Structural Calculations

for new basement at

10, Downside Crescent

Belsize Park, London

NW3

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Structural Calculations

for

10, Downside Crescent
Belsize Park, London NW3
for

Bow Tie Construction Ltd
Unit 86, Cressex Enterprise Centre, Lincoln Road
High Wycombe, Bucks
HP12 3RL

Job No 1411

Rev	Date	Notes
-	12.10.16	Structural package

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1. CALCULATION PLAN

This report contains the structural engineering calculations for the proposed new basement for 10, Downside Crescent.

The development consists of an existing semi-detached house rear extension. The extension will be composed by two levels: basement and ground floor. The access from the main building will be provided creating a new opening in the existing building back wall.

1.1. SUMMARY OF STRUCTURE

Proposed plan area – extension

Maximum plan dimensions	6.4m by 6.5m, say
Footprint area	41.6m^2
Storeys	Basement and Ground floor
Maximum height	3m over ground level

1.2. IMPOSED LOADS

The following imposed loads have been used

Typical imposed loads on pitched roofs	0.75 kN/m^2
Typical imposed loads on floors	1.50 kN/m^2
Partitions loads on floors (as imposed loads)	1.00 kN/m^2
Typical imposed loads on flat roofs allowing for maintenance	1.50 kN/m^2

1.3. REAR EXTENSION

The basement of the new extension will be realised with new reinforced concrete walls and slabs. Ground floor walls will be realized with cavity block works and the roof will be mainly constructed in timber elements and steel beams.

2. RESOURCES

2.1 CODES & REFERENCES

BS6399 Pt1 Loadings for buildings. Code of practice for dead and imposed loads.

BS6399 Pt2 Loadings for buildings. Code of practice for wind loads.

BS6399 Pt3 Loadings for buildings. Code of practice for imposed roof loads.

BS5269 Pt2 Structural use of Timber. Code of practice for permissible stress design, materials and workmanship.

BS5628 Pt1 Use of masonry. Structural use of unreinforced masonry.

BS5950 Pt1 Structural use of steelwork in building. Code of practice for design in simple and continuous construction hot rolled sections.

BS8110 Pt1 Structural use of concrete

Manual for the design of plain masonry in building structures – The Institution of Structural Engineers. July 1997.

2.2 SOFTWARE

Tekla Structural Designer suite of design and analysis tools.

Existing pitched roof

Dead	Tiles or slates		0.80 kN/m^2
	Battens and felt		0.05 kN/m^2
	Rafters		0.15 kN/m^2
	Insulation		0.01 kN/m^2
	Services		0.05 kN/m^2
	Plasterboard and skim coat		0.15 kN/m^2
			1.21 kN/m^2
	Roof Angle	45 º	1.71 kN/m^2
Imposed			0.75 kN/m^2

Existing typical floor

Dead	Finishes	0.15 kN/m^2
	Boarding	0.14 kN/m^2
	Joists	0.15 kN/m^2
	Insulation	0.05 kN/m^2
	Services	0.05 kN/m^2
	Lath and plaster	0.25 kN/m^2
		0.79 kN/m^2
Imposed		1.50 kN/m^2

External brick wall

Dead	External render	0.60 kN/m^2
	215mm brickwork	4.73 kN/m^2
	Plaster	0.25 kN/m^2
		5.58 kN/m^2

Proposed ground floor slab

Dead	Finishes	0.15 kN/m^2
	Screed	1.80 kN/m^2
	Insulation	0.05 kN/m^2
	175mm slab	4.20 kN/m^2
	Services	0.15 kN/m^2
		6.35 kN/m^2
Imposed		1.50 kN/m^2
	Partitions	1.00 kN/m^2
		2.50 kN/m^2

Proposed basement floor slab

Dead	Finishes	0.15 kN/m^2
	Screed	1.80 kN/m^2
	Insulation	0.05 kN/m^2
	500mm slab	12.00 kN/m^2
	Services	0.15 kN/m^2
		14.15 kN/m^2
Imposed		1.50 kN/m^2
	Partitions	1.00 kN/m^2
		2.50 kN/m^2

Proposed flat roof

Dead	Fibre glass waterproofing	0.15 kN/m^2
	Boarding	0.14 kN/m^2
	Insulation	0.05 kN/m^2
	Joists	0.15 kN/m^2
	Services	0.05 kN/m^2
	Plasterboard and skim coat	0.15 kN/m^2
		0.69 kN/m^2
Imposed (allowing for maintenance of structure above)		1.50 kN/m^2

Glazing

Dead	Glazing (Double)	0.65 kN/m^2
	Framing	0.20 kN/m^2
		0.85 kN/m^2
Imposed (for horizontal glazing accounting for snow)		0.75 kN/m^2

Proposed external wall

Dead	External render	0.60 kN/m^2
	100mm blockwork	1.50 kN/m^2
	Insulation	0.05 kN/m^2
	100mm block work	1.50 kN/m^2
	Plasterboard and skim coat	0.15 kN/m^2
		3.80 kN/m^2

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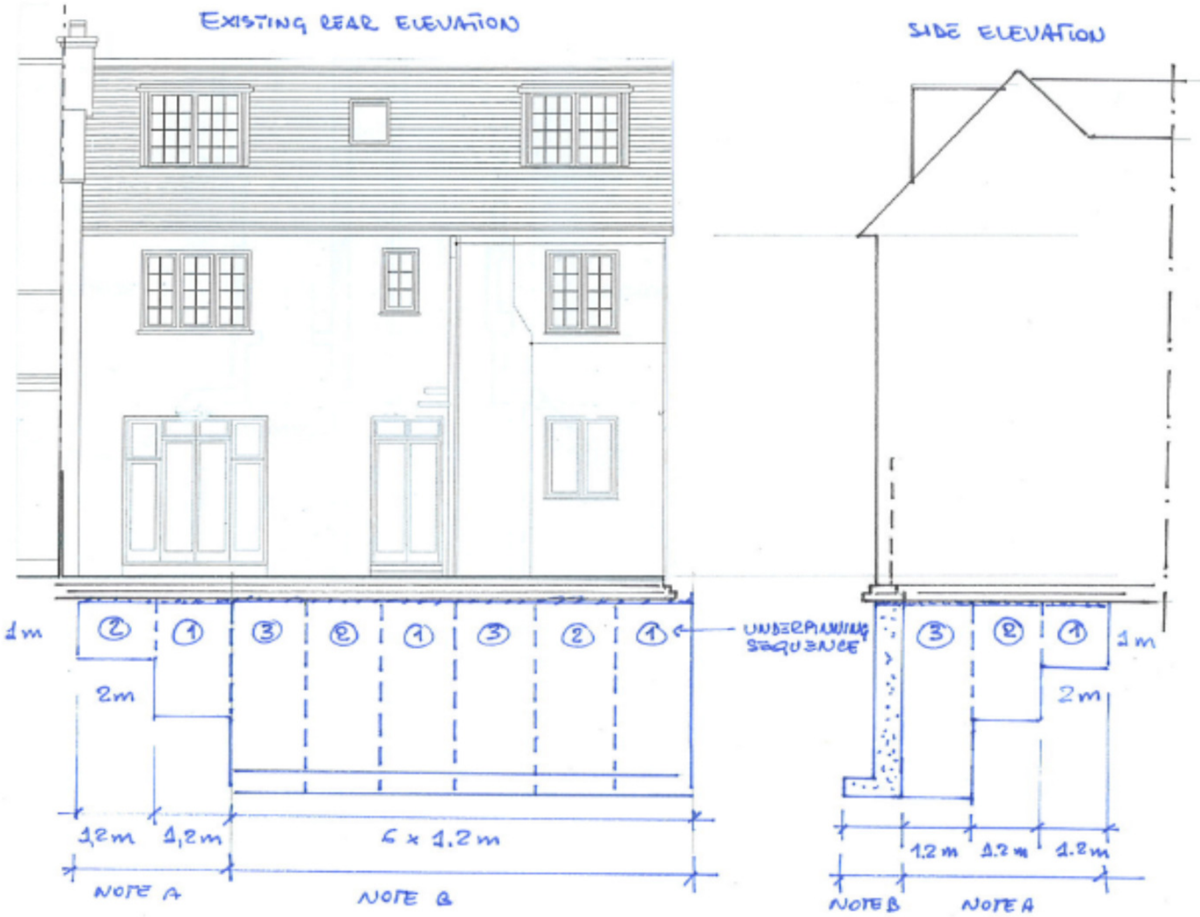
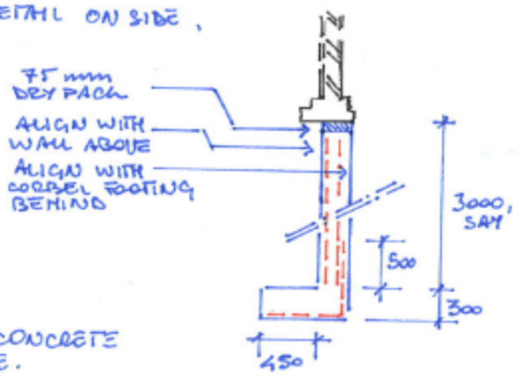
Calculations: Loads on elements & constr. sequence	Designed: ab	Date: 11/10/2016	Ckd: -

Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN
Phase 1 - underpinning of existing building back wall										



NOTE A : UNDERPIN EXISTING CORBEL FOOTING FOR THE WHOLE WIDTH USING C30 MASS CONCRETE. PINS HAVE TO BE 1.2 m LONG MAXIMUM.
DRY PACK BETWEEN TOP OF PINS AND BOTTOM SURFACE OF CORBEL FOOTING WITH 1:3 CEMENT : SAND BEDDING, 75 mm DEEP.

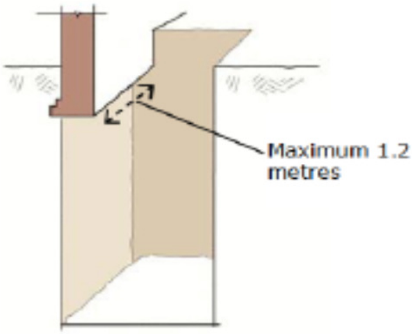
NOTE B: UNDERPIN EXISTING BACK WALL AS FOR DETAIL ON SIDE, USING C30 RC WALL WITH C503 MESH ON TOE, WALL AND STEM (φ8 @ 100 c/c AS VERTICAL).



NOTE : CONNECT PINS USING φ16 DOWEL BARS @ 300 c/c PLACED IN THE MIDDLE LINE OF WALL WIDTH. USE 500 mm LONG BARS RESIN ANCHORED FOR 250 mm IN EACH PIN.

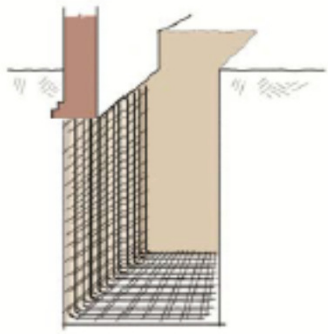
CONSTRUCTION STAGES FOR REINFORCED CONCRETE UNDERPINS ARE GIVEN ON THE NEXT PAGE.

Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN



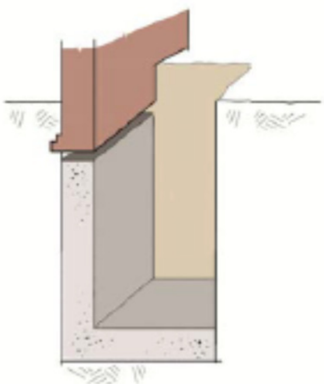
1. Excavation must be fully supported by props and shoring.
2. Edge protection to prevent falls into the excavation must be installed.
3. A temporary vertical prop or support may be placed under the wall to keep any loose bricks or masonry in place.
4. The main load from the existing wall will span onto the wall and foundations on either side of the excavation.

Stage 1. Excavation



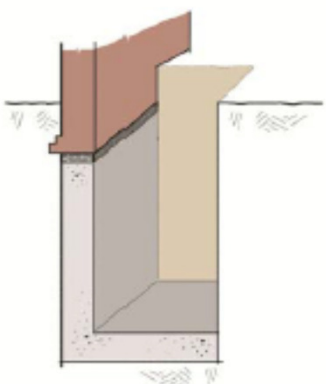
1. Reinforcement is fixed into position.
2. Reinforcement details are given in the engineering design.

Stage 2. Reinforcement



1. Concrete is placed in the toe first.
2. Once the toe is sufficiently cured the concrete wall is poured.
3. Shuttering, usually timber, is used to hold the concrete for the wall in place while it is placed.
4. Gap of approximately 75mm left between the top of the concrete and the underside of the existing foundation.

Stage 3. Concrete placement



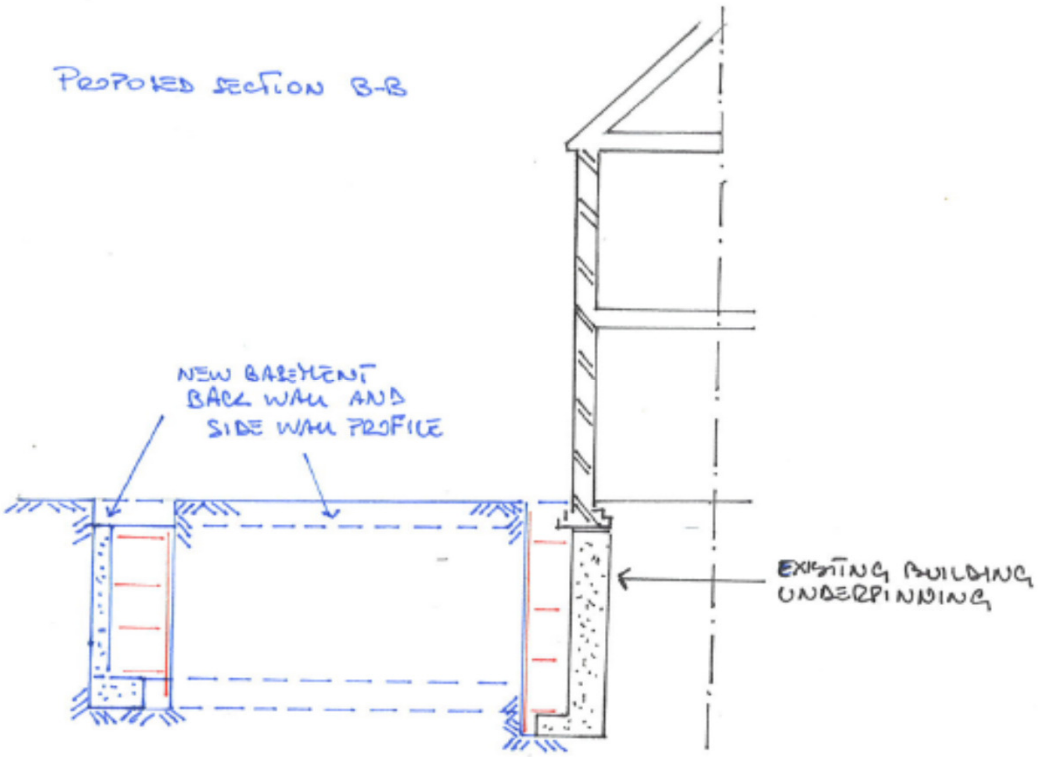
1. After a minimum of 24 hours dry-pack is rammed into the 75mm void that has been left above the new underpin.
2. Dry-pack is a mix of sharp sand and cement. It is easy to handle and has a low shrink volume, minimising settlement of the wall onto the new underpin foundation.
3. The completed underpin must be supported horizontally either by horizontal propping or by backfilling the excavation until the ground slab and possibly other permanent works are constructed.

