissue	RS	CL			
С	03/04/2020	Client Reissue	NM	CL			
D	05/05/2020	Client Reissue	NM	CL			

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

AS 1170.0 Structural Design Actions Part 0: General Principles

AS 1170.1 Structural Design Actions Part 1: Permanent, Imposed & Other Actions

AS 3600 Concrete Structures





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Sleeper Length =	2000 mm	1	Date: 03/07/20
Sleeper Depth =	200 mm		Page Numbe
Height of Wall =	2000 mm		n = 2
Thickness of Sleeper =	75 mm		dp = 10
Parameters:			<u> </u>
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	40 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	5 kPa
$\eta_0 = K_a Q$		$\eta_0 =$	1.94 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	13.30 kPa
$w = \eta_t d$		w0 =	0.39 kN/m
		w1 =	2.66 kN/m
γ = 0.85 - 0.007(f'c-28)		γ =	0.60
Design Actions:		19 8	N. I
$w^* = 1.25G^* + 1.5Q^*$		w* =	3.91 kN/m
$M^* = w^* L^2 / 8$		M* =	1.95 kNm
$V^* = w^* L/2$	The state of the s	V* =	3.91 kN
Flexural Strength of Sleeper			() () () () () () () ()
Capacity Reduction Factor (bending	g) - AS3600 Table 2.2.2	ф =	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}}(d - \sqrt{d^2 - 2.4M})$	$(1^*/\Phi_b f'_c b)$	$A_{st,req} =$	133.25 mm ²
No. of bars	A W	n =	2
Diameter of bar		$d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$A_{st}f_{st}$,	фМ —	2.27 (Alles
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_{sy}}{b df'})$	-)	$\phi M_u =$	2.27 kNm
Ductility Check	/ //	ku =	0.32 Okay
	Mu>M* Therefore, o	kay in bending	
Shear Strength of Sleeper	465	139	337
Capacity Reduction Factor (shear) -	AS3600 Table 2.2.2	φ=	0.7
AS3600 - Clause 8.2.4.1:	-79	k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	6.20 kN
V V I (C)		fV_{uc}	4.34 kN
		v uc	4.54 NN
		\/*	£/
11,7	TI 6	· ·	> fV _{uc}
φVuc>V*	Therefore, no shear r	einforcement required	

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Sleeper Length =	2000 mm]	Date: 03/07/2
Sleeper Depth =	200 mm		Page Numb
Height of Wall =	3000 mm	r	1 = 2
Thickness of Sleeper =	100 mm	C	dp = 10
Parameters:			
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	65 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	5 kPa
$\eta_0 = K_a Q$		$\eta_0 =$	1.94 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	20.30 kPa
$w = \eta_t d$		w0 =	0.39 kN/m
		w1 =	4.06 kN/m
γ = 0.85 - 0.007(f'c-28)		γ =	0.60
Design Actions:		107 E	A
$w^* = 1.25G^* + 1.5Q^*$		w* =	5.66 kN/m
$M^* = w^* L^2 / 8$		M* =	2.83 kNm
$V^* = w^* L/2$	9	V* =	5.66 kN
Flexural Strength of Sleeper	1		W W
Capacity Reduction Factor (bending	g) - AS3600 Table 2.2.2	φ =	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}} (d - \sqrt{d^2 - 2.4M})$	$M^*/\Phi_b f'_c b$)	$A_{st,req} =$	113.81 mm ²
No. of bars	A 140.00	n =	2
Diameter of bar		$d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_{st}}{b df'})$	<u>y</u>)	$\phi M_u =$	3.84 kNm
Ductility Check	c	ku =	0.20 O kay
	φMu>M* Therefore, ol	cay in bending	
Shear Strength of Sleeper	160	109	337
Capacity Reduction Factor (shear) -	- AS3600 Table 2.2.2	φ=	0.7
AS3600 - Clause 8.2.4.1:	100	k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	10.07 kN
		fV _{uc}	7.05 kN
		V*	> fV _{uc}
٨///۵۱//٨	* Therefore, no shear re		· · · · · · · · · · · · · · · · · · ·
ψνυς>ν	mererore, no snear re	ennorcement required	

