STRUCTURAL CALCULATIONS

FOR

CONCRETE SLEEPER AND PANEL

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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
E	20/10/2023	Client Reissue	HAB	CL

The following references have been used in the preparation of these design calculations:

References

1. AS/NZS 1170.0-2002 Structural Design Actions – Part 0: General Principles
2. AS/NZS 1170.1-2002 Structural Design Actions – Part 1: Permanent, Imposed & Other Actions
3. AS 1170.4-2007 Structural Design Actions Part 4: Earthquake Actions in Australia
4. AS 3600-2018 Concrete Structures Code

WGA

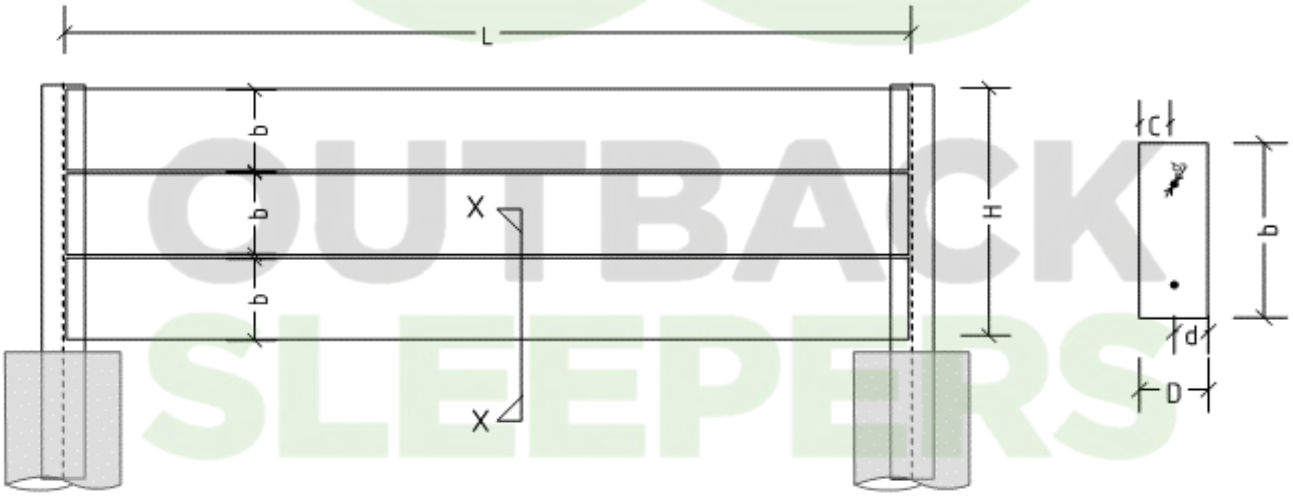
2.0m LONG SLEEPERS

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
2.0 m LONG
2 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.84	✓ 0.87
	Shear Capacity	✓ 0.27	✓ 0.29
Un-Reinforced Sections	Flexural Moment Capacity	✓ 1.00	! 1.06
	Shear Capacity	✓ 0.72	✓ 0.76

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	2000	mm	
Max Retained Height	H	2000	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	75	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	40	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.26		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

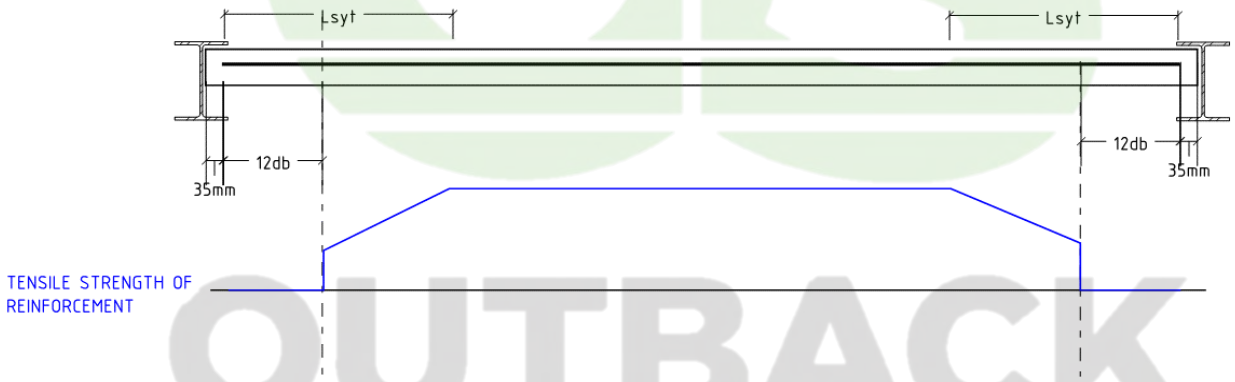
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	11.63416	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	2.326832	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	13.59	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	2.72	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	3.99	kN/m	
	M*	2.00	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	3.99	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	4.24	kN/m	
	M*	2.07	kNm	$M^* = wL^2/8$
	V*	4.18	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	2.38	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c bd))$
Utilisation LC1	*M*/ϕM*	*84%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*87%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	54	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	6.52E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	6.75E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.25		Eq. 8.2.4.2(1)
LC2 kv	kv	0.25		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	14.60	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	14.35	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

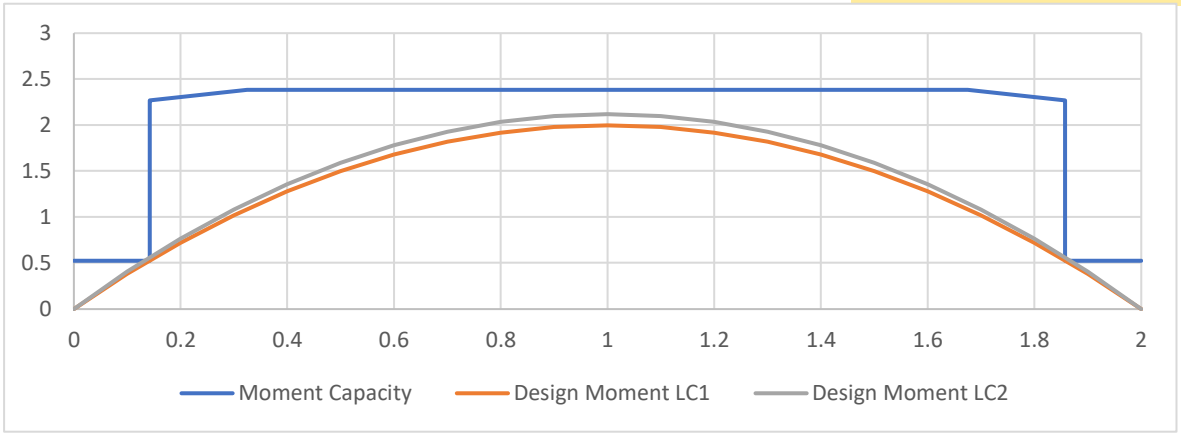
Utilisation LC1	*V*/ϕV*	*27%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*29%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	142.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	0.52	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	0.55	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	245.6897	Mpa	
	ϕMx	2.266534	kNm	

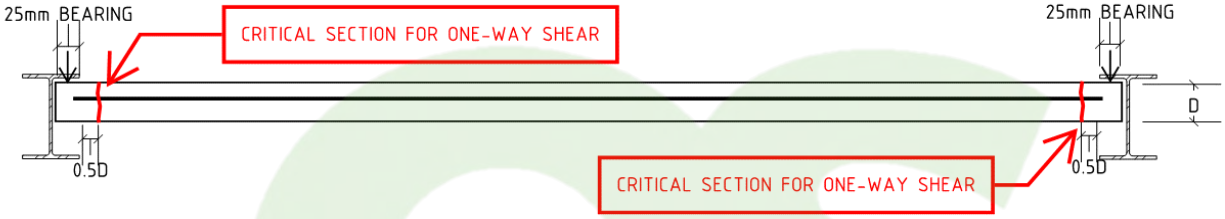


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	187500	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	0.52	kNm	
Utilisation LC1	U	100%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	106%		*Within 10% - Accept*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	50	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	3.79	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	4.02	kN	V = w(L/2-xv)



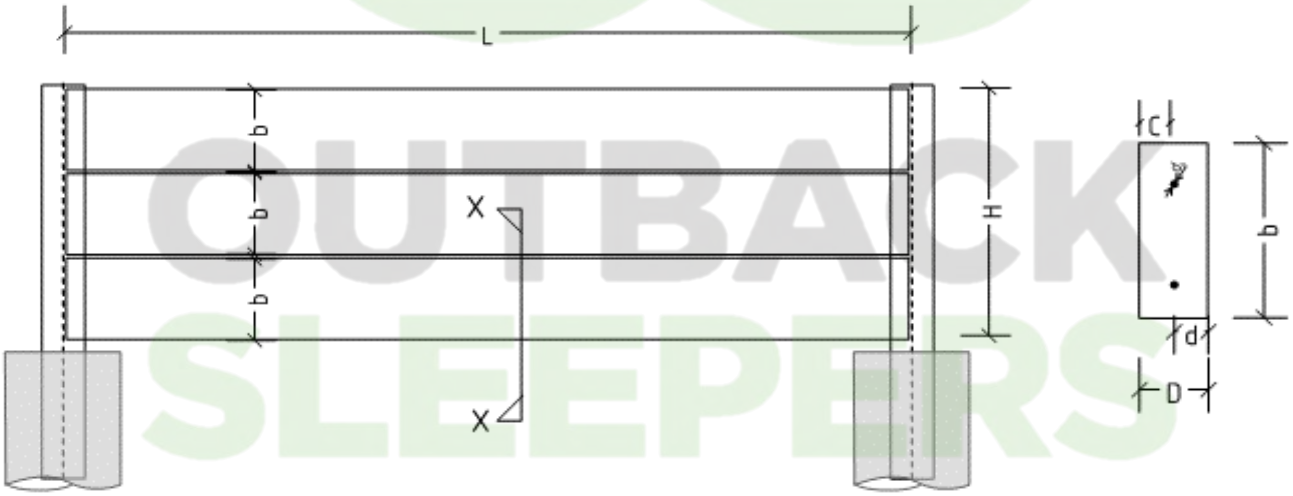
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	5.29	kN	$Vu = 0.15bD(fc)^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	72%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	76%		*fV>V* Concrete section adequate*

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
2.0 m LONG
3 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.71	✓ 0.77
	Shear Capacity	✓ 0.32	✓ 0.36
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.86	✓ 0.95
	Shear Capacity	✓ 0.77	✓ 0.85

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	2000	mm	
Max Retained Height	H	3000	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	100	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	65	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.16		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