Stage 4. Dry packing

Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN
<u>Load on main building rear wall corbel footing</u>										
	1000									
Pitched roof		1.71	0.75	2700			4.62	2.03		
Second floor		0.79	1.50	1800			1.42	2.70		
First floor		0.79	1.50	1800			1.42	2.70		
Wall SW		5.58		6000			33.48			
TOT							40.94	7.43		
<u>Load on main building rear wall at first floor level</u>										
	5000									
Pitched roof		1.71	0.75	2700			4.62	2.03		
Second floor		0.79	1.50	1800			1.42	2.70		
First floor		0.79	1.50	1800			1.42	2.70		
Wall SW		5.58		2900			16.18			
TOT							23.65	7.43		

See Sheet 5.1 for existing back wall underpinning calculations

Phase 2 - new basement back and side walls cast in place



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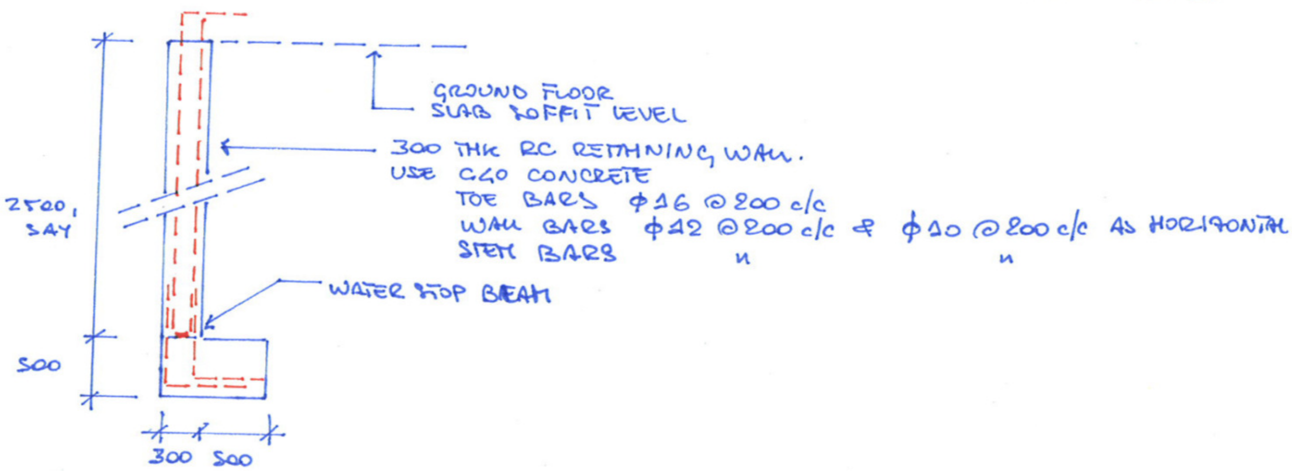
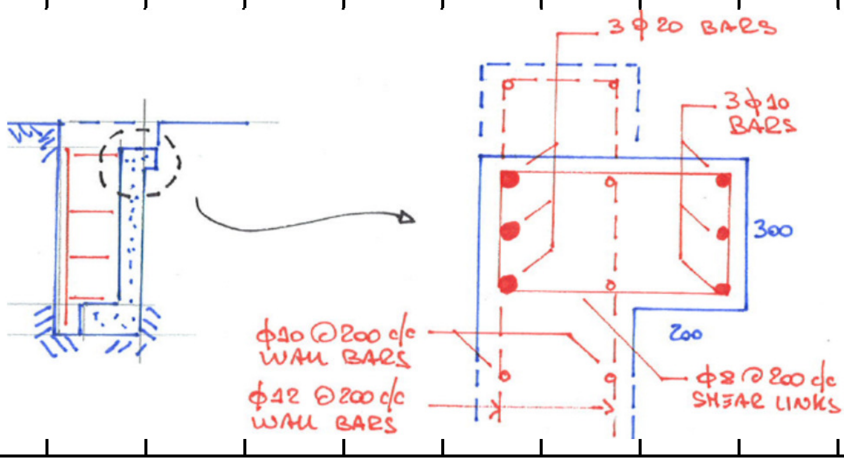
Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN

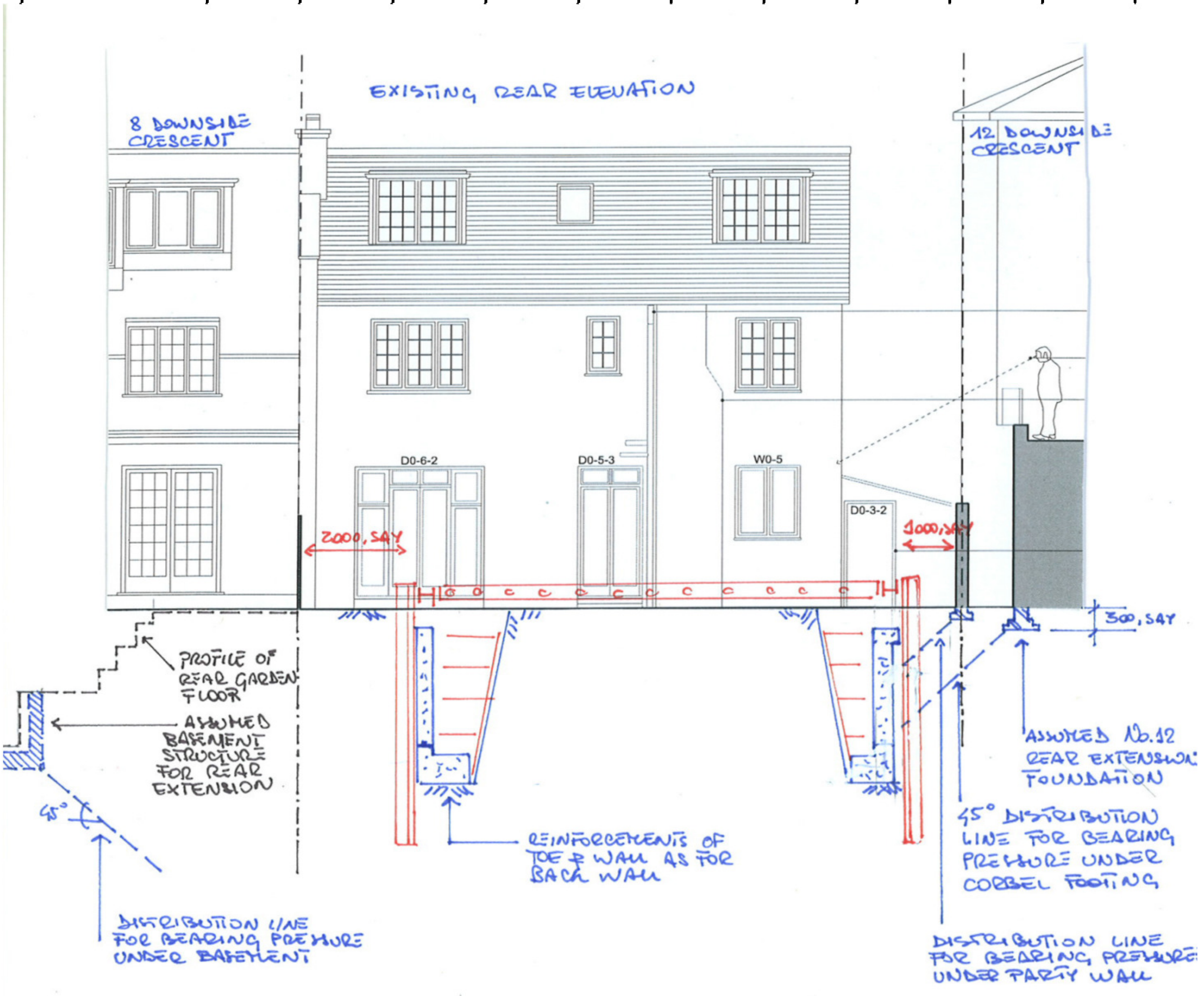
- WHILE MAIN BUILDING BACK WALL UNDERPINNING IS FULLY SUPPORTED BY PROPS AND SHORING, DIG A TRENCH FOR NEW BASEMENT BACK RETAINING WALLS.
  EXCAVATION HAS TO BE SUPPORTED BY PROPS AND SHORING AS WELL.
- PLACE REINFORCEMENT INTO POSITION AS FOR DETAIL BELOW.
- CAST THE TOE FIRST AND WHEN IT IS SUFFICIENTLY CURED THE WALL IS POURED.



Beam & Load description	Span	Area loads DL	Area loads LL	Width	Location from	Location to	UDL DL	UDL LL	Point loads DL	Point loads LL
<u>Load on back retaining wall</u>										
Ground floor		6.35	2.50	3200			20.32	8.00		
	See Sheet 5.2 for basement back retaining wall calculations									
<u>Load on side wall top beam (see sheet 5.4)</u>										
	See Sheet 5.3 and 5.4B for basement side wall and top beam calculations									



Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN



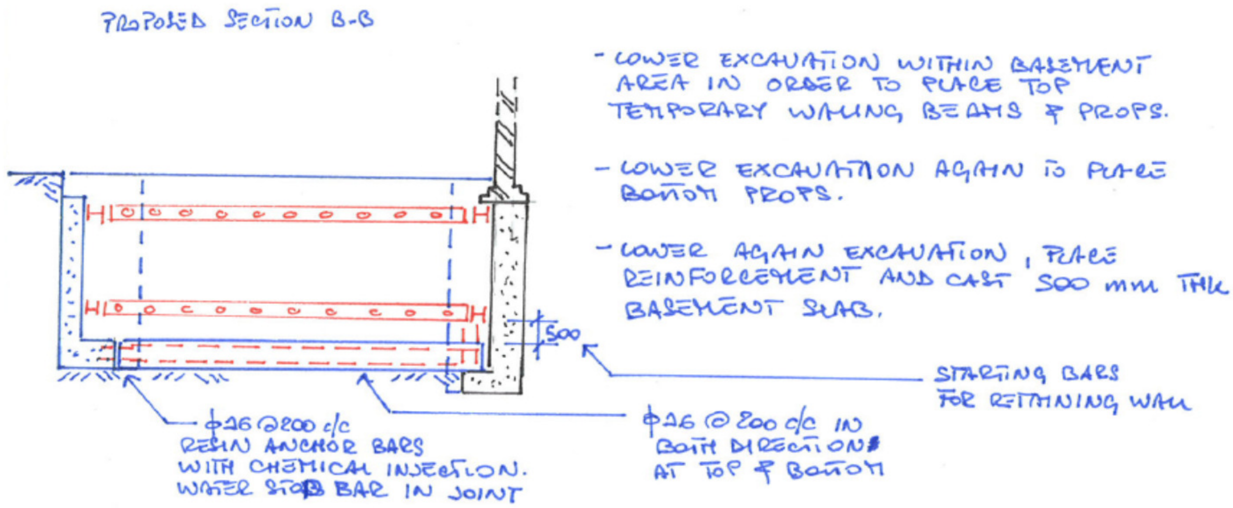
- INSERT TEMPORARY SHEET PILES
- PROP TOP OF PILES (ABOVE FUTURE GROUND FLOOR SLAB) USING HORIZONTAL WALING BEAMS AND PROPS
- DIG TRENCHES SUPPORTED BY SHORING AND CAST SIDE WALLS TOE AND STEM FIRST

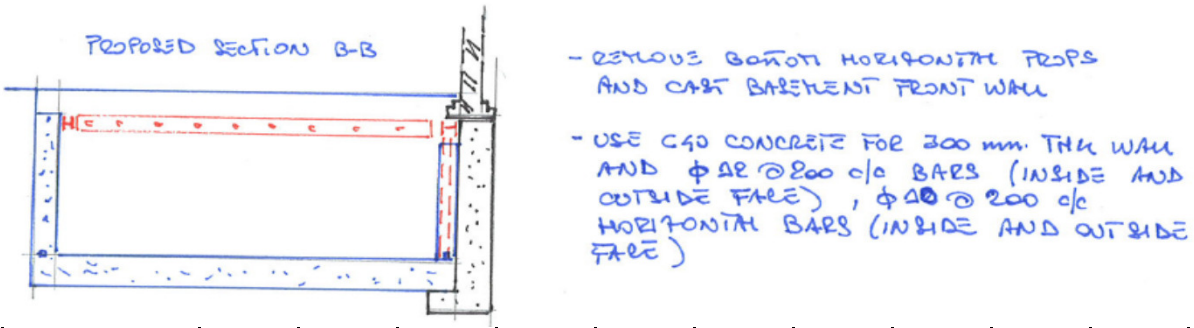
It is assumed that loads from No.8 Downside Crescent rear basement foundation do not affect No. 10 proposed basement walls, due to distance (bigger than 7m) and bearing level. This is valid even for the opposite.

At No. 12 side the boundary wall self weight has been taken into account using a surcharge on new basement wall of 10kN/sqm; foundation of No.12 rear extention does not affect new basement wall due to distance (distribution line of load fron No. 2 rear extension corbel footing intercepts only new basement slab, which is placed more than 2m far in plan).

Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN

Phase 3 - new basement front wall and slab cast in place



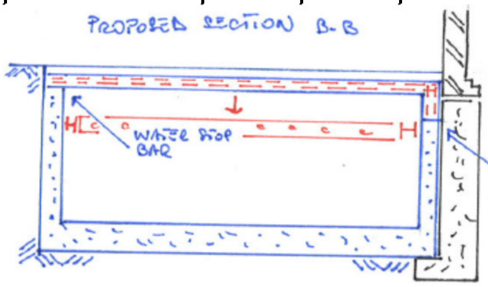


Phase 4 - new ground floor slab cast in place

<u>Load on new extension ground floor slab</u>

Beam & Load description	Span (mm)	DL (kN/m²)	LL (kN/m²)	Width (mm)	from (mm)	to (mm)	UDL DL (kN/m)	UDL LL (kN/m)	Point DL (kN)	Point LL (kN)
Ground floor	6400x3500	6.35	2.50	1000			6.35	2.50		

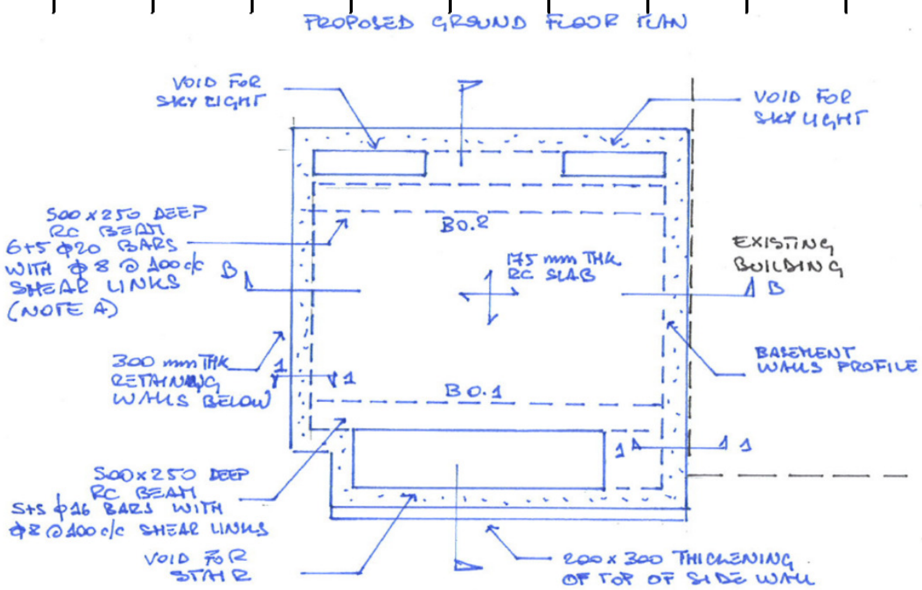
See Sheet 5.5 fro ground floor slab calculations



- PROP AGAIN RETAINING WALL AT LOWER LEVEL AND REMOVE TOP PROPS.
- CAST GROUND FLOOR SLAB 175 mm THICK. USE C40 CONCRETE, ϕ12 @ 200 c/c BARS AT TOP AND BOTTOM IN BOTH DIRECTIONS.

Beam & Load description	Span (mm)	Area loads DL (kN/m²)	Area loads LL (kN/m²)	Width (mm)	Location from (mm)	Location to (mm)	UDL DL (kN/m)	UDL LL (kN/m)	Point loads DL (kN)	Point loads LL (kN)
Beam B0.1										
	6400									
Ground floor		6.35	2.50	1750	triangular load		11.11	4.38		
Direct load on beam		2.15	2.50	500			1.08	1.25		
Beam B0.2										
	6400									
Ground floor		6.35	2.50	1750	triangular load		11.11	4.38		
		6.35	1.50	400	2000	4400	2.54	0.60		
Direct load on beam		2.15	2.50	500	0	4400	1.08	1.25		
Glazed door		0.85		2300	0	4400	1.96			
Cavity wall above		3.80		2500	4400	6400	9.50			
Roof	1600	0.69	1.50	2500	4400				2.76	6.00

See Sheet 5.6 and 5.7 for beam B0.1 and B0.2 calculations



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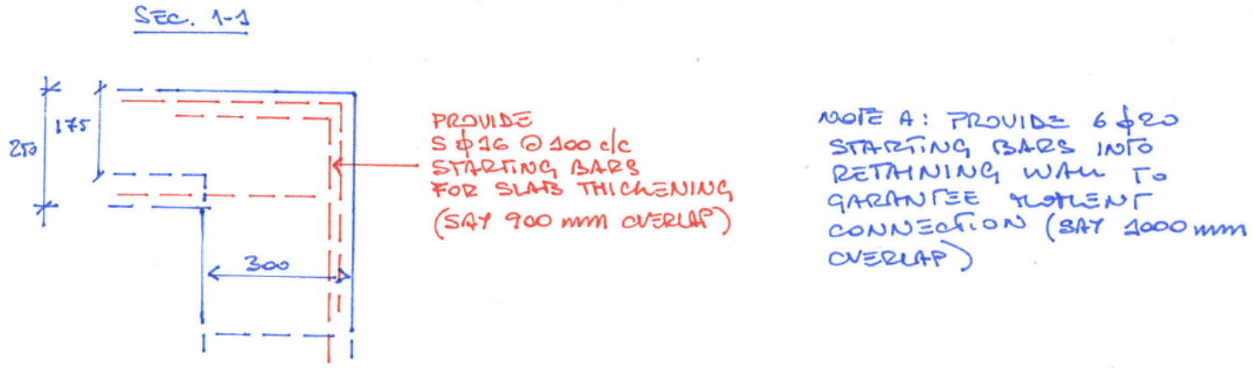
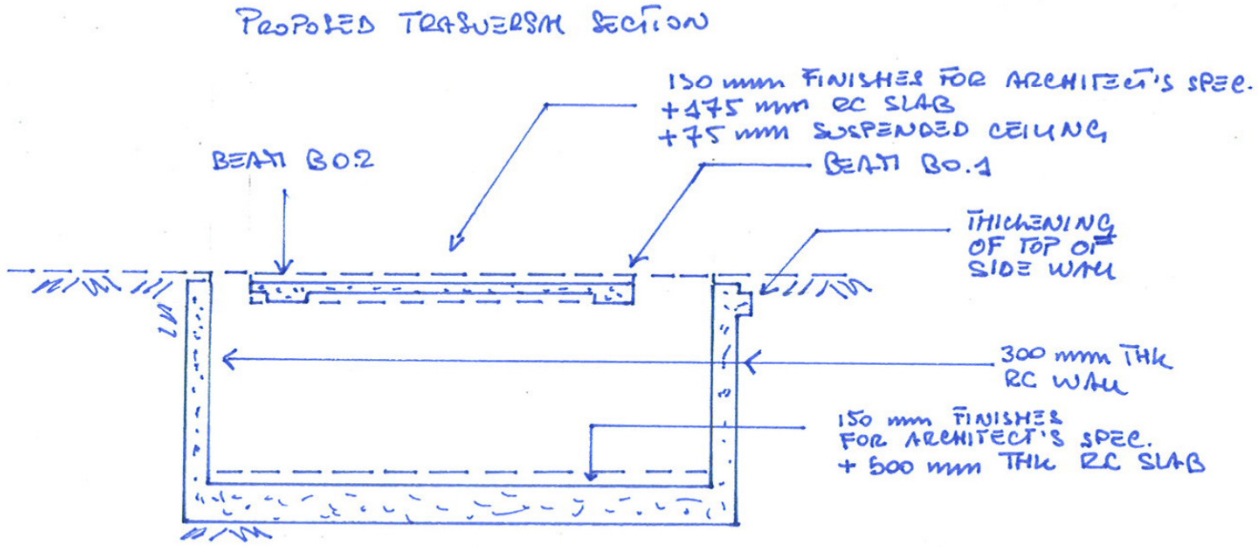
Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN



