STRUCTURAL CALCULATIONS

FOR

CONCRETE SLEEPER AND PANEL

Prepared by:
WALLBRIDGE GILBERT AZTEC
60 Wyatt Street, Adelaide SA 5000
Ph: (08) 8223 7433

PROJECT NO. 150933

DOCUMENT NO: WGA150933-CA-ST-0003[D]

REV: D

DATE: 5th May 2020

APPROVAL REGISTER				
Rev	**Date**	**Issue**	**Engineer**	**Checked**
A	09/05/2019	Client Issue	RS	CL
B	24/05/2019	Client Reissue	RS	CL
C	03/04/2020	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

2m LONG SLEEPERS

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 =	40	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:			
$w^* = 1.25G^* + 1.5Q^*$	w* =	3.91	kN/m
$M^* = w^* L^2/8$	M* =	1.95	kNm
$V^* = w^* L/2$	V* =	3.91	kN
Flexural Strength of Sleeper			
Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)}$	$A_{st,req} =$	133.25	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	2.27	kNm
Ductility Check	ku =	0.32	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} =	6.20	kN
	fV_{uc}	4.34	kN
	V*	>	fV_{uc}

ϕVuc>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 =	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:

$w^* = 1.25G^* + 1.5Q^*$	w* =	5.66	kN/m
$M^* = w^* L^2/8$	M* =	2.83	kNm
$V^* = w^* L/2$	V* =	5.66	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req} =$	113.81	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	3.84	kNm
Ductility Check	ku =	0.20	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} =	10.07	kN
	fV_{uc}	7.05	kN

V* > fV_{uc}

ϕVuc>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 =	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 =	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:

$w^* = 1.25G^* + 1.5Q^*$	w* =	7.41	kN/m
$M^* = w^* L^2/8$	M* =	3.70	kNm
$V^* = w^* L/2$	V* =	7.41	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req} =$	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	4.47	kNm
Ductility Check	ku =	0.17	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} =	11.62	kN
	fV_{uc}	8.13	kN

V* > fV_{uc}

ϕVuc>V* Therefore, no shear reinforcement required

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:

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

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	ϕVu>V*, Okay
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* =	0.46	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	ϕMu =	0.52	kNm	ϕMu>M*, Okay
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				

2.4m LONG SLEEPERS

Sleeper Length =	2400	mm
Sleeper Depth =	200	mm
Height of Wall =	1600	mm
Thickness of Sleeper =	80	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	°
$K_a = \tan(45 - \phi/2)^2$	$K_a =$	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
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	10.50	kPa
$w = \eta_t d$	w0 =	0.39	kN/m
	w1 =	2.10	kN/m
γ = 0.85 - 0.007(f'c-28)	γ =	0.60	

Design Actions:

$w^* = 1.25G^* + 1.5Q^*$	w* =	3.21	kN/m
$M^* = w^* L^2/8$	M* =	2.31	kNm
$V^* = w^* L/2$	V* =	3.85	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req} =$	139.10	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} =	6.97	kN
	fV_{uc}	4.88	kN

V* > fV_{uc}

ϕVuc>V* Therefore, no shear reinforcement required

Sleeper Length =	2400	mm
Sleeper Depth =	200	mm
Height of Wall =	2400	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 =	65	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
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	16.10	kPa
$w = \eta_t d$	w0 =	0.39	kN/m
	w1 =	3.22	kN/m
γ = 0.85 - 0.007(f'c-28)	γ =	0.60	

Design Actions:

$w^* = 1.25G^* + 1.5Q^*$	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

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b})$	$A_{st,req} =$	134.60	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	3.84	kNm
Ductility Check	ku =	0.20	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} =	10.07	kN
	fV_{uc}	7.05	kN

V* > fV_{uc}

ϕVuc>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 =	95	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
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	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:

$w^* = 1.25G^* + 1.5Q^*$	w* =	7.41	kN/m
$M^* = w^* L^2/8$	M* =	5.33	kNm
$V^* = w^* L/2$	V* =	8.89	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)}$	$A_{st,req} =$	146.00	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{bdf'_c})$	$\phi M_u =$	5.72	kNm
Ductility Check	ku =	0.14	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)	$V_{uc} =$	14.72	kN
	fV_{uc}	10.30	kN

