



## Concrete Sleeper Retaining Wall

Rev 2, Created 4 March 2022

A concrete sleeper retaining wall can be designed in Structural Toolkit using two modules – **Sleeper Walls** & **Concrete Member Design**. The following guide will show the step-by-step process of doing this.

<b>ANALYSIS</b> Analysis Properties	<b>FOOTINGS</b> Bored Piers and Pads Bulk Pier and Beams	<b>CONCRETE</b> Member Design	<b>STEEL</b> Member Design Steel Library Section Properties	<b>STEEL CONNECTIONS</b> Portal Knee Taper Haunch	<b>TIMBER</b> Member Design Timber Library
<b>LOADINGS</b> Earthquake Dead and Live	<b>PAD DESIGN</b> Pad Footing Eccentric Pad Design Post Footing Design	Deep Beams Flat Slabs Two-Way Slabs	Floor Beam Roof Beam Propped Beam Crane Beam	End Plate Base Plate Cleat Plate Fixing Plate	Floor Beam Roof Beam Propped Beam
<b>WIND</b> Wind Loads Terrain Changes Monosloped Roofs Free Roofs Canopies Hoardings Flags Purlin & Girt Loads	<b>RETAINING WALLS</b> Retaining Walls Sleeper Walls Basement Walls	Columns Walls	Mullion Columns Compression Strut	Bolts Pins Welds Reference	Columns Circular Columns Mullion
<b>DRAINAGE</b> Rainfall Intensity Stormwater Detention Drainage	<b>SLABS &amp; PAVEMENTS</b> Industrial Slabs Residential Slabs Tree Effects - Ys Tree Effects - Piers	Stairs Punching Shear Corbels Strut & Tie Plain Concrete Development Formula Reinforcement Reinft Rate	Angle Lintel Shelf Angle PFC & Angle PFC & Plate "T" Lintel Wall Tie Window Support	<b>COMPOSITE</b> Member Design	<b>MASONRY</b> Masonry Member Masonry Pier Bondbeams Masonry Library
		<b>PRECAST</b> Propping Pad			<b>UTILITIES</b> Unit Conversions Symbols



## Using Sleeper Walls

The first step of designing a concrete sleeper wall is to use the Sleeper Walls module. Upon opening module, fill in the relevant geometry values as shown below. Many of these values will be based on geotechnical recommendations. Make sure that the concrete sleepers option is set as "Y", with the intended sleeper width specified to the right.

### Geometry

Wall assumed fully drained

Geometry		Retaining height must be a multiple of the sleeper vertical dimension (1200mm)	
Retaining height (ht) =	1200 mm		
Post centres (cts) =	1200 mm		
Upright =	S (T)imber,(S)teel,(B)oth		
Concrete sleepers =	Y (Y)es,(N)o	Concrete sleeper width =	200 mm (Vert. dimension)

Risk class =	B (A),(B),(C) - Moderate damage and loss of services - Table 1.1
Backfill type =	1 Class(1), Class(2), (U)ncontrolled, (I)n-situ - Table 5.1(A)

Soil parameters	
Internal friction ( $\phi$ ) =	30 ° ( $0^\circ \leq \phi \leq 45^\circ$ )
Incline ( $\beta$ ) =	0 ° ( $0^\circ \leq \beta \leq 45^\circ$ ) 1 in 0.0
Soil weight ( $\gamma_s$ ) =	18.0 kN/m <sup>3</sup>
Cohesion (c) =	0 kPa

Footing - Cohesive	
Total footing depth (d) =	1600 mm (From surface)
Ignore top (ig) =	200 mm
Footing diameter (dia) =	450 mm
Soil cohesion (cf) =	30 kPa (0 for cohesionless)
Design $cf^* = cf * \Phi_{uc} (=0.7)$ =	21.0 kPa insitu material

Sleepers	Minor axis bending	Soil behind wall
Sleeper depth (dSD) =	N/A mm (Horz. dimension)	
Sleeper width (dSW) =	200 mm (Vert. dimension)	
Max number of layers =	6 (1200mm high)	

Live Load duration =	Permanent	Soil at footing
Long term LL factor ( $\Psi_l$ ) =	1.00 AS 1170.0 Table 4.1	
Duration factor (k1) =	0.57	

Next is to fill in any additional design loads specific to the design and the relevant load factors, as seen below. For this design, only the minimum surcharge of 5.0kPa has been added (note for risk class A this would be 2.5kPa).

