Structural Toolkit

The Essential Design Tool For Australian Structural Engineers

Concrete Sleeper Retaining Wall

Rev 1, Created 15 October 2020

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.

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.

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
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 (ø) =	30	° (0° ≤ ø ≤ 45°)
Incline (β) =	0	° (0° ≤ β ≤ 45°) 1 in 0.0
Soil weight (γs) =	18.0	kN/m³
Cohesion (c) =	0	kPa

Soil behind wall

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 cohensionless)
Design cf*=cf*Φuc(=0.7) =	21.0	kPa insitu material

Soil at footing

Sleepers		Minor axis bending
Sleeper depth (dSD) =	100	mm (Horz. dimension)
Sleeper width (dSW) =	200	mm (Vert. dimension)
Max number of layers =	6	(1200mm high)

Live Load duration =	Permanent	
Long term LL factor (Ψl) =	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 (Ψlo) =	0.40	
Va* =	0.00	kN
Ma* =	0.00	kNm
(Thrust/moment applied at the top of the wall)		

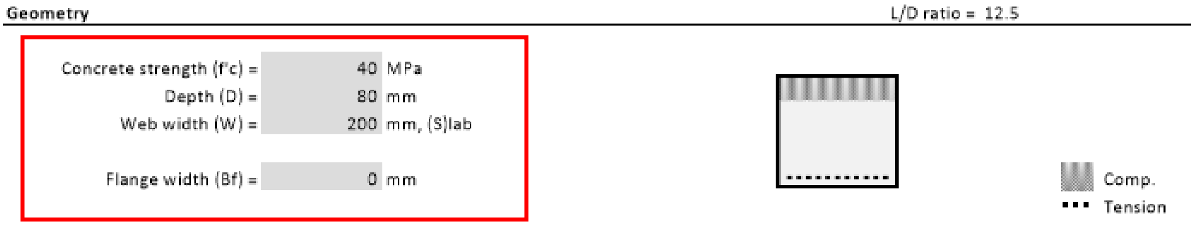
Once the geometry and design load values have been set, select the desired steel uprights using the [Select Upright] button on the right, and check the capacity section to verify it works.

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, open the [Calculations] tab at the bottom of the Sleeper Walls module, and make note of the loads and moment for the bottom layer sleeper, as seen below. Note that if the width of the intended concrete sleeper does not match up to the spacing of the layers in the [Calculations] tab, the sleeper size in the in the Sleeper Walls module will need to be adjusted accordingly using the [Select Sleeper] button (this is purely to get the correct loading distribution).

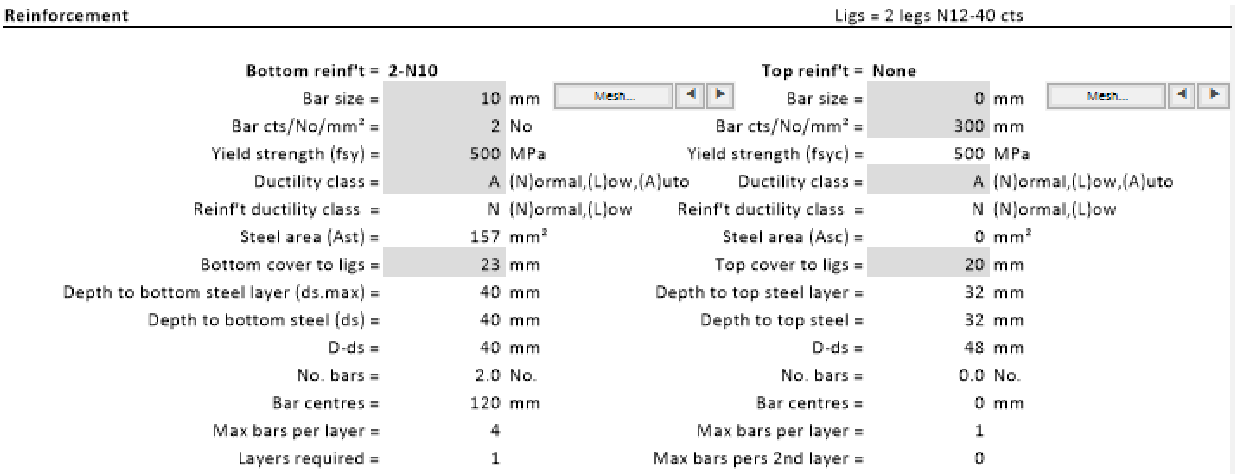
	Layer - ha mm	Sleepers	Ka.s kPa	Ka.ys.ha kPa	Total kPa	wdl kN/m	wll kN/m	w* kN/m	M* kNm	øMrd kNm	Ratio M*/øM	Def dl mm	Def(dl+ψl.ll) mm	Strength Ratio/Φn	Layer - ht mm
	0		0.00	0.00	0.00										0
1	100	1	1.75	0.63	2.38	0.13	0.35	0.68	0.12	1.73	0.07	0.1	0.4	OK (0.07)	100
	200		1.75	1.26	3.01										200
2	300	1	1.75	1.89	3.65	0.38	0.35	1.00	0.18	1.73	0.10	0.3	0.6	OK (0.10)	300
	400		1.75	2.52	4.28										400
3	500	1	1.75	3.15	4.91	0.63	0.35	1.31	0.24	1.73	0.14	0.5	0.8	OK (0.14)	500
	600		1.75	3.79	5.54										600
4	700	1	1.75	4.42	6.17	0.88	0.35	1.63	0.29	1.73	0.17	0.7	1.0	OK (0.17)	700
	800		1.75	5.05	6.80										800
5	900	1	1.75	5.68	7.43	1.14	0.35	1.95	0.35	1.73	0.20	0.9	1.2	OK (0.20)	900
	1000		1.75	6.31	8.06										1000
6	1100	1	1.75	6.94	8.69	1.39	0.35	2.26	0.41	1.73	0.24	1.1	1.4	OK (0.24)	1100
	1200		1.75	7.57	9.32										1200