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Sleeper Length = Sleeper Depth =	2000				Da	Desigr te: 03/0 Page N	07/20
Height of Wall =	4000			n =			2
Thickness of Sleeper =	110			dp =			10
Parameters:	110			ч р –			$\stackrel{1}{-}$
Compressive strength of concrete			f'c	=	60	MPa	
			Ec		37400		
Yield Strength of Steel Reinforceme	ent (N Grade	e)	fsy	/ =		MPa	
Elastic Modulus Steel	•	,	Es .		200000	MPa	
b =			b =	=	200	mm	
d =			d =	=	75	mm	
Friction Angle of Soil			ф:	=	26.1	0	
$K_a = \tan(45 - \phi/2)^2$			K_{α}	, =	0.39		
Bulk Unit Weight of Backfill Soil			γs	=	18	kN/m3	
Surcharge			Q	£10.	5	kPa	
$\eta_0 = K_a Q$			η_0	, = "	1.94	kPa	
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	alla	1	η_1	= 10	27.30	kPa	
$w = \eta_t d$			w() =	0.39	kN/m	
			W	1 =	5.46	kN/m	
γ = 0.85 - 0.007(f'c-28)			γ =	= 13	0.60		
Design Actions:			W 2		D.		
$w^* = 1.25G^* + 1.5Q^*$			w*	* =	7.41	kN/m	
$M^* = w^*L^2/8$		-	M	* =	3.70	kNm	
$V^* = w^* L/2$	¥	The second	V*	.E.,	7.41	kN	
Flexural Strength of Sleeper		All Sales	J. 188	W W		ille.	
Capacity Reduction Factor (bending			ф:	/ Y	0.8	B).	
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}}(d - \sqrt{d^2 - 2.4M})$	$M^*/\Phi_b f'_c b$		A_{s}	$_{t,req}=$	129.04	mm ²	
No. of bars			n =		2		
Diameter of bar			d_b	=	10	mm	
$A_{st} = n\pi r^2$			A_{st}		157.08	mm^2	
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_{st}}{b_s f_{st}})$	<u>y</u>)		Φ^{M}	$M_u = M_u$	4.47	kNm	

$\phi M_u =$	$\Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_{sy}}{b d f'})$		$\phi M_u =$	4.47 kNm
Ductility (Check	Allian	ku =	0.17 Okay

V.	фMu>M	* Therefore,	okay in be	ending

Shear Strength of Sleeper	///	100
Capacity Reduction Factor (shear) - AS3600 Table 2.2.2	φ =	0.7
AS3600 - Clause 8.2.4.1:	k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$	$V_{uc} =$	11.62 kN
	fV_{uc}	8.13 kN
		7
	V*	> fV _{uc}

φVuc>V* Therefore, no shear reinforcement required

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Plain Concrete End Bearing Zones - Length of 2m

Design Shear:

V* = Reduced Shear (refer Appendix A for calculation)

for t =	75 mm	H =	2000 mm	V* =	3.52 kN
for t =	100 mm	H =	3000 mm	V* =	5.09 kN
for t =	110 mm	H =	4000 mm	V* =	6.67 kN

End Region Shear Strength:

$$\phi V_u = \phi_r 0.15 tb {f'_c}^{1/3}$$

b =	200 mm	300		- D.
ϕ_r =	0.6	Bea	aring Capacity	Reduction Factor
			F 1	DA.
for t =	75 mm	$\Phi V_u =$	5.29 kN	φVu>V*, Okay
f'c =	60 MPa		All	117
for t =	100 mm	$\Phi V_u =$	7.05 kN	φVu>V*, Okay
f'c =	60 MPa			
for t =	110 mm	$\Phi V_u =$	7.75 kN	φVu>V*, Okay
f'c =	60 MPa	100	19	Yes 1

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End Region Flexural Strength - Length of 2m

Design Bending Moment:

Refer Appendix A for calculation of M*

for t =	75 mm	H =	2000 mm	Ld =	130 mm	M* =	0.46 kNm
for t =	100 mm	H =	3000 mm	Ld =	130 mm	M* =	0.67 kNm
for t =	110 mm	H =	4000 mm	Ld =	130 mm	M* =	0.88 kNm

End Region Flexural Strength:

b = 200 mm

for t = 75 mm $\phi \text{Mu} = 0.52 \text{ kNm}$ $\phi \text{Mu} > \text{M*}$, Okay

f'c = 60 MPa

f'cf = 4.65 MPa

for t = 100 mm $\phi \text{Mu} = 0.93 \text{ kNm}$ $\phi \text{Mu} > \text{M}^*$, Okay