V* > fV_{uc}

ϕVuc>V* Therefore, no shear reinforcement required

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 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 =	80 mm	$\phi V_u =$	5.64 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 =	80	mm	H =	1600	mm	Ld =	130	mm	M* =	0.56	kNm

End Region Flexural Strength:

b = 200 mm

for t =	80	mm	ϕMu =	0.59	kNm	ϕMu>M*, Okay
f'c =	60	MPa				
f'cf =	4.65	MPa				

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:

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

b = 200 mm

ϕ_r = 0.6 Bearing Capacity Reduction Factor

for t =	100	mm	$\phi V_u =$	7.05	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 =	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	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				

EARTHQUAKE DESIGN

WGA

WALLBRIDGE GILBERT AZTEC

Job Number WAD150933
Designer CL
Date JAN' 2017
Page Number

EARTHQUAKE LOADING OF RETAINING WALL

THE FOLLOWING CALCULATIONS ARE TO DETERMINE THE E/Q REQUIREMENTS AS PER AS4679 APPENDIX I

STRUCTURAL CLASSIFICATION - CLASS B TABLE 1.1 & APPENDIX A

ACCELERATION COEFFICIENT (a) - 0.10 FOR ADELAIDE, MELBOURNE VALUE IS LOWER
TABLE I1

SOIL PROFILE & SITE FACTOR (S) - 1.25 TABLE I2

E/Q DESIGN CATEGORY - C_{er} TABLE I3 (aS - 0.125)

DESIGN REQUIREMENTS - DESIGN FOR STATIC LOADS, DEAD LOAD FACTOR OF 1.5 (IN LIEU OF 1.25), NO FURTHER WORK REQ'D
TABLE I4

FOR THE E/Q LOAD CASE THE LIVE LOAD SURCHARGE CAN BE REDUCED AS PER AS1170.4

$0.4Q = 0.4 \times 5kPa = 2.0kPa$

IN THE FOLLOWING CALCULATIONS THERE ARE A COUPLE OF INSTANCES WHERE THE END REGION FLEXURAL STRENGTH FAILS.

THIS IS DUE TO cl 13.1.2.4 WHICH STATES THAT PARTIAL DEVELOPMENT OF A BAR CANNOT BE TAKEN UNTIL $12d_b$. REALISTICALLY THE BAR WILL DEVELOP STRESS PRIOR TO THIS POINT AND WILL NOT RESULT IN BRITTLE FAILURE. WHILST DAMAGE TO THE SLEEPERS / PANELS MAY OCCUR IN THESE REGIONS HOWEVER COLLAPSE IS NOT ENVISAGED DUE TO THE REINFORCEMENT BARS (AS PER FOREWORD IN AS1170.4 COMMENTARY)

∴ ACCEPT OVERSTRESSED END FLEXURAL REGIONS (ASSUMED UNREINFORCED IN CALCS) FOR EARTHQUAKE LOADING

REFER TO SHEET 26(2) FOR ASSOCIATED CALCULATION

WGA
WALLBRIDGE GILBERT AZTEC

2m LONG SLEEPERS - EARTHQUAKE DESIGN

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 =	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
$\eta_0 = K_a Q$	$\eta_0 =$	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:

$w^* = 1.5G^* + 1.5Q^*$	w* =	4.22	kN/m
$M^* = w^* L^2/8$	M* =	2.11	kNm
$V^* = w^* L/2$	V* =	4.22	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req} =$	145.17	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	2.27	kNm
Ductility Check	ku =	0.32	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} =	6.20	kN
	fV_{uc}	4.34	kN

V* > fV_{uc}

ϕVuc>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 =	65	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 =	2	kPa
$\eta_0 = K_a Q$	$\eta_0 =$	0.78	kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	20.30	kPa
$w = \eta_t d$	w0 =	0.16	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* =	6.32	kN/m
$M^* = w^* L^2/8$	M* =	3.16	kNm
$V^* = w^* L/2$	V* =	6.32	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)}$	$A_{st,req} =$	127.91	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{bdf'_c})$	$\phi M_u =$	3.84	kNm
Ductility Check	ku =	0.20	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} =	10.07	kN
	fV_{uc}	7.05	kN