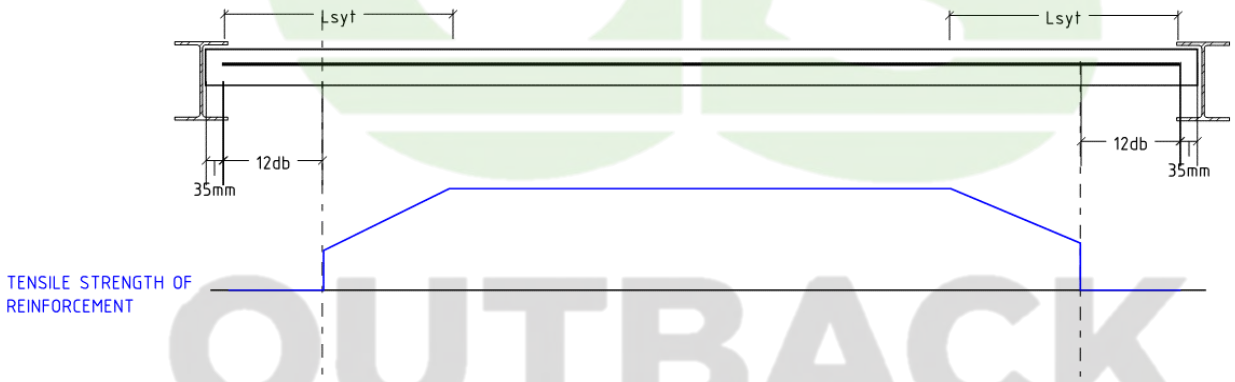
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	17.7574	kPa	$\eta_o = K_a \gamma H - K_a \gamma (b/2)$
	w_1	3.551481	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	20.75	kPa	$\eta_o = K_a \gamma H - K_a \gamma (b/2)$
	w_1	4.15	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	5.78	kN/m	
	M*	2.89	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	5.78	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	6.38	kN/m	
	M*	3.11	kNm	$M^* = wL^2/8$
	V*	6.30	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	4.05	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c b d))$
Utilisation LC1	*M*/ϕM*	*71%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*77%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	72	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	7.31E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	7.88E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.23		Eq. 8.2.4.2(1)
LC2 kv	kv	0.22		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	18.06	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	17.35	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

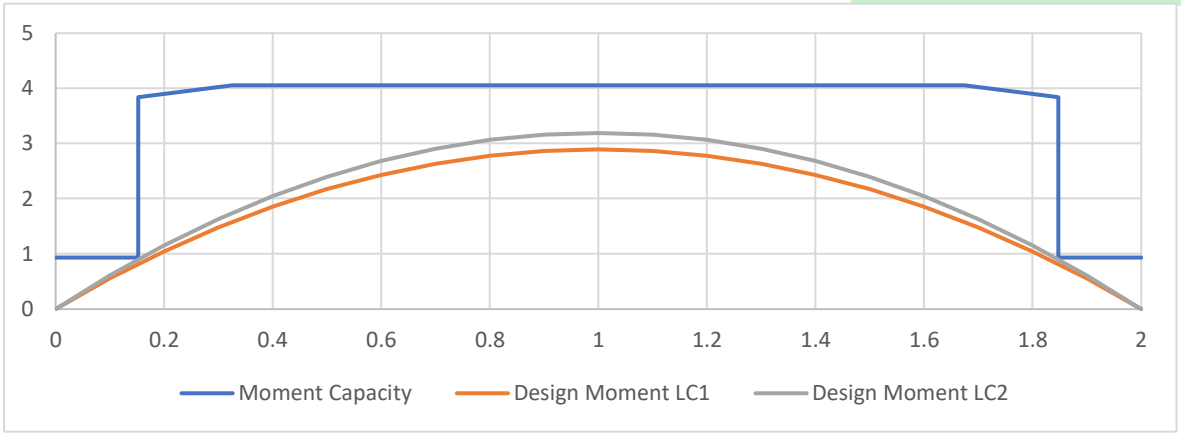
Utilisation LC1	*V*/ϕV*	*32%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*36%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	152.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	0.80	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	0.89	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	262.931	Mpa	
	ϕMx	3.83733	kNm	

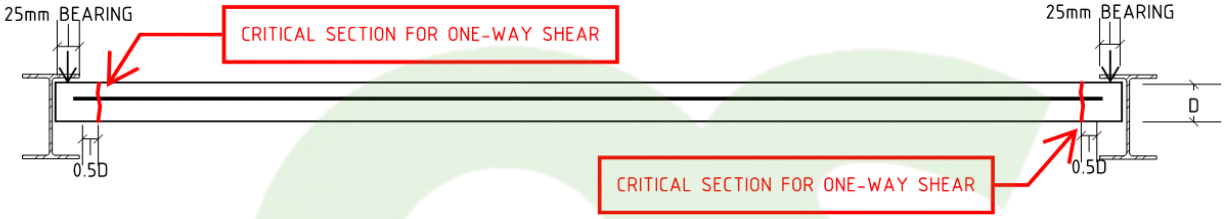


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	333333.3	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	0.93	kNm	
Utilisation LC1	U	86%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	95%		*fV>V* Concrete section adequate*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	62.5	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	5.42	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	5.98	kN	V = w(L/2-xv)



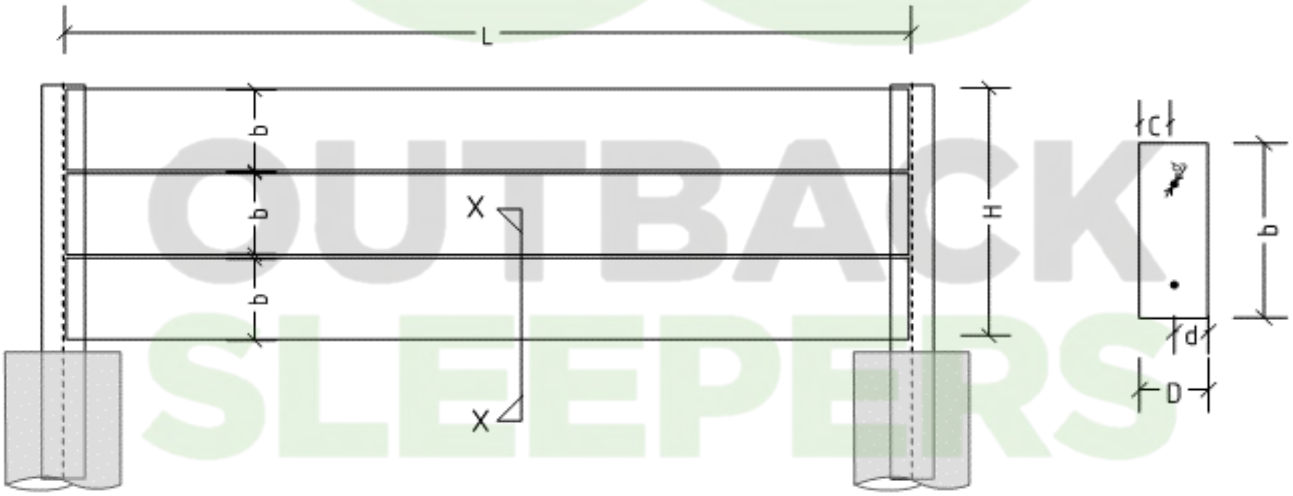
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	7.05	kN	$Vu = 0.15bD(fc)^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	77%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	85%		*fV>V* Concrete section adequate*

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
2.0 m LONG
4 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.80	✓ 0.88
	Shear Capacity	✓ 0.42	✓ 0.50
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.94	! 1.05
	Shear Capacity	✓ 0.91	! 1.03

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	2000	mm	
Max Retained Height	H	4000	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	110	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	75	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.14		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

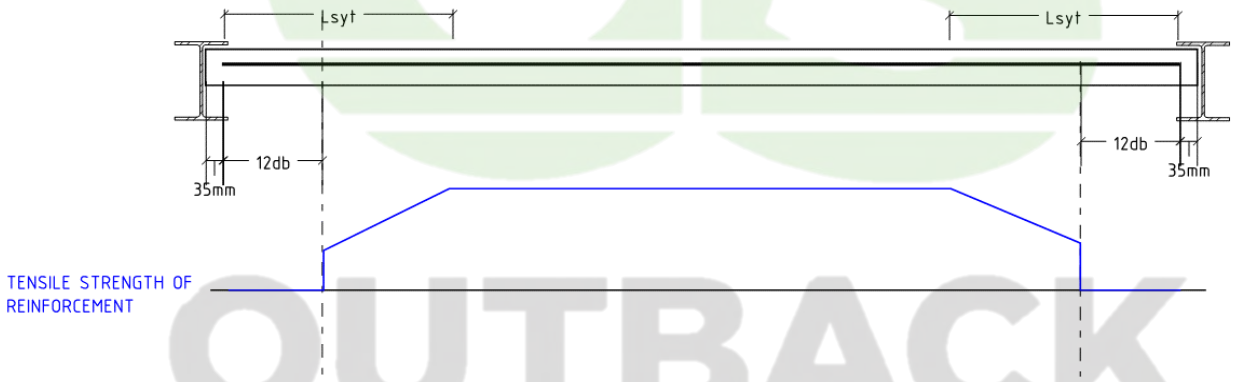
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	23.88065	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	4.776129	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	27.90	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	5.58	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	7.57	kN/m	
	M*	3.79	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	7.57	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	8.53	kN/m	
	M*	4.16	kNm	$M^* = wL^2/8$
	V*	8.42	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	4.72	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c bd))$
Utilisation LC1	*M*/ϕM*	*80%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*88%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	79.2	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	8.81E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	9.70E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.21		Eq. 8.2.4.2(1)
LC2 kv	kv	0.20		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	17.82	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	16.86	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

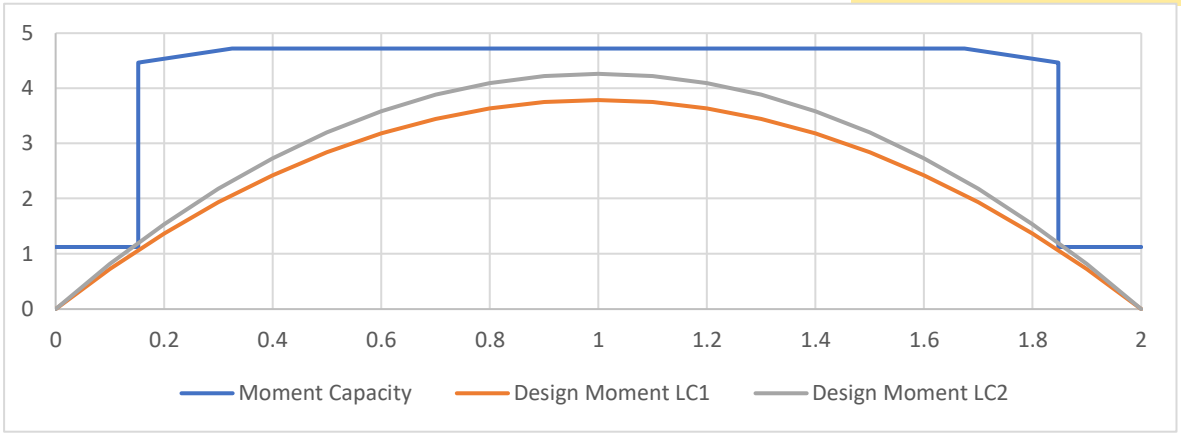
Utilisation LC1	*V*/ϕV*	*42%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*50%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	152.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	1.05	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	1.19	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	262.931	Mpa	
	ϕMx	4.465649	kNm	