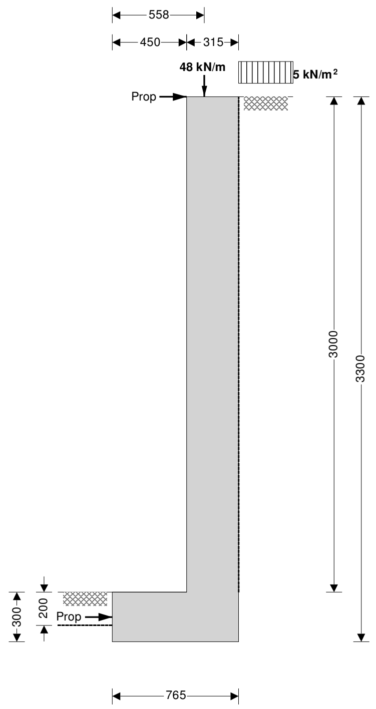


Phase 5 - support main building back wall with props, create new opening to extension and install steel frame

Phase 6 - build up back extension ground floor walls and flat roof

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **315** mm
Length of toe	l_{toe} = **450** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **765** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **15** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3300** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **200** mm
Height of ground water behind wall	h_{water} = **0** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **0** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3300** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **18.6** deg

Angle of wall friction δ = **0.0** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **16.5** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **100** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.516}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{2.835}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi') = \mathbf{0.681}$

Loading details

Surcharge load on plan Surcharge = **5.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **41.0** kN/m

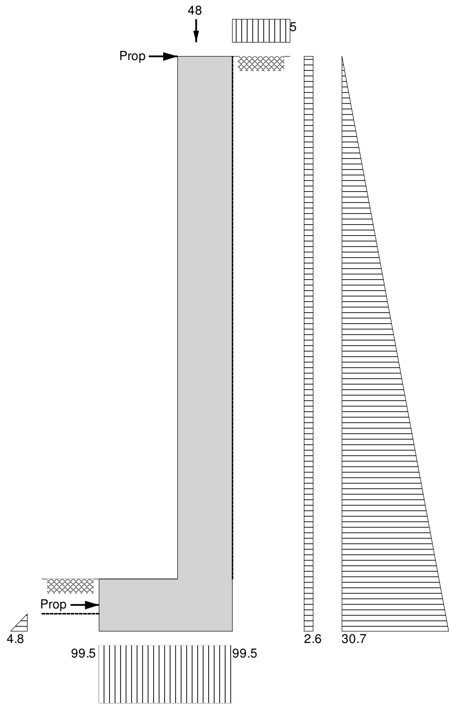
Applied vertical live load on wall W_{live} = **7.4** kN/m

Position of applied vertical load on wall l_{load} = **558** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **22.3** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **5.4** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **48.4** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **76.1** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **8.5** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **50.6** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a}$ = **59.1** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **0.2** kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop} = **35.8** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **14.1** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **55.7** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a}$ = **69.7** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **13.5** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **2.1** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **22.9** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **38.5** kNm/m

Check bearing pressure

Total vertical reaction $R = W_{total}$ = **76.1** kN/m

Distance to reaction $x_{bar} = l_{base} / 2$ = **383** mm

Eccentricity of reaction $e = \text{abs}((l_{base} / 2) - x_{bar})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **99.5** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **99.5** kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **17.460** kN/m

Propping force to base of wall $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **18.299** kN/m

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **31.2** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **7.6** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **69.2** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **108** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **18** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **93.4** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f}$ = **111.4** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **0.3** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **78.7** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **29.7** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **102.8** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f}$ = **132.5** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **19** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **2.9** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **38.6** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **60.5** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **108.0** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **383** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **141.2** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **141.2** kN/m²

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m²/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **141.2** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **141.2** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2)$ = **141.2** kN/m²

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **32.225** kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f}$ = **46.487** kN/m

Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete f_{cu} = **30** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in toe c_{toe} = **45** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2$ = **63.6** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base}$ = **4.5** kN/m

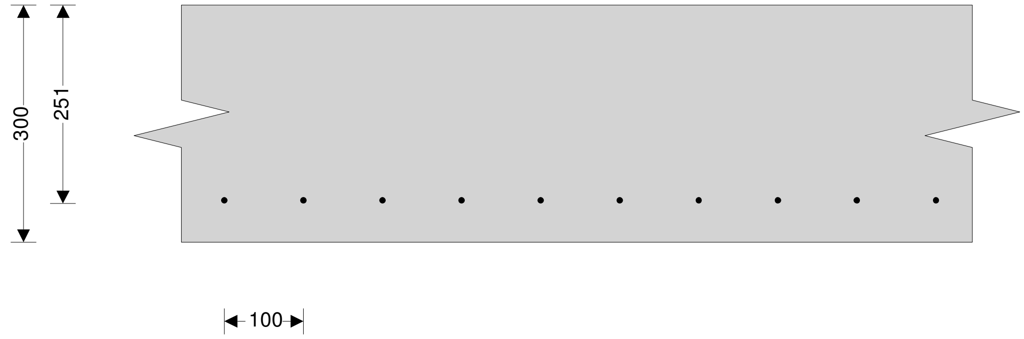
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base}$ = **59.1** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6$ = **26.1** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2)$ = **1.8** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base}$ = **24.2** kNm/m



Check toe in bending

Width of toe b = **1000** mm/m

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2)$ = **251.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.013**

Compression reinforcement is not required

Lever arm $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$

z_{toe} = **238** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **234** mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base}$ = **390** mm^2/m

Area of tension reinforcement required $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **390** mm^2/m

Reinforcement provided **C503 mesh**

Area of reinforcement provided $A_{s\_toe\_prov}$ = **503** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.235** N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \mathrm{N/mm^2})}, 5) \times 1\ \mathrm{N/mm^2}$ = **4.382** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.441** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall stem (BS 8002:1994)

Material properties

Characteristic strength of concrete f_{cu} = **30** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **45** mm

Cover to reinforcement in wall c_{wall} = **45** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **16.3** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **77.2** kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8$ = **10.2** kN/m

Moist backfill above water table $V_{s\_m\_a\_f} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - b_l^2) / (5 \times L^3)$ = **60.2** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f}$ = **70.4** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8$ = **6.4** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2)$ = **35.2** kNm/m

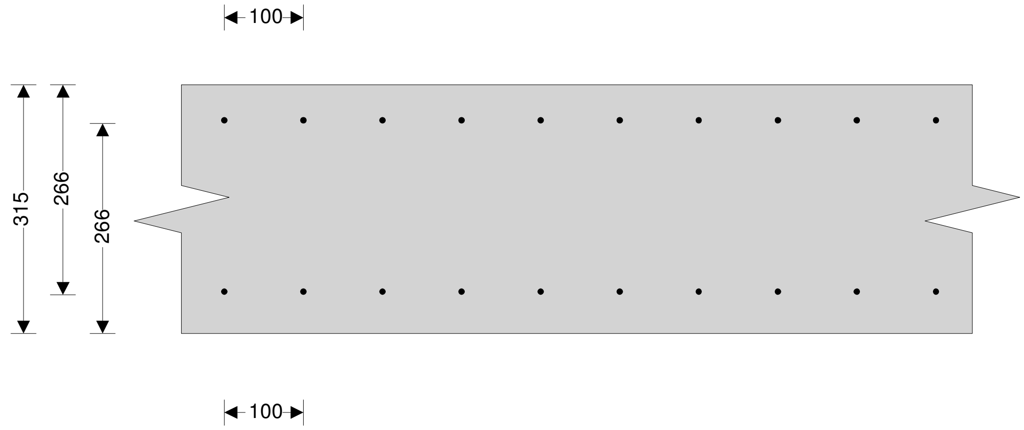
Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a}$ = **41.6** kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128$ = **3.6** kNm/m

Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3]$ = **14.6**
kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a}$ = **18.2** kNm/m



Check wall stem in bending

Width of wall stem b = **1000** mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **266.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.020**

Compression reinforcement is not required

Lever arm $z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

z_{stem} = **253** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **379** mm^2/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall} = \mathbf{410}$ mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = Max(A_{s\_stem\_des}, A_{s\_stem\_min}) = \mathbf{410}$ mm²/m

Reinforcement provided **C503 mesh**

Area of reinforcement provided $A_{s\_stem\_prov} = \mathbf{503}$ mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.265}$ N/mm²

Allowable shear stress $v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2 = \mathbf{4.382}$ N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_stem} = \mathbf{0.427}$ N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check mid height of wall in bending

Depth of reinforcement $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2) = \mathbf{266.0}$ mm

Constant $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu}) = \mathbf{0.009}$

Compression reinforcement is not required

Lever arm $z_{wall} = Min(0.5 + \sqrt{(0.25 - (min(K_{wall}, 0.225) / 0.9))}, 0.95) \times d_{wall}$

$z_{wall} = \mathbf{253}$ mm

Area of tension reinforcement required $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall}) = \mathbf{166}$ mm²/m

Minimum area of tension reinforcement $A_{s\_wall\_min} = k \times b \times t_{wall} = \mathbf{410}$ mm²/m

Area of tension reinforcement required $A_{s\_wall\_req} = Max(A_{s\_wall\_des}, A_{s\_wall\_min}) = \mathbf{410}$ mm²/m

Reinforcement provided **C503 mesh**

Area of reinforcement provided $A_{s\_wall\_prov} = \mathbf{503}$ mm²/m

PASS - Reinforcement provided to the retaining wall at mid height is adequate

Check retaining wall deflection

Basic span/effective depth ratio $ratio_{bas} = \mathbf{20}$

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov}) = \mathbf{271.6}$ N/mm²

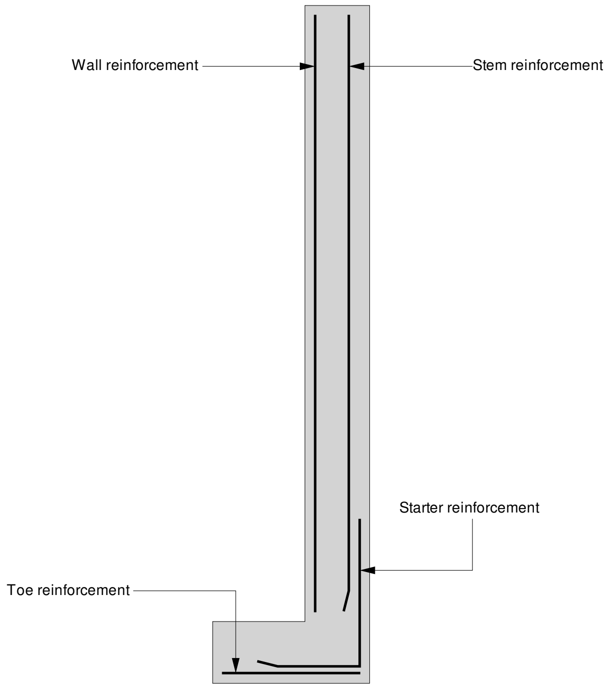
Modification factor $factor_{tens} = min(0.55 + (477\ N/mm^2 - f_s)/(120 \times (0.9\ N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))),2) = \mathbf{1.70}$

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens} = \mathbf{34.00}$

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem} = \mathbf{11.28}$

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



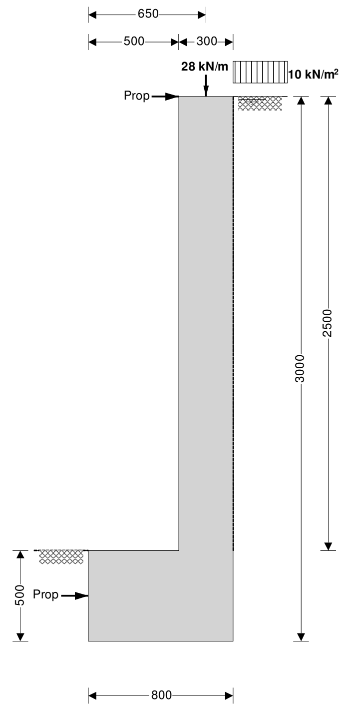
Toe mesh - C503 - (503 mm^2/m)

Wall mesh - C503 - (503 mm^2/m)

Stem mesh - C503 - (503 mm^2/m)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **2500** mm
Thickness of wall stem	t_{wall} = **300** mm
Length of toe	l_{toe} = **500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **800** mm
Thickness of base	t_{base} = **500** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **15** mm
Thickness of downstand	t_{ds} = **500** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3000** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **3000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ mm)$ = **2500** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3000** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m³

Design shear strength ϕ' = **18.6** deg

Angle of wall friction δ = **0.0** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m³

Design shear strength ϕ'_b = **16.5** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **100** kN/m²

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.516}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{2.835}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi') = \mathbf{0.681}$

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m²

Applied vertical dead load on wall W_{dead} = **20.3** kN/m

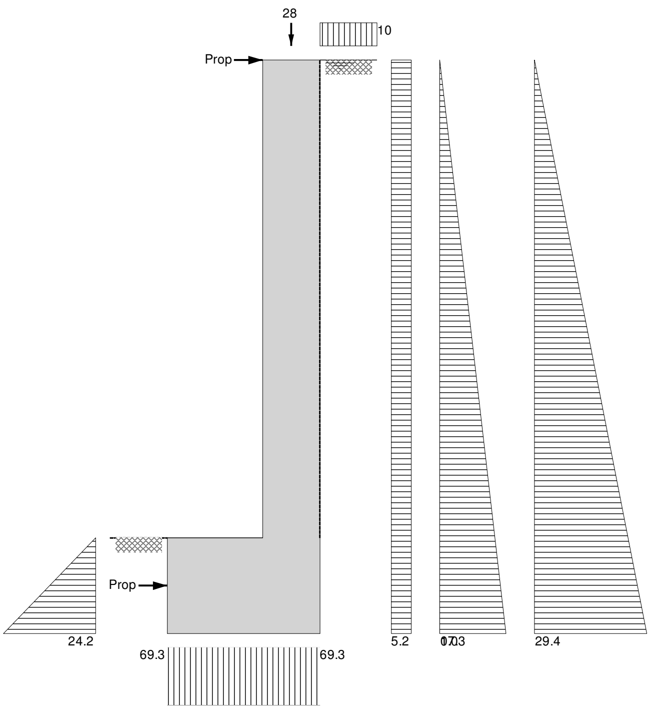
Applied vertical live load on wall W_{live} = **8.0** kN/m

Position of applied vertical load on wall l_{load} = **650** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m²

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **17.7** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **9.4** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **28.3** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **55.5** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times Surcharge \times h_{eff}$ = **15.5** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **26** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **44.1** kN/m

Total horizontal load $F_{total} = F_{sur} + F_s + F_{water}$ = **85.6** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6** kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0\ kN/m)$

F_{prop} = **63.6** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **23.2** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **26** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **44.1** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_s + M_{water}$ = **93.4** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **11.5** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **3.8** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **13.2** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **28.5** kNm/m

Check bearing pressure

Total vertical reaction $R = W_{total}$ = **55.5** kN/m

Distance to reaction $x_{bar} = l_{base} / 2$ = **400** mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **69.3** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **69.3** kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **25.881** kN/m

Propping force to base of wall $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **37.737** kN/m

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **24.8** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **13.2** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **41.2** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **79.2** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **32.7** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **48** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **61.8** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{s\_f} + F_{water\_f}$ = **142.5** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **8.5** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **111.7** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **49** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **48** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **61.8** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{s\_f} + M_{water\_f}$ = **158.8** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **16.1** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **5.3** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **26.8** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **48.2** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **79.2** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **400** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **99.1** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **99.1** kN/m²

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m²/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **99.1** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **99.1** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2)$ = **99.1** kN/m²

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = \mathbf{41.608}$ kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} = \mathbf{70.070}$ kN/m

Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete $f_{cu} = \mathbf{40}$ N/mm²

Characteristic strength of reinforcement $f_y = \mathbf{500}$ N/mm²

Base details

Minimum area of reinforcement $k = \mathbf{0.13}$ %

Cover to reinforcement in toe $c_{toe} = \mathbf{45}$ mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{49.5}$ kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{8.3}$ kN/m

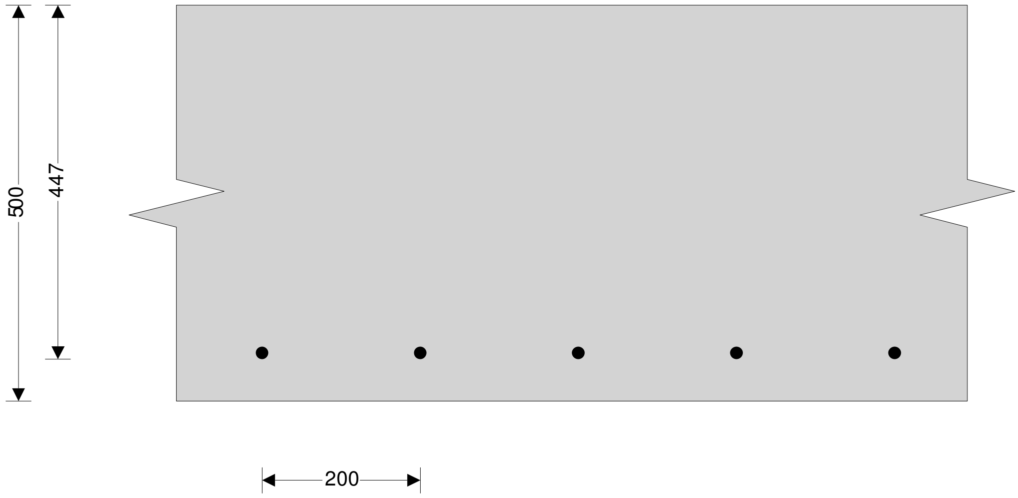
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{41.3}$ kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{20.9}$ kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{3.5}$ kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{17.4}$ kNm/m



Check toe in bending

Width of toe $b = \mathbf{1000}$ mm/m

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{447.0}$ mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.002}$

Compression reinforcement is not required

Lever arm $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$

$z_{toe} = \mathbf{425}$ mm

Area of tension reinforcement required $As_{toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{94}$ mm²/m

Minimum area of tension reinforcement $As_{toe\_min} = k \times b \times t_{base} = \mathbf{650}$ mm²/m

Area of tension reinforcement required $As_{toe\_req} = \mathrm{Max}(As_{toe\_des}, As_{toe\_min}) = \mathbf{650}$ mm²/m

Reinforcement provided **16 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $As_{toe\_prov} = \mathbf{1005}$ mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.092}$ N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = \mathbf{5.000}$ N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_toe} = \mathbf{0.450}$ N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall stem (BS 8002:1994)

Material properties

Characteristic strength of concrete $f_{cu} = \mathbf{40}$ N/mm^2

Characteristic strength of reinforcement $f_y = \mathbf{500}$ N/mm^2

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem $c_{stem} = \mathbf{45}$ mm

Cover to reinforcement in wall $c_{wall} = \mathbf{45}$ mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = \mathbf{27.2}$ kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 = \mathbf{33.3}$ kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2 = \mathbf{42.9}$ kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8 = \mathbf{17}$ kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) = \mathbf{26.7}$ kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) = \mathbf{34.3}$ kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_s\_f} + V_{s\_water\_f} = \mathbf{78}$ kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8 = \mathbf{9.4}$ kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2) = \mathbf{12.2}$ kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2) = \mathbf{15.7}$

kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_s} + M_{s\_water} = \mathbf{37.3}$ kNm/m

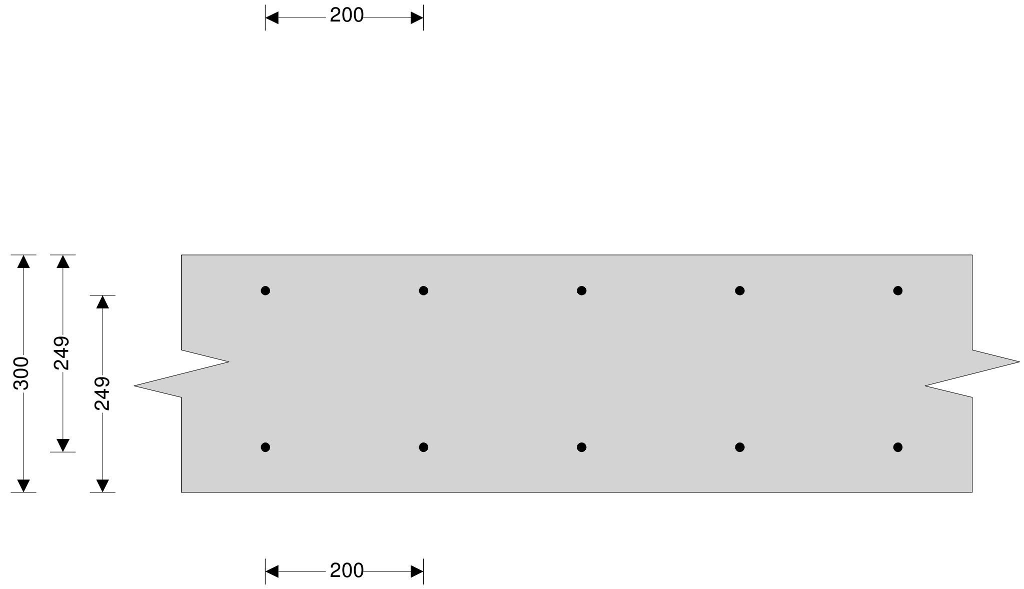
Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128 = \mathbf{5.3}$ kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l) / (20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] = \mathbf{5.5}$ kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l) / (20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] = \mathbf{7}$ kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_s} + M_{w\_water} = \mathbf{17.8}$ kNm/m



Check wall stem in bending

Width of wall stem: b = **1000** mm/m

Depth of reinforcement: $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **249.0** mm

Constant: $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.015**

Compression reinforcement is not required

Lever arm: $z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

z_{stem} = **237** mm

Area of tension reinforcement required: $As_{\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **363** mm²/m

Minimum area of tension reinforcement: $As_{\_stem\_min} = k \times b \times t_{wall}$ = **390** mm²/m

Area of tension reinforcement required: $As_{\_stem\_req} = \text{Max}(As_{\_stem\_des}, As_{\_stem\_min})$ = **390** mm²/m

Reinforcement provided: **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided: $As_{\_stem\_prov}$ = **565** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress: $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.313** N/mm²

Allowable shear stress: $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress: v_{c_stem} = **0.508** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check mid height of wall in bending

Depth of reinforcement: $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2)$ = **249.0** mm

Constant: $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu})$ = **0.007**

Compression reinforcement is not required

Lever arm: $z_{wall} = \text{Min}(0.5 + \sqrt{(0.25 - (\min(K_{wall}, 0.225) / 0.9))}, 0.95) \times d_{wall}$

z_{wall} = **237** mm

Area of tension reinforcement required: $As_{\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall})$ = **173** mm²/m

Minimum area of tension reinforcement: $As_{\_wall\_min} = k \times b \times t_{wall}$ = **390** mm²/m

Area of tension reinforcement required: $As_{\_wall\_req} = \text{Max}(As_{\_wall\_des}, As_{\_wall\_min})$ = **390** mm²/m

Reinforcement provided **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $A_{s\_wall\_prov}$ = **565** mm²/m

PASS - Reinforcement provided to the retaining wall at mid height is adequate

Check retaining wall deflection

Basic span/effective depth ratio $ratio_{bas}$ = **20**

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **229.9** N/mm²

Modification factor $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.92**

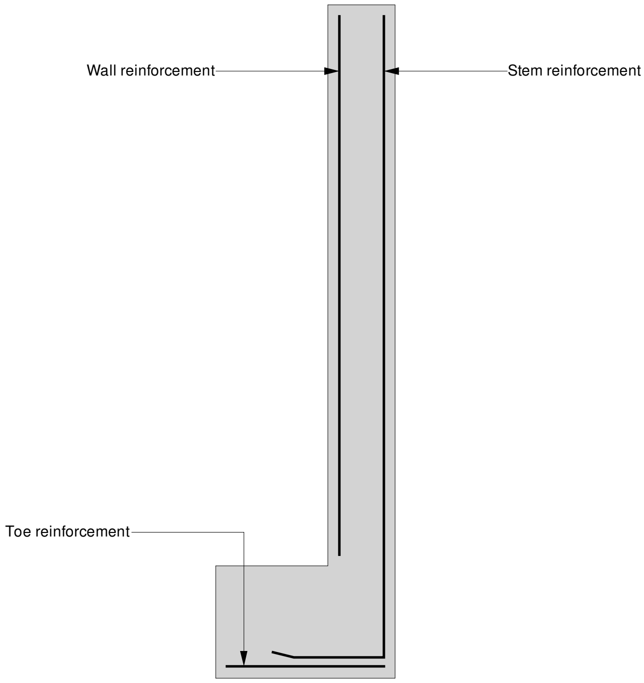
Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **38.42**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **10.04**

PASS - Span to depth ratio is acceptable

RODRIGUES ASSOCIATES 1 AMWELL STREET LONDON EC1R 1UL	Project 10 Downside Crescent				Job no. 1411	
	Calcs for new basement back retaining wall				Start page no./Revision 5.2. 9	
	Calcs by ab	Calcs date 12/10/2016	Checked by	Checked date	Approved by	Approved date

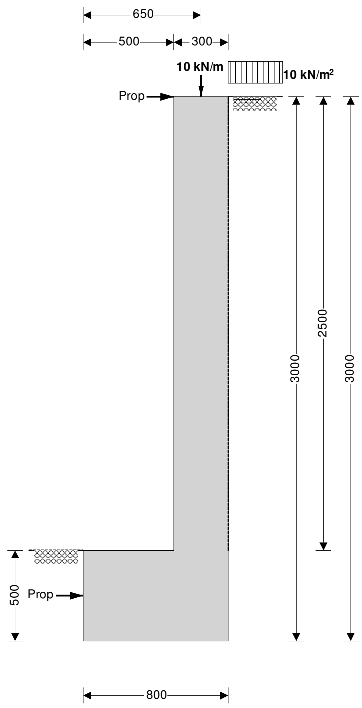
Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)
Wall bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)
Stem bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **2500** mm
Thickness of wall stem	t_{wall} = **300** mm
Length of toe	l_{toe} = **500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **800** mm
Thickness of base	t_{base} = **500** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **300** mm
Thickness of downstand	t_{ds} = **500** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3000** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **3000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **2500** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3000** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m³

Design shear strength ϕ' = **18.6** deg

Angle of wall friction δ = **0.0** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m³

Design shear strength ϕ'_b = **16.5** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **100** kN/m²

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.516}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{2.835}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi') = \mathbf{0.681}$

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m²

Applied vertical dead load on wall W_{dead} = **10.3** kN/m

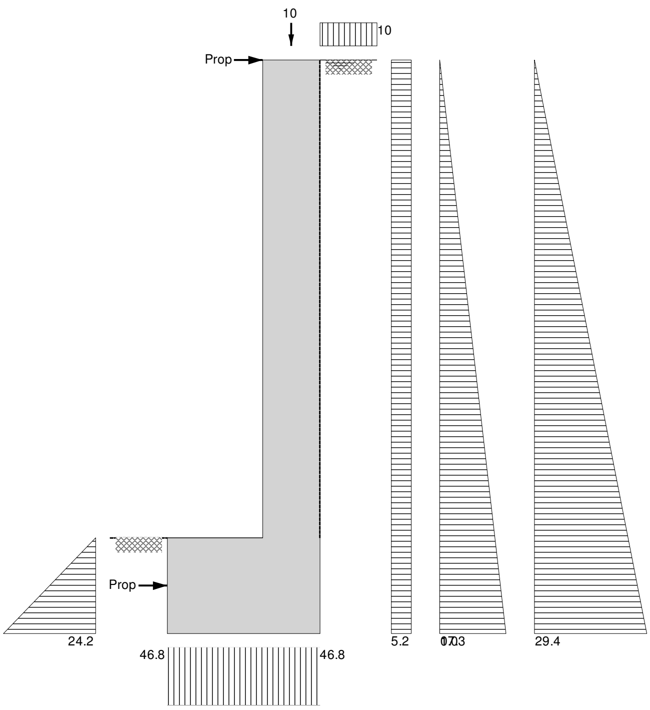
Applied vertical live load on wall W_{live} = **0.0** kN/m

Position of applied vertical load on wall l_{load} = **650** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m²

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **17.7** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **9.4** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **10.3** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **37.4** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **15.5** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **26** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **44.1** kN/m

Total horizontal load $F_{total} = F_{sur} + F_s + F_{water}$ = **85.6** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6** kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total}) \times \tan(\delta_b), 0\text{ kN/m})$

F_{prop} = **67.0** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **23.2** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **26** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **44.1** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_s + M_{water}$ = **93.4** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **11.5** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **3.8** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **6.7** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **22** kNm/m

Check bearing pressure

Total vertical reaction $R = W_{total}$ = **37.4** kN/m

Distance to reaction $x_{bar} = l_{base} / 2$ = **400** mm

Eccentricity of reaction $e = \text{abs}((l_{base} / 2) - x_{bar})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **46.8** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **46.8** kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **25.324** kN/m

Propping force to base of wall $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **41.679** kN/m

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **24.8** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **13.2** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **14.4** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **52.4** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **32.7** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **48** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **61.8** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{s\_f} + F_{water\_f}$ = **142.5** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **8.5** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **116.4** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **49** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **48** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **61.8** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{s\_f} + M_{water\_f}$ = **158.8** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **16.1** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **5.3** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **9.3** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **30.7** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **52.4** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **400** mm

Eccentricity of reaction $e_f = abs((l_{base} / 2) - x_{bar\_f})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **65.5** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **65.5** kN/m²

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m²/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **65.5** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **65.5** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2)$ = **65.5** kN/m²

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) =$ **43.621** kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} =$ **72.797** kN/m

<u>Design of reinforced concrete retaining wall toe (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete $f_{cu} =$ **40** N/mm^2

Characteristic strength of reinforcement $f_y =$ **500** N/mm^2

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in toe $c_{toe} =$ **45** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **32.7** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **8.3** kN/m

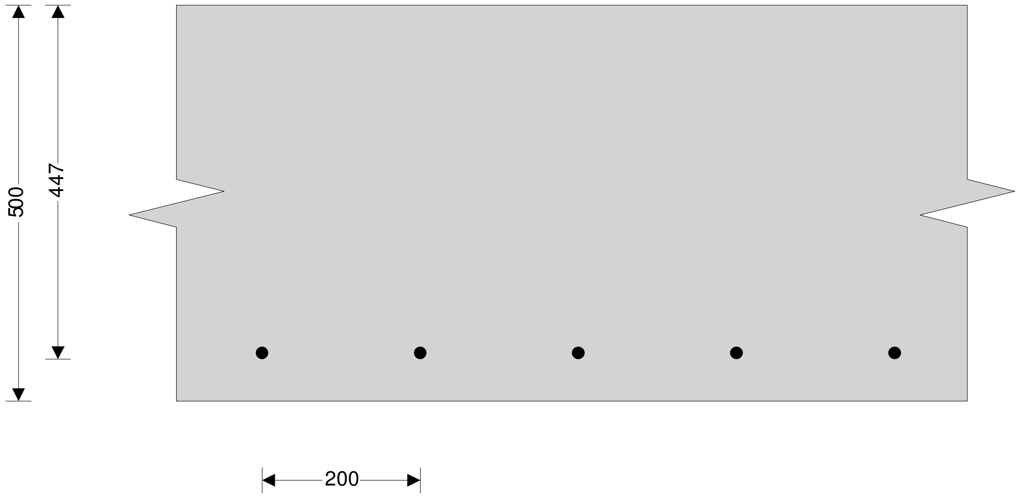
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **24.5** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **13.8** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **3.5** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **10.3** kNm/m



Check toe in bending

Width of toe b = **1000** mm/m

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **447.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.001**

Compression reinforcement is not required

Lever arm $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))},0.95) \times d_{toe}$

$z_{toe} =$ **425** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **56** mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} =$ **650** mm^2/m

Area of tension reinforcement required $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **650** mm^2/m

Reinforcement provided **16 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov} =$ **1005** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.055}$ N/mm²

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2 = \mathbf{5.000}$ N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_toe} = \mathbf{0.450}$ N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall stem (BS 8002:1994)

Material properties

Characteristic strength of concrete $f_{cu} = \mathbf{40}$ N/mm²

Characteristic strength of reinforcement $f_y = \mathbf{500}$ N/mm²

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem $c_{stem} = \mathbf{45}$ mm

Cover to reinforcement in wall $c_{wall} = \mathbf{45}$ mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = \mathbf{27.2}$ kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 = \mathbf{33.3}$ kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2 = \mathbf{42.9}$ kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8 = \mathbf{17}$ kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) = \mathbf{26.7}$ kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) = \mathbf{34.3}$ kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_s\_f} + V_{s\_water\_f} = \mathbf{78}$ kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8 = \mathbf{9.4}$ kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2))/(60 \times L^2) = \mathbf{12.2}$ kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2))/(60 \times L^2) = \mathbf{15.7}$

kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_s} + M_{s\_water} = \mathbf{37.3}$ kNm/m