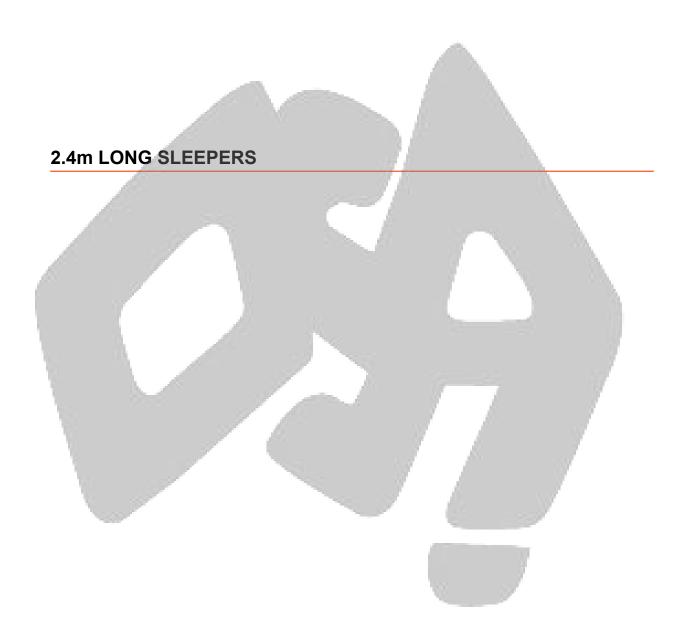
f'c = 60 MPa f'cf = 4.65 MPa

for t = 110 mm ϕ Mu = 1.12 kNm ϕ Mu>M*, Okay

f'c = 60 MPa

f'cf = 4.65 MPa





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Sleeper Length =	2400 mm]	Date: 03/07/20
Sleeper Depth =	200 mm		Page Numb
Height of Wall =	1600 mm	ı	n = 2
Thickness of Sleeper =	80 mm		dp = 10
Parameters:			
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	45 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	5 kPa
$\eta_0 = K_a Q$	-00	$\eta_0 =$	1.94 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	10.50 kPa
$w = \eta_t d$	M	w0 =	0.39 kN/m
///		w1 =	2.10 kN/m
$\gamma = 0.85 - 0.007 (f'c-28)$		γ =	0.60
Design Actions:		37 /	
$w^* = 1.25G^* + 1.5Q^*$		w* =	3.21 kN/m
$M^* = w^* L^2 / 8$		M* =	2.31 kNm
$V^* = w^* L/2$	Y Don.	V* =	3.85 kN
Flexural Strength of Sleeper		Miles III	V
Capacity Reduction Factor (bending		ф =	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}}(d - \sqrt{(d^2 - 2.4M)})$	$M^*/\Phi_b f'_c b$)	$A_{st,req} =$	139.10 mm ²
No. of bars	A No.	n =	2
Diameter of bar		$d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_{sy}}{b df'})$	<u>y</u>)	$\phi M_u =$	2.58 kNm
Ductility Check	C	ku =	0.29 Okay
37	φMu>M* Therefore, ol	kay in bending	7
Shear Strength of Sleeper	163	734	37
Capacity Reduction Factor (shear) -	AS3600 Table 2.2.2	φ =	0.7
AS3600 - Clause 8.2.4.1:	-	k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	6.97 kN
		fV_{uc}	4.88 kN
		V*	> fV _{uc}
φVuc>V*	Therefore, no shear re	einforcement required	

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 fV_{uc}

		1	Desig Date: 03/	
Sleeper Length =	2400 mm		Page	
Sleeper Depth =	200 mm			
Height of Wall =	2400 mm		n =	2
Thickness of Sleeper =	100 mm		dp =	10
Parameters:		C	50 110	
Compressive strength of concrete		f'c =	60 MPa	
A. Her H. ter H t	1 (N C 1)	Ec =	37400 MPa	
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa	
Elastic Modulus Steel b =		Es =	200000 MPa	
d =		b = d =	200 mm	
u – Friction Angle of Soil		u – φ =	65 mm	
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39	
Bulk Unit Weight of Backfill Soil		$\kappa_a = \gamma_s =$	0.39 18 kN/m3	
Surcharge		γs – Q =	5 kPa)
$\eta_0 = K_a Q$		$\eta_0 =$	1.94 kPa	
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	and the	$\eta_1 =$	16.10 kPa	
		w0 =	0.39 kN/m	
$w = \eta_t d$		w1 =	3.22 kN/m	
γ = 0.85 - 0.007(f'c-28)		ν =	0.60	
Design Actions:		39 3		
$w^* = 1.25G^* + 1.5Q^*$		w* =	4.61 kN/m	
$M^* = w^* L^2 / 8$		M* =	3.32 kNm	
$V^* = w^* L/2$		V* =	5.53 kN	
Flexural Strength of Sleeper	200	AC	V., 20	
Capacity Reduction Factor (bending		ф =	0.8	
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}}(d - \sqrt{d^2 - 2.4M})$	$M^*/\Phi_b f'_c b$)	$A_{st,req} =$	134.60 mm ²	
No. of bars	A W	n =	2	
Diameter of bar		$d_h =$	10 mm	
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²	
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_{st}}{b df'})$	<u>y</u>)	$\phi M_u =$	3.84 kNm	
Ductility Check	c	lu -	0.20 O kov	
Ductility Check	φMu>M* Therefore, ok	ku =	0.20 Okay	
Shear Strength of Sleeper	φινια» IVI Therefore, σκ	dy iii beliding		
Capacity Reduction Factor (shear) -	AS3600 Table 2.2.2	φ=	0.7	
AS3600 - Clause 8.2.4.1:	7.55000 Tubic Z.Z.Z	φ – k _v =	0.100	
10000	~			
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	10.07 kN	
		fV_{uc}	7.05 kN	