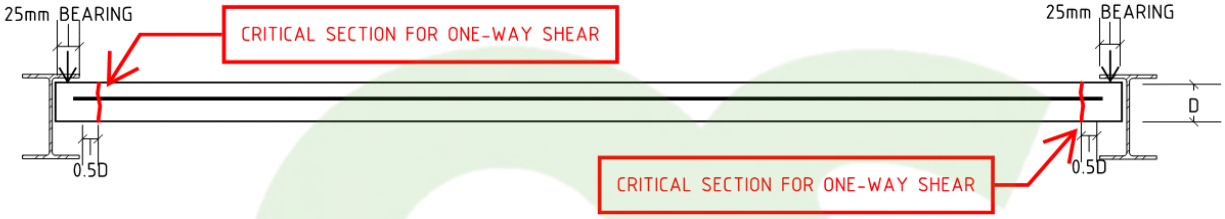


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	403333.3	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	1.12	kNm	
Utilisation LC1	U	94%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	105%		*Within 10% - Accept*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	67.5	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	7.06	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	7.95	kN	V = w(L/2-xv)



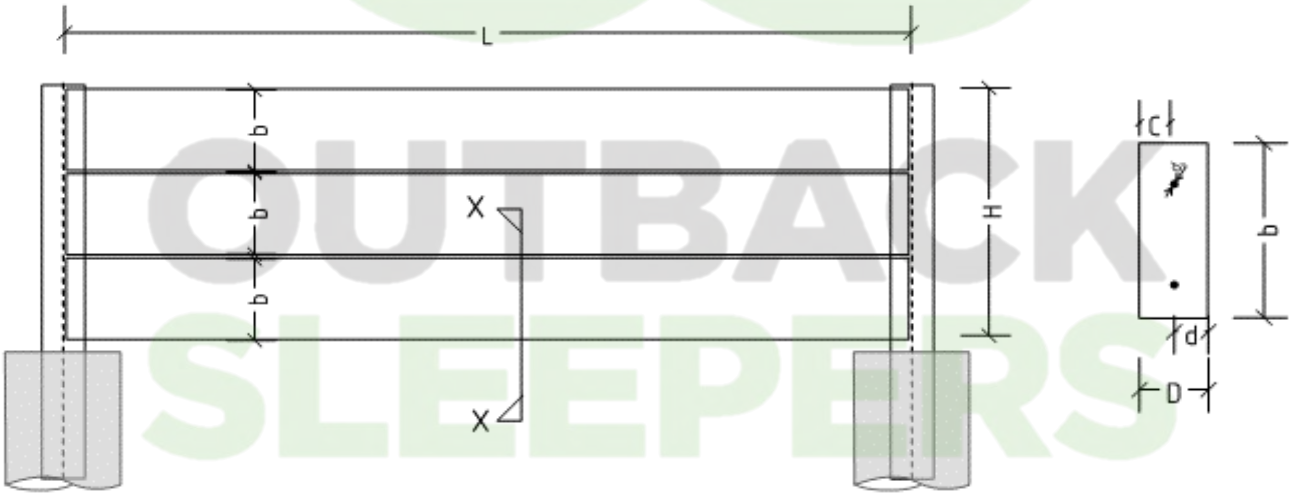
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	7.75	kN	$Vu = 0.15bD(fc)^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	91%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	103%		*Within 10% - Accept*

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
2.4 m LONG
1.6 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.87	✓ 0.88
	Shear Capacity	✓ 0.27	✓ 0.27
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.93	✓ 0.96
	Shear Capacity	✓ 0.67	✓ 0.69

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	2400	mm	
Max Retained Height	H	1600	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	80	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	45	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.23		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

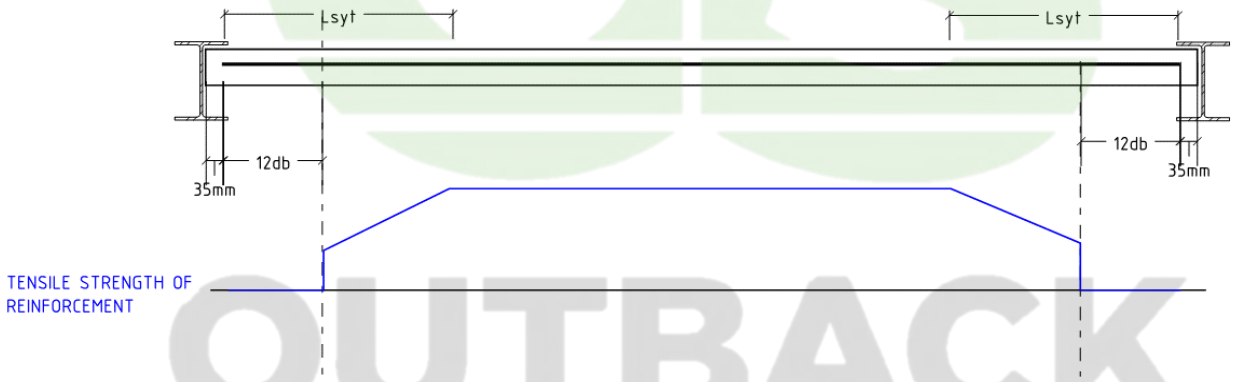
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	9.184863	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	1.836973	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	10.73	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	2.15	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	3.28	kN/m	
	M*	2.36	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	3.93	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	3.38	kN/m	
	M*	2.38	kNm	$M^* = wL^2/8$
	V*	4.01	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	2.72	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c bd))$
Utilisation LC1	*M*/ϕM*	*87%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*88%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	57.6	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	7.15E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	7.22E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.24		Eq. 8.2.4.2(1)
LC2 kv	kv	0.24		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	14.82	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	14.74	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

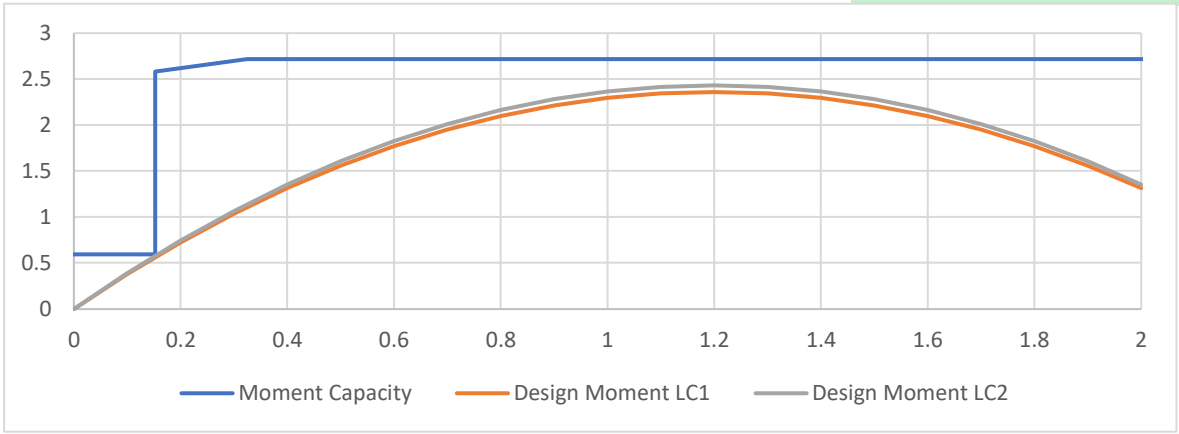
Utilisation LC1	*V*/ϕV*	*27%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*27%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	152.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	0.56	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	0.57	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	262.931	Mpa	
	ϕMx	2.580693	kNm	

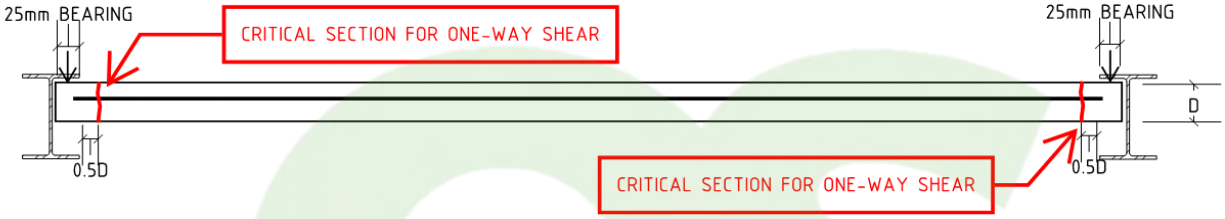


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	213333.3	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	0.59	kNm	
Utilisation LC1	U	93%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	96%		*fV>V* Concrete section adequate*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	52.5	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	3.76	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	3.88	kN	V = w(L/2-xv)



Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	5.64	kN	$Vu = 0.15bD(fc)^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	67%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	69%		*fV>V* Concrete section adequate*

WGA

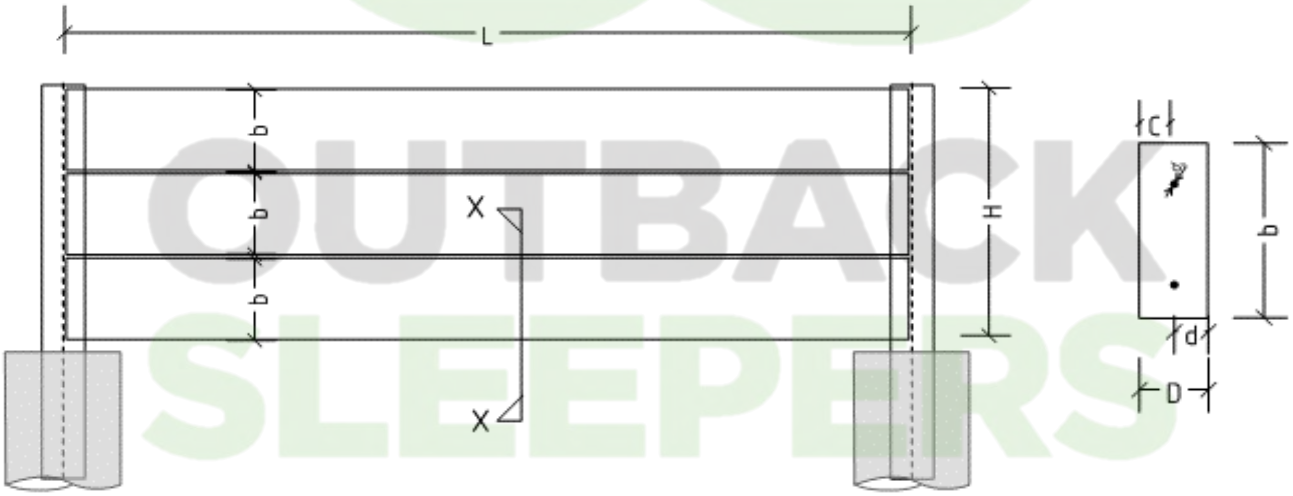
2.4m LONG SLEEPERS

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
2.4 m LONG
2.4 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.84	✓ 0.89
	Shear Capacity	✓ 0.34	✓ 0.37
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.86	✓ 0.93
	Shear Capacity	✓ 0.76	✓ 0.82