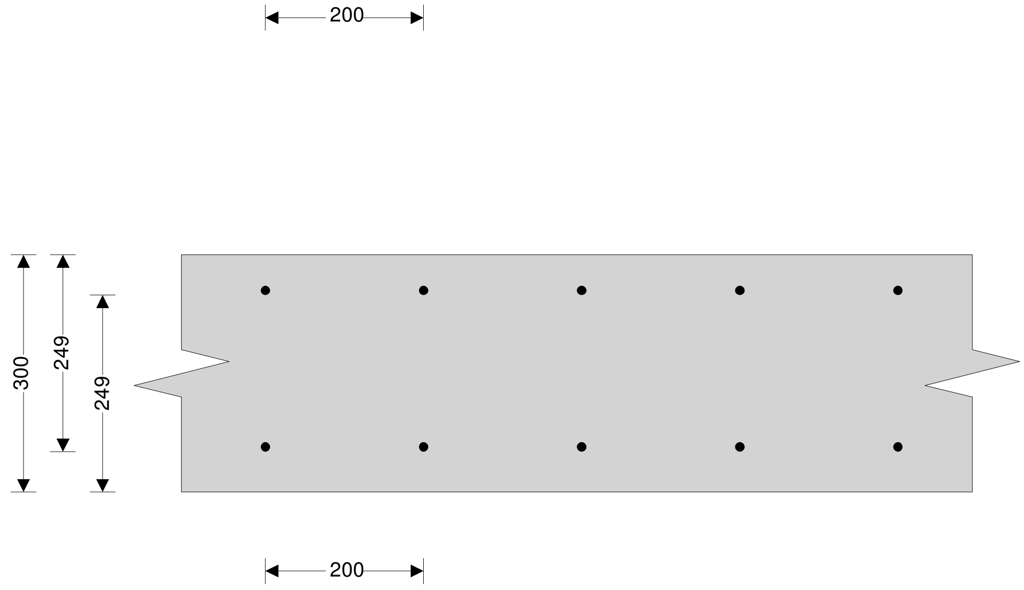
Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128 = \mathbf{5.3}$ kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] = \mathbf{5.5}$ kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] = \mathbf{7}$ kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_s} + M_{w\_water} = \mathbf{17.8}$ kNm/m



Check wall stem in bending

Width of wall stem — $b = \mathbf{1000}$ mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) = \mathbf{249.0}$ mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = \mathbf{0.015}$

Compression reinforcement is not required

Lever arm — $z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

$z_{stem} = \mathbf{237}$ mm

Area of tension reinforcement required — $As_{stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) = \mathbf{363}$ mm²/m

Minimum area of tension reinforcement — $As_{stem\_min} = k \times b \times t_{wall} = \mathbf{390}$ mm²/m

Area of tension reinforcement required — $As_{stem\_req} = \mathrm{Max}(As_{stem\_des}, As_{stem\_min}) = \mathbf{390}$ mm²/m

Reinforcement provided — **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided — $As_{stem\_prov} = \mathbf{565}$ mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.313}$ N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = \mathbf{5.000}$ N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — $v_{c\_stem} = \mathbf{0.508}$ N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check mid height of wall in bending

Depth of reinforcement — $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2) = \mathbf{249.0}$ mm

Constant — $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu}) = \mathbf{0.007}$

Compression reinforcement is not required

Lever arm — $z_{wall} = \mathrm{Min}(0.5 + \sqrt{(0.25 - (\min(K_{wall}, 0.225) / 0.9))}, 0.95) \times d_{wall}$

$z_{wall} = \mathbf{237}$ mm

Area of tension reinforcement required — $As_{wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall}) = \mathbf{173}$ mm²/m

Minimum area of tension reinforcement — $As_{wall\_min} = k \times b \times t_{wall} = \mathbf{390}$ mm²/m

Area of tension reinforcement required — $As_{wall\_req} = \mathrm{Max}(As_{wall\_des}, As_{wall\_min}) = \mathbf{390}$ mm²/m

Reinforcement provided **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $A_{s\_wall\_prov}$ = **565** mm^2/m

PASS - Reinforcement provided to the retaining wall at mid height is adequate

Check retaining wall deflection

Basic span/effective depth ratio $ratio_{bas}$ = **20**

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **229.9** N/mm^2

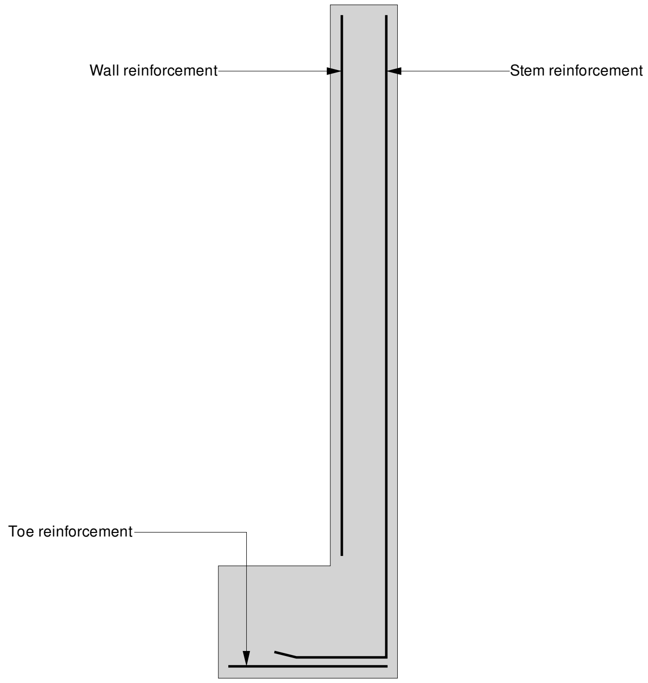
Modification factor $factor_{tens} = \min(0.55 + (477 N/mm^2 - f_s)/(120 \times (0.9 N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.92**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **38.42**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **10.04**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)
Wall bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)
Stem bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)

Horizontal load on side wall top beam

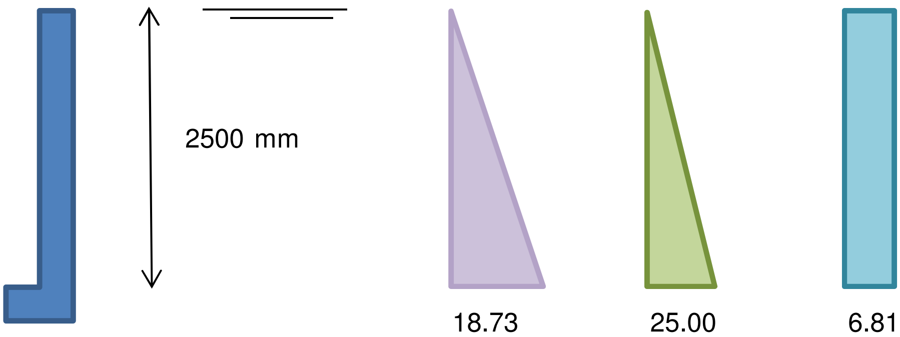
At rest. pressure coefficient

K0 0.681

Sat. backfill		Water density		Surcharge	
21	kN/m3	10	kN/m3	10	kN/m2

basement level

It is assumed max water table



18.73 kN/m2	25.00 kN/m2	6.81 kN/m2

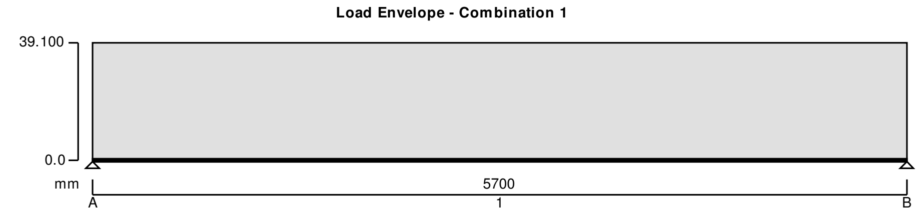
Reaction at top and base of reatining wall	TOP	7.8031 kN/m	10.417 kN/m	8.5125 kN/m
assuming 1m length	BASE	15.606 kN/m	20.833 kN/m	8.5125 kN/m

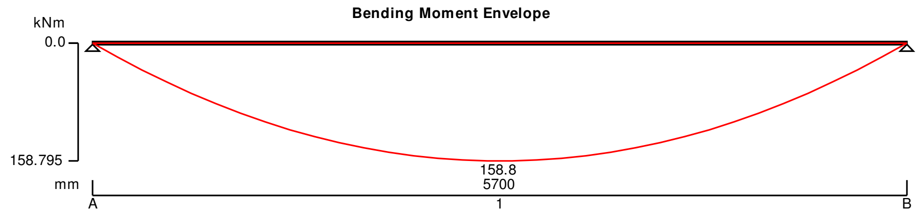
Ultimate reaction on underpinning	TOP	**39.1 kN/m**
(1,4xDEAD+1,6xIMPOSED)	BASE	**64.6 kN/m**

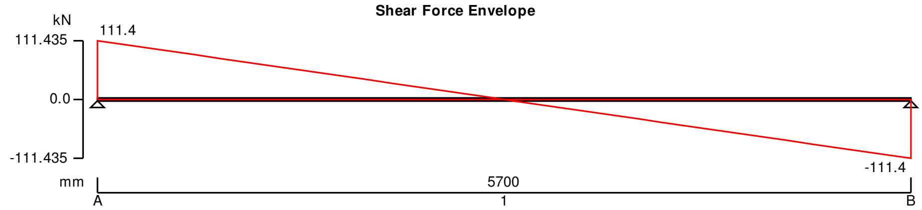
Tekla Tedds RODRIGUES ASSOCIATES 1 AMWELL STREET LONDON EC1R 1UL	Project 10 Downside Crescent				Job no. 1411	
	Calcs for side retaining wall top beam				Start page no./Revision 5.4B. 1	
	Calcs by ab	Calcs date 11/10/2016	Checked by	Checked date	Approved by	Approved date

RC BEAM ANALYSIS & DESIGN BS8110

TEDDS calculation version 2.1.12







Support conditions

Support A	Vertically restrained
	Rotationally free
Support B	Vertically restrained
	Rotationally free

Applied loading

Dead self weight of beam × 0

Dead full UDL 39.1 kN/m

Load combinations

Load combination 1	Support A	Dead × 1.00
		Imposed × 1.00
	Span 1	Dead × 1.00
		Imposed × 1.00
	Support B	Dead × 1.00
		Imposed × 1.00

Analysis results

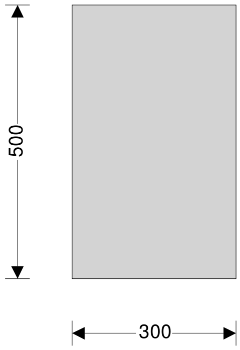
Maximum moment support A	M_{A_max} = **0** kNm	M_{A_red} = **0** kNm
Maximum moment span 1 at 2850 mm	M_{s1_max} = **159** kNm	M_{s1_red} = **159** kNm

Maximum moment support B	M_{B_max} = **0** kNm	M_{B_red} = **0** kNm
Maximum shear support A	V_{A_max} = **111** kN	V_{A_red} = **111** kN
Maximum shear support A span 1 at 447 mm	$V_{A\_s1\_max}$ = **94** kN	$V_{A\_s1\_red}$ = **94** kN
Maximum shear support B	V_{B_max} = **-111** kN	V_{B_red} = **-111** kN
Maximum shear support B span 1 at 5253 mm	$V_{B\_s1\_max}$ = **-94** kN	$V_{B\_s1\_red}$ = **-94** kN
Maximum reaction at support A	R_A = **111** kN	
Unfactored dead load reaction at support A	R_{A_Dead} = **111** kN	
Maximum reaction at support B	R_B = **111** kN	
Unfactored dead load reaction at support B	R_{B_Dead} = **111** kN	

Rectangular section details

Section width b = **300** mm

Section depth h = **500** mm



Concrete details

Concrete strength class **C32/40**

Characteristic compressive cube strength f_{cu} = **40** N/mm^2

Modulus of elasticity of concrete E_c = 20kN/mm^2 + 200 × f_{cu} = **28000** N/mm^2

Maximum aggregate size h_{agg} = **20** mm

Reinforcement details

Characteristic yield strength of reinforcement f_y = **500** N/mm^2

Characteristic yield strength of shear reinforcement f_{yv} = **500** N/mm^2

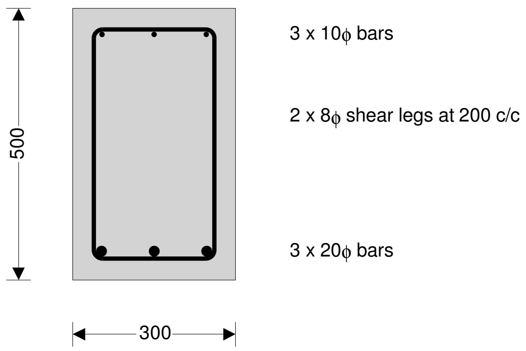
Nominal cover to reinforcement

Nominal cover to top reinforcement c_{nom_t} = **35** mm

Nominal cover to bottom reinforcement c_{nom_b} = **35** mm

Nominal cover to side reinforcement c_{nom_s} = **35** mm

<u>Support A</u>



Rectangular section in shear

Design shear force span 1 at 447 mm — $V = max(V_{A\_s1\_max}, V_{A\_s1\_red})$ = **94** kN

Design shear stress — $v = V / (b \times d)$ = **0.700** N/mm^2

Design concrete shear stress — $v_c = 0.79 \times min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times max(1, (400 /d)^{1/4}) \times (min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$

v_c = **0.657** N/mm^2

Allowable design shear stress — $v_{max} = min(0.8 N/mm^2 \times (f_{cu}/1 N/mm^2)^{0.5}, 5 N/mm^2)$ = **5.000** N/mm^2

PASS - Design shear stress is less than maximum allowable

Value of v from Table 3.7 — $0.5 \times v_c < v < (v_c + 0.4 N/mm^2)$

Design shear resistance required — $v_s = max(v - v_c, 0.4 N/mm^2)$ = **0.400** N/mm^2

Area of shear reinforcement required — $A_{sv,req} = v_s \times b / (0.87 \times f_{yv})$ = **276** mm^2/m

Shear reinforcement provided — $2 \times 8\phi$ legs at 200 c/c

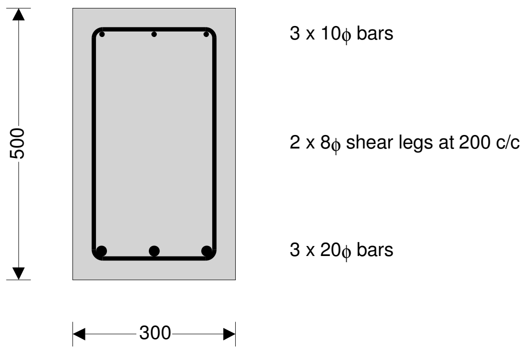
Area of shear reinforcement provided — $A_{sv,prov}$ = **503** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing — $s_{vl,max} = 0.75 \times d$ = **335** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Mid span 1



Design moment resistance of rectangular section (cl. 3.4.4) - Positive moment

Design bending moment — $M = abs(M_{s1\_red})$ = **159** kNm

Depth to tension reinforcement — $d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2$ = **447** mm

Redistribution ratio — $\beta_b = min(1 - m_{rs1}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{cu})$ = **0.066**

$K' = 0.156$

K' > K - No compression reinforcement is required

Lever arm — $z = min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d)$ = **411** mm

Depth of neutral axis — $x = (d - z) / 0.45$ = **79** mm

Area of tension reinforcement required — $A_{s,req} = M / (0.87 \times f_y \times z)$ = **888** mm^2

Tension reinforcement provided — $3 \times 20\phi$ bars

Area of tension reinforcement provided — $A_{s,prov}$ = **942** mm^2

Minimum area of reinforcement — $A_{s,min} = 0.0013 \times b \times h$ = **195** mm^2

Maximum area of reinforcement — $A_{s,max} = 0.04 \times b \times h$ = **6000** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Rectangular section in shear

Shear reinforcement provided — $2 \times 8\phi$ legs at 200 c/c

Area of shear reinforcement provided — $A_{sv,prov}$ = **503** mm^2/m

Minimum area of shear reinforcement (Table 3.7) $A_{sv,min} = 0.4N/mm^2 \times b / (0.87 \times f_{yv})$ = **276** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (cl. 3.4.5.5) $s_{vl,max} = 0.75 \times d$ = **335** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Design concrete shear stress $v_c = 0.79N/mm^2 \times \min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400mm / d)^{1/4}) \times (\min(f_{cu}, 40N/mm^2) / 25N/mm^2)^{1/3} / \gamma_m$ = **0.657** N/mm²

Design shear resistance provided $v_{s,prov} = A_{sv,prov} \times 0.87 \times f_{yv} / b$ = **0.729** N/mm²

Design shear stress provided $v_{prov} = v_{s,prov} + v_c$ = **1.386** N/mm²

Design shear resistance $V_{prov} = v_{prov} \times (b \times d)$ = **185.9** kN

Shear links provided valid between 0 mm and 5700 mm with tension reinforcement of 942 mm²