φVuc>V* Therefore, no shear reinforcement required

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Sleeper Length =	2400 mm	1	Date: 03/07/20
Sleeper Depth =	200 mm		Page Numb
Height of Wall =	4000 mm		n = 2
Thickness of Sleeper =	130 mm		dp = 10
Parameters:		L	
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	95 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	5 kPa
$\eta_0 = K_a Q$	-00	$\eta_0 =$	1.94 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	27.30 kPa
$w = \eta_t d$		w0 =	0.39 kN/m
		w1 =	5.46 kN/m
$\gamma = 0.85 - 0.007 (f'c-28)$		γ =	0.60
Design Actions:		10/1/	
$w^* = 1.25G^* + 1.5Q^*$		w* =	7.41 kN/m
$M^* = w^* L^2 / 8$		M* =	5.33 kNm
$V^* = w^* L/2$	Y Down	V* =	8.89 kN
Flexural Strength of Sleeper			V "
Capacity Reduction Factor (bending		φ =	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}} (d - \sqrt{d^2 - 2.4M})$	$M^*/\Phi_b f'_c b$)	$A_{st,req} =$	146.00 mm ²
No. of bars	A No.	n =	2
Diameter of bar	4 N	$d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_{st}}{b df'})$	<u>y</u>)	$\phi M_u =$	5.72 kNm
Ductility Check	c	ku =	0.14 Okay
	φMu>M* Therefore, ok		7
Shear Strength of Sleeper	****	707	377
Capacity Reduction Factor (shear) -	AS3600 Table 2.2.2	φ =	0.7
AS3600 - Clause 8.2.4.1:	-	k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	14.72 kN
V V V I VC		fV _{uc}	10.30 kN
		V*	> fV _{uc}
φ\/us>\/\	Therefore, no shear re		✓ Vuc
φvuc>v	mererore, no snear re	simorcement required	

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Plain Concrete End Bearing Zones - Length of 2.4m

Design Shear:

V* = Reduced Shear (refer Appendix A for calculation)

for t = 80 mm H = 1600 mm $V^* = 3.53 \text{ kN}$

End Region Shear Strength:

$$\phi V_u = \phi_r 0.15 tb {f'_c}^{1/3}$$

b = 200 mm $\phi_r = 0.6$ Bearing Capacity Reduction Factor

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End Region Flexural Strength - Length of 2.4m

Design Bending Moment:

Refer Appendix A for calculation of M*

for t = 80 mm H = 1600 mm Ld = 130 mm $M^* = 0.56 \text{ kNm}$

End Region Flexural Strength:

b = 200 mm

for t = 80 mm $\phi \text{Mu} = 0.59 \text{ kNm}$ $\phi \text{Mu} > \text{M*, Okay}$ f'c = 60 MPa



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Plain Concrete End Bearing Zones - Length of 2.4m

Design Shear:

V* = Reduced Shear (refer Appendix A for calculation)

for t =	100 mm	H =	2400 mm	V* =	5.07 kN
for t =	130 mm	H =	4000 mm	V* =	8.15 kN

End Region Shear Strength:

$$\phi V_u = \phi_r 0.15 tb {f'_c}^{1/3}$$

b =	200 mm	All Addition		10.
Φ_r =	0.6		Bearing Capacity R	eduction Factor
for t = f'c =	100 mm 60 MPa	$\phi V_u =$	7.05 kN	фVu>V*, Okay
for t =	130 mm	$\Phi V_u =$	9.16 kN	φVu>V*, Okay

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End Region Flexural Strength - Length of 2.4m

Design Bending Moment:

Refer Appendix A for calculation of M*

for t =	100 mm	H =	2400 mm	Ld =	130 mm	M* =	0.80 kNm
for t =	130 mm	H =	4000 mm	Ld =	130 mm	M* =	1.28 kNm