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	2400	mm	
Max Retained Height	H	2400	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	100	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	65	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.16		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

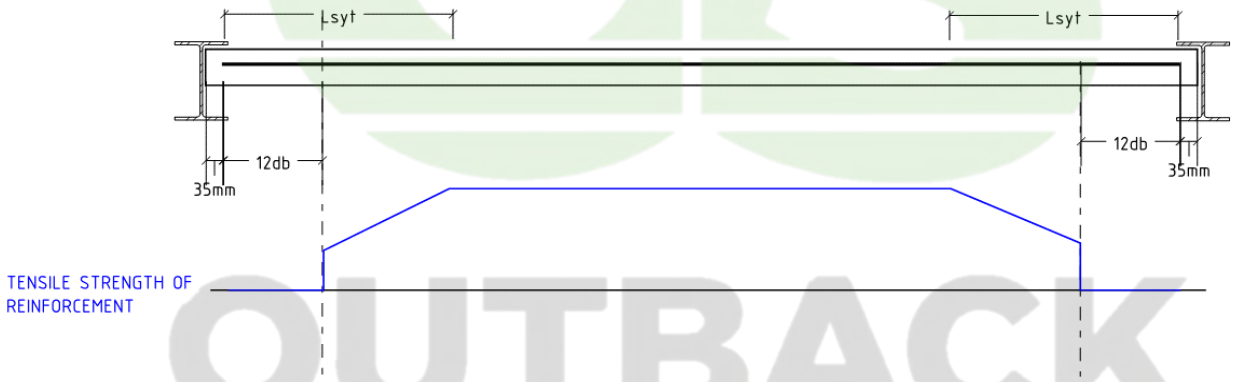
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	14.08346	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	2.816691	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	16.45	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	3.29	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	4.71	kN/m	
	M*	3.39	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	5.65	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	5.10	kN/m	
	M*	3.59	kNm	$M^* = wL^2/8$
	V*	6.05	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	4.05	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c bd))$
Utilisation LC1	*M*/ϕM*	*84%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*89%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	72	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	8.40E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	8.90E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.21		Eq. 8.2.4.2(1)
LC2 kv	kv	0.21		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	16.76	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	16.22	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

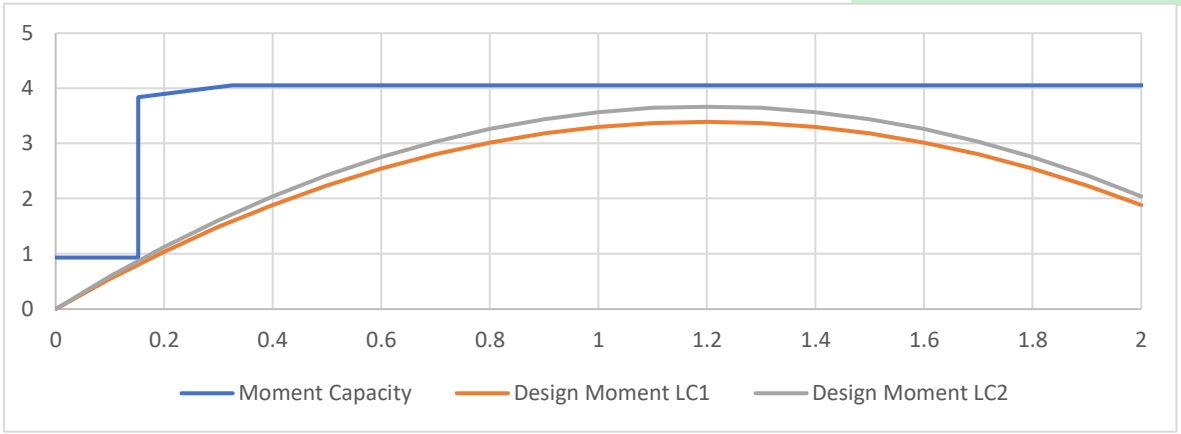
Utilisation LC1	*V*/ϕV*	*34%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*37%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	152.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	0.80	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	0.86	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	262.931	Mpa	
	ϕMx	3.83733	kNm	

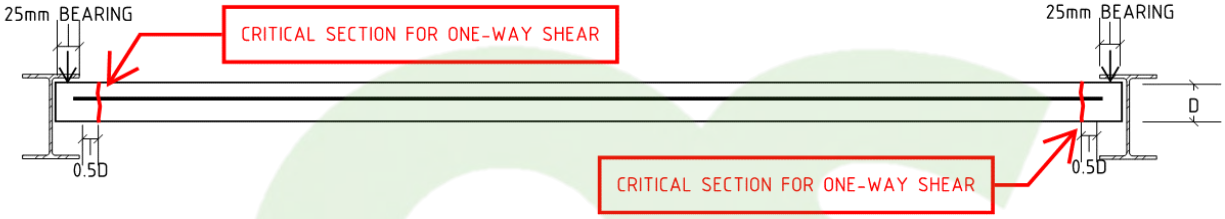


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	333333.3	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	0.93	kNm	
Utilisation LC1	U	86%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	93%		*fV>V* Concrete section adequate*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	62.5	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	5.36	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	5.80	kN	V = w(L/2-xv)



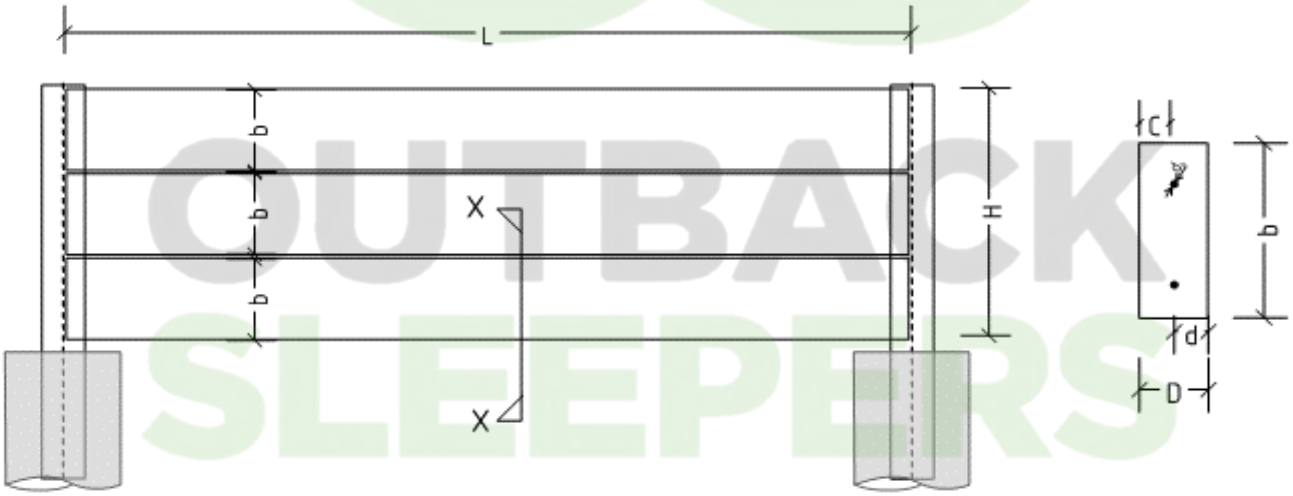
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	7.05	kN	$Vu = 0.15bD(fc)^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	76%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	82%		*fV>V* Concrete section adequate*

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
2.4 m LONG
4 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.90	✓ 0.99
	Shear Capacity	✓ 0.49	✓ 0.58
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.82	✓ 0.92
	Shear Capacity	✓ 0.93	! 1.05

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	2400	mm	
Max Retained Height	H	4000	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	130	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	95	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.11		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

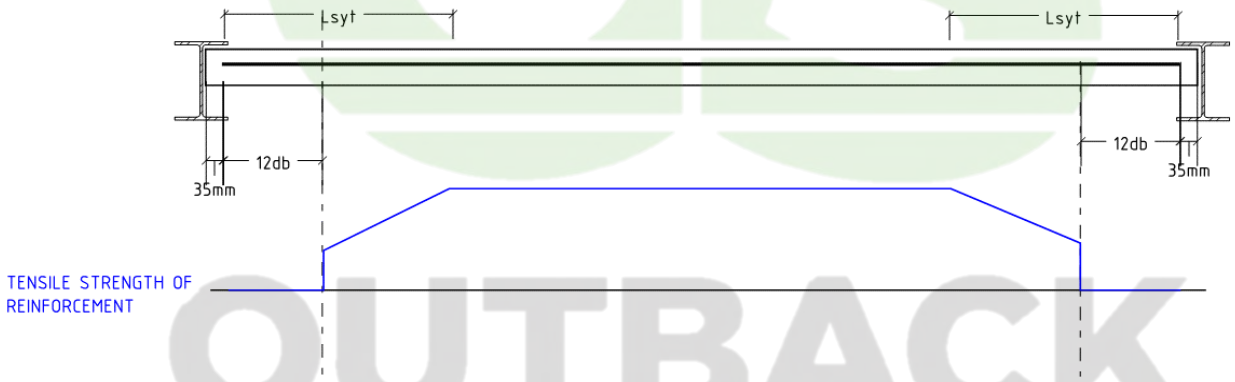
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	23.88065	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	4.776129	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	27.90	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	5.58	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	7.57	kN/m	
	M*	5.45	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	9.09	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	8.53	kN/m	
	M*	6.01	kNm	$M^* = wL^2/8$
	V*	10.13	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	6.05	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c bd))$
Utilisation LC1	*M*/ϕM*	*90%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*99%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	93.6	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	1.07E-03		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	1.18E-03		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.18		Eq. 8.2.4.2(1)
LC2 kv	kv	0.17		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	18.51	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	17.39	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

