STRUCTURAL CALCULATIONS

FOR

CONCRETE SLEEPER AND PANEL

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PROJECT NO. 150933

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REV: C

DATE: 3rd July 2019

APPROVAL REGISTER				
Rev	**Date**	**Issue**	**Engineer**	**Checked**
A	09/05/2019	Client Issue	RS	CL
B	24/05/2019	Client Reissue	RS	CL
C	03/07/2019	Client Reissue	RS	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

Project Number: 150933
Designer: RS
Date: 03/07/2019

Sleeper Length =	2000	mm
Sleeper Depth =	200	mm
Height of Wall =	2000	mm
Thickness of Sleeper =	75	mm

n = 2
dp = 10

Parameters:

Compressive strength of concrete	f'c =	60	MPa
	Ec =	37400	MPa
Yield Strength of Steel Reinforcement (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	o
$K_a = \tan(45 - \phi/2)^2$	$K_a =$	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:

$w^* = 1.5G^* + 1.5Q^*$	w* =	4.57	kN/m
$M^* = w^* L^2/8$	M* =	2.29	kNm
$V^* = w^* L/2$	V* =	4.57	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)}$	$A_{st,req} =$	137.57	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{bdf'_c})$	$\phi M_u =$	2.58	kNm
Ductility Check	ku =	0.29	Okay

ϕMu>M* Therefore, okay in bending

Shear Strength of Sleeper

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} =	309.83867	kN
	fV_{uc}	216.88707	kN
	$0.65fV_{uc}$	140.98	kN
	V*	>	$0.65fV_{uc}$

0.65ϕVuc>V* Therefore, no shear reinforcement required

Sleeper Length =	2000	mm
Sleeper Depth =	200	mm
Height of Wall =	3000	mm
Thickness of Sleeper =	100	mm

n = 2
dp = 10

Parameters:

Compressive strength of concrete	f'c =	60	MPa
	Ec =	37400	MPa
Yield Strength of Steel Reinforcement (N Grade)	fsy =	500	MPa
Elastic Modulus Steel	Es =	200000	MPa
b =	b =	200	mm
d =	d =	70	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:

$w^* = 1.5G^* + 1.5Q^*$	w* =	6.67	kN/m
$M^* = w^* L^2/8$	M* =	3.34	kNm
$V^* = w^* L/2$	V* =	6.67	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req} =$	124.74	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	4.15	kNm
Ductility Check	ku =	0.18	Okay

ϕMu>M* Therefore, okay in bending

Shear Strength of Sleeper

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)	$V_{uc} =$	309.83867	kN
	fV_{uc}	216.88707	kN
	$0.65fV_{uc}$	140.98	kN
	V*	>	$0.65fV_{uc}$

0.65ϕVuc>V* Therefore, no shear reinforcement required

Sleeper Length =	2000	mm
Sleeper Depth =	200	mm
Height of Wall =	4000	mm
Thickness of Sleeper =	110	mm

n = 2
dp = 10

Parameters:			
Compressive strength of concrete	f'c =	60	MPa
	Ec =	37400	MPa
Yield Strength of Steel Reinforcement (N Grade)	fsy =	500	MPa
Elastic Modulus Steel	Es =	200000	MPa
b =	b =	200	mm
d =	d =	80	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
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	27.30	kPa
$w = \eta_t d$	w0 =	0.39	kN/m
	w1 =	5.46	kN/m
γ = 0.85 - 0.007(f'c-28)	γ =	0.60	
Design Actions:			
$w^* = 1.5G^* + 1.5Q^*$	w* =	8.77	kN/m
$M^* = w^* L^2/8$	M* =	4.39	kNm
$V^* = w^* L/2$	V* =	8.77	kN
Flexural Strength of Sleeper			
Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req} =$	143.54	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{bdf'_c})$	$\phi M_u =$	4.78	kNm
Ductility Check	ku =	0.16	Okay

ϕMu>M* Therefore, okay in bending

Shear Strength of Sleeper			
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} =	309.83867	kN
	fV_{uc}	216.88707	kN
	$0.65fV_{uc}$	140.98	kN
	V*	>	$0.65fV_{uc}$

0.65ϕVuc>V* Therefore, no shear reinforcement required

	Project Outback Sleepers				Job Ref. WAD150933
	Calc. by RS	Date JULY '19	Chk'd by CL	Date JULY 19'	Sheet no./Rev. 04/C

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* =	4.12	kN
for t =	100	mm	H =	3000	mm	V* =	6.01	kN
for t =	110	mm	H =	4000	mm	V* =	7.90	kN

End Region Shear Strength:

$$\phi V_u = \phi_r 0.15 t b {f'_c}^{1/3}$$

b = 200 mm

ϕ_r = 0.6   Bearing Capacity Reduction Factor

for t =	75	mm	$\phi V_u =$	5.29	kN	ϕVu>V*, Okay
f'c =	60	MPa				
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	WITHIN 10%
f'c =	60	MPa				