End Region Flexural Strength:

b = 200 mm

for t = 100 mm ϕ Mu = 0.93 kNm ϕ Mu>M*, Okay

f'c = 60 MPa f'cf = 4.65 MPa

for t = 130 mm ϕ Mu = 1.57 kNm ϕ Mu>M*, Okay

f'c = 60 MPa f'cf = 4.65 MPa







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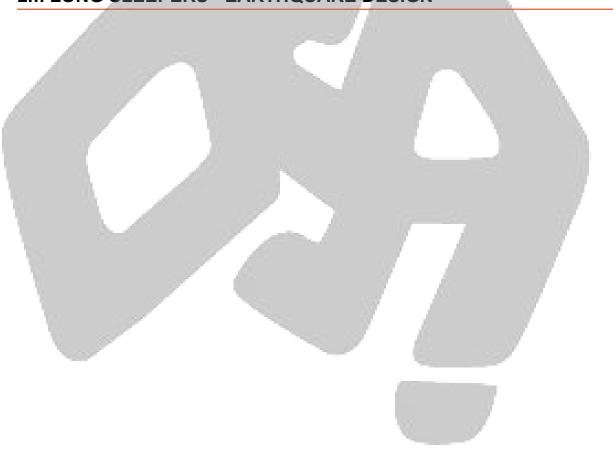
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WHER THIS A PEVE BRIT OCC TO	is THE	E EA CAN STRES FAILL IN T RCINI PT	TO NOT S HESE FORCER OVER	REGION BE PRIOR RE WENT STRESSE	I F IA IO LST GION BNG	LE XVI 2. 4 Ken TM DA S END	RAC VINTI IS IMME HOWE (AS	STA WINIGH POIN VER PE PE XG	S 12 db T An 2 14 COL	TATES ID E : LAPSE REHOR	REAL WILL SLEET	THAT ISTLI N PERS IS	Phr GALL) IOT Pal NOT As	TIAL T RE NELS	DE HE SVLT ENVIS	VELO BAK MAY MGE COI	rme). IN D Mmei	T WILL DUE WIARY)



2m LONG SLEEPERS - EARTHQUAKE DESIGN



Designer: NM Date: 03/07/2019 Page Number: 19

Sleeper Length =	2000 mm		Date: 03/07/20
Sleeper Depth =	200 mm		Page Numb
Height of Wall =	2000 mm		n = 2
Thickness of Sleeper =	75 mm		dp = 10
Parameters:			
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	40 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	2 kPa
$\eta_0 = K_a Q$	-00	$\eta_0 =$	0.78 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	13.30 kPa
$w = \eta_t d$		w0 =	0.16 kN/m
		w1 =	2.66 kN/m
γ = 0.85 - 0.007(f'c-28)		γ =	0.60
Design Actions:		- W A	
$w^* = 1.5G^* + 1.5Q^*$		w* =	4.22 kN/m
$M^* = w^* L^2 / 8$		M* =	2.11 kNm
$V^* = w^* L/2$	Y book	V* =	4.22 kN
Flexural Strength of Sleeper		N Y	V "
Capacity Reduction Factor (bending	g) - AS3600 Table 2.2.2	2 φ=	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}} (d - \sqrt{d^2 - 2.4M})$	$M^*/\Phi_b f'_c b$)	$A_{st,req} =$	145.17 mm ²
No. of bars	A No.	n =	2
Diameter of bar		$d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_s}{b df'})$	<u>y</u>)	$\phi M_u =$	2.27 kNm
Ductility Check		ku =	0.32 Okay
	φMu>M* Therefore, α	okay in bending	
Shear Strength of Sleeper	460	107	NV.
Capacity Reduction Factor (shear) -	AS3600 Table 2.2.2	φ =	0.7
AS3600 - Clause 8.2.4.1:		k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	6.20 kN
···v-·v-·v ·· · · · · · · · · · · ·		fV _{uc}	4.34 kN
		vuc	7.57 KIV
		V*	> fV _{uc}
φVuc>V*	Therefore, no shear	reinforcement required	