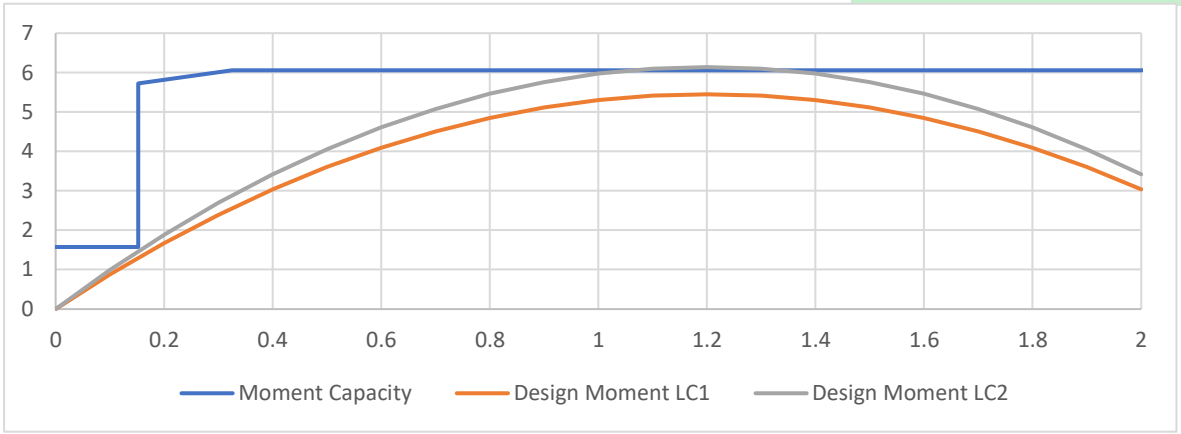
Utilisation LC1	*V*/ϕV*	*49%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*58%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	152.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	1.28	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	1.45	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	262.931	Mpa	
	ϕMx	5.722286	kNm	

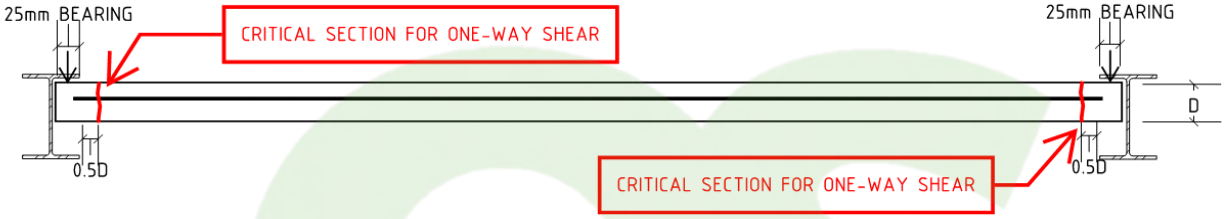


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	563333.3	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	1.57	kNm	
Utilisation LC1	U	82%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	92%		*fV>V* Concrete section adequate*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	77.5	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	8.50	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	9.57	kN	V = w(L/2-xv)



Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	9.16	kN	$Vu = 0.15bD(fc)^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	93%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	105%		*Within 10% - Accept*

WGA

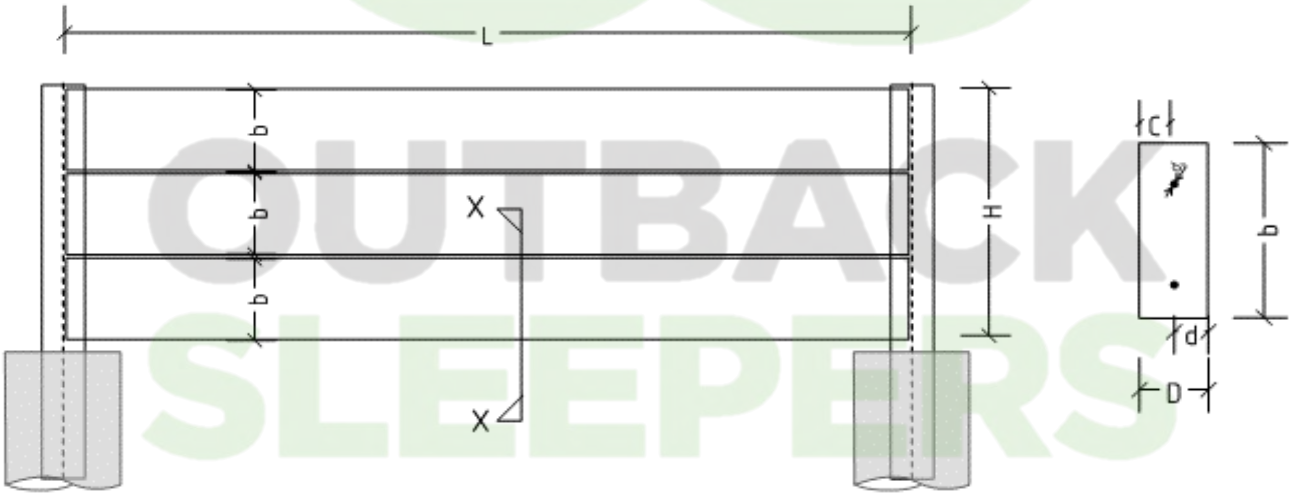
1.5m LONG SLEEPERS

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
1.5 m LONG
2.6 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.60	✓ 0.63
	Shear Capacity	✓ 0.23	✓ 0.25
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.92	! 1.00
	Shear Capacity	✓ 0.67	✓ 0.73

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	1500	mm	
Max Retained Height	H	2600	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	75	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	40	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.26		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

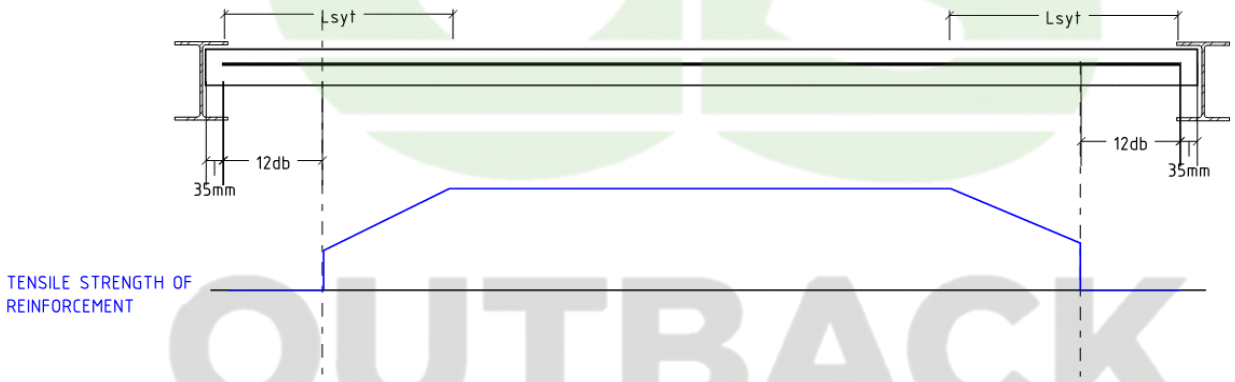
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	15.30811	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	3.061621	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	17.89	kPa	$\eta_o = K_a\gamma H - K_a\gamma(b/2)$
	w_1	3.58	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	5.07	kN/m	
	M*	1.43	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	3.80	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	5.52	kN/m	
	M*	1.50	kNm	$M^* = wL^2/8$
	V*	4.07	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	2.38	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c bd))$
Utilisation LC1	*M*/ϕM*	*60%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*63%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	54	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	4.81E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	5.08E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.29		Eq. 8.2.4.2(1)
LC2 kv	kv	0.28		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	16.79	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	16.40	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

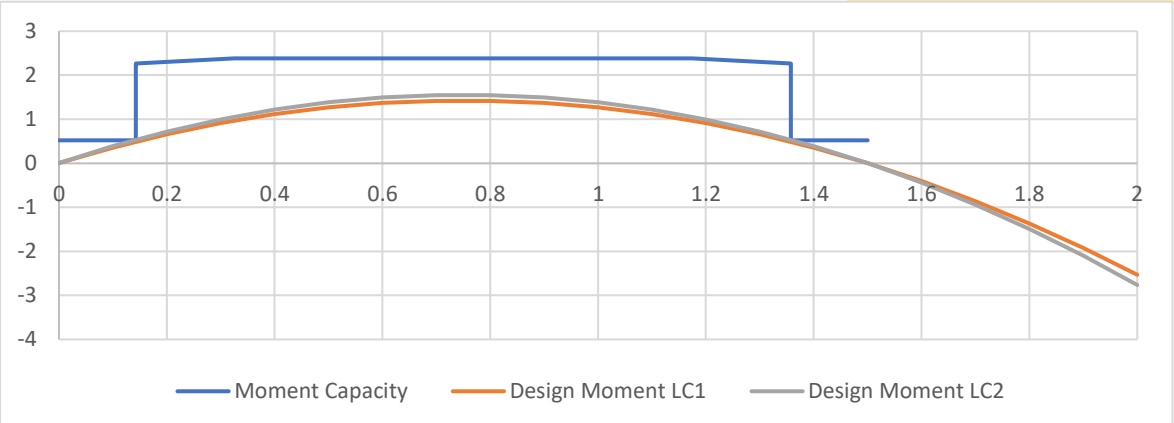
Utilisation LC1	*V*/ϕV*	*23%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*25%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	142.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	0.48	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	0.52	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	245.6897	Mpa	
	ϕMx	2.266534	kNm	

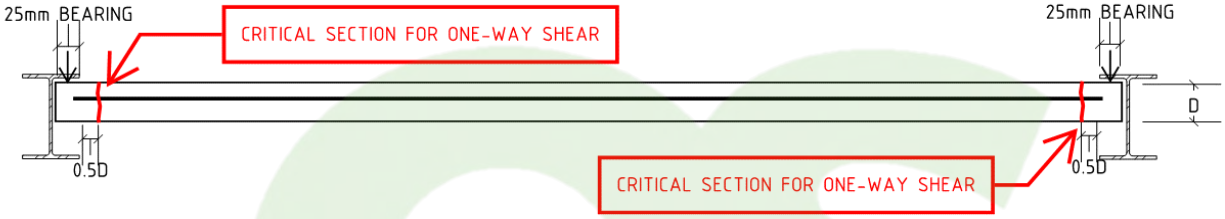


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	187500	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	0.52	kNm	
Utilisation LC1	U	92%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	100%		*Within 10% - Accept*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	50	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	3.55	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	3.87	kN	V = w(L/2-xv)



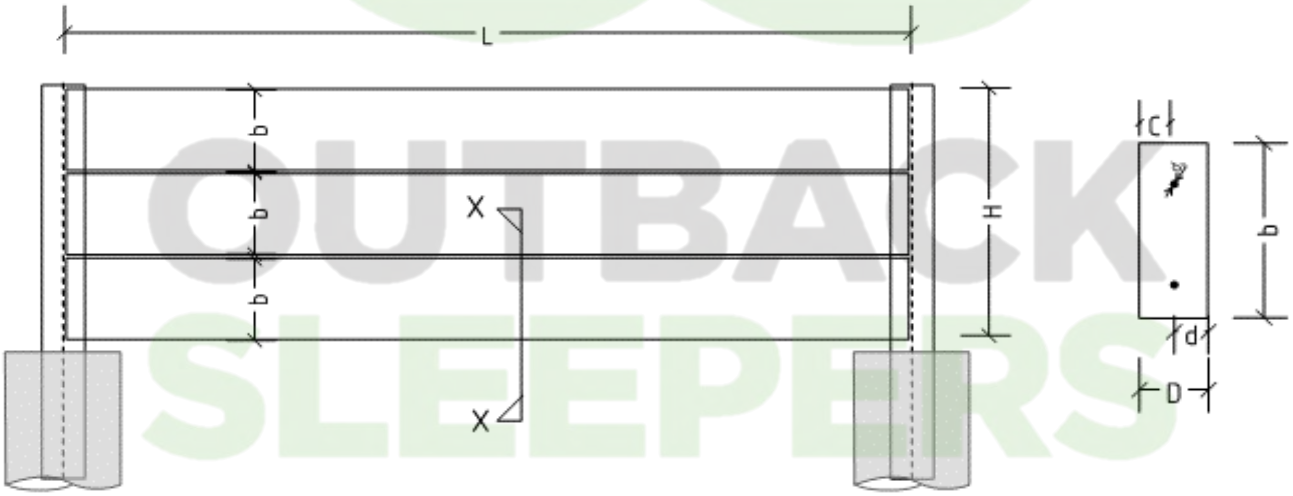
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	5.29	kN	Vu = 0.15bD(fc)$^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	67%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	73%		*fV>V* Concrete section adequate*