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.

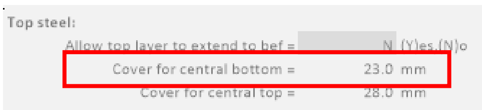


Next the reinforcement needs to be specified. In this case, only the bottom reinforcement is needed, so the bar size of the top reinforcement is put as zero. The recommended "Bottom cover to ligs" can be found to the bottom right under "Top Steel" – refer image below. In this case, 23.0mm was used.

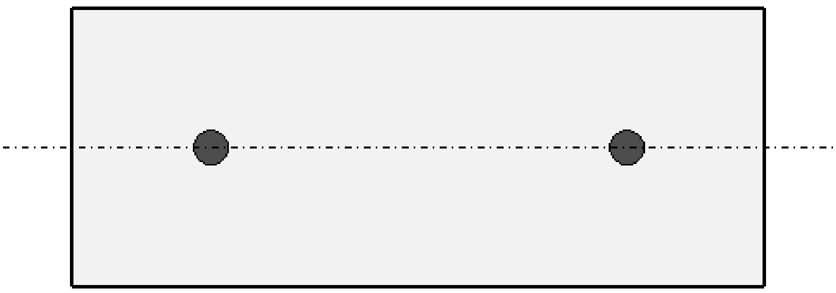


Reinforcement — Ligs = 2 legs N12-40 cts

Bottom reinf't =	2-N10		Top reinf't =	None	
Bar size =	10	mm	Bar size =	0	mm
Bar cts/No/mm² =	2	No	Bar cts/No/mm² =	300	mm
Yield strength (fsy) =	500	MPa	Yield strength (fsyc) =	500	MPa
Ductility class =	A	(N)ormal,(L)ow,(A)uto	Ductility class =	A	(N)ormal,(L)ow,(A)uto
Reinf't ductility class =	N	(N)ormal,(L)ow	Reinf't ductility class =	N	(N)ormal,(L)ow
Steel area (Ast) =	157	mm²	Steel area (Asc) =	0	mm²
Bottom cover to ligs =	23	mm	Top cover to ligs =	20	mm
Depth to bottom steel layer (ds.max) =	40	mm	Depth to top steel layer =	32	mm
Depth to bottom steel (ds) =	40	mm	Depth to top steel =	32	mm
D-ds =	40	mm	D-ds =	48	mm
No. bars =	2.0	No.	No. bars =	0.0	No.
Bar centres =	120	mm	Bar centres =	0	mm
Max bars per layer =	4		Max bars per layer =	1	
Layers required =	1		Max bars pers 2nd layer =	0	