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{bot}/2)) /(N_{bot} - 1) - \phi_{bot}$ = **77** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension $s_{min} = h_{agg} + 5$ mm = **25** mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b)$ = **313.9** N/mm²

Maximum distance between bars in tension $s_{max} = \min(47000 N/mm / f_s, 300 mm)$ = **150** mm

PASS - Satisfies the maximum spacing criteria

Span to depth ratio (cl. 3.4.6)

Basic span to depth ratio (Table 3.9) $span\_to\_depth_{basic}$ = **20.0**

Design service stress in tension reinforcement $f_s = (2 \times f_y \times A_{s,req})/ (3 \times A_{s,prov} \times \beta_b)$ = **313.9** N/mm²

Modification for tension reinforcement

$f_{tens} = \min(2.0, 0.55 + (477N/mm^2 - f_s) / (120 \times (0.9N/mm^2 + (M / (b \times d^2)))))$ = **0.933**

Modification for compression reinforcement

$f_{comp} = \min(1.5, 1 + (100 \times A_{s2,prov} / (b \times d)) / (3 + (100 \times A_{s2,prov} / (b \times d))))$ = **1.055**

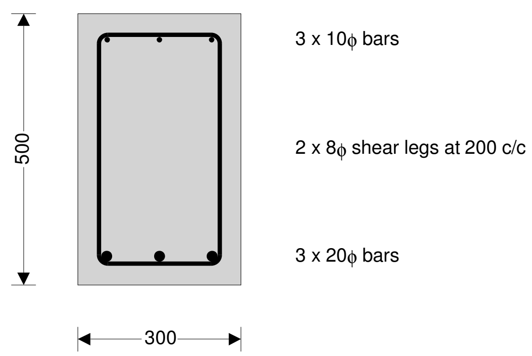
Modification for span length f_{long} = 1.000

Allowable span to depth ratio $span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp}$ = **19.7**

Actual span to depth ratio $span\_to\_depth_{actual} = L_{s1} / d$ = **12.8**

PASS - Actual span to depth ratio is within the allowable limit

Support B



Rectangular section in shear

Design shear force span 1 at 5253 mm $V = abs(\min(V_{B\_s1\_max}, V_{B\_s1\_red}))$ = **94** kN

Design shear stress $v = V / (b \times d)$ = **0.700** N/mm²

Design concrete shear stress $v_c = 0.79 \times \min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400 /d)^{1/4}) \times (\min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$

v_c = **0.657** N/mm²

Allowable design shear stress $v_{max} = \min(0.8\ N/mm^2 \times (f_{cu}/1\ N/mm^2)^{0.5}, 5\ N/mm^2)$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum allowable

Value of v from Table 3.7 $0.5 \times v_c < v < (v_c + 0.4\ N/mm^2)$

Design shear resistance required $v_s = \max(v - v_c, 0.4\ N/mm^2)$ = **0.400** N/mm²

Area of shear reinforcement required $A_{sv,req} = v_s \times b / (0.87 \times f_{yv})$ = **276** mm²/m

Shear reinforcement provided $2 \times 8\phi$ legs at 200 c/c

Area of shear reinforcement provided $A_{sv,prov}$ = **503** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing $s_{vl,max} = 0.75 \times d$ = **335** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

RC SLAB DESIGN (BS8110:PART1:1997)

TEDDS calculation version 1.0.04

TWO WAY SPANNING SLAB DEFINITION – SIMPLY SUPPORTED

Overall depth of slab $h = \mathbf{175}$ mm

Outer sagging steel

Cover to outer tension reinforcement resisting sagging $c_{sag} = \mathbf{25}$ mm

Trial bar diameter $D_{tryx} = \mathbf{12}$ mm

Depth to outer tension steel (resisting sagging)

$d_x = h - c_{sag} - D_{tryx}/2 = \mathbf{144}$ mm

Inner sagging steel

Trial bar diameter $D_{tryy} = \mathbf{12}$ mm

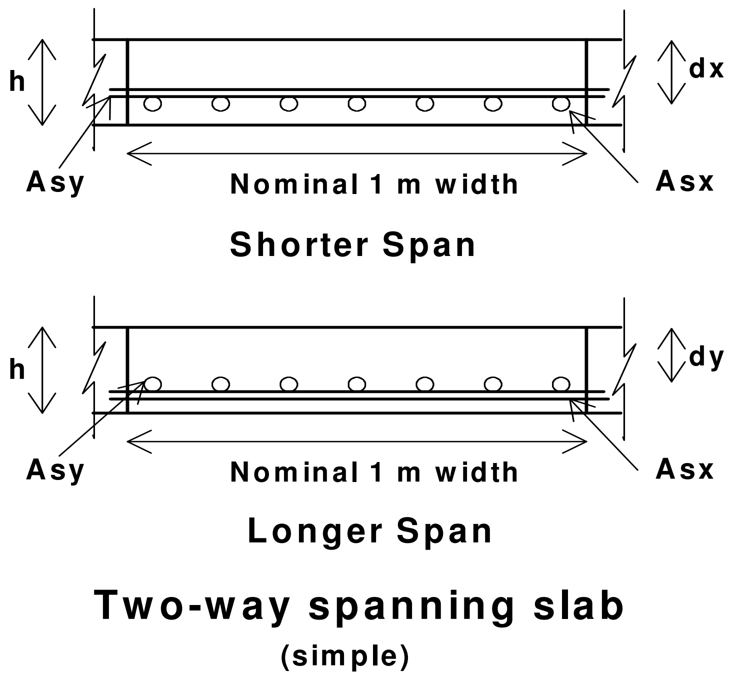
Depth to inner tension steel (resisting sagging)

$d_y = h - c_{sag} - D_{tryx} - D_{tryy}/2 = \mathbf{132}$ mm

Materials

Characteristic strength of reinforcement $f_y = \mathbf{500}$ N/mm^2

Characteristic strength of concrete $f_{cu} = \mathbf{40}$ N/mm^2



MAXIMUM DESIGN MOMENTS

Length of shorter side of slab $l_x = \mathbf{3.500}$ m

Length of longer side of slab $l_y = \mathbf{6.400}$ m

Design ultimate load per unit area $n_s = \mathbf{12.9}$ kN/m^2

Moment coefficients

$\alpha_{sx} = (l_y / l_x)^4 / (8 \times (1+(l_y / l_x)^4))$ = **0.115**

$\alpha_{sy} = (l_y / l_x)^2 / (8 \times (1+(l_y / l_x)^4))$ = **0.034**

Maximum moments per unit width - simply supported slabs

$m_{sx} = \alpha_{sx} \times n_s \times l_x^2$ = **18.1** kNm/m

$m_{sy} = \alpha_{sy} \times n_s \times l_x^2$ = **5.4** kNm/m

CONCRETE SLAB DESIGN – SAGGING – OUTER LAYER OF STEEL (CL 3.5.4)

Design sagging moment (per m width of slab) m_{sx} = **18.1** kNm/m

Moment Redistribution Factor β_{bx} = **1.0**

Area of reinforcement required

$K_x = abs(m_{sx}) / (d_x^2 \times f_{cu})$ = **0.022**

$K'_x = min (0.156 , (0.402 \times (\beta_{bx} - 0.4)) - (0.18 \times (\beta_{bx} - 0.4)^2))$ = **0.156**

Outer compression steel not required to resist sagging

Slab requiring outer tension steel only - bars (sagging)

$z_x = min ((0.95 \times d_x),(d_x\times(0.5+\sqrt{(0.25-K_x/0.9)})))$ = **137** mm

Neutral axis depth $x_x = (d_x - z_x) / 0.45$ = **16** mm

Area of tension steel required

$A_{sx\_req} = abs(m_{sx}) / (1/\gamma_{ms} \times f_y \times z_x)$ = **305** mm²/m

Tension steel

Provide 12 dia bars @ 200 centres outer tension steel resisting sagging

$A_{sx\_prov} = A_{sx}$ = **565** mm²/m

Area of outer tension steel provided sufficient to resist sagging

Concrete Slab Design - Sagging - Inner layer of steel (cl. 3.5.4)

Design sagging moment (per m width of slab) m_{sy} = **5.4** kNm/m

Moment Redistribution Factor β_{by} = **1.0**

Area of reinforcement required

$K_y = abs(m_{sy}) / (d_y^2 \times f_{cu})$ = **0.008**

$K'_y = min (0.156 , (0.402 \times (\beta_{by} - 0.4)) - (0.18 \times (\beta_{by} - 0.4)^2))$ = **0.156**

Inner compression steel not required to resist sagging

Slab requiring inner tension steel only - bars (sagging)

$z_y = min ((0.95 \times d_y),(d_y\times(0.5+\sqrt{(0.25-K_y/0.9)})))$ = **125** mm

Neutral axis depth $x_y = (d_y - z_y) / 0.45$ = **15** mm

Area of tension steel required

A_{sy_req} = abs(m_{sy}) / (1/γ_{ms} × f_y × z_y) = **99** mm^2/m

Tension steel

Provide 12 dia bars @ 200 centres inner tension steel resisting sagging

A_{sy_prov} = A_{sy} = **565** mm^2/m

Area of inner tension steel provided sufficient to resist sagging

Check min and max areas of steel resisting sagging

Total area of concrete A_c = h = **175000** mm^2/m

Minimum % reinforcement k = **0.13** %

A_{st_min} = k × A_c = **228** mm^2/m

A_{st_max} = 4 % × A_c = **7000** mm^2/m

Steel defined:

Outer steel resisting sagging A_{sx_prov} = **565** mm^2/m

Area of outer steel provided (sagging) OK

Inner steel resisting sagging A_{sy_prov} = **565** mm^2/m

Area of inner steel provided (sagging) OK

SHEAR RESISTANCE OF CONCRETE SLABS (CL 3.5.5)

Outer tension steel resisting sagging moments

Depth to tension steel from compression face d_x = **144** mm

Area of tension reinforcement provided (per m width of slab) A_{sx_prov} = **565** mm^2/m

Design ultimate shear force (per m width of slab) V_x = **41** kN/m

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Applied shear stress

v_x = V_x / d_x = **0.29** N/mm^2

Check shear stress to clause 3.5.5.2

$v_{allowable}$ = min ((0.8 N$^{1/2}$/mm) × √(f_{cu}), 5 N/mm^2) = **5.00** N/mm^2

Shear stress - OK

Shear stresses to clause 3.5.5.3

Design shear stress

f_{cu_ratio} = if (f_{cu} > 40 N/mm^2 , 40/25 , f_{cu}/(25 N/mm^2)) = **1.600**

v_{cx} = 0.79 N/mm^2 × min(3,100 × A_{sx_prov} / d_x)$^{1/3}$ × max(0.67,(400 mm / d_x)$^{1/4}$) / 1.25 × $f_{cu\_ratio}{}^{1/3}$

v_{cx} = **0.70** N/mm^2

Applied shear stress

v_x = **0.29** N/mm^2

No shear reinforcement required

SHEAR RESISTANCE OF CONCRETE SLABS (CL 3.5.5)

Inner tension steel resisting sagging moments

Depth to tension steel from compression face d_y = **132** mm

Area of tension reinforcement provided (per m width of slab) A_{sy_prov} = **565** mm²/m

Design ultimate shear force (per m width of slab) V_y = **26** kN/m

Characteristic strength of concrete f_{cu} = **40** N/mm²

Applied shear stress

$v_y = V_y / d_y$ = **0.20** N/mm²

Check shear stress to clause 3.5.5.2

$v_{allowable} = \min((0.8\ N^{1/2}/mm) \times \sqrt{(f_{cu})}, 5\ N/mm^2)$ = **5.00** N/mm²

Shear stress - OK

Shear stresses to clause 3.5.5.3

Design shear stress

f_{cu_ratio} = if (f_{cu} > 40 N/mm², 40/25, f_{cu}/(25 N/mm²)) = **1.600**

$v_{cy} = 0.79\ N/mm^2 \times \min(3,100 \times A_{sy\_prov} / d_y)^{1/3} \times \max(0.67,(400\ mm) / d_y)^{1/4} / 1.25 \times f_{cu\_ratio}^{1/3}$

v_{cy} = **0.73** N/mm²

Applied shear stress

v_y = **0.20** N/mm²

No shear reinforcement required

CONCRETE SLAB DEFLECTION CHECK (CL 3.5.7)

Slab span length l_x = **3.500** m

Design ultimate moment in shorter span per m width m_{sx} = **18** kNm/m

Depth to outer tension steel d_x = **144** mm

Tension steel

Area of outer tension reinforcement provided A_{sx_prov} = **565** mm²/m

Area of tension reinforcement required A_{sx_req} = **305** mm²/m

Moment Redistribution Factor β_{bx} = **1.00**

Modification Factors

Basic span / effective depth ratio (Table 3.9) $ratio_{span\_depth}$ = **20**

The modification factor for spans in excess of 10m (ref. cl 3.4.6.4) has not been included.

$f_s = 2 \times f_y \times A_{sx\_req} / (3 \times A_{sx\_prov} \times \beta_{bx})$ = **179.8** N/mm²

$factor_{tens} = \min(2, 0.55 + (477\ N/mm^2 - f_s) / (120 \times (0.9\ N/mm^2 + m_{sx} / d_x^2)))$ = **1.946**

Calculate Maximum Span

This is a simplified approach and further attention should be given where special circumstances exist. Refer to clauses 3.4.6.4 and 3.4.6.7.

Maximum span l_{max} = $ratio_{span\_depth} \times factor_{tens} \times d_x$ = **5.60** m

Check the actual beam span

Actual span/depth ratio l_x / d_x = **24.31**

Span depth limit $ratio_{span\_depth} \times factor_{tens}$ = **38.91**

Span/Depth ratio check satisfied

CHECK OF NOMINAL COVER (SAGGING) – (BS8110:PT 1, TABLE 3.4)

Slab thickness h = **175** mm

Effective depth to bottom outer tension reinforcement d_x = **144.0** mm

Diameter of tension reinforcement D_x = **12** mm

Diameter of links L_{diax} = **0** mm

Cover to outer tension reinforcement

$c_{tenx} = h - d_x - D_x / 2$ = **25.0** mm

Nominal cover to links steel

$c_{nomx} = c_{tenx} - L_{diax}$ = **25.0** mm

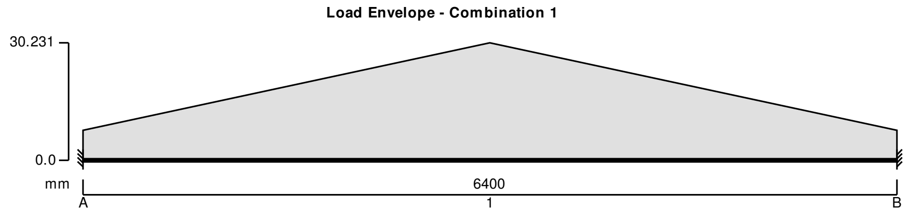
Permissable minimum nominal cover to all reinforcement (Table 3.4)

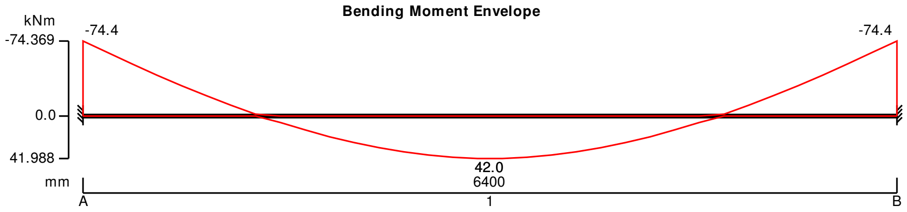
c_{min} = **25** mm

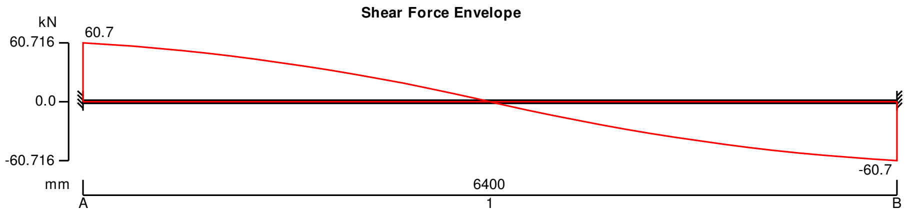
Cover over steel resisting sagging OK

RC BEAM ANALYSIS & DESIGN BS8110

TEDDS calculation version 2.1.12







Support conditions

Support A	Vertically restrained
	Rotationally restrained
Support B	Vertically restrained
	Rotationally restrained

Applied loading

Dead self weight of beam × 1
Dead trapezoidal load 11.11 kN/m from 3200 mm to 3200 mm
Imposed trapezoidal load 4.35 kN/m from 3200 mm to 3200 mm
Dead full UDL 1.08 kN/m
Imposed full UDL 1.25 kN/m

Load combinations

Load combination 1	Support A	Dead × 1.40
		Imposed × 1.60
	Span 1	Dead × 1.40
		Imposed × 1.60
	Support B	Dead × 1.40
		Imposed × 1.60