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
1.5 m LONG
4 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.53	✓ 0.57
	Shear Capacity	✓ 0.28	✓ 0.32
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.77	✓ 0.87
	Shear Capacity	✓ 0.74	✓ 0.83

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	1500	mm	
Max Retained Height	H	4000	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	100	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	65	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.16		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

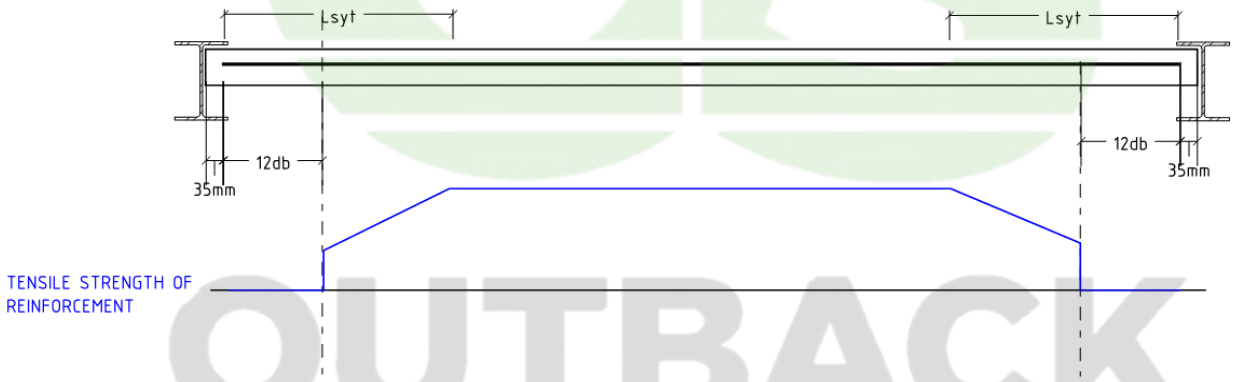
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	23.88065	kPa	$\eta_o = K_a \gamma H - K_a \gamma (b/2)$
	w_1	4.776129	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	27.90	kPa	$\eta_o = K_a \gamma H - K_a \gamma (b/2)$
	w_1	5.58	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	7.57	kN/m	
	M*	2.13	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	5.68	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	8.53	kN/m	
	M*	2.32	kNm	$M^* = wL^2/8$
	V*	6.29	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	4.05	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c b d))$
Utilisation LC1	*M*/ϕM*	*53%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*57%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	72	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	5.61E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	6.13E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.26		Eq. 8.2.4.2(1)
LC2 kv	kv	0.25		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	20.57	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	19.73	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

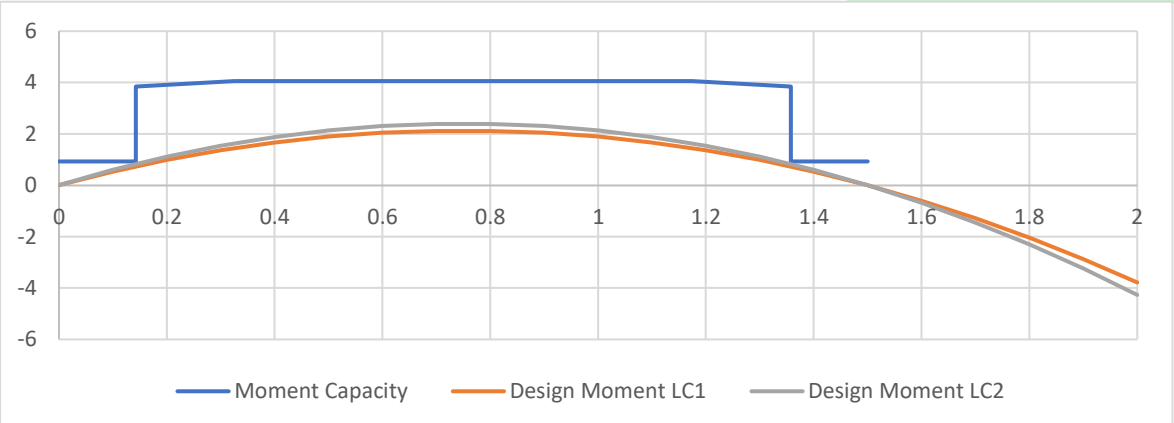
Utilisation LC1	*V*/ϕV*	*28%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*32%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	142.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	0.72	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	0.81	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	245.6897	Mpa	
	ϕMx	3.83733	kNm	

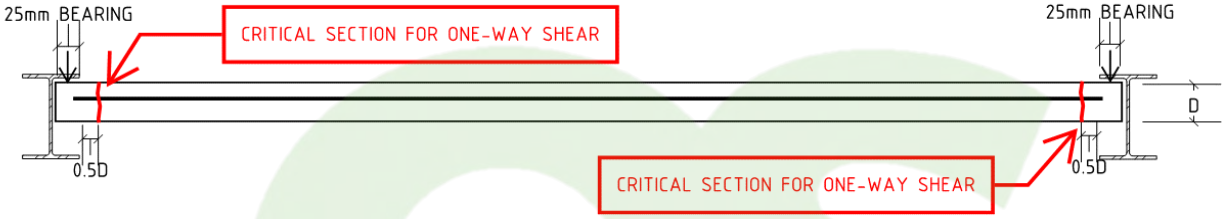


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	333333.3	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	0.93	kNm	
Utilisation LC1	U	77%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	87%		*fV>V* Concrete section adequate*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	62.5	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	5.21	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	5.86	kN	V = w(L/2-xv)



Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	7.05	kN	Vu = 0.15bD(fc)$^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	74%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	83%		*fV>V* Concrete section adequate*

WGA

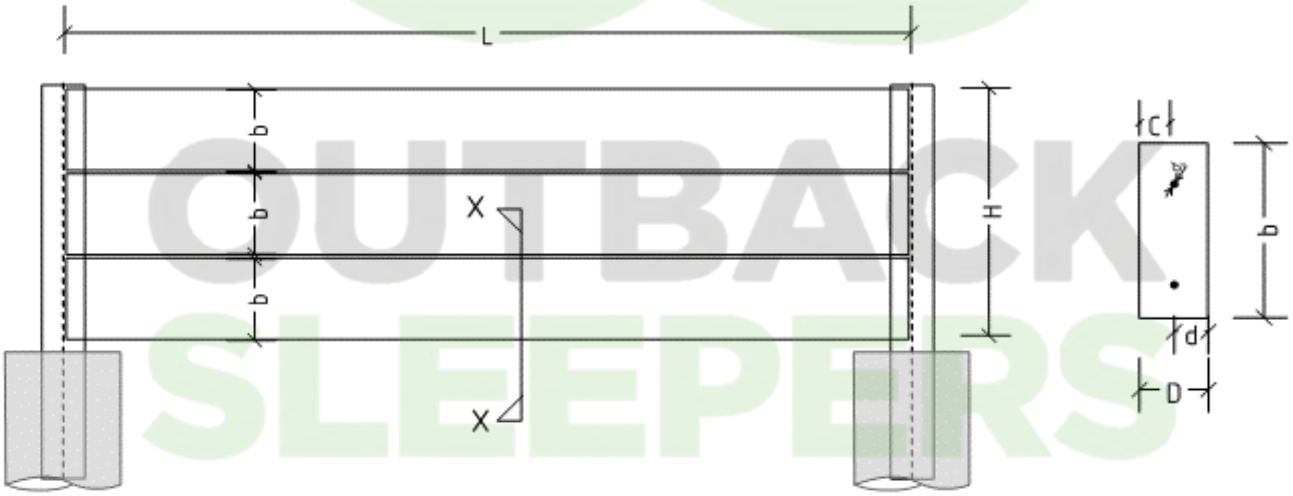
1.8m LONG SLEEPERS

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
1.8 m LONG
2 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.68	✓ 0.70
	Shear Capacity	✓ 0.22	✓ 0.24
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.89	✓ 0.94
	Shear Capacity	✓ 0.64	✓ 0.68

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	1800	mm	
Max Retained Height	H	2000	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	75	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	40	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.26		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

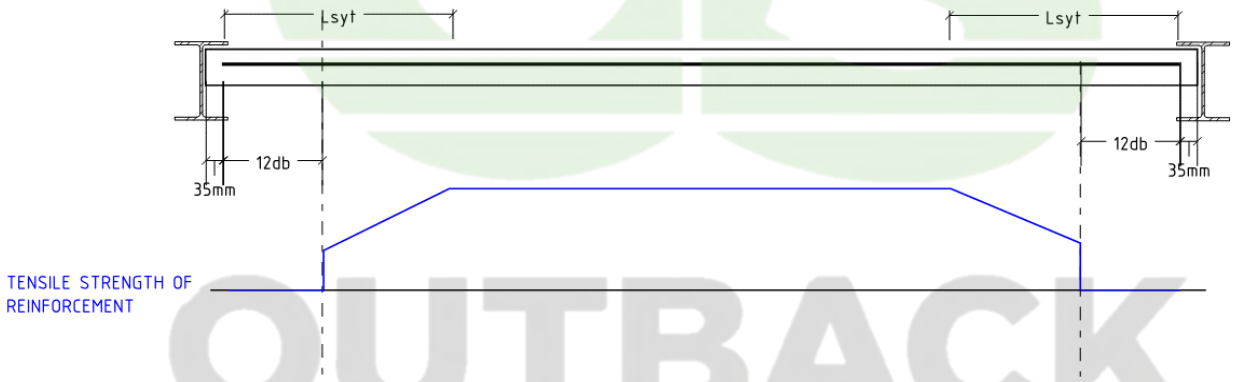
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	11.63416	kPa	$\eta_o = K_a \gamma H - K_a \gamma (b/2)$
	w_1	2.326832	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	13.59	kPa	$\eta_o = K_a \gamma H - K_a \gamma (b/2)$
	w_1	2.72	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	3.99	kN/m	
	M*	1.62	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	3.59	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	4.24	kN/m	
	M*	1.67	kNm	$M^* = wL^2/8$
	V*	3.76	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	2.38	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c b d))$
Utilisation LC1	*M*/ϕM*	*68%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*70%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	54	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	5.34E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	5.52E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.27		Eq. 8.2.4.2(1)
LC2 kv	kv	0.27		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	16.04	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	15.81	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