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Sleeper Length =	2000 mm	7	Date: 03/07/2
Sleeper Depth =	200 mm		Page Numl
Height of Wall =	3000 mm		n = 2
Thickness of Sleeper =	100 mm		dp = 10
Parameters:			
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforcem	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	65 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	2 kPa
$\eta_0 = K_a Q$	-00	$\eta_0 =$	0.78 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	20.30 kPa
$w = \eta_t d$	Maria de la companya della companya	w0 =	0.16 kN/m
		w1 =	4.06 kN/m
γ = 0.85 - 0.007(f'c-28)		γ =	0.60
Design Actions:		37.0	- N
$w^* = 1.5G^* + 1.5Q^*$		w* =	6.32 kN/m
$M^* = w^* L^2 / 8$		M* =	3.16 kNm
$V^* = w^* L/2$	Y be	V* =	6.32 kN
Flexural Strength of Sleeper			V "
Capacity Reduction Factor (bendin	g) - AS3600 Table 2.2.2	2 φ=	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}} (d - \sqrt{d^2 - 2.4l})$	$M^*/\Phi_b f'_c b$)	$A_{st,req} =$	127.91 mm ²
No. of bars	A No.	n =	2
Diameter of bar	() Y	$d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_s}{b df'})$	<u>y</u>)	$\phi M_u =$	3.84 kNm
Ductility Check	С	ku =	0.20 Okay
	φMu>M* Therefore, α	okay in bending	7
Shear Strength of Sleeper	765	107	NV NV
Capacity Reduction Factor (shear)	- AS3600 Table 2.2.2	φ=	0.7
AS3600 - Clause 8.2.4.1:	-	k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	10.07 kN
··v·- v -·v1· •(··c/		fV _{uc}	7.05 kN
		1 V uc	7.U3 KIN
		V*	> fV _{uc}
φVuc>V	* Therefore, no shear	reinforcement required	

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Sleeper Length =	2000 mm		Date: 03/07/2
Sleeper Depth =	200 mm		Page Num
Height of Wall =	4000 mm		n = 2
Thickness of Sleeper =	110 mm		dp = 10
Parameters:			
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	75 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	2 kPa
$\eta_0 = K_a Q$		$\eta_0 =$	0.78 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	all and	$\eta_1 =$	27.30 kPa
$w = \eta_t d$		w0 =	0.16 kN/m
$W = \Pi_t u$		w1 =	5.46 kN/m
γ = 0.85 - 0.007(f'c-28)		γ =	0.60
Design Actions:		107 J	,
$w^* = 1.5G^* + 1.5Q^*$		w* =	8.42 kN/m
$M^* = w^*L^2/8$		M* =	4.21 kNm
$V^* = w^* L / 2$		V* =	8.42 kN
Flexural Strength of Sleeper		- T	V 10
Capacity Reduction Factor (bending		φ =	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}} (d - \sqrt{(d^2 - 2.4M)})$	$M^*/\Phi_b f'_c b$	$A_{st,req} =$	147.68 mm ²
No. of bars	A 100 100 100 100 100 100 100 100 100 10	n =	2
Diameter of bar		$d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_{st}}{b df'})$	<u>y</u>)	$\phi M_u =$	4.47 kNm
Ductility Check	С	ku =	0.17 Okay
	φMu>M* Therefore, o	kay in bending	7
Shear Strength of Sleeper	763	107	87
Capacity Reduction Factor (shear) -	- AS3600 Table 2.2.2	φ=	0.7
AS3600 - Clause 8.2.4.1:		k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	11.62 kN
		fV _{uc}	8.13 kN
		*	< fV _{uc}
	VA/ITUUNI 400/		< tV _{uc}
	WITHIN 10%	ACCEPT	

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Plain Concrete End Bearing Zones - Length of 2m

Design Shear:

V* = Reduced Shear (refer Appendix A for calculation)

for t =	75 mm	H =	2000 mm	V* =	3.80 kN
for t =	100 mm	H =	3000 mm	V* =	5.69 kN
for t =	110 mm	H =	4000 mm	V* =	7.58 kN

End Region Shear Strength:

$$\Phi V_u = \Phi_r 0.15 tb {f'_c}^{1/3}$$

b =	200 mm	Maria San	. //	10h
ϕ_r =	0.6	Ве	aring Capacity F	Reduction Factor
	All		3 /	The state of the s
for t =	75 mm	$\Phi V_u =$	5.29 kN	φVu>V*, Okay
f'c =	60 MPa	τ·u	r All	11/2
for t =	100 mm	$\Phi V_u =$	7.05 kN	φVu>V*, Okay
f'c =	60 MPa			A
for t =	110 mm	$\Phi V_u =$	7.75 kN	φVu>V*, Okay
f'c =	60 MPa			V.

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End Region Flexural Strength - Length of 2m

Design Bending Moment:

Refer Appendix A for calculation of M*

for t =	75 mm	H =	2000 mm	Ld =	130 mm	M* =	0.50 kNm
for t =	100 mm	H =	3000 mm	Ld =	130 mm	M* =	0.75 kNm
for t =	110 mm	H =	4000 mm	Ld =	130 mm	M* =	1.00 kNm