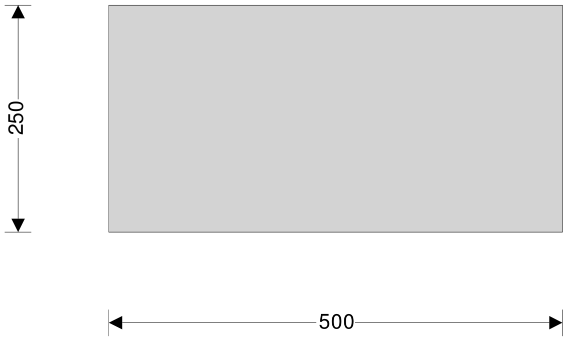
Analysis results

Maximum moment support A	M_{A_max} = **-74** kNm	M_{A_red} = **-74** kNm
Maximum moment span 1 at 3200 mm	M_{s1_max} = **42** kNm	M_{s1_red} = **42** kNm
Maximum moment support B	M_{B_max} = **-74** kNm	M_{B_red} = **-74** kNm
Maximum shear support A	V_{A_max} = **61** kN	V_{A_red} = **61** kN
Maximum shear support A span 1 at 199 mm	$V_{A\_s1\_max}$ = **59** kN	$V_{A\_s1\_red}$ = **59** kN
Maximum shear support B	V_{B_max} = **-61** kN	V_{B_red} = **-61** kN
Maximum shear support B span 1 at 6201 mm	$V_{B\_s1\_max}$ = **-59** kN	$V_{B\_s1\_red}$ = **-59** kN
Maximum reaction at support A	R_A = **61** kN	
Unfactored dead load reaction at support A	R_{A_Dead} = **31** kN	
Unfactored imposed load reaction at support A	$R_{A\_Imposed}$ = **11** kN	
Maximum reaction at support B	R_B = **61** kN	
Unfactored dead load reaction at support B	R_{B_Dead} = **31** kN	
Unfactored imposed load reaction at support B	$R_{B\_Imposed}$ = **11** kN	

Rectangular section details

Section width b = **500** mm

Section depth h = **250** mm



Concrete details

Concrete strength class **C32/40**

Characteristic compressive cube strength f_{cu} = **40** N/mm^2

Modulus of elasticity of concrete E_c = 20kN/mm^2 + 200 × f_{cu} = **28000** N/mm^2

Maximum aggregate size h_{agg} = **20** mm

Reinforcement details

Characteristic yield strength of reinforcement f_y = **500** N/mm^2

Characteristic yield strength of shear reinforcement f_{yv} = **500** N/mm^2

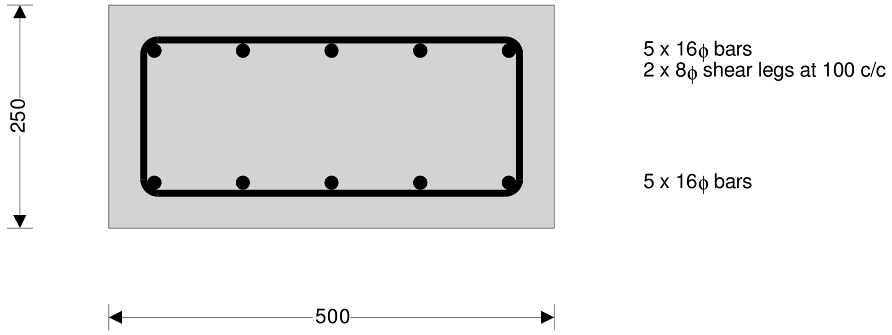
Nominal cover to reinforcement

Nominal cover to top reinforcement c_{nom_t} = **35** mm

Nominal cover to bottom reinforcement c_{nom_b} = **35** mm

Nominal cover to side reinforcement c_{nom_s} = **35** mm

Support A



Rectangular section in flexure (cl.3.4.4)

Design bending moment $M = abs(M_{A\_red}) = \mathbf{74}$ kNm

Depth to tension reinforcement $d = h - c_{nom\_t} - \phi_v - \phi_{top} / 2 = \mathbf{199}$ mm

Redistribution ratio $\beta_b = min(1 - m_{rA}, 1) = \mathbf{1.000}$

$K = M / (b \times d^2 \times f_{cu}) = \mathbf{0.094}$

$K' = 0.156$

K' > K - No compression reinforcement is required

Lever arm $z = min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d) = \mathbf{175}$ mm

Depth of neutral axis $x = (d - z) / 0.45 = \mathbf{52}$ mm

Area of tension reinforcement required $A_{s,req} = M / (0.87 \times f_y \times z) = \mathbf{974}$ mm²

Tension reinforcement provided $5 \times 16\phi$ bars

Area of tension reinforcement provided $A_{s,prov} = \mathbf{1005}$ mm²

Minimum area of reinforcement $A_{s,min} = 0.0013 \times b \times h = \mathbf{163}$ mm²

Maximum area of reinforcement $A_{s,max} = 0.04 \times b \times h = \mathbf{5000}$ mm²

PASS - Area of reinforcement provided is greater than area of reinforcement required

Rectangular section in shear

Design shear force span 1 at 199 mm $V = max(V_{A\_s1\_max}, V_{A\_s1\_red}) = \mathbf{59}$ kN

Design shear stress $v = V / (b \times d) = \mathbf{0.593}$ N/mm²

Design concrete shear stress $v_c = 0.79 \times min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times max(1, (400 /d)^{1/4}) \times$

$(min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$

$v_c = \mathbf{0.883}$ N/mm²

Allowable design shear stress $v_{max} = min(0.8 \text{ N/mm}^2 \times (f_{cu}/1 \text{ N/mm}^2)^{0.5}, 5 \text{ N/mm}^2) = \mathbf{5.000}$ N/mm²

PASS - Design shear stress is less than maximum allowable

Value of v from Table 3.7 $0.5 \times v_c < v < (v_c + 0.4 \text{ N/mm}^2)$

Design shear resistance required $v_s = max(v - v_c, 0.4 \text{ N/mm}^2) = \mathbf{0.400}$ N/mm²

Area of shear reinforcement required $A_{sv,req} = v_s \times b / (0.87 \times f_{yv}) = \mathbf{460}$ mm²/m

Shear reinforcement provided $2 \times 8\phi$ legs at 100 c/c

Area of shear reinforcement provided $A_{sv,prov} = \mathbf{1005}$ mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing $s_{vl,max} = 0.75 \times d = \mathbf{149}$ mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{top}/2)) /(N_{top} - 1) - \phi_{top} = \mathbf{84}$ mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension $s_{min} = h_{agg} + 5\text{ mm} = \mathbf{25}\text{ mm}$

PASS - Satisfies the minimum spacing criteria

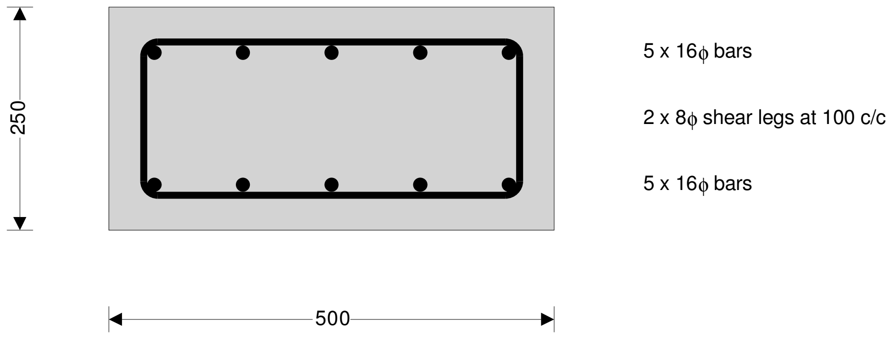
Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) = \mathbf{323.1}\text{ N/mm}^2$

Maximum distance between bars in tension $s_{max} = \min(47000\text{ N/mm} / f_s, 300\text{ mm}) = \mathbf{145}\text{ mm}$

PASS - Satisfies the maximum spacing criteria

Mid span 1



Design moment resistance of rectangular section (cl. 3.4.4) - Positive moment

Design bending moment $M = \text{abs}(M_{s1\_red}) = \mathbf{42}\text{ kNm}$

Depth to tension reinforcement $d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2 = \mathbf{199}\text{ mm}$

Redistribution ratio $\beta_b = \min(1 - m_{rs1}, 1) = \mathbf{1.000}$

$K = M / (b \times d^2 \times f_{cu}) = \mathbf{0.053}$

$K' = 0.156$

K' > K - No compression reinforcement is required

Lever arm $z = \min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d) = \mathbf{186}\text{ mm}$

Depth of neutral axis $x = (d - z) / 0.45 = \mathbf{28}\text{ mm}$

Area of tension reinforcement required $A_{s,req} = M / (0.87 \times f_y \times z) = \mathbf{518}\text{ mm}^2$

Tension reinforcement provided $5 \times 16\phi$ bars

Area of tension reinforcement provided $A_{s,prov} = \mathbf{1005}\text{ mm}^2$

Minimum area of reinforcement $A_{s,min} = 0.0013 \times b \times h = \mathbf{163}\text{ mm}^2$

Maximum area of reinforcement $A_{s,max} = 0.04 \times b \times h = \mathbf{5000}\text{ mm}^2$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Rectangular section in shear

Shear reinforcement provided $2 \times 8\phi$ legs at 100 c/c

Area of shear reinforcement provided $A_{sv,prov} = \mathbf{1005}\text{ mm}^2/\text{m}$

Minimum area of shear reinforcement (Table 3.7) $A_{sv,min} = 0.4\text{N/mm}^2 \times b / (0.87 \times f_{yv}) = \mathbf{460}\text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (cl. 3.4.5.5) $s_{vl,max} = 0.75 \times d = \mathbf{149}\text{ mm}$

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Design concrete shear stress $v_c = 0.79\text{N/mm}^2 \times \min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400\text{mm} /d)^{1/4}) \times (\min(f_{cu}, 40\text{N/mm}^2) / 25\text{N/mm}^2)^{1/3} / \gamma_m = \mathbf{0.883}\text{ N/mm}^2$

Design shear resistance provided $v_{s,prov} = A_{sv,prov} \times 0.87 \times f_{yv} / b = \mathbf{0.875}\text{ N/mm}^2$

Design shear stress provided $v_{prov} = v_{s,prov} + v_c = \mathbf{1.758}\text{ N/mm}^2$

Design shear resistance $V_{prov} = v_{prov} \times (b \times d) = \mathbf{174.9}\text{ kN}$

Shear links provided valid between 0 mm and 6400 mm with tension reinforcement of 1005 mm²

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension — $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{bot}/2)) / (N_{bot} - 1) - \phi_{bot}$ = **84** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension — $s_{min} = h_{agg} + 5$ mm = **25** mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress — $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b)$ = **171.6** N/mm²

Maximum distance between bars in tension — $s_{max} = \min(47000 \text{ N/mm} / f_s, 300 \text{ mm})$ = **274** mm

PASS - Satisfies the maximum spacing criteria

Span to depth ratio (cl. 3.4.6)

Basic span to depth ratio (Table 3.9) — $span\_to\_depth_{basic}$ = **20.0**

Design service stress in tension reinforcement — $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b)$ = **171.6** N/mm²

Modification for tension reinforcement

$f_{tens} = \min(2.0, 0.55 + (477\text{N/mm}^2 - f_s) / (120 \times (0.9\text{N/mm}^2 + (M / (b \times d^2)))))$ = **1.393**

Modification for compression reinforcement

$f_{comp} = \min(1.5, 1 + (100 \times A_{s2,prov} / (b \times d)) / (3 + (100 \times A_{s2,prov} / (b \times d))))$ = **1.252**

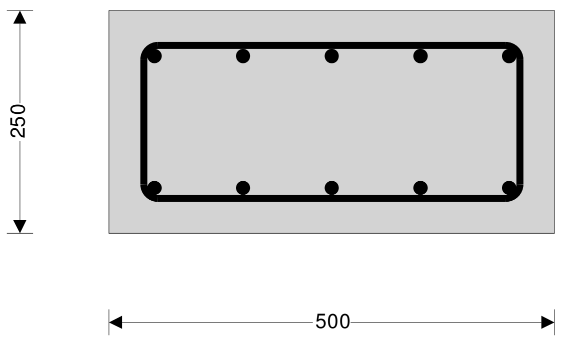
Modification for span length — f_{long} = 1.000

Allowable span to depth ratio — $span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp}$ = **34.9**

Actual span to depth ratio — $span\_to\_depth_{actual} = L_{s1} / d$ = **32.2**

PASS - Actual span to depth ratio is within the allowable limit

Support B



Rectangular section in flexure (cl.3.4.4)

Design bending moment — $M = \text{abs}(M_{B\_red})$ = **74** kNm

Depth to tension reinforcement — $d = h - c_{nom\_t} - \phi_v - \phi_{top} / 2$ = **199** mm

Redistribution ratio — $\beta_b = \min(1 - m_{rB}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{cu})$ = **0.094**

K' = 0.156

K' > K - No compression reinforcement is required

Lever arm — $z = \min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d)$ = **175** mm

Depth of neutral axis — $x = (d - z) / 0.45$ = **52** mm

Area of tension reinforcement required — $A_{s,req} = M / (0.87 \times f_y \times z)$ = **974** mm²

Tension reinforcement provided — 5 × 16ϕ bars

Area of tension reinforcement provided — $A_{s,prov}$ = **1005** mm²

Minimum area of reinforcement — $A_{s,min} = 0.0013 \times b \times h$ = **163** mm²

Maximum area of reinforcement $A_{s,max} = 0.04 \times b \times h =$ **5000** mm²

PASS - Area of reinforcement provided is greater than area of reinforcement required

Rectangular section in shear

Design shear force span 1 at 6201 mm $V = abs(min(V_{B\_s1\_max}, V_{B\_s1\_red})) =$ **59** kN

Design shear stress $v = V / (b \times d) =$ **0.593** N/mm²

Design concrete shear stress $v_c = 0.79 \times min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times max(1, (400 /d)^{1/4}) \times (min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$

$v_c =$ **0.883** N/mm²

Allowable design shear stress $v_{max} = min(0.8 N/mm^2 \times (f_{cu}/1 N/mm^2)^{0.5}, 5 N/mm^2) =$ **5.000** N/mm²

PASS - Design shear stress is less than maximum allowable

Value of v from Table 3.7 $0.5 \times v_c < v < (v_c + 0.4 N/mm^2)$

Design shear resistance required $v_s = max(v - v_c, 0.4 N/mm^2) =$ **0.400** N/mm²

Area of shear reinforcement required $A_{sv,req} = v_s \times b / (0.87 \times f_{yv}) =$ **460** mm²/m

Shear reinforcement provided 2 × 8ϕ legs at 100 c/c

Area of shear reinforcement provided $A_{sv,prov} =$ **1005** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing $s_{vl,max} = 0.75 \times d =$ **149** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{top}/2)) /(N_{top} - 1) - \phi_{top} =$ **84** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension $s_{min} = h_{agg} + 5 mm =$ **25** mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) =$ **323.1** N/mm²

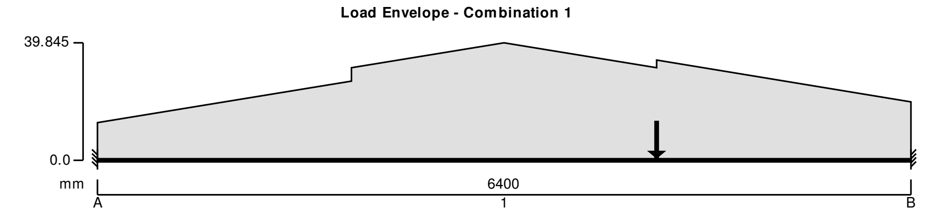
Maximum distance between bars in tension $s_{max} = min(47000 N/mm / f_s, 300 mm) =$ **145** mm

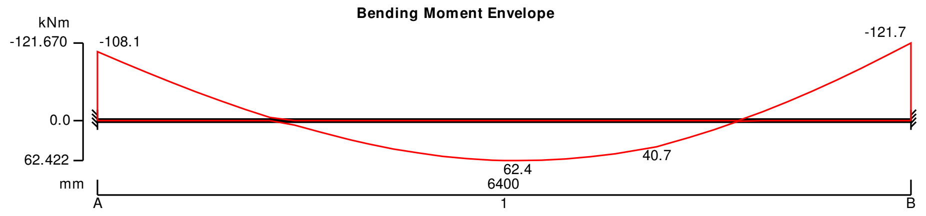
PASS - Satisfies the maximum spacing criteria

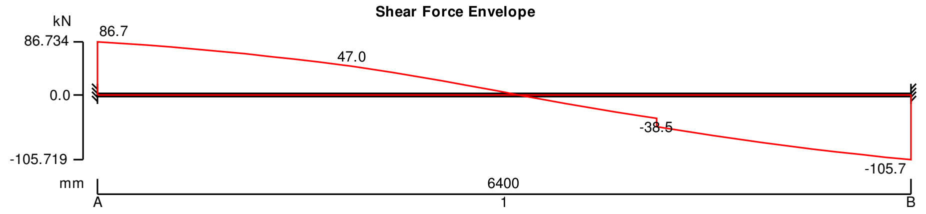
Tekla Tedds RODRIGUES ASSOCIATES 1 AMWELL STREET LONDON EC1R 1UL	Project 10 Downside Crescent			Job no. 1411	
	Calcs for beam B0.2			Start page no./Revision 5.7. 1	
	Calcs by ab	Calcs date 12/10/2016	Checked by	Checked date	Approved by	Approved date