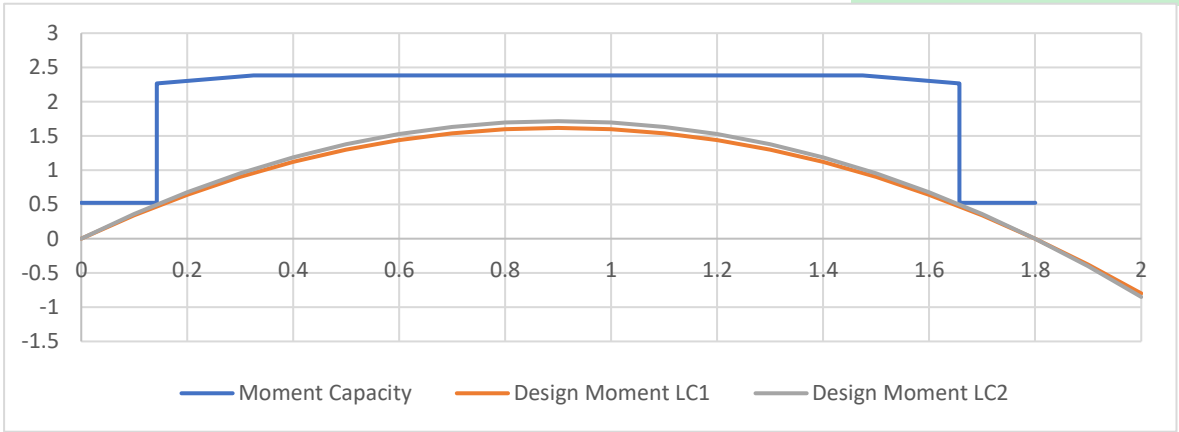
Utilisation LC1	*V*/ϕV*	*22%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*24%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	142.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	0.46	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	0.49	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	245.6897	Mpa	
	ϕMx	2.266534	kNm	

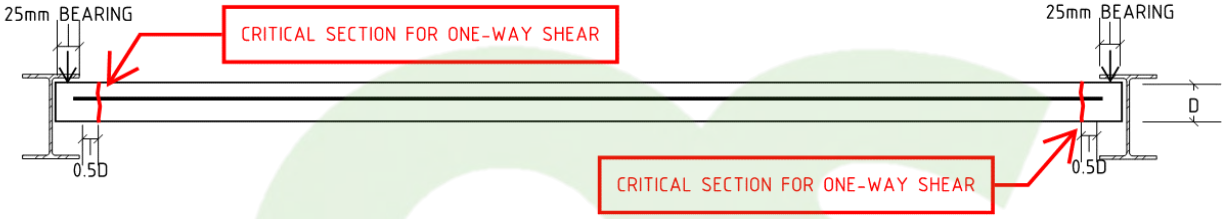


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	187500	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	0.52	kNm	
Utilisation LC1	U	89%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	94%		*fV>V* Concrete section adequate*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	50	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	3.40	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	3.60	kN	V = w(L/2-xv)



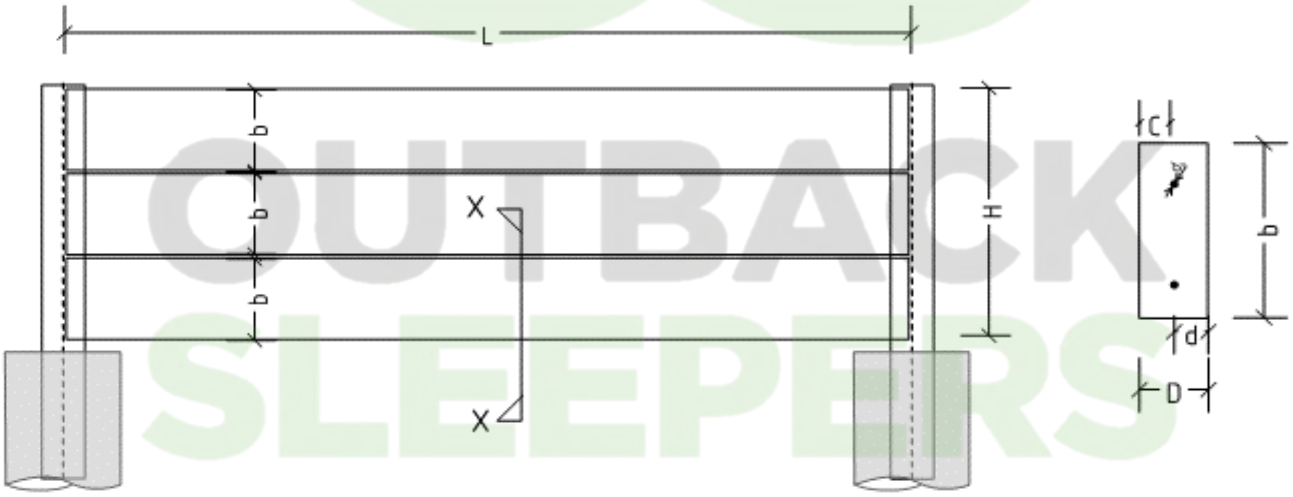
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	5.29	kN	$Vu = 0.15bD(fc)^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	64%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	68%		*fV>V* Concrete section adequate*

OUTBACK SLEEPERS - CONCRETE SLEEPER DESIGN

SLEEPER ID:
1.8 m LONG
3.8 m MAX RETAINED HEIGHT

		LC1	LC2 - EQ
Reinforced Sections	Flexural Moment Capacity	✓ 0.72	✓ 0.79
	Shear Capacity	✓ 0.36	✓ 0.42
Un-Reinforced Sections	Flexural Moment Capacity	✓ 0.90	! 1.01
	Shear Capacity	✓ 0.86	✓ 0.96

DESIGN PARAMETERS	Mark	Value	Unit	Comment
Sleeper Length	L	1800	mm	
Max Retained Height	H	3800	mm	
Sleeper Depth	b	200	mm	Standard sleeper depth
Thickness of Sleeper	D	100	mm	
Concrete cover	c	30	mm	Measured from tension face
Side cover	ce	35	mm	
Reinforcement Size	d_b	10	mm	
Number of Bars	n_b	2		
Bearing Width		25	mm	
Area of Steel	Ast	157.0796	mm^2	Ast = $n_b\pi(d_b/2)^2$
Depth to Reinforcement	d	65	mm	Formula = D-c-d_b/2



Compressive Strength Conc	fc'	60	MPa	
Elastic Modulus Concrete	Ec	36533.33	MPa	Refer table 3.1.2, AS3600
	α_2	0.76		$\alpha_2 = 0.85-0.0015f_c'$
	γ	0.82		$\gamma = 0.97-0.0025f_c'$
Ratio neutral axis to comp edge	k_{uo}	0.16		$k_{uo} = Astf_y/(\alpha f_c \gamma bd)$ ensure < 0.36
Yield Strength Reinforcement	fy	500	MPa	
Elastic Modulus Steel	Es	200000	MPa	
Inclined Slope Behind Wall	β	5.75	°	
Bulk Unit Weight of Backfill	γ	18	kN/m^3	
Surcharge	q	5	kPa	
Friction Angle of Soil	ϕ	30	degrees	Serviceability

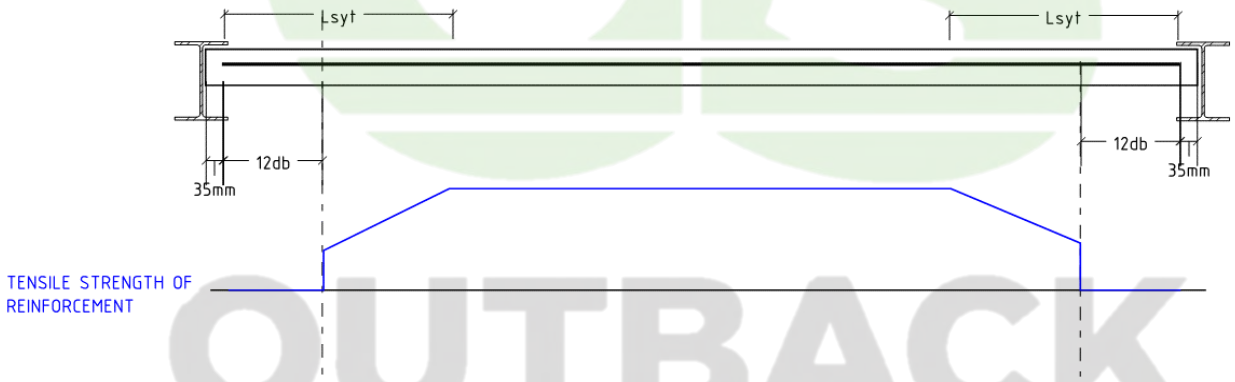
LOADING	Mark	Value	Unit	Comment
Active Coefficient of Earth Pressure	Ka	0.34		Serviceability: (1-sin(ϕ))/(1+sin(ϕ))
Serviceability Surcharge Loading	η_o	1.701	kPa	$\eta_o = K_a q$
	w_0	0.34	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	22.656	kPa	$\eta_o = K_a \gamma H - K_a \gamma (b/2)$
	w_1	4.531199	kN/m	$w_1 = \eta_1 b$
Ultimate Friction Angle	ϕ_u	26.1	degrees	Ultimate: arctan(0.85*tan(ϕ))
Active Coefficient of Earth Pressure	Ka	0.40		Ultimate: (1-sin(ϕ))/(1+sin(ϕ))
Ultimate Surcharge Loading	η_o	1.99	kPa	$\eta_o = K_a q$
	w_0	0.40	kN/m	$w_0 = \eta_o b$
Serviceability Soil Loading	η_1	26.47	kPa	$\eta_o = K_a \gamma H - K_a \gamma (b/2)$
	w_1	5.29	kN/m	$w_1 = \eta_1 b$

DESIGN ACTIONS	Mark	Value	Unit	Comment
1.25G +1.5Q (LC1)	w*	7.21	kN/m	
	M*	2.92	kNm	$M^* = wL^2/8$ at midspan - relevant for reinforced section
	V*	6.49	kN	V* = wL/2
1.5G + 0.4Q (LC2 - earthquake)	w*	8.10	kN/m	
	M*	3.19	kNm	$M^* = wL^2/8$
	V*	7.19	kN	V* = wL/2