End Region Flexural Strength:

b = 200 mm

for t = 75 mm $\phi \text{Mu} = 0.52 \text{ kNm}$ $\phi \text{Mu} > \text{M*}$, Okay

f'c = 60 MPa

f'cf = 4.65 MPa

for t = 100 mm $\phi \text{Mu} = 0.93 \text{ kNm}$ $\phi \text{Mu} > \text{M}^*$, Okay

f'c = 60 MPa f'cf = 4.65 MPa

for t = 110 mm ϕ Mu = 1.12 kNm ϕ Mu>M*, Okay

f'c = 60 MPa

f'cf = 4.65 MPa







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Sleeper Length =	2400 mm		Date: 03/07/2
Sleeper Depth =	200 mm		Page Numb
Height of Wall =	1600 mm		n = 2
Thickness of Sleeper =	80 mm		dp = 10
Parameters:			
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	45 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	2 kPa
$\eta_0 = K_a Q$	-276	$\eta_0 =$	0.78 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	10.50 kPa
$w = \eta_t d$		w0 =	0.16 kN/m
		w1 =	2.10 kN/m
γ = 0.85 - 0.007(f'c-28)		γ =	0.60
Design Actions:		37.0	A.
$w^* = 1.5G^* + 1.5Q^*$		w* =	3.38 kN/m
$M^* = w^* L^2 / 8$		M* =	2.44 kNm
$V^* = w^* L/2$	Y bo	V* =	4.06 kN
Flexural Strength of Sleeper	1		V "
Capacity Reduction Factor (bending	g) - AS3600 Table 2.2.2	φ =	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}} (d - \sqrt{d^2 - 2.4M})$	$M^*/\Phi_b f'_c b$	$A_{st,req} =$	147.43 mm ²
No. of bars	_0	n =	2
Diameter of bar	($d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_s}{b df'})$	<u>y</u>)	$\phi M_u =$	2.58 kNm
Ductility Check	c	ku =	0.29 Okay
	φMu>M* Therefore, o		7
Shear Strength of Sleeper	465	TW A	137
Capacity Reduction Factor (shear)	- AS3600 Table 2.2.2	φ =	0.7
AS3600 - Clause 8.2.4.1:	100	k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	6.97 kN
V V V 1 (C)		fV_{uc}	4.88 kN
			7
		V*	> fV _{uc}
φVuc>V*	* Therefore, no shear r	einforcement required	

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Sleeper Length =	2400 mm		Date: 03/07/2
Sleeper Depth =	200 mm		Page Numl
Height of Wall =	2400 mm		n = 2
Thickness of Sleeper =	100 mm		dp = 10
Parameters:			
Compressive strength of concrete		f'c =	60 MPa
		Ec =	37400 MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500 MPa
Elastic Modulus Steel		Es =	200000 MPa
b =		b =	200 mm
d =		d =	65 mm
Friction Angle of Soil		φ =	26.1 °
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39
Bulk Unit Weight of Backfill Soil		γs =	18 kN/m3
Surcharge		Q =	2 kPa
$\eta_0 = K_a Q$	-00	$\eta_0 =$	0.78 kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	16.10 kPa
$w = \eta_t d$	M	w0 =	0.16 kN/m
		w1 =	3.22 kN/m
γ = 0.85 - 0.007(f'c-28)		γ =	0.60
Design Actions:		- W A	
$w^* = 1.5G^* + 1.5Q^*$		w* =	5.06 kN/m
$M^* = w^* L^2 / 8$		M* =	3.65 kNm
$V^* = w^* L/2$	Y bo	V* =	6.08 kN
Flexural Strength of Sleeper			V
Capacity Reduction Factor (bending	g) - AS3600 Table 2.2	.2 φ=	0.8
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}} (d - \sqrt{(d^2 - 2.4M)})$	$I^*/\Phi_b f'_c b$)	$A_{st,req} =$	148.75 mm ²
No. of bars	A 14 14 14 15 15 15 15 15 15 15 15 15 15 15 15 15	n =	2
Diameter of bar		$d_b =$	10 mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08 mm ²
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_s}{b df'})$	<u>y</u>)	$\phi M_u =$	3.84 kNm
Ductility Check	c	ku =	0.20 Okay
	φMu>M* Therefore,	okay in bending	7
Shear Strength of Sleeper	163	337	NV NV
Capacity Reduction Factor (shear) -	AS3600 Table 2.2.2	φ=	0.7
AS3600 - Clause 8.2.4.1:	79	k _v =	0.100
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	10.07 kN
y y y1: -1: ()		fV _{uc}	7.05 kN
		uc	7
		V*	> fV _{uc}
φVuc>V*	Therefore, no shear	reinforcement required	