### Design loads - Appendix J & Section 4 - AS4678

Min. surcharge =	5.0 kPa - Table 4.1
Water height (hw) =	0.0 mm (Drained)
Surcharge (s) =	5.0 kPa
Dead only factor =	1.35 (1.35)
Earth factor =	1.25 (1.25)
Live load factor =	1.50 (1.50 - 0.0 for stabilising effect)
Stabilising factor =	0.80 AS4678 - Appendix J2

Additional upright overturning	
Thrust (Va) =	0.00 kN
Overturning (Ma) =	0.00 kNm
Load factor =	1.50
Long term LL factor ( $\Psi_{lo}$ ) =	0.40
Va* =	0.00 kN
Ma* =	0.00 kNm

(Thrust/moment applied at the top of the wall)



Once the geometry and design load values have been set, select the desired steel uprights using the [Select Upright] button on the right, and check the capacity section to verify it works.

Once the upright has been verified, the next step is to then design the concrete sleepers. However, before moving on to the Concrete Member Design, make note of the maximum loads and moment found in the summary tab at the top (refer below).

Wall: (Sleeper Wall SW01) 1200mm high, 5.0kPa surcharge (Drained)  
Loads: Surcharge = 5.00kPa, Drained  
Steel Upright: 100UC14.8 (G300) (Galv.)  
 $M^* = 5.00\text{kNm} < \phi M = 21.43\text{kNm}$ ,  $V^* = 10.60\text{kN} < \phi V_{vm} = 83.81\text{kN}$  OK (0.23,0.13)  
 $\delta(dI) = ht/9999$  (1.0mm),  $\delta(dI + \Psi I.II) = ht/651$  (1.8mm) OK  
Timber Upright: Not Applicable

Footing:  $M^*_o = 7.12\text{kNm} < \phi M_r = 23.15\text{kNm}$  OK (0.31)  
Sleepers: Concrete sleepers - refer Concrete Member Design or manufacturer's specifications  
 $w_{dl} = 1.39\text{kN/m}$ ,  $w_{ll} = 0.35\text{kN/m}$ ,  $w^* = 2.26\text{kN/m}$ ,  $M^* = 0.41\text{kNm}$




## Using Concrete Member Design


With the loading distribution found from the Sleeper Walls module, the concrete sleeper can be designed. The first step is to input the geometry of the concrete sleeper, as shown below. Usually the concrete strength and reinforcement information is provided by the sleeper wall manufacturer.

**Geometry** L/D ratio = 12.5

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Concrete strength (f'c) =	40 MPa
Depth (D) =	80 mm
Web width (W) =	200 mm, (S)lab
Flange width (Bf) =	0 mm





Next the reinforcement needs to be specified. In this case, only the bottom reinforcement is needed, so the bar size of the top reinforcement is put as zero. The recommended "Bottom cover to ligs" can be found to the bottom right under "Top Steel" – refer image below. In this case, 23.0mm was used.

**Reinforcement** Ligs = 2 legs N12-40 cts

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<p><b>Bottom reinft = 2-N10</b></p> <p>Bar size = 10 mm <span style="float: right;">Mesh...</span></p> <p>Bar cts/No/mm<sup>2</sup> = 2 No</p> <p>Yield strength (fsy) = 500 MPa</p> <p>Ductility class = A (N)ormal,(L)ow,(A)uto</p> <p>Reinft ductility class = N (N)ormal,(L)ow</p> <p>Steel area (Ast) = 157 mm<sup>2</sup></p> <p>Bottom cover to ligs = 23 mm</p> <p>Depth to bottom steel layer (ds.max) = 40 mm</p> <p>Depth to bottom steel (ds) = 40 mm</p> <p>D-ds = 40 mm</p> <p>No. bars = 2.0 No.</p> <p>Bar centres = 120 mm</p> <p>Max bars per layer = 4</p> <p>Layers required = 1</p>	<p><b>Top reinft = None</b></p> <p>Bar size = 0 mm <span style="float: right;">Mesh...</span></p> <p>Bar cts/No/mm<sup>2</sup> = 300 mm</p> <p>Yield strength (fsyc) = 500 MPa</p> <p>Ductility class = A (N)ormal,(L)ow,(A)uto</p> <p>Reinft ductility class = N (N)ormal,(L)ow</p> <p>Steel area (Asc) = 0 mm<sup>2</sup></p> <p>Top cover to ligs = 20 mm</p> <p>Depth to top steel layer = 32 mm</p> <p>Depth to top steel = 32 mm</p> <p>D-ds = 48 mm</p> <p>No. bars = 0.0 No.</p> <p>Bar centres = 0 mm</p> <p>Max bars per layer = 1</p> <p>Max bars pers 2nd layer = 0</p>
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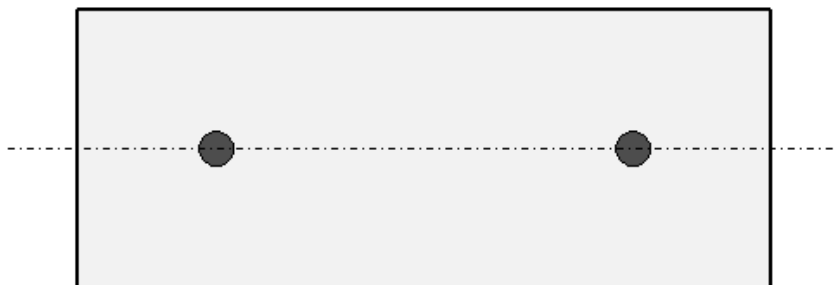
Top steel:

Allow top layer to extend to hef =  N (Yes (N)o

Cover for central bottom = 23.0 mm

Cover for central top = 28.0 mm

Refer to the [Preview] tab to check that the geometry appears correct, as shown below.





Once the geometry and reinforcement has been set, click on the [Analysis] button to the right, which will open up a linked Analysis document. In this document, input the span and load values taken from the Sleeper Walls module (the span will be the pier spacing). In addition, set the "Live Load type" to Permanent, turn the self-weight off, and set the "Dead load factor (DLF)" to 1.25 (Refer AS4678 Clause 4.1 (a) (iii)) unless input as otherwise in the Sleeper Walls module. If done correctly, the maximum moment should equal that from the Sleeper Walls module, in this case it was 0.41kNm.

### Geometry for (Concrete Member CB01): Concrete simple beam

Description =	80mm (D) x 200mm (W) beam	ix =	8.533333333 x10 <sup>6</sup> mm <sup>4</sup>
Span (L) =	1200 mm	Ag =	16000 mm <sup>2</sup>
Span type =	S (Simple),(E)xt,(I)nt,(C)ant,(P)rop,(F)ixed,(O)ther	Density =	25 kN/m <sup>3</sup>
Material type =	C (Timber),(S)teel,(C)onc.,(S)C comp. steel,(O)ther	E =	32724 MPa

### Loading

Uniform loads (kN/m)				Point loads (kN)			
Uniform loads	UDL	Partial 1	Partial 2	Point loads	PL 1	PL 2	PL 3
Dead load (wdl) =	1.39			Dead load (pdl) =			
Live load (wll) =	0.35			Live load (pll) =			
Start from LHS (mm) =	0			Pos. from LHS (mm) =			
End from LHS (mm) =	1200			Ultimate load (p*) =	0.00	0.00	0.00
S.Wt =	0.00	kN/m		Include S.Wt =	N (Yes,(N)o		
Ultimate load (w*) =	2.26	0.00	0.00	Strength loadcase =	C (D)ead Only,(C)omb.		
Live Load type =	Permanent (Concrete)						
Short term LL (Ψsu) =	1.00	(Ψsp) =	1.00				
Long term LL (Ψlu) =	1.00	(Ψlp) =	1.00				
Actual LL (Ψsa) =	1.00	(Ψla) =	1.00				

### Results at midspan (Max +ve M)

Position of result (x) = 600 mm

**1.25\*G+1.50\*Q analysed**

	Left	At x	Right	Max	At	Min	At	Units	
Rdl	0.83		0.83					kN	
Rll	0.21		0.21					kN	
R*	1.36		1.36					kN	
M*	0.00	0.41	0.00	0.41	600	0.00	0	kNm	
V*	1.36	0.00	-1.36	1.36	0			kN	Span /
δdl	0.00	0.13	0.00	0.13	600	0.00	0	mm	8929
δll	0.00	0.03	0.00	0.03	600	0.00	0	mm	35459
δdl+Ψs*δll	0.00	0.17	0.00	0.17	600	0.00	0	mm	7133

Combinations:

Ultimate = 1.25\*G+1.50\*Q

Dead load factor (DLF) =	1.25
Dead load only factor (DLOF) =	1.35
Dead load uplift factor (DLUF) =	0.90
Live load factor (LLF) =	1.50
Wind load factor (WLF) =	1.00



With the correct loads set, switch back to the design document, and click the [Max M+\*] button, which will transfer the maximum positive moment from the linked Analysis. From here check that the specific limit states are met, as seen below.

It should be noted that bars specified by manufacturers generally result in an overdesigned concrete sleeper. This may result in the  $k_u > 0.36$  (i.e. non-ductile) (refer AS3600 Clause 8.1.5). To prove that the design still works, a smaller bar size can be selected such that the capacity is reached while  $k_u < 0.36$ . If the limit states are not met, readjust as with any other design.