V* > fV_{uc}

ϕVuc>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 =	75	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 =	2	kPa
$\eta_0 = K_a Q$	$\eta_0 =$	0.78	kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	27.30	kPa
$w = \eta_t d$	w0 =	0.16	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* =	8.42	kN/m
$M^* = w^* L^2/8$	M* =	4.21	kNm
$V^* = w^* L/2$	V* =	8.42	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)}$	$A_{st,req} =$	147.68	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	4.47	kNm
Ductility Check	ku =	0.17	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} =	11.62	kN
	fV_{uc}	8.13	kN

V* < fV_{uc}

WITHIN 10% - ACCEPT

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:

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

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	ϕVu>V*, Okay
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* =	0.50	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	ϕMu =	0.52	kNm	ϕMu>M*, Okay
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				

WGA

WALLBRIDGE GILBERT AZTEC

2.4m LONG SLEEPERS - EARTHQUAKE DESIGN

Sleeper Length =	2400	mm
Sleeper Depth =	200	mm
Height of Wall =	1600	mm
Thickness of Sleeper =	80	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	°
$K_a = \tan(45 - \phi/2)^2$	$K_a =$	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
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	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:

$w^* = 1.5G^* + 1.5Q^*$	w* =	3.38	kN/m
$M^* = w^* L^2/8$	M* =	2.44	kNm
$V^* = w^* L/2$	V* =	4.06	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)}$	$A_{st,req} =$	147.43	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	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} =	6.97	kN
	fV_{uc}	4.88	kN

V*	>	fV_{uc}

ϕVuc>V* Therefore, no shear reinforcement required

Sleeper Length =	2400	mm
Sleeper Depth =	200	mm
Height of Wall =	2400	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 =	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
$\eta_0 = K_a Q$	$\eta_0 =$	0.78	kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	16.10	kPa
$w = \eta_t d$	w0 =	0.16	kN/m
	w1 =	3.22	kN/m
γ = 0.85 - 0.007(f'c-28)	γ =	0.60	

Design Actions:

$w^* = 1.5G^* + 1.5Q^*$	w* =	5.06	kN/m
$M^* = w^* L^2/8$	M* =	3.65	kNm
$V^* = w^* L/2$	V* =	6.08	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req} =$	148.75	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	3.84	kNm
Ductility Check	ku =	0.20	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} =	10.07	kN
	fV_{uc}	7.05	kN

V* > fV_{uc}

ϕVuc>V* Therefore, no shear reinforcement required

Sleeper Length =	2375	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 =	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 =	2	kPa
$\eta_0 = K_a Q$	$\eta_0 =$	0.78	kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	$\eta_1 =$	27.30	kPa
$w = \eta_t d$	w0 =	0.16	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* =	8.42	kN/m
$M^* = w^* L^2/8$	M* =	5.94	kNm
$V^* = w^* L/2$	V* =	10.00	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.8	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b})$	$A_{st,req} =$	163.34	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	$\phi M_u =$	5.72	kNm
Ductility Check	ku =	0.14	Okay

WITHIN 10% - ACCEPT

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} =	14.72	kN
	fV_{uc}	10.30	kN

V* > fV_{uc}

ϕVuc>V* Therefore, no shear reinforcement required

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:

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

b =	200 mm		
ϕ_r =	0.6	Bearing Capacity Reduction Factor	
for t =	80 mm	$\phi V_u =$ 5.64 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 =	80	mm	H =	1600	mm	Ld =	130	mm	M* =	0.59	kNm

End Region Flexural Strength:

b =	200	mm				
for t =	80	mm	ϕMu =	0.59	kNm	ϕMu>M*, Okay
f'c =	60	MPa				
f'cf =	4.65	MPa				

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:

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

b =	200 mm	
ϕ_r =	0.6	Bearing Capacity Reduction Factor

for t =	100 mm	$\phi V_u =$	7.05 kN	ϕVu>V*, Okay
f'c =	60 MPa			
for t =	130 mm	$\phi V_u =$	9.16 kN	WITHIN 10%
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 =	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	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				