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Sleeper Length =	2375 mm		Dat	te: 03/07/20
Sleeper Depth =	200 mm			Page Numb
Height of Wall =	4000 mm		n =	2
Thickness of Sleeper =	130 mm		dp =	10
Parameters:			•	
Compressive strength of concrete		f'c =	60	MPa
		Ec =	37400	MPa
Yield Strength of Steel Reinforceme	ent (N Grade)	fsy =	500	MPa
Elastic Modulus Steel		Es =	200000	MPa
b =		b =	200	mm
d =		d =	95	mm
Friction Angle of Soil		ф =	26.1	0
$K_a = \tan(45 - \phi/2)^2$		$K_a =$	0.39	
Bulk Unit Weight of Backfill Soil		γs =	18	kN/m3
Surcharge		Q =	2	kPa
$\eta_0 = K_a Q$	-276	$\eta_0 =$	0.78	kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$		$\eta_1 =$	27.30	kPa
$w = \eta_t d$		w0 =		kN/m
		w1 =		kN/m
γ = 0.85 - 0.007(f'c-28)		γ =	0.60	
Design Actions:		- W /	- N	
$w^* = 1.5G^* + 1.5Q^*$		w* =	100.	kN/m
$M^* = w^* L^2 / 8$		M* =	5.94	
$V^* = w^* L/2$	Y bo	V* =	10.00	kN
Flexural Strength of Sleeper		- N	V.	l).
Capacity Reduction Factor (bending		φ =	0.8	30%
$A_{st,req} = \frac{f'_{c}b}{1.2f_{sy}} (d - \sqrt{d^2 - 2.4M})$	$M^*/\Phi_b f'_c b$)	$A_{st,req} =$	163.34	mm ²
No. of bars	A No.	n =	2	
Diameter of bar		$d_b =$	10	mm
$A_{st} = n\pi r^2$		$A_{st} =$	157.08	mm^2
$\Phi M_u = \Phi_b f_{sy} A_{st} d(1 - 0.6 \frac{A_{st} f_s}{b df'})$	<u>y</u>)	$\phi M_u =$	5.72	kNm
Ductility Check	c	ku =	0.14	Okay
1	WITHIN 10% - A		7	,
Shear Strength of Sleeper	160	707	W	
Capacity Reduction Factor (shear)	- AS3600 Table 2.2.2	φ =	0.7	
AS3600 - Clause 8.2.4.1:		k _v =	0.100	
$Vuc = k_v b_v d_v * sqrt(f_c)$		V _{uc} =	14.72	kN
14 ac 14,000 aq. 16(1 _c)				
		fV_{uc}	10.30	KIN
		V*	>	fV_{uc}
φVuc>V	* Therefore, no shear re	einforcement required		

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Plain Concrete End Bearing Zones - Length of 2.4m

Design Shear:

V* = Reduced Shear (refer Appendix A for calculation)

for t = 80 mm H = 1600 mm V* = 3.72 kN

End Region Shear Strength:

$$\phi V_u = \phi_r 0.15 tb {f'_c}^{1/3}$$

b = 200 mm $\phi_r = 0.6$ Bearing Capacity Reduction Factor

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End Region Flexural Strength - Length of 2.4m

Design Bending Moment:

Refer Appendix A for calculation of M*

for t = 80 mm H = 1600 mm Ld = 130 mm $M^* = 0.59 \text{ kNm}$

End Region Flexural Strength:

b = 200 mm

for t = 80 mm $\phi \text{Mu} = 0.59 \text{ kNm}$ $\phi \text{Mu} > \text{M*, Okay}$ f'c = 60 MPa



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Plain Concrete End Bearing Zones - Length of 2.4m

Design Shear:

V* = Reduced Shear (refer Appendix A for calculation)

for t =	100 mm	H =	2400 mm	V* =	5.57 kN
for t =	130 mm	H =	4000 mm	V* =	9.16 kN

End Region Shear Strength:

$$\phi V_u = \phi_r 0.15 tb {f'_c}^{1/3}$$

b =	200 mm	all the second		III.
Φ_r =	0.6		Bearing Capacity R	eduction Factor
for t = f'c =	100 mm 60 MPa	$\Phi V_u =$	7.05 kN	фVu>V*, Okay
for t =	130 mm	$\Phi V_u =$	9.16 kN	WITHIN 10%

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End Region Flexural Strength - Length of 2.4m

Design Bending Moment:

Refer Appendix A for calculation of M*

for t =	100 mm	H =	2400 mm	Ld =	130 mm	M* =	0.88 kNm
for t =	130 mm	H =	4000 mm	Ld =	130 mm	M* =	1.43 kNm

End Region Flexural Strength:

b = 200 mm

for t = 100 mm ϕ Mu = 0.93 kNm ϕ Mu>M*, Okay

f'c = 60 MPa f'cf = 4.65 MPa

for t = 130 mm ϕ Mu = 1.57 kNm ϕ Mu>M*, Okay

f'c = 60 MPa f'cf = 4.65 MPa