SLEEPER CAPACITY	Mark	Value	Unit	Comment
FLEXURAL STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{flex}	0.85		0.65 =< 1.24 - 13kuo/12 =< 0.85. Refer Table 2.2.2 AS3600
Flexural Strength	ϕM	4.05	kNm	$\phi M = \phi f_y A_{st} d(1-(0.6 f_y A_{st})/(f_c b d))$
Utilisation LC1	*M*/ϕM*	*72%*		*fM>M* Flexural strength adequate*
Utilisation LC2 - earthquake	*M*/ϕM*	*79%*		*fM>M* Flexural strength adequate*
SHEAR STRENGTH (REINFORCED SECTION)				
Safety Factor	ϕ_{shear}	0.7		Refer Table 2.2.2 AS3600
Effective Shear Depth	dv	72	mm	Greater of 0.72D and 0.9d Clause 8.2.19, AS3600
Longitudinal Strain in Concrete LC1	εx	7.49E-04		Eq. 8.2.4.2.2(1) AS3600
Longitudinal Strain in Concrete LC2	εx	8.20E-04		Eq. 8.2.4.2.2(1) AS3600
	kdg	1		Assuming max agg size greater than 16mm
LC1 kv	kv	0.23		Eq. 8.2.4.2(1)
LC2 kv	kv	0.22		Eq. 8.2.4.2(1)
	sqrt(fc)	7.75		
Shear Strength LC1	ϕV	17.83	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$
Shear Strength LC2 - eq	ϕV	16.99	kN	$V_{uc} = k_v b_v d_v \sqrt{f_c}$

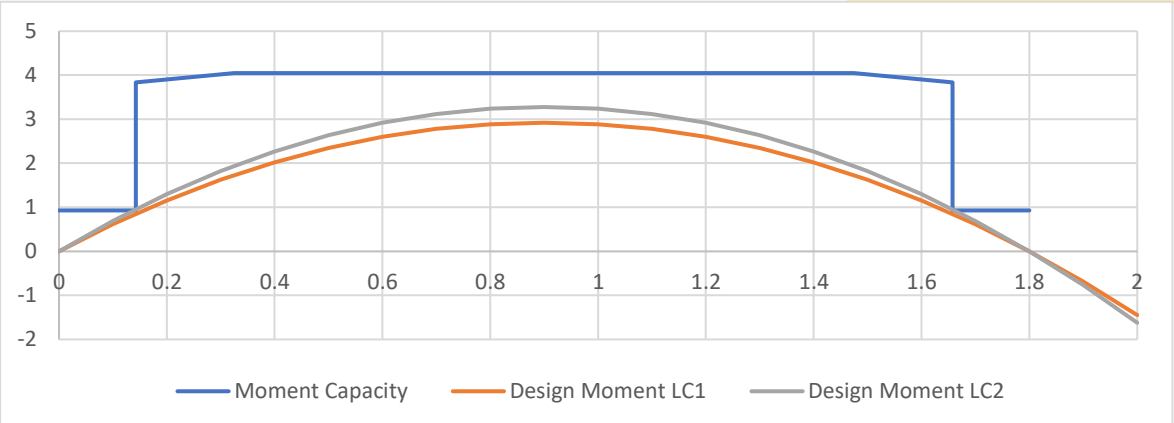
Utilisation LC1	*V*/ϕV*	*36%*	*fV>V* No shear reinforcement required*
Utilisation LC2 - earthquake	*V*/ϕV*	*42%*	*fV>V* No shear reinforcement required*

PLAIN CONCRETE CHECK	Mark	Value	Unit	Comment
FLEXURAL STRENGTH				
Point where reinforcement begins to develop	x	142.5	mm	x = ce+12db-25mm/2 (bearing length)
Design Moment LC1	M*x	0.84	kNm	wx/2*(L-x)
Design Moment LC2 - eq	M*x	0.94	kNm	wx/2*(L-x)
Development Length	k1	1		
	k2	1.22		
	cd	30		
	k3	0.7		
	Lsyt	290	mm	Eq. 13.1.2.2, AS3600
Stress development at x	σ	245.6897	Mpa	
	ϕMx	3.83733	kNm	

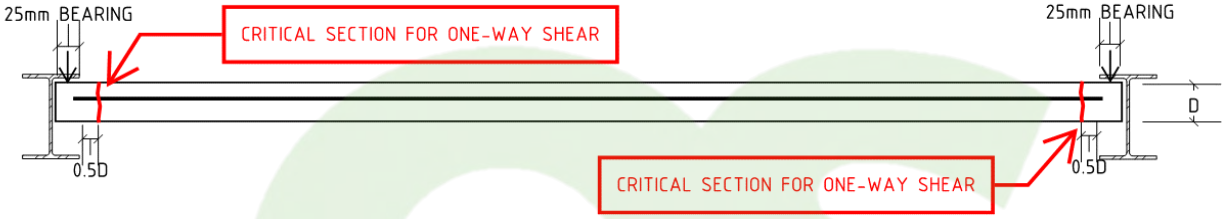


Flexural Strength (Unreinforced Section)

Elastic Section Modulus	Z	333333.3	mm3	$Z = bD^2/6$
Flexural Strength Concrete	fct	4.64758	MPa	0.6*sqrt(fc)
Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Moment Capacity	ϕMu	0.93	kNm	
Utilisation LC1	U	90%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	101%		*Within 10% - Accept*



	Mark	Value	Unit	Comment
SHEAR STRENGTH				
Critical Section	x_v	62.5	mm	xv = 0.5D + 25mm/2 (assuming 25mm bearing). Refer Cl 20.4.3 AS3600
Shear at Critical Section - LC1	V^*_{xv}	6.04	kN	V = w(L/2-xv)
Shear at Critical Section - LC2 eq	V^*_{xv}	6.78	kN	V = w(L/2-xv)



Safety Factor	ϕ	0.6		Table 2.2.2, AS3600
Max design bearing strength	ϕV	7.05	kN	$Vu = 0.15bD(fc)^{(1/3)}$ refer Eq. 20.4.3(1) AS3600
Utilisation LC1	U	86%		*fV>V* Concrete section adequate*
Utilisation LC2 - EQ	U	96%		*fV>V* Concrete section adequate*

WGA

UNDER FENCE PLINTH

Sleeper Length =	2340	mm
Sleeper Depth =	200	mm
Height of Wall =	400	mm
Thickness of Sleeper =	50	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 =	25	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
$\eta_0 = K_a Q$	η_0 =	1.94	kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	η_1 =	2.10	kPa
$w = \eta_t d$	w0 =	0.39	kN/m
	w1 =	0.42	kN/m
γ = 0.97-.0025f'c ≥ 0.67	γ =	0.82	

Design Actions:

$w^* = 1.25G^* + 1.5Q^*$	w* =	1.12	kN/m
$M^* = w^* L^2/8$	M* =	0.76	kNm
$V^* = w^* L/2$	V* =	1.31	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.83309	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req}$ =	79.73	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	ϕM_u =	1.38	kNm
Ductility Check	ku =	0.38	

ϕMu>M* Therefore, okay in bending

Shear Strength of Sleeper

Capacity Reduction Factor (shear) - AS3600 Table 2.2.2	ϕ =	0.7	
	dv	22.5	mm
	θv	36.0	°
	tan(θv)	0.727	
AS3600 - Clause 8.2.4.3:	k_v =	0.100	
Vu,max	Vu,max	70.6	
Vuc = $k_v b_v d_v$*sqrt(f_c)	V_{uc} =	3.5	kN
	fV_{uc}	2.4	kN

V* < fV_{uc}

ϕVuc>V* Therefore, no shear reinforcement required

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	Outback Sleepers				WAD150933
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Plain Concrete End Zones

Design Shear :
V* = Reduced Shear

Lreduced 2315 mm taking into account bearing length of sleeper at each end
for t = 50 mm H = 400 mm V* = 1.27 kN
dv away from support

End Region Shear Strength:

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

b = 200 mm
ϕ_r = 0.6 Plain Concrete Capacity Reduction Factor

for t = 50 mm $\phi V_u =$ 3.52 kN ϕVu>V*, Okay
f'c = 60 MPa

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End Region Flexural Strength

Design Bending Moment:

M* = reduced bending

Ld 155.0 mm

x 142.5 mm

for t = 50 mm H = 400 mm M* = 0.17 kNm

End Region Flexural Strength:

b = 200 mm

for t = 50 mm ϕMu = 0.23 kNm ϕMu>M*, Okay

f'c = 60 MPa

f'cf = 4.65 MPa

HD UFP

Project Number: 150933
Designer: CL
Date: 04/09/2020
Page Number:

Sleeper Length =	2355	mm
Sleeper Depth =	200	mm
Height of Wall =	400	mm
Thickness of Sleeper =	65	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 =	32.5	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
$\eta_0 = K_a Q$	η_0 =	1.94	kPa
$\eta_1 = K_a \gamma_s H - K_a \gamma_s H(b/2)$	η_1 =	2.10	kPa
$w = \eta_t d$	w0 =	0.39	kN/m
	w1 =	0.42	kN/m
γ = 0.97-.0025f'c ≥ 0.67	γ =	0.82	

Design Actions:

$w^* = 1.25G^* + 1.5Q^*$	w* =	1.12	kN/m
$M^* = w^* L^2/8$	M* =	0.77	kNm
$V^* = w^* L/2$	V* =	1.31	kN

Flexural Strength of Sleeper

Capacity Reduction Factor (bending) - AS3600 Table 2.2.2	ϕ =	0.85	
$A_{st,req} = \frac{f'_c b}{1.2 f_{sy}}(d - \sqrt{(d^2 - 2.4M^*/\phi_b f'_c b)})$	$A_{st,req}$ =	58.67	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
$\phi M_u = \phi_b f_{sy} A_{st} d(1 - 0.6\frac{A_{st} f_{sy}}{b d f'_c})$	ϕM_u =	1.91	kNm
Ductility Check	ku =	0.29	

ϕMu>M* Therefore, okay in bending

Shear Strength of Sleeper

Capacity Reduction Factor (shear) - AS3600 Table 2.2.2	ϕ =	0.7	
	dv	29.3	mm
	θv	36.0	°
	tan(θv)	0.727	
AS3600 - Clause 8.2.4.3:	k_v =	0.100	
Vu,max	Vu,max	91.8	
Vuc = $k_v b_v d_v$*sqrt(f_c)	V_{uc} =	4.5	kN
	fV_{uc}	3.2	kN

V* < ϕV_{uc}

ϕVuc>V* Therefore, no shear reinforcement required

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Plain Concrete End Zones

Design Shear :
V* = Reduced Shear

Lreduced 2330 mm taking into account bearing length of sleeper at each end
for t = 45 mm H = 400 mm V* = 1.27 kN
dv away from support

End Region Shear Strength:

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

b = 200 mm
ϕ_r = 0.6 Plain Concrete Capacity Reduction Factor

for t = 45 mm ϕV_u = 3.17 kN ϕVu>V*, Okay
f'c = 60 MPa

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	Outback Sleepers				WAD150933
	Calc. by	Date	Chk'd by	Date	Sheet no./Rev.
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End Region Flexural Strength

Design Bending Moment:

M* = reduced moment

Ld 155.0 mm

x 142.5 mm

for t = 45 mm H = 400 mm M* = 0.17 kNm

End Region Flexural Strength:

b = 200 mm

for t = 45 mm ϕMu = 0.19 kNm ϕMu>M*, Okay

f'c = 60 MPa

f'cf = 4.65 MPa