<b>Section:</b>	<b>(Concrete Member CB01) 80mm (D) x 200mm (W) beam, f'c=40MPa</b>	
<b>Reinf't:</b>	<b>2-N10 bottom, <math>k_u = 0.36</math></b>	
<b>Strength:</b>	<b>(+ve M) <math>M^+ = 0.4\text{kNm} &lt; \phi M_{uo} = 2.3\text{kNm}</math></b>	<b>OK (0.18)</b>
<b>Cracking:</b>	<b>fscr = 57MPa &lt; Fscr = 265MPa &amp; fscr1 = 57MPa &lt; Fscr1 = 400MPa, crack width = 0.1mm</b>	<b>OK (0.14,0.22)</b>
<b>Ast.min:</b>	<b>Ast.min = 49mm<sup>2</sup> &lt; Ast = 157mm<sup>2</sup> (Minimum of Deemed and actual)</b>	<b>OK (0.31)</b>
	<b>Temperate environment with <math>\epsilon_{csd}.b^* = 800 \times 10^{-6}</math>, <math>\epsilon_{cs}^* = 680 \times 10^{-6}</math></b>	

Once these limit states are met, the deflection will then also need to be checked by clicking on the [Defl] tab at the bottom of the document – see below.



On this tab ensure the [Max Deflection] and [Transfer Reinf't] buttons have been clicked. This will transfer the results and point of maximum deflection, along with the reinforcement specified in the [Design] tab earlier.

Next, check that the correct reinforcement has been transferred. As can be seen below the 2-N10 bars used earlier have been transferred. As there is only a positive sagging moment in the centre of the sleeper (simply supported), the "Ast =" only designates reinforcement to this segment ("At x"). Once checked, verify the deflection shown at the top meets the design requirements.

Section: (Concrete Member CB01) 80mm (D) x 200mm (W) beam, f'c=40MPa  
 Reinf't: 2-N10 bottom (Additional reo specified)  
 Defl'n:  $\delta.d = 2.6\text{mm}$ ,  $\delta.l = 0.3\text{mm}$ ,  $\delta.inc = 3.5\text{mm}$ ,  $\delta.total = 4.8\text{mm}$  (span / 248) Warning

ocs for Temperate environment with  $\epsilon_{csd}.b^* = 800 \times 10^{-6}$ ,  $\epsilon_{cs}^* = 680 \times 10^{-6}$

Deflections - Cl 8.5.3 simple beam at midspan (Max +ve Def)

Concrete density ( $\rho$ ) =	2400 kg/m <sup>3</sup> Cl 3.1.3	Gross area ( $A_g$ ) =	16000 mm <sup>2</sup>	Stiffness based on bef or bf: Use bef =
Use fcmi? =	Y (Y)es,(N)o	Uncr.g. neutral axis (NA) =	40 mm from top	
fcmi =	43.5 MPa	Gross Stiffness ( $I_g$ ) =	$9 \times 10^8$ mm <sup>4</sup> (w/o reinf't)	Position (x) for deflection: Ensure position is at maximu
Deflection at =	X (M)anual, (C)ritical, (L)eft, Position (X) from analysis, (R)ight	Steel Modulus ( $E_s$ ) =	200000 MPa Cl 3.2.2	
Position (x) =	600 mm	Modular ratio ( $n = E_s/E_c$ ) =	6.112	
Span type =	S)d. of elast. ( $E_c = \rho^{1.3} \cdot (0.024 \cdot \sqrt{f_{cmi} + 0.12})$ ) =		32724 MPa $\pm 20\%$ Cl 3.1.2	

Deflection calculation

	Left	At x	Right	Units	
Manual ( $M^*$ ) =				kNm	<span style="color:red">Red values of <math>M^*/M_s^*</math> manually input</span>
Manual ( $M_s^*$ ) =				kNm	
Analysis ( $M^*$ ) =	0.0	0.4	0.0	kNm	
Analysis ( $M_s^*$ ) =	0.0	0.3	0.0	kNm	
Top reinf't:					
Ast req'd =	0	0	0	mm <sup>2</sup>	
Design Ast =	0	0	0	mm <sup>2</sup>	
Ast =	0	0	0	mm <sup>2</sup>	
Bottom reinf't:					
Ast req'd =	0	24	0	mm <sup>2</sup>	
Design Ast =	157	157	157	mm <sup>2</sup>	
Ast =	0	157	0	mm <sup>2</sup>	
	-	2.0-N10	-		

Short term LL factor ( $\psi_s$ ) = 1.0  
 Long term LL factor ( $\psi_l$ ) = 1.0

Area of steel:  
 +ve value overrides, -ve value  
 Comp.  
 Tension

Max Deflection...

Transfer Reinf't...

Note that there is a warning for **ocs** shown at the top in red. This is to alert the user to ensure the correct environment has been selected in the [Creep & Shrink] tab at the bottom – refer Clause 3.1.7.2. This variable will affect the  $M_{cr}$  (Cracking) value. For this document, temperate was chosen.