RC BEAM ANALYSIS & DESIGN BS8110

TEDDS calculation version 2.1.12







Support conditions

Support A — Vertically restrained

Rotationally restrained

Support B — Vertically restrained

Rotationally restrained

Applied loading

Dead self weight of beam × 1

Dead trapezoidal load 11.11 kN/m from 3200 mm to 3200 mm

Imposed trapezoidal load 4.35 kN/m from 3200 mm to 3200 mm

Dead partial UDL 2.54 kN/m from 2000 mm to 4400 mm

Imposed partial UDL 0.6 kN/m from 2000 mm to 4400 mm

Dead partial UDL 3.04 kN/m from 0 mm to 4400 mm

Imposed partial UDL 1.25 kN/m from 0 mm to 4400 mm

Dead partial UDL 9.5 kN/m from 4400 mm to 6400 mm

Dead point load 2.76 kN at 4400 mm

Imposed point load 6 kN at 4400 mm

Load combinations

Load combination 1 — Support A — Dead × 1.40

Imposed × 1.60

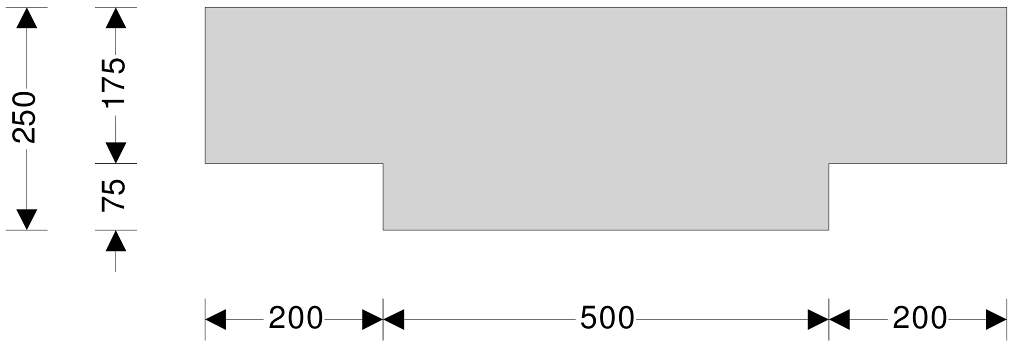
	Span 1	Dead × 1.40
		Imposed × 1.60
	Support B	Dead × 1.40
		Imposed × 1.60

Analysis results

Maximum moment support A	M_{A_max} = **-108** kNm	M_{A_red} = **-108** kNm
Maximum moment span 1 at 3309 mm	M_{s1_max} = **62** kNm	M_{s1_red} = **62** kNm
Maximum moment support B	M_{B_max} = **-122** kNm	M_{B_red} = **-122** kNm
Maximum shear support A	V_{A_max} = **87** kN	V_{A_red} = **87** kN
Maximum shear support A span 1 at 197 mm	$V_{A\_s1\_max}$ = **84** kN	$V_{A\_s1\_red}$ = **84** kN
Maximum shear support B	V_{B_max} = **-106** kN	V_{B_red} = **-106** kN
Maximum shear support B span 1 at 6203 mm	$V_{B\_s1\_max}$ = **-102** kN	$V_{B\_s1\_red}$ = **-102** kN
Maximum reaction at support A	R_A = **87** kN	
Unfactored dead load reaction at support A	R_{A_Dead} = **47** kN	
Unfactored imposed load reaction at support A	$R_{A\_Imposed}$ = **13** kN	
Maximum reaction at support B	R_B = **106** kN	
Unfactored dead load reaction at support B	R_{B_Dead} = **60** kN	
Unfactored imposed load reaction at support B	$R_{B\_Imposed}$ = **14** kN	

Flanged section details

Section width	b = **500** mm
Section depth	h = **250** mm
Maximum flange width	b_f = **900** mm
Flange depth	h_f = **175** mm



Concrete details

Concrete strength class	**C32/40**
Characteristic compressive cube strength	f_{cu} = **40** N/mm^2
Modulus of elasticity of concrete	E_c = 20kN/mm^2 + 200 × f_{cu} = **28000** N/mm^2
Maximum aggregate size	h_{agg} = **20** mm

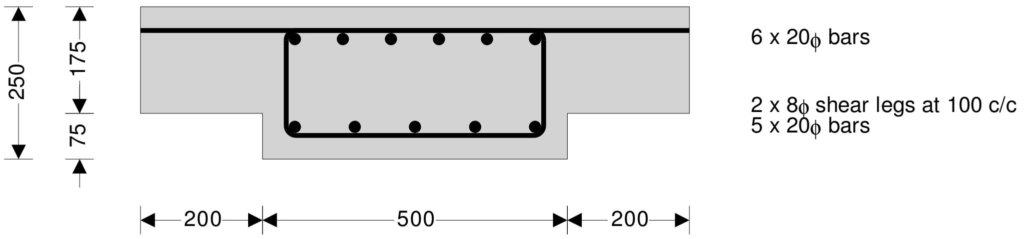
Reinforcement details

Characteristic yield strength of reinforcement	f_y = **500** N/mm^2
Characteristic yield strength of shear reinforcement	f_{yv} = **500** N/mm^2

Nominal cover to reinforcement

Nominal cover to top reinforcement	c_{nom_t} = **35** mm
Nominal cover to bottom reinforcement	c_{nom_b} = **35** mm
Nominal cover to side reinforcement	c_{nom_s} = **35** mm

Support A



Rectangular section in flexure (cl.3.4.4)

Design bending moment $M = abs(M_{A\_red})$ = **108** kNm

Depth to tension reinforcement $d = h - c_{nom\_t} - \phi_v - \phi_{top} / 2$ = **197** mm

Redistribution ratio $\beta_b = \min(1 - m_{rA}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{cu})$ = **0.139**

$K' = 0.156$

K' > K - No compression reinforcement is required

Lever arm $z = \min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d)$ = **159** mm

Depth of neutral axis $x = (d - z) / 0.45$ = **84** mm

Area of tension reinforcement required $A_{s,req} = M / (0.87 \times f_y \times z)$ = **1559** mm²

Tension reinforcement provided 6 × 20ϕ bars

Area of tension reinforcement provided $A_{s,prov}$ = **1885** mm²

Minimum area of reinforcement $A_{s,min} = 0.0013 \times b \times h$ = **163** mm²

Maximum area of reinforcement $A_{s,max} = 0.04 \times b \times h$ = **5000** mm²

PASS - Area of reinforcement provided is greater than area of reinforcement required

Rectangular section in shear

Design shear force span 1 at 197 mm $V = \max(V_{A\_s1\_max}, V_{A\_s1\_red})$ = **84** kN

Design shear stress $v = V / (b \times d)$ = **0.854** N/mm²

Design concrete shear stress $v_c = 0.79 \times \min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400 /d)^{1/4}) \times$ $(\min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$

v_c = **1.095** N/mm²

Allowable design shear stress $v_{max} = \min(0.8 \text{ N/mm}^2 \times (f_{cu}/1 \text{ N/mm}^2)^{0.5}, 5 \text{ N/mm}^2)$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum allowable

Value of v from Table 3.7 $0.5 \times v_c < v < (v_c + 0.4 \text{ N/mm}^2)$

Design shear resistance required $v_s = \max(v - v_c, 0.4 \text{ N/mm}^2)$ = **0.400** N/mm²

Area of shear reinforcement required $A_{sv,req} = v_s \times b / (0.87 \times f_{yv})$ = **460** mm²/m

Shear reinforcement provided 2 × 8ϕ legs at 100 c/c

Area of shear reinforcement provided $A_{sv,prov}$ = **1005** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing $s_{vl,max} = 0.75 \times d$ = **148** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{top}/2)) /(N_{top} - 1) - \phi_{top}$ = **59** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension $s_{min} = h_{agg} + 5$ mm = **25** mm

PASS - Satisfies the minimum spacing criteria

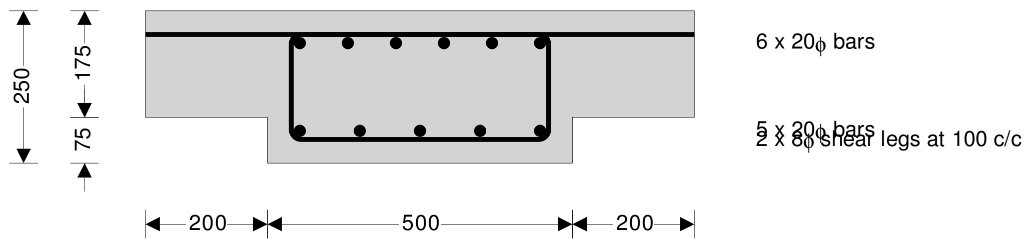
Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) = \mathbf{275.8}$ N/mm^2

Maximum distance between bars in tension $s_{max} = \min(47000 \text{ N/mm} / f_s, 300 \text{ mm}) = \mathbf{170}$ mm

PASS - Satisfies the maximum spacing criteria

Mid span 1



Flanged section in flexure - Positive moment

Design bending moment $M = \text{abs}(M_{s1\_red}) = \mathbf{62}$ kNm

Distance between points of zero moment $L_0 = 0.85 \times L_{s1} = \mathbf{5440}$ mm

Effective flange width $b_{eff} = \min(0.2 \times l_0 + b, b_f) = \mathbf{900}$ mm

Depth to tension reinforcement $d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2 = \mathbf{197}$ mm

Percentage redistribution $m_{rs1} = M_{s1\_red} / M_{s1\_max} - 1 = \mathbf{0}$ %

Redistribution ratio $\beta_b = \min(1 - m_{rs1}, 1) = \mathbf{1.000}$

$K = M / (b_{eff} \times d^2 \times f_{cu}) = \mathbf{0.045}$

$K' = 0.156 = \mathbf{0.156}$

K' > K - No compression reinforcement is required

Lever arm $z = \min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d) = \mathbf{187}$ mm

Depth of neutral axis $x = (d - z) / 0.45 = \mathbf{23}$ mm

Area of tension reinforcement required $A_{s,req} = M / (0.87 \times f_y \times z) = \mathbf{769}$ mm^2

Tension reinforcement provided $5 \times 20\phi$ bars

Area of tension reinforcement provided $A_{s,prov} = \mathbf{1571}$ mm^2

Minimum area of reinforcement $A_{s,min} = 0.0013 \times b \times h = \mathbf{163}$ mm^2

Maximum area of reinforcement $A_{s,max} = 0.04 \times b \times h = \mathbf{5000}$ mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Rectangular section in shear

Shear reinforcement provided $2 \times 8\phi$ legs at 100 c/c

Area of shear reinforcement provided $A_{sv,prov} = \mathbf{1005}$ mm^2/m

Minimum area of shear reinforcement (Table 3.7) $A_{sv,min} = 0.4\text{N/mm}^2 \times b / (0.87 \times f_{yv}) = \mathbf{460}$ mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (cl. 3.4.5.5) $s_{vl,max} = 0.75 \times d = \mathbf{148}$ mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Design concrete shear stress $v_c = 0.79\text{N/mm}^2 \times \min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400\text{mm} /d)^{1/4}) \times (\min(f_{cu}, 40\text{N/mm}^2) / 25\text{N/mm}^2)^{1/3} / \gamma_m = \mathbf{1.031}$ N/mm^2

Design shear resistance provided $v_{s,prov} = A_{sv,prov} \times 0.87 \times f_{yv} / b = \mathbf{0.875}$ N/mm^2

Design shear stress provided $v_{prov} = v_{s,prov} + v_c = \mathbf{1.906}$ N/mm^2

Design shear resistance $V_{prov} = v_{prov} \times (b \times d) = \mathbf{187.7}$ kN

Shear links provided valid between 0 mm and 6400 mm with tension reinforcement of 1571 mm^2

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{bot}/2)) /(N_{bot} - 1) - \phi_{bot}$ = **79** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension $s_{min} = h_{agg} + 5\ mm$ = **25** mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b)$ = **163.1** N/mm^2

Maximum distance between bars in tension $s_{max} = \min(47000\ N/mm / f_s, 300\ mm)$ = **288** mm

PASS - Satisfies the maximum spacing criteria

Span to depth ratio (cl. 3.4.6)

Basic span to depth ratio (Table 3.9) $span\_to\_depth_{basic}$ = **17.5**

Design service stress in tension reinforcement $f_s = (2 \times f_y \times A_{s,req})/ (3 \times A_{s,prov} \times \beta_b)$ = **163.1** N/mm^2

Modification for tension reinforcement

$f_{tens} = \min(2.0, 0.55 + (477N/mm^2 - f_s) / (120 \times (0.9N/mm^2 + (M / (b_{eff} \times d^2)))))$ = **1.523**

Modification for compression reinforcement

$f_{comp} = \min(1.5, 1 + (100 \times A_{s2,prov} / (b_{eff} \times d)) / (3 + (100 \times A_{s2,prov} / (b_{eff} \times d))))$ = **1.262**

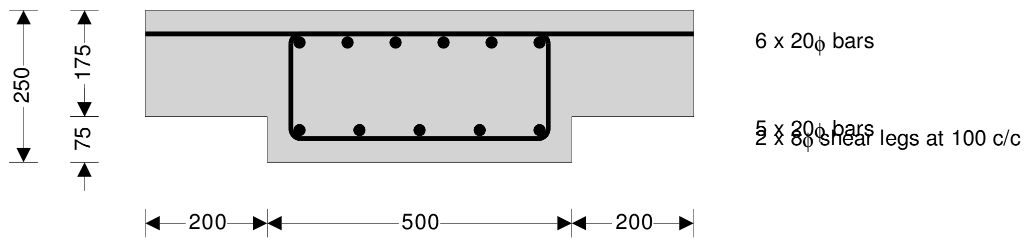
Modification for span length f_{long} = 1.000

Allowable span to depth ratio $span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp}$ = **33.6**

Actual span to depth ratio $span\_to\_depth_{actual} = L_{s1} / d$ = **32.5**

PASS - Actual span to depth ratio is within the allowable limit

<u>Support B</u>



Rectangular section in flexure (cl.3.4.4)

Design bending moment $M = abs(M_{B\_red})$ = **122** kNm

Depth to tension reinforcement $d = h - c_{nom\_t} - \phi_v - \phi_{top} / 2$ = **197** mm

Redistribution ratio $\beta_b = \min(1 - m_{rB}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{cu})$ = **0.157**

$K' = 0.156$

K > K' - Compression reinforcement is required

Lever arm $z = d \times (0.5 + (0.25 - K' / 0.9)^{0.5})$ = **153** mm

Depth of neutral axis $x = (d - z) / 0.45$ = **98** mm

Depth of compression reinforcement $d_2 = c_{nom\_b} + \phi_v + \phi_{bot} / 2$ = **53** mm

Area of compression reinforcement required $A_{s2,req} = (K - K') \times f_{cu} \times b \times d^2 / (0.87 \times f_y \times (d - d_2))$ = **9** mm^2

Compression reinforcement provided $5 \times 20\phi$ bars

Area of compression reinforcement provided $A_{s2,prov}$ = **1571** mm^2

Maximum area of reinforcement (cl.9.2.1.1(3)) $A_{s,max} = 0.04 \times b \times h$ = **5000** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Area of tension reinforcement required $A_{s,req} = K' \times f_{cu} \times b \times d^2 / (0.87 \times f_y \times z) + A_{s2,req}$ = **1828** mm^2

Tension reinforcement provided — $6 \times 20\phi$ bars

Area of tension reinforcement provided — $A_{s,prov}$ = **1885** mm^2

Minimum area of reinforcement (exp.9.1N) — $A_{s,min} = 0.0013 \times b \times h$ = **163** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Rectangular section in shear

Design shear force span 1 at 6203 mm — $V = abs(min(V_{B\_s1\_max}, V_{B\_s1\_red}))$ = **102** kN

Design shear stress — $v = V / (b \times d)$ = **1.032** N/mm^2

Design concrete shear stress — $v_c = 0.79 \times min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times max(1, (400 /d)^{1/4}) \times$ $(min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$

v_c = **1.095** N/mm^2

Allowable design shear stress — $v_{max} = min(0.8 N/mm^2 \times (f_{cu}/1 N/mm^2)^{0.5}, 5 N/mm^2)$ = **5.000** N/mm^2

PASS - Design shear stress is less than maximum allowable

Value of v from Table 3.7 — $0.5 \times v_c < v < (v_c + 0.4 N/mm^2)$

Design shear resistance required — $v_s = max(v - v_c, 0.4 N/mm^2)$ = **0.400** N/mm^2

Area of shear reinforcement required — $A_{sv,req} = v_s \times b / (0.87 \times f_{yv})$ = **460** mm^2/m

Shear reinforcement provided — $2 \times 8\phi$ legs at 100 c/c

Area of shear reinforcement provided — $A_{sv,prov}$ = **1005** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing — $s_{vl,max} = 0.75 \times d$ = **148** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension — $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{top}/2)) /(N_{top} - 1) - \phi_{top}$ = **59** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension — $s_{min} = h_{agg} + 5$ mm = **25** mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress — $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b)$ = **323.3** N/mm^2

Maximum distance between bars in tension — $s_{max} = min(47000 N/mm / f_s, 300 mm)$ = **145** mm

PASS - Satisfies the maximum spacing criteria

Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN
Water uplift force										
3m high	7000	30.00		7300					**1533.0**	
water table										
Gravitational load										
Roof dead load	7000	0.69		5000					24.2	
GF dead load	7000	6.35		6300					280.0	
Basement slab	7000	14.15		7300					723.1	
Basement wall SW		7.20		71500	sqmm				514.8	
TOT									**1542.1**	**PASS**