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* =	0.54	kNm
for t =	100	mm	H =	3000	mm	Ld =	130	mm	M* =	0.79	kNm
for t =	110	mm	H =	4000	mm	Ld =	130	mm	M* =	1.04	kNm

End Region Flexural Strength:

b =	200	mm				
for t =	75	mm	ϕMu =	0.52	kNm	WITHIN 10%
f'c =	60	MPa				
f'cf =	4.65	MPa				
for t =	100	mm	ϕMu =	0.93	kNm	ϕMu>M*, Okay
f'c =	60	MPa				
f'cf =	4.65	MPa				
for t =	110	mm	ϕMu =	1.12	kNm	ϕMu>M*, Okay
f'c =	60	MPa				
f'cf =	4.65	MPa				

Sleeper Length =	2400	mm
Sleeper Depth =	200	mm
Height of Wall =	2000	mm
Thickness of Sleeper =	100	mm

n = 2
dp = 10

Parameters:

Compressive strength of concrete	f'c =	60	MPa
	Ec =	37400	MPa
Yield Strength of Steel Reinforcement (N Grade)	fsy =	500	MPa
Elastic Modulus Steel	Es =	200000	MPa
b =	b =	200	mm
d =	d =	70	mm
Friction Angle of Soil	ϕ =	26.1	o
$K_a = \tan(45 - \phi/2)^2$	$K_a =$	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:

$w^* = 1.5G^* + 1.5Q^*$	w* =	4.57	kN/m
$M^* = w^* L^2/8$	M* =	3.29	kNm
$V^* = w^* L/2$	V* =	5.49	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)}$	$A_{st,req} =$	123.02	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{bdf'_c})$	$\phi M_u =$	4.15	kNm
Ductility Check	ku =	0.18	Okay

ϕMu>M* Therefore, okay in bending

Shear Strength of Sleeper

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} =	371.8064	kN
	fV_{uc}	260.26448	kN
	$0.65fV_{uc}$	169.17	kN
	V*	>	$0.65fV_{uc}$

0.65ϕVuc>V* Therefore, no shear reinforcement required

Sleeper Length =	2400	mm
Sleeper Depth =	200	mm
Height of Wall =	4000	mm
Thickness of Sleeper =	130	mm

n = 2
dp = 10

Parameters:			
Compressive strength of concrete	f'c =	60	MPa
	Ec =	37400	MPa
Yield Strength of Steel Reinforcement (N Grade)	fsy =	500	MPa
Elastic Modulus Steel	Es =	200000	MPa
b =	b =	200	mm
d =	d =	100	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
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	27.30	kPa
$w = \eta_t d$	w0 =	0.39	kN/m
	w1 =	5.46	kN/m
γ = 0.85 - 0.007(f'c-28)	γ =	0.60	
Design Actions:			
$w^* = 1.5G^* + 1.5Q^*$	w* =	8.77	kN/m
$M^* = w^* L^2/8$	M* =	6.32	kNm
$V^* = w^* L/2$	V* =	10.53	kN
Flexural Strength of Sleeper			
Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req} =$	164.73	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{bdf'_c})$	$\phi M_u =$	6.04	kNm
Ductility Check	ku =	0.13	Okay

WITHIN 10%

Shear Strength of Sleeper			
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} =	371.8064	kN
	fV_{uc}	260.26448	kN
	$0.65fV_{uc}$	169.17	kN
	V*	>	$0.65fV_{uc}$

0.65ϕVuc>V* Therefore, no shear reinforcement required

	Project Outback Sleepers				Job Ref. WAD150933
	Calc. by RS	Date JULY ' 19	Chk'd by CL	Date JULY ' 19	Sheet no./Rev. 08/C

Plain Concrete End Bearing Zones - Length of 2.4m

Design Shear :

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

for t =	100 mm	H =	2000 mm	V* =	4.96 kN		
for t =	130 mm	H =	4000 mm	V* =	8.04 kN		

End Region Shear Strength:

$$\phi V_u = \phi_r 0.15 t b f'_c{}^{1/3}$$

b = 200 mm

ϕ_r = 0.6 Bearing Capacity Reduction Factor

for t =	75 mm	$\phi V_u =$	5.29 kN	ϕVu>V*, Okay
f'c =	60 MPa			
for t =	130 mm	$\phi V_u =$	9.16 kN	ϕVu>V*, Okay
f'c =	60 MPa			

End Region Flexural Strength - Length of 2.4m

Design Bending Moment:
Refer Appendix A for calculation of M*

for t =	100	mm	H =	2000	mm	Ld =	130	mm	M* =	0.79	kNm
for t =	130	mm	H =	4000	mm	Ld =	130	mm	M* =	1.27	kNm

End Region Flexural Strength:

b =	200	mm				
for t =	100	mm	ϕMu =	0.93	kNm	ϕMu>M*, Okay
f'c =	60	MPa				
f'cf =	4.65	MPa				
for t =	130	mm	ϕMu =	1.57	kNm	ϕMu>M*, Okay
f'c =	60	MPa				
f'cf =	4.65	MPa				