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 $\times 10^6$ mm^4
Span (L) =	1200 mm			
Span type =	S	(S)imple,(E)xt,(I)nt,(C)ant,(P)rop,(F)ixed,(O)ther	Ag =	16000 mm^2
Material type =	C	(T)imber,(S)teel,(C)onc.,(SC)comp. steel,(O)ther	Density =	25 kN/m^3
			E =	32724 MPa

Loading

Uniform loads (kN/m)

Uniform loads	UDL	Partial 1	Partial 2
Dead load (wdl) =	1.39		
Live load (wll) =	0.35		
Start from LHS (mm) =	0		
End from LHS (mm) =	1200		
S.Wt =	0.00	kN/m	
Ultimate load (w*) =	2.26	0.00	0.00

Point loads (kN)

Point loads	PL 1	PL 2	PL 3
Dead load (pdl) =			
Live load (pll) =			
Pos. from LHS (mm) =			
Ultimate load (p*) =	0.00	0.00	0.00

Include S.Wt = N (Y)es,(N)o

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	Span /
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	
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 manufacterers generally result in an overdesigned concrete sleeper. This may result in the ku > 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 ku < 0.36. If the limit states are not met, readjust as with any other design.

Section:	**(Concrete Member CB01) 80mm (D) x 200mm (W) beam, f'c=40MPa**	
Reinf't:	**2-N10 bottom, ku = 0.36**	
Strength:	**(+ve M) M* = 0.4kNm < øMuo = 2.3kNm**	**OK (0.18)**
Cracking:	**fscr = 57MPa < Fscr = 265MPa & fscr1 = 57MPa < Fscr1 = 400MPa, crack width = 0.1mm**	**OK (0.14,0.22)**
Ast.min:	**Ast.min = 49mm² < Ast = 157mm² (Minimum of Deemed and actual)**	**OK (0.31)**
	Temperate environment with $\varepsilon_{csd.b}{}^* = 800\times10^{-6}$, $\varepsilon_{cs}{}^* = 680\times10^{-6}$	

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.

Info | Design | Preview | Detailed | Shear | Defl | Creep&Shrink | Secondary | BeamDefl | SlabDefl

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: **δ.dl = 2.6mm, δ.ll = 0.3mm, δ.inc = 3.5mm, δtotal = 4.8mm (span / 248)** — **Warning**
σcs for Temperate environment with $\varepsilon_{csd.b}{}^* = 800\times10^{-6}$, $\varepsilon_{cs}{}^* = 680\times10^{-6}$

Max Deflection...

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

Concrete density (ρ) =	2400 kg/m³ Cl 3.1.3	Gross area (Ag) =	16000 mm²	Stiffness based on bef or bf:
Use fcmi? =	Y (Y)es,(N)o	Uncr.g. neutral axis (NA) =	40 mm from top	Use bef =
fcmi =	43.5 MPa	Gross Stiffness (Ig) =	9 x10⁶ mm⁴ (w/o reinf't)	Note: Ag, Ig and na shown as
Deflection at =	X (M)anual, (C)ritical, (L)eft, Position (X) from analysis, (R)ight			when bf used (rather than be
Position (x) =	600 mm	Steel Modulus (Es) =	200000 MPa Cl 3.2.2	
Span type =	S	Cod. of elast. (Ec = $\rho^{1.5}$*(0.024*√fcmi+0.12)) =	32724 MPa ± 20% Cl 3.1.2	Position (x) for deflection:
		Modular ratio (n = Es/Ec) =	6.112	Ensure position is at maximu

Deflection calculation

		Left	At x	Right	Units
	Manual (M*) =				kNm
	Manual (Ms*) =				kNm
	Analysis (M*) =	0.0	0.4	0.0	kNm
	Analysis (Ms*) =	0.0	0.3	0.0	kNm
Top reinf't:	Ast req'd =	0	0	0	mm²
	Design Ast =	0	0	0	mm²
	Ast =	0	0	0	mm²
Bottom reinf't:	Ast req'd =	0	24	0	mm²
	Design Ast =	157	157	157	mm²
	Ast =	0	157	0	mm²
		-	2.0-N10	-	

Red values of M*/Ms* manually input

Short term LL factor (ψs) = 1.0
Long term LL factor (ψl) = 1.0

Transfer Reinf't...

Manual values:
To calculate the correct lav, s
type in the Analysis module.

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

Note that there is a warning for **σcs** 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 Mcr (Cracking) value. For this document, temperate was chosen.